AMS Superconducting Magnet Cryogenic Safety

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Basis of the hazard (1)

- Density of liquid helium at 16 mbar, 1.8 K is 145.4 g/l
- Density of helium gas at 1013 mbar, 295 K is 0.1652 g/l
- The volume of the helium can potentially increase by a factor 880

Basis of the hazard (2)

- Energy change is 224.9 kJ per liquid litre
- To raise 2500 litres from 1.8 K to 295 K would require 562.3 MJ of heat
- This amount of energy can only be released by destroying the insulating vacuum

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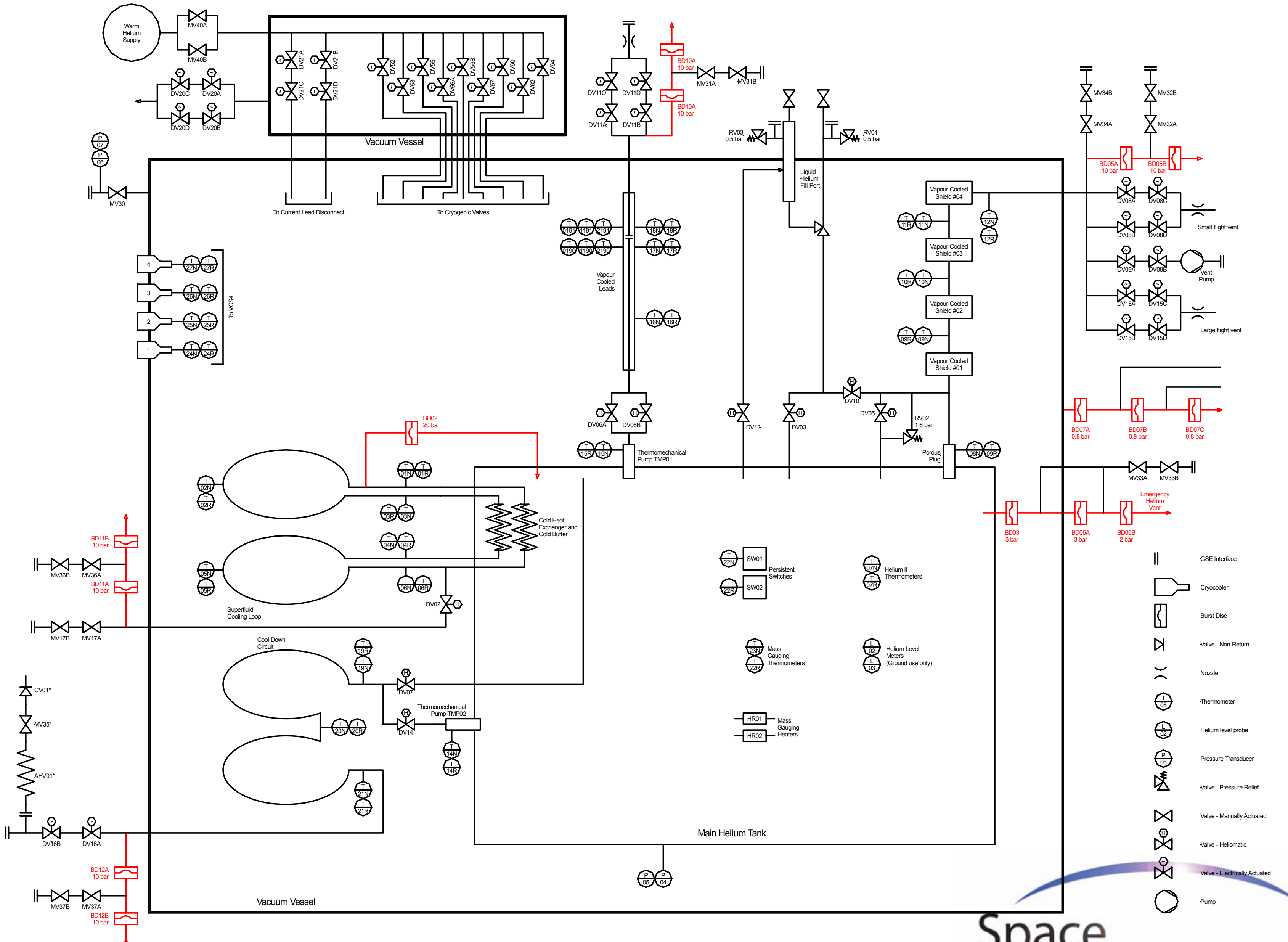

