



**SPACE SHUTTLE PROGRAM**  
**Space Shuttle Projects Office (MSFC)**  
NASA Marshall Space Flight Center, Huntsville, Alabama



# STS-108/ET-111 Flight Readiness Review

## External Tank Project



November 15, 2001



## Overview

Presenter L. Servay / LMSSC-ET

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- **Limited Life Component Status**

- All within required life through scheduled launch date plus 90 days except for pyrotechnic device installed in the GUCP separator assembly
  - Pyrotechnic device will expire 4 year lot certification on January 27, 2002
  - Lot certification test is scheduled for completion in December 2001

- **Significant Changes**

- Redesigned Ground GH2 Vent Disconnect
  - Presented and approved at PRCB on October 18, 2001

- **Significant Processing Anomalies**

- LH2 Recirculation Line Burst Disc Leakage
  - Rationale presented and accepted at the STS-108 Orbiter Rollout Milestone Review

- **Readiness Statement**



## Redesigned Ground GH2 Vent Disconnect

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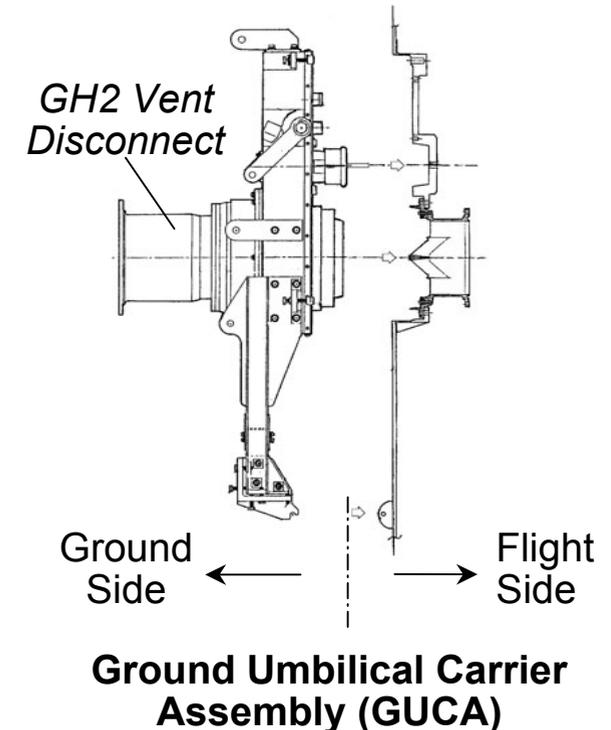
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### • Background

- GH2 vent disconnect is a component of ET Ground Umbilical Carrier Assembly (GUCA)
  - A Quick Disconnect (QD) poppet interfaces with the ET flight disconnect to allow venting of ET LH2 tank to facility
- At launch, the interface separates and the QD poppet closes to contain H2 vapors in the facility vent lines

### • Reason for Change

- Disconnect was redesigned as part of Shuttle Upgrades to minimize refurbishment efforts at KSC and to enhance sealing capability between ground and flight sides
  - Planned implementation was ET-122
- Early implementation of the design was requested by team investigating the STS-105 disconnect poppet stem failure
  - Authorized by PRCBD S053132AC





## Redesigned Ground GH2 Vent Disconnect

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- **Description of Change**
  - Two-piece adjustable disconnect body design was replaced with a one-piece design
    - Eliminated adjustment capability never used during Shuttle Ground Operations
    - Eliminated 17 detail parts, including a seal between two pieces of the ground disconnect
  - Minimum required bellows spring force in the mated configuration was increased from 165 lbs to 225 lbs to enhance the seal capability
- Added pins for the ice suppression shroud interface
  - Locking bolts for the adjustment mechanism were utilized for the interface
- Replaced safety wire with safety cable around fasteners



## Redesigned Ground GH2 Vent Disconnect

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### • Basis for Certification

- Acceptance testing and inspection is performed on each unit delivered
  - Dimensional verification
  - Verification of bellows probe spring rate, load at working length
  - Proof load - 36,000 lbs axial tension with no permanent deformation
  - Proof pressure - unmated ground side / ground side mated with flight side
  - Leakage - ambient and cryogenic testing in both mated and unmated configuration
  - Functional test - ambient and cryogenic temperatures
- Qualification of redesigned part successfully completed in June 2001
  - Liftoff random vibration testing of mated disconnect
    - 1 minute per axis, including separation
  - Operating cycles - engagement and separation
    - 50 cycles at ambient temperatures, 50 cycles at cryogenic temperatures
  - Leakage - ambient and cryogenic testing in both mated and unmated configuration
  - Burst pressure - mated and unmated

