

November 3, 1997

**Space Shuttle
External Tank**

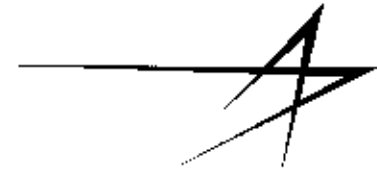
**STS-87/ET-89
Flight Readiness
Review**

Michoud Space Systems



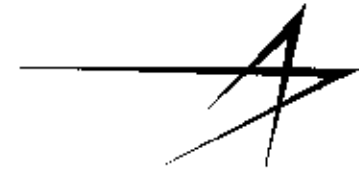
ET-1

Overview



- **No significant changes**
- **Out-of-family anomalies**
 - LH2 tank forward dome contour deviation
 - LH2 tank extrusion issue
- **Limited life component status**
 - All items within required life
- **Open work/paper - No constraints to flight**
- **Readiness Statement**

LH2 Forward Dome Contour Deviation



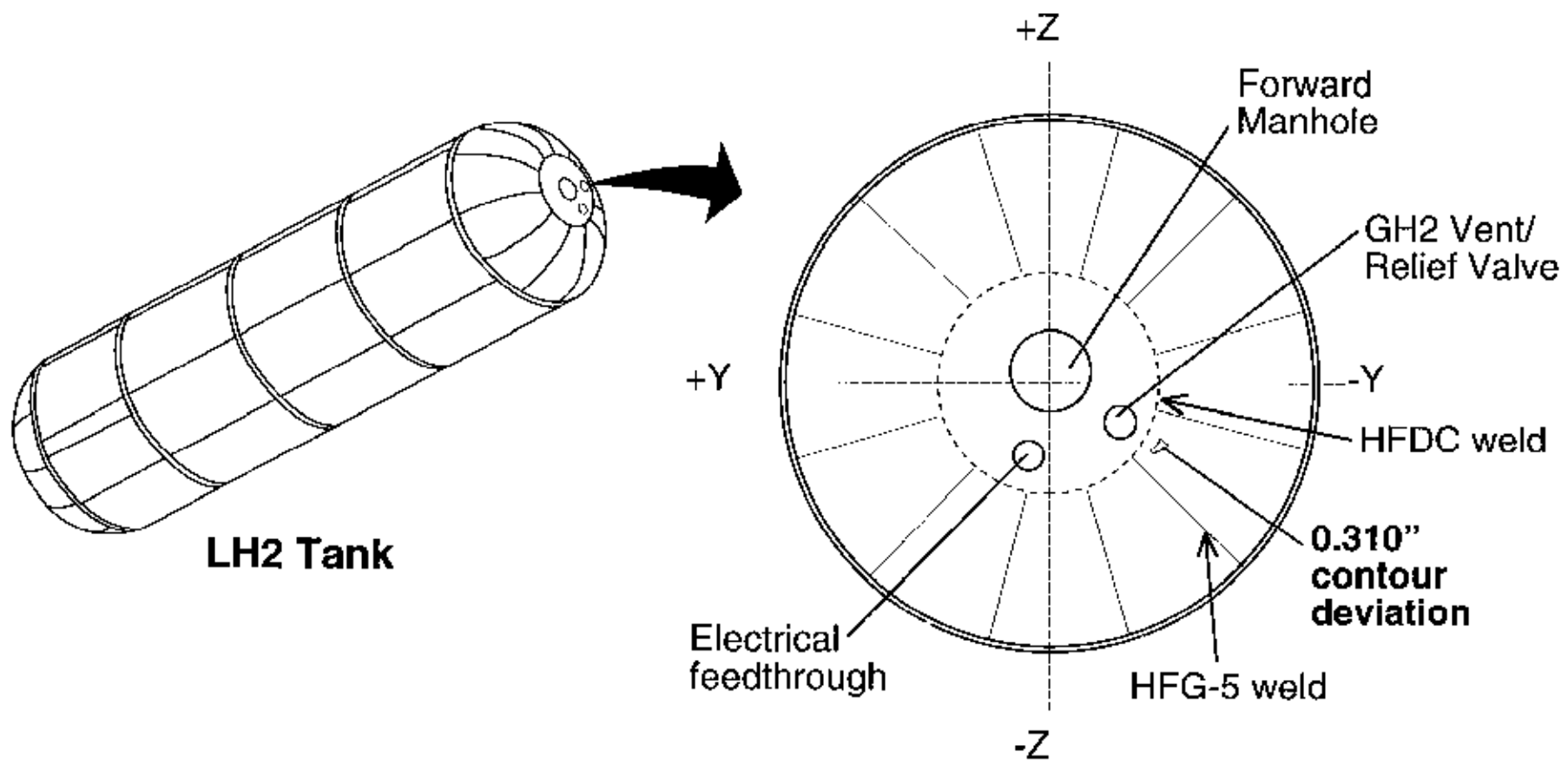
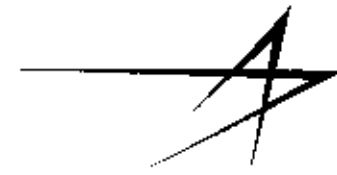
Issue:

- Negative contour deviation exists on LH2 tank forward dome
 - Maximum allowable deviation = ± 0.125 "
 - Deviation on ET-89 = 0.310"

Background:

- During weld of the dome at subassembly level an unscheduled weld machine tailout resulted in a burn-thru with excessive penetration
 - Multiple heat repairs were accomplished
 - 12 planishing passes to improve contour
 - Resulting contour deviation had max depth of 0.250"
 - Contour and weld repairs acceptable by analysis
 - NCD closed
- Dome subsequently welded to LH2 tank
 - Visual observation of dome indicated that contour had changed
 - Re-measurement determined contour deviation increased in size and depth (0.310")
- SMR item because contour was max deviation observed to date

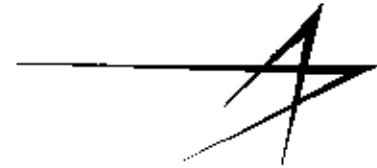
LH2 Forward Dome Contour Deviation



LH2 Tank

LH2 Tank Forward Dome

LH2 Forward Dome Contour Deviation



Cause:

- Initially induced by significant weld repairs
- Contour changed after previous MRB action possibly due to
 - Rounding of dome for mechanical installation
 - Fit up and welding of dome to barrel
 - Orientation of dome from horizontal to vertical

Disposition:

- Use as is

Rationale for Flight:

- Proof test
 - HFG-5 and HFDC welds and membranes are adequately proofed from a fracture basis and proofed to 119% of flight limit load from a strength basis
- Stress analysis
 - Structural: Meets required FS (1.25)
 - Shell
 - Was: 1.46
 - Now: 1.33 (failure mode: ultimate tension)
 - Weld
 - Was: 1.79
 - Now: 1.28 (failure mode: ultimate tension)
 - TPS: Meets required FS (1.10)
 - Was: 2.38
 - Now: 1.34 (failure mode: outer fiber strain)
- ET-89 meets all flight requirements

LH2 Tank Extrusion Issue



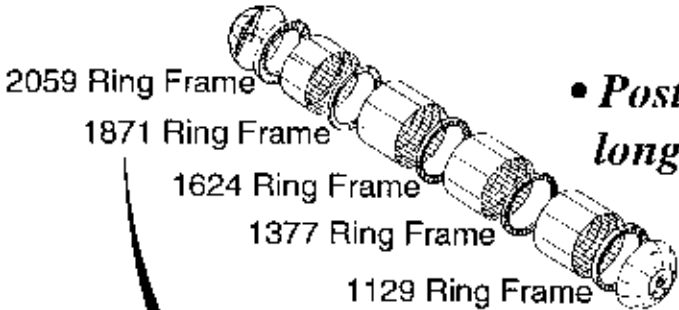
Issue:

- Three x-ray indications were detected after initial proof test of the ET-89 LH2 tank
 - Located adjacent to weld in extrusion forward of longerons at Station 1871
 - Lengths were 1.00 inch, 0.48 inch and 0.75 inch

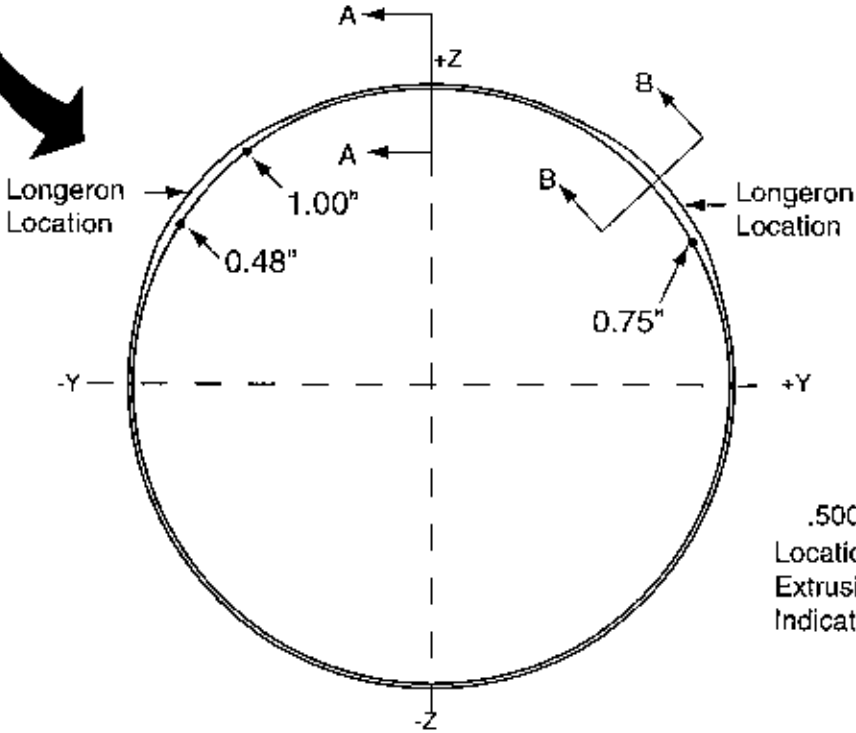
Background:

- Located in extrusion heat affected zone adjacent to initial weld
 - First time occurrence - Considered to be out of family
- Fault tree initiated - Investigation indicated root cause was low material strength due to re-crystallized grain structure
 - Proof test facility integrity verified by instrumentation
 - Parent extrusion strength and integrity verified by test
- Complete assessment of vehicle revealed multiple first-time events
 - First use of extrusion “buy” at Station 1871
 - First use of revised tooling for SLWT welding
 - First full use of revised proof test facility
 - First failure of supporting jack stands

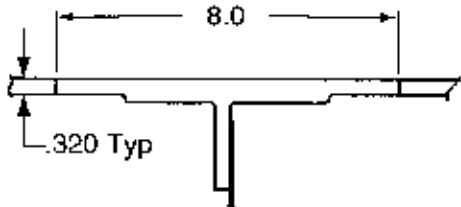
LH2 Tank Extrusion Issue



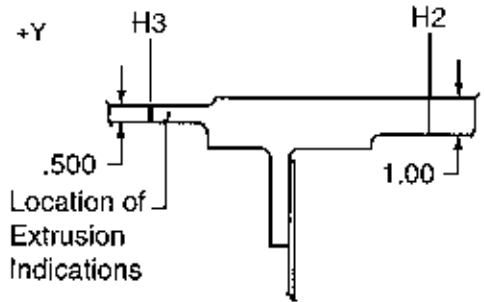
• *Post-proof indications were located in the longeron areas of the Station 1871 Chord*