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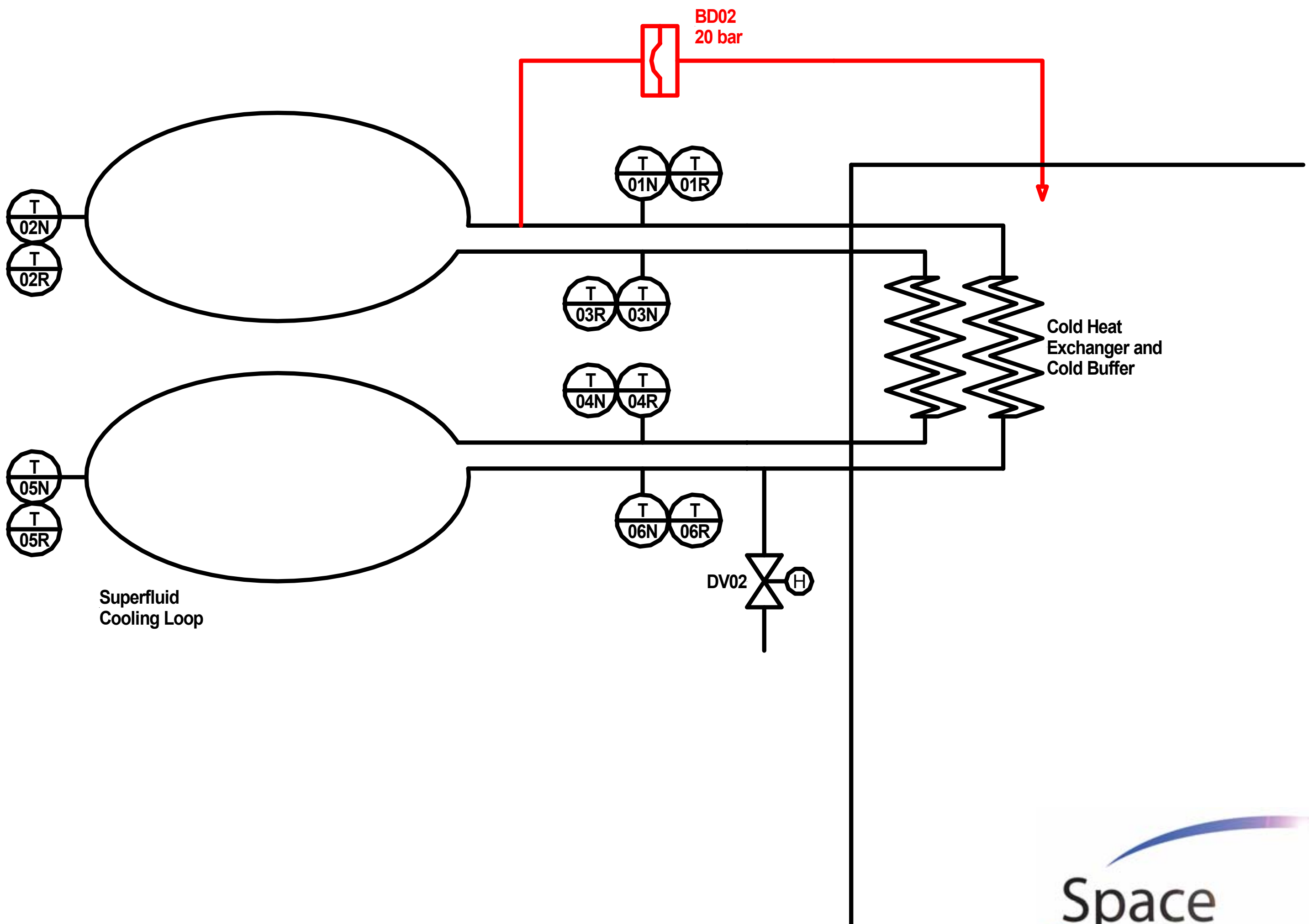
Helium to helium relief



