FLIGHT READINESS STATEMENT
ST[redacted]
EXTERNAL TANK PROJECT
PRE-FLIGHT REVIEW

EXTERNAL TANKS ET-103/STS-106 & ET-104/STS-92, AS IDENTIFIED IN THE EXTERNAL TANK PROJECT PRE-FLIGHT REVIEW DATED AUGUST 15, 2000, ARE CONSIDERED READY TO SUPPORT FLIGHT UPON ACCEPTABLE DISPOSITION OF OPEN/PLANNED WORK AND/OR OPEN ACTIONS.

N. E. OTTE/MP31

A. A. McCOOL/MP01

for J. BULLMAN/ED10

For J. W. KILPATRICK/ED20

for A. F. WHITAKER/ED30

for D. A. KROSS/ED40

for A. O. GOODSON/QS01

for C. E. SINGER/TD01

for J. W. SMELSER/MP31, CHAIRMAN

August 15, 2000

Space Shuttle
External Tank

ET Project Pre-Flight Review

STS-106/ET-103 & STS-92/ET-104

LOCKHEED MARTIN

103&104ETProjPFR.4250.08/00

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Overview — ***Jim Feeley***

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- ***STS-101/ET-102***

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- ***STS-106/ET-103***
- ***STS-92/ET-104***

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Overview

This review for STS-106/ET-103 and STS-92/ET-104 includes:

- Items specific to missions STS-106 and STS-92
- First time differences and "out-of-family" non-conformances not previously flown and/or reviewed
- Previously presented items are included in Appendix E
  - STS-101/ET-102 performance (LO2 100% level sensor failure and crack in +Y longeron foam closeout)
  - Discrepant NDE records for ET welds
  - Diagonal strut mechanical testing
  - Incorrect weld rod on External Tank hardware

FRR Series

- *STS-106/ET-103*

- ET/SRB Mate Review	03/03/2000 (A)
- Michoud Operations Pre-Flight Review	07/26/2000 (A)
- ET Project Pre-Flight Review	**8/15/2000**
- Space Shuttle Vehicle FRR	08/29/2000
- MMT Simulation	08/30/2000
- Pre-launch Mission Management Team Review	09/06/2000 (NET)

- *STS-92/ET-104*

- ET/SRB Mate Review	06/26/2000 (A)
- Michoud Operations Pre-Flight Review	07/26/2000 (A)
- ET Project Pre-Flight Review	**08/15/2000**
- Space Shuttle Vehicle FRR	09/21/2000
- Pre-launch Mission Management Team Review	10/03/2000

Prior Mission Performance Summary

STS-101/ET-102 Launch Attempts

System	***04/24/2000*** *(Scrub due to high cross winds for RTLS landing)*	***04/25/2000*** *(Scrub due to high cross winds for RTLS landing)*	***04/26/2000*** *(Scrub due to high cross winds at TAL site)*
• ***OMRSD/LCC***	• No violations	• No violations	• No violations

• ***Instrumentation***	• No violations	• No violations	• LO2 100% #1 level sensor failed wet in replenish
			  • Instrument failure - Orbiter circuit checks were nominal
			• Sensor is used for LO2 fill and level control
			  • Pre-planned contingency was used to continue operations using 100% #2 sensor

• ***ET Hazardous Gas***	• Backup Mass spec off line; HUMS used for ET and as backup for orbiter aft compartment	• Nominal	• Nominal

Prior Mission Performance Summary

STS-101/ET-102 Launch Attempts

System	04/24/2000	04/25/2000	04/26/2000
• *MPS*	• No ET violations	• No ET violations	• No ET violations

• *TPS*	• Six cracks in the Intertank thrust panel foam**
	• Crack in -Y vertical strut foam
	• All acceptable per NSTS 08303
		• Twelve cracks in the Intertank thrust panel foam**
		• Crack in -Y vertical strut foam
		• Frost ball on +Y longeron
		• All acceptable per NSTS 08303
			• Fourteen cracks in the Intertank thrust panel foam **
			• 2 cracks in -Y vertical strut foam
			• Intertank and vertical strut cracks acceptable per NSTS 08303
			• MRB for two cracks on +Y longeron TPS closeout
			  • No thermal and/or stress concerns for ascent/ reentry
			  • BNA debris analysis
			  • Any ice particles from this location would result in minimal damage to the Orbiter
			  • No transport mechanism for foam debris to impact Orbiter from this location

*** Intertank TPS Performance discussed in detail following Launch Day Performance Summary*

Prior Mission Performance Summary

STS-101/ET-102, 05/19/2000 Launch

System	***Performance***

• ***OMRSD/LCC***	• OMRS Exception to allow LO2 propellant loading with LO2 100% level sensor #1 failed wet
	  • Pre-planned contingency (LCC ET-10) was used to continue operations using 100% #2 sensor
	  - Replenish control requires only one of the 100% and 100.15% level sensors

• ***Instrumentation***	• LO2 100% #1 level sensor failed wet
• ***MPS***	• Nominal
• ***ET Hazardous Gas***	• Nominal

Prior Mission Performance Summary

STS-101/ET-102, 05/19/2000 Launch

System	Performance
• ***TPS***	• Two cracks in +Y longeron closeout *(Same as previous tanking)* – Violated NSTS 08303 – PR dispositioned use as is • Two cracks in -Y vertical strut foam *(Same as previous tanking)* – Acceptable per NSTS 08303 • Fifteen cracks in Intertank foam *(One additional crack from previous tanking)* – Acceptable per NSTS 08303
• ***Orbiter Tile Damage***	• Foam performance greatly improved over NCFI average
• ***Post Flight Photo Review***	• Crew photos from cockpit - Poor resolution • Umbilical well photos - No significant anomalies • *Longeron closeout remained in tact*
• ***ET Disposal***	• Nominal

	STS-101 Lower Surface Damage Sites	*Forward of Main Landing Gear*	
		STS-101	*Avg*
– Diameter > 1"	19	5	33
– Total	70	23	88

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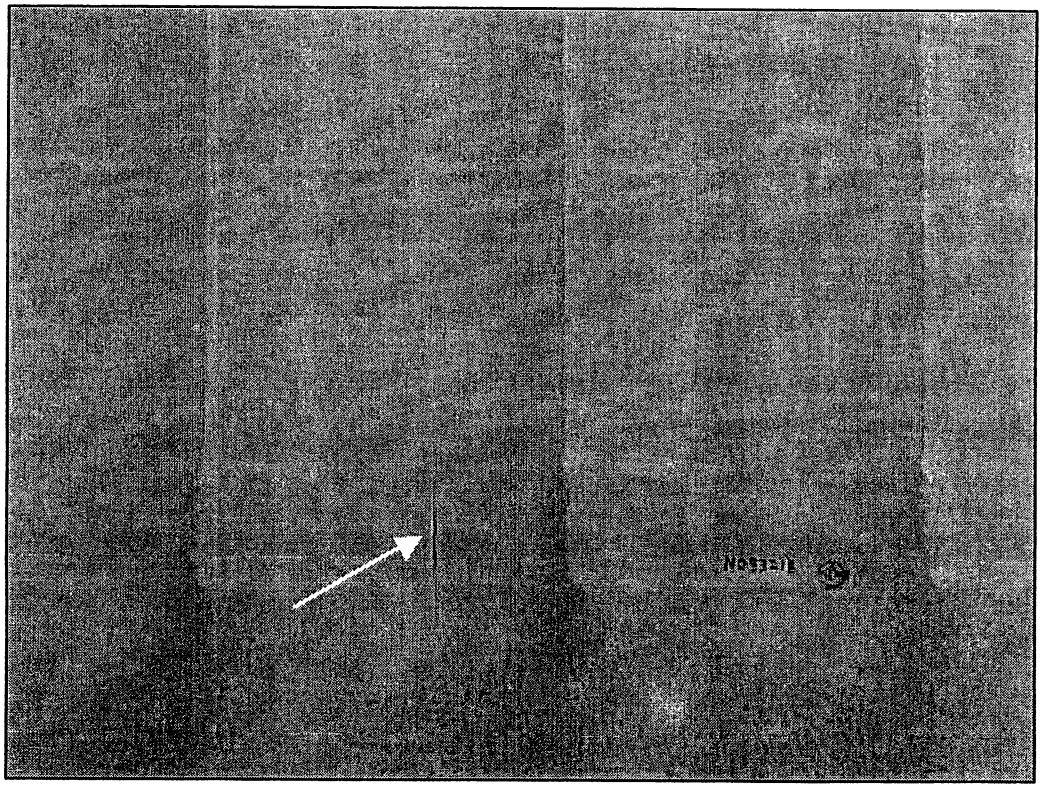
Prior Mission Performance Summary

Intertank TPS Performance Discussion

- ***TPS intertank cracks are caused by thermal induced skin flexure***



Typical Crack in Intertank Foam
+Y side, 15th valley from -Z
(Photo from 1st cryo load)

- Cracks range from 2" to 18" in length
  - Largest recorded width = 3/16"
  - Cracks originated near Intertank/LH2 tank flange
- Length and number of cracks tend to increase with number of cryogenic loadings
  - Cracks then close up following detank
- Cracks are inspected by Final Inspection Team to ensure no offset or ice/frost is present prior to launch

Mission/External Tank Highlights

STS-106/ET-103 (as of 08/02/2000)

Mission	***STS-106***
Launch	***09/08/2000 (NET)***
• Window	8:31 - 8:41 a.m. ET
• Pad	B
• Orbiter	Atlantis (OV-104)
• Orbital Inclination	51.6 degrees/177 nautical miles
• ET Photo Coverage	• Crew photos from cockpit window • Umbilical well cameras
Primary Payload	***ISS fourth flight (2A.2b)***
Landing	***09/19/2000***
• Time	03:12 a.m. ET
• Location	KSC
External Tank	***ET-103***
DD250 Acceptance	*06/22/1999*
• Age at launch	14 months
Shipped to Launch Site	*09/22/1999*

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Mission/External Tank Highlights

STS-92/ET-104 (as of 08/02/2000)

Mission	***STS-92***
Launch	***10/05/2000***
• Window	9:49 - 9:59 p.m. ET
• Pad	A
• Orbiter	Discovery (OV-103)
• Orbital Inclination	51.6 degrees/177 nautical miles
• ET Photo Coverage	• Crew photos from cockpit window • Umbilical well cameras
Primary Payload	***ISS fifth flight (3A)/Z-1 truss and PMA-3***
Landing	***10/16/2000***
• Time	TBD
• Location	KSC
External Tank	***ET-104***
DD250 Acceptance	*06/01/1999*
• Age at launch	• 16 months - Will be the oldest tank flown to date with HCFC 141b blowing agent
Shipped to Launch Site	*06/10/1999*

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Mass Properties

- ***ET-103 Status***
- ***ET-104 Status***

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Rick Spring

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Mass Properties Status

STS-106/ET-103

Specification Weight = 58,466 lbs.

ET-103 Weighing

- Platform scale weighing (10/5/99) resulted in a suspect PR (ET-103-ST-0006) written against KSC weight / weighing system
- ET-103 was re-weighed (3/27/00) with tension link system at KSC
  - Predicted Weight 58,309 lbs.
  - As-weighed 58,394 lbs.
  - Delta to Predicted +85 lbs.
- Re-weighing of ET-103 supports the closure of the PR ET-103-ST-0006

Mission Planning

- MMC-ET-SE40, ET Project - Mass Properties Weight and Balance Report, has been resubmitted to update the ET-103 as-weighed data (3/29/00)
- Coordination with Level II on 08/07/00 indicates approximately 3,095 LB performance margin for STS-106

Mass Properties Status

STS-92/ET-104

Specification Weight = 58,466 lbs.

ET-104 Weighing

- Platform scale weighing (6/24/99) resulted in a suspect PR (ET-104-ST-0002) written against KSC weight / weighing system
- ET-104 was re-weighed (2/8/00) with tension link system at KSC
  - Predicted Weight 58,356 lbs.
  - As-weighed 58,434 lbs.
  - Delta to Predicted +78 lbs.
- Re-weighing of ET-104 supports the closure of the PR ET-104-ST-0002

Mission Planning

- MMC-ET-SE40, ET Project - Mass Properties Weight and Balance Report, has been resubmitted to update the ET-104 as-weighed data (2/16/00)
- Coordination with Level II on 08/07/00 indicates approximately 2,362 LB performance margin for STS-92

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Changes

- ***As Production Permits Implementation***
  - ***Revised penetrant inspection specifications (J31211)*** — ***Don Bolstad***
- ET-103 & sub
  - ET/SRB aft fairing closeout (B02051) — Bob Thorner
  - LH2 tank proof test (J31197) — Jeff Pilet
- ET-104 & sub
  - Decrease post proof inspection requirements (J31201) — Jim McAllister
  - LH2 tank barrel sta. 1973 fitting (B01982AA)

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Revised Penetrant Inspection Specifications

J31211

Change

- Approved use of self-ballasted black lights for penetrant inspection per STP2501 and STP2507
  - Prior to change, only black lights with transformers were used
- Increased frequency of intensity certification from weekly to daily

Reason/Background

- Producibility - Self-ballasted lights are lighter and easier to use (one unit rather than separate light and transformer)
  - Tank entry inspections are required
- Daily certification is required because self-ballasted lights can degrade more abruptly

Basis for Certification

- Similarity - No change to black light intensity requirement
- Test
  - Daily certification is consistent with current industry practice (ASTM E1417)
  - If black light fails certification after an inspection is performed, hardware will be reinspected with certified black light to verify results

Revised Penetrant Inspection Specifications

J31211

Change

- Replace I-319 penetrant with P-135E for penetrant inspection at MAF per STP 2501 (Penetrant Inspection) except in applications where LO2 compatibility is required
  - If penetrant inspection is required by MRB after LO2 final cleaning in STP 2501 for 2219/2319 welds, I-319 will be used
- Change will be implemented "as production permits"

Reason/Background

- Reliability - Standardize one penetrant at MAF for all types of welds
- P135E penetrant was previously available as an option (P-135E usage expanded)
- Added conservatism
  - P-135E is more sensitive than I-319

Basis for Certification

- Similarity
  - No change in approved penetrant
    - P135E penetrant was previously available as an option
  - Requirement is the same as for STP 2507 for 2195/2219/4043 welds
- Final cleaning shown to be effective on P-135E
  - No LO2 compatibility issue when used prior to final cleaning

Revised Penetrant Inspection Specifications

J31211

Change

- Change dwell time for P135E penetrant inspection at MAF as specified in STP2501 (Penetrant Inspection) and STP2507 (Penetrant Inspection of 2195 Aluminum Alloys) from 2 minutes to 5 minutes minimum
  - Dwell time is the amount of time after application the penetrant is allowed to soak into cracks

Reason/Background

- Reliability - Changed specification to be consistent with vendor recommendation

Basis for Certification

- Test
  - No difference in results of inspections with 2 and 5 minute dwell times using pre-cracked panels used to certify inspectors
  - No difference in POD flaw size (90% Probability of Detection flaw size with 95% confidence)
- Approved by MAF FCB

Revised Penetrant Inspection Specifications

J31200/J31211

Change

- Reduced maximum development time from 8 to 4 hours
  - Development time is the amount of time following wipe off of excess penetrant and inspection

Reason/Background

- Producibility - Optimized development time based on inspector's ability to detect cracks and production processing requirements
- Vendor recommended 2 hour development time
  - Testing showed that 1 crack out of 29 was missed using the eight hour development time
  - Penetrant may dry and not bleed back out as easily after wipe during inspection
  - No significant difference in the ability of the inspector to detect defects using 10 minute, 2 hour and 4 hour development times

Basis for Certification

- Test - Internal test results indicate a decrease in sensitivity with the eight hour development time but no decrease in sensitivity for four hour development time
- Existing hardware accepted based on proof test and post proof inspection
- Approved by MAF and MSFC FCB

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- As Production Permits Implementation
  - Revised penetrant inspection specifications (J31211) — Don Bolstad
- ***ET-103 & sub***
  - ***ET/SRB aft fairing closeout (B02051)*** — ***Bob Thorner***
  - ***LH2 tank proof test (J31197)*** — ***Jeff Pilet***
- ET-104 & sub
  - Decrease post proof inspection requirements (J31201) — Jim McAllister
  - LH2 tank barrel sta. 1973 fitting (B01982AA)

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ET/SRB Aft Fairing Closeout

B02051

Change

- Added RTV silicone sealant bead to reduce or eliminate foam migration into the ET/SRB fairings

Reason/Background

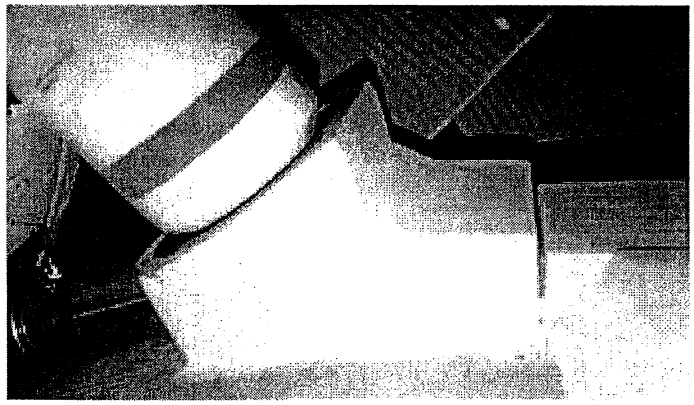
- Flow enhancement - Eliminate foam migration into fairing cavity
- The upper aft ET/SRB fairing closeout has a history of foam migration into the ET/SRB fairings
- A foam closeout is required to seal the fairings at the base to prevent ice/frost formation internal and external to the fairing, and also to prevent flow from entering the fairing compartment during ascent
- When a predetermined charge of mixed PDL is poured into forward mold, the foam (in its liquid state) migrates through a small gap and into the fairing internal surfaces
  - The gap, by design, exists between the ET/SRB fairings and LH2 barrel foam
- Since the foam charge is sized for the capacity of the mold, the closeout is sometimes under-filled and requires rework to meet required design requirements