Station 1871 Ring Frame Arrangement



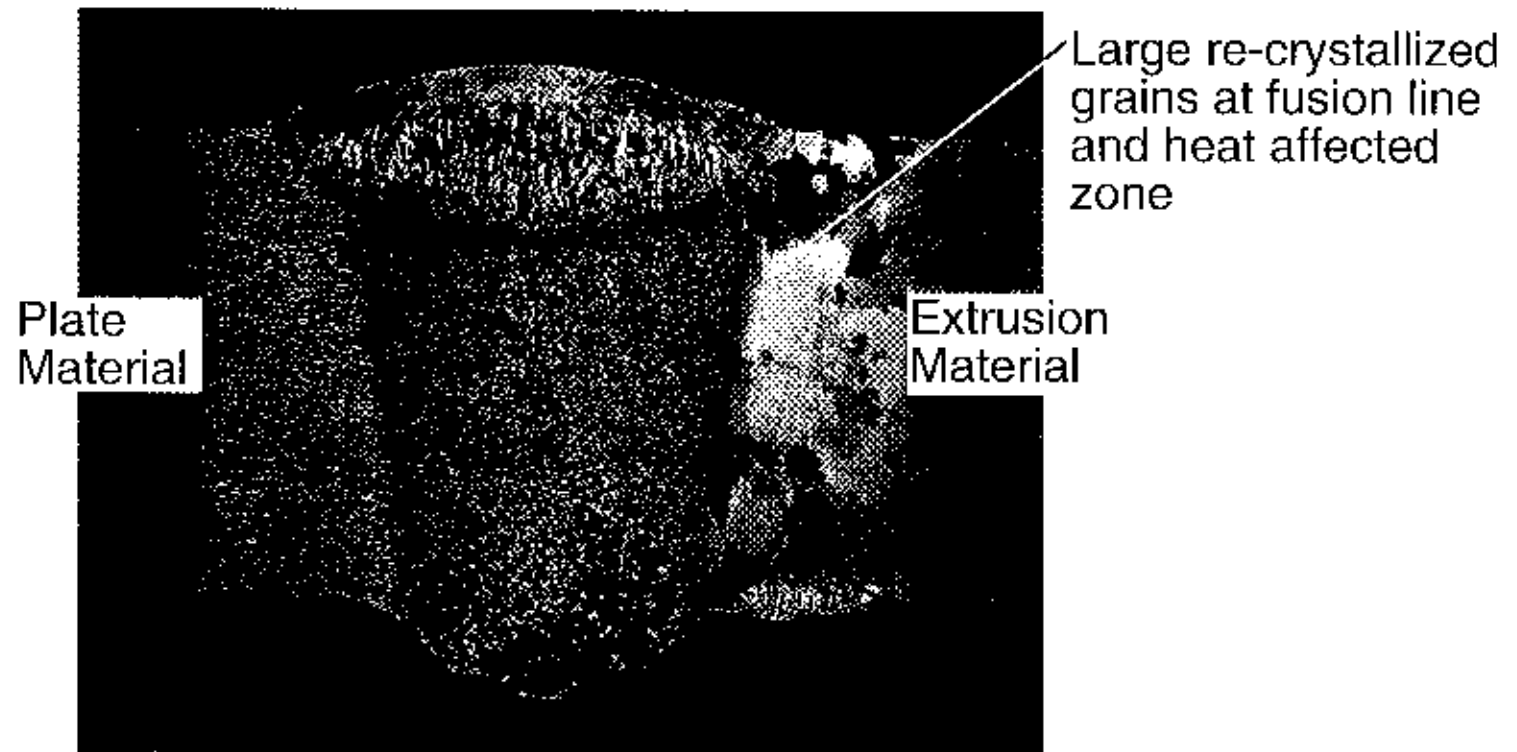
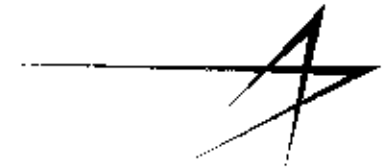
Section A-A (Typical)



Section B-B (Longeron Area)

