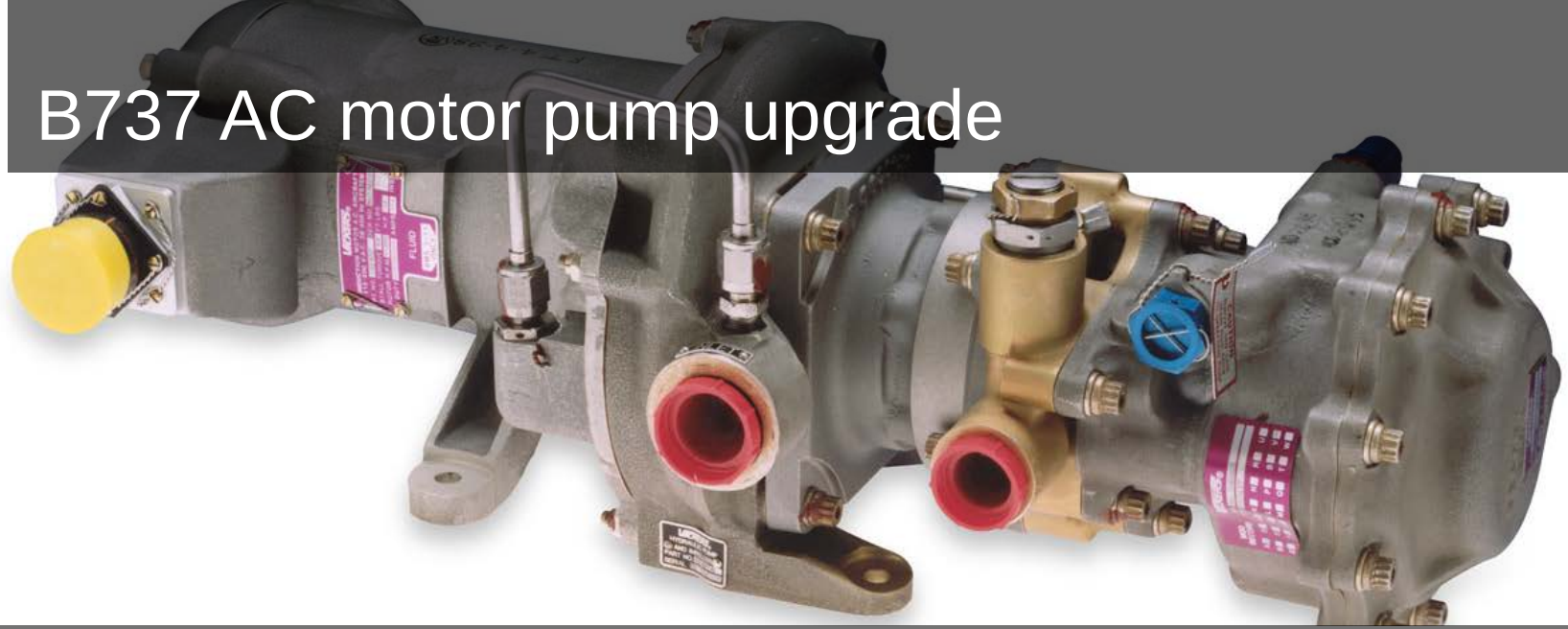
B737 AC motor pump upgrade



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Agenda

- History of new 737 containment requirements
  - Review of Boeing model record
  - Recent fleet containment events
- Overview of Eaton 737 ACMP upgrade
  - Upgrade configuration
  - Benefits
  - Current status
  - Schedule

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Issue/application

- B737 classic through max
- AC motor-pump overheat failure possible
- Current motor design does not adequately contain 2 phase electrical failure
- Model MPEV3-056-7A / PN 887477
  - Boeing PN 10-60556-32
- Pump overheat / stator failure

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Eaton product evolution

- The Eaton motor electrical configuration has remained the same throughout the history of the 737 fleet
  - Originally introduced as part of 10-60556-1
- 10-60556-32 (added in 1990) is a derivative of earlier models featuring product improvements to the hydraulic pump
  - The 10-60556 SCD requirements for the Eaton models do not reflect the electrical containment requirements developed for the -10, -12, and -20 configurations

