

The Leak Before Burst Behaviour
A Demonstration provided by Test on a 70L Pressure Vessel

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All the space you need



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LBB Definition – Objectives of the Study

- Leak Before Burst : to demonstrate the capability of the tank to withstand the internal pressure at MEOP when a leak occurs (crossing crack of the liner)
- To demonstrate the Leak Before Burst failure mode by test at MEOP for high pressure vessels
- To meet the standard requirements :
 - CSG requirement
 - US launch requirements
 - ECSS E-ST-32-02

Standards overview

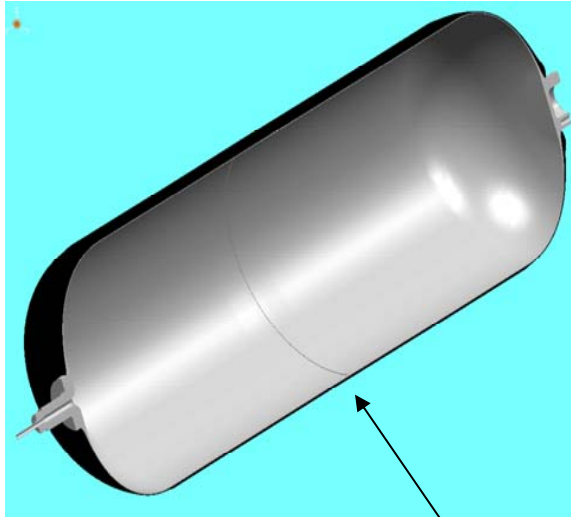
- MIL1522 / EWR127-1 / USAF Letter / CSG RS020, ECSS E-ST-32-02

- Demonstration of the failure mode demonstration by :
 - analysis : acceptable by all standards excepted USAF letter
 - elementary tests : accepted by MIL1522 and ECSS E-ST-32-02
 - test on a full scale high pressure vessel : CSG if safety factor 1.5
 - similarity : USAF letter accepts the similarity approach if the demonstration has been already carried out by test on a similar hp vessel

- Requirements take into account initial flaws on metallic part (liner):
 - sizes and geometries of the flaws
 - flaws must propagate in a stable way through the wall thickness of the liner
 - failure shall occur during pressure cycling close to MEOP (USAF letter)

Definition of the tank

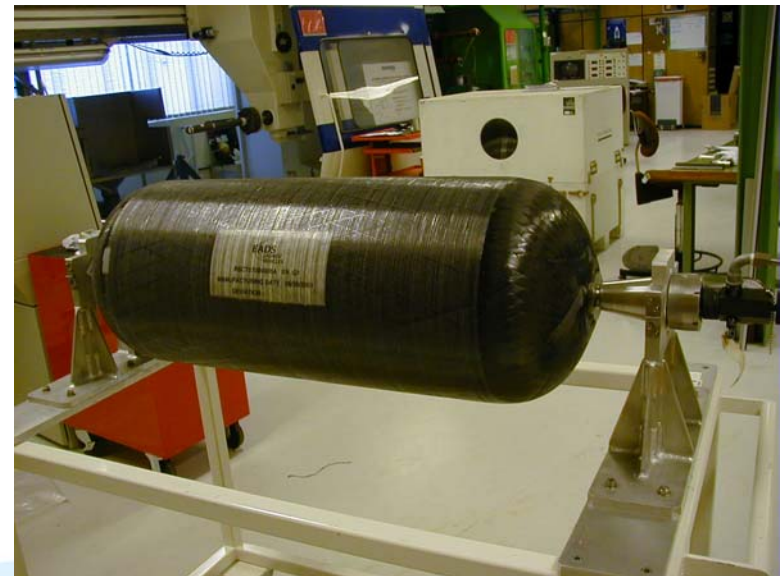
70 l high pressure vessel



- 70L xenon COPV
- developed in 1998
- carbon T800/TA6V lined
- MEOP:19 MPa
- safety factor:1.5
- designed safe life, LBB

