Update on Introduction of KEROJET 100 (TSA2) to ADF and The World

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Topics

- Challenges of new modern fast jet propulsion system
- F-35 versus F-34 fuel (BASF Aviation Fuel Additives Technology)
- Kerojet® 100: 2nd Generation Thermal Stability Additive (TSA2) presented as the solution
- Kerojet®100: Benefits for end users
  - Focus on thermal stability improvement – What it means for end users?
  - Flexible Dosing/ Additisation Points means minimal administration/logistic effort
- Global TSA2 Mission
- Status update on introduction of Kerojet®100 to ADF
$17 billion on 72 of the F-35 aircraft, with the first expected to be delivered to Australia in 2018 and enter service in 2020.

Capable of supersonic flight whilst retaining stealth, the F-35A has a top speed of 1975 km/h and "extraordinary manoeuvrability".

New Fleets presents New Challenges Example – 5th Generation

- **Huge investment!**
  12 EA-18G Growlers @RAAF Base Amberley by the MID 2017

- **It’s all about improving capability!**
  “Australia is the only country outside the United States flying the EA-18G Growler and its arrival is a significant leap forward in Australia’s joint electronic warfare capability and introduces a dedicated electronic attack option,”

“This is a $250m investment by the Turnbull Government that will future proof the Growler’s capability,” Minister Payne said.

**Avalon 2017 Australian International Airshow**

**Thermal Stability is becoming more important to optimize service life of this demanding weapon system**

Engine is complex and each of them is unique

**Engines most affected:**
Not all engines are equal. Those most affected are:

- Latest generation
- Military engines
- Fast jet
- Afterburning
- Single engine

*TAE ‘interest’ as a Total Logistics Support provider (TLS includes MRO&U, engineering, fleet management, material supply), under Performance Based Contract regimes for **F135** (Asia Pacific), **F414** (RAAF), F404 (RAAF, RMAF) and previously **TF30** (RAAF).

Can we proactively deliver a fuel that is needed for the most affected engines; but will also deliver benefits for all other engines?
Effects of Deposit Formation (field data by DSTG and TAE)

Some examples

TF30 Main fuel nozzle, before and after 10 hour clean up run Amberley TC2

TF30 Fuel oil Heat exchanger, compromised heat transfer

AGT1500 fuel nozzle, 6 months installed use

PT6A fuel nozzle, coking sufficient to fail spray test 300 enhr mandatory replacement due to IFSD risk
The Importance of Optimized Fuel Atomization and Spray Pattern in Combustion Chamber and Fatal Damage to Expensive Parts

- Normal spray pattern

- Main fuel nozzle spray pattern compromised
- Combustion efficiency reduced
- Increased fuel flow for given thrust/power
- Boundary layer of cooling air compromised
- Hot section damage e.g. NGV shown
- Emissions increased

- NGV aerofoil breached
- Compromised air cooling
- HCF excitation of HPT blades (IFSD risk)
- Expensive, time to repair
Issues associated with deposit formation

The Problem:
Modern gas turbine engine designs increasingly suffer from carbon deposit formation due to increased:

- use of fuel as an aircraft & engine heat sink - avionics cooling, engine oil cooling, etc
- engine combustion temperatures – resulting in hotter, residually wetted, fuel contacting components
- use of fuel to actuate engine components - especially afterburner Exhaust Nozzle (EN)
- number and smaller fuel orifices – that are more susceptible to coking
- speed of control system actuation – FADEC enabled, results in more and quicker activations which increases cycles, loads and criticality of actuation.
- Sustainability focus on increased use of bio fuels and potential for reduced thermal stability.
- Variable fuel properties including thermal stability.
BASF Aviation Fuel Additives

Introduction

- **Antioxidant**
  - Kerobit® TP 26: approved to 24 mg/litre

- **Metal Deactivator**
  - Keromet® MD 100: approved to 5.7 ppm.

- **Fuel Icing Inhibitor (FSII/DiEGME)**
  - Keroﬂuid® MIL–AL 41: approved to 0.15% v/v.

