FLIGHT READINESS STATEMENT
STS-98/ET-106
EXTERNAL TANK PROJECT
DELTA PRE-FLIGHT REVIEW

EXTERNAL TANK ET-106/STS-98, AS IDENTIFIED IN THE EXTERNAL TANK PROJECT DELTA PRE-FLIGHT REVIEW DATED DECEMBER 4, 2000, IS CONSIDERED READY TO SUPPORT FLIGHT UPON ACCEPTABLE DISPOSITION OF OPEN/PLANNED WORK AND/OR OPEN ACTIONS.

N. E. OTTE/MP31

A. A. McCOOL/MP01

J. BULLMAN/ED10

P. K. McCONNAUGHEY/ED20

P. M. MUNAFO/ED30

D. A. KROSS/ED40

for A. O. GOODSON/QS01

C. E. SINGER/TD01

J. W. SMELSER/MP31, CHAIRMAN

12/04/2000

Space Shuttle
External Tank

ET Project Delta Pre-Flight Review

STS-98/ET-106

LOCKHEED MARTIN

106ΔPFR.4250.12/00

Implementation of One Piece Vertical Strut

B02028

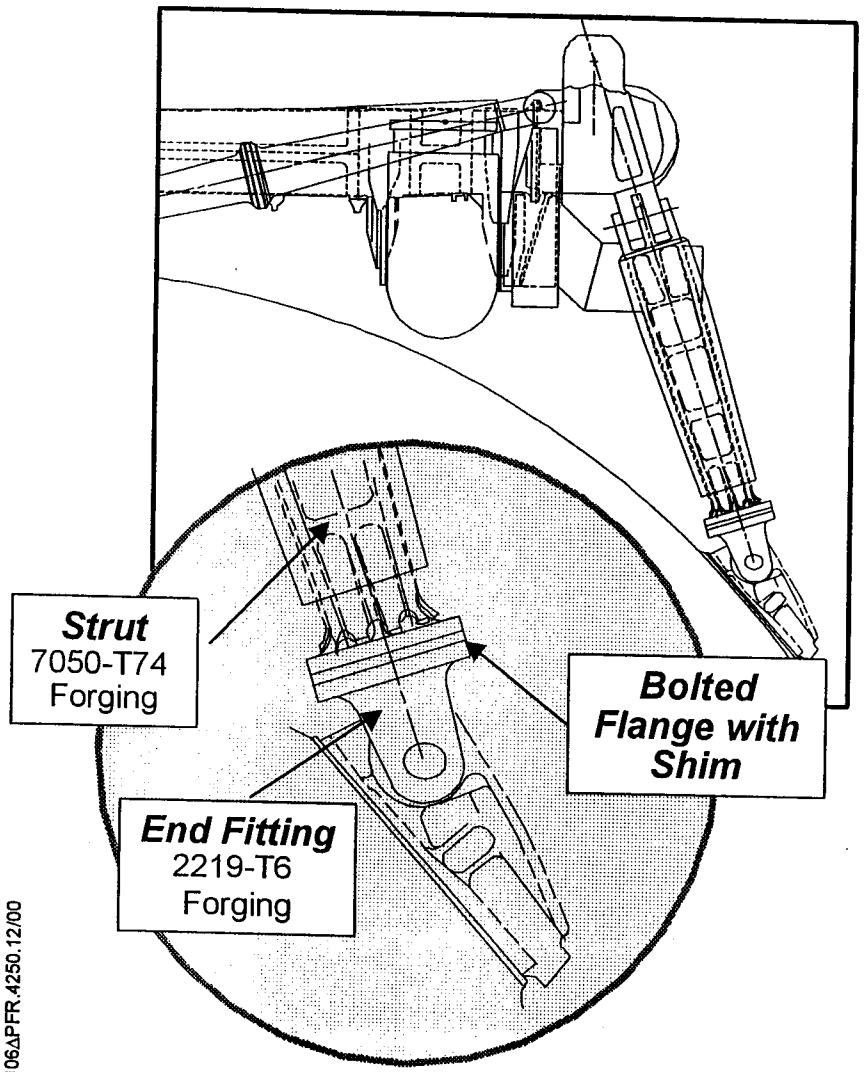
Change Description

- Vertical strut redesigned to one-piece configuration to achieve 95 lbs. weight savings on SLWT tank
  - Weight savings required to offset implementation of Al 2219 frame chord extrusions
  - Al 2219 frame chord extrusion required to mitigate production welding issue with Al 2195 frame chords
- Redesigned one-piece configuration eliminates end fitting with bolted flange and uses eccentric bushing pairs to accommodate strut length adjustments
- Eliminated CIL for strut end fitting assembly (4.5.24.1)
  - Revised existing CIL for the vertical strut (4.5.25.1) to include the new one piece design
  - Revised existing CIL for the aft ET/Orbiter Structural Installation (4.5.34.1) to include the new configuration
- No impact to ICD
  - Matched and Coordinated Tooling used for strut installation unchanged
- No change to the loads model
  - Change in strut stiffness insignificant
  - Redesigned strut is more robust than previous design

Implementation of One Piece Vertical Strut

B02028

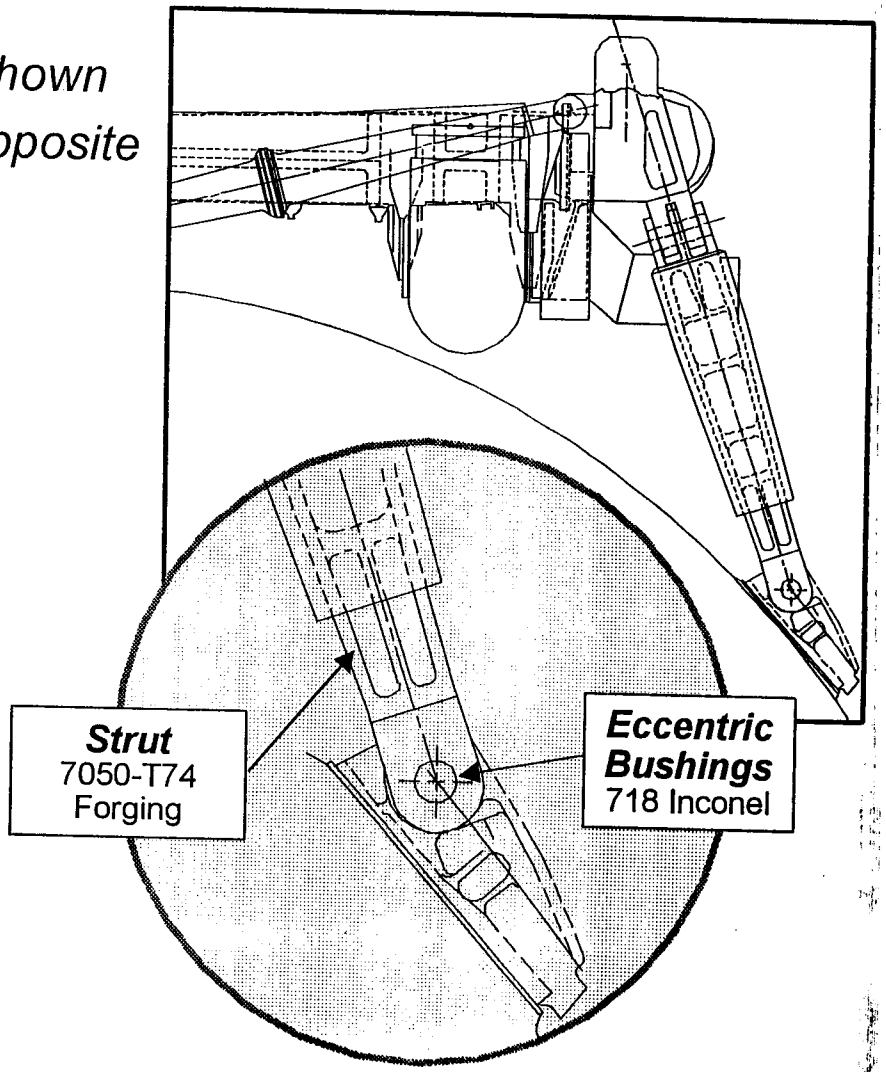
Was: Two-Piece Strut



+Y Shown

-Y Opposite

ET-106 & Up: One-Piece Strut



106ΔPFR.4250.12/00

Implementation of One Piece Vertical Strut

B02028

Functional Description

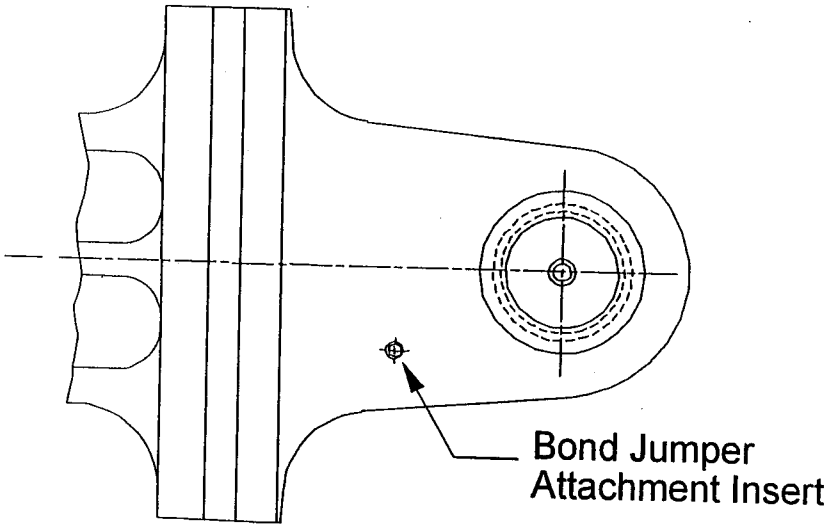
- Two sets of eccentric bushings are installed in the vertical strut lugs to adjust strut length
  - Both sets of bushings are rotated in equal and opposite directions simultaneously to obtain proper strut length
  - Equal and opposite rotation of the bushings ensures strut load line-of-action remains through the clevis pin centerline
  - Lubrication of sliding surfaces between inner and outer bushings is necessary for installation
  - Excess lubrication is removed after strut length adjustments are complete to allow TPS adhesion
- Design uses internal surface friction to 'lock' bushings in place and maintain strut length adjustment
  - Internal surface friction prevents the rotation of bushings under static loading
- Positive restraint pins are installed following strut length adjustment to provide 'locking' feature when load is not applied
  - Analogous to a bolt with lockwired nut
- Strut design does not rely on friction for load carrying capability
  - Design change increases load carrying capability of the vertical strut lower lugs
- Shoulder bushings, end caps, and 3" diameter pin are retained by a 0.375" diameter bolt and locking nut
  - Similar to prior configuration

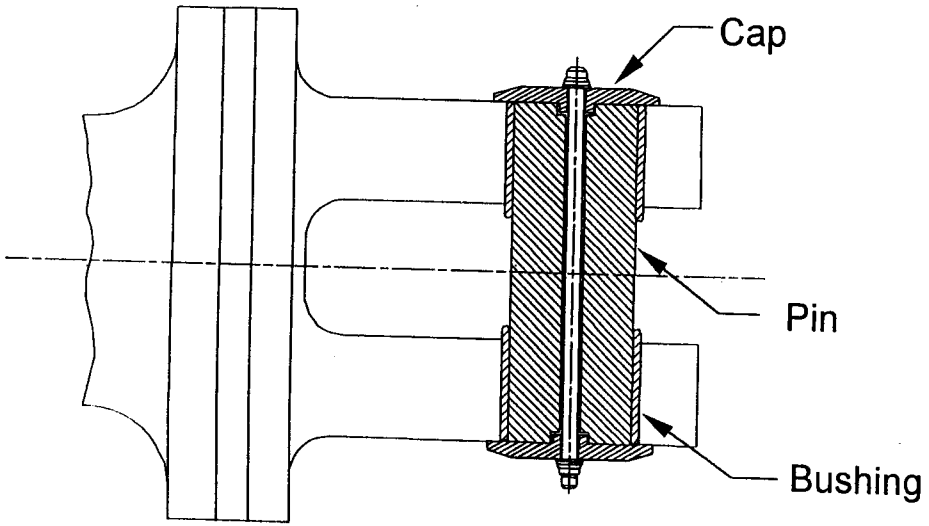
Implementation of One Piece Vertical Strut