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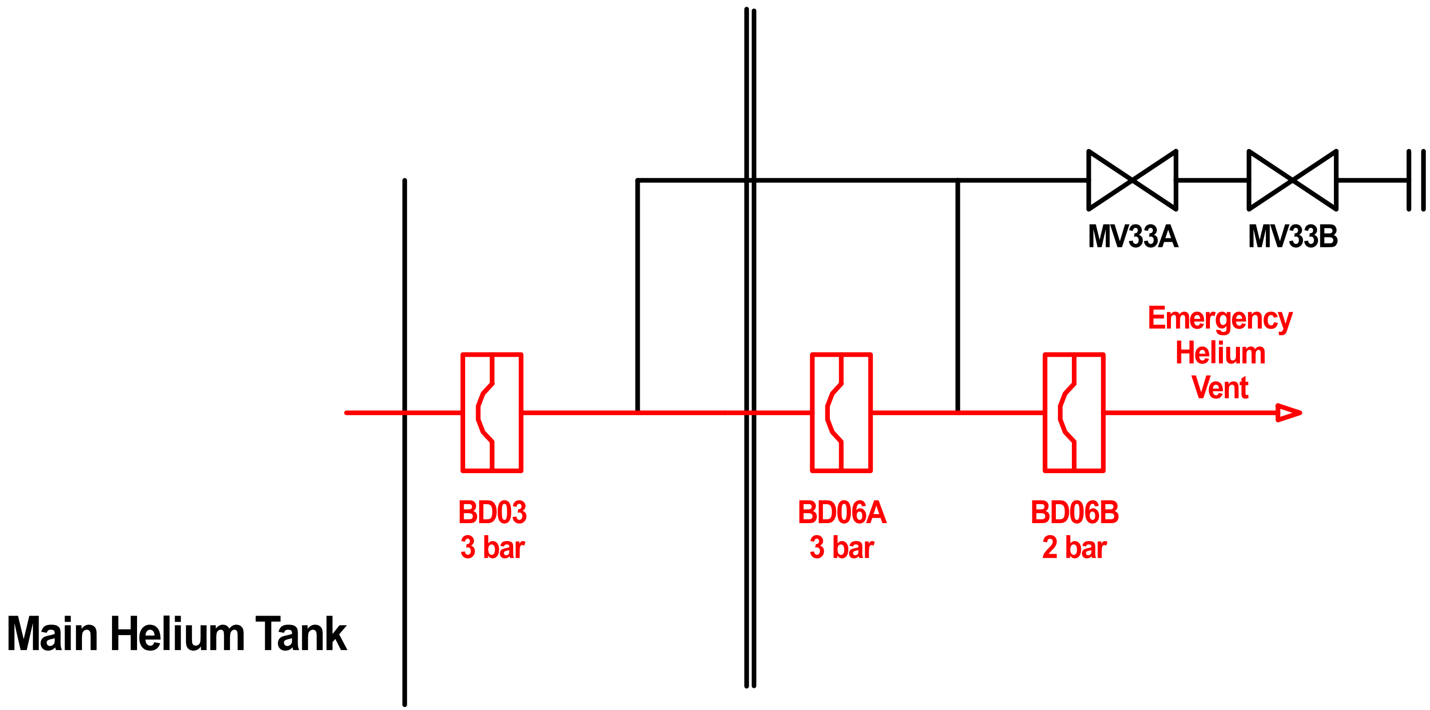
Warm trapped volume relief

Helium vessel external relief



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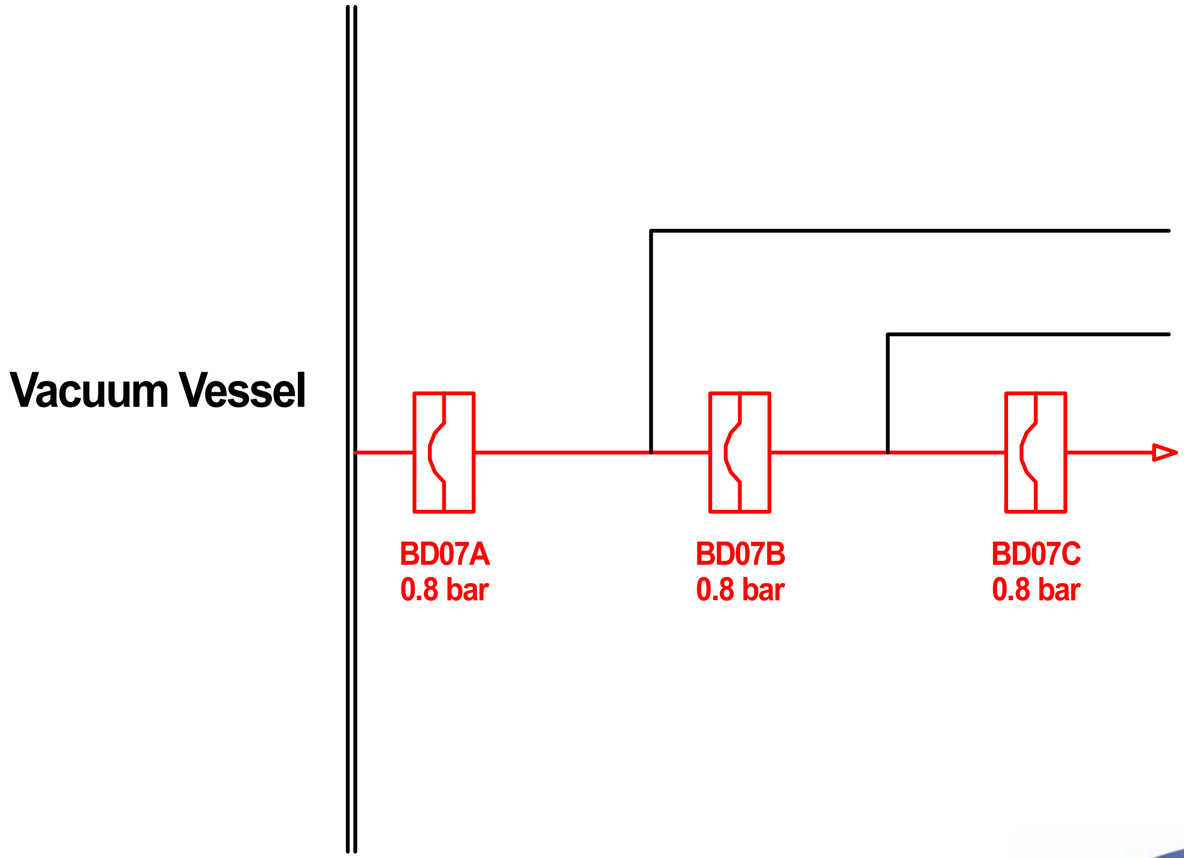
Vacuum vessel relief