General parameters :

- liner technology with only one weld (stronger design for the safety approach)
- length : 1026 mm
- Diameter : 338 mm
- Masse : 10 kg



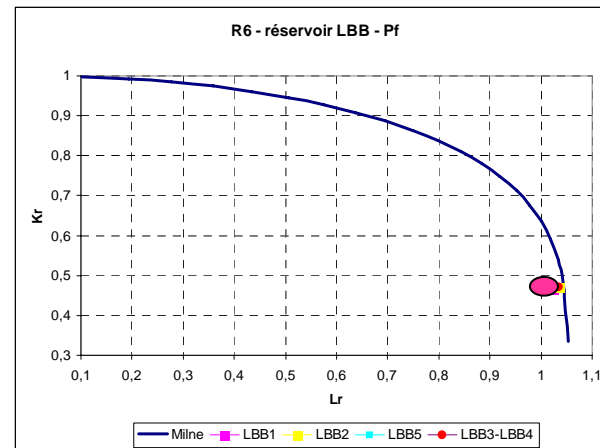
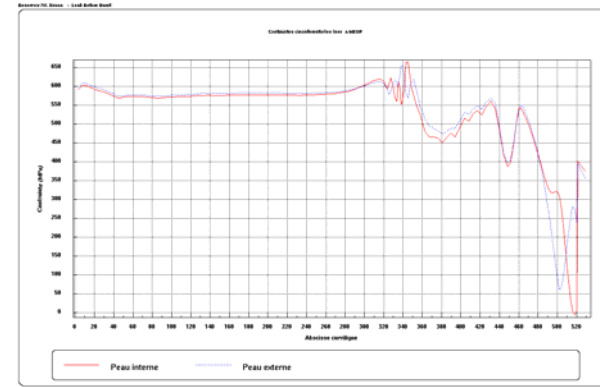
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Logic of the LBB demonstration of the 70L

- To demonstrate the LBB requirement by a full scale test
- The failure mode of the tank is driven by both :
 - the demonstration of the stable propagation of the cracks through the liner
 - ⇒ analysis and/or elementary tests
 - the demonstration of the capability of the composite shell to withstand the loads after the liner fails
 - ⇒ full scale test demonstration
- Test processing on the 70L tank :
 - to perform crack initiations on the liner
 - to manufacture the tank and perform the acceptance tests
 - to perform the pressure cycling at MEOP to validate 4 lives
 - to perform the pressure cycling at MEOP with gas until the leak occurs
 - to demonstrate the capability of the tank to withstand the stresses after the leak during a load hold at MEOP

Analysis

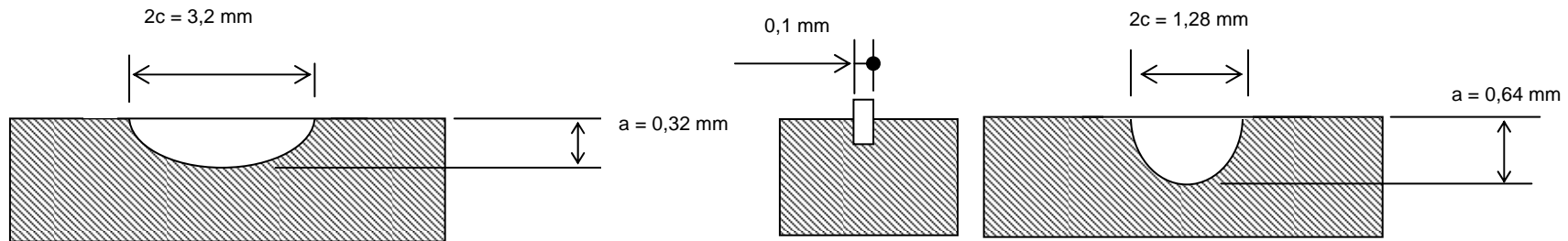
- Finite Element analysis of the tank :
 - ➡ stress mapping in the liner
- Defect behaviour when the liner plastifies
 - ➡ during the sizing pressure of the tank
 - R6 rule => crack stability
- Crack propagation analysis performed with
 - ➡ ESACRACK software



