AIRCRAFT WIRE DEGRADATION STUDY

6 November 2002

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This work is being performed under contract to the FAA Technical Center (Contract No. DTFA03-02-C-00040)
Goal

• To study the degradation mechanisms of five wire types commonly used for commercial airframe wiring, in order to understand and model the “aging” mechanisms.

• WHY?

To ensure safe long term operation of aircraft by fully understanding the reliability of electrical wire used in aircraft electrical interconnect systems.
Wire Issues

Exposed to Heat / Humidity

Exposed to Heat, Flex

Other examples in previous presentation
Specific Goals

• To attempt to develop algorithms in an effort to predict the degradation of wire in aircraft.

• To determine degradation of wire relative to original performance specifications.

• To establish relationships between performance degradation and potential failure modes, and to determine the critical thresholds.

• To determine how thresholds can be used to eliminate or mitigate potential wiring hazards.

• To identify major model perturbations.
Tasks

- Phase I: Development of Test Program Aug 01 - May 02
- Phase II: Execution of Test Program Oct 02 - Aug 04
- Phase III: Analysis and Reporting Apr 04 - Dec 04
The Team

• Direct Team
  • Raytheon Technical Services (lead)
  • Brookhaven National Laboratories
  • Sandia National Laboratories
  • Lectromechanical Design Company
  • Qualstat Services

• Indirect Team
  Airbus Industries
  Bombardier Aerospace
  NASA
  Barcel/CDT
  Tyco Electronics (Raychem)
  Airtran
  SR Technics

  Boeing Company
  Dupont Company
  QinetiQ
  Tensolite Company
  Northwest Airlines
  United Airlines
Phase I: Develop and Plan Study

• Required Items for the study
  • Background study
  • Determine baseline data
  • Define Wire types to evaluate
  • Identify aging variables
  • Identify perturbations to the aging process
  • Develop a test plan
  • Develop a project plan
  • Develop a quality assurance plan
  • Draft test procedures
  • Define test protocols
  • Develop Statements of Work for subcontractors
  • Coordinate with industry stakeholders
• Complete
Wire Types to Evaluate

• Aromatic polyimide (PI) tape wrap (US & European versions)
• Aromatic polyimide tape wrap with fluorocarbon bonding layers and polytetrafluoroethylene outer wrap (PI/PTFE) composite
• Crosslinked aliphatic polyimide (XPI), extruded
• Crosslinked modified ethylene tetrafluoroethylene (XLETFE), extruded
• Polyvinyl chloride with extruded polyamide outer jacket (PVC/Nylon)
Variables that may Affect Wire Aging

- Time
- Thermal
- Electrical
- Mechanical
  - Bend, static
  - Bend, dynamic (Flex)
  - Abrasion, Vibration
  - Thermal Expansion
- Chemical
  - Aircraft Fluids (cleaners, hydraulic fluid, lubricants, deicing fluids, etc.)
  - Humidity
  - Oxidizers (Ozone, NOx, SOx, etc.)
- Radiation
  - Heat
  - Ultraviolet
- Biological Organisms
Perturbations

• Identify perturbations to the wire aging process
• Uncontrollable Stressors that can include
  • wiring design
  • wiring installation or installation deficiencies
  • maintenance (EIS or aircraft)
  • operational extremes outside of the design guidelines
  • exposure to various debris outside of the design guidelines
  • exposure to high temperature caused by unpredicted environmental conditions
    • lightning
    • electrical shorts
    • component failure
• Actual conditions any specific wire is exposed to during its life is unknown
Evaluation Tests

- Tests that will be utilized
  - Some specific techniques currently used
    - Visual
    - IR/DWV
    - Tensile and Elongation
    - Flammability
    - Time Domain Reflectometry (TDR)
  - Some new techniques to evaluate
    - Terahertz
    - Insulation Modulus/Hardness
    - Inherent Viscosity
    - Weight Loss
    - Oxidation Induction Time
    - FTIR Spectroscopy
    - UV/VIS Spectroscopy
Test Method & Failure Criteria

• Method based on the standard ASTM Method 3032 for wire.
• “Accelerated Aging” type conditioning of wire specimens
  • Using test variables
    • Stressors (Flex, Thermal Shock, Vibration, Fluid Exposure)
    • Conditions (Temperature, Humidity, Static Bend)
  • Not all variables can be examined
  • Each wire type has unique test protocol
  • Cycle specimens through conditioning and testing until failure
• Test specimens
  • Start with new wire
  • Test wire following periods of accelerated aging
• Wire specimens fail when...
  • Insulation Resistance cannot be held
  • Wire cannot hold dielectric voltage
  • Conductor cannot pass current
Test Protocol Example

• FIGURE 1: TEST PROTOCOL I – STRESSOR 1 & CONDITIONS A, A⁺, B, C, D, E, and J 1/

1/ See test block descriptions for test frequencies.
2/ Test L+ after sixth L specimen fails.
Phase II: Execution

- Get subcontractors under contracts
- Procure all required materials
- Finalize test plan
- Finalize test protocol
- Finalize test procedures
- Disposition comments to test plan
- Finalize Schedule in a project plan
- Execution of test program
Phase III: Analysis & Reporting

• Full Data analysis
• Draft Report
• Lab Reports
• Final Report
• Request Industry Comments
• Present to FAA

• Scheduled to begin April 2004, and to complete December 2004
Anticipated Results

- Baseline standard for conditioned wire samples.
- Benchmark for correlation of novel aircraft wiring test techniques.
- Method for evaluation for future wire studies.
- Curves that represent the time to failure of the samples under specific environments.
- Curves that correlate the change of the “state of wire” to data obtained from other techniques.
- Thresholds that may be established to mitigate increased potential safety risks.
Possible Correlation of Data

- Modeling Degradation Times and Property Results
  - Model: $\log \text{Time} = [a + b \times (1/\text{Temp}) + c \times (\# \text{Cycles stressed})] \log \text{time}$
  - $f(\text{Property}) = \text{model of similar form? linear, quadratic, etc.}$
  - Model developed for each combination of Dynamic Stressor Test and Aging Condition. Several models per wire type.
  - Will also compare life estimates (e.g. temperature indexes) versus the design variables & interactions