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Hazard definition

"A meeting was held on September 5, 2001 at JSC to discuss the status of the AMS-02 Helium Vent Tests at Space Cryomagnetics Ltd. (SCL) and to establish further test and analyses plans. Attendees included Rick Miller, Brad Harris, Mark Fields, Ray Serna, Jim Bates, Rick Sanchez, Daniel Newswander, Doug Cline, Trent Martin, Phil Mott, and myself . (Details on this meeting are included in Trent Martin's e-mail dated September 6th below.) Jim Bates and I then followed up with Dave O'Brien (PSRP Chair) on September 5th as well.

It was agreed that there is no credible scenario that could lead to a sudden loss of vacuum in the AMS-02 Cryomagnet Dewar after the Orbiter payload bay doors were closed and prior to launch. The temperature of the Superfluid Helium (SFHe) Tank and pressure of the SFHe Tank as well as pressure of the Cryomagnet Vacuum Case (VC) will be monitored until Launch minus 9 minutes. At that time a go/no-go call on the status of the cryogenic systems will be made by AMS. The requirements for the frequency of measurements, number of sensors, etc. are still TBD.

The following leak scenario was worked out with Dave O'Brien on September 5th and reviewed with Bill Manha on September 17th:

There are two large O-ring seals (~9 ft. diameter x ¼ inch diameter cross-section) at each of the four joints between the VC Outer Cylinder to Support Rings and Support Rings to the Conical Flanges; i.e. 8 large O-rings in all. There are several other dual O-rings throughout the hardware but they are much smaller (< 6 inches). We will consider two large O-rings to be pinched at assembly and that the pinches are right next to each other on the same joint. Both "pinches" will be ~3 inches long but will not be detected during initial leak tests on the individual O-rings using the test ports between the seals. We will then assume that it is determined (via the test ports) that one of them is leaking at the launch pad. It would be a monumental undertaking lasting SEVERAL months to disassemble the entire experiment, grind out the welds on the VC, open it up, repair the leaking O-ring(s), reassemble the Cryomagnet and re-weld the VC, reassemble the entire experiment, and recalibrate it. Obviously, we would argue against the need to do this.

So, we will then assume the second pinched O-ring starts leaking due to vibrations from SRB ignition at launch. Using the assumption that the leak path is ~3 inches long by the maximum gap we could possibly have gives us the maximum equivalent hole we should use in the next small dewar vent tests. This is still quite conservative since a very narrow, long, deep hole will never allow as much flow as a round, shallow hole of the same area.

Therefore, if the maximum gap is 0.001 inch, the area is 0.003 square inches, which is the equivalent area of a ~0.062 inch diameter hole. A 0.001" gap with 192 bolts at ~1¾ inch spacing is highly unlikely since the flanges will be in direct contact with each other and can be inspected. However, this will be assumed for the next small dewar vent test. For the last test, an even more unrealistic 0.003 inch gap will be assumed. This is the equivalent of a ~0.107 inch diameter hole. Both these hole sizes will be scaled down from the full-scale flight SFHe Tank (~2500 liters) geometry to the small dewar SFHe Tank (~15 liters) used in the vent tests. In these tests, there will be no insulation on the small dewar SFHe Tank. If successful, the flight SFHe Tank will be insulated with four vapor-cooled shields and ~200 layers of MLI. There would be no Cryocoat or other insulation on it.