Stator electrical failures resulting in penetration of the ACMP housing are not recorded in the Eaton repair history records

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Recent failure containment history

- In 2014, an Eaton unit on a 777 aircraft experienced an aircraft-induced two-phase electrical event
  - The loss of a single phase significantly increases overheating within a motor and simultaneously reduces the cooling available to the motor
- Boeing and Eaton investigated the 777 unit
  - Damage occurred to the stator
  - No external surface damage or burn through was noted

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Boeing two-phase validation testing

- Eaton understands that as a result of the 777 event, the FAA has elected to deny qualification-by-similarity for electrical motor failure containment requirements for new aircraft certification
  - This decision impacts the 777x and 737MAX
- Boeing executed a series of validation tests for 737MAX ACMP configurations
  - During the two-phase test, the 10-60556-32 configuration failed to contain the internal failure

Eaton has identified the source of the containment failure by evaluating the test results and hardware

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Boeing new 737 ACMP requirement

- Boeing issued a RFP for a compliant derivative ACMP **Oct-14**
  - Must operate under specified conditions without
    - Exceeding surface temperature limits
    - Allowing penetration of an external surface
- Eaton submitted a proposal for a compliant derivative ACMP **Jan-15**
- Boeing submitted desist letter to Eaton **Mar-15**
- Boeing and Eaton initiated the program for a compliant derivative ACMP **May-15**

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Solution: stator end-turn shielding

Finding

The Boeing test hardware indicates that the stator end-windings expose the ACMP interior to high temperature and energized conductive particles.

Solution

Ensure thermal and electrical isolation by incorporating two high-temperature non-conductive shields between the structure and the stator windings.

Solution: electrical isolation

Finding

Test hardware indicates that the stator phase leads should be isolated from each other and the structure to prevent internal damage.

Solution

Ensure electrical isolation by redesigning the stator, incorporating non-conductive shields, and implementing improved wire routing.

Solution: phase lead supports

Finding

Test hardware indicates that the leads should be supported to prevent post-damage contact with conductive surfaces.

Solution

Ensure isolation after the phase lead is severed from the stator end-windings by incorporating wiring supports into the non-conductive shield.

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Solution

Introduce a new AC motor pump that meets 2 and 3 phase failure containment requirements

- Introduce new model MPEV3-056-7B / PN 3033096-100
- New design has been validated and tested:
  - Locked rotor tests
  - Two phase power tests

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2 phase test validation

Design validation test completed to date

- Numerous performance calibration checks completed
- Thermal mapping of key motor components
- Eighteen 2 Phase tests successfully completed
- Twenty-four -65°F cold starts demonstrating peak inrush current behavior
- Fifty Thousands start / stop cycles completed

Development test continue through the development phase

- Endurance testing
- Vibration
- Complete 100,000 start / stop cycles

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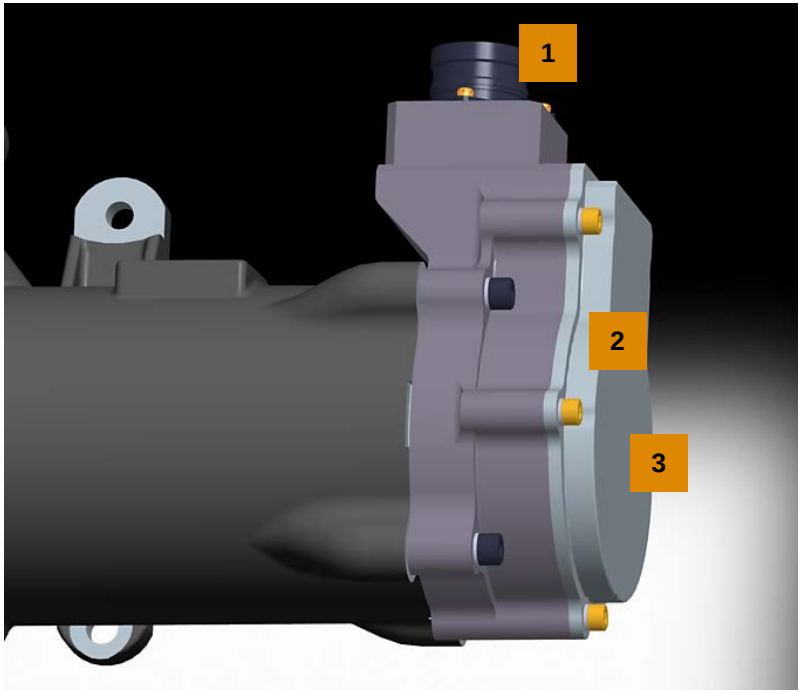
Envelope exterior



