

Diamond Light Source Ltd.

**Superconducting RF
Cavities
&
Helium Refrigeration**

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Diamond Light Source Ltd.



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What is Diamond Light Source?

- The largest scientific facility in the UK for 40 years.
- The National Synchrotron Facility as part of the UK science infrastructure – funded, through UKRI/STFC, by UK Government (86%), and in partnership with the Wellcome Trust (14%).
- A third generation 3 GeV synchrotron with a beam current of 300mA.
- The synchrotron is free at the point of access through a competitive application process, provided that the results are in the public domain.
- Over 7000 researchers p.a. from both academia and industry use Diamond to conduct experiments, assisted by 800 plus staff.
- 561.6m circumference.

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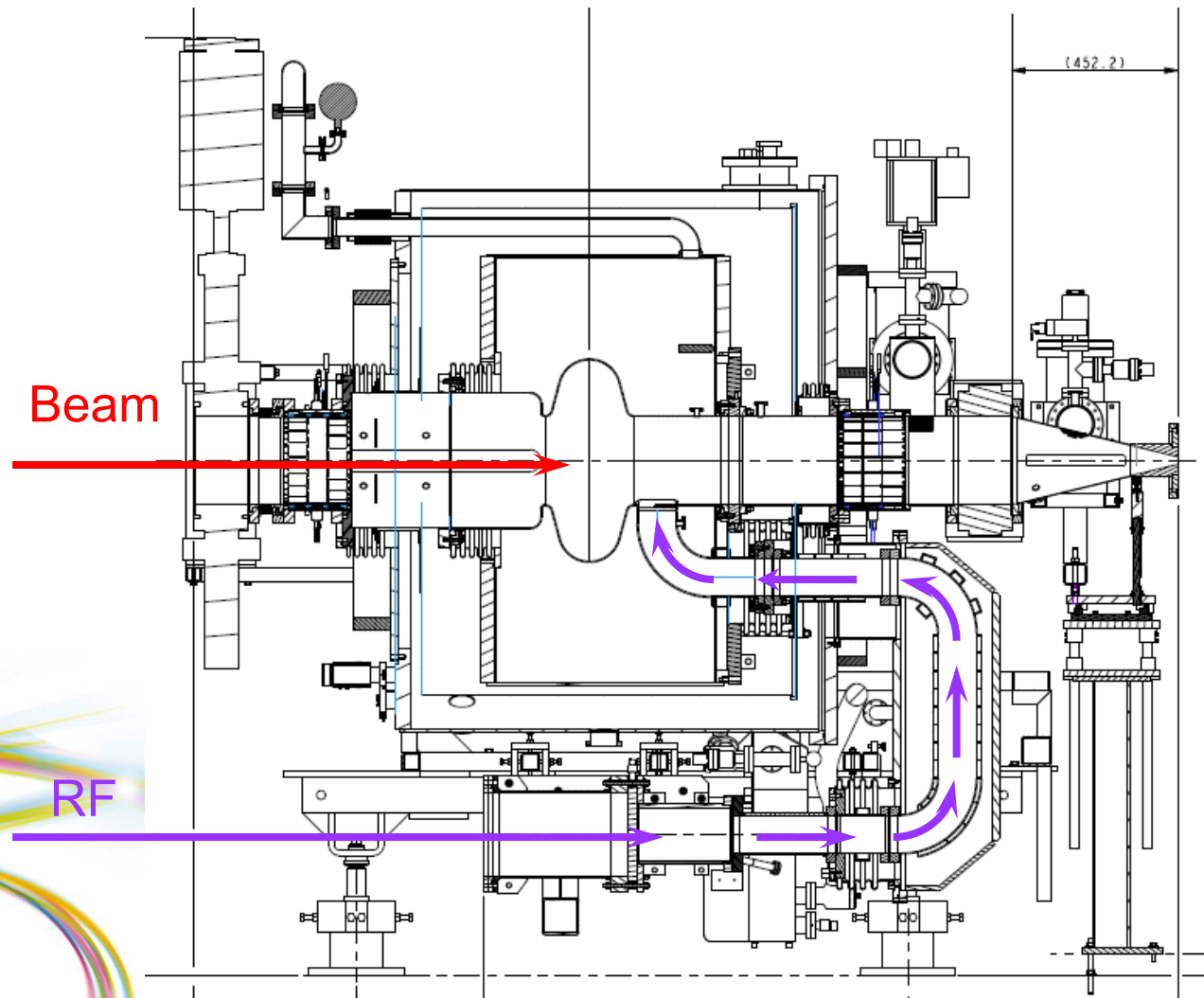
- 48-sided pentacontagon Storage Ring.
- Max. 936 electron bunches. Usually— 900 bunches, 2 ns apart, 0.62nC (0.33mA) & bunch train gap of 72ns.
- Electrons bend through dipole magnets and insertion devices, synchrotron light emitted and focused down a Beamline.
- Light is filtered and focused for either diffraction, absorption or x-ray imaging of a sample.
- Energy topped up through a series of Radio Frequency Cavities that couple energy into each bunch as they pass through.

