AIRCRAFT ENGINE ELECTRICAL WIRING

(Design / Features / Maintenance)

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SCOPE:

- This presentation is limited to GE Aircraft Engine’s experience on commercial wide body aircraft.
- GE’s CF6 engine family has powered these aircraft since 1980, with 182 customers and over 200 million hours of operation.

<table>
<thead>
<tr>
<th>Engine</th>
<th>Aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF6-6</td>
<td>DC10-10</td>
</tr>
<tr>
<td>CF6-50</td>
<td>DC10-15, DC10-30, A300, 747-200/300</td>
</tr>
<tr>
<td>CF6-80A</td>
<td>767-200, A310-200</td>
</tr>
<tr>
<td>CF6-80C</td>
<td>A300-600, A310-200/300, 747-200/300/400, 767-200ER/300/400</td>
</tr>
<tr>
<td>CF6-80E1</td>
<td>A330</td>
</tr>
</tbody>
</table>
DESIGN REQUIREMENTS

• Internal
  – Designs are controlled by internal design practices based on “Lessons Learned”
  – GE certifies a harness to FAR 33.91, similar to other control components
  – GE defined engineering tests are conducted to determine the design margin of a particular design
  – GE has incorporated many industry best practices (AS50881) for harness design and support on the engine

• Airframer
  – Individual airframer reqts may dictate design features (fire resistance, repairability, maintainability-LRU)
DESIGN BACKGROUND/HISTORY

• Basic design features (materials) are derivatives of designs originally qualified on military engines
  – Military engines have a total life of approx. 3,000-5000 hrs
  – Commercial engines may accumulate this many hours per year of operation

• Continued reliable operation of our electrical harnesses is dependent on the following criteria:
  – Correct selection of materials to survive the environment
    » Temperature, Fluids, Vibration
  – Using proven design features
    » Basic design features and materials that have proven their durability are rarely changed
  – Selective use of design upgrades based on improvements in materials / technology
DESIGN TYPES

• Three basic types of electrical harnesses are used:
  – 1 High Temp (Rigid) > 800 F
- 2 High Temperature (flexible)  500 F - 800 F
3 Emphasis of this presentation - Standard Construction < 500 F

Most common (highest qty of connections)
Design Features

• Typical “Standard” Harness Construction

CONNECTOR

BACKSHELL

WIRE BUNDLE / SHIELD / JACKET
# Design Features

- **Electrical Connectors (Stainless Steel Only)**
  - Three main connector families are utilized

<table>
<thead>
<tr>
<th>Connector Type</th>
<th>Common Location</th>
<th>Advantages (+)</th>
<th>Disadvantages (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M83723</td>
<td>*Component &amp; FADEC</td>
<td>GE developed design for robustness</td>
<td># of pin patterns (inserts) are limited -</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Standard design not scoop proof</td>
</tr>
<tr>
<td>D38999</td>
<td>Component &amp; *FADEC &amp; *Major interfaces</td>
<td>High pin density – Scoop proof – Single turn to uncouple</td>
<td>Design can be vibration sensitive – Mating different suppliers plug/receptacle</td>
</tr>
<tr>
<td>M5015</td>
<td>Components</td>
<td>Interface to older components – no technical advantage</td>
<td>Not originally designed for the aircraft engine environment</td>
</tr>
</tbody>
</table>

