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APPENDIX 2

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**ELECTRICAL CONDUCTIVITY OF HITTS ADDITIVE PACKAGES FOR THE
JP8+100 PROGRAMME**

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ABSTRACT

The behaviour of two HITTS high temperature additive packages has been studied to examine possible interference with existing conductivity improver and also to assess their potential as conductivity improvers. The HITTS additives are shown to impart sufficient conductivity to fuels to meet certain fuel conductivity specifications without the addition of Stadis. Use of the HITTS additives with Stadis is shown to produce values of conductivity above the fuel specification. The conductivity performance of the HITTS additives is unaffected by the presence of phenolic or sodium salt impurities in the fuel which have been shown to have a detrimental effect on the performance of Stadis. The conductivity behaviour of the individual components of the HITTS additives is discussed. The dispersant is the main conducting component in the additive packages, but there are variations in the magnitude of the conductivity observed.

1. INTRODUCTION AND AIMS

The major objective of the JP8+100 programme is to improve the thermal stability of jet fuel using carefully selected additives. However, in this paper we examine the effects of such additives on properties which are unrelated to thermal stability characteristics, but which can have important consequences for the handling characteristics of the fuel.

In earlier papers^{1,2,3} we examined the effects of a wide range of compounds, representative of naturally-occurring fuel components, on the performance of static dissipators (conductivity improvers). The work identified highly polar species capable of substantially reducing their effectiveness.

Certain HITTS packages are known to impart some conductivity to fuel. This work investigates the magnitude of this conductivity effect, on a model fuel and on three real fuels, for two Betz JP8+100 additives based on SPEC-AID 8Q405. SPEC-AID 8Q405, alone, at a concentration of

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100mg^l⁻¹, has been reported to produce an average conductivity increase of ~140pSm⁻¹ in three reference fuels⁴. The spread of values in these fuels was not stated. The two fully formulated HITS packages NB 345 S286 and SPEC-AID 8Q460 have been examined and components of the packages have been studied separately to identify components contributing to the conductivity.

The sensitivity of these HITS packages to model impurities, phenols and sodium salts, has been determined and is compared with that of Stadis450. The effects of the HITS additives on Stadis450 have also been measured.

Brief comments are made on the potential for the use of such additives as conductivity improvers.

2. EXPERIMENTAL

2.1 Materials: The composition of the HITS additive packages NB 345 S286 and SPEC-AID 8Q460 are given in Table 1. The fully-formulated additives, SPEC-AID 8Q460 and NB234 S286A, the partially formulated package SPEC-AID8Q406 and the components SPEC-AID 8Q405 (dispersant batch-1) and SPEC-AID8Q400 (Betz metal deactivator) were supplied directly via Wright Patterson AFB by Betz Process Chemicals Inc. A second sample of SPEC-AID 8Q405 (batch-2), was supplied via British Petroleum. The additive BHT (2,6-di-*t*-butyl-4-methyl phenol) was obtained from Aldrich Chemical Co Ltd., "conventional" metal deactivator (NN-disalicylidene 1,2-propane diamine - abbreviated to c-MDA) from Pfalz and Bauer Inc., m-cresol from British Drug Houses and octylamine from Fluka Chemica.

Stocks of the HITS fuels were held by and supplied to us by Shell. These were, an additive-free Mercox base fuel (Mercox-AF), having a kinematic viscosity of 3.698 mm²s⁻¹ at -20C, and two fuels produced from this to JetA1 and JP8 specification. These are designated Jet A1-MA1, which contains 1.87mg^l⁻¹ reformulated Stadis450 and JP8-MA2 which contains 1.87mg^l⁻¹ reformulated Stadis450 plus AL-48 to give a concentration of 1300mg^l⁻¹ of FSI and 27mg^l⁻¹ of Nalco 5403. The sources and purification procedures employed for materials used previously, have been described^{1,2,3}.

2.2 Equipment and measurements: All measurements were made with the apparatus described previously^{2,3} and made at 25C. The series of measurement was as follows:

- i) time dependence of conductivity for NB 345 S286 and SPEC-AID8Q460 in dodecane.
- ii) the conductivity of NB 345 S286 and SPEC-AID 8Q460 in dodecane and HITS Fuels over

a concentration range of 10 mg^l⁻¹ to 800 mg^l⁻¹.

iii) the conductivity of NB 345 S286 and SPEC-AID 8Q460, over a range 10mg^l⁻¹ to 800mg^l⁻¹, in dodecane containing 3mg^l⁻¹ Stadis450

iv) *m*-cresol and 2,6-di-*tert*-butyl-4-methylphenol were added separately over the concentration range 50-1000 mg^l⁻¹ to solutions of 135mg^l⁻¹ NB 345 S286 in dodecane and HITTs Fuels and 127mg^l⁻¹ SPEC-AID 8Q460 in dodecane and HITTs Fuels. The conductivity was measured after each addition of the phenol.

v) sodium naphthenate was added, over the concentration range 0.3 to 18 mg^l⁻¹, to solutions of 135mg^l⁻¹ NB 345 S286 in dodecane and 127mg^l⁻¹ SPEC-AID 8Q460 in dodecane. Conductivity measurements were made after each addition of sodium naphthenate.

vi) components of the additive packages namely SPEC-AID8Q405, SPEC-AID8Q400 and c-MDA were added separately to HITTs Fuels and the conductivity measured.

vii) test of the variability of samples of SPEC-AID8Q405 dispersant between batches (where impurity levels could be different) by measurement of the conductivity of batch 2 SPEC-AID,8Q405 in the three HITTs fuels to compare with similar results from batch 1.

viii) neutralisation of possible acidic impurities using SPEC-AID 8Q406 (SPEC-AID8Q405 + BHT antioxidant) was shaken for five minutes with finely divided CaCO₃ diluted with hexane, then separated and the solvent removed by evaporation. A control sample was treated in a similar way but without the CaCO₃.

Acid and Base Additions: In a preliminary attempt to investigate ion production mechanisms we have examined the effects of an amine and an acid on the conducting species. Octylamine, diluted in toluene, was added to a solution of 100mg^l⁻¹dispersant SPEC-AID 8Q405 in the Merox-AF and the conductivity was measured after each addition. Similar measurements were made using dodecylbenzenesulphonic acid.

3. RESULTS AND DISCUSSION

3.1 The Time dependence of the Conductivity of Fully-Formulated Additives, NB345 S286 and SPEC-AID8Q460 in Dodecane Solutions

The time dependence of conductivity has been examined in a limited series of measurements over a three-hour period. These measurements were required in order to see if any large drifts in conductivity occurred during the time-scale of the experiments. The conductivity of the NB345 S286 solution(135mg^l⁻¹) increases slowly with time whereas that for SPEC-AID8Q460 (127mg^l⁻¹)

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shows a slow decrease. However in neither case were the changes sufficient to warrant detailed corrections to data obtained during the period of the experiments—normally about an hour.

3.2 Effect of Concentration of Fully-Formulated Additives on the Conductivity of Dodecane Solutions

Data in dodecane were required to provide a baseline for comparison with behaviour in real fuels. In these experiments only the the fully-formulated HITTs additive packages SPEC-AID 8Q460 and NB345 S286 were examined.

Figure 1 shows the effect of these packages on dodecane and demonstrates their ability to impart conductivity. We note also that the conductivity varies approximately linearly with concentration of the additive package, with the NB345 S286 giving a larger gradient than SPEC-AID8Q460. The recommended in-fuel concentrations of these additives are 135mg l^{-1} for the former and 127mg l^{-1} for the latter .

The behaviour of these packages in dodecane containing 3mg l^{-1} of original Stadis450 is shown in figure 2. The results of repeat runs, undertaken after an interval of nineteen months show a measurable change in behaviour. The fact that the stadis450/dodecane solution had a conductivity close to that in the original experiments suggests that the observed changes are due to ageing effects in the Hitts additives. The cause of the low concentration behaviour is not yet clear, however at concentrations $>200\text{mg l}^{-1}$ the variation of conductivity with concentration for each package is similar to that observed in the absence of Stadis450. These low concentration effects are reminiscent of the effects of salts on Stadis450.

3.3 Effects of Polar Fuel Components on the Conductivity of Hitts Additives in Dodecane

Figure 3 shows the influence of m-cresol concentration on the conductivity of solutions containing given concentrations of (i) original-Stadis450, (ii) NB345 S286 and (iii) SPEC-AID8Q460. The concentrations chosen are recorded on the figures and correspond approximately to those used in jet fuels.

We previously reported on the influence of m-cresol on original-Stadis450³ and this is also further discussed in an accompanying paper⁵. For SPEC-AID8Q460 we observe a small decrease in conductivity with concentration which is probably insignificant from a user viewpoint. For NB345 S286 conductivity appears to increase gradually with m-cresol concentration and the increase, after allowance for a small time correction, would be $\sim 30\text{pS m}^{-1}$ at 1000mg l^{-1} m-cresol. For comparison figure 4 shows the effects of a highly hindered phenol of the type employed as

antioxidants. This is a good example of an almost complete lack of any antagonistic interaction with any of the three additives.

Earlier results on the effects sodium salts of a naphthenic acid, a phenol and dodecylbenzenesulphonic acid, on the behaviour of original-Stadis450, showed strong antagonistic effects on conductivity response³ and these were qualitatively similar for all three types of salt. Sodium naphthenate was chosen as representative of these and its influence on the additive packages is shown in figure 5. For each HITTs package the concentration dependence of conductivity is quite different from that of Stadis solutions. There is no minimum, the conductivity remains approximately constant up to a concentration of $\sim 2\text{mg l}^{-1}$ and then increases with concentration. We note that sodium naphthenate alone imparts some conductivity³, but this cannot account for the total observed increase. However, in this case, because the concentration of such compounds in fuels is likely to be low-probably $<1\text{mg l}^{-1}$, the practical effect of this will be very small.

3.4 Effects of Fully-Formulated Additives on the Conductivity of Hitts Fuels

We note that the conductivities of Jet A1-M1A and JP8-M2A, measured at the start of the study, are very similar, having values of $\sim 500\text{ pSm}^{-1}$. However, during the period of the work conductivity is seen to decrease for each fuel, with that for JP8 showing a fall of $\sim 34\%$ and for JetA1 a fall of $\sim 20\%$ over 250 days. This is taken into account in our comparisons of behaviour. The only difference between these fuel solutions is the presence of AL-48 in JP8-M2A. We know that in short-duration experiments AL-48 has no measurable effect on the performance of Stadis450⁶. No long-duration experiments ie up to ~ 250 days have yet been done.

Figure 6 shows the response of HITTs fuels to NB345 S286. This is represented by the increase in conductivity over the initial conductivity of the fuel. Dodecane data are shown for comparison. Clearly there are differences in response which follow the order: JP8 > Jet A1 > Merox-AF > Dodecane. Likewise figure 7 shows the response of HITTs fuels to SPEC-AID8Q460. In this case the differences in response are much less clear cut, though JP8 and Jet A1 again show greater response than Merox-AF and Dodecane. ie JetA1 \sim JP8 > Dodecane \sim Merox-AF. The lower viscosity for Merox-AF ($1.45\text{mm}^2\text{s}^{-1}$) compared with dodecane ($1.86\text{mm}^2\text{s}^{-1}$) at 25C would lead us to expect a higher conductivity in Merox-AF. Mixtures of aromatic and alkane liquids of a given viscosity are expected to promote a higher conductivity than an isoviscous pure alkane at the same temperature. Therefore the presence of aromatic components in Merox-AF(19%) will

raise the conductivity⁶. To these effects must also be added those due to interactions between additives. The net result on ion production is seen in the measured conductivity. Paradoxically the low concentration behaviour observed with these additives in Stadis/dodecane mixtures is not observed in the more complex real fuel systems. In these cases however, the ageing effect has not yet been examined.