B02028

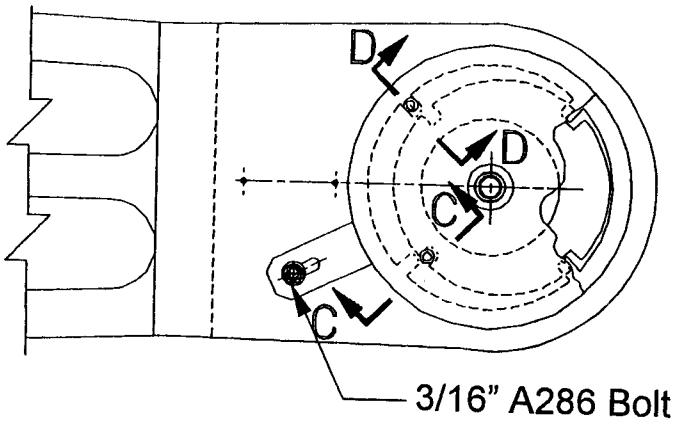
Installation Configuration

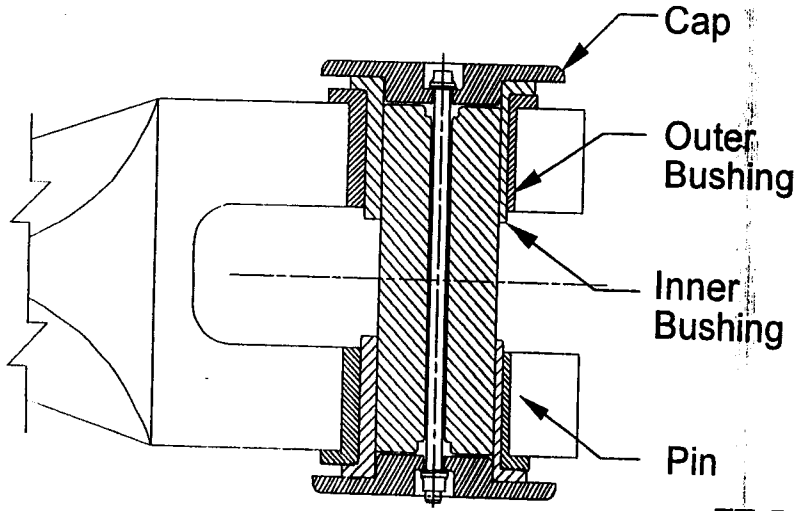
Was





ET-106 & Up



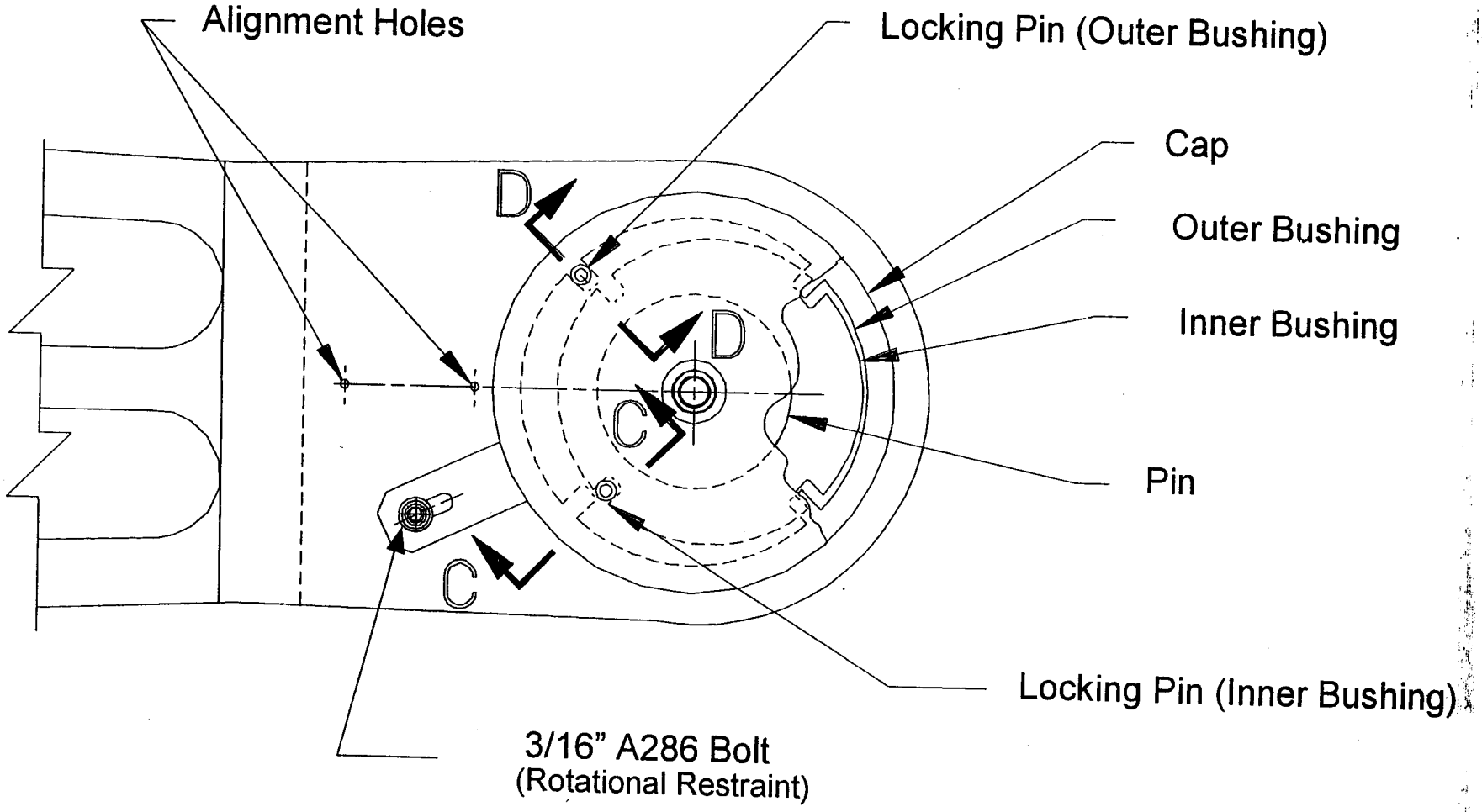


106ΔPFR.4250.12/00

Implementation of One Piece Vertical Strut

B02028

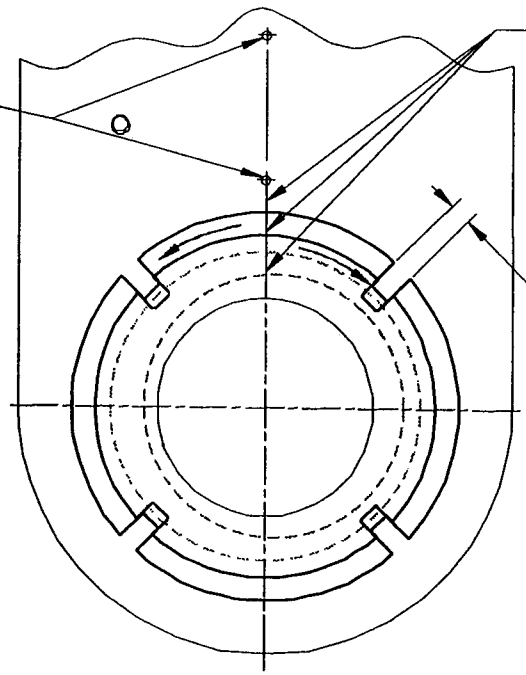
Bushing Installation & Adjustment



Implementation of One Piece Vertical Strut

B02028

Bushing Installation & Adjustment



±.25 Pin CL Adjustment
Reqd Along CL of Strut.
Counter-Rotate Bushings

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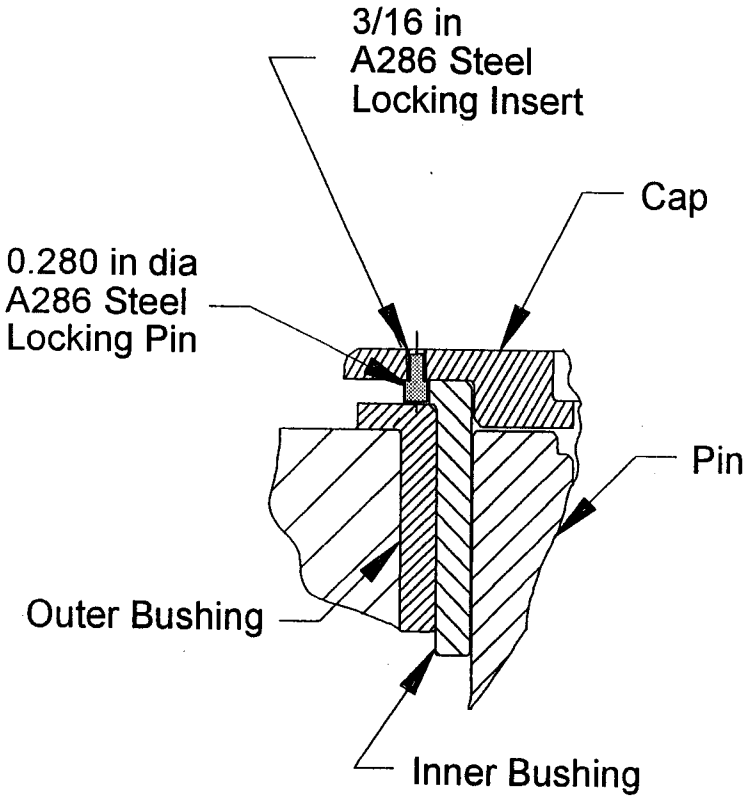
Implementation of One Piece Vertical Strut

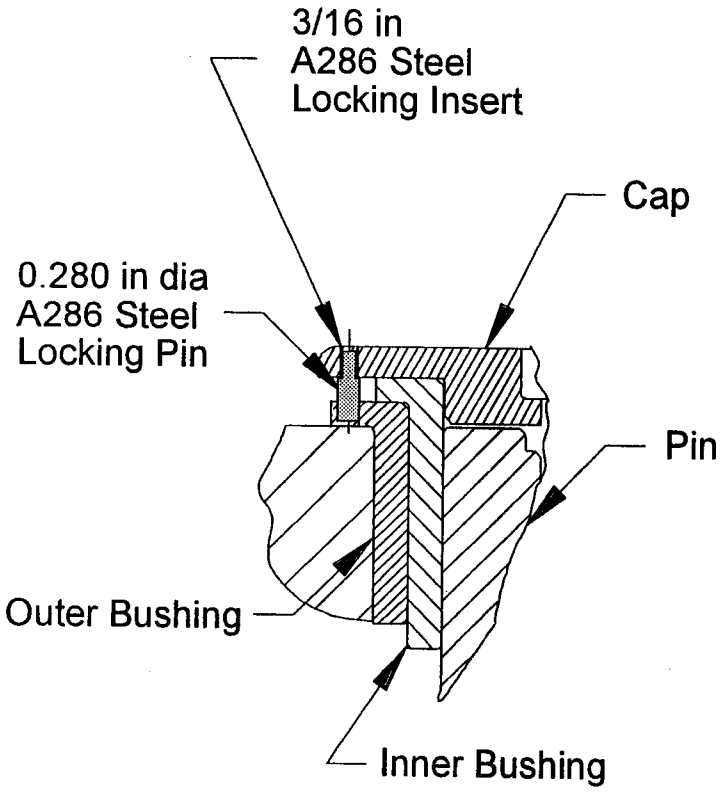
B02028

Locking Pin for Inner Bushing



Section C - C
Rotated 45° CW

Locking Pin for Outer Bushing

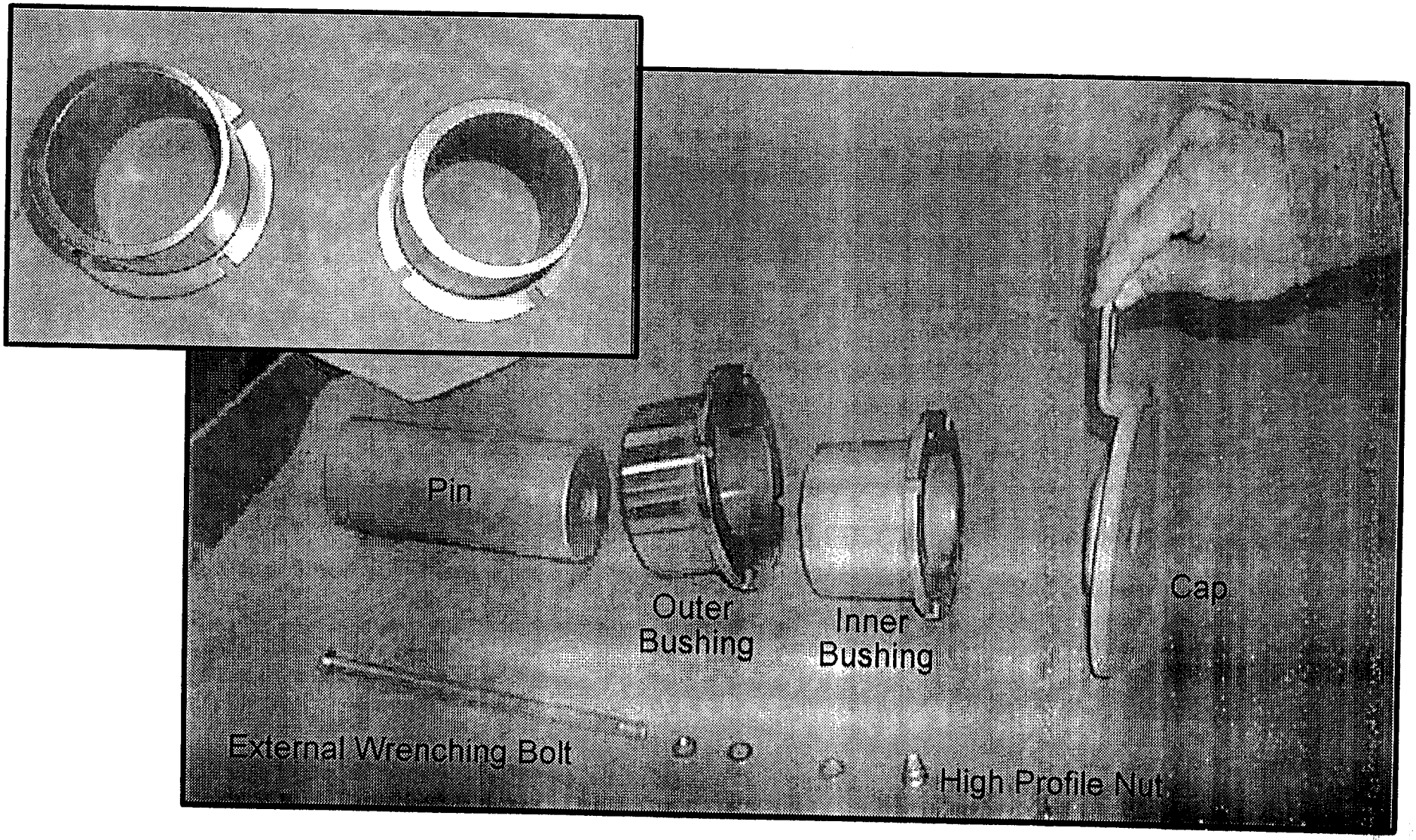


Section D - D
Rotated 45° CCW

106ΔPFR.4250.12/00

Implementation of One Piece Vertical Strut

B02028



Implementation of One Piece Vertical Strut

B02028

Basis for Certification - Strut

- Test
  - Structural Test successfully performed at MSFC to demonstrate strength of strut
    - Demonstrated 207% of design limit tension load
      - Testing of previous two piece design demonstrated 159% of design limit tension load
    - Bushings loaded across thinnest section
    - Test did not exercise bushing non-rotation features