- **New: Static Dissipater Additive**
  - Kerojet® 8118: approval to 5 mg/litre.

- **New Thermal Stability Additive**
  - Kerojet® 100: approved to 256 mg/litre.

- **New: Water Scavenger Additive**
  - Kerojet® Aquarius: approval to 250 ppm.

A long-standing reputation for aviation product quality and technical expertise.

Additives = better fuel = improved engine = cost saving and increased mission capability!
Kerojet® 100: 2nd Generation TSA (TSA2) Thermal Stability Additive

Why KEROJET®100?

- The only 2nd generation TSA listed in MIL-DTL 88133J - the best performer!
- It has been approved by the engine OEMs Pratt & Whitney, GE Aviation, Rolls-Royce and Honeywell early 2012.
- Kerojet 100 was tested on Pratt & Whitney FX and GE CFM-56 nozzles.
- The selected fuel had a thermal oxidation breakpoint of 260 °C (severe!)
- Coalescer friendly based on US Navy Filtration Test
- No harms
- Reduced surface corrosion in some alloys
- Cost of using Kerojet®100 (circa 1%) is less than the cost of not using it.
- Good storage stability: 24 months in 0 - 40°C

Due to extreme fouling the baseline nozzle stuck in an open position after 20 hours.

The Kerojet® 100 additive performed the entire test of 50 hours with only 1–2 % flow reduction.
Kerojet®100: Treating the symptoms

How it helps an engine:
F-34 dosed with KJ100 at 256mg/L prevents varnish, gum and coke build-up (& removes existing deposits) in:
- Afterburner (AB) spray bars
- Main fuel nozzles
- Flow divider valves
- Exhaust Nozzle Pumps
- Actuators
- Heat Exchangers (HE)
Kerojet®100: The ultimate benefits in the field (Thermal Stability Performance)

The Benefits:
Reduced varnish and coke build-up in fuel nozzles, afterburner spray bars, flow divider valves, pumps, actuators & heat exchangers leading to:

- Improved engine combustion efficiency & fuel cost savings (cost reduction)
- Eliminate scheduled fuel nozzle and afterburner spray bar removals (maintainability, availability)
- Less hot section damage during deeper maintenance visits (maintainability, cost reduction)
- Less fuel component cleaning – decarbonizing is the most used cleaning tank (maintainability, cost reduction)
- Average Time On Wing (ATOW) improvements, less engine removals (availability)
- Improved asset availability (availability)
- Improved operational performance (capability)
- Improved flight safety (safety)
- Reduced emissions – visible smoke (particle), NOx & green house gas (capability, environment)
- Protection against poor quality or bio fuel (risk mitigation)
F-37 dosing and delivery options:

- With Kerojet®100 a number of different delivery options are available.
  - Bulk delivery to defence base as F-37
  - Bulk delivery to defence base as F-34 and inject TSA2 when filling base tanker
    - Bulk delivery to defence base as F-34 and inject TSA2 at skin of aircraft – Provides choice of F-34 or F-37, compatible with existing filtration and coalescer infrastructure but requires tanker injection. Defuel requires less/no blend back as TSA2 storage stability and filter/coalescer unaffected. FQC testing of skin injected fuel not possible.

- Ideally, global use of F-37 TSA2, bulk delivered to base in lieu of F-34, would deliver greatest benefit with minimal administrative effort.

*NB M series filter elements are recommended during introduction /infrastructure clean up, as they are commercially available, drop in replacements, improve filtration efficiency and have a longer service life (typically 2x) for similar price.*
Consequences of Water In Jet Fuel

Problems associated with water contamination in jet fuel:

- Free water won’t burn in jet engines:
  - Flameout, reduced power
- Causes corrosion and component failure
- Free water cooling can produce ice (can aggregate and block engine filters). "Boeing: Low temperature operations is a concern for fuel transfer, boost pump inlets, and in fuel lines"
- Fuel contaminated with free water = bacterial growth which leads to fuel degradation, corrosion, filter plugging, damage to fuel sensors and fuel systems. *IATA: MBC Guidance Material. SAE: AS6401 (09) App G etc*
Why Coalescer Friendly feature of TSA is needed?
**Category M** - For Military Jet Fuel (JP-4, JP-5, JP-8, JP-5/8 ST, NATO F-34, NATO F35) that contains the basic military additives, including FSII, SDA and CI, but **NOT** “+100” TSA.

