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FRACTURE CONTROL PLAN FOR PROPELLANT AND PRESSURANT TANKS

Messerschmitt-Boelkow-Blohm GMBH

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1. Purpose of the Fracture Control Plans

The purpose of this Fracture Control Plan (called FCP in the following) is to define criteria, requirements and execution requirements which will guarantee the functional integrity of the GLL-RPM fuel and pressurized gas tank during the entire mission.

Fracture or leakage cannot occur for the case where the tank structure has cracks or defects similar to cracks, which were not discovered during preliminary tests. All of the activities which influence the tank structure such as design, manufacture, cleaning, test operations and flight test operations, storage, testing, etc., will be discussed in this document and will be controlled by it.

Load assumptions, which define material characteristics for the components, as well as manufacturing processes used, must correspond to the present state of the art of engineering science (literature, experience values, handbooks, tests, etc.).

2. Application Range of the FCP

The FCP must be applied for all flight tanks and qualification tanks for the following:

- fuel tank according to drawing RPM-DW 3200-00-00-00 (identical for fuel and oxidizer)
- helium tank according to drawing RPM-DW 3300-00-00-00

The Plan must give a monitoring of all of the events during the entire lifetime of the tank, from manufacture up to the end of the mission.

The QS must ensure that the criterion mentioned in this document will be maintained and the resulting requirements will be guaranteed. A card describing events in the life of each component must be attached.

Whether or not the tank satisfies the criteria and requirements of the FCP and can be used as a flight tank is decided by the members of the committee mentioned in this document in the case of doubt.

3. Documents

The documents mentioned in the following are part of this FCP for the application mentioned here. If nothing else is mentioned, the most recent issue of each document applies.

3.1. Documents Which Are Applicable

. NASA SP8040	Fracture Control of Metallic Pressure Vessels
. NASA NSS/HP - 1740.1	NASA Aerospace Pressure Vessel Safety Standard
. MIL HDBK - 5	
. Materials Handbook of German Aviation	
. Interface Requirements Document (IRD)	
. RPM-DS 1200-02-01	Delivery requirements for forged hemispheres and rings made of material 3.7164.7 (TiAl6V4)
. RPM-TS 1200-02-01	Test requirements for forged parts made of material 3.7164.7 (TiAl6V4)

3.2. Reference Documents

. NASA SP 8095
. JPL SS 80 - PD - 108
. Rockwell International SD 73-SH-0082A
. Aerospace Structural Metals HDBK

Reference documents are not binding.

4. Organization

The application of this document to fuel containers and pressurized gas containers will be ensured by the committee mentioned in the following, associated with the project management. Basically, this committee will formulate requirements for the assured lifetime of the tank according to guidelines and data provided by NASA and accepted by NASA. If there are deviations from this document or in cases of conflict, or in the case where new knowledge is obtained, it becomes active. The QS will have direct supervision.

The committee is composed of the following responsible engineers from the following departments:

- Project
- Design and Strength
- Materials Laboratory
- Quality Assurance

5. Definition of the Mechanical Fracture Terms

All of the relevant mechanical fracture terms are contained in Appendix A, Paragraph 3, of the Interface Requirements Document (IRD).

6. Requirements

6.1. Mechanical Fracture Design Requirements

The design of the tanks is done using the "Safe-life" philosophy, i.e., the largest crack, which can no longer be protected by the prescribed by the nondestructive testing methods, is not allowed to lead to failure of the tank over the entire lifetime. The tank design is done according to NASA document SP 8040 "Fracture Control of Metallic Pressure Vessels", also according to the material data mentioned in the documents given in Section 3.1.

All of the design criteria and requirements mentioned in the Interface Requirements Document (IRD) in Chapter 6.1.1.2 have to be considered. A tank "Loading Plan" (Appendix A of this FCP) is to be prepared. It has to contain all of the loads and environmental conditions in the expected sequence over the entire lifetime of the tank. Influences on tank design have to be considered. The Loading Plan must at the latest be available and released during the first pressure loading of the tank. A copy of this loading plan must be contained in the lifetime documents of each tank. Any operational conditions and environmental condition deviations have to be approved by the committee mentioned in Chapter 4, before the tank is exposed to these conditions.

6.2. Eigen Stresses

The magnitude of the eigen stress caused by the circumferential welded seam in each tank has to be considered, it is σ_E = 100 N/nm^2 (experience value of JPL). The actually occurring eigen stresses have to be determined in a qualification test. For this

purpose, a qualification welding ring is used, which actually compares to the actual tank geometry in the region of the welded seam.

If the measured values exceed the design value, then the committee mentioned in Chapter 4 will decide on further action.

6.3. Load Assumptions

The following load cases have to be considered for designing the tank, at a minimum:

- maximum internal pressure for maximum temperature;
- maximum internal pressure during launch or for maximum temperature together with the valid starting loads as defined in the IRD;
- 10 times the number of actually occurring load cycles by internal pressure (from zero to maximum operating pressure) must not lead to fracture of the tank.