- Analysis
  - Stress analysis shows improved factor of safety for redesigned lower lugs

	Was	Now	Req'd
Lug Tension	1.54	1.79	1.40

Implementation of One Piece Vertical Strut

B02028

Basis of Certification - Bushing Mechanism

- Analysis was performed to ensure strut length is maintained during ground and flight operations
  - Design is certified for both static and dynamic loading environments

- Static Loading
  - Internal joint friction is the predominant force resisting 'slippage' during static loading
  - Analysis based on 'free-body' force balance of sliding surfaces to relate joint available 'frictional' force to applied 'rotational' force
    - Bushing rotation requires two surfaces to 'slide' within the joint
    - Both resisting force and rotational forces are functions of the applied normal load and therefore the magnitude of the applied strut load is cancelled out
    - Analysis simplifies to a relationship between bushing slope angle (rotational force) and coefficient of friction (resisting force)
      - Slope between bushing surfaces averages 2.5°
      - Bushing angle can be compared to 26L2 A286 bolt thread angle which ranges between 1.5° and 3.0°
      - Lowest coefficient of friction for any of the joint interface surfaces is used in the analysis (.061)

Implementation of One Piece Vertical Strut

B02028

Basis of Certification - Bushing Mechanism

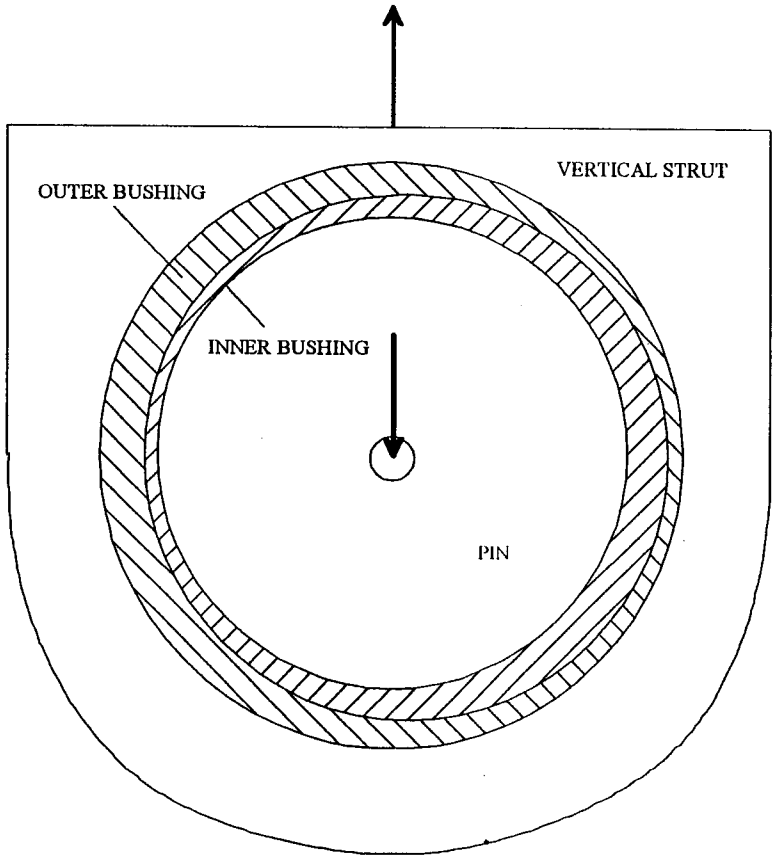
- Static Loading
  - Analysis conservatively neglects the following physical realities of the design
    - Bushing rotation requires BOTH sets of bushing to slide simultaneously by the same amount
      - Any non-uniform rotation between the bushing sets will effectively lock the strut in place
    - Local bushing deformation under static load
      - Deformation will bind the bushings together and prevent rotation

Implementation of One Piece Vertical Strut

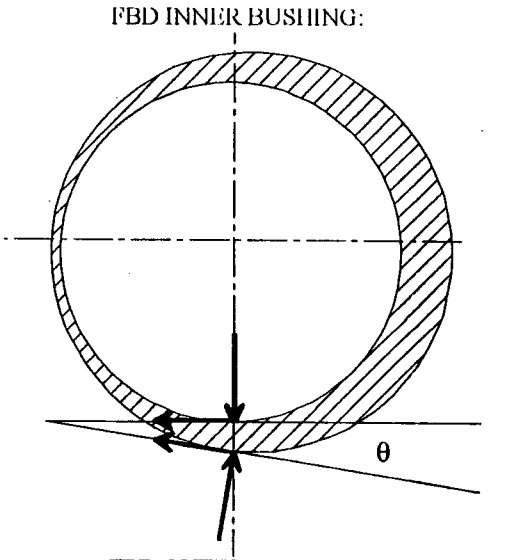
B02028

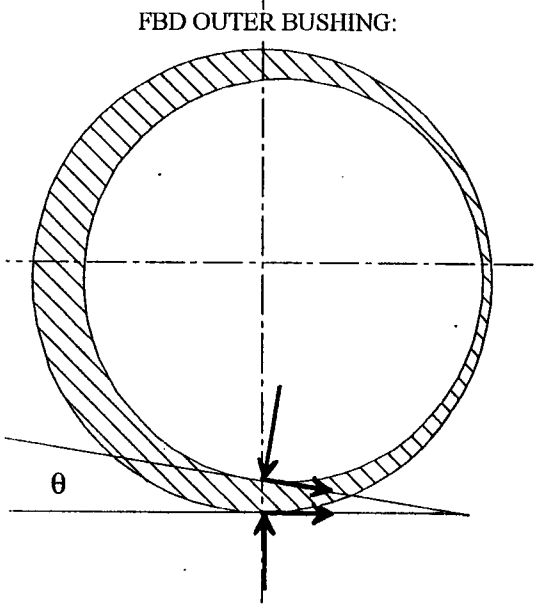
Basis of Certification - Bushing Mechanism

- Free Body Diagram of Pin and Bushings



NOTE: NOT TO SCALE



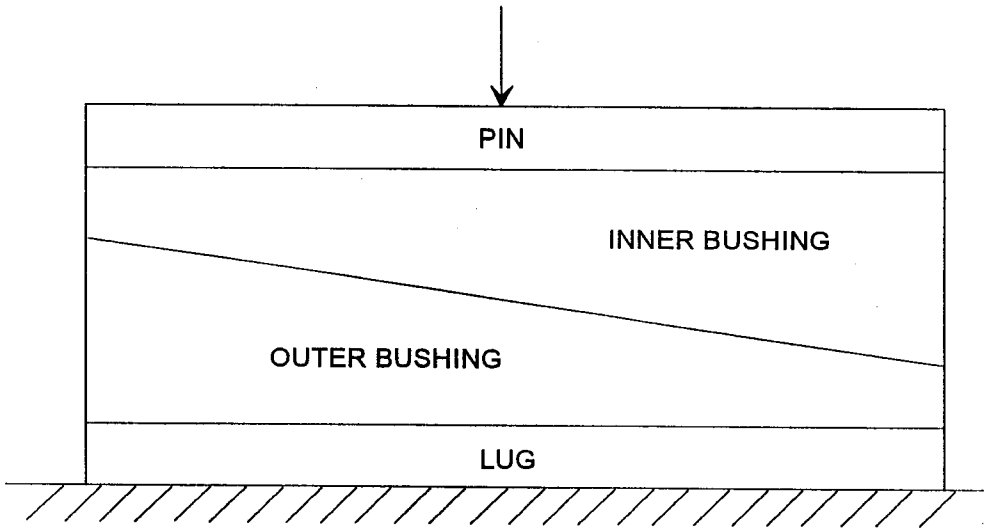


Implementation of One Piece Vertical Strut

B02028

Basis of Certification - Bushing Mechanism

- Bushing Surfaces 'unfolded' for analytical representation

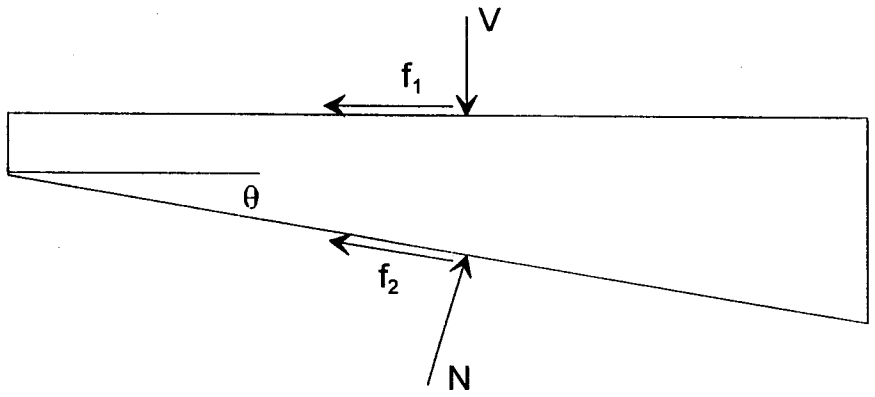


Assumptions :

$\sin(\theta) = \circ\theta$

$N := V$

since , $\cos(\theta) \equiv 1$ and, $N := V \cdot \cos(\theta)$



Frictional Forces > Sliding Forces

$f_1 + f_2 \cdot \cos(\theta) > N \cdot \sin(\theta)$

$\mu \cdot V + \mu \cdot V > V \cdot \sin(\theta)$

$2 \cdot \mu > \theta$

$2 \cdot \frac{\mu}{\theta} > 1$

106ΔPFR.4250.12/00

Implementation of One Piece Vertical Strut

B02028

Basis of Certification - Bushing Mechanism

- Contacted lubricant (Molykote G) manufacturer (Dow Corning) to obtain design minimum values for static coefficient of friction (COF)
  - Provided typical kinetic COF of 0.080 and lowest static COF value found in lab reports of 0.070
  - No guaranteed minimum values provided

- LM testing was performed to investigate the static COF of the lubricant on Inconel
  - Minimum static COF = 0.061

- LM test results are used in the analysis to show adequate 'Factor of Safety' against bushing rotation under static load
  - FS = 2.80 (minimum COF)

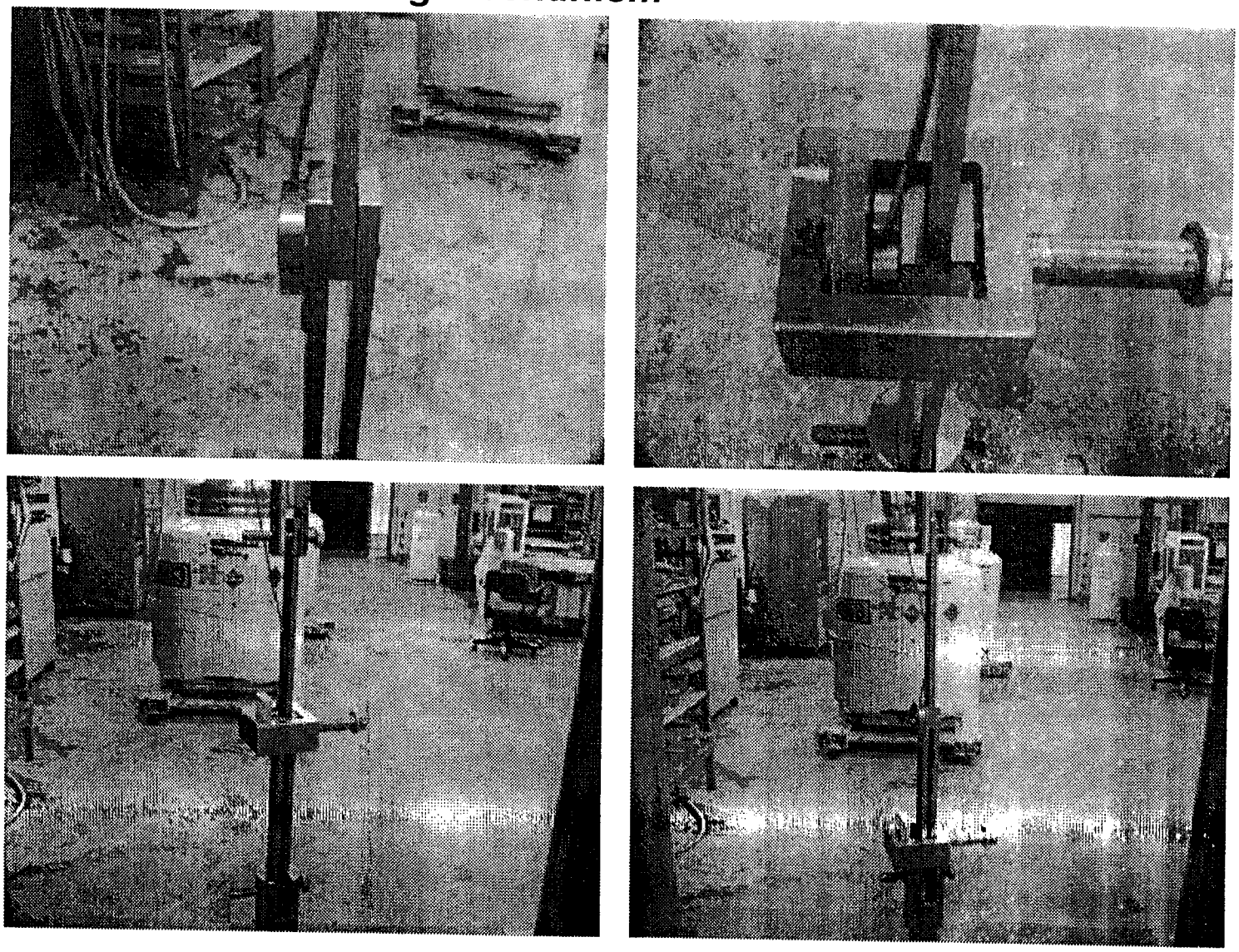
Molykote G Static Fricton Test Results

Test #	Specimen #	Bearing Pressure (psi)	N243A Can	Friction Force (lbs)	Static Friction, u
1	1	1000	A	129	0.065
2	2	1000	B	135	0.068
3	3	1000	C	150	0.075
4	1	2500	A	499	0.100
5	2	2500	B	451	0.090
6	3	2500	C	324	0.065
7	1	4400	A	663	0.075
8	2	4400	B	538	0.061
9	3	4400	C	838	0.095