**Category M100** - For Military Jet Fuel that contains “+100” type of additive. This fuel may also contain the additives in category “M”, above.


Filter water separator vessels are the primary defence against dirt and water contamination in fuel.
Kerojet®100 vs First generation TSA in coalescer performance

Water Coalescence Tests (Flow rate 84 l/min)

6” M100, SBS filter, EI 1581 5th ed. spec, refer KVA 5208 dated 07 Oct 2008

Ultimately TOTAL CLEANING SYSTEM (~ZERO Water Content)
Kerojet®100 vs First generation TSA in coalescer/ filtration performance

Water Coalescence Tests (Flow rate 124 l/min)

6” M100, SBS filter, EL 1581 5th ed. spec, refer KVA 5208 dated 07 Oct 2008
Kerojet®100 effect on coalesce is virtually the same as unadditised fuel

Jet Fuel Treatment with 2xCanister Type FAUDI C 9420480 (35 l/min, Tank Capacity 1000 l)

6” M100, SBS filter, EI 1581 5th ed. spec, refer KVA 5208 dated 07 Oct 2008
Kerojet®100 effect on coalesce is virtually the same as unadditised fuel

- Filtration time was halved!
- No Clay Filter change necessary!
- Maximum solids in effluent was 0.2 mg/l
TAE is going global in TSA2 Mission
Leveraging TAE’s in house fast jet MRO expertise

- Highlight on the current and future challenges that ‘Fuel Stability’ presents to the aeronautical gas turbine’s
  - availability,
  - operational capability,
  - safety,
  - environment and
  - cost effective sustainment.

- TAE is using its capability to introduce KEROJET® 100 concept to the Defence Forces in the world:
  - State of the art engine workshop and test facilities (including those of F404, F414, AGT1500, components currently affected by poor thermal stability)
    - Demonstrate the extensive benefits of using of Kerojet®100 using real life/ field maintenance data.
  
  - Uninstalled engine testing capability
  
  - Discuss concerns for future (F135) engines and their variants
  
  - F-35 manufacturing capability
  
  - Australian use of performance based Contracting
  
  - Insights into ADF use of F414 (that power or Super Hornets and Growlers);
  
  - Collaboration opportunities (R&D and other interest)
Continuation of approach to promote KEROJET® 100 to USDF, CANDF and NZDF – clarification in gum test result (ongoing) and coalesce performance concerns (completely addressed).

In collaboration with BASF, TAE have completed formal introduction of KEROJET® concept to some major European and Asian Defence Defence Forces (Finland, Belgium, France, Dutch)

Unified Feedback on realization of how KEROJET® concept can solve their problems due to its benefits

Direct involvement in various world conferences to raise the awareness of TSA2 KEROJET®100:

- AFC
- CRC
- IASH
Kerojet®100: Australian Defence Force F-37 Introduction status

- DASA request for investigation into TSA benefit for ADF – Jan 2015
- Kerojet®100 is confirmed as highest performing Second Gen TSA by FSB and DSTG – Dec 2015
- FSB presentation on TSA2 KEROJET®100 at ASIC Meeting - April 2016
- Approval on Kerojet®100’s coalescer performance by DSTG and FSB - Nov 16
- DEF(AUST) 5240D being redrafted to reflect Kerojet®100 as the approved second generation TSA - no first generation TSA to be used by ADF.
- CASG approval to procure KEROJET®100 is being pursued.
- Installation of 5M100 in the next cartridge replacement to comply with EI 1581 5th ed filtration spec.
BACK UP SLIDES
Type S is meant to be used at filtration points where significant levels of water and dirt in the jet fuel can be expected. Limit for Differential Pressure at both 50 mins and 75 mins are 15 psi.