ET/SRB Aft Fairing Closeout

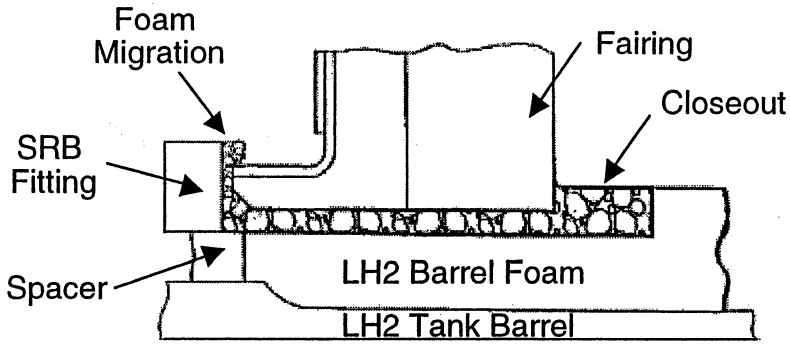
B02051

Description

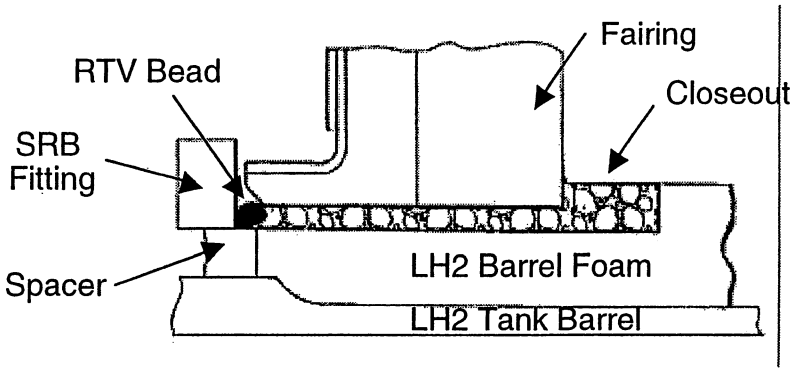
- Prior to the installation of the fairings, an RTV silicone sealant bead is applied to the LH2 Barrel foam and SRB Fitting forward side
  - RTV bead will seal the gap where foam migration has previously occurred
- The fairings are installed within one hour of RTV application
  - PDL foam closeouts are performed around base of fairings



ET-102



ET-103 and up



ET/SRB Aft Fairing Closeout

B02051

Basis for Certification

- Change is a producibility enhancement only and does not affect the performance of the flight hardware

- Engineering Inspection
  - RTV does not see direct aerodynamic impingement and is not a debris source
  - No change in venting performance

- Similarity
  - RTV has been previously accepted for use on ET hardware in similar applications
    - Composite nose cone installation

- MAF personnel performed closeout validation of this configuration and KSC USA technicians were brought to MAF to demonstrate validated closeout on a mock up
  - No issues with RTV bead installation or foam migration into fairing cavity

LH2 Tank Proof Test

J31197

Change

- Implementation of new proof test requirements for the SLWT LH2 tank
  - Revised proof test requirements common for LWT and SLWT
  - ET92 first LWT tank to implement the revised proof test requirements

Reason/Background

- Reliability - Reduced number of under-proofed inches of weld (approximately 2100 inches)
- Review of LH2 tank proof test requirements showed potential reduction in post proof x-ray inspection
  - Supports philosophy that it is "Better to Test than to Inspect"
  - Improved proof test and safety of flight
- Proof test loads were optimized to increase the amount of adequately proofed circumferential welds
  - Proof pressure unchanged
  - Majority of LH2 pressure wall sized for proof pressure

LH2 Tank Proof Test

J31197

Background

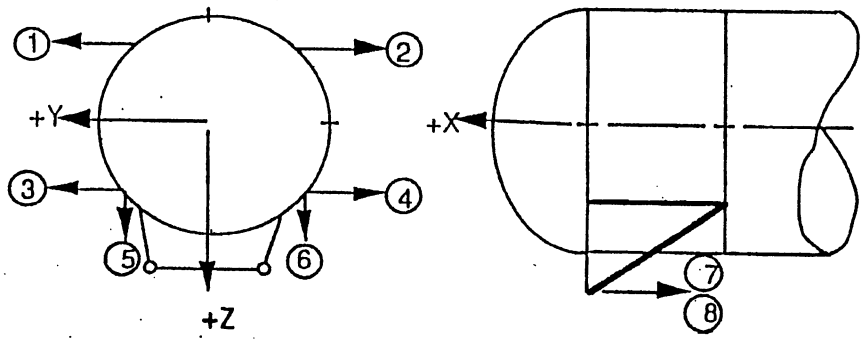
- Comparison of Proof Test Requirements

ET-102

Jack No.	Test Conditions Jack Load (kips)				
	A	B	C	D	E
1	88.0	0.0	207.0	0.0	94.5
2	0.0	94.5	207.0	88.0	0.0
3	88.0	0.0	207.0	0.0	94.5
4	0.0	94.5	207.0	88.0	0.0
5	0.0	-16.5	0.0	0.0	-16.5
6	0.0	-16.5	0.0	0.0	-16.5
7	400.0	0.0	-145.0	400.0	0.0
8	400.0	0.0	-145.0	400.0	0.0
Ullage Pressure	38.5+/-0.3	38.5+/-0.3	38.5+/-0.3	38.5+/-0.3	38.5+/-0.3

ET-103 and up

Jack No.	Test Conditions Jack Load (kips)					
	A	B	C	H	D	E
1	**105.0**	0.0	207.0	**-95.0**	0.0	**100.0**
2	0.0	**100.0**	207.0	**-95.0**	**105.0**	0.0
3	**105.0**	0.0	207.0	**-165.0**	0.0	**100.0**
4	0.0	**100.0**	207.0	**-165.0**	**105.0**	0.0
5	0.0	**-17.5**	0.0	**0.0**	0.0	**-17.5**
6	0.0	**-17.5**	0.0	**0.0**	0.0	**-17.5**
7	**470.0**	0.0	-145.0	**-145.0**	**470.0**	0.0
8	**470.0**	0.0	-145.0	**-145.0**	**470.0**	0.0
Ullage Pressure	38.5+/-0.3	38.5+/-0.3	38.5+/-0.3	**38.5+/-0.3**	38.5+/-0.3	38.5+/-0.3

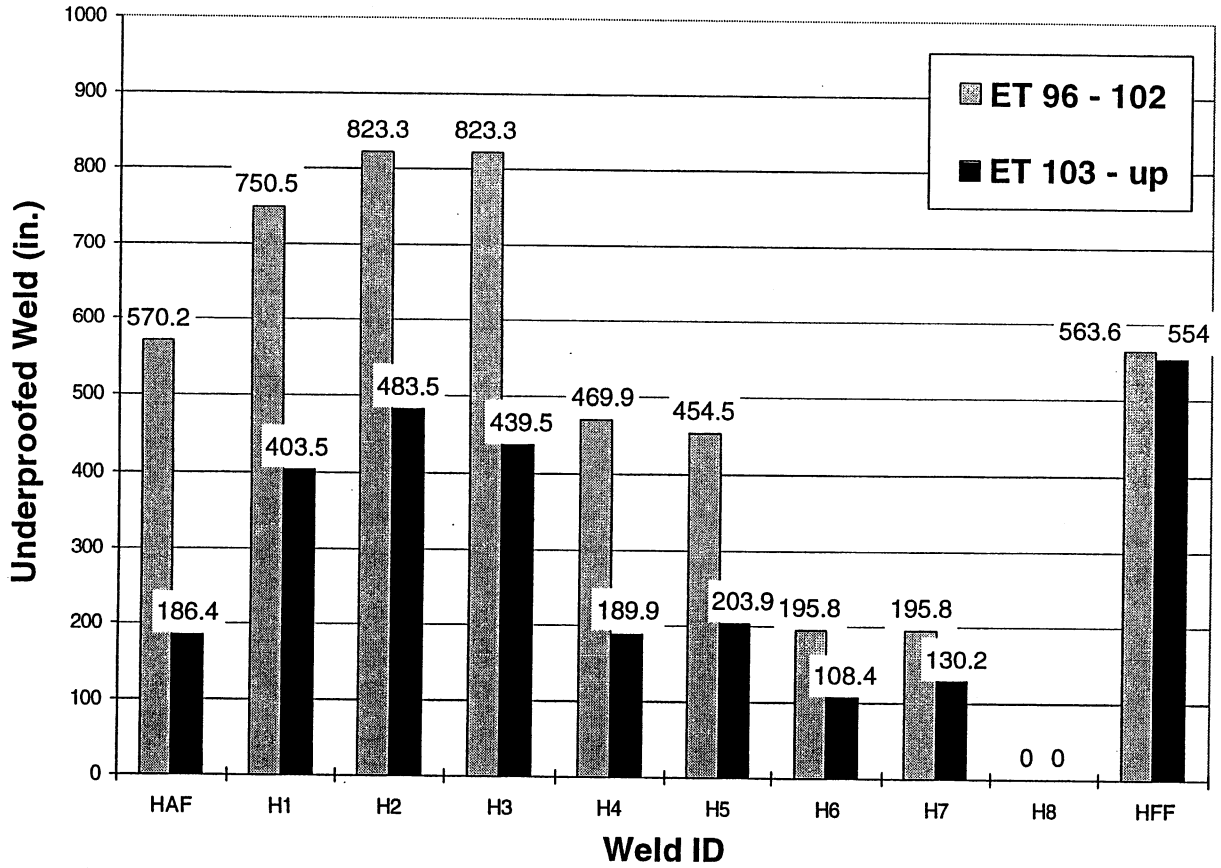


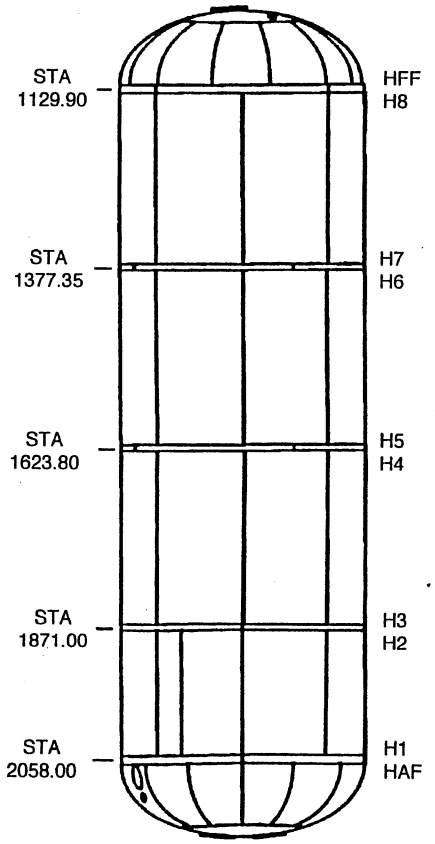
LH2 Tank Proof Test

J31197

Background

- Comparison of length of under proofed weld (requiring post-proof inspection) for LH2 tank circumferential welds





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LH2 Tank Proof Test

J31197

Basis for Certification

- Test and Inspection
  - Successful completion of LH2 Tank proof test and post-proof inspection
    - LH2 Tank common proof test implemented with increased loads
- Analysis
  - Weld acceptance criteria document (LM Dwg. 80900000069) updated to reflect stress analysis results using increased proof test loads
    - Weld peaking and mismatch criteria revised to accommodate higher proof loading
    - No change to critical FS

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- As Production Permits Implementation
  - Revised penetrant inspection specifications (J31211) — Don Bolstad
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  - ET/SRB aft fairing closeout (B02051) — Bob Thorner
  - LH2 tank proof test (J31197) — Jeff Pilet
- ***ET-104 & sub***
  - ***Decrease LO2 tank post proof inspection (J31201)*** — ***Jim McAllister***
  - ***LH2 tank barrel sta. 1973 fitting (B01982AA)***

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Decrease LO2 Tank Post Proof Inspection

J31202

Change

- Eliminated post proof test radiographic inspection on approximately 2300 inches of ODG (Dome gore to gore welds) and OAF (Dome gore to frame) welds
- Reduced post proof test penetrant inspection on LO2 tank external welded lugs from 28 lugs to 10 lugs (approximately 200" of weld)
  - Maintained only one form of NDE (radiographic inspection) on lug welds on adequately proofed welds (proof factor > 1)
  - Maintained both forms of NDE (radiographic and penetrant inspection) on lug welds that are under proofed (proof factor < 1)

Reason

- Producibility - Reduced number of redundant/unnecessary post proof inspections

Decrease LO2 Tank Post Proof Inspection

J31202

Background

- Post proof radiographic inspection of 'interpass lack of fusion' susceptible welds was implemented for the SLWT program because of concern for potential undetected flaws in pre-proof x-rays
  - Since ET-96 (SLWT-1), no undetected pre-proof flaws have been found in post proof x-rays of these welds
  - Subsequent to ET-96, a test program was performed to show that lack of fusion did not impact strength unless it could be detected on pre proof radiographic inspection
    - Additional weld process enhancements mitigated concern for lack of fusion
    - Pre-proof radiography is adequate
    - Weld processes are fully certified
  - Lug weld penetrant and radiographic inspections were added on SLWT because of uncertainty over behavior of lug welds on highly loaded Al 2195 pressure vessel shell
- MAF and MSFC Fracture Control Boards agreed to eliminate post proof radiographic inspections of the ODG and OAF welds and reduce post proof test penetrant inspections of 18 lug welds

Basis for Certification

- Welds adequately proof tested
- Inspection
  - Pre proof penetrant and radiographic inspection of ODG, OAF and lug welds
  - Post proof radiographic inspection of lug welds

LH2 Tank Barrel Sta. 1973 Fitting

B01982AA/J31195C/H35809-872/H36809-227

Change

- Changed from machined fittings to forged frame attach fittings at Sta 1973 in 48 of 96 locations

Reason/Background

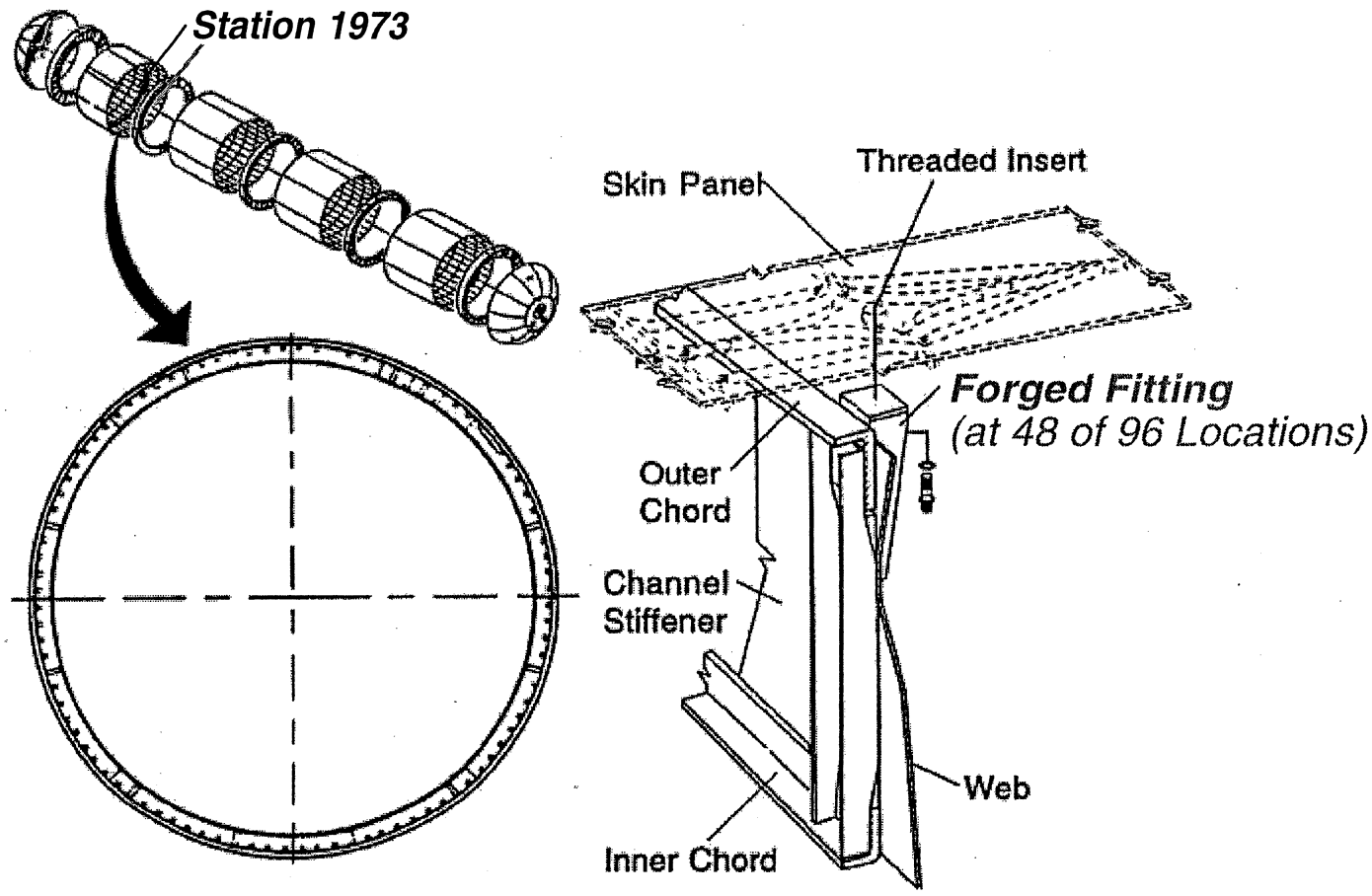
- Cost savings - Forged fittings identified as cost savings candidate
- Producibility
  - Change from machined to forged fittings originally planned for ET-105
  - However, LH2 tank barrel assembly #1 reallocated from ET-105 to ET-104
- Use of forgings allowed in low stress areas only - Higher stressed fittings are still machined

