DemTa-MT-175-RP-1019

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Phase A

Demisable Propellant Tank

Executive Summary Report (D15)

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Pages (incl.appendices) 14	Appendices	

Abstract

This executive summary report presents a comprehensive analysis of the demisable propellant tank, a critical component designed to mitigate space debris by disintegrating upon atmospheric re-entry. The report outlines the tank's innovative design features, performance characteristics, and potential applications in spacecraft, while also addressing key challenges and recommendations for further development and implementation in future space missions..

Acceptance

System Engineering	Design	RAMS	Strength	Quality Assurance	Manu-facturing	Test Engineering	

External Distribution

Name	Company	Purpose		
		Approv.	Accept.	Inform.

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Issue and Rev. No.	Date	Pages changed, added, deleted	Reasons for change /Change notice
Issue 1 Revision -	2024-12-06		Initial issue

Contents:

1 General

1.1 Documents

1.1.1 Applicable Documents

Ref.-No	Document No.	Document Titel	Iss. / Rev. (Rel. Date)	Comment
[A1]	4000126390/19/NL/LvH	Development, Test and Qualification of Demisable Propellant Tanks		
[A2]	ECSS-E-ST-10	Space engineering – System engineering general requirements	C/1 2017-02-15	
[A3]	DemTa-MT-175- PL-1014	Development and Verification Plan and Report	1/-	

1.1.2 Reference Documents

Ref.-No	Document No.	Document Titel	Iss. / Rev. (Rel. Date)	Comment
[R1]	None			

1.2 Acronyms and Abbreviations

ABCL	As-Built Configuration List
BoL	Beginning of Life
CDR	Critical Design Review
CIDL	Configuration Item Data List
CoG	Centre of Gravity
DDTP	Design & Development Test Plan
DPPT	Demisable Pressurized Propellant Tank
DRB	Delivery Review Board
EB	Electron Beam (Welding)
EC	Eddy Current (Inspection)
EM	Engineering Model
EoL	End of Life
EPDM	Ethylene Propylene Diene Monomer
GD&T	Geometrical Dimensions and Tolerances
I/F	Interface
ICD	Interface Control Document
ICDrw	Interface Control Drawing
MEOP	Maximum Expected Operating Pressure
MoI	Moment of Inertia
MoS	Margin of Safety
MPCB	Material and Process Control Board
MRR	Manufacturing Readiness Review
MT	MT-A, Augsburg
N/A	Not Applicable
NDI	Non-Destructive Inspection
PA/S	Product Assurance and Safety
PDR	Preliminary Design Review
PFM	Protoflight Model
PTD	Propellant Tank with Diaphragm
QM	Qualification Model
QRB	Qualification Review Board
S/C	Spacecraft
SOP	Standard Operating Procedure (MT Management Handbook)
SOW	Statement of Work
TBC	To Be Confirmed
TBD	To Be Defined
TBI	To Be Issued
TIG	Tungsten Inert Gas
TL	Technische Lieferbedingung (procurement specification)
TR	Technology Review
TRR	Test Readiness Review
US	Ultrasound (Inspection)

2 Executive Summary

2.1 Abstract

MT concept of a demisable 177-L Hydrazine monopropellant tank for spacecraft

MT Aerospace AG, Augsburg, has concepted, analyzed and designed a 177-L demisable hydrazine monopropellant tank for spacecraft. For separation of propellant and pressurant the tank utilizes the established diaphragm from MT proprietary EPDM-5078M040 as already used in non-demisable Ti-6Al-4V PTD-177L tanks of MT´s portfolio.

For demisability, Aluminum alloys have been evaluated and AA2219 has been selected for tank concept as this AA appears to offer best combination of properties such as strength, weld strength, weldability, demisability, availability and manufacturability. A near-spherical tank design has been established including features as equatorial mounting by three equatorial planar 120°-equi-spaced lugs, internal diaphragm clamping and sealing, and redundantly sealed bolted pressurant and propellant ports up to ½" diameter. Alternatively, on demand bi-metallic transition joints to S/C tubing can be welded as tank ports.

The tank has been designed for net volume of 177 liters, hydrazine loading of up to 175 kg (then, blow down operation requires an auxiliary external pressurant reservoir), MEOP of 24 bar, proof/burst pressure factors 1.5/2, and all axis accelerations and vibrations up to 13 g. The tank is expected to have a dry mass of 18 kg, based on AA2219 properties as established at MT for the Ariane 5 programs but TBC for this application and respective raw part production. The design can be enlarged for loading 175 kg hydrazine and internal pressurant for blow-down operation, then not needing an external reservoir.