A practical point is that, at the recommended dosing concentration for HITTs additives in JP8 and JetA1, the total conductivities, as shown in table 2, are above the upper limit specification values of 600 pSm^{-1} and 450 pSm^{-1} respectively. We also note that the conductivity of Merox-AF, containing the recommended concentrations is within the specification conductivity range for JetA1 without the addition of Stadis 450, but 8Q460 falls slightly short of the minimum value for JP8. However we feel that more data is required on batch-to-batch variations and on fuel composition effects.

3.5 Effect of Model Phenolic Impurities on the Conductivity of HITTs Additives in HITTs Fuels

Figure 8 shows that the total measured conductivities of SPEC-AID 8Q460 in Merox-AF are *insensitive* to the presence of *m*-cresol "impurities". Results for NB345 S286 are similar. The apparent sensitivity to *m*-cresol in the JP8 and JETA1 fuels can therefore be attributed to the interaction of the *m*-cresol with the Stadis450 in these fuels and not to any interaction of the *m*-cresol with NB 345 S286 or SPEC-AID8Q460.

3.6 Effects of Additive Components on the Conductivity of HITTs Fuels

Work on a range of phenol types⁵ in dodecane has shown that highly hindered phenols have little or no effect on the conductivity of hydrocarbons nor do they adversely affect the performance of Stadis450. We have confirmed that BHT does not contribute to the conductivity of the additive package in any of the HITTs fuels.

Earlier measurements on conventional-MDA in dodecane showed it had no effect on conductivity¹

Figure 9 shows that this is also true for solutions in Merox-AF and JP8. For Jet A1 a small decrease of ~10% is observed in the concentration range 0 to 100 mg l^{-1} .

In marked contrast, the Betz MDA, see figure 10, although it contributes only a small amount to the conductivity of Merox-AF, nevertheless has a considerable enhancing effect on the conductivity of Jet A1 and causes a modest reduction in the conductivity of JP8. These effects are clearly indicative of interaction between this MDA and components present in these fuels.

Repeat runs with this additive, after an ageing period of eighteen months, demonstrated an increased response. However, during this period the USAF decided not to consider a new MDA but to continue with conventional MDA. For this reason work on Betz MDA was discontinued. Figure 11 shows that the dispersant SPEC-AID8Q405 imparts significant conductivity to each of the fuels and conductivity varies linearly with concentration above $\sim 50\text{mg l}^{-1}$. We note the response follows the order JP8 > Jet A1 > Merox-AF as observed for the fully-formulated additive packages. In view of the results for BHT and c-MDA discussed above, it is clear that SPEC-AID8Q405 is the only conducting component in SPEC-AID8Q460 and is the main, but not the sole conducting component in NB345 S286.

3.7 Effect of Batch Variation on the Behaviour of SPEC-AID 8Q405

Figure 11, also demonstrates batch to batch variation on the conductivity-improving ability of SPEC-AID 8Q405 with Batch 2 giving generally lower conductivity values. At a concentration of 100mg l^{-1} , batch-1 in Merox-AF meets the Jet-A1 and JP8 conductivity specifications, without Stadis, whereas batch-2 meets that for Jet-A1 only. Either batch added to Jet-A1 fuel causes the conductivity to be out of specification. This is also the case for addition of batch-1 to JP8 fuel. The magnitudes of some of the observed effects seems also to be influenced by ageing of the fuels and we hope to examine this further.

3.8 Preliminary Investigation of the Conducting Species

The conductivities of both carbonate-treated and untreated SPEC-AID8Q406 samples (see para 2.2) are identical. This suggests that participation of acidic species in the conduction process is unlikely.

Figure 12 shows that both dodecylbenzenesulphonic acid n-octylamine interact to increase the conductivity. Repeat experiments after an interval of sixteen months show, that apart from some small apparent differences at very low concentrations, the behaviour is generally unchanged within the experimental uncertainty. In the case of the sulphonic acid the effect is partly due to the acid itself³. However, this cannot be the explanation for the effect of the amine which alone has no effect on the conductivity⁶. More information is required before much speculation can be justified.

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4. SUMMARY AND CONCLUSIONS

4.1 CONDUCTIVITY BEHAVIOUR OF HITTS PACKAGES

4.1.1 In Model Fuel (Dodecane) with Model Impurities

- 1 Both the HITTS packages impart conductivity which shows a small time dependence.
- 2 Both the HITTS packages can impart conductivity to fuel, without the use of Stadis450.
- 3 The conductivity response of both the HITTS packages is insensitive to phenolic impurities.
- 4 The conductivity response of both the HITTS packages is insensitive to sodium salts.
- 5 The HITTS packages have the advantage of imparting the required conductivity to fuels without the sensitivity to fuel impurities, such as phenols and sodium salts, which is detrimental to Stadis450.

4.1.2 In HITTS Fuels

- 1 Both the HITTS additive packages used at the recommended concentration in the HITTS fuels JP8 MA2 and JETA1 M1A, gave conductivities *above* the fuel specification.
- 2 The conductivity of the Merox-A-F containing the recommended levels of both HITTS packages was within the fuel conductivity specification for Jet-A1 *without* the use of Stadis450. For JP8 with the additive 8Q460, conductivity falls slightly short of the minimum conductivity specification
- 3 There is a simple linear relationship between conductivity and the concentration of the HITTS additives.
- 4 Both the HITTS additive packages appear to be unaffected by the presence of phenolic impurities in fuel.
- 5 Reduction in conductivity in the HITTS JP8 and JET A1 with the HITTS additives in the presence of phenolic impurities is attributed to interaction of the phenol with the Stadis 450 in these fuels.
- 6 The HITTS additives show potential as conductivity improvers. Additional work is required on batch-to batch variation, ageing effects and on the temperature dependence of conductivity before these additives can be given serious consideration as sole conductivity improvers.

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4.2 CONDUCTIVITY BEHAVIOUR OF *INDIVIDUAL COMPONENTS OF HITT*S ADDITIVES

- 1 The c-MDA contributes little to the conductivity of the HITT*S* additive.
- 2 The contribution of the Betz MDA to conductivity is complex. In the Merox-AF the Betz MDA contributes a small increment to the conductivity. In the JP8 it produced a reduction in conductivity and in the JETA1 it produced an increase in conductivity. The reasons for the variations could be due to interaction with Stadis450 and/or water in the fuels. Recently the Betz MDA has ceased to be of interest to USAF.
- 3 The BHT antioxidant does not contribute to the conductivity of the HITT*S* additives.
- 4 The dispersant SPEC-AID8Q405 is the main conducting component in the HITT*S* additives. At 100mg l^{-1} in the presence of Stadis, conductivity will generally exceed the specification upper limit. In the absence of Stadis it is likely that the Jet-A1 specification will be met but there is uncertainty with respect to JP8.

5. ACKNOWLEDGEMENTS

The authors wish to thank additive manufacturers and oil companies, in particular BP, for their constructive cooperation and for supplies of additives and fuels. Especially they would like to thank BP and DRA for many helpful and enjoyable discussions during the course of this work. They also wish to express their thanks to the DRA for its funding support provided under DRA Contract LSF/E 20093.

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6. Dacre, B.; Hetherington, J.I. Preliminary unpublished work.

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Commercial Additive	Description	Concentration Added to Fuel	Comments
BHT	Antioxidant 2,6-di- <i>tert</i> -butyl-4-methylphenol	25mg ⁻¹	
MDA (conventional)	Metal Deactivator NN'-disalicylidene-1,2-propanediamine	10mg ⁻¹	
8Q405	Dispersant BETZ (proprietary)	100mg ⁻¹	
Spec Aid 8Q400	Betz Metal Deactivator	10mg ⁻¹	Different chemistry from conventional DuPont MDA
Spec Aid 8Q406	8Q405 / BHT dispersant / antioxidant	125mg ⁻¹	
NB 345 S286A	Experimental 8Q405/BHT/8Q400 Dispersant / Antioxidant / Betz MDA	135mg ⁻¹	Assumed composition: 8Q405 100mg ⁻¹ BHT 25mg ⁻¹ MDA 10mg ⁻¹ (Betz)
Spec Aid 8Q460	8Q405 / BHT /MDA Dispersant / Antioxidant / MDA (conventional chemistry)	127mg ⁻¹	Assumed composition: 8Q405 100mg ⁻¹ BHT 25mg ⁻¹ MDA 2mg ⁻¹ (conventional)

Table 1 Composition of HITTS High Temperature Additive Packages

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FUELS	SPEC AID8Q460 127mg ^l ⁻¹	NB 345 S286 135mg ^l ⁻¹
Merox-AF	123	221
Jet-A1	666	817
JP8	668	864
Dodecane	132	200

Values taken from data in figures 7 and 8.

Specification Conductivity ranges: Jet-A1 50--450pSm⁻¹
 JP8 150--600pSm⁻¹

Table 2 Measured Conductivities (pSm⁻¹) in HITTS Fuels

Fuel	Batch-1 100mg ^l ⁻¹	Batch-2 100mg ^l ⁻¹
Merox-AF	158	115
Jet-A1	689	584
JP8	671	557

Values taken from data in figure 11.

