NASA

SECTION 36

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack	Presenter: David Rigby
	Date: Orbiter 01/14/03

Other Feedline Assembly BSTRA Ball Inspections

Feedline Description	Status
MPTA LH2 12 Inch Engine Feedlines	E1 In-Work E2, E3 Complete
MPTA LO2 12 Inch Engine Feedlines	Complete
Qual Unit LH2 12 Inch Engine Feedline	Complete
MPTA LH2 17 Inch Feedline	Complete
MPTA LO2 17 Inch Feedline	Complete
Separation Test LH2 17 Inch Feedline	Complete

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Qualification Test History

- 1977 Rockwell / Arrowhead qualification testing
  - Simulated flight qualification environment thermal shock and loading (400 cycles)
  - Test utilized both LN2 and LH2
  - Conclusion
    - No failures occurred in test
    - No defects noted post test penetrant inspection
    - No cracks noted post test by metallurgical sectioning

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Qualification Test History (cont):

- 1978 MSFC testing
  - MSFC concerns over the use of Stoody #2 in the feedlines
  - Stoody #2 bearings were already installed in the MPTA and cost and schedule considerations made it highly desirable to not change materials
  - Extreme thermal shock and loading
  - Tested bearings with and without cracks present
  - Test utilized both LN2 and LH2

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Qualification Test History (cont):

- 1978 MSFC testing (cont):
  - Conclusions
    - Material is prone to cracking from thermal/mechanical shock
    - Bearings may be cracked on receipt
    - Penetrant inspection is unreliable as compared to eddy current
    - No catastrophic failures and all bearings retained capability to perform intended function
  - The conclusion reached was that risk of failure was low; recommendation was to continue with MPTA with Stoody #2 bearings installed in MPTA ET lines
  - Program effects
    - ET project moved to Inconel 718 for BSTRA balls
    - Due to wear capability and plans for individual cyrogenic ATP of the balls, the Orbiter project continued with Stoody #2 balls

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Qualification Test History (cont):

- LO2 and LH2 17" feedline qualification tests
  - 100 mission qualification tests
  - Post test inspection – no BSTRA related anomalies
- Build Records and Acceptance Testing of BSTRA Balls
- No anomalies found during search of build records
- Acceptance test procedures perform dye penetrant inspection following LN2 thermal dunk
  - Use of dye penetrant inspection as detection method for pre-existing cracks is inadequate to detect cracks

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Approaches to Flight Rationale:

- For OV-102 / STS-107, the working assumption is that OV-102 has cracks since ATP screening of the balls is found to be inadequate
- Three options considered
  - On-vehicle repair
    - Technical concerns eliminated this option due to accessibility issues
  - Off-vehicle repair
    - Turnaround time is prohibitive to near term flight schedules
  - Fly as is

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Flight Rationale Based on Resolution of Two Issues

- Joint performance with cracked balls
  - Cracks must be self-limiting
    - Ball remains intact
    - Load margins remain positive
  - Joint angulation capability not compromised
    - Friction
    - Binding
- FOD from cracked balls
  - Crack propagation does not create FOD
  - No spalling

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Testing Activity to Support Flight Rationale

- Additional testing is required to support flight rationale development
  - Previous MSFC testing supported crack arrest mechanism for MPTA test program
    - Limited thermal / mechanical cycles
  - Qualification test program did not produce cracks
    - Arrest mechanism not demonstrated

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Severe Environments Needed to Crack Test Balls

- Extreme heat transfer required to crack test balls
  - 275 - 400 F (oven) to –100 F (glycol / dry ice)
  - Rapid thermal cycles 212 F (boiling water) to 32 F (ice water)
- Balls with and without notches did not start / propagate cracks despite multiple thermal and thermal / load cycles
  - May provide some rationale that OV-103 is unique

Ball Size	Total	Severely Cracked Balls	Less Severely Cracked Balls	Naturally Cracked Balls
2.24"	4	3	1	0
1.75"	2	1	0	1
1.25"	1	1	0	0

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Cracks Must Be Self-Limiting

- Nominal Testing
  - Thermal and mechanical cycling of cracked balls until crack(s) arrest for minimum of 5 cycles at each load level
    - Slow Fill (5 cycles minimum)
    - Nominal Flight Profile (35 cycles minimum)
    - Maximum Engine Operating Pressure (5 cycles minimum)
- Load Margin Testing
  - 1.5x Nominal Flight Profile (5 cycles minimum)
  - 1.75x Nominal Flight Profile (5 cycles minimum)
  - Material property variability may be encompassed through success of margin testing

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Cracks Must Be Self-Limiting (cont):

- Cyclic Margin Testing
  - Traditional shuttle testing methodology uses scatter factor on cycles for margin
  - Factor of 4 on nominal load cycles
  - For OV-102, ~30 flights coverage would require 120 cycles at nominal load levels; no scatter factor on higher load cases
  - Crack arrest on 2.24 / 1.75 inch balls may be able to show crack arrest on 1.25 inch balls acceptable
    - Alternate thermal profile may speed up testing and allow full additional cycles

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Cracks Must Be Self-Limiting (cont):

- If crack fails to arrest in severely cracked balls
  - Less severely cracked ball testing

  AND/OR
  - OV-103 inspection / harvest
- If crack fails to arrest in naturally cracked ball (1.75")
  - Full visual inspection on OV-102 to ensure no cracks
- Complete Eddy Current and CT scan of remaining spare balls to determine potential use for testing
- Testing ECDs
  - 2.24 inch balls: 1/11/03
  - 1.75 inch balls: 1/11/03
  - 1.25 inch balls: 1/12/03*

    * Using 287 F (oven) to –100 F (glycol / dry ice) to simulate LH2 thermal profile

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Joint angulation capability not compromised

- Friction
- Binding
- For all balls with cracks, vertical offset between surfaces will be measured
  - If offset greater than vitrolube thickness actual friction will be measured
    - MSFC developing testing capability
  - Initial work on a severely cracked 2.24 inch ball by MSFC M&P showed no issue
    - Measured 180 microinches offset maximum
    - 500 microinch vitrolube thickness minimum

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BSTRA Ball FOD Testing

- System design limits
  - Oxygen: 800 microns
  - Hydrogen: 400 microns
  - Prevalve screen: 1000 microns
    - 17" line upstream of screen
    - 12" line downstream of screen
  - Actions in work to determine acceptability of FOD with the SSME project

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BSTRA Ball FOD Testing (cont):

- FOD related issues
  - Branching cracks
  - Material islands
  - Loss of parent material

Type of cracks	Total Samples	Balls with Branching Cracks	Balls with Material Islands	Balls with Loss of Parent Material
Severe	4	4	4	2
Less Severe	1	0	0	0
Natural	1	1	1	0