Keep in mind, that the burst disks and ground vent plumbing still must be sized and designed to adequately protect the system against over-pressure and personnel exposure during all phases of ground processing at all sites."

Ken Bollweg

September 20, 2001

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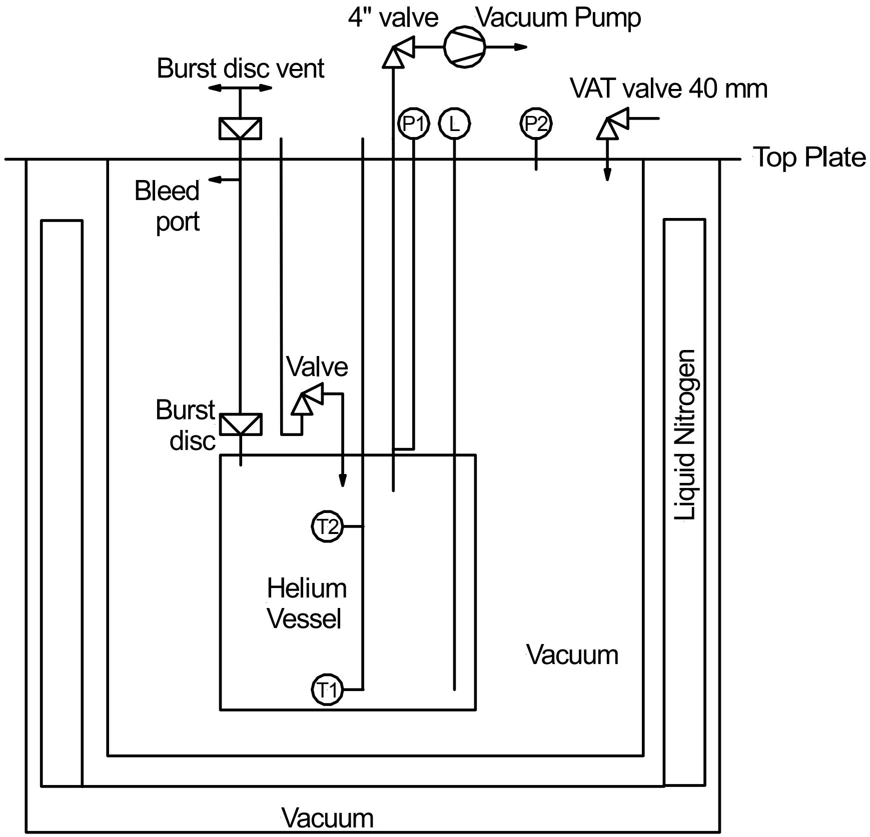
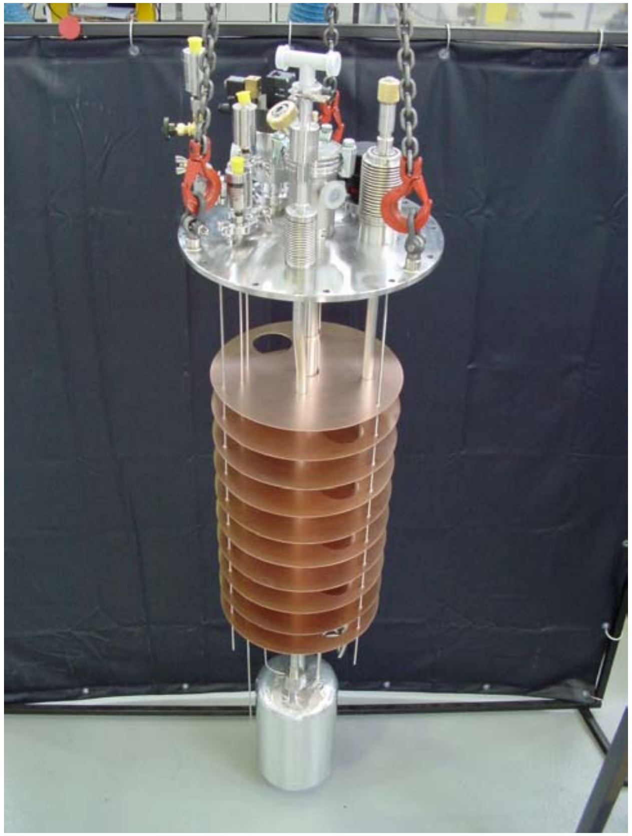
Test facility