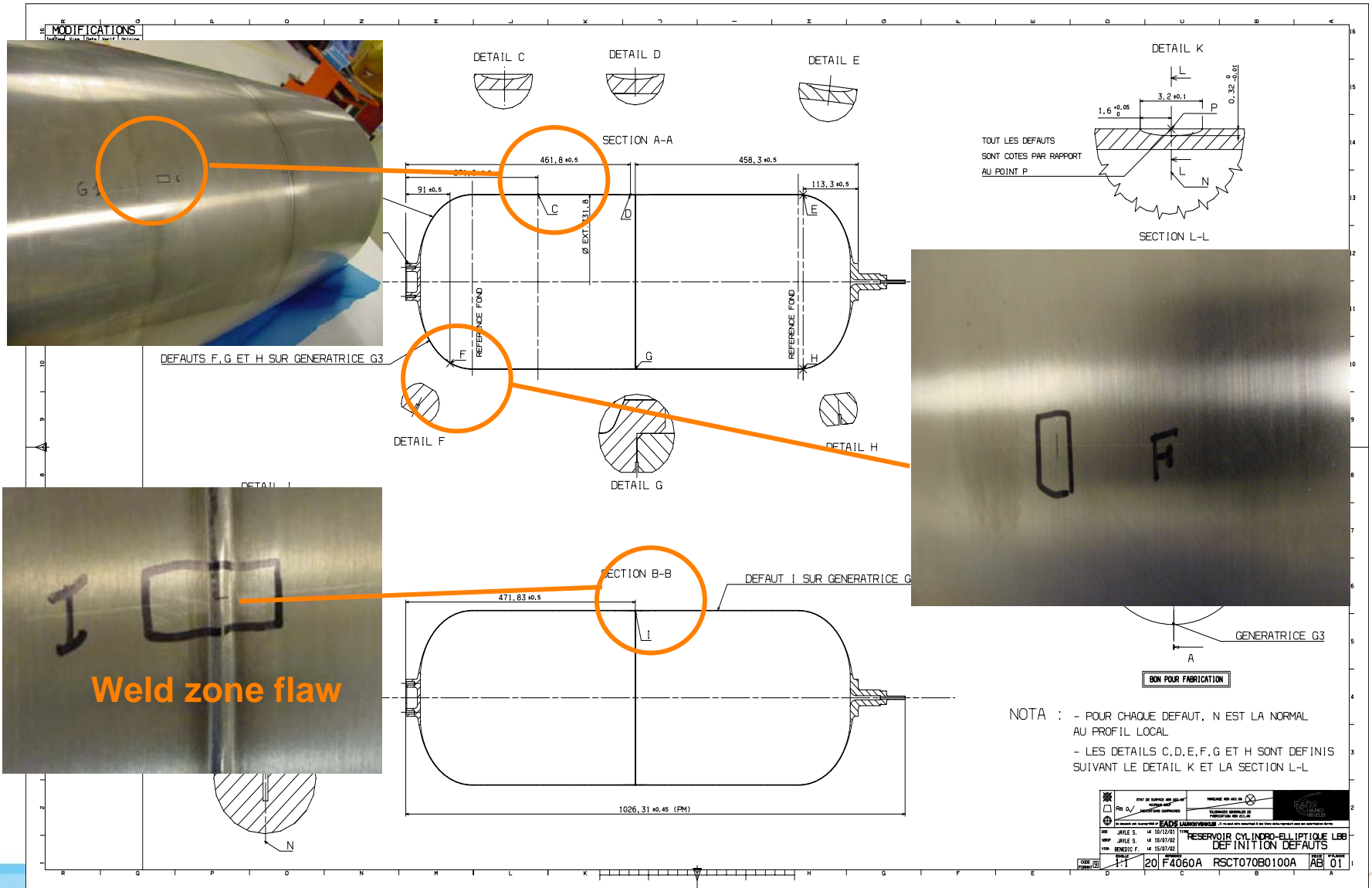
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Crack initiation in the liner (1/2)

