

An Investigation of Hot Surface Ignition Temperatures of Polyalphaolefin-Based Dielectric Coolants

by

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Outline

- Background Hot Surface Ignition Temperature (HSIT)
- Description of Test Apparatuses
 - Previously simulated engine nacelle HSIT (AENFTS) testing [1]
 - BlazeTech's simpler hot duct experimental rig
- Comparison of ignition criteria used in the 2 test facilities
- Scoping tests to determine effect of injection conditions on HSIT
- Comparison of the HSIT temperatures for 3 Polyalphaolefins (PAOs) and Hydraulic Oil:
 - Mil Hydraulic Oil (MIL-PRF-83282)
 - Dielectric Coolant
 - ROYCO 602 (MIL-PRF-87252C)
 - Castrol Brayco Micronic 889 (MIL-PRF-87252C)
 - Radcolube 500m (MIL-PRF-87252E)
- Summary



Background

- Polyalphaolefins (PAOs) are being used as coolants for electronic equipment (dielectric)
- Their ignition hazards in case of leaks next to hot surfaces are not studied
- Standard rule is to maintain surface temperature < 400°F to avoid ignition
 - Temperature close to the autoignition temperature (AIT) of PAOs
- AIT is not representative of the dynamic conditions of a leak onto a hot surface
- BlazeTech measured hot surface ignition temperatures (HSIT) for leaks for various aircraft fluids under a range of conditions
- The HSIT for a fluid exceeded its AIT by a significant amount
- The purpose of this project is to directly measure the HSITs for PAOs

Minimum Hot Surface Ignition Temperature By Different Investigators vs. AIT





SAE Conference Paper 901950 provides a summary of test results and proposes guidelines for safety



Approach

- Boeing and BlazeTech have documented HSIT in a simulated aircraft engine nacelle (AENFTS) under high-realism conditions [1]
 - Summarized in Wright Labs report AFWAL-TR-88-2101
- This test facility produced a database of HSITs on aircraft fluids that is well accepted by industry but the facility has been decommissioned
- While using a simpler test rig, BlazeTech varied the fluid injection conditions to match the results obtained in [1] for MIL-PRF-83282
- The conditions can then be used to measure HSIT for Various PAO Dielectric Coolants to compare them to Mil Hydraulic Oil under identical conditions
 - PAOs will all conform to MIL-PRF-87252
- This allows for the comparable risk of fire associated with a leak of PAO coolant as compared to Mil Hydraulic Oil 83282



Test Rig Simulating F-16 Nacelle (AENFTS)



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Key Features of BlazeTech Test Rig

- 4-inch cylindrical, Inconel duct with high thermal diffusivity and high thermal mass
- Injection of small fluid volumes using accurate micropump
- Stream consist of small droplets that impact and flow over duct
- Result: minimal surface quenching during test
 - $T_{Surface}$ (before liquid injection) ~ $T_{Surface}$ (at ignition)
 - Confirmed by measurements on flat SiC plate
 - Constant temp. enables us accurate measurement of HSIT



Hot Duct Setup with no External Ventilation





Ignition Criteria: AFWAL report vs. BlazeTech

AFWAL-TR-88-2101 Report Criterion (AENFTS):

- HSIT is lowest temperature at which an ignition occurred in 3 consecutive tests.
- Temperature is varied in 50 °F increments
- Uncertainty in HIST is + 25 $^\circ F$ and -75 $^\circ F$

BlazeTech Criterion:

- Six tests are performed at each temperature
- Probability of ignition, p = Number of ignitions/Number of Tests, varies from 0 to 1
- HSIT = function of probability of ignition
- Temperature varied by 25°F increments close to ignition

Criteria used for ignition will affect the resulting temperature



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Scoping Tests: HSIT Depends on Test Parameters

- Use MIL-PRF-83282 as the baseline test fluid
 - Dosage Volume
 - $50 500 \ \mu L$
 - Injection Height
 - 10 cm 50 cm relative to hot surface
 - Injection Nozzle Inner Diameter (ID)
 - 0.6 mm 0.8 mm
 - Air velocity
 - To be added later