***Ground GH2 Vent Disconnect is Certified for Use***

## LH2 Recirculation Line Burst Disc Leakage

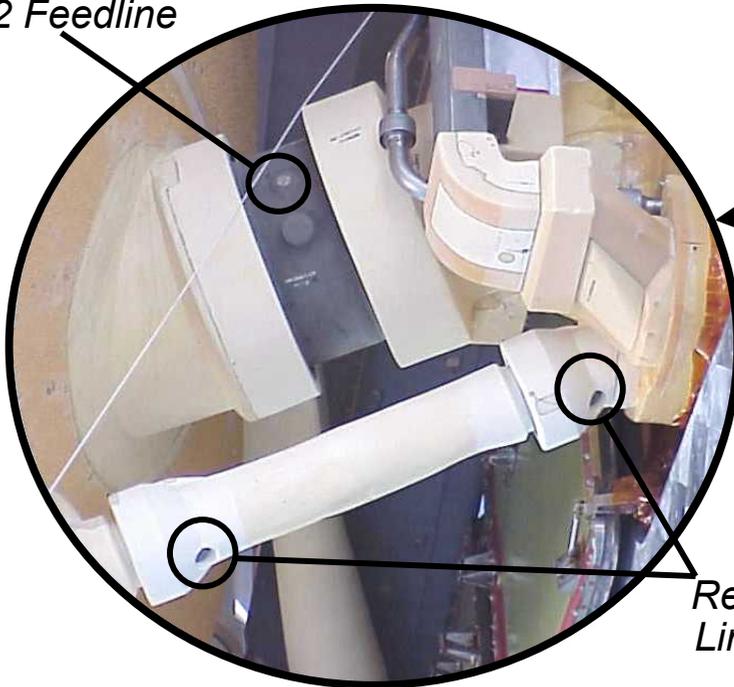
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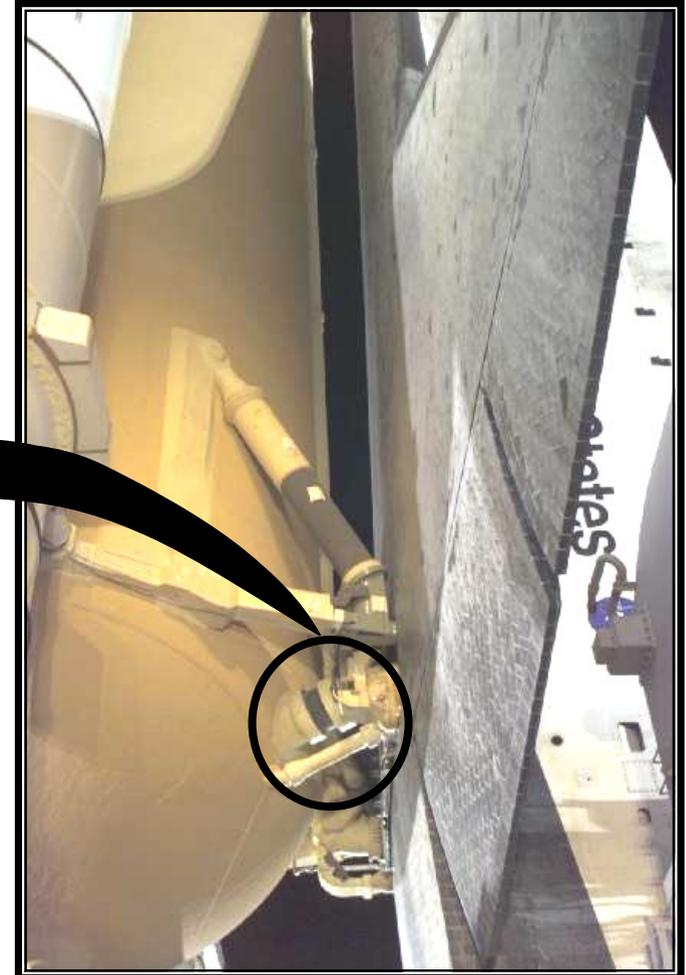
### • Issue

- LH2 recirculation line burst disc leaked during the acceptance testing at the supplier
  - Burst disc is a safety feature on jacketed lines to prevent hardware damage due to annulus over-pressure
- Three burst discs are installed on each ET