- Flaws are implemented by machining (electroerosion) in the most critical areas of the liner defined by fracture mechanics analysis using ESACRACK software
- Size of flaws have been defined in accordance with the greater flaw non detectable by NDI used during liner inspection. The size of flaws are compliant with the standard requirements



Crack initiation in the liner (2/2)



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Tests sequence

- Acceptance tests : Pf , proof test , leak test, NDI :

➡ **successful**

- Cycling Pressure at MEOP : 96 cycles (4 lives)

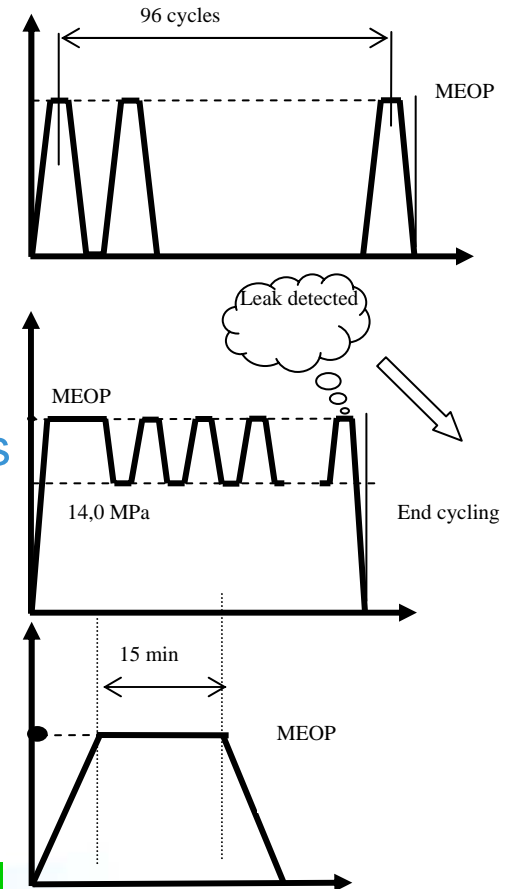
➡ **successful**

- Cycling Pressure at MEOP until leak after 23296 cycles

➡ **successful**

- A load hold has been successfully performed at MEOP

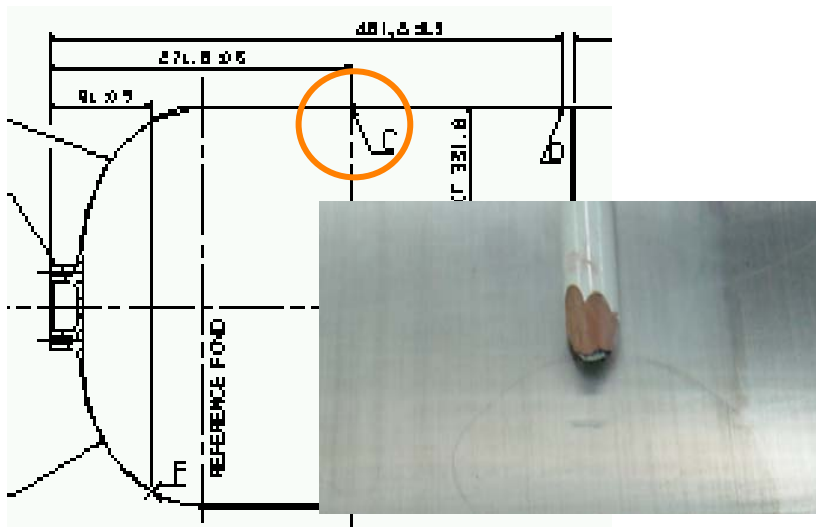
➡ **successful : no rupture of the tank
integrity of the composite shell**