Table 3 Measured Conductivities (pSm⁻¹) of 8Q405 in HITTS Fuels

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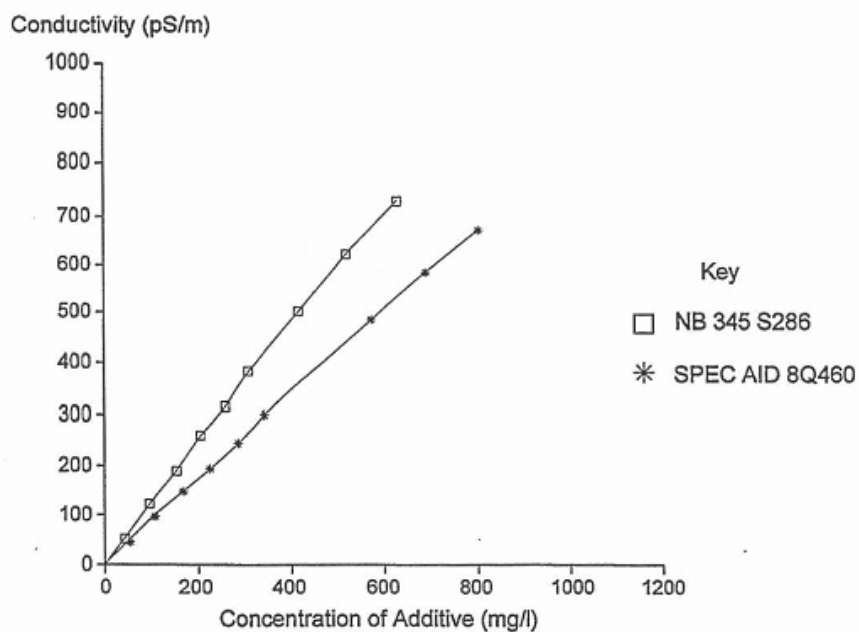


Fig. 1 Conductivity vs. Concentration for High Temperature Additive Packages in Dodecane

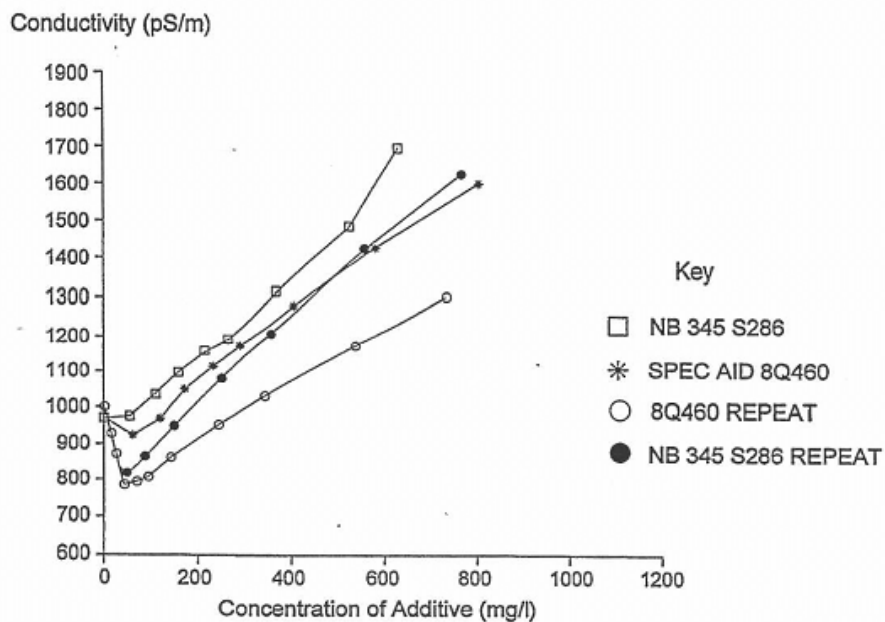


Fig. 2 Effect of High Temperature Additive Packages on Conductivity of 3mg/l STADIS 450 in Dodecane

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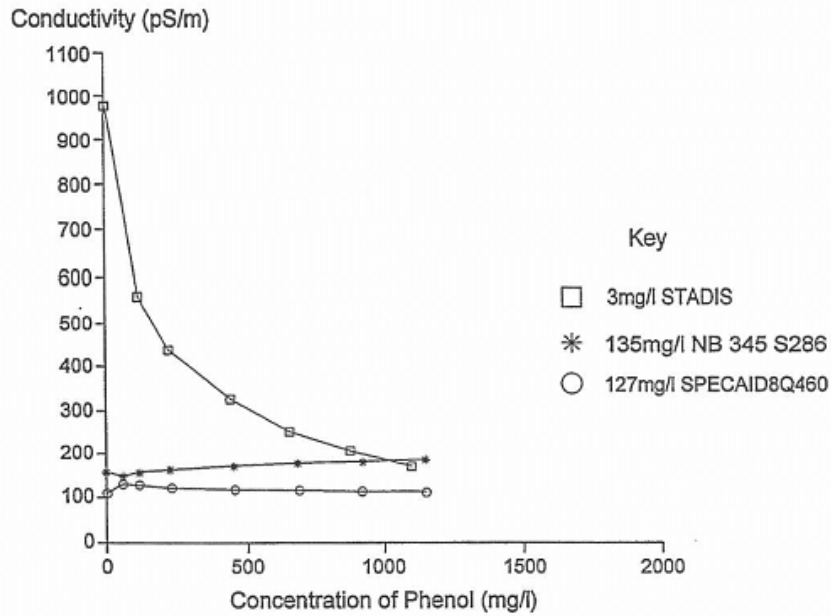


Fig. 3 Effect of m-Cresol on Conductivity of Stadis 450 and High Temperature Additive Packages in Dodecane

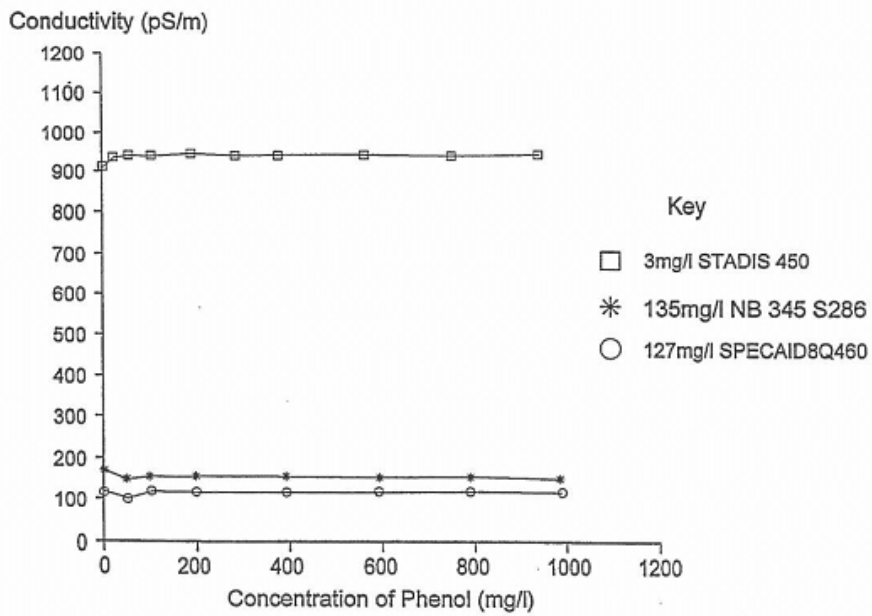


Fig. 4 Effect of 2,6-di(tert)butyl-4-methylphenol on Conductivity of Stadis 450 and High Temperature Additive Packages in Dodecane

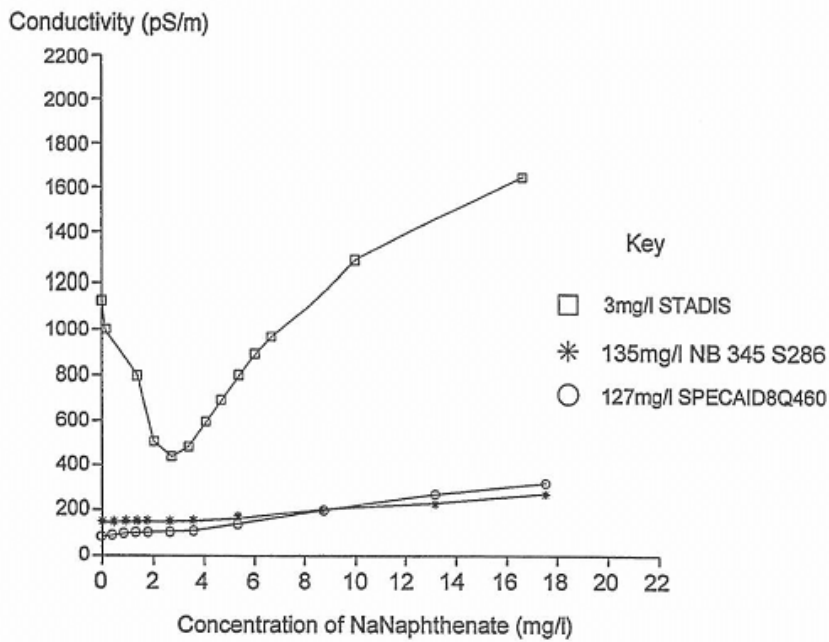


Fig. 5 Effect of Sodium Naphthenate on Conductivity of Stadis 450 and High Temperature Additive Packages in Dodecane

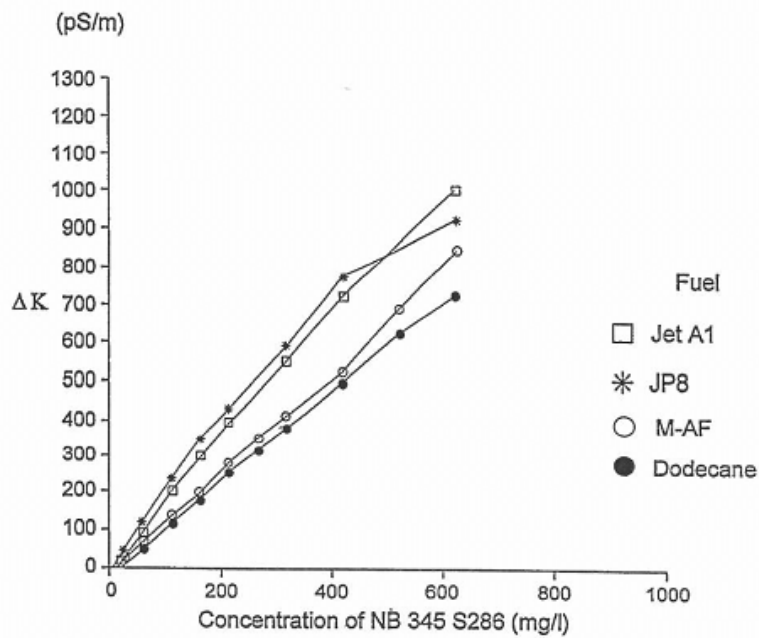


Fig. 6 Effect of NB 345 S286 on the Conductivity of HITS Fuels

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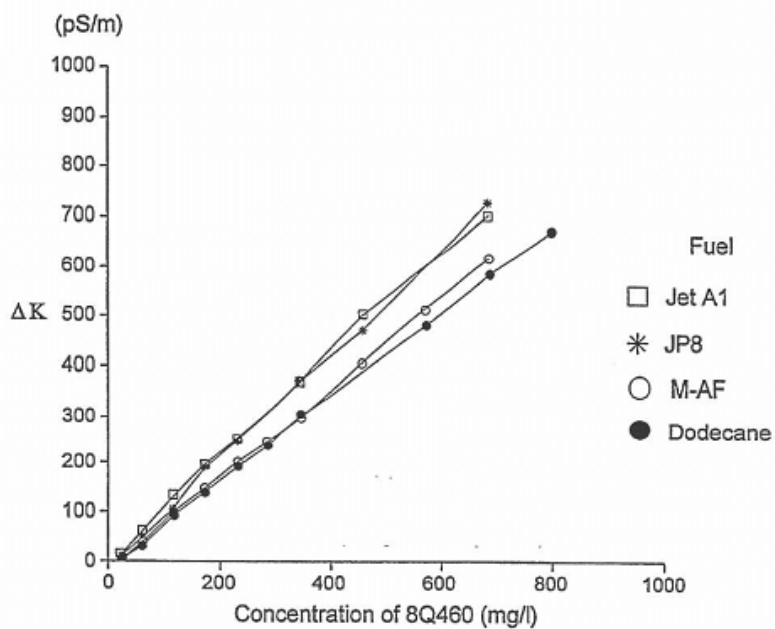