Basis for Certification

- Test
  - Bench test demonstrates ≈ 300% DLL at critical flight location
- Analysis: Stress analysis using empirical "bath-tub" analysis shows positive margin of safety is maintained
  - FS Required = 1.31
    - Was = 1.56
    - Now = 1.38 (Failure mode: *Ultimate end pad bending)*

LH2 Tank Barrel Sta. 1973 Fitting

B01982AA/J31195C/H35809-872/H36809-227



Ring Frame at Sta 1973

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- ***ET-104 LH2 Tank Barrel Longitudinal Rib Repair (SMR-98-007A)*** — ***Glen Wadge***

Special Topics

SRM&QA Assessment

KSC Processing

Verification/Certification

Mission Unique Assessment

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ET-104 LH2 Tank Barrel Longitudinal Rib Repair

SMR-98-007A

Issue

- Cracks in 3 LH2 tank barrel #3 longitudinal ribs dispositioned for repair by installation of splice plates

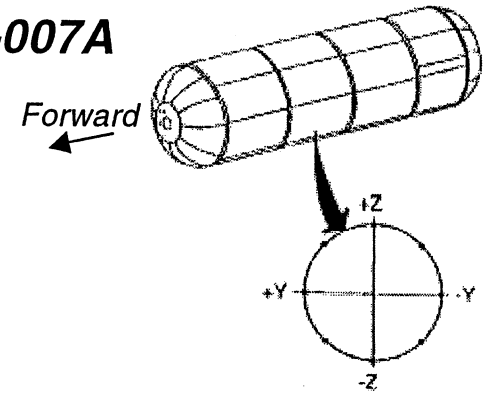
Background

- As the purge lines were being connected to the weld purge box, the box detached from the swaged monoball fitting and impacted barrel #3
  - Damage included:
    - Three (3) gouges in panel skin with a worst case defect size of 0.120" x 0.010" x 0.001"
    - Fourteen (14) gouges in panel ribs with a worst case defect size of 0.450" x 0.060" x 0.015" (located at the rib intersection)
    - Three (3) cracks in panel ribs

Crack Locations (Station)	*Angle*	*Length of Crack (in.)*
1446	153.75	6.35
1446	161.75	3.30
1416	168.75	3.25

ET-104 LH2 Tank Barrel Longitudinal Rib Repair

SMR-98-007A



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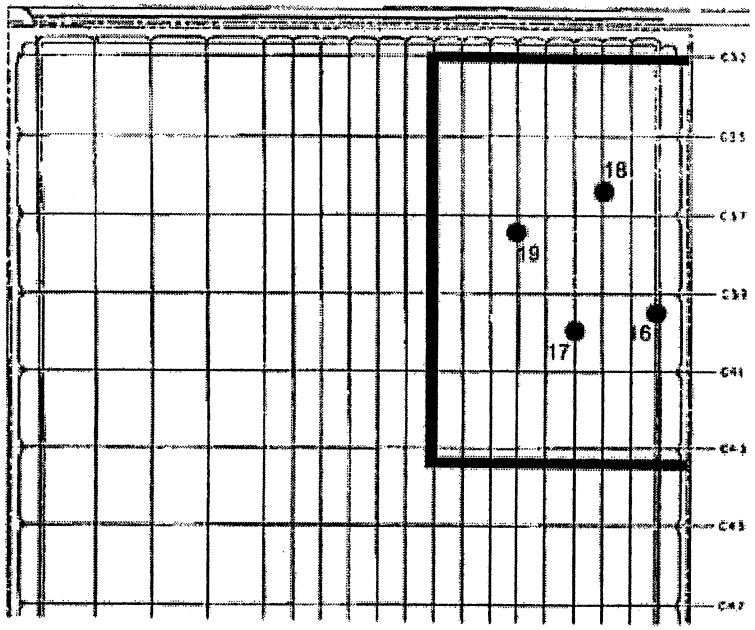

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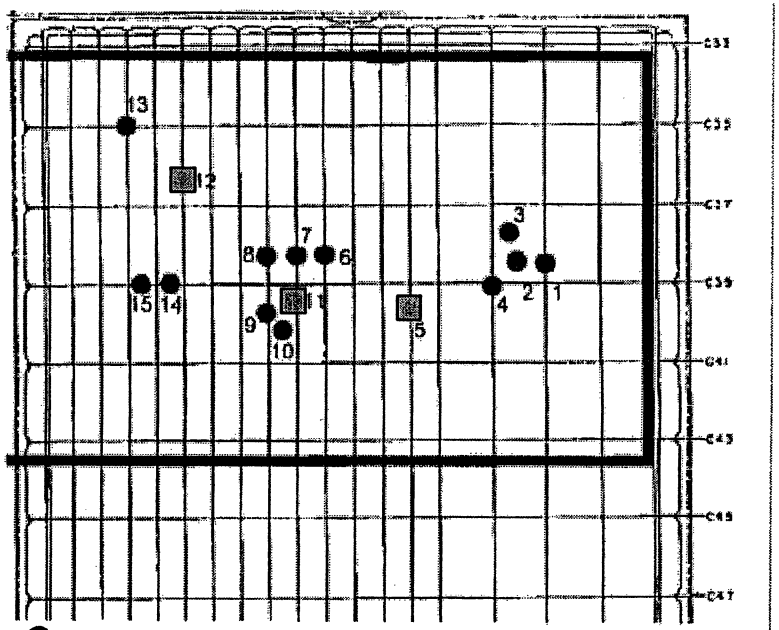

● *Gouged panel skin/rib locations*

■ *Cracked rib locations 5, 11, and 12*

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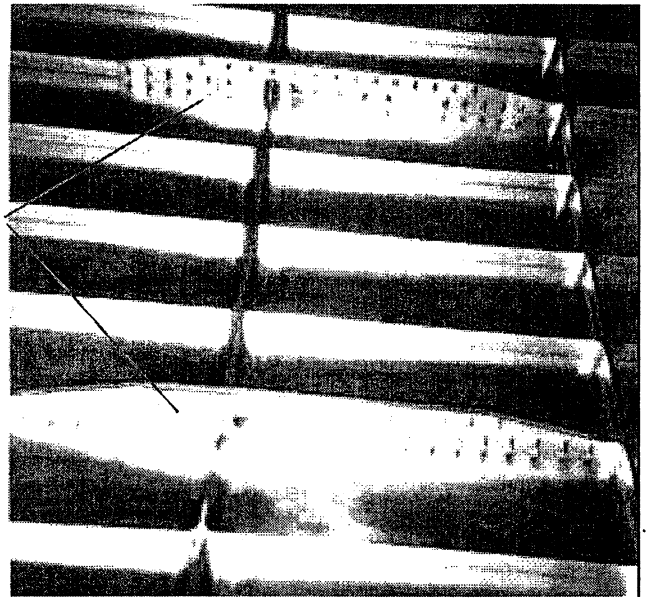
ET-104 LH2 Tank Barrel Longitudinal Rib Repair

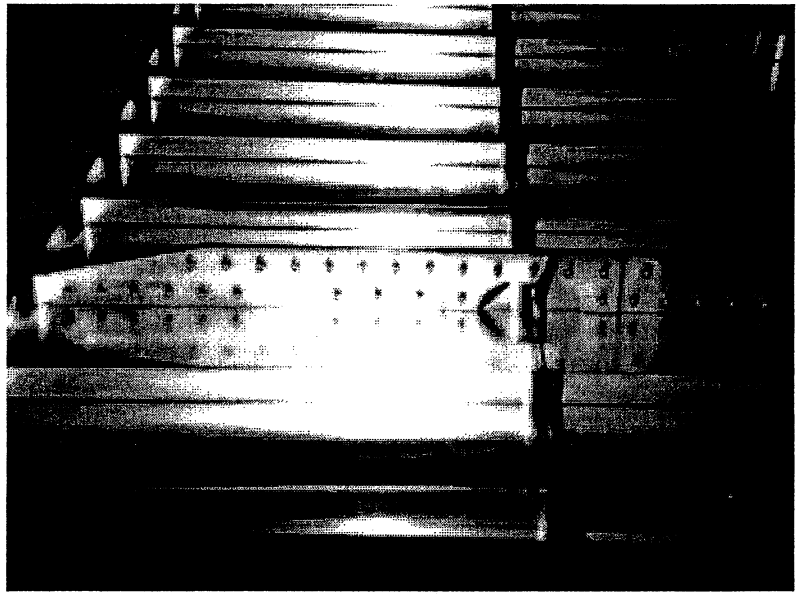
SMR-98-007A

Background (continued)

- Dispositioned to use as repaired
  - Removed raised metal, smoothed and blended minor damage areas (scratches/gouges)
    - Penetrant inspected repaired areas and entire region on OSL and ISL
  - Removed portions of 3 cracked ribs and smoothed/blended into remaining rib
    - Installed doublers on either side of ribs and installed shims between doublers
      - Match drilled fastener holes
      - Attached with 3/16" Hi-Lok fasteners

Doublers attached with 3/16" Hi-Lok fasteners





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ET-104 LH2 Tank Barrel Longitudinal Rib Repair

SMR-98-007A

Basis for Certification

- Inspection
  - Acceptable penetrant inspection of repaired areas and entire region of OSL and ISL

- Analysis of gouged areas on panel skin and ribs shows actual factors of safety exceed requirements

Item No./Location	Condition	Required	Was	Now
• 10 / Panel skin (Worst case)	Tension	1.25	1.28	1.28
• 15 / Rib (Worst case)	Tension	1.26	1.58	1.57
• Repair of cracked ribs (Worst case)				
– Item 12 / Sta 1416	Rib/Membrane tension	1.26	1.29	1.29
	Stability *	1.25	4.39	1.41

* *Conservatively assumes rib removed from panel*

Note: Stability is only critical at prelaunch. No net compression during flight in the repair regions

Summary

- Cracked ribs have been removed, blended into remaining ribs and repaired
  - Repaired ribs with splice plates have proof test demonstrated flight ultimate load for rib tension
- Other damaged areas have been smoothed and blended
- Penetrant inspection of the forward region of the affected panels is acceptable
- Analysis for the splice plate repairs and other damaged areas show positive factors of safety

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Special Topics

- ***Thrust Panel Penetrant Inspection*** — ***Katherine Jakielski***
- ***Discrepant Weld Bead Profile*** — ***Don Bolstad***

SRM&QA Assessment

KSC Processing

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Thrust Panel Penetrant Inspection

Issue

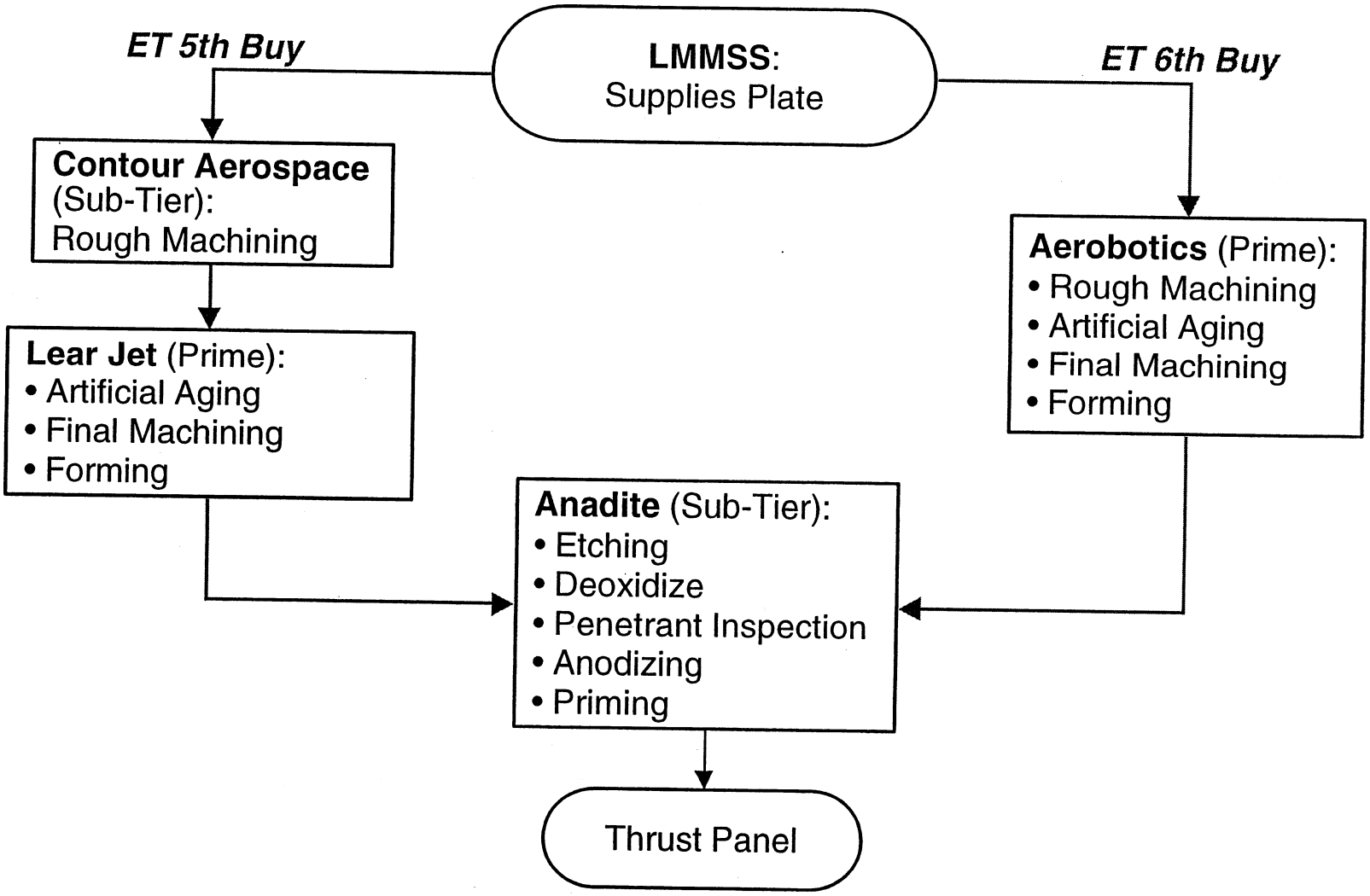
- Etching and penetrant inspections were improperly performed on SLWT Thrust Panels
  - Twelve areas (2 inch square) obscured by handling fixture clamps were not etched as required prior to penetrant inspection
  - 2 inch areas of 18 rib tops obscured by an inspection fixture were not penetrant inspected as required
  - Areas of the panel were not accessible for close black light inspection

Background

- Penetrant inspection process inadequacy at sub-tier supplier discovered during a first article validation for Intertank Thrust Panels for External Tank 6th Buy
  - 5th buy parts were processed in the same manner at the same sub-tier supplier
- This is an isolated incident
  - Reviewed Etching & Penetrant Inspection processes for other large ET components
    - No other process deficiencies found

Thrust Panel Penetrant Inspection

Intertank Thrust Panel Production Flow



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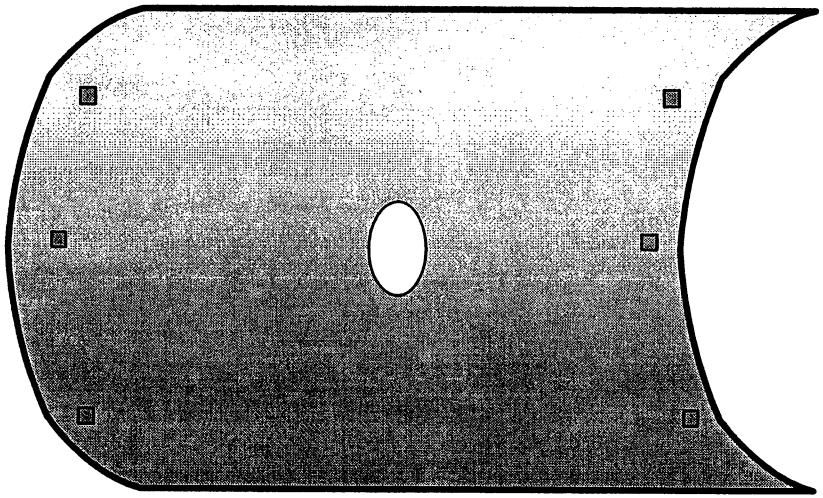
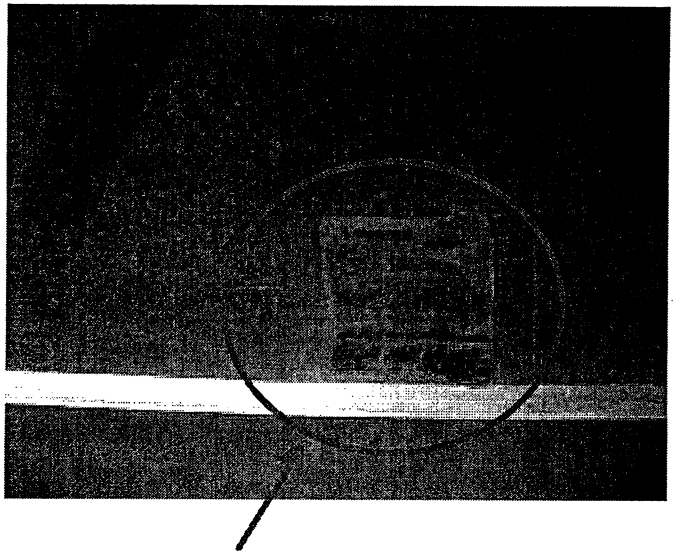
Thrust Panel Penetrant Inspection

Discussion

- Issue 1
  - Etching not performed in areas of the inside and outside skin line (ISL and OSL)
- Concern: Validity of penetrant inspection in unetched areas
  - Six clamps are used to move the thrust panel when etching
    - 3 along the forward end; 3 along the aft end
  - Total of twelve 2" x 2" areas were not etched
    - Clamps cover 2" x 2" squares on the ISL and OSL during etching
  - These areas were fully penetrant inspected in the un-etched condition