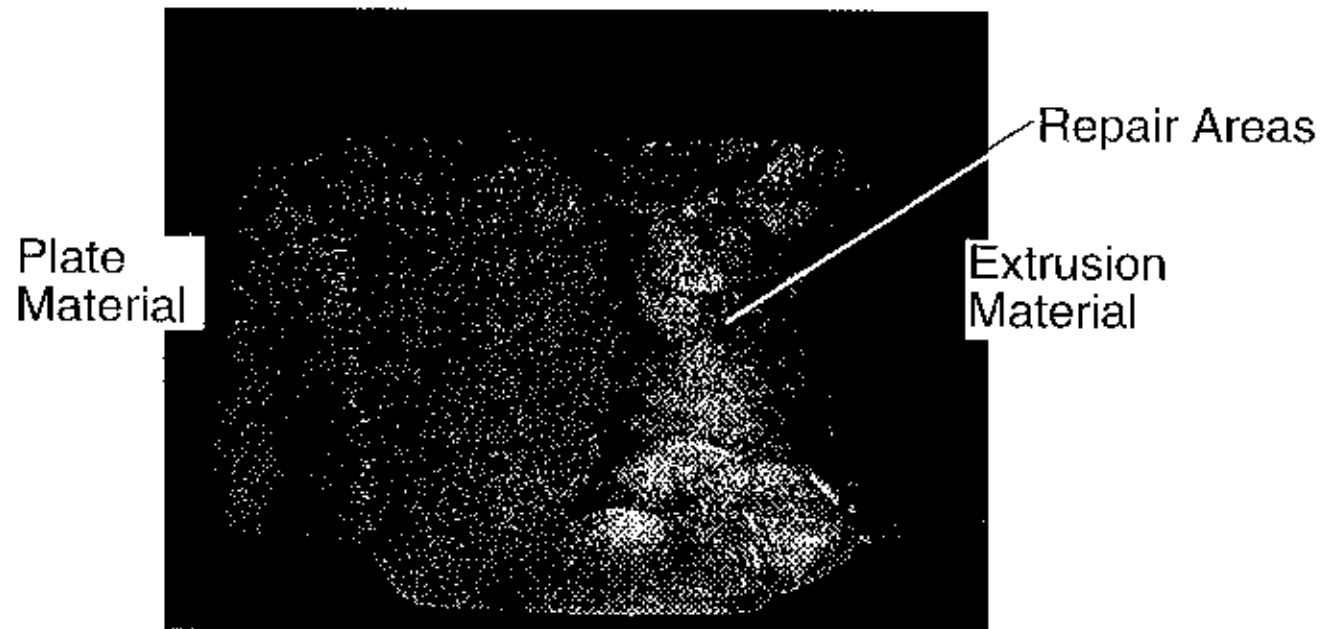
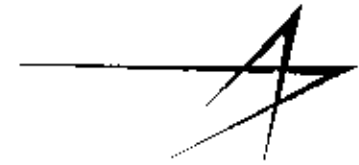
LH2 Tank Extrusion Issue

As Welded Extrusion Cross-Section

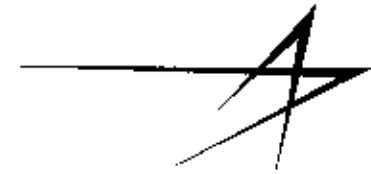


LH2 Tank Extrusion Issue

As Repaired Cross-Section



LH2 Tank Extrusion Issue



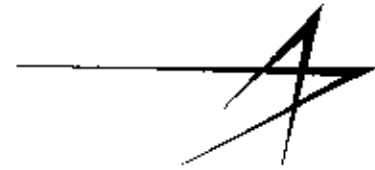
Cause:

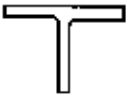
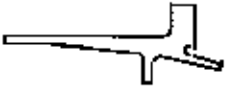
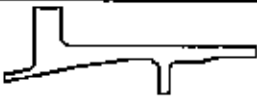