1	Aircraft connections identical
2	New machined cover and end bell
3	New envelope validated by Boeing

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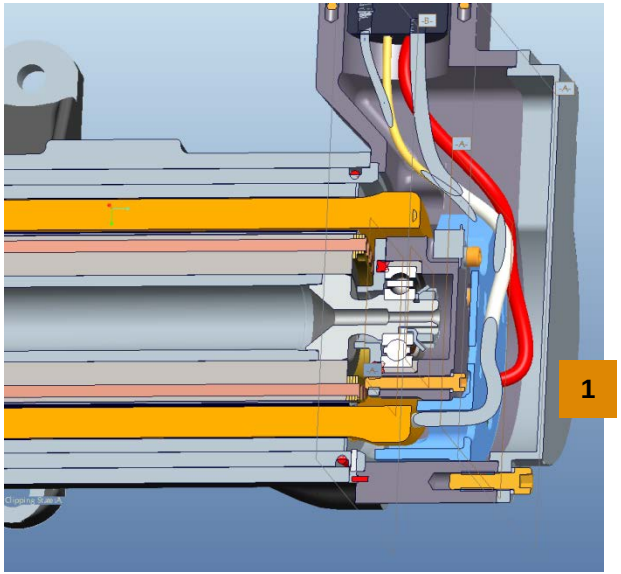
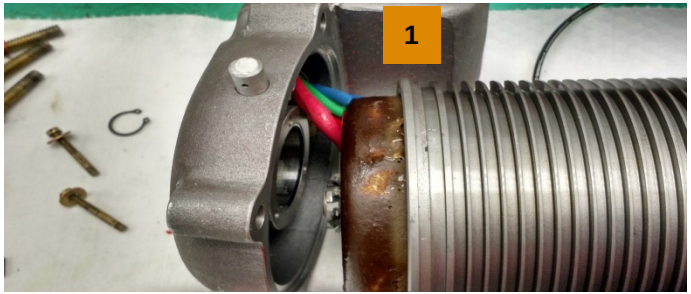
End-turn shielding

Upgraded configuration



1 New insulator providing end turn shielding

Incumbent configuration



1 No shielding in the incumbent configuration

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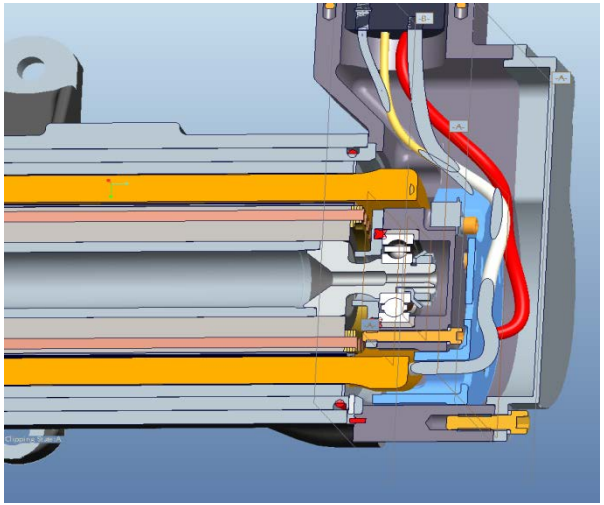
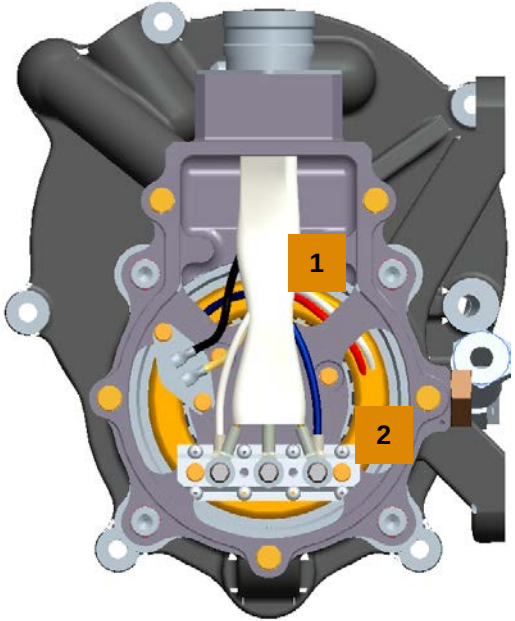
2 phase test validation