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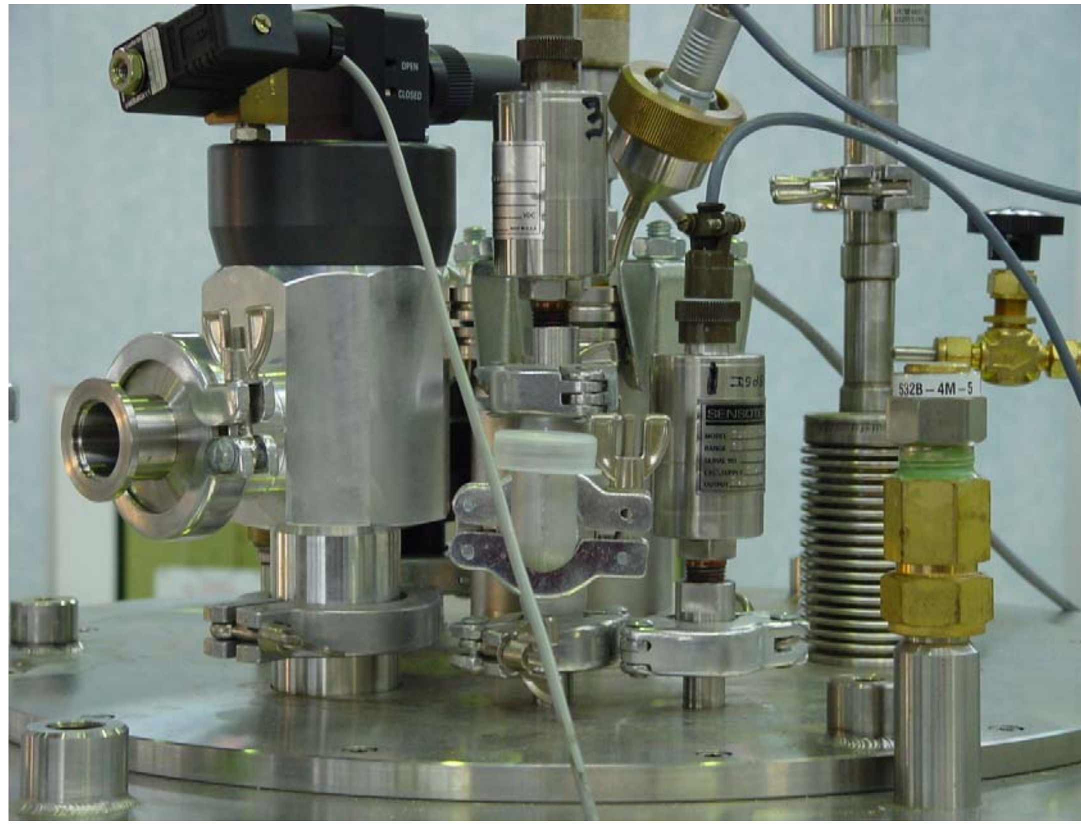
Test facility (2)

The vent can be capped with a laser-drilled orifice of the required diameter.



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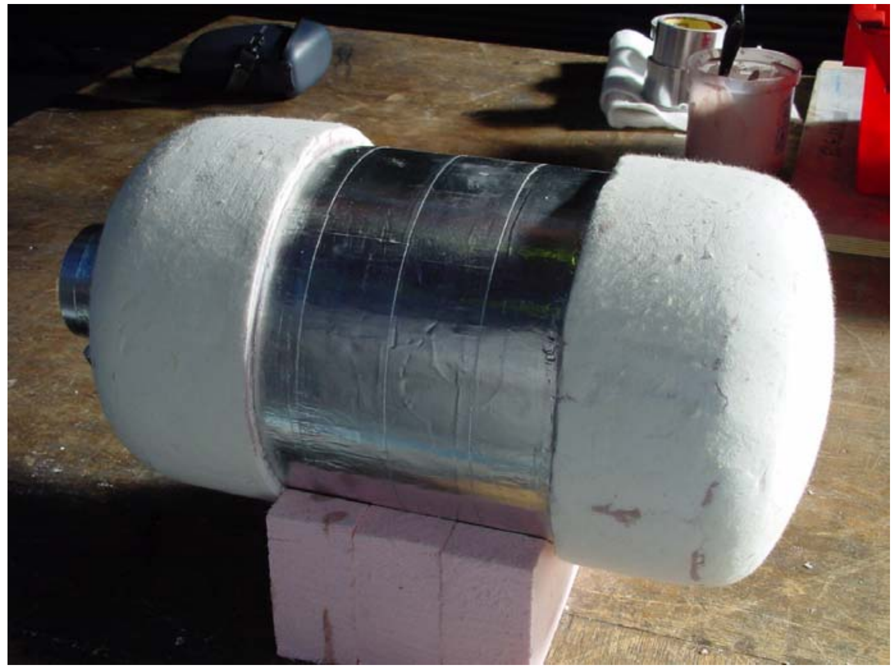
Test facility (3)



Test vessel insulated to give the same A/V ratio as the AMS helium tank.