Fig. 7 Effect of 8Q460 on the Conductivity of HITS Fuels

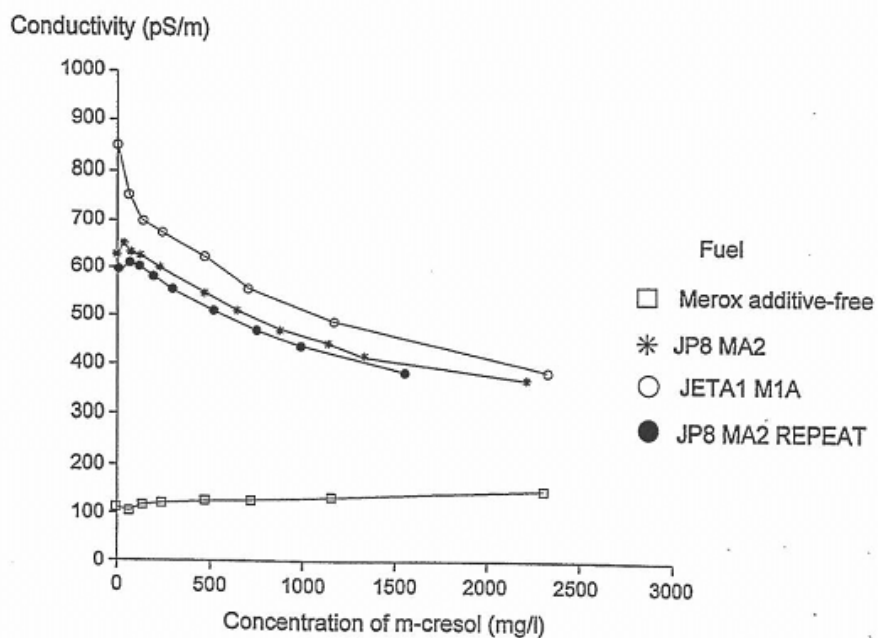


Fig. 8 Effect of m-cresol on Conductivity of 127 mg/l SPECAID 8Q460 in HITS Fuels

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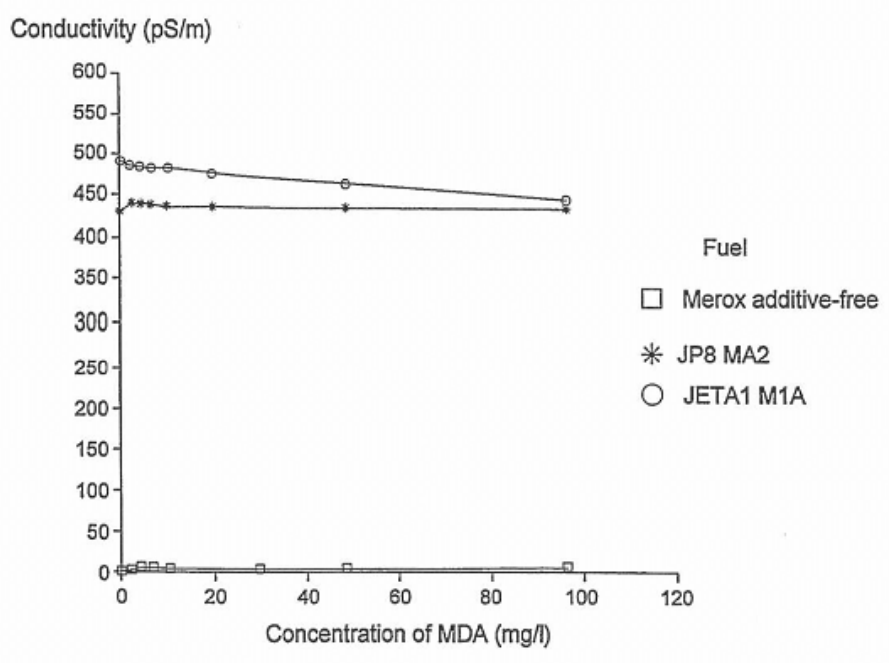


Fig. 9 Effect of MDA (conventional) on Conductivity of HITTS Fuels

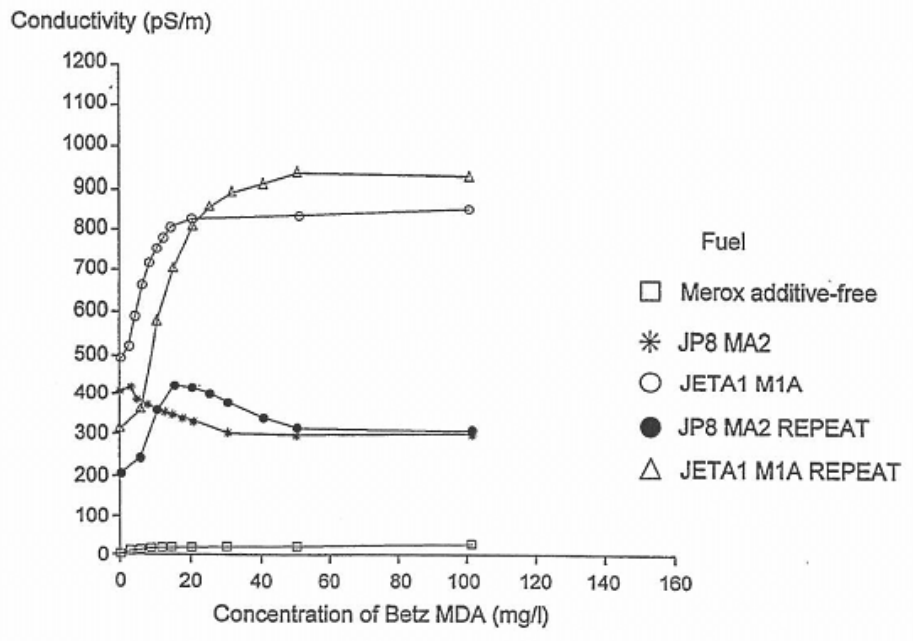


Fig. 10 Effect of Betz MDA on Conductivity of HITTS Fuels

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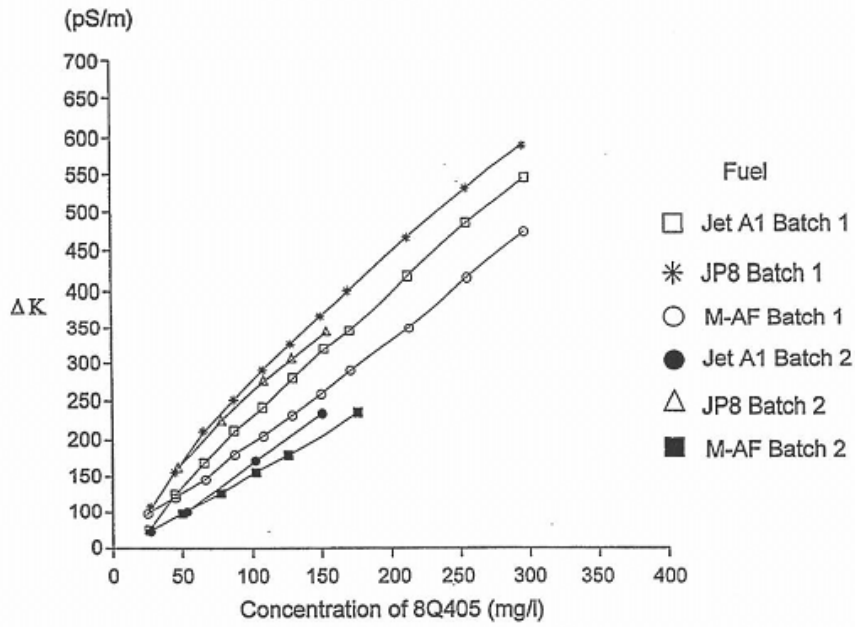


Fig. 11 Effect of 8Q405 and Batch Variation on the Conductivity of HITTS Fuels

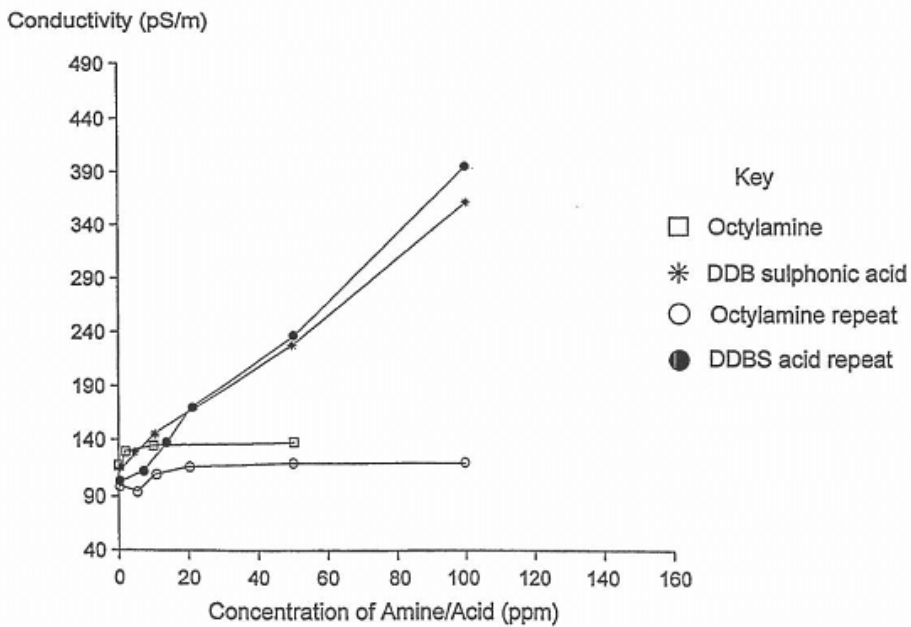


Fig. 12 Betz Dispersant 8Q405(Batch 2) 100mg/l in HITTS Additive-free Merox
Effect of Acid or Amine on Conductivity

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METRIC

MIL-DTL-83133F

11 April 2008

SUPERSEDING

MIL-DTL-83133E

1 April 1999

DETAIL SPECIFICATION

TURBINE FUEL, AVIATION, KEROSENE TYPE, JP-8 (NATO F-34), NATO F-35, and JP-8+100 (NATO F-37)

This specification is approved for use by all Departments and Agencies of the Department of Defense.

Comments, suggestions, or questions on this document should be addressed to HQ AFPET/AFTT, 2430 C Street, Bldg 70, Area B, Wright-Patterson AFB OH 45433-7632 or e-mailed to AFPET.AFTT@wpafb.af.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at <http://assist.daps.dla.mil>.

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MIL-DTL-83133F

1. SCOPE

1.1 Scope. This specification covers three grades of kerosene type aviation turbine fuel, JP-8 (NATO F-34), NATO F-35, and JP-8+100 (NATO F-37). This specification was thoroughly reviewed as a part of acquisition reform. While most of the requirements were converted to performance terms, not all requirements could be converted due to the military-unique nature of the product (see 6.1) and the need for compatibility with deployed systems. The issuance of this specification as "detail" is not intended to constrain technology advances in future systems.