Implementation of One Piece Vertical Strut

B02028

Basis of Certification - Bushing Mechanism



Implementation of One Piece Vertical Strut

B02028

Basis of Certification - Bushing Mechanism

Dynamic Loading

- Vertical strut is major structure and is not responsive to acoustic vibrations
  - However, random vibration environments defined in NASA RP1074 for Frame Xt 2058 were used conservatively to produce maximum strut 'vibration' loading of 5.5 kips due to assumed ET filling vibration
  - Vibration loading only effective as strut load reverses from compression to tension and thus experiences a 'zero' static load condition (i.e. no static normal load - no friction load)
  - Positive restraint pins provide necessary 'locking' feature to accommodate 'vibration' loading
- Analysis shows FS > 5.0 for pin shear using the conservatively calculated vibration loads and zero frictional resistance

Readiness Statement

The External Tank, ET-106, is hereby certified and ready for STS-98 flight pending completion/closure of open and planned work

Ronald W. Wetmore
Vice President, External Tank Project
Lockheed Martin Space Systems Company

LOCKHEED MARTIN

KSC Processing - Status

as of 01/03/2000

Changes

- ET modifications
  - Mod Kits 0
  - DC&R 0
  - Bldg 45 2
  - FEC 1
  - OMRSD/LCC 6
- Software 0

- Calibrate 10 AC30 Portable Aircraft Scales (2)
- Thrust panel foam venting
- Intertank Door Closeout (3) **
- LO2 Orbiter/ET Carrier Plate Purge Pressure **
- Tank Pressure Monitoring Requirements (2)

***** Process change first implemented/flown on STS-103/ET-101***

Agenda

Overview	Lynn Servay
Prior Mission Performance Summary	
Current Mission/External Tank Highlights	
Previously Presented Items	
• Intertank Foam IFA: ET-92 Thrust Panel Enhancements	
ET-92 Mass Properties Status	Rick Spring
Special Topics	
• Certification of ET-92 Weld Specifications	Don Bolstad
• Suspect Weld Rod on ET Hardware	
• LO2 Level Sensor Wire Contamination	Greg Daughdrill
SRM&QA Assessment	Terry McKeough
KSC Processing	Doug Powell
Verification/Certification	***Lynn Servay***
Readiness Statement	
Appendices	
• A: Minor Changes	
• B: SRM&QA Assessment	
• C: KSC Processing	
• D: Level II Waivers/Level III Deviations	
• E: Previously Presented Items	

92Δpfr.4250.ls.01/00

Verification/Certification

as of 01/03/2000

Item	Status
NSTS 07700, Volume X Baseline • Revision M, Change ***258***	No Issues
Certification documentation • Hardware Certification Sheets (HCS) • Certificates of Qualification (COQ)	Complete - No Issues
Waivers/Deviations	No new items

92Δpfr.4250.ls.01/00

Readiness Statement

The External Tank, ET-92, is hereby certified and ready for STS-99 flight pending completion/closure of open and planned work

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Terry L. Hibbard
Vice President, External Tank Project
Lockheed Martin Michoud Space Systems

92Δpfr.4250.ls.01/00

Appendices

A: Minor Changes

B: SRM&QA Assessment
- NCD Assessment Criteria

C: KSC Processing
- PR/MRB Summaries
- Modification Summaries/Status
- Limited Life Component Status
- Alternate Blowing Agent Usage at KSC
- Facility Modifications
- Software Changes: None
- OMRSD Exceptions/Waivers: None
- OMRSD Changes (RCNs)

D: Level II Waivers/Level III Deviations

E: Previously Presented Items

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 Configuration Changes

Change	Description	Basis for Certification
Deletion of ET Range Safety Systems (B02010)	▪ Added insert to install cable clamp on the Intertank Electrical installation not installed on lower assembly as required ▪ Shortened a screw length to accommodate clamp removal on the pneumatic tube installation by deletion of CDF	▪ Similarity - Insert installed to Standard Processes. Standard hardware used. ▪ Engineering Inspection - Deletion of RSS bracket called for shorter screw
B02022/J31158	▪ Implement 2219 Class II Extrusions on Frame 1871	▪ Materials Testing, Stress Analysis, Proof Tests

Minor Changes - Structural

Change No.	Description
H35809-868	Revised 25L13-8 grip length quantities and revised process specification to add STP2006 with note reference. Added rivet code XE = 25L1 and 25L6. Added view to locate XE8N-7 in place of XV8-7 and XE8N-3 in place of XV8-3 on stringer
H35809-878	Gaging per STP2014 added to drawing to reflect build process
H35809-820, 892, 894 & 896 H36809-024 & 027	Corrected drawings missing reference to STP2003, countersink and flushness requirements
H36809-016	Revised cross beam mechanical assembly to allow trimming of gussets to prevent interference
H36809-052	Revised Slosh Baffle Assembly to add note stating tooling holes are optional and may be omitted by manufacturing
H36809-078	Revise Cable Tray Support Installation to call out correct part number
H36809-084	Revised Cable Tray Cover drawing to include STP1002 and STP2501 requirements that were erroneously omitted from the drawing but correctly reflected in vendor build paper
H36809-086	Revised LO2 Tank Mechanical Assembly & Lug Weld drawing to include graphics inadvertently left out in a previous revision
H36809-092	Revised fastener type in LH2 Barrel #1 Frame Intermediate Frame Installation

Minor Changes – Propulsion/Mechanical

Change No.	Description
H36809-123	Revised Propellant Feed Installation drawing to correct the quantity of bolts called out. MPP reflected correct quantity.
H36809-154, -155	Added alternate rivet for use in Cable Tray Guide Rail Assemblies

Minor Changes - TPS

Change No.	Description
H35809-979	Revised note 4 on LO2 Tank Foam Application drawing to remove the plug pull core height requirement. Core height is specified in Operations Procedure OP-13M50-FT and also accounts for foam rind removal at .75 inch min. thickness where drawing does not.
H35809-982	Delete note in drawing requiring Barry Mount caps as matched pairs after ablator application. MPPs now require match pair traceability prior to ablator application.
H36809-022	Clarify ablator closeout requirements on LO2 umbilical cable tray TPS application component build to eliminate interference at installation.
H36809-076	Revised drawing to specify part identification using standard ink stamping instead of marking with stencil; stamping is current standard method used on TPS parts. Also removed dimension associated with deleted top coat application.
H36809-111	Revised views on Intertank foam application drawing to include local foam trims and dimensions aft of the Intertank GH2 umbilical vent attachments to allow clearance for Launch Pad GSE
H36809-135	Added missing dimensions for foam closeout trims on the LO2 feedline flanges that were inadvertently removed by previous change.
H50001-797	Revised crossbeam assembly TPS Application to delete redundant dimensions and added future closeout notation to ablator trim bond lines.

Minor Changes - TPS

Change No.	Description
H50001-798	Revised Intertank press line foam aero ramp application to allow aero ramp mold seal PDL to remain on acreage NCFI 24-124 surface; added note that allows for configuration that may vary for ICD foam trim on thrust panel; revised views to adjust nominal foam thickness and minimum foam thickness with actual spray targets used.
H50001-805	Added foam migration allowance to aft SRB fittings into the crevices of adjacent acreage foam.

Minor Changes - Electrical

Change No.	Description
H36809-013	Revised clamp sizes to reflect the actual callout on recording table of MPP

Minor Changes - Systems

Change No.	Description
B02046-001, 005, & 006	ET Weighing Requirements changes to support ET weighing capability at MAF; parallel weighing activity in work to verify MAF process
H36809-075	Revised Load Case H deflections in LH2 Tank Proof test requirements.
H36809-079	Revised weld acceptance manual to add ET allowable structural contour deviations for TPS.
H36809-089	Revised peaking and mismatch of O3, O4, H1 and H8 welds to reflect constraints due to Class I extrusion allowables; revised post-proof inspection requirements.
H36809-090	Revised LH2 Post Proof Test Requirements to, section 3.3 to call out STMY320 for Nitrogen gas used for proof testing; requirements not changed.

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-92 DR/PR/OMRSD Waiver/Exceptions

as of 01/03/2000 **

System	Discrepancy	Problem	MRB Items	Exceptions/ Waivers
• Electrical	0	1	0	0
• Propulsion/ Pneumatics	0	5	0	0
• Structures	0	7	1	0
• Thermal (TPS)	0	7	2	0
Total	0	20	3	0

*** Updated to include new items since last presented*

92Δpfr.4250.ls.01/00

ET-92 PR/MRBs

PR No./Status	Title/Description	Disposition
PET-92-TS-0004 Item 1	Underfill at +Z end of the -Yaft fairing lower periphery closeout	• Repair with PDL-1034 • Additional bondlines will not affect closeout peformance
PET-92-TS-0004 Item 2	Ramp missing from forward periphery closeout	• Repair with PDL-1034 • Additional bondlines will not affect closeout peformance
PET-92-ST-0005*	***ET/SRB crossover fairing to gimbal housing vent gaps below drawing minimum***	• ***Analysis shows adequate vent area remains*** • ***Not a debris concern***
PET-92-TS-0006*	***35 areas of bird damage on LO2 ogive***	• ***Use-as-repaired*** • ***Remove loose material and apply topcoat***

*** New items since last presented*

92Δpfr.4250.ls.01/00

ET-92 KSC Modification Summary/Status

Modification No.	Description	Status
FEC KET-0053	Intertank Thrust Panel Foam Venting	Complete

ET-92 Limited Life Components

Cycle Sensitive

Description	Part No.	Serial No.	Limit	Required	Remaining
LH2 Manhole Cover Assy	80914081488 -019	0000737290	100	2	100
LO2 Tank Mechanical Assy	80912002000 -019	0000748780	100	2	100
LH2 Tank Proof Test	80914002000 -019	0000749310	100	2	100
LO2 Manhole Cover Assy	80911001205 -010	0000781680	100	2	100
LO2 Fwd Ogive Cover Plate	80911001207 -029	0000763550	100	2	100
LH2 Manhole Cover Assy -Aft	80911001444 -010	0000727160 0000768950	100	2	100

ET-92 Limited Life Components

Age Sensitive

Description	Part No.	Serial No.	Limit	Initiation	Expiration
External Tank	80901000000 -289	00000085	6 Yrs	4/99	4/2005

ET-92 Limited Life Components

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	0001149	02/24/1998	01/2002
Cartridge Assy	PD5000020-030	AAH	0001304	02/24/1998	01/2002
Cartridge Assy	PD5000020-030	AAH	0001305	02/24/1998	01/2002

ET-92 Alternate Blowing Agent Usage at KSC

Foam	Document	Description	Location	Size
SS-1171	T5141	Aft Hardpoint Closeout	Xt 1973-2076, 180 degrees	4410 sq. in.
PDL-1034	T5249	ET/SRB Aft Fairing Closeout	Xt 2058, 70/290 degrees	240 sq. in.
PDL-1034	T5244	ET/ORB Jack Pad Closeout	Xt 1129, 15/345 degrees	9 sq. in.