■ Clamp locations during etching

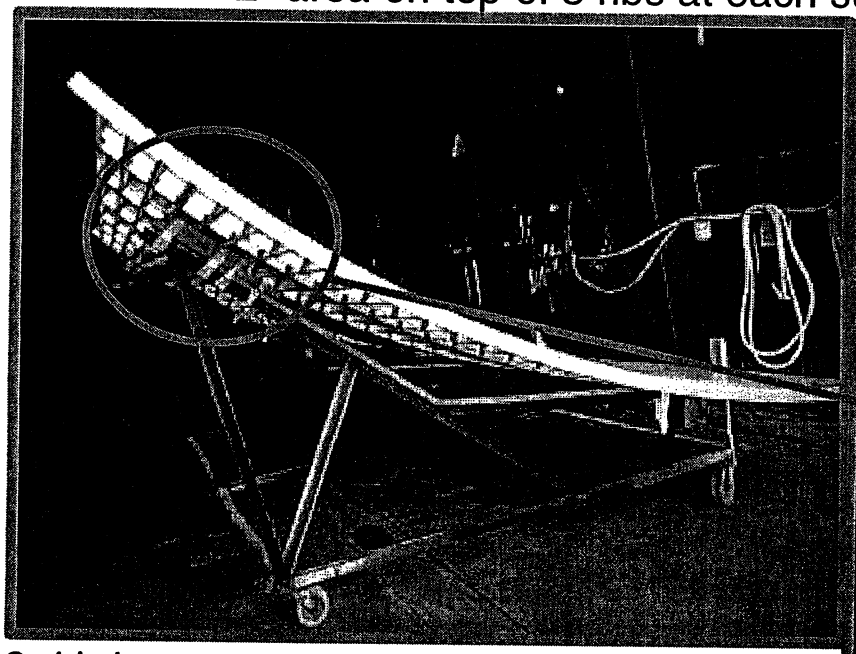


Area Not Etched

Thrust Panel Penetrant Inspection

Discussion

- Issue 2
  - Rib edge sections obscured by inspection fixture
- Concern:
  - Inadequate penetrant inspection of rib tops
    - Inspection fixture 2” x 4” support blocks contact OSL at six locations
      - 2 supports at forward, center, and aft sections
    - 2" area on top of 3 ribs at each support was not inspected

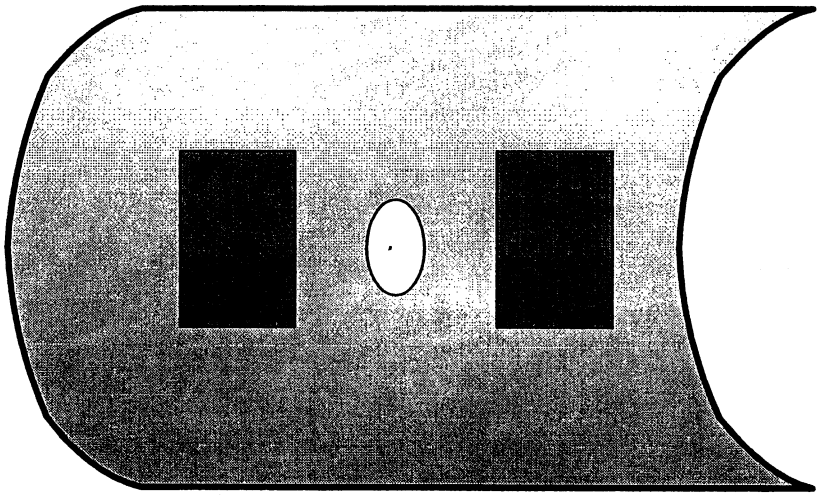


2x4 is in contact with the rib tops in six locations
- Rib tops cannot be inspected
- Pocket under the 2x4 is difficult to inspect

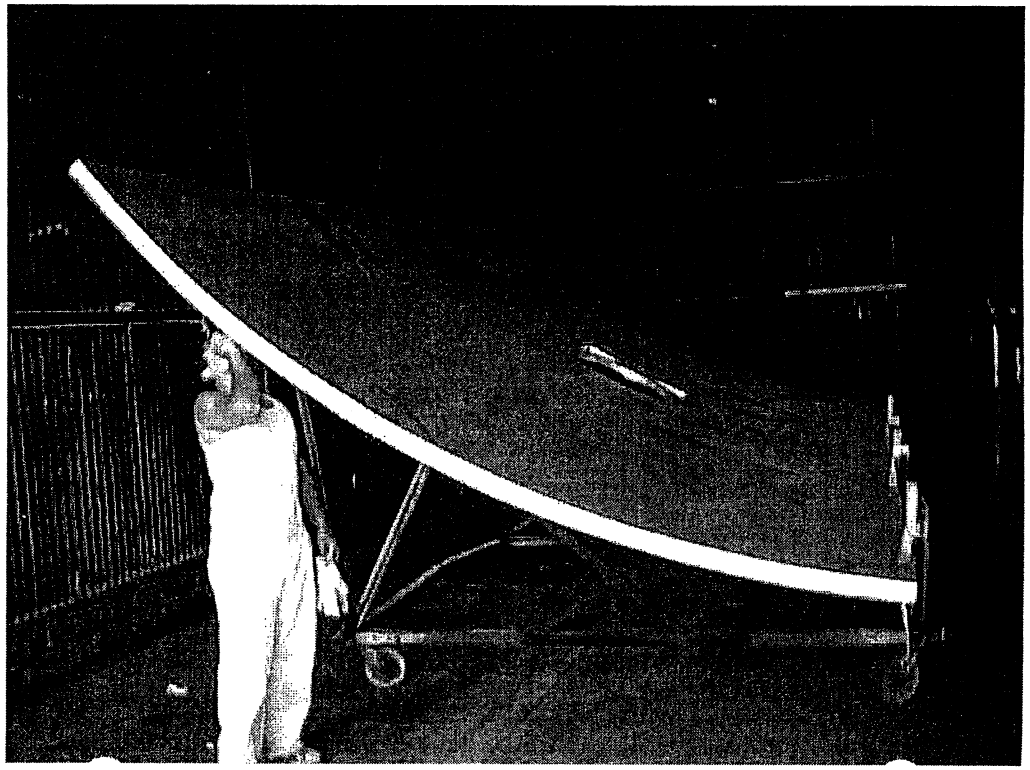
Thrust Panel Penetrant Inspection

Discussion

- Issue 3:
  - Inadequate Inspection: ISL
- Concern:
  - Fixture geometry prevents inspector from standing next to inspection area
    - Level 3 POD flaw size (0.086”) could be missed
      - Inspector can be 3 to 5 ft from inspection area
    - Two 2 ft x 3 ft areas affected



2 ft wide by 3 ft high areas on ISL that are difficult to read due to the position of part on check fixture and inspector accessibility.

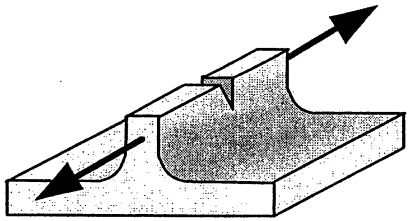


Thrust Panel Penetrant Inspection

Rationale for Acceptance

- *All hardware deemed acceptable for flight based on fracture analysis*
  - For analysis of each issue, identified thickness and stresses in affected area

- *Fracture analysis results indicate all critical defects would be visually detected*
  - Issue 1: Unetched Areas
    - Critical initial through flaw size greater than 3.8"
      - Assumed through crack in center of the Plate Model
  - Issue 2: Rib edge sections obscured by inspection fixture
    - Critical initial through flaw size greater than 1.15"
      - Assumed through crack propagating from rib top would be visible when inspecting the pockets
      - Used single edge through crack model



  - Issue 3: Inadequate inspection: ISL
    - Critical initial through flaw size greater than 2.68"
    - Verified that surface flaw can not fail (flaw would show up on ISL)
    - Areas fully inspected on the OSL would reject critical flaw

- *Rationale for acceptance was reviewed and accepted by the MAF FCB and by NASA*

Discrepant Weld Bead Profile

Issue

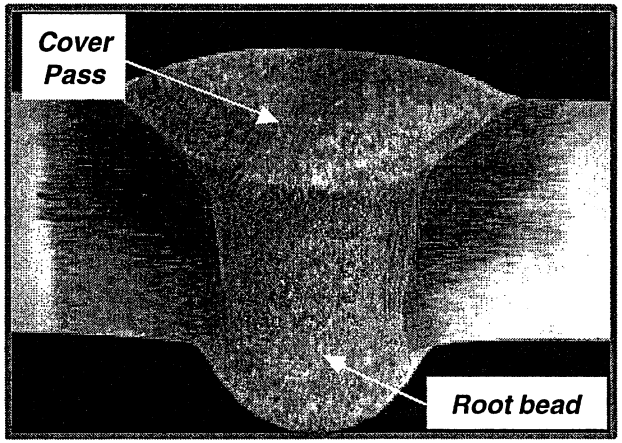
- NEQA (NASA Engineering Quality Audit) Phase 1 discrepancy/observation
  - "Dressing" (sanding/shaving) weld bead penetrant indications (porosity, inclusions and cracks) could result in unacceptable weld strength

Background

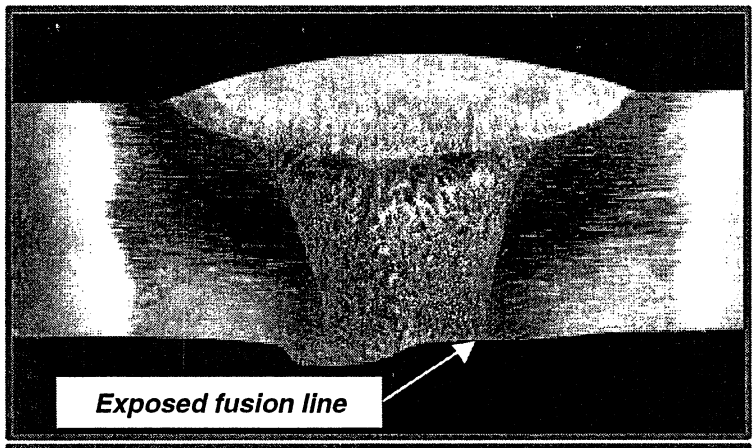
- Procedures allow dressing of weld bead penetrant indications down to 0.040" minimum bead height without documentation or MRB disposition
  - Dressing is typically performed to remove penetrant indications
  - Test data was developed and used to accept moderate dressing
  - Weld reinforcement required to transition smoothly into adjacent parent material
- Condition isolated to welding of Al 2195 material
  - Shaving of Al 2195 material weld bead typically reduces weld strength
  - No strength reduction for shaving of Al 2219 material
- Fracture properties not affected
  - Allowables based on shaved flush condition
- Methodology presented and approved to clear STS-106/ET-103 (08/01/00) and STS-92 ET-104 (06/26/00) for continued processing at KSC

Discrepant Weld Bead Profile

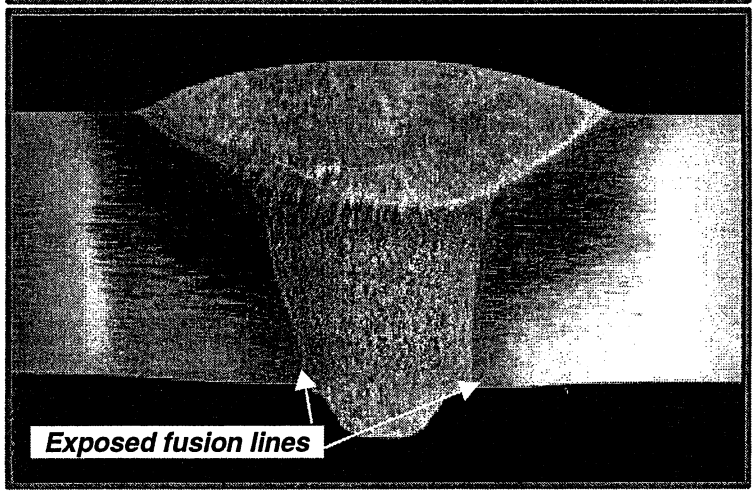
Background



As-Welded Bead



Toe sanding resulting in exposed fusion line and substantial reinforcement removal



Toe sanding (both sides) resulting in both fusion lines exposed

Conditions of Concern

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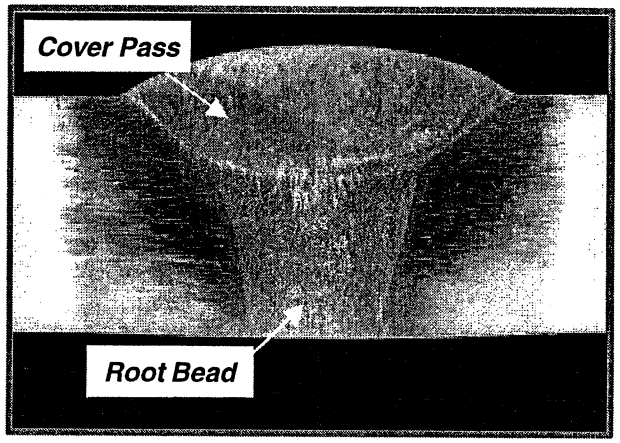
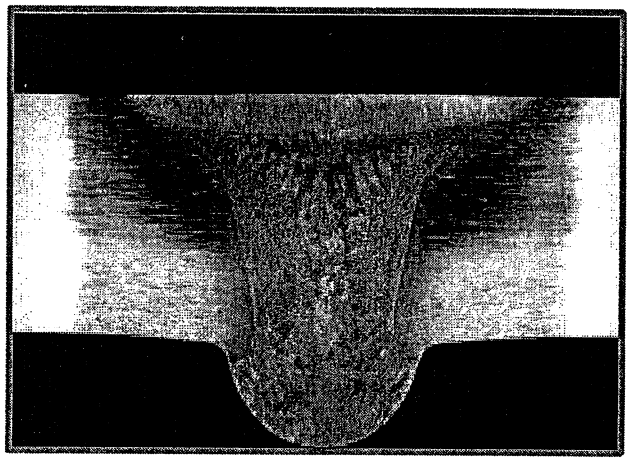
Discrepant Weld Bead Profile

Actions Taken

- Dressing of welds halted except for that directed by MRB
- In-process tanks and tank components have been inspected and all instances of sanding/shaving are being recorded and analyzed (ET-112 and up)
- Completed or nearly completed tanks are being evaluated using the conservative assumption that all welds have been shaved flush on one side (ET 103 - 111)
  - "As-built" records of peaking, mismatch, and repairs used in the analysis where needed