LH2 Feedline



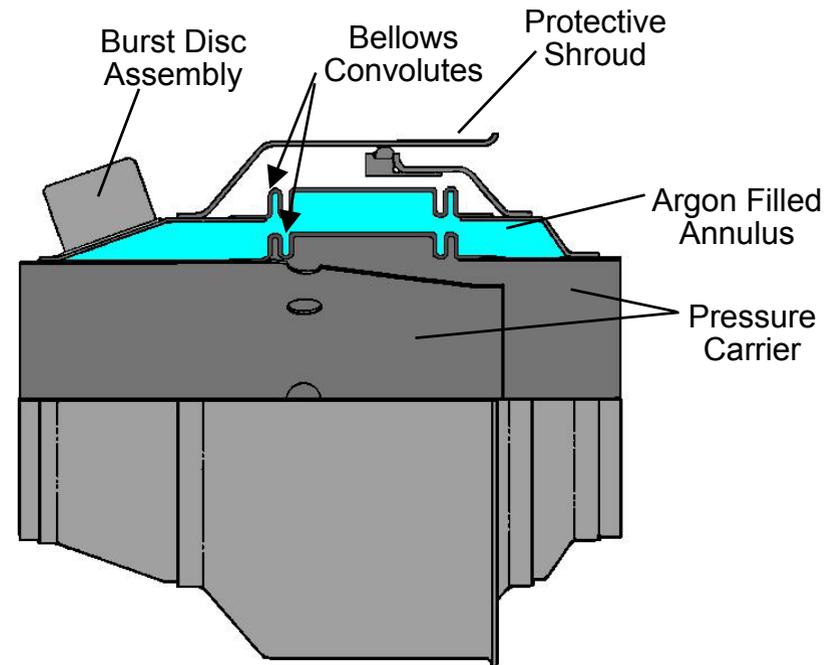
LH2  
Recirculation  
Line Bellows



|                                                    |  |                                |        |
|----------------------------------------------------|--|--------------------------------|--------|
| <h1>LH2 Recirculation Line Burst Disc Leakage</h1> |  | Presenter L. Servay / LMSSC-ET |        |
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• **Background - Design**

- LH2 recirculation line and LH2 external feedline on the ET have articulating bellows to allow for relative movement between the ET and the Orbiter
- Jacketed sections provide a vacuum thermal barrier during cryogenic operations
  - Annulus is evacuated and back filled with argon
- Failure mode (loss of vacuum)
  - Criticality 1 for LH2 external feedline
  - Criticality 3 for LH2 recirculation line
- Loss of vacuum in the annulus would allow air to condense in and around the annulus and freeze
  - Hard ice formation in the convolutes has potential of locking the bellows



*Recirculation Line Bellows*



|                                                  |                                       |               |
|--------------------------------------------------|---------------------------------------|---------------|
| <b>LH2 Recirculation Line Burst Disc Leakage</b> | <b>Presenter</b> L. Servay / LMSSC-ET |               |
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**• Investigation Background**

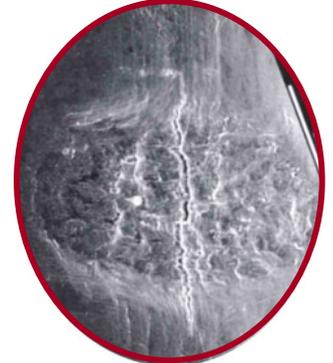
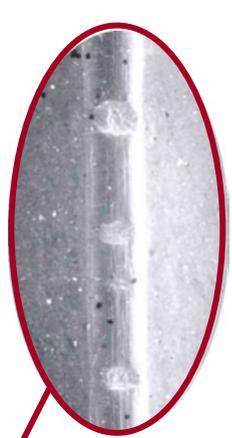
- Failure occurred on part from CY 2000 lot
  - In-process (non-ATP) leakage failure history of 2000 lot is higher than previous lots
  - Leakage occurred at microscopic cracks observed on the part during failure analysis
    - Cracking observed only on small “bumps” in the center of the disc

| Lot  | Parts Delivered | In Process Loss |       | Flown | Fleet | In-Process | Sub-Tier Changes                                                                  |
|------|-----------------|-----------------|-------|-------|-------|------------|-----------------------------------------------------------------------------------|
|      |                 | Leakage         | Other |       |       |            |                                                                                   |
| 1985 | 63              | 2               | 2     | 59    | 0     | 0          | None                                                                              |
| 1993 | 81              | 0               | 0     | 78    | 3     | 0          | Company ownership change;<br>no personnel changes<br>Tool modified to add “bumps” |
| 1996 | 41              | 0               | 2     | 14    | 17    | 8          | None                                                                              |
| 1998 | 25              | 1               | 0     | 0     | 1     | 23         | Manufacturing location change                                                     |
| 2000 | 60              | 4               | 1     | 0     | 0     | n/a        | None                                                                              |

- STS-108/ET-111 hardware
  - LH2 Feedline has one 1993 burst disc
  - LH2 Recirculation line has two 1996 burst discs

