Fire Testing of Aero Engine Components

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22nd March 2023

Element Materials Technology

De-Risking the Compliance Process in the Aero & Defence Market

Why do we do Fire Testing?

What are the Certification Standards?

Aircraft Fire Protection

- Certification requirement for all Aircraft Engines
- *'To give assurance that the design, materials and construction techniques used will minimize the probability of the occurrence, the consequences and the spread of fire'*

Engine Certification Standards

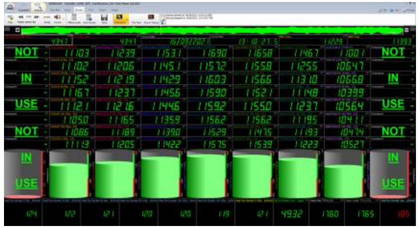
- **EASA – CS-E 130 – Certification Specification for Engines – Fire Protection**
- FAA – Power Plant Engineering Report No.3, AC 20-135 and AC 33-17
- RTCA/DO-160 Section 26
- **ISO 2658 – Resistance to Fire in Designated Zones**
  - AS4273 – Method for Fluid Handling Components
  - AS1055 – Method for Flexible Hoses and Tubes
  - TS370 – Method for Electrical Connectors
  - Etc.

Aircraft Certification Standards

- EASA – CS-25.851-869 – Aircraft Fire Protection
  - Flammability, Heat Release, Smoke Density, Toxic Gas Emissions, Flame Penetration etc.

ISO2685: What are a Standard Burner and a Standard Flame?

Two types of Burner are defined:
- Propane
- Kerosene

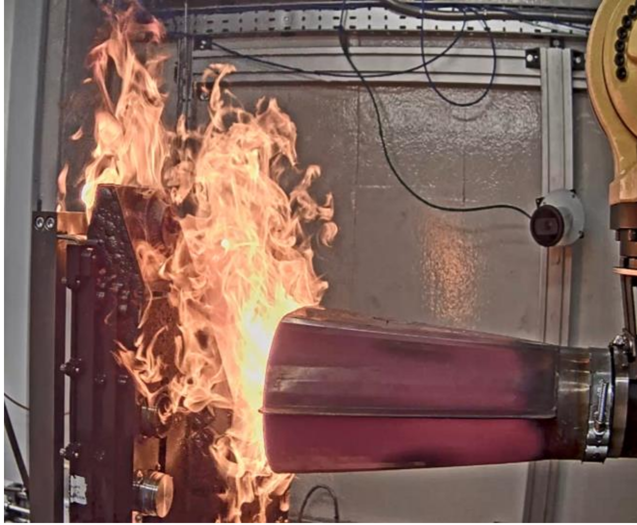


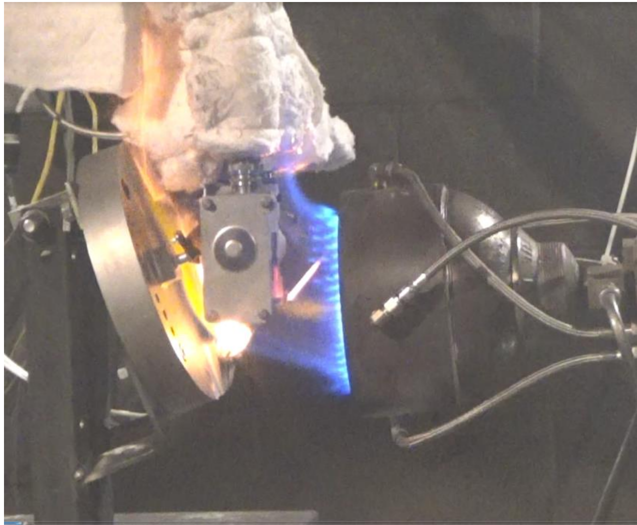
Standard Burner Types

- Both Burner types have to meet the same 'Standard Flame' specification
- Historically Propane more readily used
  - Easier calibration, more repeatable / controlled
  - Perceived as 'easier' for the unit under test
- Kerosene is now typically mandated by EASA/FAA
  - More realistic of an engine fire condition
- Propane 'Grandfather Rights'

Standard Flame

- Temperature: 1100±80°C
  - Calibrated by array of thermocouples
  - *Average temperature >1093°C*
- Heat Flux Density: 116±10kW/m^2
  - Continuous Flow Calorimeter
- Calibration Equipment Control
  - Thermocouple Type & Spacing, Relative Flame Position, Water Flow and Temperature, Tube Material & Size etc
- Calibration Method
  - Burner Stabilisation Time, Calibration Time, Data Logging
- Post-Test Repetition





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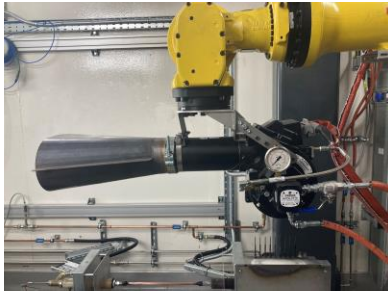