Ignition Criterion: HSIT measured when probability of ignition, p = 0.5



BlazeTech HSIT (°F) Measurements for MIL-PRF-83282 under both Criteria

	HSIT (°F)				
			BlazeTech using		
Trial	p=0.17	p=0.5	AFWAL report Criterion		
1	870	884	903	HSIT in	
2	877	893	865	AFWKL Report was	
3	884	941	904	800 - 840 °F	
Average	877	906	891		
Standard Deviation	6	25	18		

Data is for injected volume of $500 \ \mu$ L, height of 50 cm and orifice=6 mm Average HSIT based on AFWAL-TR-88-2101 Criterion corresponds to an ignition probability between 0.17 and 0.5



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Effect of injection volume for 4 Fluids Height is 20 cm, diameter is 0.6 mm, BlazeTech HSIT criteria at p=0.5





Effect of 2 Injection Heights for 4 Fluids

Diameter=6mm for all; heights: 20cm at p=0.5, 50cm with criterion in AFWAL





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Effect of Orifice Diameter for 4 Fluids 500ml volume, 50cm height and AFWAL report ignition criterion



●83282 ●Royco ●Castro ●Radcolube



Summary of HSIT Dependence on Test Parameters

For all 4 fluids with BlazeTech ignition criterion:

- 1. HSIT decreases with increasing injection volume)
- 2. HSIT decreases with increasing injection height \int
- 3. HSIT lowest for 0.6 mm orifice diameter

consistent with previous work on fuels [2]



HSIT Based on AFWAL Report Criterion for MIL-PRF-83282 at Various Test Conditions

Orifice Diameter (mm)	Injection Height (cm)	Injection Volume (uL)	83282 HSIT (F)
0.6	20	300	1018
0.6	20	200	1082
0.6	20	100	1107
0.6	20	50	1158
0.6	50	500	865
0.6	50	300	891
0.8	50	500	878
1	50	500	954
0.4	50	500	878
0.3	50	500	941

HSIT in AFWAL report = 800 to 840 °F for stream/spray @ ventilation air: 14.4 psia, 120 °F and 2 ft/s Test Conditions Producing HSIT Closest to AFWAL report (Green Row) are used in future testing

PAOs HSIT Test Results -

Injected volume is 500 µL, Height is 50 cm, diameter is 0.6 mm,



- - - Trial 1 - ▲ - Trial 2 - - - Trial 3





- - - Trial 1 - ▲ - Trial 2 - - - Trial 3





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• Trial 1

- Trial 2 - - - Trial 3



PAOs' HSIT > 83282' HSIT for both Ignition Criteria HSIT > AIT for the 4 fluids

		AIT (F)		
Fluid	p=0.17	p=0.5	AFWAL Rpt	ASTM
			Criterion	E659
Royco	908	955	908	428
Castrol	948	1000	985	423
Radcolube	917	959	925	423
83282	877	906	884	662

* HSITs are averaged over the trials except when p=1; then it is the lowest ignition temp.



Conclusions

- BlazeTech measured hot surface ignition temperatures for leaks for various aircraft fluids under a range of conditions
- Scoping tests demonstrated that the effects of fluid injection parameters on HSIT are similar for the 4 fluids
 - The HSIT for a fluid exceeded its AIT by a significant amount
- 500 µL Volume, 50 cm injection Height, and 0.6mm orifice Diameter yielded HSIT values for 83282 similar to the AFWAL report using the associated ignition criterion
- These injection parameters were then used to measure HSIT for the 4 fluids using BlazeTech probabilistic ignition criterion
 - Probability of ignition, p = Number of ignitions/Number of Tests
- Under identical conditions and ignition criterion, the HSITs of the 3 PAOs exceed those of 83282 by up to 100 $^\circ F$



References

- 1. Johnson, A.M., Roth, A. J. and N. Albert Moussa, "Hot surface ignition tests of aircraft fluids," Boeing Advanced Systems and BlazeTech Corp. report to the Air Force Aero Propulsion Laboratory, WPAFB, 1988, AFWAL-TR-88-2101.
- 2. Moussa, N. Albert, et al Hot Surface Ignition Temperature of Aviation Fluids, presented at Presented at FAA 9th Triennial International Aircraft Fire and Cabin Safety Research Conference, Atlantic City, NJ, Oct. 28-31, 2019.