**LH2 Recirculation Line Burst Disc Leakage**

|           |                      |         |
|-----------|----------------------|---------|
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**Typical Crack**  
 Approx. 0.008" in length

**Bumps**



**Disc from 1985 Lot**



**Disc from 2000 Lot**



|                                                  |  |                                |
|--------------------------------------------------|--|--------------------------------|
| <b>LH2 Recirculation Line Burst Disc Leakage</b> |  | Presenter L. Servay / LMSSC-ET |
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• **Hardware Clearance Logic**

**Are leaks limited to 2000 lot?**

- No**
- Burst discs from all available lots had bumps and showed evidence of cracking
  - Leakage could not be attributed to any supplier processing changes

**Does ATP screen for cracks that would leak in service?**

- No**
- ATP does not adequately screen for this type of defect, which is attributed to the bump feature on the disc
- 2 of 16 discs leaked during simulated supplier production cycles
  - 3 additional discs leaked during simulated operational cycles

**Is risk of operating with leaking disc acceptably low?**

- Yes**
- No evidence of crack growth based on microscopic evaluation of discs at various stages of testing
  - Risks associated with a leaking burst disc were evaluated (See following page)

**Can discs be repaired to prevent potential leakage?**

Yes

**ET-111 Hardware Acceptable for Flight**

**Develop and Validate Method of Repair**



|                                                  |  |                                              |
|--------------------------------------------------|--|----------------------------------------------|
| <b>LH2 Recirculation Line Burst Disc Leakage</b> |  | <b>Presenter</b> L. Servay / LMSSC-ET        |
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- **Hardware Clearance - Analysis of Risks**
  - **Assessed Risk of Structural Damage to Pressure Carrier**  
*(Ice formation restricting bellows movement - results from loss of vacuum)*
    - LH2 Feedline (Criticality 1 for loss of vacuum)
      - Maximum leak rate observed during testing ( $4.6 \times 10^{-2}$  sccs helium) is not sufficient to affect bellows performance
        - Accumulated liquid/solid volume of air and argon in the annulus would be less than 0.25% of the total annulus volume
          - Assumes multiple consecutive cryogenic loadings with continuous air leakage into the annulus
        - Vacuum is maintained with the low leakage rate
    - Recirculation Line (Criticality 3 for loss of vacuum)
      - Testing at MSFC in 1989 demonstrated the bellows performed as required with total loss of annulus vacuum



|                                                  |  |                                |
|--------------------------------------------------|--|--------------------------------|
| <b>LH2 Recirculation Line Burst Disc Leakage</b> |  | Presenter L. Servay / LMSSC-ET |
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- **Hardware Clearance - Analysis of Risks**
  - **Evaluated Risk of Propellant Quality Degradation**
    - Analysis using a worst case heat load shows a small increase in temperature of propellant supplied to engines
      - Less than 0.01 deg during flight; less than 1.0 deg during loading
    - Temperature would remain within requirements and propellant quality would not be adversely affected
  - **Evaluated Risk of Burst Disc Rupture Following Propellant Drain**  
*(Line replacement required)*
    - Analysis predicts that with maximum measured leakage rate, burst disc will not rupture during a scrub turnaround
      - Analysis performed for recirculation line (due to the smaller annulus volume)
      - Assumed ISS mission and a maximum of two consecutive 24 hour turnarounds
        - Longest duration of annulus pressures lower than ambient pressure
      - Ambient temperature reflects 95% temperature from KSC weather data for November - January
    - Annulus pressure will not reach the minimum burst disc rupture pressure during the line warm-up to ambient temperatures



|                                                  |                                              |
|--------------------------------------------------|----------------------------------------------|
| <b>LH2 Recirculation Line Burst Disc Leakage</b> | <b>Presenter</b> L. Servay / LMSSC-ET        |
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- **Clearance Rationale**

- **Ground Operations Not Affected by Disc Leakage**

- Analysis shows that leakage rates are not sufficient to cause disc rupture during a scrub turnaround

- **Safety of Flight Not Affected by Disc Leakage**

- Testing demonstrated that loss of vacuum / ice formation does not affect the structural performance of the LH2 recirculation line
- Analysis shows that the maximum leak rate seen during testing would not adversely affect the structural performance of the LH2 feedline bellows
- Loss of vacuum insulation does not affect propellant quality

***ET-111 Burst Discs Acceptable for Flight on STS-108***



|                            |                                       |                |
|----------------------------|---------------------------------------|----------------|
| <b>Readiness Statement</b> | <b>Presenter</b> L. Servay / LMSSC-ET |                |
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**The External Tank, ET-111, is certified and  
ready for STS-108 flight pending  
completion/closure of open and planned work**