For evaluation of the demise of Aluminum alloys and analysis of tank demisability, a continuous co-operation through several design loops with DLR and HTG has been performed using the DLR plasma wind tunnel and established analysis tools DRAMA and, finally, SCARAB. Items representative of different Aluminium alloys and massive features of the tank design have been tested. The design demises completely if released by S/C breakup at 78 km altitude, and demises largely if released by 72 km.

The next logical step needed is definition of metallic raw part production and processing path, confirmation of material properties, and testing of a manufactured unit, and then ideally testing demise at re-entry.

2.2 Final Präsentation

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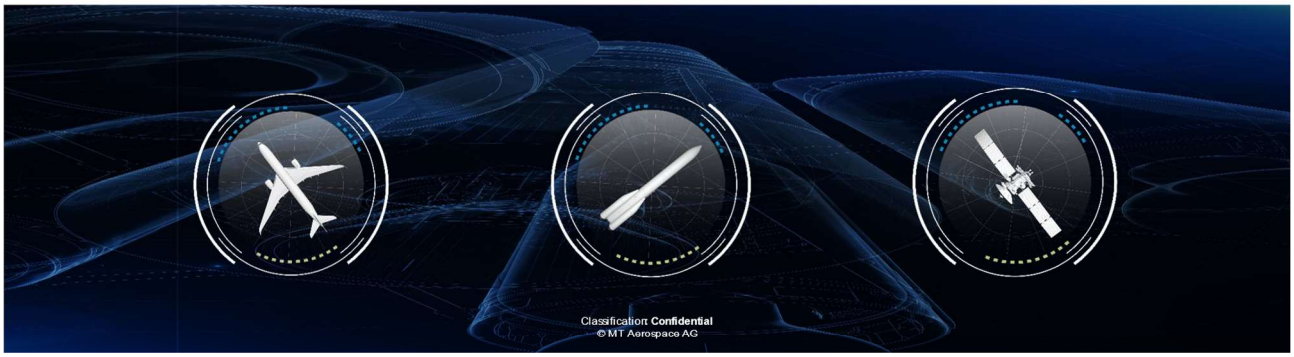

6TH INTERNATIONAL SPACE DEBRIS RE -ENTRY WORKSHOP
DEMISABLE PROPELLANT TANK – DESIGN, ANALYSIS, PERFORMANCE

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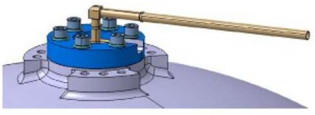
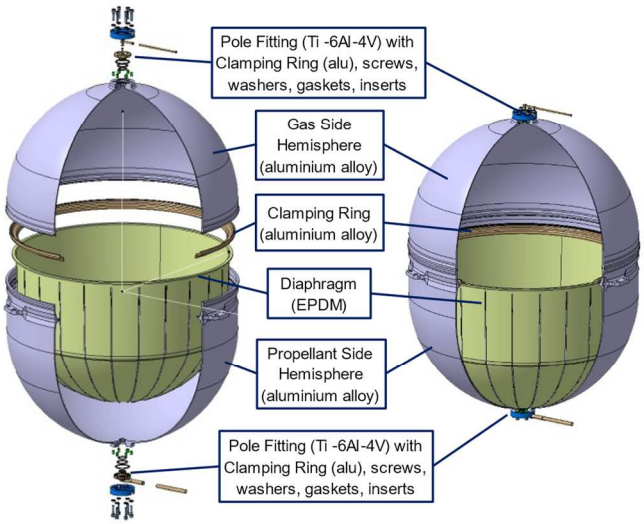
DEMISABLE PROPELLANT TANK – DESIGN

- General Design:
  - Tank Shell: All -Metallic, Aluminium Alloy
  - Propellant Management by Diaphragm (derived from PTD 177L, qualified design)
  - „Transition Fittings“ at Poles: Ti-6Al-4V or IN718 or CRES, triple sealed by metallic gaskets against tank shell
- Mechanical Interfaces:
  - Mounting to S/C: Equatorial via Lugs or Polar via Flanges, possibly with Adapters
  - Tubing: ¼“ or ⅜“ or ½“, straight or elbow