STS-99 Facility Modifications

ESR 0.2729 ET/Intertank Heater Installation

- Existing ET intertank heaters were replaced with new Chromalox 100 kw heaters
  - Heater installation and system validation completed

Level II Waivers - Baseline

Document / Requirement	Authority	Paragraph	Waiver No.	Effectivity
NSTS 07700 Vol V – Information Management Requirements				
Generic part name, type, common designation, and part manufacturer H4 code are not required for EEE parts status print out	S00127B 6/28/88	Table C.5 Item 2SR-10	6	ETs 49 & up
Data required in limited life status report is supplied in acceptance data package	S00127B 6/28/88	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	S00127B 6/28/88	Table C.6 Item 2SR-7	10	ETs 49 & up

Level II Waivers - Baseline

Document / Requirement	Authority	Paragraph	Waiver No.	Effectivity
NSTS 07700 Vol X – Space Shuttle Flight and Ground System Specification, Book 1 Requirements				
Electrical wiring of redundant systems NSTS 08080-1, 20A/4B	S040732G 6/18/88	Table 2.0	362	ETs 23, 27-29, 31 & up
Soldering, circuit boards, and connectors	S040732M 9/9/88	3.6.15.1.1	379	ETs 23, 27-29, 31 & up
PD7400106 circuit boards	S040732M 9/9/88	3.6.15.2.1	382	ETs 23, 27-29, 31 & up
Pressure transducer circuit boards	S040732M 9/9/88	3.6.15.2.1	383	ETs 23, 27-29, 31 & up

Level II Waivers - Baseline

Document / Requirement	Authority	Paragraph	Waiver No.	Effectivity
NSTS 07700 Vol X – Space Shuttle Flight and Ground System Specification, Book 1 Requirements				
Debris prevention	S082962A 10/2/98	3.2.1.2.14	675	ETs 92, 97-105
NSTS 07700-10-MVP-01– Shuttle Master Verification Plan				
Environmental acceptance of ET components	S002130H 3/7/89	3.7.1	13	ETs 23, 27-29, 31 & up
NSTS 08123 Certification of Flexible Hoses and Bellows				
LH2 feedline bellows	S005203G-R1 8/2/91	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	S40732K 9/27/89	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 GUCP leg	S87020L 8/17/88	3.4.2.1	21	ETs 23, 27-29, 31 & up

Level III Deviations

Document / Requirement	Paragraph	Waiver No.	Effectivity
CPTO1M09A, External Tank Contract End Item Specification			
• 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	3.2.5	233	ETs 92, 97-99, 101-105

Appendix E: Previously Presented Items

Items Presented at STS-99/ET-92 Pre-Flight Review

- Significant Process & Configuration Changes
  - Performance Enhancement (PE) High Q Loads Implementation
  - Implementation of LH2 Common Proof Test
  - LH2 Tank Changes to Accommodate SSME Block II Implementation
    - *GH2 vent/relief valve with revised acceptance flown on STS-103/ET-101*
  - LH2 Tank Siphon Screen Installation Hardware Changes
  - LWT Intertank Thrust Panel Structural Change
  - Intertank Thrust Panel Foam Venting
- Class II Process Changes

Items Presented at STS-103/ET-101 Pre-Flight Review

- STS-99/ET-92 Pre-Flight Review Action Item
  - Criteria for Critical Process and Critical Process Change Control

Performance Enhancement High Q Loads Implementation

B02034

Change:

- Certified LWT for Performance Enhancement (PE) High Q loads and updated LH2 operational ullage pressure requirements

Background:

- High Q trajectories are part of an overall performance enhancement for ISS missions
- SLWT was designed for PE High Q trajectories
  - Three SLWTs flown with PE High Q trajectories
- PE induced environments were implemented for LWT
  - LWT algorithms were updated to reflect the PE loads

Performance Enhancement High Q Loads Implementation

B02034

Discussion:

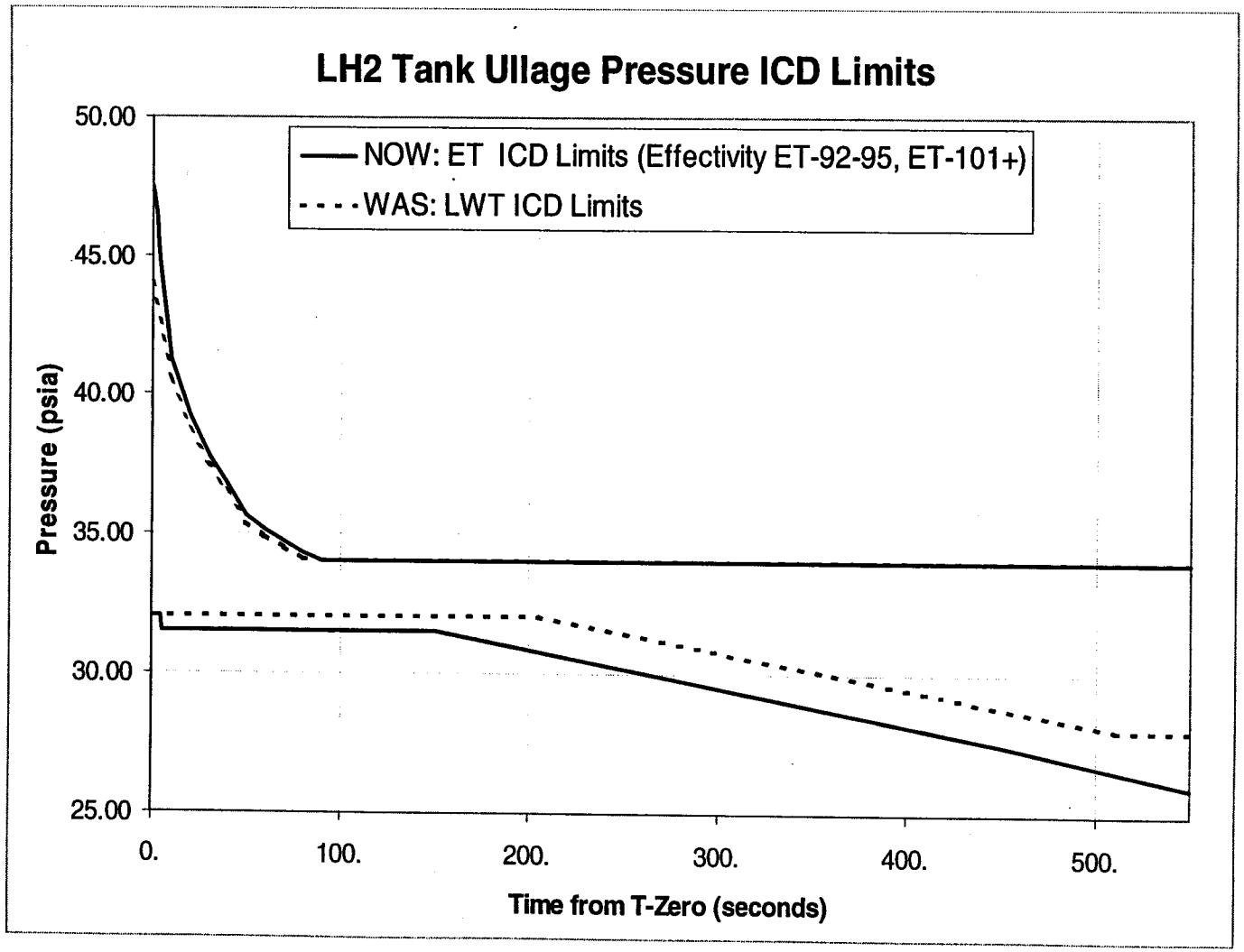
- Implementation of PE High Q loads required additional post proof inspections
  - Additional 1,791 inches of post proof weld x-ray on LH2 Tank circumferential welds
  - Additional 450 inches of post proof weld x-ray on LO2 Tank circumferential welds

- LH2 Proof Test enhanced to adequately proof more welds and mitigate post proof NDE requirements
  - Additional 1,791 inches of post proof weld x-ray inspection was reduced to 249 inches with modified proof test

- Changes in LH2 Proof Test led to implementation of a Common LH2 Proof Test for ET Program
  - Common set of post High Q loads supplied by Level II
    - Approved by PRCBD S052158BA on 8/21/98
  - Common LH2 ullage pressure ICD supplied by Level II
    - Approved by PRCBD S060604P on 8/25/98

Performance Enhancement High Q Loads Implementation

B02034



Performance Enhancement High Q Loads Implementation

B02034

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
    - 249 inches of additional weld inspected
  - Successful completion LO2 Tank proof test and post proof inspection
    - 450 inches of additional weld inspected
- Analysis
  - Structural analysis shows overall critical factor of safety unchanged
    - Factor of Safety for critical circumferential welds (failure mode: ultimate tension)

				Proof Test Demonstrated	
Weld ID	***Required***	***Was***	***Now***	***Was***	***Now***
LH2 Tank HAF	1.31	1.49	1.49	1.13	1.19
LH2 Tank H7	1.32	1.82	1.74	1.28	1.32

LH2 Tank Changes for SSME Block II Implementation

B02034

Change:

- Increased Pre-Launch ullage pressure requirement to accommodate future SSME Block II implementation
  - Revised LCC for LH2 Tank pre-launch ullage pressure and ICD for ullage pressure during flight

Background:

- Advanced high pressure fuel turbopump in the Block II SSME has increased preburner temperature spikes during engine start transient, causing reduced turbine blade life
  - PSIG action resulted in decision to modify the Block II Start Transient by increasing the LH2 inlet pressure at engine start command
  - Required modification of the ET pre-pressurization control bands and LH2 ullage pressure ICD
- Raised pre-pressurization control band will be used only on flights with three Block II SSMEs
  - Not required for STS-99/ET-92
  - First flight of three Block II SSMEs TBD (NET 2000)

LH2 Tank Changes for SSME Block II Implementation

B02034

Description:

- Revised LH2 Tank ullage pressure LCC limits during pre-pressurization
  - The new Block II SSME limits will not be used for STS-99/ET-92

LH2 Tank Pressure Limit Change for Block II SSMEs

	Time (sec)	Maximum Pressure Limit		Minimum Pressure Limit	
		WAS (psia)	NOW (psia)	WAS (psia)	NOW (psia)
Pre-Launch (LCC):		44.1	48.9	40.9	46.1
Flight (ICD):	0	44.0	47.5	:	:
	1	43.7	47.3		
	2	43.3	46.4		
	3	43	45.4		
	4	42.6	44.8		
	10	40.5	41.25		
	:	:	:		

LH2 Tank Changes for SSME Block II Implementation

B02034

Description (continued):

- ET GH2 vent/relief valve requirements revised for higher pre-press level
  - No design change required
  - Reseat Pressure
    - ***Was:*** 34.0 psig minimum
    - ***Now:*** 34.25 psig minimum
  - Acceptance test instrumentation and requirements revised

LH2 Tank Changes for SSME Block II Implementation

B02034

Basis for Certification:

- Test
  - No change to critical test demonstrated LH2 Tank factor of safety
  - Raised LH2 Tank pre-press band was demonstrated on STS-91 Tanking Test
    - Narrow band with 0.5 second GHe bursts was demonstrated
    - Pre-press level demonstrated was 0.3 psi lower than planned for use with three Block II SSMEs
      - Changes to GH2 Vent/Relief Valve acceptance not implemented on STS-91/ ET-96
- Analysis
  - Stress analysis shows no change in critical factor of safety
  - Propulsion analysis shows LH2 Tank ullage pressure will be within LCC limits during pre-press

LH2 Tank Siphon Screen Installation Hardware Changes

B02038

Change:

- Modified hardware for the LH2 Tank siphon screen installation
  - Replaced gang nut channels with new standard dome gang nut channels
  - Replaced cadmium plated bolts/screws with passivated A286 bolts/screws

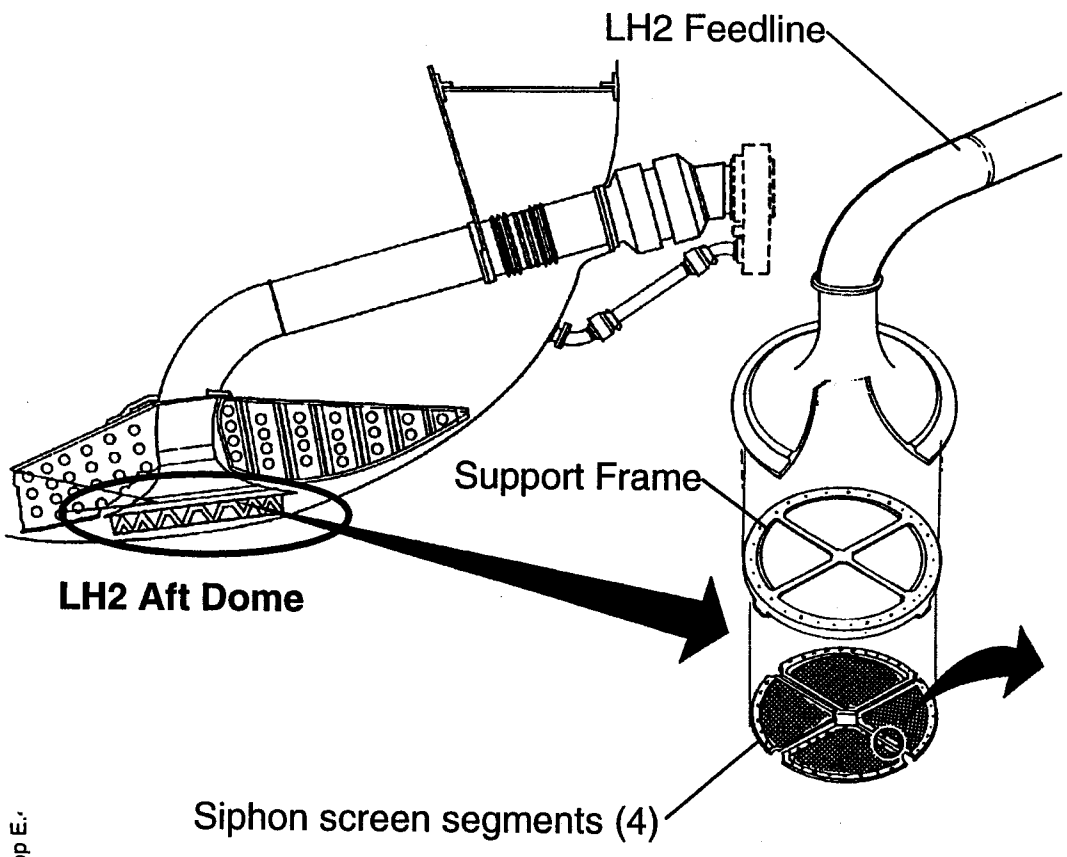
Background:

- Inspection of ET-99 LH2 internal siphon feedline screen installation identified particles (greater than 400 microns) on downstream side of screens
- Review conducted of process flow for LH2 aft dome for potential source of contamination
  - Contamination found to be created during installation of LH2 screens onto the gang nut channel on the siphon support frame
- Particles collected and submitted for laboratory analysis
  - Material collected determined to be from screen bolt/nutplate installation and removal process

LH2 Tank Siphon Screen Installation Hardware Changes

B02038

Description:



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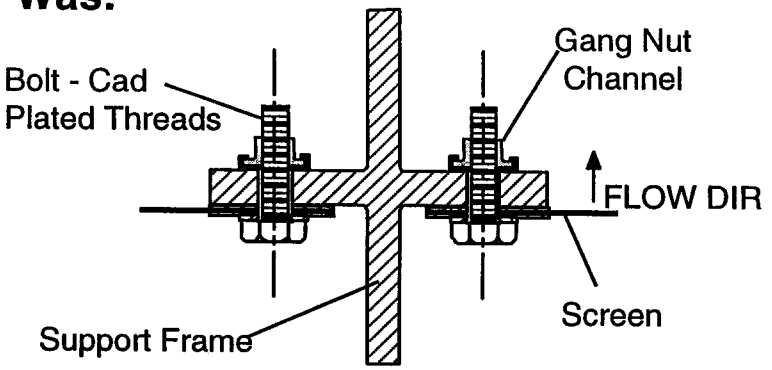

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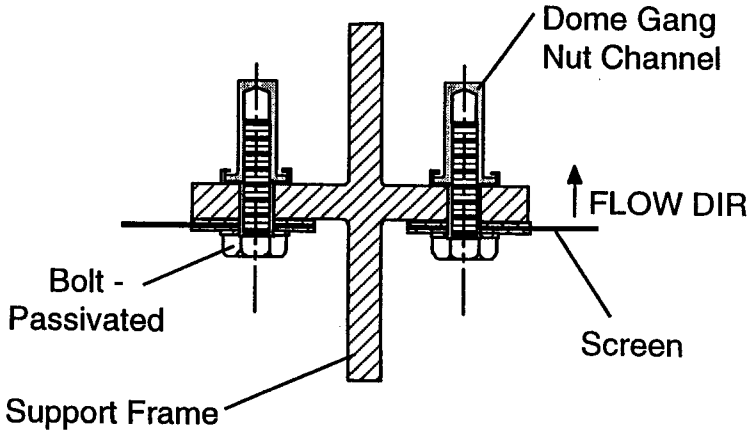


LH2 Tank Siphon Screen Installation Hardware Changes

B02038

Basis for Certification:

- Similarity
  - Addition of passivated bolts/dome nuts does not affect the capability or function of the siphon screen assembly
    - Passivated bolts eliminate a potential source of contamination
    - Dome nuts on siphon screen assembly capture potential contamination from the bolts on the downstream side of the siphon screen

LWT Intertank Thrust Panel Structural Change

B02039

Change:

- LWT Intertank thrust panel structure modified to add stiffeners

Background:

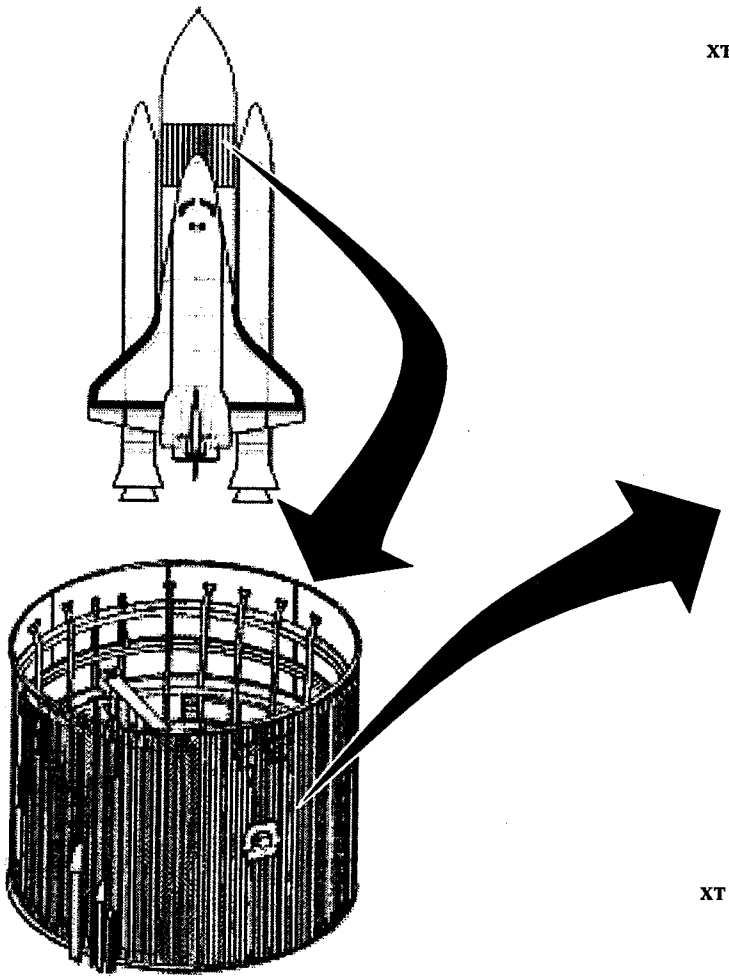
- Intertank thrust panel flexure was initially believed to be a contributor to thrust panel foam loss
  - Internal stiffeners were identified as a design change to decrease thrust panel flexure

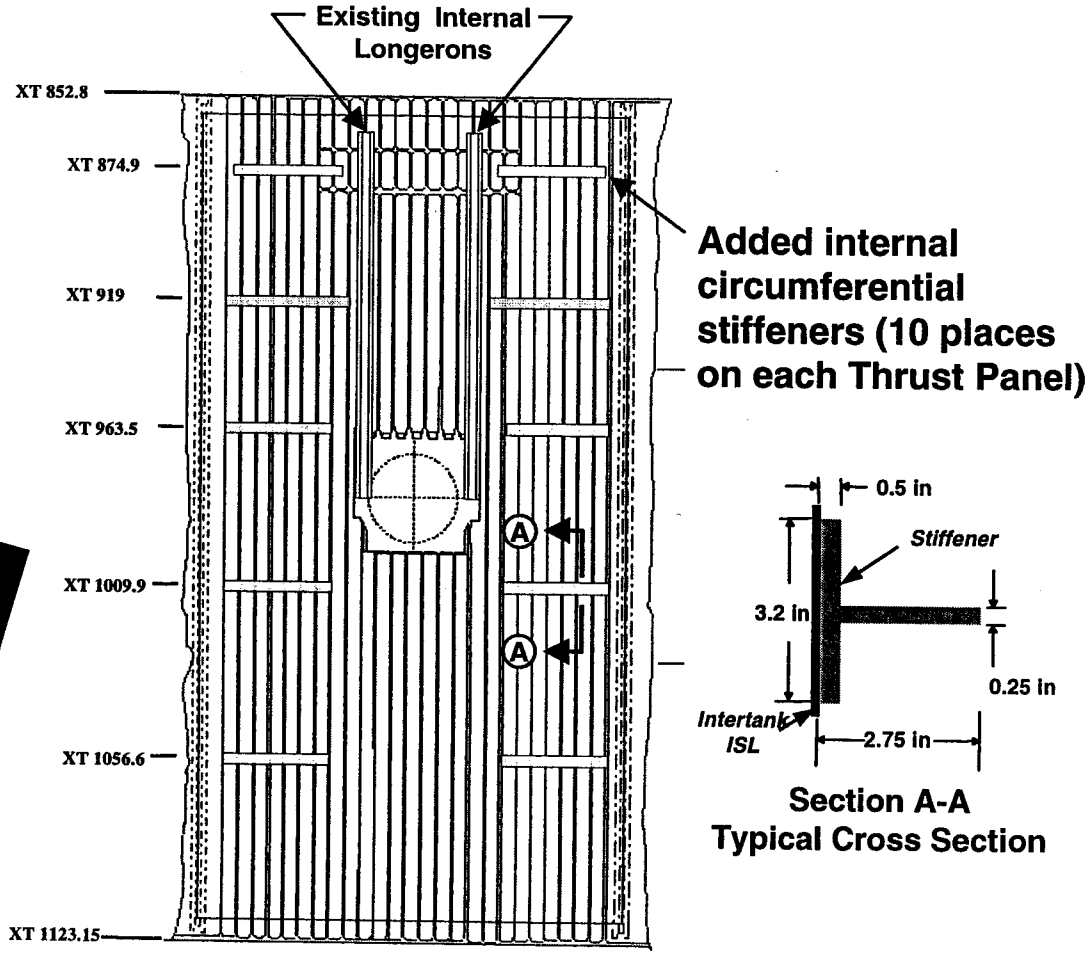
Description:

- Ten circumferential Al 7075 stiffeners added to each Intertank thrust panel
  - Located on inside of Intertank
  - Installed with Hi-Lok fasteners
  - Stiffener material same as used for Station 985 outer chord extrusions

LWT Intertank Thrust Panel Structural Change

B02039





LWT Intertank Thrust Panel

Intertank Thrust Panel Foam Venting

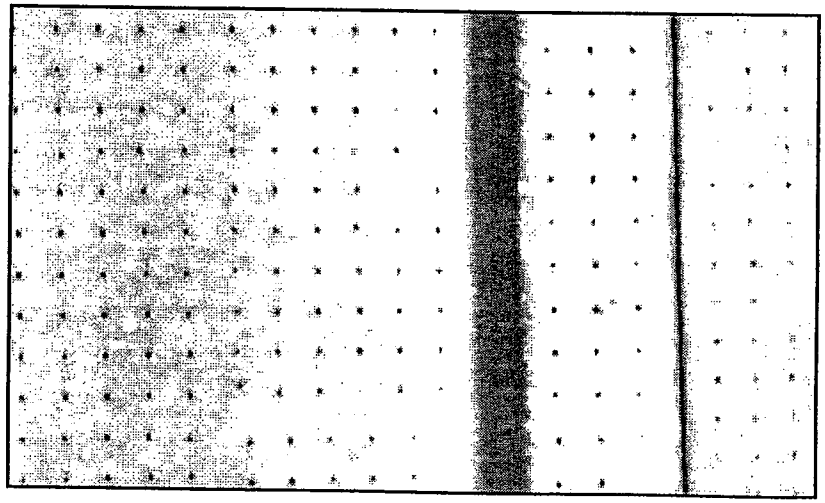
FEC KET-0053

Change:

- Vent portions of the Intertank thrust panel foam
  - 0.032" diameter pin holes will be spaced 0.30" apart

Background:

- Post flight inspection of STS-87 revealed out-of-family damage to the Orbiter tiles caused by foam loss from the ET Intertank thrust panel
- A rigorous test program has demonstrated the potential for vented foam to reduce popcorn-type debris
- Vented foam configuration has been certified by test and analysis to do no harm
- Venting of Intertank foam implemented on STS-96/ET-100 and STS-93/ET-99
- Review of SRB video following May 27, 1999 flight of STS-96/ET-100 confirmed performance enhancement realized through foam venting
- Based upon STS-96/ET-100 data and additional analysis, areas of Intertank thrust panel vented on STS-93/ET-99 was increased
  - Review of STS-93/ET-99 SRB video confirmed performance enhancement through venting