1.2 Classification. Aviation turbine fuel will be of the following grades, as specified (see 6.2).

Grade	NATO Code No.	Description
JP-8	F-34	Kerosene type turbine fuel which will contain a static dissipator additive, corrosion inhibitor/lubricity improver, and fuel system icing inhibitor, and may contain antioxidant and metal deactivator.
	F-35	Kerosene type turbine fuel which will contain a static dissipator additive, may contain antioxidant, corrosion inhibitor/lubricity improver, and metal deactivator but will not contain fuel system icing inhibitor.
JP-8+100	F-37	JP-8 type kerosene turbine fuel which contains thermal stability improver additive (NATO S-1749) as described in 3.3.6.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, or 5 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this specification, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-DTL-5624	Turbine Fuel, Aviation, Grades JP-4 and JP-5
MIL-PRF-25017	Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble
MIL-DTL-85470	Inhibitor, Icing, Fuel System, High Flash NATO Code Number S-1745

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DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-290 Packaging of Petroleum and Related Products

QUALIFIED PRODUCTS LIST

QPL-25017 Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble

(Copies of these documents are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia PA 19111-5094 or online at <http://assist.daps.dla.mil>)

2.3 Non-government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

ASTM International

ASTM D 56	Standard Test Method for Flash Point by Tag Closed Cup Tester (DoD Adopted)
ASTM D 86	Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure (DoD Adopted)
ASTM D 93	Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester (DoD Adopted)
ASTM D 129	Standard Test Method for Sulfur in Petroleum Products (General Bomb Method) (DoD Adopted)
ASTM D 130	Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test (DoD Adopted)
ASTM D 156	Standard Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method) (DoD Adopted)
ASTM D 381	Standard Test Method for Gum Content in Fuels by Jet Evaporation (DoD Adopted)
ASTM D 445	Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity) (DoD Adopted)
ASTM D 976	Standard Test Methods for Calculated Cetane Index of Distillate Fuels (DoD Adopted)
ASTM D 1094	Standard Test Method for Water Reaction of Aviation Fuels (DoD Adopted)
ASTM D 1266	Standard Test Method for Sulfur in Petroleum Products (Lamp Method) (DoD Adopted)
ASTM D 1298	Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method (DoD Adopted)
ASTM D 1319	Standard Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption (DoD Adopted)
ASTM D 1322	Standard Test Method for Smoke Point of Kerosine and Aviation Turbine Fuels (DoD Adopted)
ASTM D 1840	Standard Test Method for Naphthalene Hydrocarbons in Aviation

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	Turbine Fuels by Ultraviolet Spectrophotometry (DoD Adopted)
ASTM D 2276	Standard Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling (DoD Adopted)
ASTM D 2386	Standard Test Method for Freezing Point of Aviation Fuels (DoD Adopted)
ASTM D 2622	Standard Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-Ray Fluorescence Spectrometry (DoD Adopted)
ASTM D 2624	Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels (DoD Adopted)
ASTM D 2887	Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography (DoD Adopted)
ASTM D 3120	Standard Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry (DoD Adopted)
ASTM D 3227	Standard Test Method for (Thiol Mercaptan) Sulfur in Gasoline, Kerosine, Aviation Turbine, and Distillate Fuels (Potentiometric Method) (DoD Adopted)
ASTM D 3241	Standard Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels (JFTOT Procedure) (DoD Adopted)
ASTM D 3242	Standard Test Method for Acidity in Aviation Turbine Fuel (DoD Adopted)
ASTM D 3338	Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels (DoD Adopted)
ASTM D 3343	Standard Test Method for Estimation of Hydrogen Content of Aviation Fuels (DoD Adopted)
ASTM D 3701	Standard Test Method for Hydrogen Content of Aviation Turbine Fuels by Low Resolution Nuclear Magnetic Resonance Spectrometry (DoD Adopted)
ASTM D 3828	Standard Test Methods For Flash Point by Small Scale Closed Cup Tester (DoD Adopted)
ASTM D 3948	Standard Test Method for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer (DoD Adopted)
ASTM D 4052	Standard Test Method for Density and Relative Density of Liquids by Digital Density Meter (DoD Adopted)
ASTM D 4057	Standard Practice for Manual Sampling of Petroleum and Petroleum Products (DoD Adopted)
ASTM D 4177	Standard Practice for Automatic Sampling of Petroleum and Petroleum Products (DoD Adopted)
ASTM D 4294	Standard Test Method for Sulfur in Petroleum and Petroleum Products by Energy-Dispersive X-Ray Fluorescence Spectrometry (DoD Adopted)
ASTM D 4306	Standard Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination (DoD Adopted)
ASTM D 4529	Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
ASTM D 4737	Standard Test Method for Calculated Cetane Index by Four Variable Equation

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ASTM D 4809	Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method) (DoD Adopted)
ASTM D 4952	Standard Test Method for Qualitative Analysis for Active Sulfur Species in Fuels and Solvents (Doctor Test) (DoD Adopted)
ASTM D 5001	Standard Test Method for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)
ASTM D 5006	Standard Test Method for Measurement of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels (DoD Adopted)
ASTM D 5186	Standard Test Method for Determination of the Aromatic Content and Polynuclear Aromatic Content of Diesel Fuels and Aviation Turbine Fuels by Supercritical Fluid Chromatography
ASTM D 5452	Standard Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration (DoD Adopted)
ASTM D 5453	Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence
ASTM D 5972	Standard Test Method for Freezing Point of Aviation Fuels (Automatic Phase Transition Method)
ASTM D 6045	Standard Test Method for Color of Petroleum Products by the Automatic Tristimulus Method
ASTM D 7153	Standard Test Method for Freezing Point of Aviation Fuels (Automatic Laser Method)
ASTM D 7154	Standard Test Method for Freezing Point of Aviation Fuels (Automatic Fiber Optical Method)
ASTM D 7224	Standard Test Method for Determining Water Separation Characteristics of Kerosine-type Aviation Turbine Fuels Containing Additives by Portable Separometer
ASTM E 29	Standard Practice for Using Significant Digits in Test Data to Determine Conformance with the Specifications (DoD Adopted)
IEEE/ASTM SI 10	American National Standard for Use of the International System of Units (SI): The Modern Metric System (DoD Adopted)

(Copies of these documents are available at ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken PA 19428-2959. Electronic copies of ASTM standards may be obtained from <http://www.astm.org>)

2.4 Order of precedence. In the event of a conflict between the text of this document and the references cited herein (except for related specification sheets), the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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3. REQUIREMENTS

3.1 Materials. Fuel supplied under this specification shall be refined hydrocarbon distillate fuel oils containing additives in accordance with 3.3. The feedstock from which the fuel is refined shall be crude oils derived from petroleum, tar sands, oil shale, or mixtures thereof.

3.1.1 Materials for Blending. With the approval of both the procuring activity and the applicable fuel technical authorities listed below, up to 50 volume % of the finished fuel may consist solely of Synthetic Paraffinic Kerosene (SPK) derived from a Fischer-Tropsch (FT) process meeting requirements of Appendix A. Finished fuel shall contain additives in accordance with 3.3. During the platform certification/approval process, JP-8 containing SPK will be designated JP-8/SPK.

Procuring Activity: Product Technology and Standardization, DESC, 8725 John J. Kingman Road, Fort Belvoir, VA 22060

Cognizant activity for the Navy and Marine Corps: Naval Fuels and Lubricants Cross Functional Team, AIR-4.4.1, Building 2360, 22229 Elmer Road, Patuxent River, MD 20670-1534.

Cognizant activity for the Air Force: Fuels Certification Office, 77th Monohan Street, Area B, Wright-Patterson AFB, OH 45433-7017.

Cognizant activities for the Army:

Army Ground: US Army TARDEC/RDECOM, 6501 E. 11 Mile Road, AMSRD-TAR-D (MS-110), Warren, MI 48397-5000.

Army Aviation: US Army RDECOM, Attn: AMSRD-AMR-AE-P, Building 4488, Room C-211, Redstone Arsenal, AL 35898-5000

3.1.2 Non-FT Materials. The use of synthetic blending materials represents a potential departure from experience and from the key assumptions which form the basis for fuel property requirements. It is the long-term goal of this specification to fully encompass fuels derived from synthetic materials and non-conventional sources once they have been defined but, this is only partially complete. Until this is accomplished, specific fuel formulations from synthetic materials or non-conventional sources may be submitted to AFRL/RZTG, Bldg 490, 1790 Loop Road N, WPAFB, OH 45433 to begin evaluation of compliance with the intent of this specification.

3.2 Chemical and physical requirements. The chemical and physical properties of a finished fuel containing only the materials described in 3.1 shall conform to the requirements listed in Table 1.

3.2.1 Chemical and physical requirements of blended finished fuels. The chemical and physical properties of a finished fuel blend containing any amount of synthetic SPK as described in 3.1.1 shall conform to the requirements listed in Table 2.

3.3 Additives. The type and amount of each additive used shall be made available when requested by the procuring activity or user (6.2.d). The only additives approved for use are those referenced in this specification.

3.3.1 Antioxidants. Immediately after processing and before the fuel is exposed to the atmosphere (such as during rundown into feed/batch tankage), an approved antioxidant (3.3.1.1) shall be blended into the fuel in order to prevent the formation of gums and peroxides after manufacture. The concentration of the antioxidant to be added shall be:

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a. Not less than 17.2 milligrams (mg) nor more than 24.0 mg of active ingredient per liter (L) of fuel (6.0 to 8.4 lb/1000 barrels) to all JP-8 fuel that contains blending stocks that have been hydrogen treated or were manufactured from a Fischer-Tropsch process.

b. At the option of the supplier, not more than 24.0 mg of active ingredient per liter of fuel (8.4 lb/1000 barrels) may be added to JP-8 fuels that do not contain hydrogen treated blending stocks nor Fischer-Tropsch products.

3.3.1.1 Antioxidant formulations. The following antioxidant formulations are approved:

- a. 2,6-di-tert-butyl-4-methylphenol
- b. 6-tert-butyl-2,4-dimethylphenol
- c. 2,6-di-tert-butylphenol
- d. 75 percent min-2,6-di-tert-butylphenol
25 percent max tert-butylphenols and tri-tert-butylphenols
- e. 72 percent min 6-tert-butyl-2,4-dimethylphenol
28 percent max tert-butyl-methylphenols and tert-butyl-dimethylphenols
- f. 55 percent min 2,4-dimethyl-6-tert-butylphenol and
15 percent min 2,6-di-tert-butyl-4-methylphenol and
30 percent max mixed methyl and dimethyl tert-butylphenols

3.3.2 Metal deactivator. A metal deactivator, N,N'-disalicylidene-1,2-propanediamine, may be blended into the fuel. The concentration of active material used on initial batching of the fuel at the refinery shall not exceed 2.0 mg/L. Cumulative addition of metal deactivator when redoping the fuel, shall not exceed 5.7 mg/L. Metal deactivator additive shall not be used in JP-8 unless the supplier has obtained written consent from the procuring activity and user.

3.3.3 Static dissipater additive. An additive shall be blended into the fuel in sufficient concentration to increase the conductivity of the fuel at the point of injection to within the range specified in Table 1 for fuel offered in accordance with 3.1 or as specified in Table 2 for finished fuel when allowed per 3.1.1. The point of injection of the additive shall be determined by agreement between the purchasing authority and the supplier. The following electrical conductivity additive is approved: Stadis® 450 marketed by Innospec Fuel Specialties LLC (formerly Octel Starreon LLC), Newark, DE 19702.