Root Bead Shaved Flush

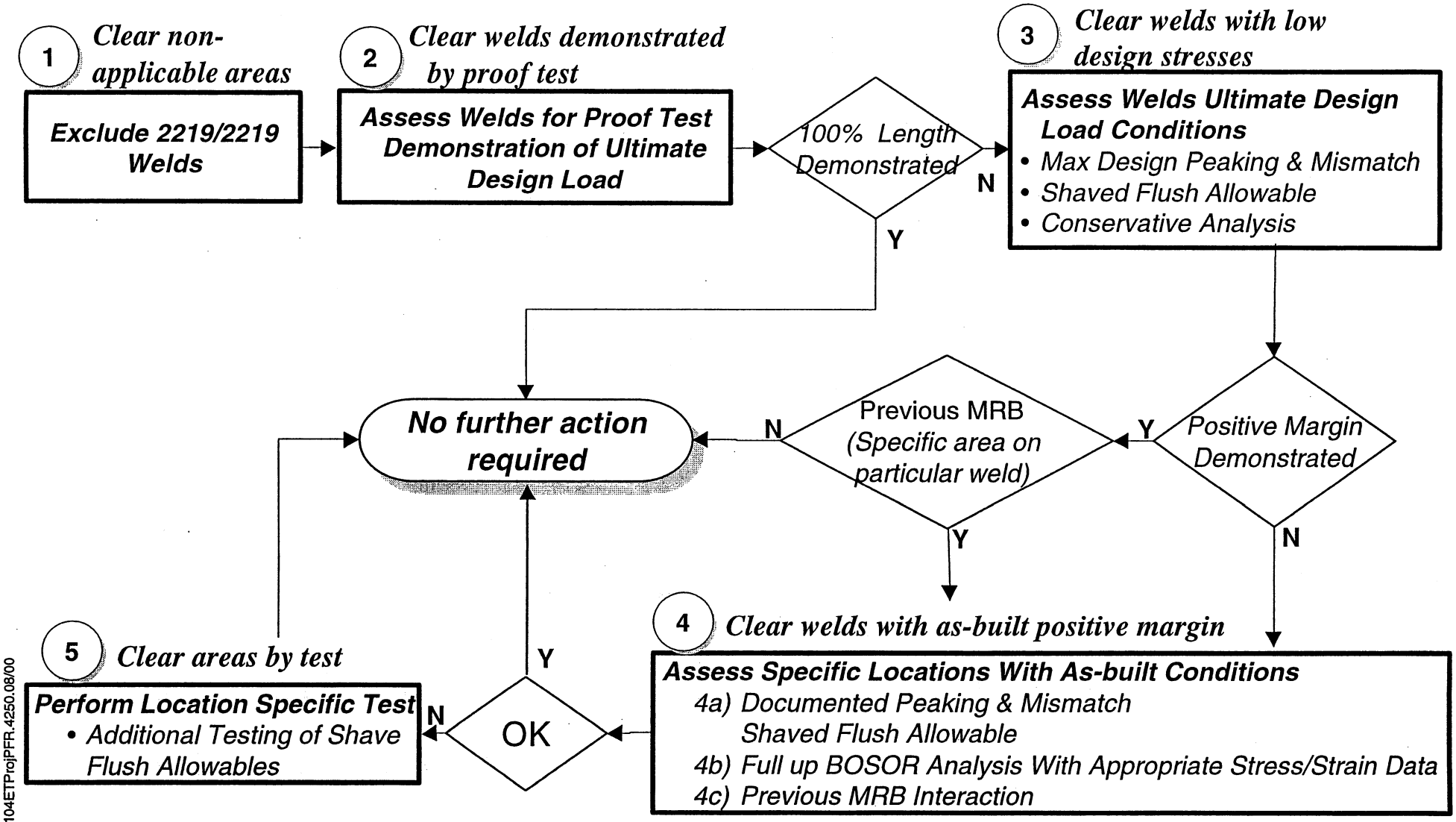


Cover Pass Shaved Flush

Conditions Assumed for Analysis

Discrepant Weld Bead Profile

Generic Weld Clearance Plan



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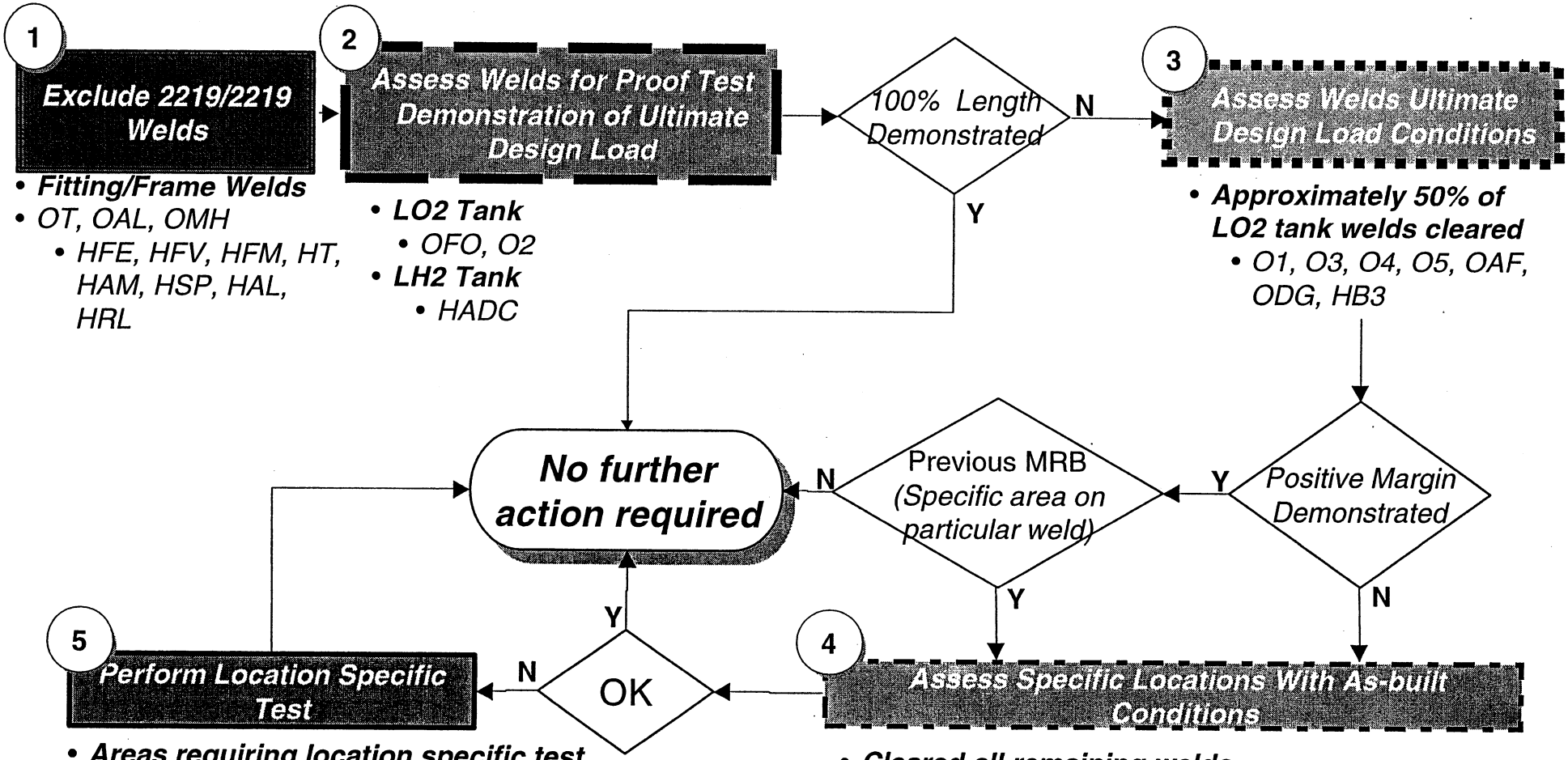
Discrepant Weld Bead Profile

STS-106/ET-103 and STS-92/ET-104 Clearance Has Been Completed



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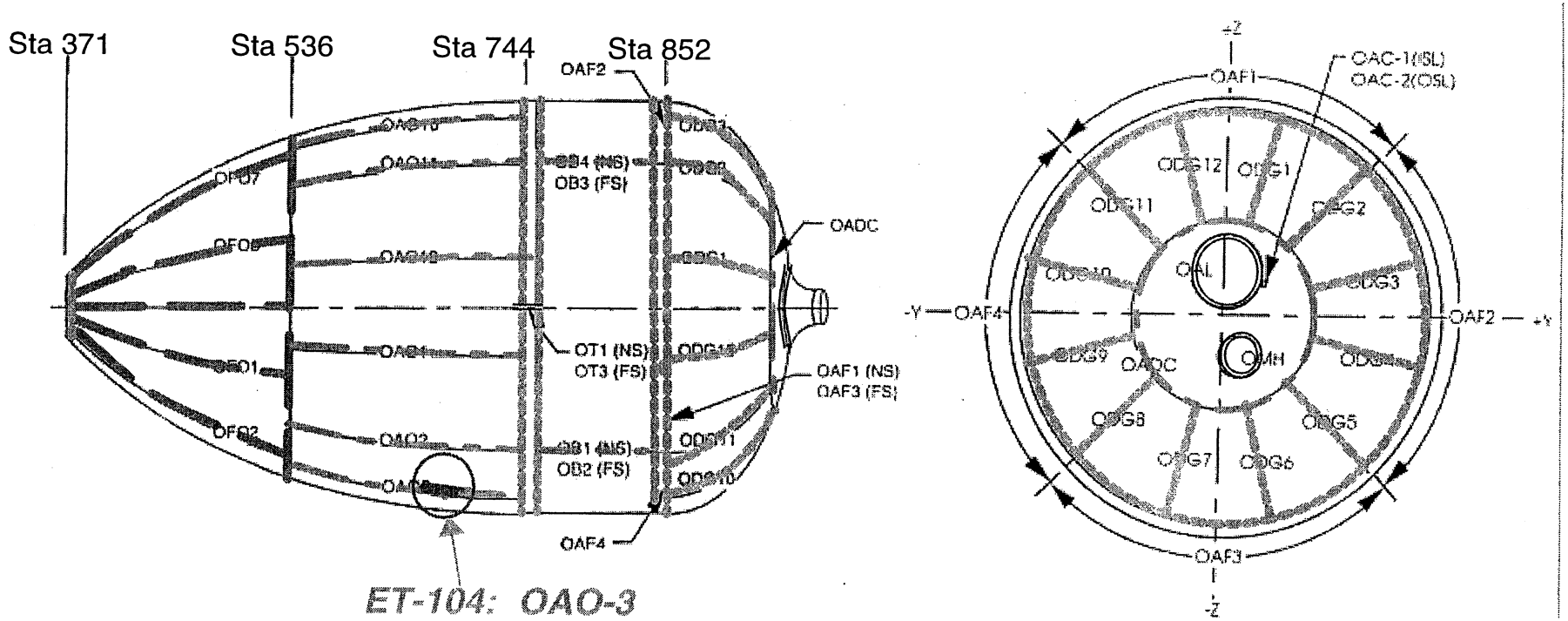
Discrepant Weld Bead Profile

Location Specific Analysis/Test Required for LO2 Tank

- *STS-106/ET-103: None*
- *STS-92/ET-104: OAO-3*



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Discrepant Weld Bead Profile

Results of STS-92/ET-104 LO2 Tank Location Specific Analysis/Test

Condition

- Peaking and mismatch on OAO-3 weld 18" from O3 weld was outside limits

Test Results

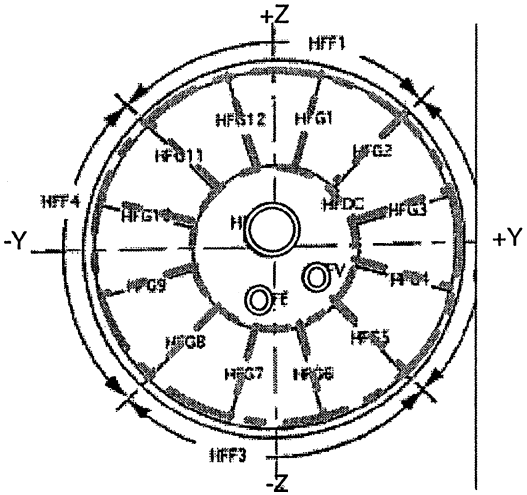
Weld Condition	Average (Range), ksi	Std Dev	Sample Count	A-Basis Design Value (–320°F, ksi)
As-welded (Control) @ RT	47.2 (43.9 – 49.0)	1.504	16	50.8
As-welded (Control) @ -320°F	55.2 (51.6 – 59.4)	3.165	8	41.4
Root Shaved: tested @ -320°F	56.0 (51.9 – 59.9)	2.064	24	49.4
Cover Shaved: tested @ -320°F	***48.2 (46.0 – 50.4)***	***1.475***	***12***	***42.7***
Specification Value				40.3

- Positive margins demonstrated using specific test/analysis
  - FS = 1.38 (1.32 required)

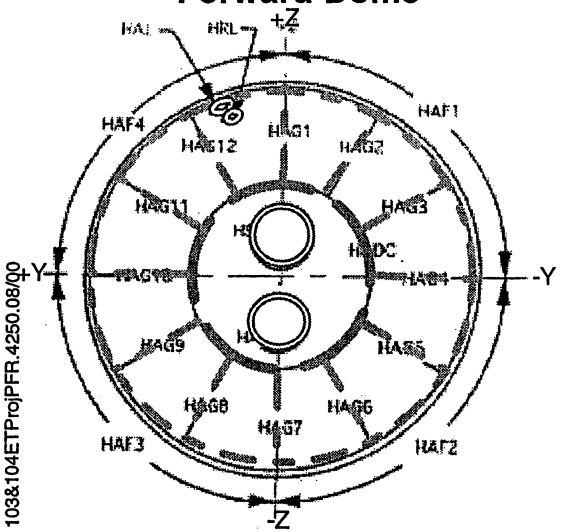
Discrepant Weld Bead Profile

Location Specific Analysis/Test Required for LH2 Tank

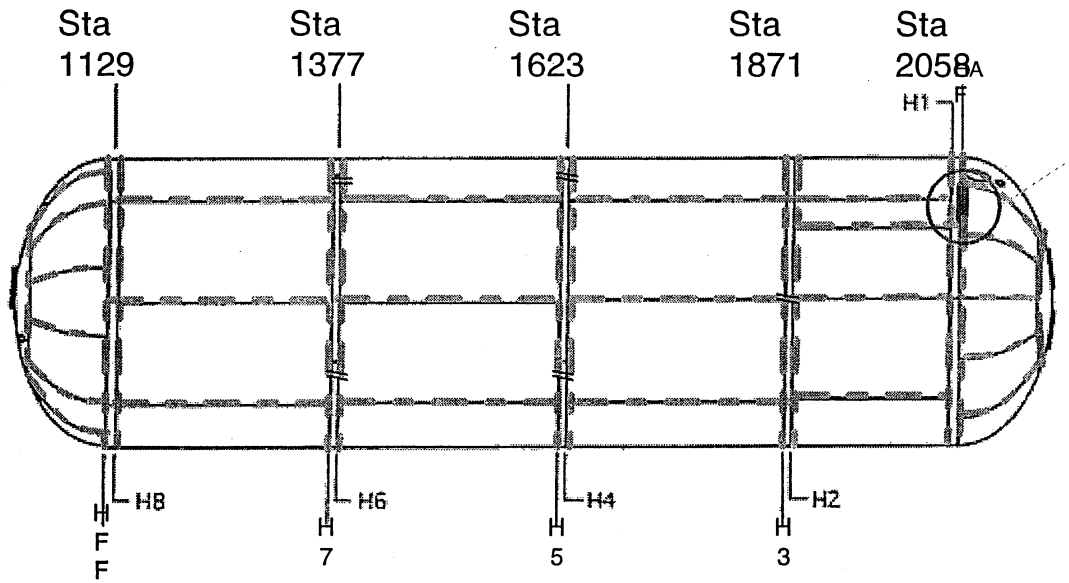
- *STS-106/ET-103: HAF-1*
- *STS-92/ET-104: HAF-1*



Forward Dome



Aft Dome



ET-103 and ET-104: HAF-1 Weld

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Discrepant Weld Bead Profile

Results of STS-106/ET-103 LH2 Tank Location Specific Analysis/Test

Condition

- Mismatch on the HAF-1 weld at 116" to 147" was outside limits
  - Previously documented and accepted on nonconformance document (NCD)

Test Results

Weld Condition	Avg UTS (Range) (-423°F, ksi)	Std Dev (-423°F, ksi)	Sample Count	A-Basis Design Value (-423°F, ksi)
As-welded	68.1 (65.9 – 69.8)	1.48	5	59.6
Root Shaved	64.7 (61.9 – 66.1)	1.88	5	53.9
Cover Shaved	60.3 (58.5 – 62.3)	1.46	5	51.9
Both Shaved	***62.0 (51.0 – 66.9)***	***3.01***	***15***	***51.5***
Specification Value				42.0

- Positive margins demonstrated using specific test/analysis
  - FS = 1.38 (1.32 required)

Discrepant Weld Bead Profile

Results of STS-92/ET-104 LH2 Tank Location Specific Analysis/Test

Condition

- Peaking and mismatch on the HAF-1 weld at 129" to 150" was outside limits

Test Results

Weld Condition (with peaking & mismatch)	**Avg UTS (Range) (-423°F, ksi)**	**Std Dev (-423°F, ksi)**	**Sample Count**	**A-Basis Design Value (-423°F, ksi)**
As-welded	55.5 (51.8-58.2)	2.11	8	46.3
Root Shaved	64.0 (56.0-71.2)	4.27	12	48.0
Cover Shaved	***56.6 (52.6-64.4)***	***3.45***	***13***	***44.0***
Both Shaved	61.3 (57.3-67.1)	2.88	15	51.2
Specification Value				42.0

- Positive margins demonstrated using specific test/analysis
  - FS = 1.33 (1.33 required)

Discrepant Weld Bead Profile

Rationale for Acceptance

- All 2219/2319/2219 welds cleared
  - Welds meet initial weld properties with shaved flush beads
- 100% proof test demonstration of ultimate design load for OFO, O2 and HADC welds
- Analysis/Test
  - Location specific allowables for shaved flush welds
  - All MRB impacts considered (As-built conditions)
  - Positive margins demonstrated
    - STS-106/ET-103
      - HAF-1: FS = 1.38 (1.32 required)
    - STS-92/ET-104
      - OAO-3: FS = 1.30 (1.27 required)
      - HAF-1: FS = 1.33 (1.33 required)

Discrepant Weld Bead Profile

Summary

- NEQA (NASA Engineering Quality Audit) found that production practice of weld bead dressing was not meeting engineering intent
- Practice has now been brought under MRB control
- Actual condition of inspectable hardware (ET-112 and up) has been recorded and analyzed
- Clearance plan assuming one side shaved flush condition is in work for built/delivered tanks
  - ETs 103, 104 and 110 have been cleared

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Terry McKeough

103&104ETProjPFR.4250.08/00

SRM&QA Assessment

as of 08/10/2000

Item	***Status***
• ***ALERTS***	• None open
• ***MRB Assessment***	• Complete - No issues/no impact to hazard controls
• ***Hazard Assessment***	• Complete - All hazard reports were re-assessed and hazard controls verified
• ***Corrective Action Problem Summary (CAPS)***	
• P-089, Incorrect weld rod usage on ET-104 GO2 press. line	• Closed • ET-103 cleared - Review of planning paper showed that correct weld rod was used on ET-103 • ET-104 dispositioned use as is - Verification of material properties obtained from tests with Hastelloy-W weld rod shows that the margin of safety is unaffected
• P-091, Leaking LO2 feedline seal on ET-111	• ET-103 & ET-104 cleared - Successfully passed leak test at MAF
• S-083, Post proof NDE concerns	• ET-103 & ET-104 cleared for all post-proof NDE issues
• S-084, Contaminated Argon gas (Air Products) for ET welding	• ET-103 & ET-104 cleared - Contaminated gas not used for ET-103 & 104 welding operations
• S-085, Sanded/shaved Al 2195 welds	• ET-103 & 104 cleared - Previously presented as Special Topic

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SRM&QA Assessment

KSC Processing ***Scott Otto***

- ***STS-106/ET-103 Status***
- ***STS-92/ET-104 Status***

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KSC Processing

as of 08/10/2000

Discrepancy Reports (DRs)/Problem Reports (PRs) Review

- PR/MRB discrepancies/dispositions similar to previously flown vehicles with one exception
  - Use of incorrect weld rod on ET-104 GO2 press. line weld at Sta 394
    - XRF analysis of weld indicates that Hastelloy-W was used in lieu of Inconel 718
    - Verification of material properties obtained from testing with Hastelloy-W weld rod shows that the margin of safety is unaffected
    - Hardware was dispositioned use as is
      - Meets flight and safety requirements
- All KSC/MRBs have been reviewed by MAF Reliability for potential SMR
  - No items were elevated to the SMR

Limited Life Component/ET Status

- All within required life through scheduled launch date plus 90 days

OMRSD Exceptions/Waivers: None

KSC Processing - Status

STS-106/ET-103 Status as of 08/10/2000

Changes

- ET modifications

- Mod Kits	0	
- DC&R	0	
- Bldg 45	2	• MPS 2" disconnect poppet inspection • Suspect ET weight data
- FEC	2	• Intertank thrust panel foam venting • Intertank + Z stringer panel foam venting
- OMRSD/LCC	1	• RCN KS13861M, Delayed need for pre-press heater until end of Orbiter MPS chilldown
- Software	1	• Moved software verification to end of Orbiter MPS chilldown

SIM Launch (S0044)	*08/07/00*
SIM Load (S0056)	*08/24/00*
MMT Simulation	*08/30/00*