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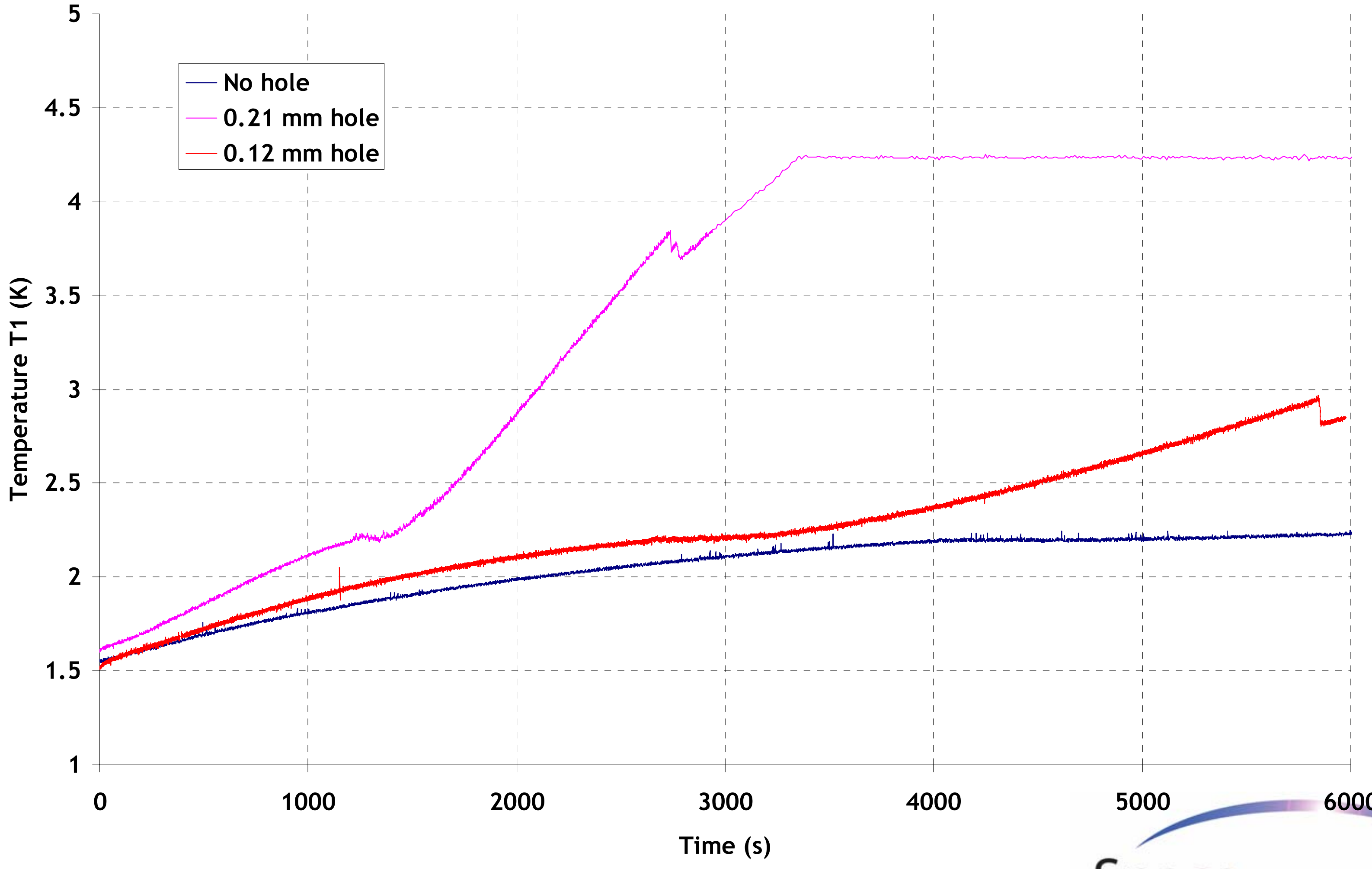
Hole size determination

MODEL HOLE DIAMETER	FULL SIZE HOLE DIAMETER	FULL SIZE O-RING GAP
0.12 mm 0.0047 inch	1.60 mm 0.063 inch	0.0264 mm x 76.2 mm 0.00104 inch x 3 inch
0.21 mm 0.0083 inch	2.79 mm 0.110 inch	0.0810 mm x 76.2 mm 0.00319 inch x 3 inch