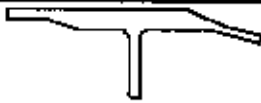
- Large re-crystallized grains extended 0.5" to 0.75" from original extruded surface
 - Not completely machined off in manufacture of chord
 - Aggravated by alignment of weld fusion line with natural flow lines of extrusion shape
 - Grains aligned normal to load path
 - Lower toughness, thickened grain boundary precipitation due to large grain size

Disposition:

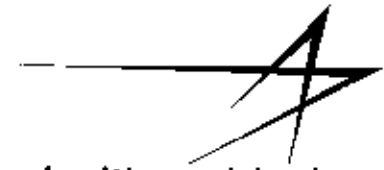
- Weakened microstructure ground out and replaced with weld wire (including reported x-ray indications)
 - Process fully replaced the extrusion weld heat affected zone
 - Resulting mechanical and fracture properties were typical of allowables established for plate-plate welds
 - Process returned hardware integrity to acceptable levels for proof and flight
- Extensive test program on other extrusions indicated adequate strength at other weld stations
 - Large vertical grain structure not noted
 - Additional post-proof inspections successfully performed to verify integrity

LH2 Tank Extrusion Issue



Location	Shape	Weld Code	Ultimate Stress (ksi)		Allowable Stress (ksi)	Factor of Safety	
			Flight	Proof		Required	Actual
744 T-ring		O3 O4	32.75	24.22	36.40	1.32	1.47
			30.40	20.03	36.40	1.32	1.58
851 Dome Chord		O5 OAF	21.56	13.60	36.40	1.34	2.26
			30.99	28.51	37.70	1.35	1.65
1129 Dome Chord		HFF H8	30.60	29.01	38.00	1.25	1.55
			29.56	24.00	33.70	1.27	1.45
1377 & 1624 Frames		H7 H6 H5 H4	31.74	28.08	39.80	1.26	1.58
			30.98	27.51	39.80	1.26	1.61
			26.21	20.95	39.80	1.30	1.98
			28.47	23.01	33.70	1.30	1.53
1871 Frame Chord		H3 H2	38.10	28.40	38.10	1.26	1.26
			42.10	36.70	42.40	1.26	1.27
2058 Dome Chord		H1 HAF	36.84	29.09	39.80	1.26	1.36
			35.81	29.25	45.60	1.29	1.64

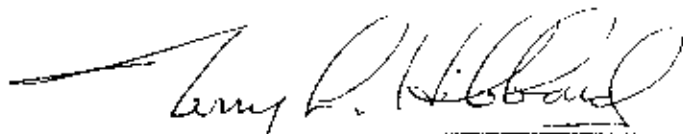
LH2 Tank Extrusion Issue



- Rationale for Flight:**
- Weakened microstructure ground out and replaced with weld wire
 - **Successful re-proof test of ET-89**
 - Post proof x-ray of entire H2 and H3 welds revealed no indications
 - All penetrant indications greater than 0.2" removed by sanding or heat repair
 - Post proof penetrant inspection of enhanced area indicated no changes resulted
 - **All extrusion welds have positive margins of safety using**
 - "As-built" peaking and mismatch
 - Reduced weld strength from recent test program
 - "Enhanced extrusion" weld properties from test program
 - Allowable methodology 99% reliability/95% confidence per Mil-HDBK-5F
 - All MRB actions re-reviewed - Positive margins are shown
 - All x-rays (pre and post proof test) have been re-reviewed - No indication changes resulted
 - **All welds are demonstrated to 100% of limit flight loads or greater by proof test**
 - Includes effect of reduced cryogenic enhancement of strength
 - Approximately 70% of entire weld length is demonstrated to ultimate design load (limit x SF) by proof test
 - Reviewed by NASA Independent Review Team
 - **Presented/approved at Level II PRCB on 11/22/96 (SR0760)**

Readiness Statement

**The External Tank, ET-89, is hereby certified
and ready for STS-87 flight pending
completion/closure of open and planned work**



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