Typical Vented Foam Configuration

Intertank Thrust Panel Foam Venting

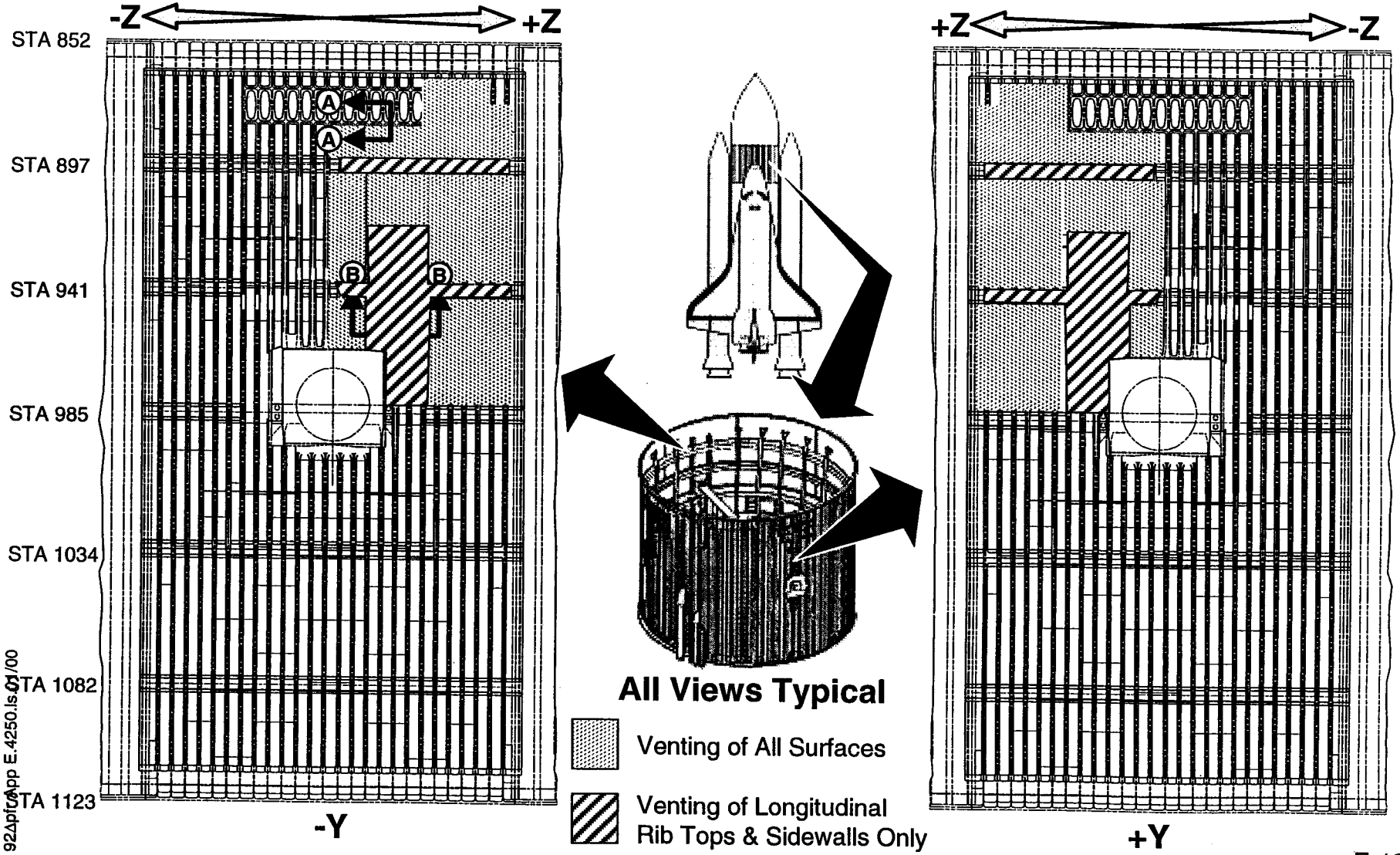
FEC KET-0053

Description:

- Foam selected for venting on STS-99/ET-92 based upon the following criteria:
  - Foam configuration demonstrated by test to do no harm
    - Longitudinal ribs and valleys with foam thickness between 0.2" and 0.9"
  - Foam located within Intertank thrust panel zone identified by Integration/BNA as having the potential to generate debris that can contact/damage the Orbiter lower surface
  - Areas that could result in foam/vent tool damage during the venting process (i.e., foam areas with fasteners or other protuberances)
  - Foam not located in a cryogenic region of the thrust panel
- Areas fulfilling these criteria cover the majority of the forward +Z quadrant of each Intertank thrust panel

Intertank Thrust Panel Foam Venting

FEC KET-0053



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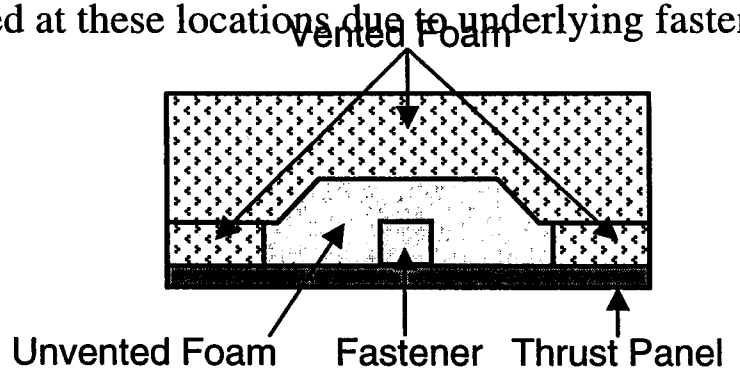
Intertank Thrust Panel Foam Venting

FEC KET-0053

Description (continued):

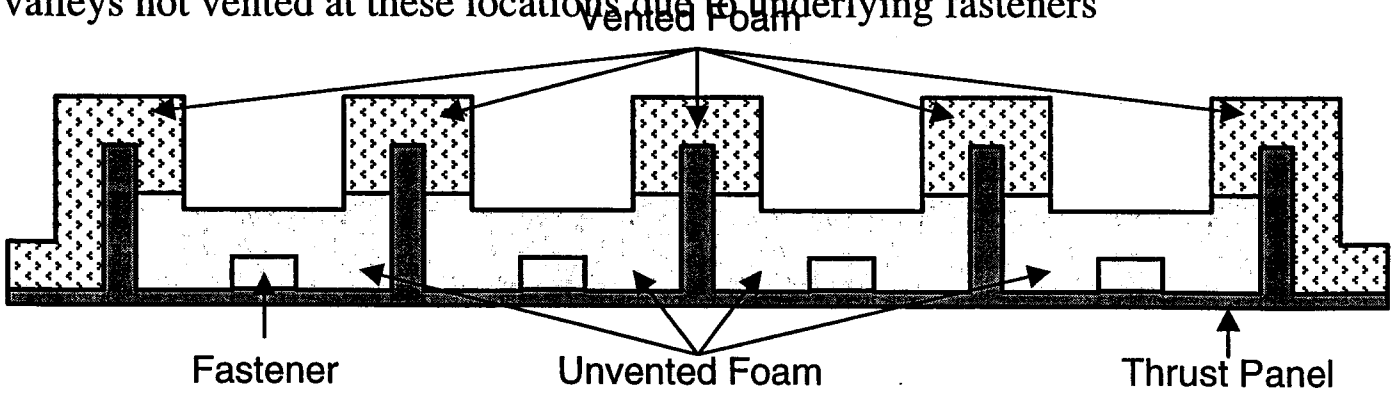
Section A-A (Typical Fastener Ramp)

- Rib valleys not vented at these locations due to underlying fasteners



Section B-B (Typical 1.05" Thick Valleys)

Rib valleys not vented at these locations due to underlying fasteners



Intertank Thrust Panel Foam Venting

FEC KET-0053

Basis for Certification:

- Test
  - Tests performed in different test beds following various environmental conditioning
  - Results from all performance testing show that vented foam performs as well as or better than the non-vented foam configuration and measurably reduces foam loss
- Similarity
  - Vented foam configuration similar to configuration flown on STS-96/ET-100 and STS-93/ET-99

Certification Test	No. of Tests	Humidity	Salt Fog	Vented
Vented Foam Certification Testing				
Mechanical Properties/Acceptance Testing				
Density	200			X
Bond Tension	540	X	X	X
Flatwise Tension	540	X	X	X
Lap Shear	360	X		X
Plug Pulls	144		X	X
Flexure (Ribbed panels)	24	X		X
Thermal Properties				
Thermal Conductivity	24	X	X	X
Flight Verification				
Hot Gas - Flat Panels, Machined foam	20	X	X	X
Hot Gas - Rib Panels, Machined foam	63	X	X	X
Thermal/Vacuum, Flat Panels, Machined foam	40	X	X	X
Thermal/Vacuum, Single Rib Panels, Machined foam	14			X
Thermal/Vacuum, Rib Panels, Machined foam	24	X	X	X
Wind Tunnel (AEDC), Machined foam	4			X
Vibro/Acoustic Test (DOE C Addendum Testing)	6	X		X
Process Verification/Acceptance				
Full-Scale Process Pathfinder (GVTA)	1			X

Class II Process Changes

H35809-967

Change Description:

- Changed ablator process from sprayed ablator to molded ablator on the +Y Vertical Strut Cable Tray splice cover at LH2 Dog Leg Cable Tray

Reason for Change:

- Change to molded ablator process allows testing on witness panel and eliminates repair of test area
  - Repair covered ~ 50% of the component

Basis for Certification:

- Similarity
  - Several ET parts of comparable size have flown with molded ablator

Aft Interface Crossbeam
LH2/LO2 Cable Tray Gap Closures
Aft Interface Press Line Guide Rails
GHe Inject Box Enclosure Cover
LH2 Umbilical Cable Tray Supports
Left/Right SRB Cable Tray Gap Cover
GO2/GH2 Press Line Barry Mounts

Class II Process Changes

H35809-973 through -976

Change Description:

- Added 8 hour minimum adhesive cure requirement to drawings where closeouts have greater thickness requirements
  - Previously required 2 hour minimum cure time for these parts
  - Parts include:

LH2/Intertank Flange Closeout	Bipod Ramps
LO2/Intertank Flange Closeout	LH2 Elect. Feedthru
LO2, LH2 & SRB PAL Ramps	Vertical Strut Closeout

Reason for Change:

- The longer cure time prevents foam debond at bond line

Basis for Certification:

- Test
  - Material development test program included extended cure times
- Demonstration
  - Experience showed longer cure time provided better product for thicker closeout
    - Longer cure time has been standard practice
    - Change documents practice in engineering drawings

Class II Process Changes

H35809-985

Change Description:

- For manual foam spray application process on the LO2 Dome, added application of BX-250 per STP1503 as an alternative to application of SS1171 per STP1536

Reason for Change:

- Use of BX-250 reduced non-conformance and rework activities

Basis for Certification:

- Similarity
  - BX-250 application per STP1503 used prior to the implementation of HCFC-141B foams

Class II Process Changes

H36809-202 / STP6514

Change Description:

- Revised Process for wire bonding to LH2 interior to:
  - Reference STP5011 for cleaning wires and STP5013 Method 3 for substrates
  - Remove Freon PCA from list of materials and associated specific cleaning instructions
    - Isopropyl Alcohol (IPA) will be used instead of Freon PCA

Reason for Change:

- Standardization initiative for MAF specifications to call out cleaning per another specification rather than each specification including cleaning instructions
- Removed Freon PCA in an effort to minimize/eliminate use of chemicals that cause ozone depletion

Basis for Certification:

- Test
  - IPA was qualified in test program to be an acceptable replacement for Freon PCA
    - Equivalent removal efficiency of flushing oils, cutting fluids, and tape residue
    - Material compatibility studies identified no issues

Class II Process Changes

H35809-991, H35809-953, H36809-036

Change Description:

- Change weld process from VPPA to TIG on the following assemblies:
  - LO2 Dome Cap
  - LH2 Forward Dome Cap
  - LH2 Barrel Panel Welds on Barrels 2, 3 & 4

Reason for Change:

- Production has experienced better results with TIG than VPPA in the downhand weld orientation used for these welds

Basis for Certification:

- Similarity
  - TIG used on prior LWT builds
- Test
  - Weld certification performed prior to weld on production tooling
    - All Post-DD250 WIC / certification issues for ET-92 have been resolved

STS-99/ET-92 Pre-Flight Review Action Item

Action Item

- Develop and document criteria for critical processes and present how critical process changes are controlled

Response

- Definition of critical processes is documented in NSTS 5300.4 (1D-2)
  - A material process (I.e., a process which changes the chemical/ physical properties of a material) which could have a significant performance effect on hardware identified on the CIL (Critical Items List), hardware designated for fracture control and ordnance, and where design conformance cannot be assured by inspection.

STS-99/ET-92 Pre-Flight Review Action Item

Response

- External Tank critical processes are consistent with critical process definition in NSTS 5300.4
  - Forming & Fabrication of Metals
  - Forming & Fabrication of Non-metals
  - Fasteners
  - Non-Destructive Evaluation
  - Finishes
  - Testing
  - Lubrication
  - Identification & Packaging
  - Cleaning & Contamination Control
  - Welding, Brazing & Soldering
  - Adhesive/Bonding
  - Electrical and Electronic Fabrication
  - Sealing & Potting
  - Composites
  - Heat Treat
- Adequate controls in place to ensure adequate review and control of process changes
- MAF processes
- Supplier processes
- Facilities and tooling processes

STS-99/ET-92 Pre-Flight Review Action Item

Process Change Control

- Current change system used for changes in process requirements is same system used for preparation/review/release of all engineering changes

  - Process changes initiated by Technical Operations/Material Sciences
    - Initiated as a result of in-house/supplier liaison calls, NASA direction, industry developments, etc.
  - Proposed process change is prepared/reviewed by appropriate MAF disciplines
    - Procurement (coordinates with Suppliers)
    - Production Operations
    - Environmental/Facilities
    - Quality/Safety
    - Technical Operations
    - Contracts
  - Change release
    - Contracts verifies authority for release, ensuring contract compliance
    - Release of engineering change concurrent with manufacturing process change
    - Released change forwarded to NASA Materials, Processes, and Manufacturing
  - Process changes are included in readiness review process
    - Not ET specific - Change is briefed prior to a potential effectivity

STS-99/ET-92 Pre-Flight Review Action Item

Supplier Process Change Control (Flowed Down to Supplier)

- Following process revision, Procurement Quality reviews specification to determine if changes are mandatory for Supplier
- If mandatory, Materiel Operations (Buyer) directs Supplier to incorporate change
  - Supplier incorporates change and provides modified Process Instruction (PI) to Procurement Quality Control Field Representative for review
    - Critical processes and PI violating LMMSS process requirements are routed to Buyer via Documentation Acceptance Sheet (DAS)
      - Processes meeting LMMSS process requirements can be approved by Field Representative
    - Buyer routes DAS/PI for review
      - Product Technical Support
      - Material Sciences
      - Systems Engineering
      - Procurement Quality
    - If adequate, approved DAS/PI is routed back to supplier along with validation/re-validation requirements