3.3.4 Corrosion inhibitor/lubricity improver additive. A corrosion inhibitor/lubricity improver (CI/LI) additive conforming to MIL-PRF-25017 shall be blended into the F-34 (JP-8) grade fuel by the contractor. The CI/LI additive is optional for F-35. The amount added shall be equal to or greater than the minimum effective concentration and shall not exceed the maximum allowable concentration listed in the latest revision of QPL-25017. The contractor or transporting agency, or both, shall maintain and upon request shall make available to the Government evidence that the CI/LI additives used are equal in every respect to the qualification products listed in QPL-25017. The point of injection of the CI/LI additive shall be determined by agreement between the purchasing authority and the supplier.

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TABLE 1. *Chemical and physical requirements and test methods.*

Property	Min	Max	Test Methods ASTM Standards
Color, Saybolt ¹			D 156 ² or D 6045
Total acid number, mg KOH/gm		0.015	D 3242
Aromatics, vol percent		25.0	D 1319
Sulfur, total, mass percent		0.30	D 129, D 1266, D 2622, D 3120, D 4294 ² , or D 5453
Sulfur mercaptan, mass percent or Doctor test		0.002 negative	D 3227 D 4952
Distillation temperature, °C ³ (D 2887 limits given in parentheses)			D 86 ² or D 2887
Initial boiling point ¹			
10 percent recovered		205 (186)	
20 percent recovered ¹			
50 percent recovered ¹			
90 percent recovered ¹			
Final boiling point		300 (330)	
Residue, vol percent		1.5	
Loss, vol percent		1.5	
Flash point, °C ⁴	38		D 56, D 93 ² , or D 3828
Density			D 1298 or D 4052 ²
Density, kg/L at 15°C or	0.775	0.840	
Gravity, API at 60°F	37.0	51.0	
Freezing point, °C		-47	D 2386 ² , D 5972, D 7153, or D 7154
Viscosity, at -20°C, mm ² /s		8.0	D 445
Net heat of combustion, MJ/kg	42.8		D 3338, D 4529, or D 4809 ²
Hydrogen content, mass percent	13.4		D 3343 or D 3701 ²
Smoke point, mm, or	25.0		D 1322
Smoke point, mm, and	19.0		D 1322
Naphthalenes, vol percent		3.0	D 1840
Calculated cetane index ¹			D 976 ⁵ or D 4737
Copper strip corrosion, 2 hr at 100°C (212°F)		No. 1	D 130
Thermal stability			D 3241 ⁶
change in pressure drop, mm Hg		25	
heater tube deposit, visual rating		<3 ⁷	

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TABLE 1. Chemical and physical requirements and test methods – Continued

Property	Min	Max	Test Methods ASTM Standards
Existent gum, mg/100 mL		7.0	D 381
Particulate matter, mg/L ⁸		1.0	D 2276 or D 5452 ²
Filtration time, minutes ⁸		15	
Water reaction interface rating		1 b	D 1094
Water separation index ⁹			D 3948 or D 7224 ²
Fuel system icing inhibitor, vol percent	0.10	0.15	D 5006 ¹⁰
Fuel electrical conductivity, pS/m ¹¹			D 2624

NOTES:

- To be reported – not limited.
- Referee Test Method.
- A condenser temperature of 0° to 4°C (32° to 40°F) shall be used for the distillation by ASTM D 86.
- ASTM D 56 may give results up to 1°C (2°F) below the ASTM D 93 results. ASTM D 3828 may give results up to 1.7°C (3°F) below the ASTM D 93 results. Method IP170 is also permitted.
- Mid-boiling temperature may be obtained by either ASTM D 86 or ASTM D 2887 to perform the cetane index calculation. ASTM D 86 values should be corrected to standard barometric pressure.
- See 4.5.3 for ASTM D 3241 test conditions and test limitations.
- Peacock or Abnormal color deposits result in a failure.
- A minimum sample size of 3.79 liters (1 gallon) shall be filtered. Filtration time will be determined in accordance with procedure in Appendix B. This procedure may also be used for the determination of particulate matter as an alternate to ASTM D 2276 or ASTM D 5452.
- The minimum microseparometer rating using a Micro-Separometer (MSEP) shall be as follows:

JP-8 Additives	MSEP Rating, min.
Antioxidant (AO)*, Metal Deactivator (MDA)*	90
AO*, MDA*, and Fuel System Icing Inhibitor (FSII)	85
AO*, MDA*, and Corrosion Inhibitor/Lubricity Improver (CI/LI)	80
AO*, MDA*, FSII and CI/LI)	70

*Even though the presence or absence does not change these limits, samples submitted for specification or conformance testing shall contain the same additives present in the refinery batch. Regardless of which minimum the refiner selects to meet, the refiner shall report the MSEP rating on a laboratory hand blend of the fuel with all additives required by the specification.

- Test shall be performed in accordance with ASTM D 5006 using the DiEGME scale of the refractometer.
- The conductivity must be between 150 and 600 pS/m for F-34 (JP-8) and between 50 and 600 pS/m for F-35, at ambient temperature or 29.4°C (85°F), whichever is lower, unless otherwise directed by the procuring activity. In the case of JP-8+100, JP-8 with the thermal stability improver additive (see 3.3.6), the conductivity limit must be between 150 to 700 pS/m at ambient temperature or 29.4°C (85°F), whichever is lower, unless otherwise directed by the procuring activity.

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TABLE 2. Chemical and physical requirements and test methods for JP-8 with up to 50 percent SPK blend component

Property	Min	Max	Test Methods ASTM Standards
Color, Saybolt ¹			D 156 ² or D 6045
Total acid number, mg KOH/gm		0.015	D 3242
Aromatics, vol percent	8.0	25.0	D 1319
Olefins, vol percent		5.0	D 1319
Sulfur, total, mass percent		0.30	D 129, D 1266, D 2622, D 3120, D 4294 ² , or D 5453
Sulfur mercaptan, mass percent or Doctor test		0.002 negative	D 3227 D 4952
Distillation temperature, °C ³			D 86
Initial boiling point ¹			
10 percent recovered (T10)	157	205	
20 percent recovered ¹			
50 percent recovered (T50)	168	229	
90 percent recovered (T90)	183	262	
Final boiling point		300	
T50 – T10	15		
T90 – T10	40		
Residue, vol percent		1.5	
Loss, vol percent		1.5	
Flash point, °C ⁴	38	68	D 56, D 93 ² , or D 3828
Density			D 1298 or D 4052 ²
Density, kg/L at 15°C or Gravity, API at 60°F	0.775 37.0	0.840 51.0	
Freezing point, °C		-47	D 2386 ² , D 5972, D 7153, or D 7154
Viscosity, at -20°C, mm ² /s		8.0	D 445
Net heat of combustion, MJ/kg	42.8		D 3338, D 4529, or D 4809 ²
Hydrogen content, mass percent	13.4		D 3343 or D 3701 ²
Smoke point, mm, or	25.0		D 1322
Smoke point, mm, and	19.0		D 1322
Naphthalenes, vol percent		3.0	D 1840
Calculated cetane index ¹			D 976 ⁵ or D 4737
Copper strip corrosion, 2 hr at 100°C (212°F)		No. 1	D 130
Thermal stability			D 3241 ⁶
change in pressure drop, mm Hg		25	
heater tube deposit, visual rating		<3 ⁷	

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TABLE 2. Chemical and physical requirements and test methods for JP-8 with up to 50 percent SPK blend component – Continued

Property	Min	Max	Test Methods ASTM Standards
Existent gum, mg/100 mL		7.0	D 381
Particulate matter, mg/L ⁸		1.0	D 2276 or D 5452 ²
Filtration time, minutes ⁸		15	
Water reaction interface rating		1 b	D 1094
Water separation index ⁹			D 3948 or D 7224 ²
Fuel system icing inhibitor, vol percent	0.10	0.15	D 5006 ¹⁰
Fuel electrical conductivity, pS/m ¹¹			D 2624
Lubricity, wear scar diameter, mm		0.85	D 5001

NOTES:

- To be reported – not limited.
- Referee Test Method.
- A condenser temperature of 0° to 4°C (32° to 40°F) shall be used for the distillation by ASTM D 86.
- ASTM D 56 may give results up to 1°C (2°F) below the ASTM D 93 results. ASTM D 3828 may give results up to 1.7°C (3°F) below the ASTM D 93 results. Method IP170 is also permitted.
- Mid-boiling temperature may be obtained by ASTM D 86 to perform the cetane index calculation. ASTM D 86 values should be corrected to standard barometric pressure.
- See 4.5.3 for ASTM D 3241 test conditions and test limitations.
- Peacock or Abnormal color deposits result in a failure.
- A minimum sample size of 3.79 liters (1 gallon) shall be filtered. Filtration time will be determined in accordance with procedure in Appendix B. This procedure may also be used for the determination of particulate matter as an alternate to ASTM D 2276 or ASTM D 5452.
- The minimum microseparator rating using a Micro-Separator (MSEP) shall be as follows:

JP-8 Additives	MSEP Rating, min.
Antioxidant (AO)*, Metal Deactivator (MDA)*	90
AO*, MDA*, and Fuel System Icing Inhibitor (FSII)	85
AO*, MDA*, and Corrosion Inhibitor/Lubricity Improver (CI/LI)	80
AO*, MDA*, FSII and CI/LI)	70

*Even though the presence or absence does not change these limits, samples submitted for specification or conformance testing shall contain the same additives present in the refinery batch. Regardless of which minimum the refiner selects to meet, the refiner shall report the MSEP rating on a laboratory hand blend of the fuel with all additives required by the specification.

- Test shall be performed in accordance with ASTM D 5006 using the DIEGME scale of the refractometer.
- The conductivity must be between 150 and 600 pS/m for F-34 (JP-8) and between 50 and 600 pS/m for F-35, at ambient temperature or 29.4°C (85°F), whichever is lower, unless otherwise directed by the procuring activity. In the case of JP-8+100, JP-8 with the thermal stability improver additive (see 3.3.6), the conductivity limit must be between 150 to 700 pS/m at ambient temperature or 29.4°C (85°F), whichever is lower, unless otherwise directed by the procuring activity.

3.3.5 **Fuel system icing inhibitor.** The use of a fuel system icing inhibitor shall be mandatory for JP-8 and shall conform to MIL-DTL-85470. The point of injection of the additive for JP-8 shall be determined by agreement between the purchasing authority and the supplier. The fuel system icing inhibitor is not to be added to NATO F-35 unless so directed by the purchasing authority.

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3.3.6 Thermal stability improver additive. Due to logistic concerns, personnel at the operating location shall request written approval from the cognizant activity to add a thermal stability improver additive to the fuel. If approval is given, the concentration of the additive and location of injection shall be specified by the cognizant service activity listed below. For USAF aircraft, this approval does not override the single manager's authority for specifying allowed/disallowed fuels. JP-8 fuel with an approved thermal stability improver additive at the required concentration shall be designated as JP-8+100. Thermal stability improver additive shall not be used in JP-8 without approval, in writing, from:

Cognizant activity for the Navy and Marine Corps: Naval Fuels and Lubricants Cross Functional Team, AIR-4.4.1, Building 2360, 22229 Elmer Road, Patuxent River, MD 20670-1534.

Cognizant activity for the Air Force: HQ Air Force Petroleum Agency, HQ AFPET/AFT, 2430 C Street, Building 70, Area B, Wright-Patterson AFB 45433-7632.