Loss of Vacuum



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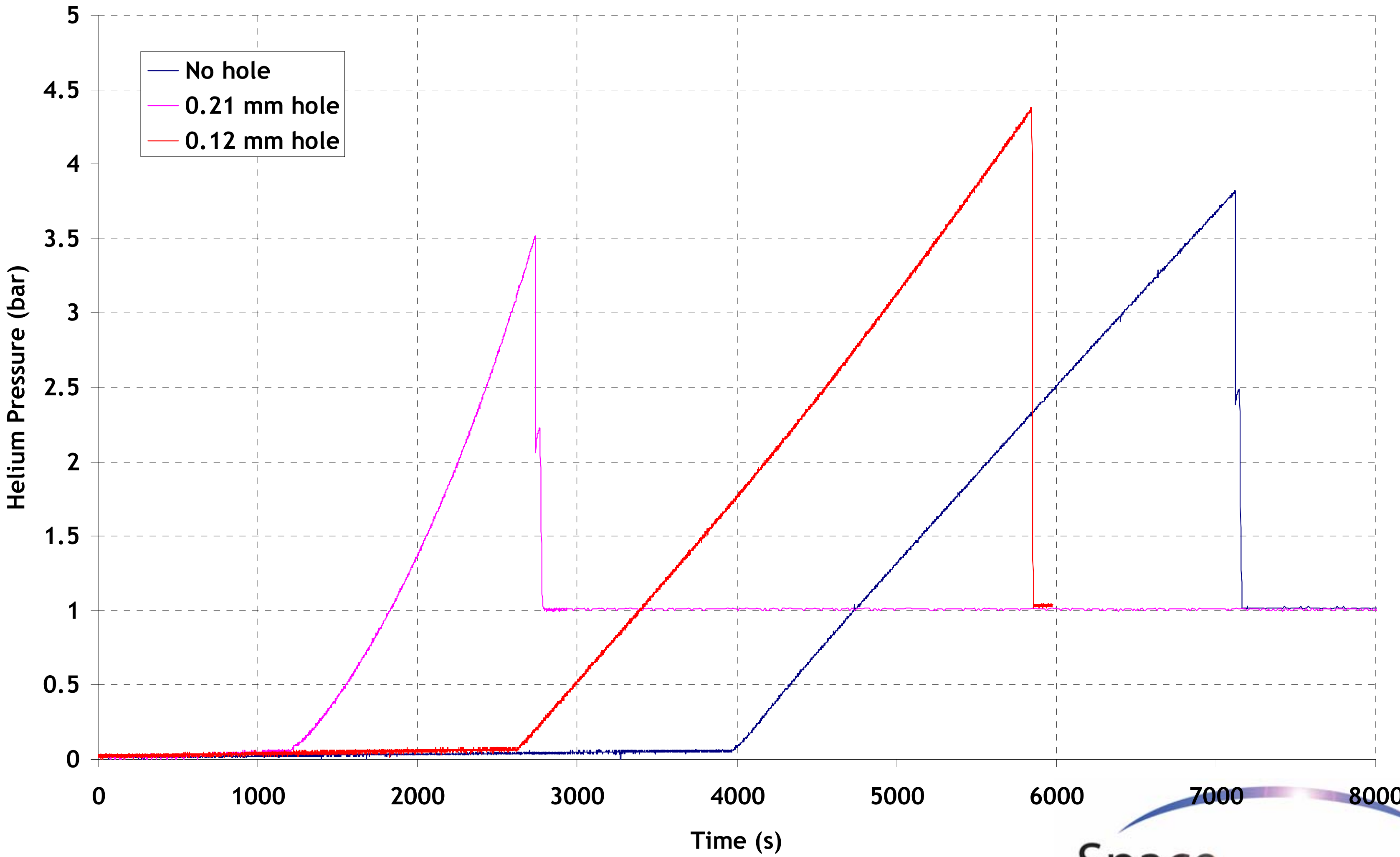
Loss of Vacuum



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Worst case scenario (1)

If:

- Two vacuum case O-rings leak at the same point;
- The gap between the vacuum case flanges exceeds 0.003 inches;
- The leak was not detected in the 12+ months before launch;
- The second leak begins to admit air only at the instant of launch;
- The background heat load on the system is 200 times worse than expected;
- The system is launched partially full or at an elevated temperature;

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Worst case scenario (2)

Then:

- The helium tank will not pressurise enough to begin venting helium until 23 minutes after launch.

And:

- This analysis is conservative because it does not account for the insulating effect of the shields and 200 layers of MLI.