STS-99/ET-92 Pre-Flight Review Action Item

Supplier Process Change Control (Flow Up from Supplier)

- If Supplier desires to change PI, Supplier provides a modified PI to Procurement Quality Control Field Representative for review
  - Field Representative coordinates with MAF Procurement Quality to determine appropriate action
    - Activities similar to Process Requirements Flow Down
      - e.g. DAS, validation/revalidation requirements, etc.
- Other process changes (i.e. those which would not necessarily involve a PI change) are required to be coordinated through LMMSS
  - LMMSS reviews changes for adequacy and provides validation/revalidation requirements
- For "sixth-buy" procurement, Suppliers are required to provide/maintain Process Flow Charts
  - Process Flow Charts illustrate the sequence in which PI are used at Supplier
  - LMMSS reviews changes for adequacy

STS-99/ET-92 Pre-Flight Review Action Item

Facilities & Tooling (associated with ET manufacture) Change Control

- Operational Readiness Reviews are conducted to review facilities and tooling changes
- Mission Success/Safety reviews scope of change to identify what type of Operational Readiness Inspection (ORI) is warranted
  - ORI verifies readiness of flight article, Facilities, Tooling, procedures, and personnel to perform specified operations
  - ORI attendees include NASA representatives
- Facilities and tooling changes associated with major ET design changes are presented and reviewed in the readiness reviews

STS-99/ET-92 Pre-Flight Review Action Item

Summary

LMMSS change control management systems encompass supplier, sub-tier, and on-site operations and provide end-to-end oversight

- Process changes are evaluated and reviewed to ensure successful implementation

LMMSS systems and management practices are designed to ensure that no unplanned changes occur

Process changes included in this readiness review are not ET specific

- Change is briefed prior to a potential effectivity

FLIGHT READINESS STATEMENT
STS-99/ET-92
EXTERNAL TANK PROJECT
2nd DELTA PRE-FLIGHT REVIEW

EXTERNAL TANK ET-92/STS-99, AS IDENTIFIED IN THE EXTERNAL TANK PROJECT 2nd DELTA PRE-FLIGHT REVIEW DATED JANUARY 26, 2000, IS CONSIDERED READY TO SUPPORT FLIGHT UPON ACCEPTABLE DISPOSITION OF OPEN/PLANNED WORK AND/OR OPEN ACTIONS.

J. L. LUSK/MP31

A. A. McCOOL/MP01

for J. BULLMAN/ED10

D. L. DUMBACHER/ED20

for A. F. WHITAKER/ED30

D. A. KROSS/ED40

for A. O. GOODSON/QS01

P. K. McCONNAUGHEY/TD01

P. V. COUNTS/MP31, CHAIRMAN

January 26, 2000

Space Shuttle
External Tank

STS-99/ET-92 Delta Pre-Flight Review #2

92Δpfr2.4250.ls.01/00

Agenda

Changes on ET-92

- ***Revised ET EIS Screw Thread Requirements*** — ***J. Hart***

Special Topic for ET-92

- Contaminated Argon Gas for ET-92 Welds — D. Bolstad

92Δpfr2.4250.ls.01/00

Revised ET EIS Screw Thread Requirements

B81524

Change

- Change to the External Tank End Item Specification (EIS) was submitted to allow the use of NAS1351N and NAS1352N fasteners
  - NAS1351 and NAS1352 use UNR thread form
  - "N" designates A-286 CRES with 160 ksi minimum

Discussion

- UNR thread forms may be used for fastener material strength at or above 160 ksi only when specifically approved by the element project
  - Specified in NSTS 07700, Volume X, 3.6.17.3
- UNJ unified thread form is typically used in the aerospace industry for the higher fastener material strengths because the geometry provides higher fatigue life
- NAS1351 and NAS1352 fasteners have UNR unified thread forms and are socket head cap screws with unique features essential for some ET applications
  - Smaller head than either hex head or 12 point head fasteners
  - Internal wrenching capability
  - Extra long threads
- Several joints on the ET use these fasteners made of 300 series corrosion resistant steel
  - Designated by the material code "C" in the part number
  - Acceptable because tensile strength is less than 160 ksi

Revised ET EIS Screw Thread Requirements

B81524

Discussion (continued)

- For some applications, the A-286 CRES NAS1351N and NAS1352N fasteners were used
  - These fasteners are stronger, work better with the mating self locking nuts, and the passivated parts have a broader temperature range than the permitted 300 series CRES parts
  - Going to a UNJ fastener would have required a new fastener design for these applications
- NAS1351N fasteners are currently used in the composite nose cone installation of the ET
- NAS1351N will be used on the ET side of the GH2 vent disconnect on future tanks
- NAS1351N and NAS1352N will be used on the ground side of the GH2 vent disconnect on future tanks
- A request to change to the External Tank End Item Specification (EIS) was submitted to allow the use of these higher strength UNR unified thread form fasteners
  - This change, however, does not restrict the use of these parts to the locations at which they are currently installed

Revised ET EIS Screw Thread Requirements

B81524

Rationale for Acceptance

- Fatigue is not a concern where these fasteners are used
- Socket head cap screws are a proven fastener design
- A-286 CRES alloy provides better performance than 300 series CRES
- All bolted joints are analyzed using a bolt program that complies with NSTS 08307, "Criteria for Preloaded Bolts"
- The only application on ET-92 is at the bottom of the nose cone louvers
  - Each louver uses seven NAS1351N4-10P socket head cap screws (0.250" diameter, 0.625" total length) which screw into inserts
    - Tightened to 65 to 75 inch pounds
  - Factor of safety is >10.0 ultimate tension
    - Required F.S. = 1.40
  - No joint gapping and no alternating load

Agenda

Changes on ET-92

- Revised ET EIS Screw Thread Requirements — J. Hart

Special Topic for ET-92

- ***Contaminated Argon Gas for ET-92 Welds*** — ***D. Bolstad***

Contaminated Argon Gas for ET Welding

SI-00-S001

Issue

- High indication of CO2 detected in bottles of Argon gas used for welding at MAF
  - CO2 potentially causes reduced weld strength and reduced Margins of Safety

Background

- During fabrication of weld test panels at MAF, weld technician noticed a distinct visual change in the quality of a 2195 weld after changing the bottle of weld gas
  - Argon is used in both shield gas and plasma gas in variable polarity plasma arc welds (VPPAW)
  - Argon is also used in the backside shielding gas for 2195 welds

- Testing of Argon in K-bottle indicated that gas had Carbon bearing gases (including CO2) at a level greater than 5 ppm maximum allowable (22 ppm)

- Most recent lot received from supplier had highest level of CO2 (40 ppm)

Contaminated Argon Gas for ET Welding

SI-00-S001

Discussion

- All VPPA welds on ET-92 are suspect
  - Welds performed between May 1997 and August 1998

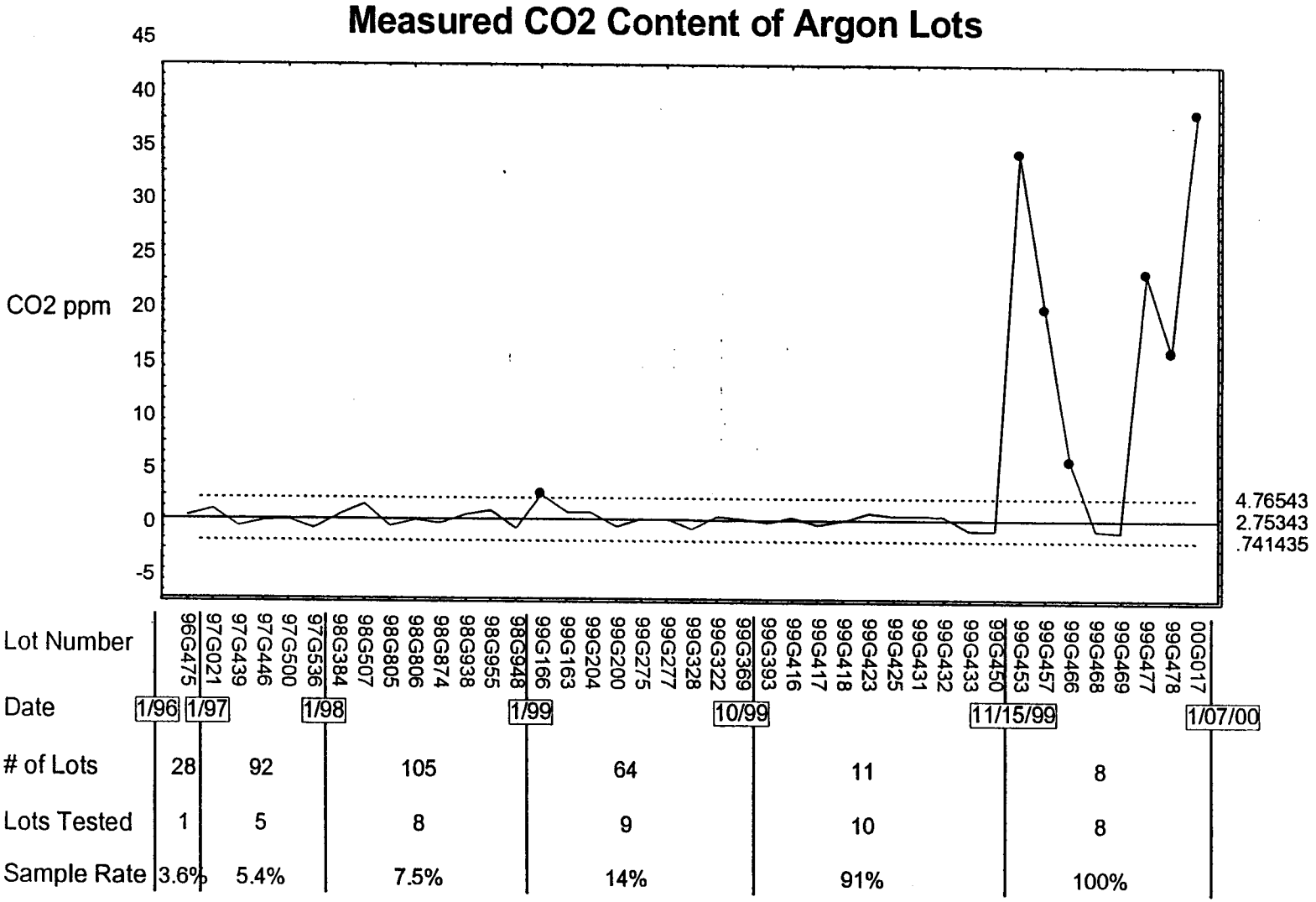
- 41 different lots of Argon weld gas were available at MAF and were tested for CO2 content
  - Delivery dates of the 41 lots ranged from 10/1996 to 01/2000
  - Total of 290 lots were delivered to MAF in this time period
  - Six lots had high levels of CO2 in the 11/1999 to 01/2000 time span

- The trend chart indicates a "special processing event" occurred after 11/13/1999

- Though gaps of test data exist, the evidence of similar "special events", if present, should have been detected in the samples that were available for testing

Contaminated Argon Gas for ET Welding

SI-00-S001



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Contaminated Argon Gas for ET Welding

SI-00-S001

Discussion

- The high purity Argon gas was supplied by Doussan Tri-Gas Facility in New Orleans
  - Facility is also used for the production of 75% Argon/25% CO2 weld gas
- A team was formed to review supplier processes for an indication of a "special event"
- During a walk-down of the facility, at least three shut-off valves and one check valve in the high purity Argon system had a common interface with CO2 plumbing system
- With the existing layout of the facility, several scenarios are possible to contaminate the Argon with CO2
  - The exact source of the CO2 contamination has not been isolated at this time
- The onset of the known CO2 contamination coincides with the replacement of the system vacuum pump
  - There were no other recent facility hardware or processing changes documented
- Corrective action will include additional isolation of the CO2 from Argon processing
  - Installation of new shut-off and check valves

Contaminated Argon Gas for ET Welding

SI-00-S001

Rationale for Acceptance

- By observation, the "special event" did not occur until after the build time frame for ET-92
- ET-92 successfully completed proof test and post proof inspection
- All ET-92 welds receiving less than 100% proof were previously evaluated by LMMSS and MSFC teams for the Weld Instruction Card (WIC) issue
  - Assessment of ET-92 weld strength included
    - Weld by weld review
    - Review of as-built parameter charts
    - ET-92 as-delivered weld tests
    - Parameter range test data (room temperature and cryogenic temperature)
    - Proof test stresses
    - Flight stress analysis
    - Successful LWT launches

Contaminated Argon Gas for ET Welding

SI-00-S001

Rationale for Acceptance (continued)

- LMMSS performed tests of welds produced using the Argon gas with the highest observed levels of CO2 contamination
  - Test procedures/practices included
    - 2219/2219 with 2319 weld wire
    - Variable polarity plasma arc weld (VPPAW)
    - t=0.140" and 0.550"
    - Argon shield gas containing 40 ppm CO2
    - Nominal weld schedule and hot weld schedules (high amperage/high voltage)
    - Room temperature and cryogenic tests
      - 0.140" @ -320°F
      - 0.550" @ -423°F
      - As-welded and root bead shaved flush configurations
  - Test results showed all conditions indicative of the ET-92 weld schedules passed acceptance

The ET-92 fabrication date, weld test results, and WIC review indicate there are no concerns for use of contaminated Argon gas on STS-99/ET-92 welding

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Readiness Statement

The External Tank, ET-92, is hereby certified and ready for STS-99 flight pending completion/closure of open and planned work

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Terry L. Hibbard
Vice President, External Tank Project
Lockheed Martin Michoud Space Systems

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