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KSC Processing - Status

STS-92/ET-104 Status as of 08/10/2000

Changes

- ET modifications
  - Mod Kits 0
  - DC&R 0
  - Bldg 45 2
    - MPS 2" disconnect poppet inspection
    - Suspect ET weight data
  - FEC 2
    - Intertank thrust panel foam venting
    - Intertank + Z stringer panel foam venting
  - OMRSD/LCC 0
  - Facility 0
  - Software 0

SIM Launch (S0044) *08/21/00 (U/R)*

SIM Load (S0056) *09/21/00*

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KSC Processing

Verification/Certification ***Jim Feeley***

Mission Unique Assessment

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Appendices

- A: Minor Changes
- B: SRM&QA Assessment
- C: KSC Processing
- D: Level II Waivers/Level III Deviations
- E: Previously Presented Items

Verification/Certification

as of 08/10/2000

Item	***Status***
NSTS 07700, Volume X, Book 1, Baseline	No issues
• Revision M, Change 265	
Certification Documentation	
• Hardware Certification Sheets (HCS)	Complete - No issues
• Certificates of Qualification (COQ)	No new items
Waivers/Deviations	No new items

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Mission Unique Assessment

	STS-106/ET-103	STS-92/ET-104
Review of MRB actions using updated loads	*ECD 08/29/2000 (UR)*	*ECD 09/25/2000 (UR)*
MPS Preflight Prediction Package	*ECD 08/29/2000 (UR)*	*ECD 09/25/2000 (UR)*

103&104ETProjPFR.4250.08/00

Readiness Statement

The External Tank, ET-103, is hereby certified and ready for STS-106 flight pending completion/closure of open and planned work

Readiness Statement

The External Tank, ET-104, is hereby certified and ready for STS-92 flight pending completion/closure of open and planned work

Appendices

A: Minor Changes

B: SRM&QA Assessment

- NCD Assessment Criteria

C: KSC Processing

- PR/MRB Summaries
- OMRSD Exceptions/Waivers: None
- Modification Summaries/Status
- Limited Life Component Status
- OMRSD Changes (RCNs)
- Software Changes
- Facility Modifications: None

D: Level II Waivers/Level III Deviations

E: Previously Presented Items

- STS-101/ET-102 performance
  - LO2 100% level sensor failure
  - Crack in +Y longeron foam closeout
- Discrepant NDE records for ET welds
- Diagonal strut mechanical testing
- Incorrect weld rod on ET-104 GO2 pressurization line

Change Presentation Criteria

- Changes for Presentation
  - *Type I Documentation*
  - *Requirements*
  - *Configuration* (affects part interchangeability)
  - *Materials* (requires SE16 revision)
  - *Technical Changes to Processes* (STPs)
- Changes for inclusion in Appendix
  - *Minor configuration* (affects part interchangeability)
  - *Minor updates* - Does not affect part interchangeability, materials or processes
    - Revise point of incorporation
    - Drawing clarification
    - Non-flight hardware installation/removal
    - Datum changes
    - Update usage/List of Materials
    - Drawing incorporation errors
    - Manufacturing aid
    - Drawing errors
    - Fastener type/grip
    - Producibility
    - Update vendor list
    - Laboratory test procedures
    - Materials
- All Class I and Class II changes have been reviewed by the MSFC Resident Office
- All Class II STP/STM/Standard/Code sheet changes have been submitted to the MSFC Materials, Processes and Manufacturing Department for concurrence

Minor Change – Configuration

Change	Description	Basis for Certification
Reallocated ET-106 LO2 tank aft dome to ET-104 (B02022A/A)	Frame chord material at Sta 851 changed from Al 2195 to Al 2219 ▪ Incremental return to Al 2219 chord material	Similarity – Al 2219 extrusions previously flown at other locations on ET
Allocation of 2219 Class II Extrusion (B02022/J31158)	Frame outer chord extrusions at Sta 1377, 1624, and 1871 changed from Al 2219 Class I to Al 2219 Class II ▪ Incremental return to Al 2219 chord material	Similarity – Al 2219 Class II extrusions previously flown at other locations on ET

Minor Changes

Change No.	Discipline	Description	Effectivity
H35809-764	Structural	Replaced XV-6-5 fastener callout with XV-6-4 on Intertank panel #3 assembly drawing. Correct fasteners installed per requirements of this change.	ET-104 & sub
H35809-801	Structural	Changed primer stay-out areas on cable tray from far side of nut plate to near side for installation of bond jumpers	ET-104 & sub
H35809-894	Structural	Revised LO2 umbilical cable tray installation drawing to include STP 2003 (Countersinking and flushness requirements for 100 degree fasteners) on list of process specification. Drawing specified use of 100 degree fastener but failed to callout STP 2003	ET-104 & sub
H35809-996	Structural	Added dimension to forward and aft ogive assembly to verify LO2 ogive length prior to O3 weld to Sta 744 T-ring • Dimension added to verify sub assembly length after making the O3 weld to ensure making the overall length on the next assembly	ET-104 & sub
H36809-075	Structural	Increased LH2 tank proof test load case deflection limits to preclude proof test abort – No change to proof test loads	ET-104 & sub
H36809-090	Structural	Revised LH2 tank proof test requirements document to replace Mil-Spec for GN2 with Lockheed Martin equivalent specification	ET-104 & sub
H35809-862	Structural	Revised I/T Panel No. 6 Installation to correct the fastener head direction called out on Sheet 14, Zones 6E, 7E & 8E. Installed correctly on previous builds.	ET-103 & sub
H35809-877	Structural	Revised I/T Panel No. 3 Installation to add an inadvertently omitted fastener callout on Sheet 13, Zone 7E. Hi-Set rivet installed at this location on previous builds by auto riveter program (Requirement prior to ET-56)	ET-103 & sub

Minor Changes

Change No.	Discipline	Description	Effectivity
H35809-901	Structural	Added option to trim forgings in order to meet required dimensions and clean up Forging	ET-103 & sub
H35809-918	Structural	Due to unavailability of correct grip length bolts in Sta 1973 frame installation, drawing changed to permit limited use of longer bolts with extra washers	ET-103 thru 107
H35809-961	Structural	Revised drawing to swap weld start/stop location for penetrant pass with start/stop location for cover pass on OADC weld (manufacturing convenience)	ET-103
H35809-996	Structural	Added dimension to verify ogive assembly length prior to welding to T744 T-Ring to ensure meeting overall length on next assy after 04 weld	ET-104 & sub
H36809-037	Structural	Deleted requirement to chem film insert holes on LH2 Fwd Dome Insert Assy. Parts chem filmed at detail level	ET-103, 106 & sub
H36809-051	Structural	Delete requirement for full-length penetrant inspection of H2 and H3 welds. Full-length penetrant inspection was required only on Class I extrusions. Inadvertently left on drawing during implementation of Class II extrusion	ET-103 & sub
H36809-077	Structural	Deleted weld inspection angles for HT2-1 thru -4 H4/H5 Intersects and HT3-1 thru -4 H6/H7 Intersects because of material change from Al 2195 to Al 2219	ET-103 & sub
H36809-207	Structural	Issued rework DCN to use alternate screws for ET-103 only; parts not available	ET-103

Minor Changes

Change No.	Discipline	Description	Effectivity
H36809-183	Electrical	Added note to cabling manufacture drawing (AWS) to define type of copper (alloy or soft) conductor that is on the LO2 ullage temperature sensor. Note inadvertently omitted during data ~~base~~ conversion	ET-104, 108 & sub
H36809-195	Electrical	Corrected part callout on field of aft cable tray harness installation drawing. Part number on list of materials is correct	ET-104 & sub
H36809-198	Electrical	Corrected part callout on field of Aft I/F Cable Tray Harness Installation drawing. Previous builds used correct parts per list of materials.	ET-103 & sub
H50001-806	Electrical	Corrected dimensions on electrical interconnection diag. 305W1 to agree with those in note. MPPs per correct dimension in note.	ET-103 & sub
H36809-107	TPS	Deleted erroneous radius callout on field of umbilical fairing TPS application drawing	ET-104 & sub

Minor Changes

Change No.	Discipline	Description	Effectivity
H36809-225	TPS	Revised GO2 vent TPS installation drawing to allow for 3 extra wraps of J463A tape around the GO2 vent component part if the part does not conform to their respective faying surface	ET-103 & sub
H36809-343	TPS	Removed hard dimension from LH2 apex foam closeout drawing. Erroneous dimension was applied at a prior control point	ET-104 & sub
H36809-235/ H50001-810	TPS	• Straightened foam trim lines at bipod fitting & LH2 Tank flange closeout and revised dimensions accordingly • Opened dimensional tolerances at both LH2 Tank longerons • Revised point of origin for longeron foam trim • Revised LH2 Tank third hard point trim to allow for foam shadowing • Added future foam closeout note to LH2 longeron • Revised Hardware Certification Sheets (T501E, T503H, T504G and T507G) to reflect revised configuration	ET-104 & sub
H36809-158	TPS	• Corrected dimensional point of origin on LH2 Tank Barrel Foam Application trim to remove contradiction • Relocated leader line from aft side of LH2 Tank flange to fwd side of flange	ET-103
H36809-210	TPS	Revise rework DCN and Intertank foam machining drawing to clarify foam hand machining.	ET-103 & sub
H36809-215	TPS	Removed groove in ablator from support bracket of Sta 371, which was required for metal nose cone. • Not required for composite nose cone.	ET-103 & sub

Minor Changes

Change No.	Discipline	Description	Effectivity
H50001-797	TPS	Revised aft interface crossbeam TPS assembly detail to delete redundant dimensions and add process allowance for those surfaces which see further ablator processing	ET-103 & sub

Minor Changes – STD/STM/STP/AVL

Change No.	Document	Description
B02047-004	809-3600	Periodic revision of the book form drawing to update list of inactive/cancelled Mil Specs and equivalent superceding documents
B02061-001 B02061-002	32L8-group 32L10-group	Revised process for convoluting the liner for flexible hoses. No change in material, form, fit or function. Old and new parts are interchangeable and traceable/serialized.
H35809-742	82621011018 LO2 Feedline Test Spec	Revised test specification to add reference to new oxidizer feedline straight section
H36809-247	STP2012 Tube Fabrication & Installation	Revised specification to permit alternate fluids for purging and testing and to permit alternate specifications for tube bending and flaring
H36809-268	57L14-group 57L9-group	Revised cap assembly standards to specify that the plug shall be captivated to the nut by staking the end of the plug
H36809-325	STP6502 Cable Prep and Shield Termination	Revised specification to reflect build practices of unshielded cables that violated STP requirements but have been determined as acceptable and optimal by engineering. • Specified that the 1" to 4" exposed jacket requirement is for shielded cable • Added requirement for unshielded cable that the strip length be such that the cable jacket edge falls underneath the strain relief clamp wrapping material. Added requirement on how closely to terminate glass fiber sleeving on the connector side of LO2 harnesses
H36809-368	AVL32L5 Non-Metallic Hose Assembly	Revised approved vendor list to show Titeflex Corp. as the approved supplier of standard 32L5 hoses

Minor Changes – STD/STM/STP/AVL

Change No.	Document	Description
H36809-369	AVL55L12 Silicone Rubber O-Ring Packing	Revised approved vendor list for 55L12 O-rings to include both the standard number and vendor part numbers for a new size of O-ring recently required for use on the umbilical carrier plate
H36809-374	STP2001 Installation of Rivets	Revised specification to allow burrs under the shop formed heads of rivets. Inspection of hole cannot be performed in areas where rivets are installed by automated riveting equipment. Permission will also be given to engineering to waive this allowance and require that holes be burr free if presence of burrs presents a problem.
H36809-380	STP7534 Sealing of Comp. Details & Assys	Revised specification to add IPA as a composite surface cleaning solvent
H36809-384	MMSY441 Argon Welding Gas	Revised specification to add CGA spec on Argon to applicable document section, clarify test requirements for impurities and sampling plan for acceptance testing, clarify definitions and container tag for identification
H36809-385	Y679 Argon -Liquified, Plasma Arc Welding	Revised material code sheet to add a higher purity grade liquid argon and to add a not to not allow use of Y679A (Grade B) for welding flight hardware
H36809-390	STP6501 Assembly of Electrical Connectors	Revised specification to remove the requirement of "no indication of looseness of plug coupling nut" of unassembled connectors and place the requirement after mating in the production flow process

Minor Changes – STD/STM/STP/AVL

Change No.	Document	Description
H36809-397	32L8-group 32L10-group Non-Metallic Flexible Hose	Revised hose standards to reflect changes in flex hose Teflon liner first article production
H36809-402	Q402, Q402AD, Q402AP - Bristle Brushes	• Revised code sheet to allow use of only horsehair type brushes • Revised addendum to clarify silicone compatibility test requirements for each initial shipment • Revised appendix to update supplier name and add acid #2 brush.
H36809-432	STP1535 Application of Polyisocyanurate Foam	Revised specification to broaden range of component A to B average ratio, allow for acceptance of average ration transients associated with spray gun activation
J31209-003	1118 Aluminum Alloy PL & SH Bare 2	Revised material code sheet to direct use of applicable STM when procuring aluminum plate of 0.25-0.499 inch thickness • STM1701 for Al 2219; STM1702 for Al2024; and STM1703 for Al 7075

NCD Assessment Criteria

Assessment of all MRB Items

- Adequacy of technical dispositions
- Completeness of required repair/retest
- First time occurrences/SMR
- Verification of margin of safety assessment/documented
- Review of impact to hazards
- Engineering review for impact to loads
- Engineering review for reduced extrusion to plate weld allowables

ET-103 DR/PR/OMRSD Waiver/Exceptions

as of 08/10/2000

System	Discrepancy	Problem	MRB Items	Exceptions/ Waivers
• Electrical	0	0	0	0
• Propulsion / Pneumatics	0	3	0	0
• Structures	2	7	1	0
• Thermal (TPS)	1	18	5	0
Total	3	28	6	0

ET-103 PR/MRBs, Structures

PR No./Status	Title/Description	Disposition
PET-103-ST-0005	LH2 pyro can faying surface has contamination on mating surface	• MRB approved to remove contamination and apply alodine (GFP item)

ET-103 PR/MRBs, Thermal

PR No./Status	Title/Description	Disposition
PET-103-TS-0003	Two areas of crushed SOFI on LH2 barrel caused by impact from fire bell	• MRB to repair damage with PDL-1034 using MAF developed/ validated repair process
PET-103-TS-0004	Inadvertently vented circumferential ribs on -Y thrust panel • Sta 917, ribs 23-26 • Sta 963, ribs 21-26	• MRB approved to use as is based on previous test data which indicates venting at this location does no harm
PET-103-TS-0009	Piece of wood stuck into Intertank TPS	• MRB approved to remove wood chip and use as is – Thermal evaluation determined remaining TPS thickness will maintain thermal requirements

ET-103 PR/MRBs, Thermal

PR No./Status	Title/Description	Disposition
PET-103-TS-0015	Underfill in ET/SRB lower periphery closeout	• MRB approved to inject additional 30 cc of PDL-1034 foam to fill cavity
PET-103-TS-0017	Small area of crushed foam detected on -Y bipod ramp. USA disposition written to pin gauge thickness in center of defect. Pin gauge verification is not allowed in this area due to potential for ice formation in cryo areas	• MRB approved to use as is – Crushed foam removed - TPS thickness requirements maintained – Thermal analysis indicates that pin gauge verification in this area is not a concern for ice formation or temperature increase

ET-103 KSC Modification Summary/Status

Item	Title	Status
• ***Field Engineering Changes***		
– FEC KET-0058	Intertank thrust panel foam venting	Work complete
– FEC KET-0063	Intertank +Z stringer area foam venting	Work complete
• ***Non Standard Work***		
– J5295	MPS 2" disconnect poppet inspection	Work complete
– J5297	Suspect ET weight data	Work complete

ET-103 Limited Life Components

Cycle Sensitive

Description	Part No.	Serial No.	Limit	Required	Remaining
LH2 Manhole Cover Assy	80914081488 -509	0000676870	14	2	14
LO2 Tank Mechanical Assy	80912002000 -500	0000659500	14	2	14
LH2 Tank Mechanical Assy	80914002000 -500	0000709580	14	2	14
LO2 Manhole Cover Assy	80911001205 -509	0000707140	14	2	14
LO2 Fwd Ogive Cover Plate	80911001207 -509	0000729850	14	2	14
LH2 Manhole Cover Assy -Aft	80911001444 -509	0000704090	14	2	14

ET-103 Limited Life Components

Age Sensitive

Description	Part No.	Serial No.	Limit	Initiation	Expiration
External Tank	80901000000-500	00000086	6 Yrs	6/99	6/2005

Age Sensitive Pyrotechnics - 10 Years Life/Requires Lot Verification Tests After 4 and 7 Years

Description	Part No.	Lot No.	Serial No.	Latest Retest	Expiration
Separator Assy GUCP	PD5000020-059	AAH	0001156	02/24/1998	01/2002
Cartridge Assy	PD5000020-030	AAH	0001318	02/24/1998	01/2002
Cartridge Assy	PD5000020-030	AAH	0001319	02/24/1998	01/2002

STS-106 OMRSD/Software Modifications

RCN KS13861M, LO2 Pre-Press Anti-Ice Purge Update

Change

- Delay need for pre-press heater until end of Orbiter MPS chilldown instead of at start of transfer line chilldown

Background/Reason

- Avoid operational conflict that occurs when loading following a scrub
  - Delaying heater activation when loading following a scrub will alleviate the workaround of cycling the heater on and off
- LO2 pre-press system must be activated to maintain ET pressure requirements
  - When activated, the pre-press purge stagnates the flow of the anti-icing purge
  - Anti-icing heater must be turned off to prevent heater overtemp
  - LO2 does not enter the ET until the slow fill phase of loading
    - No ice formation should occur on the LO2 pre-press line during transfer line or Orbiter MPS chilldown
    - Ice team checks entire ET for ice during inspections