Cognizant activities for the Army:

Army Ground: US Army TARDEC/RDECOM, 6501 E. 11 Mile Road, AMSRD-TAR-D (MS-110), Warren, MI 48397-5000.

Army Aviation: US Army RDECOM, Attn: AMSRD-AMR-AE-P, Building 4488, Room C-211, Redstone Arsenal, AL 35898-5000

3.3.6.1 Qualified additives. Qualified thermal stability improver additives are listed in Table 3.

TABLE 3. Qualified thermal stability improver additives.

Additive Name	Qualification Reference	Manufacturer
SPEC AID 8Q462	AFRL/PRSF Ltr, 9 Dec 97	GE Water & Process Technologies 9669 Grogan Mill Road The Woodlands, TX 77380
AeroShell Performance Additive 101	AFRL/PRSF Ltr, 13 Jan 98	Shell Aviation Limited Shell Centre York Road London, UK SE1 7NA

3.3.7 Premixing of additives. Additives shall not be premixed with other additives before injection into the fuel so as to prevent possible reactions among the concentrated forms of different additives.

3.4 Workmanship. At the time of Government acceptance, the finished fuel or finished fuel blend shall be visually free from undissolved water, sediment or suspended matter, and shall be clear and bright. In case of dispute, the fuel shall be clear and bright at 21°C (70°F) and shall contain no more than 1.0 mg/L of particulate matter as required in Table 1 for any finished fuel containing only the materials described in 3.1 or, Table 2 for finished fuel blends containing any amount of SPK as described in 3.1.1.

3.5 Recycled, recovered, or environmentally preferable materials. Recycled, recovered, or environmentally preferable materials should be used to the maximum extent possible, provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

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4. VERIFICATION

4.1 Classification of inspections. The inspection requirements specified herein are classified as quality conformance inspections (see 4.2).

4.2 Qualification inspection conditions. Test for acceptance of individual lots shall consist of tests for all applicable requirements specified in section 3. Quality conformance inspection shall include the test requirements herein.

4.2.1 Inspection lot. For acceptance purposes, individual lots shall be examined as specified herein and subjected to tests for all applicable requirements cited in section 3.

4.3 Inspection.

4.3.1 Inspection conditions. Any finished fuel containing only the materials described in 3.1 shall comply with the limiting values specified in Table 1 using the cited test methods. Any finished fuel blend containing any amount of SPK as described in 3.1.1 shall comply with the limiting values specified in Table 2 using the cited test methods. Any SPK blend component as described in 3.1.1 shall comply with the limiting values specified in Table A-I using the cited test methods. The specified limiting values must not be changed. This precludes any allowance for test method precision and adding or subtracting digits. For the purposes of determining conformance with the specified limiting values, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right hand place of digits used in expressing the specified limiting value, in accordance with the Rounding-Off Method of ASTM E 29.

4.4 Sampling plans.

4.4.1 Sampling. Each bulk or packaged lot of material shall be sampled for verification of product quality in accordance with ASTM D 4057 or ASTM D 4177, except where individual test procedures contain specific sampling instructions.

4.4.2 Sampling for inspection of filled containers. A random sample of filled containers shall be selected from each lot and shall be subjected to the examination of filled containers as specified in 4.5.1.3.

4.5 Methods of inspection.

4.5.1 Examination of product.

4.5.1.1 Visual inspection. Samples selected in accordance with 4.4.1 shall be visually examined for compliance with 3.4.

4.5.1.2 Examination of empty containers. Before filled, each unit container shall be visually inspected for cleanliness and suitability in accordance with ASTM D 4057.

4.5.1.3 Examination of filled containers. Samples taken as specified in 4.4.2 shall be examined for conformance to MIL-STD-290 with regard to fill, closure, sealing, leakage, packaging, packing, and markings. Any container with one or more defects under the required fill shall be rejected.

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4.5.2 Chemical and physical tests. Tests to determine compliance with chemical and physical requirements shall be conducted in accordance with Table 1 or Table 2 and/or Table A-I as follows. Any finished fuel containing only the materials described in 3.1 shall pass all tests listed in Table 1. Any finished fuel containing any amount of SPK as described in 3.1.1 shall pass all tests listed in Table 2. Any SPK blend component as defined in 3.1.1 shall pass all tests listed in Table A-I. No additional testing shall be required. Requirements contained herein are not subject to corrections for test tolerances. If multiple determinations are made, results falling within any specified repeatability and reproducibility tolerances may be averaged. For rounding off of significant figures, ASTM E 29 shall apply to all tests required by this specification.

4.5.3 Thermal stability tests. The thermal stability test shall be conducted using ASTM D 3241. The heated tube shall be rated visually (see Annex A1 of ASTM D 3241).

4.5.3.1 ASTM D 3241 test conditions.

- a. Heater tube temperature at maximum point: 260°C (500°F).
- b. Fuel system pressure: 3.45 MPa (500 psig).
- c. Fuel flow rate: 3.0 mL/min.
- d. Test duration: 150 minutes.

4.5.3.2 ASTM D 3241 reported data. The following data shall be reported:

- a. Differential pressure in millimeter of mercury at 150 minutes, or time to differential pressure of 25 mm Hg, whichever comes first.
- b. Heater tube deposit visual code rating at the end of the test.

5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When actual packaging of materiel is to be performed by DoD or in-house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activities within the Military Service or Defense Agency, or within the military service's system commands. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD-ROM products, or by contacting the responsible packaging activity.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. The fuels covered by this specification are intended for use in aircraft turbine engines. JP-8 contains military unique additives that are required by military weapon systems. This requirement is unique to military aircraft and engine designs. When authorized, JP-8 (F-34) may be used in ground - based turbine and diesel engines. NATO F-35 is intended for commercial aviation, but can be converted to JP-8 (F-34) by the addition of the appropriate additives.

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6.2 Acquisition requirements. Acquisition documents must specify the following:

- a. Title, number, date of this specification, and grade (type) of fuel.
- b. Quantity required and size containers desired.
- c. Level of packaging and packing required (see 5.1).
- d. Location and injection method for addition of electrical conductivity additive, fuel system icing inhibitor and corrosion inhibitor, as required.

6.3 Conversion of metric units. Units of measure have been converted to the International System of Units (SI) (Metric) in accordance with ASTM SI 10. If test results are obtained in units other than metric or there is a requirement to report dual units, ASTM SI 10, should be used to convert the units.

6.4 Definitions.

6.4.1 Bulk lot. A bulk lot consists of an indefinite quantity of a homogeneous mixture of material offered for acceptance in a single isolated container or manufactured in a single plant run through the same processing equipment, with no change in ingredient material.

6.4.2 Packaged lot. A packaged lot consists of an indefinite number of 208-liter (55-gallon) drums, or smaller unit packages of identical size and type, offered for acceptance and filled from an isolated tank containing a homogeneous mixture of material; or filled with a homogeneous mixture of material run through the same processing equipment with no change in ingredient material.

6.4.3 Homogenous product. A homogeneous product is defined as a product where samples taken at various levels of the batch tank are tested for the defining homogeneous characteristics and all values obtained meet the repeatability precision requirements for that test method.

6.4.4 Synthetic Paraffinic Kerosene (SPK) Kerosene consisting solely of n-paraffins, cyclic-paraffins, and iso-paraffins.

6.4.5 Fischer-Tropsch (FT) Process A catalyzed chemical process in which a synthesis gas consisting of carbon monoxide and hydrogen are converted into liquid hydrocarbons of various forms. Typical catalysts used are based on iron and cobalt.

6.5 Subject term (key word) listing.

Antioxidants
Corrosion inhibitor
Fischer-Tropsch
Flash point
Freezing point
Hydrocarbon distillate fuel
Hydrogen content
Icing inhibitor
Synthetic Paraffinic Kerosene (SPK)
Lubricity improver
Static dissipator
Thermal stability improver

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6.6 International agreements. Certain provisions of this specification are the subject of international standardization agreement ASIC AIR STD 15/6, ASIC AIR STD 15/9, NATO STANAG 1135, and NATO STANAG 3747. When amendment, revision, or cancellation of this specification is proposed which will modify the international agreement concerned, the preparing activity will take appropriate action through international standardization channels including departmental standardization offices, to change the agreement or make other appropriate accommodations.

6.7 Material safety data sheet. Contracting officers will identify those activities requiring copies of completed Material Safety Data Sheets prepared in accordance with FED-STD-313. The pertinent Government mailing addresses for submission of data are listed in FED-STD-313.

6.8 Test report. Test data required by 4.5 should be available for the procurement activity and user in the same order as listed in Table 1 for materials conforming to 3.2 requirements or as listed in Table 2 for materials conforming to 3.2.1 requirements. The Inspection Data on Aviation Turbine Fuels form published in ASTM D 1655 should be used as a guide. Also, the type and amount of additives used should be reported.

6.9 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

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APPENDIX A

SYNTHETIC PARAFFINIC KEROSENE (SPK)

A.1 SCOPE

A.1.1 Scope. This Appendix addresses 100 percent SPK derived from manufactured products of a Fischer-Tropsch process (identified in 3.1.1). This Appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

A.2 REQUIREMENTS

A.2.1 Chemical and physical requirements. The chemical and physical requirements of the SPK shall conform to those specified in Table A-I.

A.2.2 Additives.

A.2.2.1 Antioxidants. Addition of antioxidants shall adhere to the criteria specified in 3.3.1.

A.2.2.2 Static dissipater additive (SDA). If SPK is to be transported prior to blending with refined hydrocarbon distillate fuel, static dissipater additive shall be injected in sufficient concentration to increase the conductivity of the fuel to within the range specified in Table A-I. The point of injection of the additive shall be determined by agreement between the purchasing authority and the supplier. The following electrical conductivity additive is approved: Stadis® 450 marketed by Innospec Fuel Specialties LLC (formerly Octel Starreon LLC), Newark, DE 19702.

TABLE A-I. Chemical and physical requirements and test methods for 100 percent SPK.

Property	Min	Max	Test Method
Aromatics, vol percent		1	D 5186
Sulfur, total, mass percent		0.0015	D 2622, D 3120, or D 5453 ¹
Distillation temperature, °C			D 86
Initial boiling point ²			
10 percent recovered	157	205	
20 percent recovered ²			
50 percent recovered	168	229	
90 percent recovered	183	262	
Final boiling point		300	
Residue, vol percent		1.5	
Loss, vol percent		1.5	
Flash point, °C	38	68	D 56, D 93 ¹ , or D 3828
Density			D 1298 or D 4052 ¹
Density, kg/L at 15°C or	0.751	0.840	
Gravity, API at 60°F	37.0	57.0	

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TABLE A-I. Chemical and physical requirements and test methods for 100 percent SPK - Continued.