Configuration updates

Validation of the design with separation of lead wires has demonstrated inconsistency (pass/fail) during 2 phase testing. Time to failure is too large and the external temperature exceeds the limit of 392°F



Latest configuration



1. Incorporation of “Fuse Link” device that provides protection to the motor by failing to an open circuit during extended high current (90 amps ~60 seconds) events
2. Terminal strip – provides connection between stator leads and “Fuse Link”

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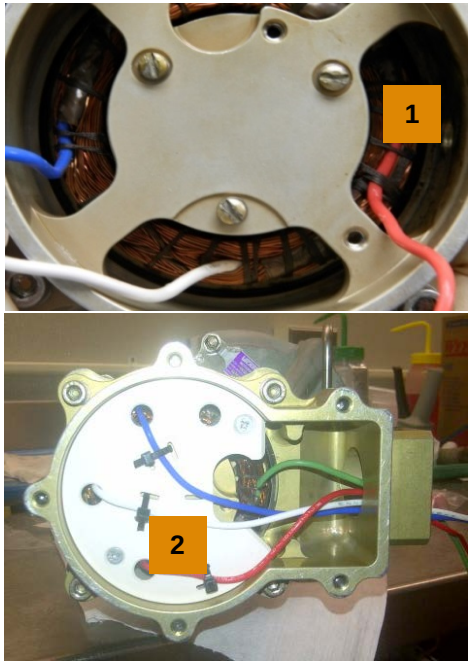
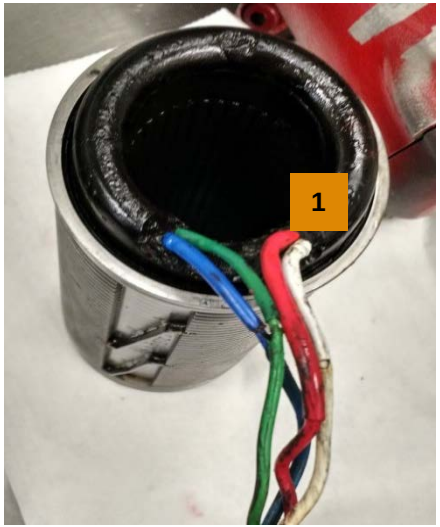
Electrical isolation and phase lead support

Upgraded configuration



1. 90 deg. phase lead separation
2. New Insulator providing phase lead isolation and support

Incumbent configuration



1. No phase lead spacing, isolation, or support

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Upgraded configuration benefits

- The upgraded configuration will meet all certification requirements for the 737 MAX application and retroactive requirements for the 737NG and C applications
  - The upgraded configuration will robustly contain both three and two phase motor failure events
- The upgraded configuration will remain point-to-point compatible with all 737 applications

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Upgraded configuration benefits

- The upgraded configuration as demonstrated to operate cooler due to an improved motor cooling jacket
  - This improvement will eliminate the hydraulic bypassing of the 10-60556-32 configuration
  - The cooling jacket will enhance the ability of the unit to self-purge air from the cooling circuit
- The upgraded configuration will relocate the thermal switch to better track the stator temperature for higher reliability

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Implementation

New Model will be Available in the 3rd quarter 2016

- Will be added to 737Max selection catalog April 2016
- New Model will become the standard for new build 737NG and Max configurations
- 737CL and 737NG pumps upgrade kits will be available 3rd quarter 2016
  - Service bulletin will be released in parallel with Model release
- Attractive Flat rate upgrade, parts kits, and retrofit programs available

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Questions/Comments

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