6.4. Materials

The material 3.7164.7 (Ti Al 6 V4) is to be used for the tank. The data used for tank design have to be taken from the most recent issue of MIL-HDBK-5 or the materials handbook of the German aviation ("A" values).

The quality of the material is defined by the MBB delivery document RPM-DS 1200-02-01 and must be demonstrated by material testing according to MBB test specification RPM-TS 1200-02-01.

The results of these acceptance tests have to be recorded in the lifetime documents and have to confirm the original assumptions.

The individual mechanical fracture data and crack growth data are to be determined in a test program for the material charge used. They must not be below the statistical value assumed for the design. The tests have to be carried out in agreement with the requirements defined in the IRD.

6.5. Analyses

6.5.1. Stress Analysis

The actual stress distribution in the tank has to be determined for the defined load cases.

They must not exceed the permissible values determined according to mechanical fracture requirements (with consideration of eigen stresses).

6.5.2. Predictable Characteristics of Possible Cracks Which May Occur

According to NASA SP 8040, a surface area initial crack can be considered as a typical defect for the component. These cracks can occur during production, processing, welding, during testing, etc. The HAZ* after welding is considered to be critical, also the transition to the connections. These defects are considered by relevant K_{IC} values in the stress analysis.

6.5.3. Analysis of Crack Growth

It has to be determined analytically and/or by tests that the

*HAZ = Heat Affected Zone (heat influence zone)

loads which occur during the individual acceptance tests and later on when the tank is used will not produce any critical crack growth.

6.6. Manufacture

Maintenance of the requirements for manufacture is done using the manufacturing specification (MBB document RPM-MS 1200-01-01), the welding document (MBB document RPM-MS 1200-02-01), the manufacturing sequence plan and the control plan (MBB documents RPM-PL 1200-04-01 and RPM-PL 1300-02-01), as well as the lifetime document. Each specified manufacturing step has to be monitored using QS. Deviations are to be approved by the committee mentioned in this document.

6.7. Permissible Liquids and Gases

The following table gives the liquids and gases with which the tanks can be filled for a pressure of > 3 bar:

Fuel tanks	MMH	MIL-P 27404
	MON-1	RPM-DS 1720-01-01
	He	MIL-P 27407
	LN_2/GN_2	MIL-P 27401
	H_2O deionized	MSC-Spec-C-20
He-Tank	He	MIL-P 27407
	LN_2/GN_2	MIL-P 27401
	H_2O (deionized)	MSC-Spec-C-20

7. Quality Assurance

The QS (Quality Assurance) provides means to ensure that the requirements of this FCP will be maintained during the entire lifetime of the tank (including manufacturing). The proof that these requirements have been satisfied is to be documented.

8. Proof That Requirements Have Been Satisfied

8.1. Analyses

The results of the analyses carried out are to be documented in report form.

8.2. Tests

In order to demonstrate that requirements of this FCP have been satisfied, the following tests have to be carried out. The results are to be documented in a test report. Tank tests and their results are to be entered in the lifetime document.

8.2.1. Mechanical Fracture Test Program

Using a testing program specified in the Fracture Mechanic Test Plan, the fracture mechanical values (K_{TH}) from the literature are verified. In addition, a comparison test with the oxidizer used at MBB (MON-1, according to RPM-DS 1720-01-01) will be carried out at JPL.

8.2.2. Qualification Tests

8.2.2.1. Static Test

With a static test, one has to demonstrate that the tank will withstand the important load cases for the design.

8.2.2.2. Cyclic Load Test

Any tank design has to be tested by means of a cyclic load test. The qualification tank is loaded from the surrounding pressure up to the maximum operating pressure. The number of test cycles has to correspond to 10 times the actual cycle numbers to be expected (Loading Plan).

8.2.2.3. Proof Test

Using a manufacturing specification RPM-MS 1200-01-01 corresponding to a cryogenic proof test, it must be demonstrated that the tank has no critical cracks.

8.2.2.4. He-Leak Test

A He-leak test is to be carried out according to the manufacturing specification RPM-MS 1200-01-01. The leakage rate must not exceed 1.10^{-6} scc/sec helium.

8.2.3. Acceptance Tests

Any flight tank has to pass acceptance tests according to 8.2.2.3 and 8.2.2.4.

ANHANG A
APPENDIX A

TANK LOADING PLAN

1. TREIBSTOFFTANK

2. DRUCKGASTANK

1. FUEL TANK

2. PRESSURIZED GAS TANK

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Tank Loadings and Operational Sequence				
Operation Description				
Mounting or Constraint				
External Environment				
Internal Environment				
Maximum Temperature				
Maximum Sustained Pressure				
Sustain Pressure Duration				
Maximum Cyclic Pressure				
Cyclic Pressure Period				
No. of Pressure Cycles				
Maximum Sustained External Load				
Sustained External Load Duration				
Maximum Cyclic External Load				
Cyclic External Load Period				
No. of External Load Cycles				
Post-Operation Cleaning				
Post-Operation Inspection				

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