Property	Min	Max	Test Method
Freezing point, °C		-47	D 2386 ¹ or D 5972
Viscosity at -20°C, mm ² /s		8.0	D 445
Viscosity at 40°C, mm ² /s ²			D 445
Net heat of combustion, MJ/kg	42.8		D 3338 or D 4809 ¹
Calculated cetane index ²			D 976 ³ or D 4737
Naphthalenes, vol percent		0.1	D 1840
Thermal stability change in pressure drop, mm Hg		25	D 3241
heater tube deposit, visual rating		<3 ⁴	
Particulate matter, mg/L ⁵		1.0	D 2276 or D 5452 ¹
Filtration time, minutes ⁵		15	
Water separation index			D 3948 or D 7224 ¹
With SDA	70		
Without SDA	85		
Electrical conductivity, pS/m ⁶	150	450	D 2624
NOTES: 1. Referee Test Method. 2. To be reported – not limited. 3. Mid-boiling temperature may be obtained by ASTM D 86 to perform the cetane index calculation. ASTM D 86 values should be corrected to standard barometric pressure. 4. Peacock or Abnormal color deposits result in a failure. 5. A minimum sample size of 3.79 liters (1 gallon) shall be filtered. Filtration time will be determined in accordance with procedure in Appendix B. This procedure may also be used for the determination of particulate matter as an alternate to ASTM D 2276 or ASTM D 5452. 6. Electrical Conductivity when required per A.2.2.2 shall be determined at ambient temperature or 29.4°C (85°F), whichever is lower, unless otherwise directed by the procuring activity.			

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APPENDIX B

METHOD FOR DETERMINATION OF FILTRATION TIME AND TOTAL SOLIDS

B.1 SCOPE

B.1.1 Scope. This Appendix describes the method for determining singularly or simultaneously the filterability characteristics and solids contamination of jet fuel. The purpose is to detect and prevent contaminants in jet fuel that can plug and cause rupture of ground filtration equipment, thereby affecting flight reliability of aircraft. This Appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

B.2 METHOD

B.2.1 Summary of method. 3.79 liters (1 gallon) of jet fuel is filtered through a membrane filter in the laboratory. The time required to filter this volume is measured in minutes and solids content is determined gravimetrically.

B.3 APPARATUS

- a. Membrane filter: White, plain, 47 mm diameter, nominal pore size 0.8 μm . The membrane filter must be approved by ASTM for use with ASTM D 5452.
- b. Filtration apparatus: The apparatus, constructed of stainless steel, consists of a funnel and a funnel base with a filter support such that a membrane filter and a flow reducing washer can be securely held between the sealing surface of the funnel and funnel base (see Figure 2 in ASTM D 5452).
- c. Flow reducing washer: A 47-mm diameter flow reducer washer with an effective filtration area of 4.8 cm^2 (Millipore Corporation Part No. XX10 04710).
- d. Vacuum flask: A minimum of 4 liters.
- e. Vacuum system: That develops in excess of 67.5 kPa (20 inches of mercury) vacuum.
- f. Oven: Of the static type (without fan assisted circulation) controlling to $90^\circ \pm 5^\circ \text{C}$ ($194^\circ \pm 9^\circ \text{F}$).
- g. Forceps: Flat-bladed with unserrated nonpointed tips.
- h. Dispenser, rinsing solvent (petroleum ether): Containing a 0.45 μm membrane filter in the delivery line. If solvent has been pre-filtered using a 0.45 μm filter then an inline filter is not required.
- i. Glass petri dish: Approximately 125 mm in diameter with removable cover.
- j. Analytical balance: Single or double pan, the precision standard deviation of which must be 0.07 mg or better.

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B.4 PREPARATION

B.4.1 Preparation of apparatus and sample containers. All components of the filtration apparatus (except the vacuum flask), sample containers and caps must be cleaned as described in paragraph 9 of ASTM D 5452. All metal parts of the filtration apparatus are to be electrically bonded and grounded, including the fuel sample container. See ASTM D 5452 for other safety precautions.

B.5 SAMPLING

B.5.1 Sampling. Obtain a representative 3.79 L (1 gallon) sample as directed in paragraph 8 of ASTM D 5452. When sampling from a flowing stream is not possible, an all level sample or an average sample, in accordance with ASTM D 4057 and/or ASTM D 4177 shall be permitted. The 3.79 L (1 gallon) sample container shall be an interior epoxy-coated metal can, a brown glass bottle, or a clear glass bottle protected by suitable means from exposure to light.

B.6 PROCEDURE

B.6.1 Test procedure.

- a. Using forceps, place a new membrane (test) filter in a clean petri dish. Place the petri dish with the lid slightly ajar in a $90 \pm 5^{\circ}\text{C}$ oven for 30 minutes. Remove the petri dish from the oven and place it near the balance with the lid slightly ajar, but still protecting the filter from airborne contamination, for 30 minutes.
- b. Weigh the test filter. A filter weighing in excess of 90 mg will not be used for time filtration testing.
- c. Place a flow reducing washer (required only for time filtration testing) on top of funnel base then place a test filter on top of the reducing washer and secure the funnel to the funnel base.
- d. Immediately prior to filtering the fuel, shake the sample to obtain a homogeneous mix and assure that fuel temperature does not exceed 30°C (86°F). Clean the exterior or top portion of the sample container to ensure that no contaminants are introduced. Any free water present in the fuel sample will invalidate the filtration time results by giving an excessive filtration time rating.
- e. With the vacuum off, pour approximately 200 mL of fuel into the funnel.
- f. Turn vacuum on and record starting time. Continue filtration of the 3.79 liters (1 gallon) sample, periodically shaking the sample container to maintain a homogenous mix. Record the vacuum (kPa or inches of mercury) 1 minute after start and again immediately prior to completion of filtration. Throughout filtration, maintain a sufficient quantity of fuel in the funnel so that the membrane filter is always covered.
- g. Report the filtration time in minutes expressed to the nearest whole number. If filtration of the 3.79 liters (1 gallon) is not completed within 30 minutes, the test will be stopped and the volume of the fuel filtered will be measured. In these cases, report filtration time as ">30 minutes" and the total volume of fuel filtered.
- h. Report the vacuum (kPa or inches of mercury) as determined from the average of the two readings taken in B.6.f.

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- i. After recording the filtration time, shut off the vacuum and rinse the sample container with approximately 100 mL of filtered petroleum ether and dispense into the filtration funnel. Turn vacuum on and filter the 100 mL rinse. Turn vacuum off and wash the inside of the funnel with approximately 50 mL of filtered petroleum ether. Turn vacuum on and filter. Repeat the funnel rinse with another 50 mL of petroleum ether but allow the rinse to soak the filter for approximately 30 seconds before turning the vacuum on to filter the rinse. With vacuum on, carefully remove the top funnel and rinse the periphery of the filter by directing a gentle stream of petroleum ether from the solvent dispenser from the edge of the filter toward the center, taking care not to wash contaminants off the filter. Maintain vacuum after final rinse for a few seconds to remove the excess petroleum ether from the filter.
- j. Using forceps, carefully remove test filter (from the funnel base and flow reducing washer if present) and place in a clean petri dish. Dry in the oven at $90^{\circ} \pm 5^{\circ}\text{C}$ ($194^{\circ} \pm 9^{\circ}\text{F}$) for 30 minutes with the cover on the petri dish slightly ajar. Remove the petri dish from the oven and place it near the balance with the lid slightly ajar, but still protecting the filter from airborne contamination, for 30 minutes. Reweigh the filter.
- k. Report the total solids content in mg/liter by using the following formula:

$$\frac{\text{Weight gain of filter in mg}}{3.785} = \text{mg/liter}$$

- l. Should the sample exceed the 30-minute filtration time and a portion of the fuel is not filtered, the solids content in mg/liter will be figured as follows: Determine the volume of fuel filtered by subtracting the mL of fuel remaining from 3.785.

$$\frac{\text{Weight gain of filter in mg}}{\text{mL of fuel filtered} \times 0.001} = \text{mg/liter}$$

B.7 Test conditions for filtration time

- a. The vacuum should exceed 67.5 kPa (20 inches of mercury) throughout the test. The differential pressure across the filter should exceed 67.5 kPa (20 inches of mercury).
- b. The fuel temperature shall be between 18° and 30°C (64° and 86°F). If artificial heat (such as a hot water bath) is used to heat the sample, erroneously high filtration times may occur, but this approach is allowed.

B.8 NOTES

B.8.1 Filtration time. If it is desired to determine the filtration time and not the total solids content, perform the test by omitting steps B.6.1i, B.6.1j, B.6.1k, and B.6.1l.

B.8.2 Total solids. If it is desired to determine the total solids content and not the filtration time, use of the flow reducing washer may be omitted. It is also permissible, but not required, to use a control filter for a specific analysis or a series of analyses. When this is accomplished, the procedures specified in ASTM D 5452 apply.

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- i. After recording the filtration time, shut off the vacuum and rinse the sample container with approximately 100 mL of filtered petroleum ether and dispense into the filtration funnel. Turn vacuum on and filter the 100 mL rinse. Turn vacuum off and wash the inside of the funnel with approximately 50 mL of filtered petroleum ether. Turn vacuum on and filter. Repeat the funnel rinse with another 50 mL of petroleum ether but allow the rinse to soak the filter for approximately 30 seconds before turning the vacuum on to filter the rinse. With vacuum on, carefully remove the top funnel and rinse the periphery of the filter by directing a gentle stream of petroleum ether from the solvent dispenser from the edge of the filter toward the center, taking care not to wash contaminants off the filter. Maintain vacuum after final rinse for a few seconds to remove the excess petroleum ether from the filter.
- j. Using forceps, carefully remove test filter (from the funnel base and flow reducing washer if present) and place in a clean petri dish. Dry in the oven at $90^{\circ} \pm 5^{\circ}\text{C}$ ($194^{\circ} \pm 9^{\circ}\text{F}$) for 30 minutes with the cover on the petri dish slightly ajar. Remove the petri dish from the oven and place it near the balance with the lid slightly ajar, but still protecting the filter from airborne contamination, for 30 minutes. Reweigh the filter.
- k. Report the total solids content in mg/liter by using the following formula:

$$\frac{\text{Weight gain of filter in mg}}{3.785} = \text{mg/liter}$$

- l. Should the sample exceed the 30-minute filtration time and a portion of the fuel is not filtered, the solids content in mg/liter will be figured as follows: Determine the volume of fuel filtered by subtracting the mL of fuel remaining from 3.785.

$$\frac{\text{Weight gain of filter in mg}}{\text{mL of fuel filtered} \times 0.001} = \text{mg/liter}$$

B.7 Test conditions for filtration time

- a. The vacuum should exceed 67.5 kPa (20 inches of mercury) throughout the test. The differential pressure across the filter should exceed 67.5 kPa (20 inches of mercury).
- b. The fuel temperature shall be between 18° and 30°C (64° and 86°F). If artificial heat (such as a hot water bath) is used to heat the sample, erroneously high filtration times may occur, but this approach is allowed.

B.8 NOTES

B.8.1 Filtration time. If it is desired to determine the filtration time and not the total solids content, perform the test by omitting steps B.6.1i, B.6.1j, B.6.1k, and B.6.1l.

B.8.2 Total solids. If it is desired to determine the total solids content and not the filtration time, use of the flow reducing washer may be omitted. It is also permissible, but not required, to use a control filter for a specific analysis or a series of analyses. When this is accomplished, the procedures specified in ASTM D 5452 apply.

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CONCLUDING MATERIAL

Custodians:

Navy – AS
Army – MR
Air Force – 68
DLA – PS

Preparing activity:

Air Force – 68
(Project 9130-2007-001)

Review activities:

Army – AR, AV, AT
Air Force – 11

Note: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information using the ASSIST Online database at <http://assist.daps.dla.mil>.