STS-106 OMRSD/Software Modifications

RCN KS13861M, LO2 Pre-Press Anti-Ice Purge Update

Software Impact

- Delayed requirement to have the heater on from the start of LO2 loading until end of Orbiter MPS chilldown
  - The pre-press anti-icing purge is initiated at the start of loading and provides adequate heating until start of LO2 slow fill
  - The pre-press anti-icing purge panel supplies both the LO2 and LH2 ET press. lines during loading but uses LH2 power to cycle the heater
  - The LH2 software turns on pre-press anti-icing heater before the end of LO2 Orbiter MPS chilldown
  - The LO2 software verifies that heater has been initiated by the end of LO2 Orbiter MPS chilldown and notifies the LO2 console operator if not on

ET-104 DR/PR/OMRSD Waiver/Exceptions

as of 08/10/2000

System	Discrepancy	Problem	MRB Items	Exceptions/ Waivers
• Electrical	0	1	0	0
• Propulsion / Pneumatics	1	1	0	0
• Structures	2	4	1	0
• Thermal (TPS)	1	8	3	0
Total	4	14	4	0

ET-104 PR/MRBs, Structures

PR No./Status	Title/Description	Disposition
PET-104-ST-0005	Improper weld rod usage on GO2 pressline weldment at Sta 394	• Use as is – Mold impressions of weldment and subsequent x-ray revealed improper weld rod usage – Engineering evaluation determined that weld will meet flight and safety requirements

ET-104 PR/MRBs, Thermal

PR No./Status	Title/Description	Disposition
PET-104-TS-0003/1A	Inadvertently vented PDL repair area Intertank near bipod strut support clip	• MRB approved to use as is – Foam properties unaffected by venting – Vented PDL foam tested during TPS venting baseline testing
PET-104-TS-0008	Underfill in ET/SRB upper and lower periphery closeout	• MRB approved to trim area with top/bottom of fairing and underlying NCFI and repair with PDL
PET-104-TS-0010	Underfill in ET/SRB upper and lower periphery closeout	• MRB approved to inject additional PDL-1034 foam to fill cavity

ET-104 KSC Modification Summary/Status

Item No.	Title	Status
• ***Field Engineering Changes***		
– FEC KET-0060	Intertank Thrust Panel Foam Venting	Work complete
– FEC KET-0065	Intertank + Z Stringer Panel Foam Venting	Work complete
• ***Non-Standard Work***		
– J5295	MPS 2" disconnect poppet inspection	Work complete
– J5297	Suspect ET weight data	Work complete

ET-104 Limited Life Components

Cycle Sensitive

Description	Part No.	Serial No.	Limit	Required	Remaining
LH2 Manhole Cover Assy	80914081488 -509	0000716750	14	2	14
LO2 Tank Mechanical Assy	80912002000 -500	0000772860	14	2	14
LH2 Tank Mechanical Assy	80914002000 -500	0000760320	14	2	14
LO2 Manhole Cover Assy	80911001205 -509	0000786120	14	2	14
LO2 Fwd Ogive Cover Plate	80911001207 -509	0000785400	14	2	14
LH2 Manhole Cover Assy -Aft	80911001444 -509	0000778410	14	2	14

ET-104 Limited Life Components

Age Sensitive

Description	Part No.	Serial No.	Limit	Initiation	Expiration
External Tank	80901000000 -500	00000097	6 Yrs	5/99	5/2005

Age Sensitive Pyrotechnics - 10 Years Life/Requires Lot Verification Tests After 4 and 7 Years

Description	Part No.	Lot No.	Serial No.	Latest Retest	Expiration
Separator Assy GUCP	PD5000020-059	AAH	0001151	04/13/1998	10/2003
Cartridge Assy	PD5000020-030	AAH	0001308	04/13/1998	10/2003
Cartridge Assy	PD5000020-030	AAH	0001309	04/13/1998	10/2003

Level II Waivers - Baseline

Document / Requirement	Authority	Paragraph	Waiver No.	Effectivity
NSTS 07700, Volume V, Information Management Requirements				
Generic part name, type, common designation, and part manufacturer H4 code are not required for EEE parts status print out	PRCBD S000127B 06/28/88	Table C.5 Item 2SR-10	6	ETs 49 & up
Data required in limited life status report is supplied in acceptance data package	PRCBD S000127B 06/28/88	Table C.6 Item 2SR-7	8	ETs 49 & up
Requirement to deliver element pressure vessel historical data to EPO will remain at contractor facility	PRCBD S000127B 06/28/88	Table C.6 Item 2SR-7	10	ETs 49 & up

Level II Waivers - Baseline

Document / Requirement	Authority	Paragraph	Waiver No.	Effectivity
NSTS 07700, Volume X, Book 1, Space Shuttle Flight and Ground System Specification, Requirements				
Electrical wiring of redundant systems NSTS 08080-1, 20A/4B	PRCBD S040732G 06/18/88	Table 2.0	362	ETs 23, 27-29, 31 & up
Soldering, circuit boards, and connectors	PRCBD S040732M 09/09/88	3.6.15.1.1	379	ETs 23, 27-29, 31 & up
PD7400106 circuit boards	PRCBD S040732M 09/09/88	3.6.15.2.1	382	ETs 23, 27-29, 31 & up
Pressure transducer circuit boards	PRCBD S040732M 09/09/88	3.6.15.2.1	383	ETs 23, 27-29, 31 & up
Debris prevention	PRCBD S082962A 10/02/98	3.2.1.2.14	675	ETs 92, 97-105

Level II Waivers - Baseline

Document / Requirement	Authority	Paragraph	Waiver No.	Effectivity
NSTS 07700, Volume X, Book 1 - Space Shuttle Flight and Ground System Specification, Book 1, Requirements				
Launch holds due to ice formation shall not occur more than 5% of time on annual basis	PRCBD S071290 03/10/00	3.2.1.2.14.1	682	ETs 102, 107 -110
NSTS 07700-10-MVP-01, Shuttle Master Verification Plan - Volume I, General Approach and Guidelines				
Environmental acceptance of ET components	PRCBD S002130H 03/07/89	3.7.1	13	ETs 23, 27-29, 31 & up
NSTS 08123 - Certification of Flexhoses and Bellows for Flow Induced Vibration				
LH2 feedline bellows	PRCBD S005203GR1 08/02/91	1.2	3	ETs 42-45, 47 & up

Level II Waivers - Baseline

Document / Requirement	Authority	Paragraph	Waiver No.	Effectivity
SL-E-0001 – Specification Electromagnetic Compatibility Requirement				
Wire marking is not applicable to the ET	PRCBD S040732K 09/27/89	3.2.5	3	ETs 23, 27-29, 31 & up
SW-E-0002 – Ground Support Equipment General Design Requirements				
Factor of safety applied to yield for feet on ground half of GUCA	PRCBD S087020L 08/17/88	3.4.2.1	21	ETs 23, 27-29, 31 & up

Level III Deviations

Document / Requirement	Paragraph	DAR No.	Effectivity
CPTO1M09A, External Tank Contract End Item Specification – Part I			
• Photographic evidence shows a loss of foam from both +Y and –Y Intertank Thrust Panels • Analysis concluded a low probability of debris impact on Orbiter critical area	3.2.1.1.17	233	ETs 92, 97-99, 101-105

Appendix E - Previously Presented Items

STS-101/ET-102 Prior Mission Performance Summary

- OMRS Exception - LO2 100% Level Sensor Failure
  - *Presentation from STS-101/ET-102 Delta PMMT Review*
- Crack in +Y Longeron Foam Closeout
  - *Presentation from STS-101/ET-102 Delta PMMT Review*

Discrepant NDE Records for ET Welds

- *Closure for FRR Action Item # 101-FRR-002*

Diagonal Strut Mechanical Testing

- *Closure for FRR Action Item # 101-DPMMT-001*

Incorrect Weld Rod on External Tank Hardware

- *Presented to and accepted by PRCB (S061435) on 04/20/00*

STS-101/ET-102 OMRS Exception EK 03930
LO2 100% No. 1 Sensor Failed Wet

Issue

- LO2 100% No. 1 liquid level sensor failed wet during STS-101 launch attempt #3

Discussion

- Sensor trended from 70% wet to 100% wet and diverged from 100% No. 2 sensor
  - Sensor check performed (per OMRSD) during stable replenish confirmed anomaly
  - Preplanned contingency procedure defined in OMI S1003 allows bypass of 100% No. 1 sensor and use of the 100% No. 2 sensor as the primary control of LO2 liquid level
- The 100% No. 1 sensor is used for transition to topping, replenish control and determination of flight mass
- For the next cryo load of STS-101/ET-102, the LO2 100% No. 1 sensor will be bypassed and the LO2 100% No. 2 sensor will be used per the preplanned contingency procedures in LCC ET-10 and OMI S1003

Status

- OMRSD exception approved at Daily Special PRCB (S053294FD) on 05/08/00

STS-101/ET-102 OMRS Exception EK 03930
LO2 100% No. 1 Sensor Failed Wet

Loading Scenarios with Failed/Bypassed LO2 100% No. 1 Liquid Level Sensor

		Potential Scenarios			
LO2 Loading Cycles	**Typical Operations & Requirements**	**Nominal Operation** *(all LL Sensors operational)*	**STS-101 Loading** *(100%#1 failed prior to loading, 100%#2 operational throughout loading)*	**Contingency: After EOT/SOR** *(100%#2 failed)*	**Contingency: Prior to EOT/SOR** *(100%#2 failed)*
• **Xfer Line Chill**		*100% Liquid Level Sensor Not Used*			
• **Orbiter Chill**	ECOs wet (typical)	*100% Liquid Level Sensor Not Used*			
• **Slowfill**		*100% Liquid Level Sensor Not Used*			
• **Fastfill**	5% wet (typical) 98%#1,#2 wet (typical)	*100% Liquid Level Sensor Not Used*			
• **Topping** *(Liquid Level Control)*	100% 10%wet (1 of 2) or 99.85% 10% wet @ EOT triggers SOR (per OMI S1003 10-008)	100%#1 10% wet @ EOT triggers SOR	100%#2 10% wet @ EOT triggers SOR	100%#2 10% wet @ EOT triggers SOR	99.85% 10% wet @ EOT triggers SOR (slightly earlier SOR)
• **Replenish** *(Liquid Level Control)*	• 100% #1,#2 wet 15%-75% • 100.15% wet 15%-75% - or - 100.15% <35% and 99.85% > 65% (per LCC ET-10)	100% #1 controls replenish valve position (per LCC ET-10) 15%-75%	100% #2 controls replenish valve position (per LCC ET-10) 15%-75%	100.15% controls replenish valve position (per LCC ET-10) 15%-75%	100.15% controls replenish valve position (per LCC ET-10) 15%-75%
• **Auto-Sequence -> T-0** *(Flight Mass Ok)*	• 100% #1,#2 wet 15%-75% • 100.15% wet 15%-75% - or - 100.15% <35% and 99.85% > 65% (per LCC ET-10)	100% #1 controls replenish valve position (per LCC ET-10) 15%-75%	100% #2 controls replenish valve position (per LCC ET-10) 15%-75%	• 100.15% controls replenish valve position (per LCC ET-10) 15%-75% • Revised terminal countdown - Additional drainback if using 100.15% to control (per LCC ET-10; ref.: OMI S1003, LCC SEQ-01)	• 100.15% controls replenish valve position (per LCC ET-10) 15%-75% • Revised terminal countdown - Additional drainback if using 100.15% to control (per LCC ET-10; ref.: OMI S1003, LCC SEQ-01)

Note: LL = Liquid Level EOT = End of Topping SOR = Start of Replenish

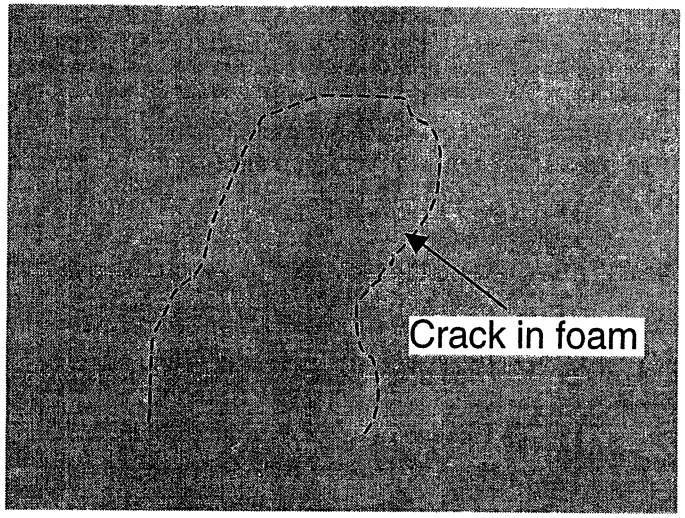
STS-101/ET-102 Crack in +Y Longeron Foam Closeout

Issue

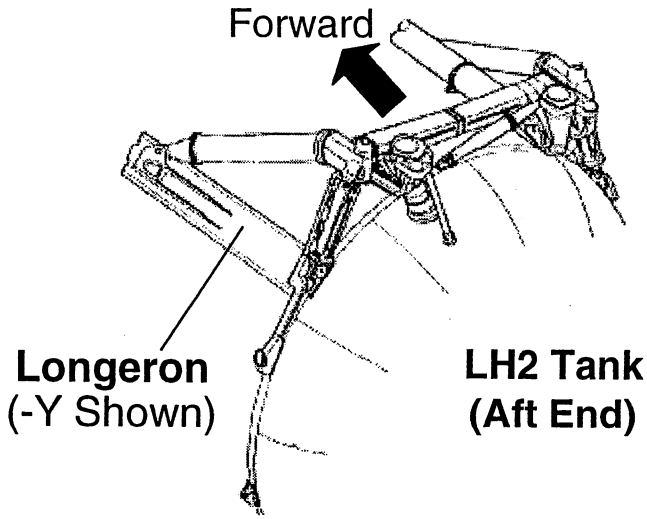
- Crack in +Y longeron foam closeout following STS-101 launch attempt #2

Discussion

- Post drain walkdown following STS-101 launch attempt #2 found a crack in the +Y longeron foam insulation (approximately 4" long x 1/8" wide and no offset)
- The crack was evaluated again during the final inspection walkdown during the 3rd launch attempt
  - Crack size was unchanged and minimal offset (1/16") was present



+Y Longeron Foam Closeout



STS-101/ET-102 Crack in +Y Longeron Foam Closeout

Discussion (continued)

- TPS debris is unlikely
  - Minimal offset at crack location
  - Foam adhesion to substrate and sidewall of longeron ribs provides adequate strength
- No thermal and/or stress concerns for ascent or reentry
  - Thick longeron is heat sink and structural temperature would not increase during ascent even in the event of foam loss
- No propellant quality issues event if material is lost at lift-off
- BNA debris analysis
  - Damage from potential ice build up
    - Orbiter impact from ice debris is only possible at speeds greater than Mach 2.5
      - Any particles originating from location this will be low energy resulting in minimal damage to the Orbiter (body flap damage with worst case depth of 0.65")
  - Damage from ET foam debris
    - No transport mechanism for foam debris to impact Orbiter from this location
  - Aero/erosion assessment
    - Hot gas divot simulation tests show rounding of back edge on similar cavities with no increased erosion within short downstream distance
- Status
  - MRB approved for "use as is"

Discrepant NDE Records for ET Welds

Issue

- Discrepant Non-Destructive Evaluation (NDE) records for LO2 and LH2 tank welds

Background

- Review of an enhancement change to the ET Weld Acceptance Document identified an error in the O-1 weld radiographic inspection +Z clocking location
  - Because the radiographic records and requirements used different +Z references, post proof x-ray of the weld was not properly performed in some locations
- O-1 weld assessment resulted in subsequent review of all NDE records for all ET LO2 and LH2 tank welds
  - Most discrepancies were for post-proof NDE
- NDE discrepancies fell into the following categories:
  - Post-proof NDE paperwork omitted for area requiring inspection
    - Inspection not performed
  - Placement of x-ray film was incorrect
  - X-ray penetrameter location was incorrect
  - Post-proof x-ray angle shots performed incorrectly
  - Radiographic film lost

Discrepant NDE Records for ET Welds

Hardware Clearance Approach

- Reviewed all available post-proof x-ray film and penetrant inspection records for all welds
  - Documented each non-conformance
  - DCMA reviewed x-ray film for all documented non-conformances
- Each non-conformance was evaluated individually and accepted based on one or more of the following:
  - Fracture analysis for adequate mission life based on using largest known weld defect or minimum detectable defect (whichever was larger)
    - Used measured peaking and mismatch
    - Used maximum predicted stress
    - Assumed defect in most vulnerable location
  - Proof test adequacy
    - Loads ≥ 100% flight limit load
    - Weld proof stresses adequate to enhance defects
  - X-ray film clarity outside of penetrameter is acceptable
  - Adequate strength margins in flight
- All non-conformance dispositions reviewed by the MAF Fracture Control Board (FCB) & NASA

Discrepant NDE Records for ET Welds

Rationale for Flight

- Review of all NDE records for STS-106/ET-103 and STS-92/ET-104 welds is complete
  - Each discrepancy was reviewed by the MAF FCB and by NASA
    - All hardware deemed acceptable for flight
    - Analysis shows adequate mission life and positive margin of safety for areas of welds with discrepant NDE records
- Plan for development of fleet clearance rationale is in progress
  - Plan to be completed by June 23, 2000
  - Hardware clearance to be completed by July 31, 2000

Discrepant NDE Records for ET Welds

Causes

- Inadequate documentation and control of NDE processes led to incorrect penetrameter placement, omission of tank specific post-proof NDE requirements, and locations incorrectly identified on tank specific post-proof NDE requirements
  - Flow down of requirements not controlled
  - Shop aids not controlled

- ±35° angle shots were unachievable in some locations
  - Inadequate NDE process verification contributed to the cause of 35° x-ray angle shots performed incorrectly in some locations
    - Tool or hardware interference prevented achievement of 35° angle shots
    - Thickness of metal prevented capture of weld and location tape on x-ray film
    - Tooling and technique produced unclear x-rays in some locations

- Inadequate control of radiographic film was the cause of lost inspection records