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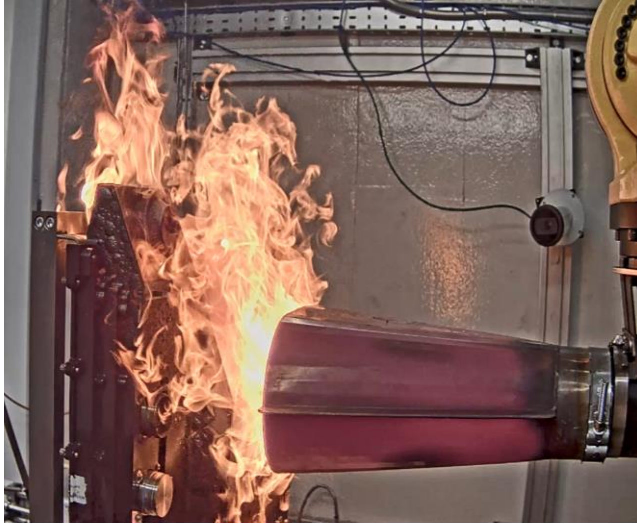


What level of Fire Protection do I need to achieve?

Two defined levels of Fire Protection with different test methods:

- Fire Resistant
- Fire Proof

Level determined by component function and engine location

Determining the Level

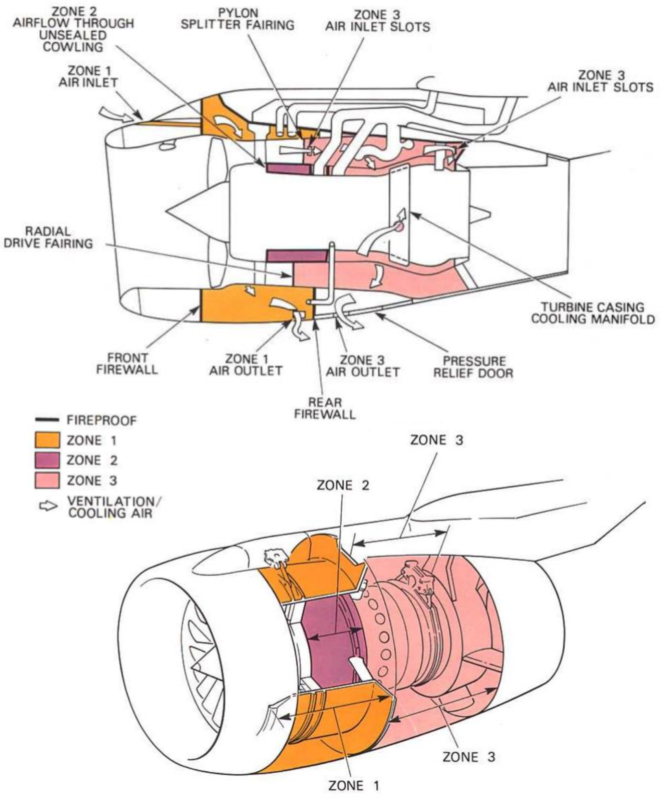
- Fire Resistant
  - All components in the Fire Zone (inside Fire Wall)
  - All Engine Control System components
  - All lines or components containing Flammable Fluids
- Fire Proof
  - All Fire Wall components
  - All Flammable Fluid Tanks and associated Shut-Off means
  - All Oil System components

Test Method

- Fire Resistant
  - 5 minute duration
  - ‘Worst Case’ operating condition
- Fire Proof
  - 15 minute duration
  - ‘Worst Case’ condition (5mins)
  - Windmill condition (10mins)

Engine Fire Zones and Fire Walls

Compartments that contain ignition sources and/or the potential for flammable fluid leakage



How do I select the Test Operating Conditions?

Determining the 'Worst Case' Operating Condition

- EASA Specification: '*The operating parameters of the test article should be consistent, but conservative, with respect to the conditions which might occur during an actual fire situation*'
    - Lower fluid flow conditions – typically Flight Idle
        - Higher flows rates increase the heat sink effect
    - Low fluid levels – typically minimum dispatchable quantity
        - Higher volumes increase the heat sink effect
    - Higher fluid pressure conditions
        - Higher pressures increase the risk of seal / material burst failures
    - Higher applied loads
        - Higher loads increase the risk of material buckling at temperature
    - Higher operating temperature
        - Higher temperatures reduce the time to reach critical material failure temperature
- Ensure selected operating conditions are representative and realistic
- Rig design and instrumentation are critical to ensure conditions can be maintained / controlled and monitored throughout test

Where do I point the Burner?