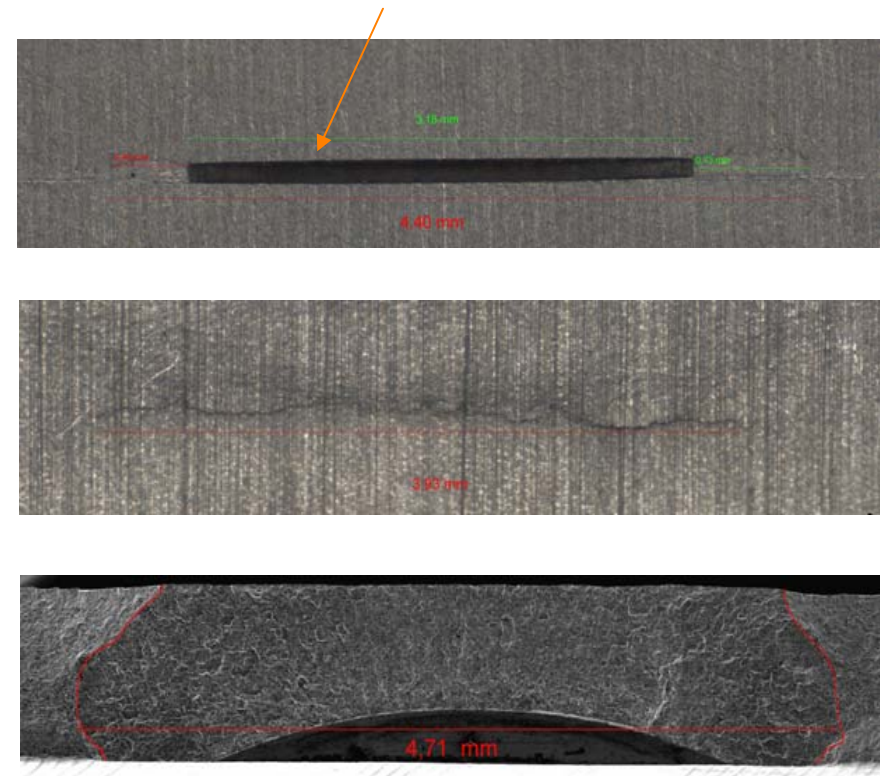
LEAK BEFORE BURST BEHAVIOUR IS DEMONSTRATED

Investigation after leakage

- macroscopic views of all the flaws,
- microscopic observation of the flaws
- result : **C** flaw is crossing



Electroerosion C flaw



- no propagation observed during the sizing pressure of the tank
- no evolution of the crack sizes observed during the final load hold at MEOP
- no discrepancy in the welded zone

LBB Justification successfully achieved for the 70 l xenon tank

LBB similarity approach for others tanks

LBB justification of the 89.5L helium tanks

- The demonstration of the failure mode for the 89.5L tank was managed by similarity from the 70 L LBB test result.
- The justification of the LBB by similarity with the 70L tank is argued as follows:
 - same materials for the composite shell and for the liner,
 - similar manufacturing process for the liner,
 - stress field covered by the 70l one.

LBB justification of the 89.5 l tank successfully achieved by similarity with the 70L tank

Conclusions

- The Leak Before Burst failure mode of the 70l Tank has been demonstrated by analysis and by test
 - ⇒ no rupture of the tank, and stability of the crossing crack at MEOP
- Robustness of the design and processes : more than 23000 cycles were needed to observe a leak (much higher than the 4 lives)
- Tools for analysis are confirmed :
 - ⇒ crack stability at sizing pressure deduced from the R6 rule
 - ⇒ crack size evolution predicted by ESACRACK software
- The similarity approach for the LBB demonstration has been justified for the 89.5 l helium tank (Spacebus & @bus back-up) derived from the 70l xenon LBB justification
- EADS Astrium is fully compliant with the Safety Regulations and all the Standards and offers a complete Leak Before Burst Justification for its new families of tanks with a safety factor of 1.5 :

70l xenon tank and 89.5 l helium tank