Discrepant NDE Records for ET Welds

Corrective Actions

- Post-proof NDE of ET welds was suspended until an audit was completed
  - LMC & NASA Audit Team was established
  - All discrepancies were evaluated for cause and corrective action

- Interim corrective actions implemented
  - All post-proof NDE requirements were verified by the LMC/NASA team for conformance
  - Added requirement for verification of film placement, penetrameter placement and x-ray angles by the x-ray supervisor, as well as by the x-ray technician
  - Employees were briefed on the importance of following requirements and of identifying when requirements cannot be achieved - Stamp Warranty
    - Deviation from ±35° angle shots currently requires documentation and engineering approval
  - Implemented tooling to assist radiographers in making shots
    - Practitioners trained on use of tool
  - All X-ray film is now in a controlled storage area

Discrepant NDE Records for ET Welds

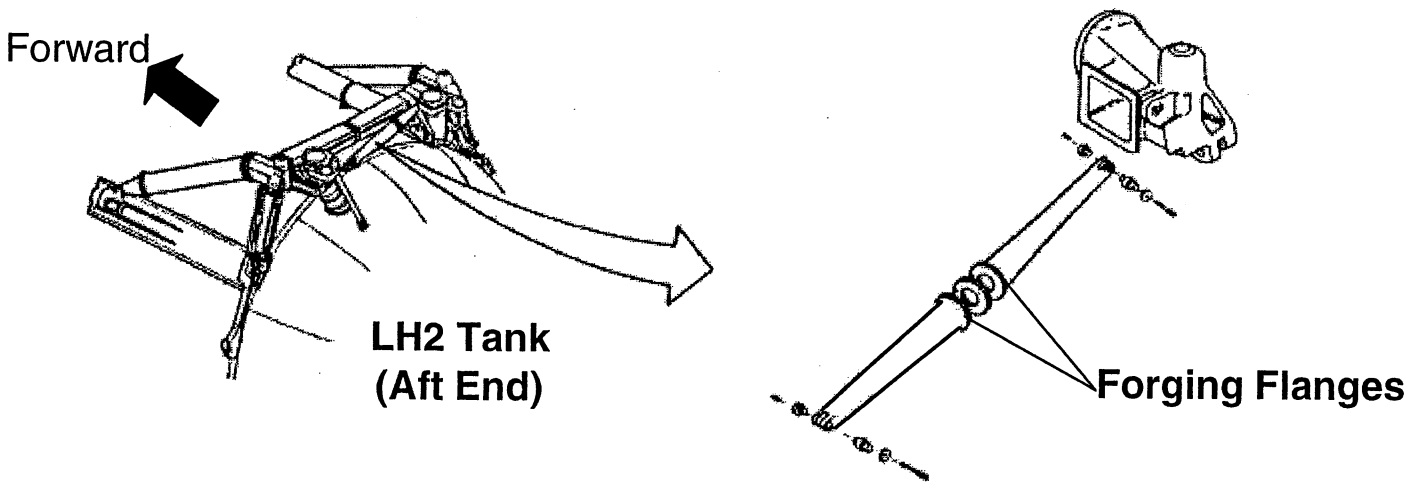
Corrective Actions (continued)

- Corrective actions in work
  - All unclear requirements will be revised to avoid confusion
  - Engineering change in progress to document required x-ray angles where physical obstructions or other limitations exist
  - NASA to perform NEQA Audit on interim actions in place
  - Development of additional improved tooling to accommodate correct x-ray film placement, angle shots, etc.

Diagonal Strut Mechanical Testing

Issue

- Incomplete mechanical properties acceptance testing of diagonal struts
  - Requirement specifies prolongation (test coupon) be tested for both longitudinal and transverse mechanical properties, elongation and electrical conductivity
  - For mechanical properties, heat treat subcontractors performed only transverse or longitudinal tests, not both



- *Each diagonal strut is assembled from identical machined forgings and bolted together at the flange ends*
- *Prolongation (test coupon) taken from flange end of each forging*

Diagonal Strut Mechanical Testing

Hardware Clearance

- Review of diagonal strut mechanical property test data indicates that the heat treat was properly performed

- Stress analysis using conservative transverse mechanical properties show factors of safety are greater than required
  - Transverse properties are lower than longitudinal properties
  - Critical stress field coincident with longitudinal direction
    - FS actual: 2.16 (failure mode: Ultimate Stability)
    - FS required: 1.40

- Diagonal strut design tested to a minimum 147% of design limit load without failure during verification testing

- Acceptance test results for all other hand forgings on the ET were reviewed to verify compliance to mechanical property testing requirements
  - All mechanical property testing was performed as required

Diagonal Strut Mechanical Testing

Cause

- Supplier implemented die forging requirements in lieu of hand forging requirements
  - Misinterpretation of engineering requirements
  - Only one test is required for die forgings

Immediate Corrective Actions

- Revised the Procurement Quality Acceptance Report (PQAR) to add pertinent requirements
- Added requirement for Procurement Quality Control at MAF to compare the content of the PQAR to the Drawing/Specification Requirements prior to approval
- Provided electronic access to Sheet 1 of engineering drawing to all Procurement Quality Control Field Representatives
- Revised process validation methodology to include verification of test requirements for each part processed
- Provided lessons learned to all Procurement Quality Control field representatives

Diagonal Strut Mechanical Testing

Corrective Actions in Work

- Provided refresher training to all PQC Field Representatives for the review and approval of:
  - Manufacturing Process Plans
  - Process Instructions
  - Supplier Purchase Orders

- Supplier process instructions have been upgraded to include references to specific testing requirements

- Supplier has added specific instructions to the purchase order of the current heat treat source for diagonal struts to test the forgings per STP 8002C

Incorrect Weld Rod on External Tank Hardware

Issue

- Item #1
  - Incorrect weld rod was found in a manual weld on External Tank (ET) GH2 pressurization line during fabrication at Arrowhead Products (AHP)

- Item #2
  - Incorrect weld filler rod was called out on the planning paper at AHP for the ET GO2 pressurization line Incorrect weld filler rod was called out on the planning paper at AHP for the ET GO2 pressurization line

Background

- Item #1
  - In December 1999, an incorrect weld rod alloy was detected in one manual weld in the forward flex section of the GH2 pressurization line during manufacture at Arrowhead Products (AHP)
    - Suspect condition first noticed by the AHP x-ray interpreter during NDE following successful proof test of the line
    - X-ray of the indicated a bimetallic condition when the joint design was for a single metal
      - Analysis of the weld bead confirmed that the wrong weld rod alloy was used
  - As part of hardware acceptance, all x-ray film is reviewed for weld defects
    - Lockheed Martin, NASA and AHP personnel developed a process for screening the x-ray film for indications of a bimetallic weld
      - Process was successfully demonstrated on test panels welded by AHP
      - Clearance for STS-103/ET-101 and STS-99/ET-92 was partially based on this process

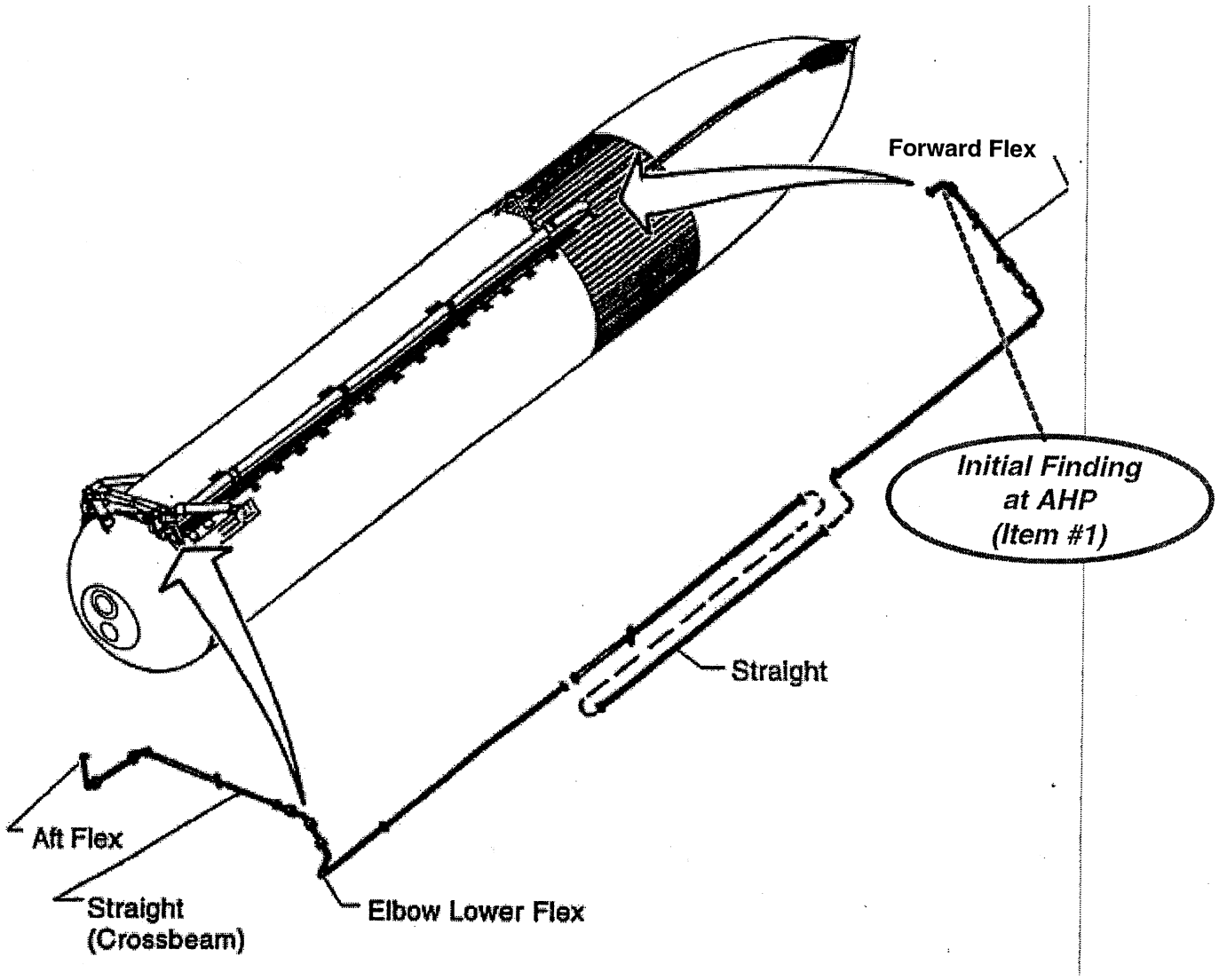
Incorrect Weld Rod on External Tank Hardware

Background (continued)

- Item #2
  - Prior to the completion of the Item #1 investigation, AHP added a requirement to verify weld rods against the drawing for the correct alloy
  - During the fabrication of the mid flex section of the GO2 pressurization line, it was discovered that AHP planning called out the incorrect weld rod alloy for one weld (#9) on the part
  - Parts fabricated with the incorrect planning were traceable by serial number
  - Nine SLWT parts were fabricated at AHP using incorrect planning
    - Seven of these parts were delivered to MAF
      - Five installed on External Tanks
      - Two remain in MAF inventory
    - Two parts were not delivered to MAF
  - LWT parts have a different dash numbers, and therefore were not affected by the planning error
  - All other planning at AHP was reviewed with no discrepancies found

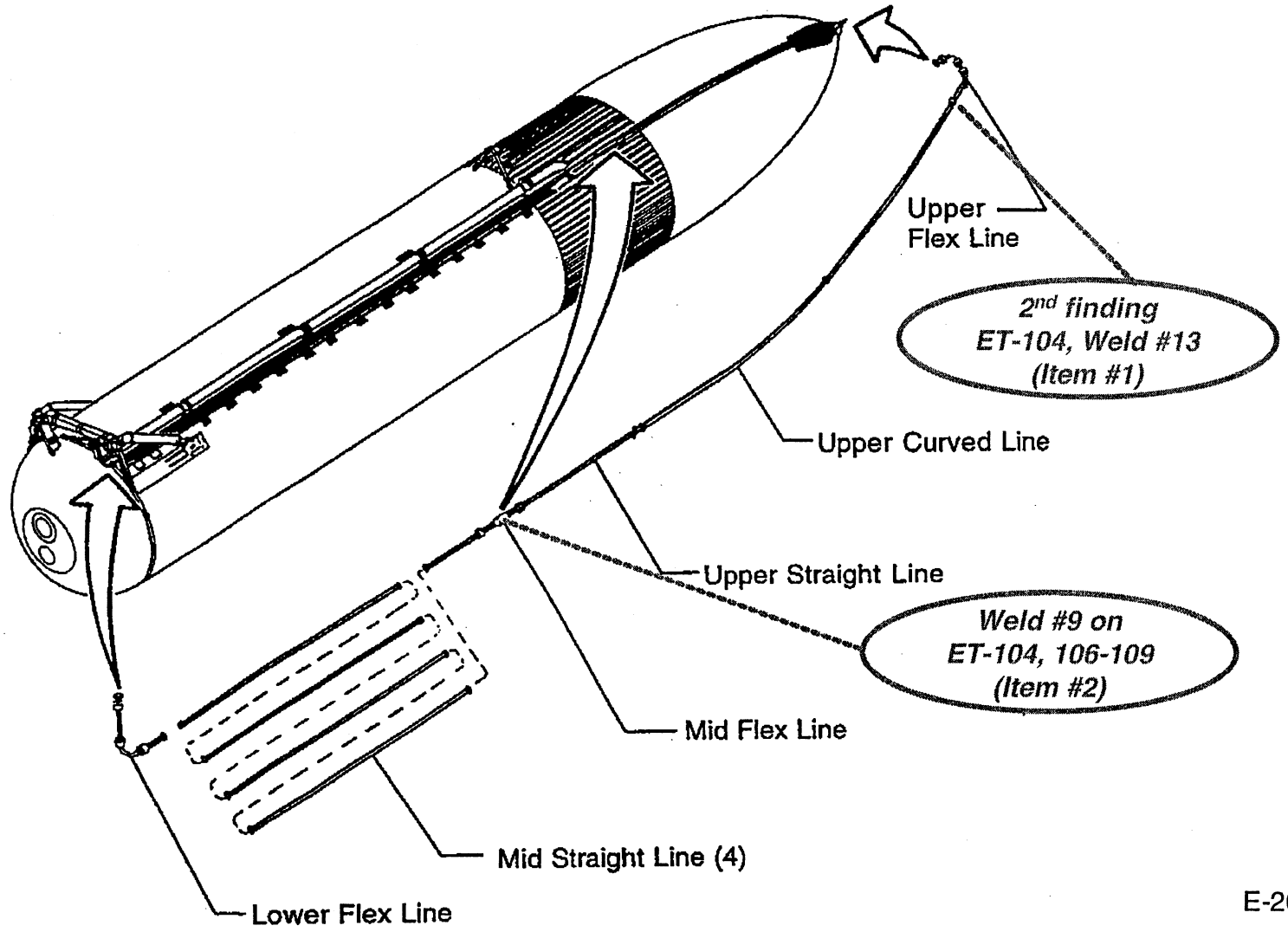
Incorrect Weld Rod on External Tank Hardware

GH2 Pressurization Line Assembly



Incorrect Weld Rod on External Tank Hardware

GO2 Pressurization Line Assembly



Incorrect Weld Rod on External Tank Hardware

Fleet Clearance Rationale

- Item #1
  - **Bimetallic Welds:** Stress analysis performed using "worst case" weld rod alloy available at AHP
    - For weld rods available for use at AHP, 300 series would produce a weld with the lowest strength
    - All resulting factors of safety were greater than required (1.40)
  - **Single Metal Welds:** Stress analysis was performed using "worst case" weld rod alloy
    - Thirteen welds were identified as critical welds having factors of safety less than 1.40 with the "worst case" weld rod alloy
    - X-ray film was reviewed for these thirteen critical welds for all delivered lines
      - 100% of x-ray film for single metal welds was reviewed for clearance of STS-103/ET101 and STS-99/ET-92
  - **Findings:** In review of x-ray film one single metal weld had indication of bimetallic weld
    - STS-92/ET-104 GO2 pressurization upper flex line in weld #13
    - XRF analysis verified that Hastelloy-W was used in lieu of Inconel 718
    - Stress analysis shows margin of safety for this weld is adequate (F.S. > 2.0)
      - Weld strengths obtained for Inconel 718 welded with Hastelloy-W were greater than the design weld allowables

Incorrect Weld Rod on External Tank Hardware

Fleet Clearance Rationale (continued)

- Item #2
  - All AHP planning was reviewed for conformance to engineering drawings
    - GO2 pressurization line mid flex section had only discrepancy
  - Discrepant weld was not among the thirteen critical welds identified by analysis performed during investigation of Item #1
    - Factor of safety greater than minimum required if worst case (300 series) weld rod used
  - XRF analysis verified that Hastelloy-W was used in lieu of Inconel 718
    - Stress analysis shows margin of safety for this weld is adequate (F.S. > 2.0)
      - Material properties obtained from Inconel 718 welded with Hastelloy-W resulted in strengths greater than the design weld allowables

Incorrect Weld Rod on External Tank Hardware

Cause

- Item#1
  - Employee error: Welder violated company policy by keeping multiple types of weld rod alloy in work area

- Item #2
  - Employee error: Incorrect weld rod specified on planning
    - Error was inadvertently introduced in a planning change that moved weld rod callout from a general note to a specific requirement in the plan
    - Inadequate change description on the planning change record caused the error to go unnoticed during Arrowhead and LMMSS review and approval

Incorrect Weld Rod on External Tank Hardware

Corrective Actions

- Item #1
  - Weld rod now issued by Quality personnel instead of the area foreman
  - Procedure revised to require disposal of all excess weld rod into secure container
  - All Shuttle program wire to be repainted to show alloy composition of weld
  - Weld work areas inspected weekly by Quality required to assure compliance

- Issue #2
  - QS-210 revision L, which defines weld rod control requirements, revised to require alloy verification by drawing, as well as by planning
  - QUALITY BULLETIN 00-03 issued to define the requirements for planning change descriptions