* preferred application
Design Features

• Electrical Connectors (continued)
  – GE specifies connectors to meet a GE connector specification and a GE source controlled drawing
    » GE connector specifications exceed the performance requirements of standard military type specifications
    » GE connector specifications control coupling and uncoupling torques to allow for hand tight installation
    » Recently European connector specifications (i.e. EN2997) have been issued specifically to meet the requirements of the jet engine environment
  – Other special connector types used for specific applications have also been GE designed and specified
    » Scoop proof M83723 connectors
    » High Temperature M5015 connectors
• Backshell
  – Provides mechanical support for the wire terminations
  – Attach point for internal and external shielding to provide a ground path from shielding to the electrical connector
    » Interfaces with connector and shielding must have low resistance and remain tight to provide adequate shielding
  – Standard materials are nickel plated aluminum, stainless steel (SS) or nickel plated stainless steel
  – Backshell geometry can be straight/ 45 / 90 degrees based on cable routing and adjacent hardware
    » Other backshell angles can be designed as required
  – Designs may be potted or unpotted
  – Unpotted backshells (SS) are oriented to prevent the collection of fluid or have drainage holes installed
Wire

- Preferred wire uses a “hybrid” insulation
  - Insulation known as T-K-T (Teflon-Kapton-Teflon)
    - Insulation offers optimum performance without the negative features of standard aerospace type wire, such as:
      - 1 Pure Teflon (PTFE) insulation
        - Material has excellent temperature and fluid resistance - but will deform and “cold flow” if stressed at engine temperatures
      - 2 Pure Kapton (Polyimide) insulation
        - Small conductor diameter and reduced weight are attractive characteristics. When exposed to engine vibration and temperature, material may degrade.
  - Minimum recommended wire sizes are:
    - Copper: AWG 20 or AWG 22 - 19 strands
    - Thermocouple: AWG 20 - 7 or 19 strands
  - Conductors may be grouped and twisted (2 = pair, 3=triplet, 4=quad) to meet electrical system reqts
  - Grouped wires can be shielded or unshielded
  - Shielded wires may be jacketed or unjacketed (outer layer of insulation)
• Shielding
  – Material is generally nickel-plated copper. Other material (nickel/stainless steel) may be specified depending on environment
  – Individual wire groups may be shielded
    » As required to meet control system reqts
  – Overall cable bundle may be shielded (overbraid)
    » Outer shielding is specified to meet EMI/Lightning reqts
  – Shielding usually terminates to the connector backshell (b/s) for electrical grounding
    » Internal shielding provides end-to-end coverage (into b/s)
    » Overbraid should provide a 360 termination @ the b/s
  – The shield termination resistance is controlled by the supplier to insure a reliable ground path
• **Chafe Protection**
  - Purpose is to protect the cable and adjacent hardware from contact damage (may be color coded to aid maintenance)

<table>
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<tr>
<th>Material</th>
<th>Advantages (+)</th>
<th>Disadvantages (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spiral Wrap (PTFE)</td>
<td>Material thickness / chafe properties</td>
<td>Weight, low cut resistance / shrinks at elevated tempertures / difficult to install</td>
</tr>
<tr>
<td>PEEK Overbraid</td>
<td>Light weight / easy to install / will not fray</td>
<td>Will chafe with heavy contact</td>
</tr>
</tbody>
</table>
FIELD PERFORMANCE / MAINTENANCE

• Engine harness are maintained based on the engine’s normal maintenance
  – Inspection interval varies based on airline customer (ex 1K, 5K, 10K hours)
  – Normal periodic maintenance includes a visual inspection (heat/vibration damage)
FIELD PERFORMANCE / MAINTENANCE

- More thorough engine rebuilds include harness removal, inspection, cleaning and minor repairs
- Harnesses are electrically checked to the CMM (continuity, IR, Hi-Pot)
- Damaged harnesses are repaired at a service shop or returned to the OEM (repair / replacement or key components)
FIELD PERFORMANCE / MAINTENANCE

• Based on our field experience, “standard” engine harnesses have no life restrictions (max # hours)
  – Electrical harnesses are not considered to be life limited parts
  – GE does not track hours on individual harness assemblies (interchangeable between engines)
    » Airlines may track hours/cycles on individual harnesses
  – Upper limit (max hours) for a standard harness in its’ designed environment has not been determined (open ended)
  – Failure rates of harnesses are closely tied to an individual engine’s characteristics (nacelle temperatures, vibration)