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DEMISABLE PROPELLANT TANK – DEMISABILITY ANALYSES

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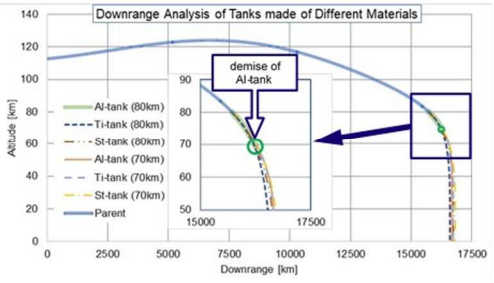
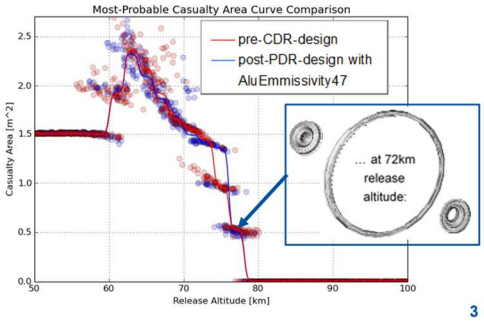
- Initial analysis with simulation programme DRAMA

  Materials compatible with propellants, mainly hydrazine
  Result: Tanks made of Aluminium Alloy will demise only for specified re -entry/reference trajectory and break -up attitude range
- Investigations on test shear & stagnation samples
  - Determining normal spectral emittance at high temperatures for different aluminium alloys (DLR)
  - Improvement of data basis for general burn -up/demising behaviour of material (AA 2219) currently used for designed tank shell
- Final analysis with SCARAB after design optimisation (HTG)

  "... demisable if released above 78 km with a 90% confidence interval extending between 76 km to 80 km release altitude."
  (Ref.: Report DEPT -SR 0.5.0, HTG)





DEMISABLE PROPELLANT TANK – STRUCTURAL ANALYSES

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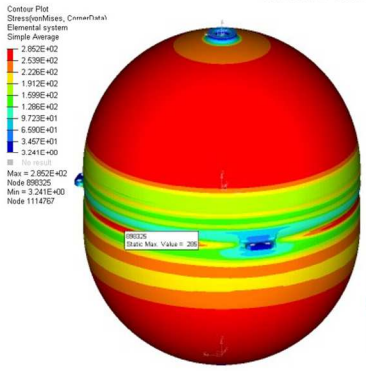
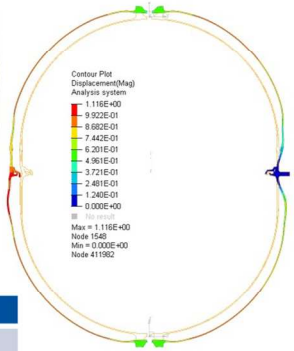
All areas of tank with acceptable MoS:

- pressure load cases
  (groove of centre section):
  Proof: 1% ; Burst: 0%
- combined mechanical load cases
  (cylinder – mounting lug area):
  Yield: 27% ; Ultimate: 47%
- lowest MoS of 0% in cylindrical section at burst acceptable, since caused by conservative approach of hard mounted condition
  ➔ detailed interface description from customer necessary
- minimum MoS for welds is 70% at proof pressure load case.



Stresses and Deformation at Proof Pressure Level



maximum deformations		
Areas	Upper Hemisphere	Lower Hemisphere
Pole	axial: 0.58mm	axial: 0.59mm
Dome	total: 0.91mm axial: 0.85mm	total: 0.92mm axial: 0.86mm
Cylinder	--	radial: 1.12mm

DEMISABLE PROPELLANT TANK – PERFORMANCE, NEXT STEPS

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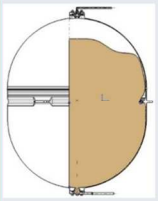
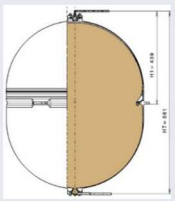
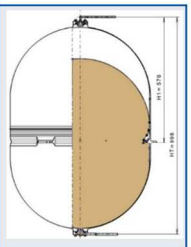
- Performance of designed propellant tank:
  - Total dry structural mass: 17.9 kg
  - Geometry:
    - spherical domes wall thickness <2.5 mm
    - height & volume: see table
    - outer diameter (except mounting interface): ∅645mm
  - Tightness of sealing at fittings: $x \leq 10^{-6}$ scc/s GHe (verified by test)
- Next steps ahead:
  - Diaphragm clamping: welding test
  - Material compatibility with green propellants
  - EM and QM Tank

					
		Baseline Design	Baseline Design	Enhanced Design	
tank height (tube-to-tube)		861mm	861mm	998mm	
mode		blow down mode 4:1	regulated mode ("non-blow down" mode)	blow down mode 4:1	blow down mode 4.5:1
tank total volume		177 l	177 l	220 l	220 l
propellant volume covered below diaphragm		0 – 132.75 l	0 – 171.4 l	0 – 165 l	0 – 171.4 l
propellant mass	Hydrazine, ρ=1.021g/cm³	≤ 135.5 kg	≤ 175.0 kg	≤ 168.5 kg	≤ 175.0 kg

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