Determine the unit feature or location that is *'the most critical with respect to surviving the effects of fire'*

Unit Vulnerability Analysis

- Analysis to consider:
  - Materials
    - Aluminium, Carbon-Fibre Composites, Titanium or Magnesium Alloys, Rubbers or Plastics
  - Seal Design
    - Extrusion Gap, Depth from Surface, Cooling Flow, Fluid Pressure, Dynamic Seals
  - Feature Geometry
    - Wall Thicknesses, Protrusion vs Recessed
  - Internal Fluids
    - Fluid Pressure and Flow
  - Fire Protection Design Features
    - Heat Shield, Surface Coatings
  - Component Function
    - Shut-down, Safety Critical
- Analysis may determine that more than one test is required…

Thermal Analysis

- 3D Thermal Analysis of identified vulnerable areas at defined test condition to predict critical temperatures

How do I determine Pass / Fail criteria and assess the result?

General Acceptance Criteria for Test Unit (EASA)

- *‘Maintain the ability to perform those functions intended to be provided in case of fire’*
  - No hazardous engine effect while continuing to operate
  - A safe engine shutdown at any time is acceptable
- *‘No leakage of hazardous quantities of flammable fluids, vapours or other materials’*
  - In general, no leakage during or after burn period – small leaks / weeps may be acceptable if demonstrated as non-hazardous to the engine
- *‘No support of a sustained fire by the constituent material of the article being tested’*
  - Rapid self-extinguishing and no re-ignition - typically must self-extinguish within 2 minutes of flame removal
- *‘No burn through of firewalls’*
  - Failure to contain the fire within the intended zone
- *‘No other conditions which could produce Hazardous Engine Effects’*

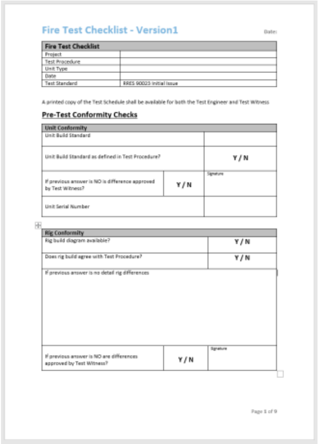
Test Definition and Rig Design

- Unit operating conditions must be maintained throughout the test
- Flame must not be disturbed during test, and conformity validated post test
- Rig instrumentation and test video evidence are critical for assessing acceptance

How do I make sure the test process is compliant?

Approved Test Witness and Compliance Checklist

- Approved Fire Test Witness
  - Test House, Design Authority, Customer, Certifying Authority
- Certifying Authority Review
- Test Process Compliance Checklist
  - Test Article Conformity
  - Test Article Function and Operating Conditions
  - Test Rig Conformity
  - Test Article and Rig Insulation
  - Burner Type and Conformity
  - Flame Calibration Equipment
  - Standard Flame Calibration Conformity
  - Instrumentation Calibration
  - Vibration Conformity
  - Burner Positioning
  - Video Camera Positions
  - Pre- and Post-Test Photographs
  - Post-Test Flame Conformity
  - Post-Test Unit Assessment



Fire Test Checklist - Version1

Date:

Fire Test Checklist	
Project	
Test Procedure	
Unit Type	
Date	
Test Standard	RRES 90023 Initial Issue

A printed copy of the Test Schedule shall be available for both the Test Engineer and Test Witness

Pre-Test Conformity Checks

Unit Conformity		
Unit Build Standard		
Unit Build Standard as defined in Test Procedure?		Y / N
If previous answer is NO is difference approved by Test Witness?	Y / N	Signature
Unit Serial Number		

Rig Conformity		
Rig build diagram available?		Y / N
Does rig build agree with Test Procedure?		Y / N
If previous answer is no detail rig differences		
If previous answer is NO are differences approved by Test Witness?	Y / N	Signature

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What are the main reasons for Fire Test Failure?

Unit Design

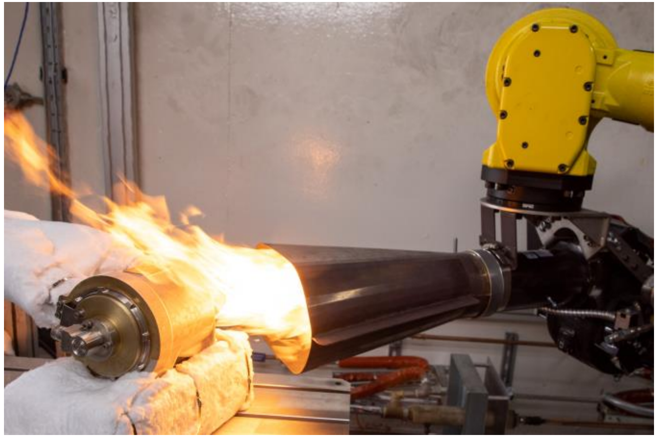
- Vulnerable Seals
- Static Fluid Volumes
- Thin-Walled Sections
- Exposed Electrical Connectors

Test Method Definition

- Unrealistic 'Worst Case' Operating Conditions
- Unachievable Operating Conditions
- Inappropriate Test Fluid Circuits (trapped volume expansion / venting)
- Poorly Defined Acceptance Criteria
- Lack of Test Witness / Process Compliance Approval & Documentation

Rolls-Royce
Fire Test Facility
Solihull

Enquiries:
Contact Element



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End