Cavity Straight

- Space for 3 Superconducting RF modules.
- As superconducting modules, they require the cell to be bathed in LHe at all times.



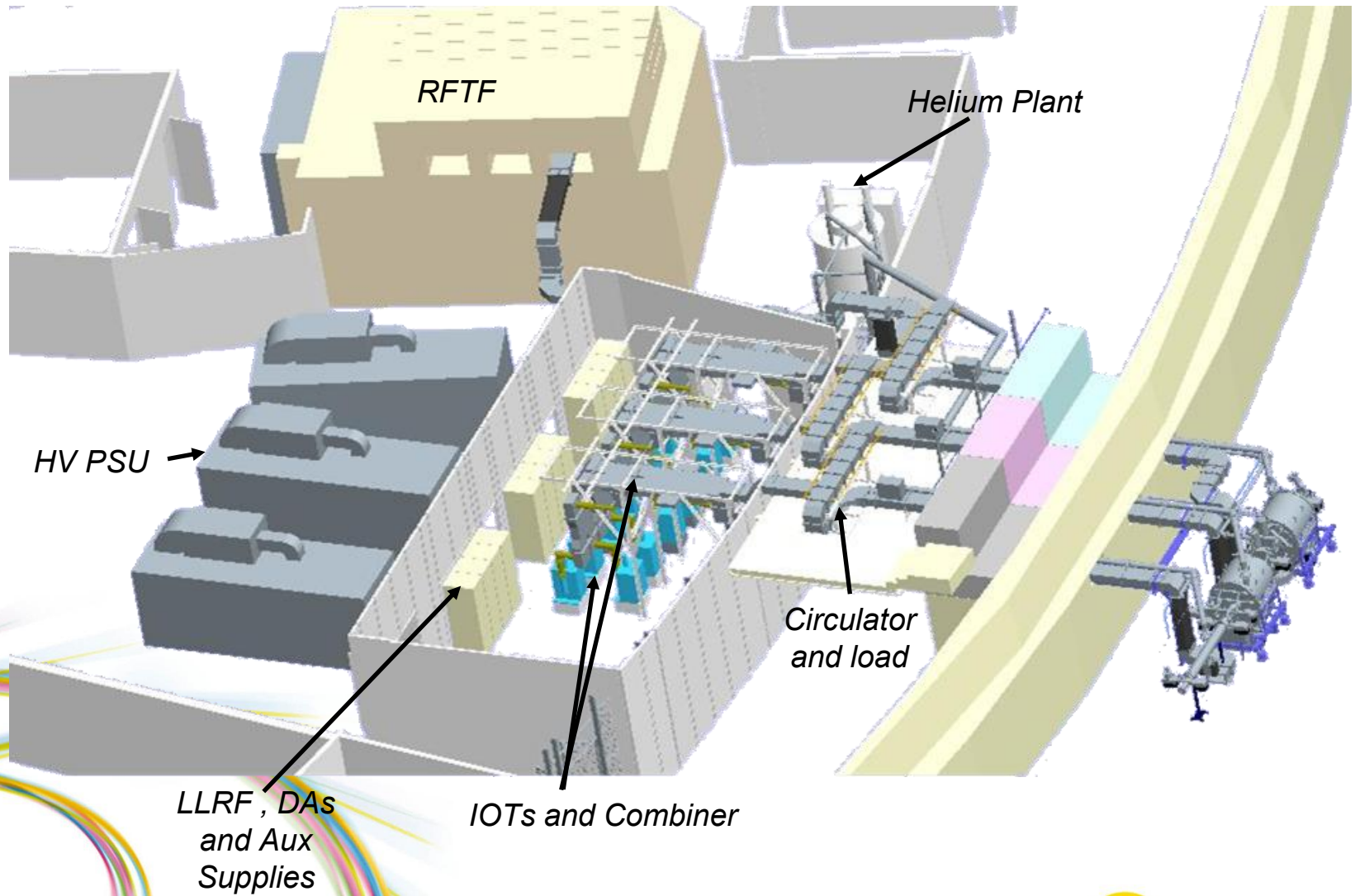
SRF Cavities



DLS RF Hall



SRF Cavities Layout

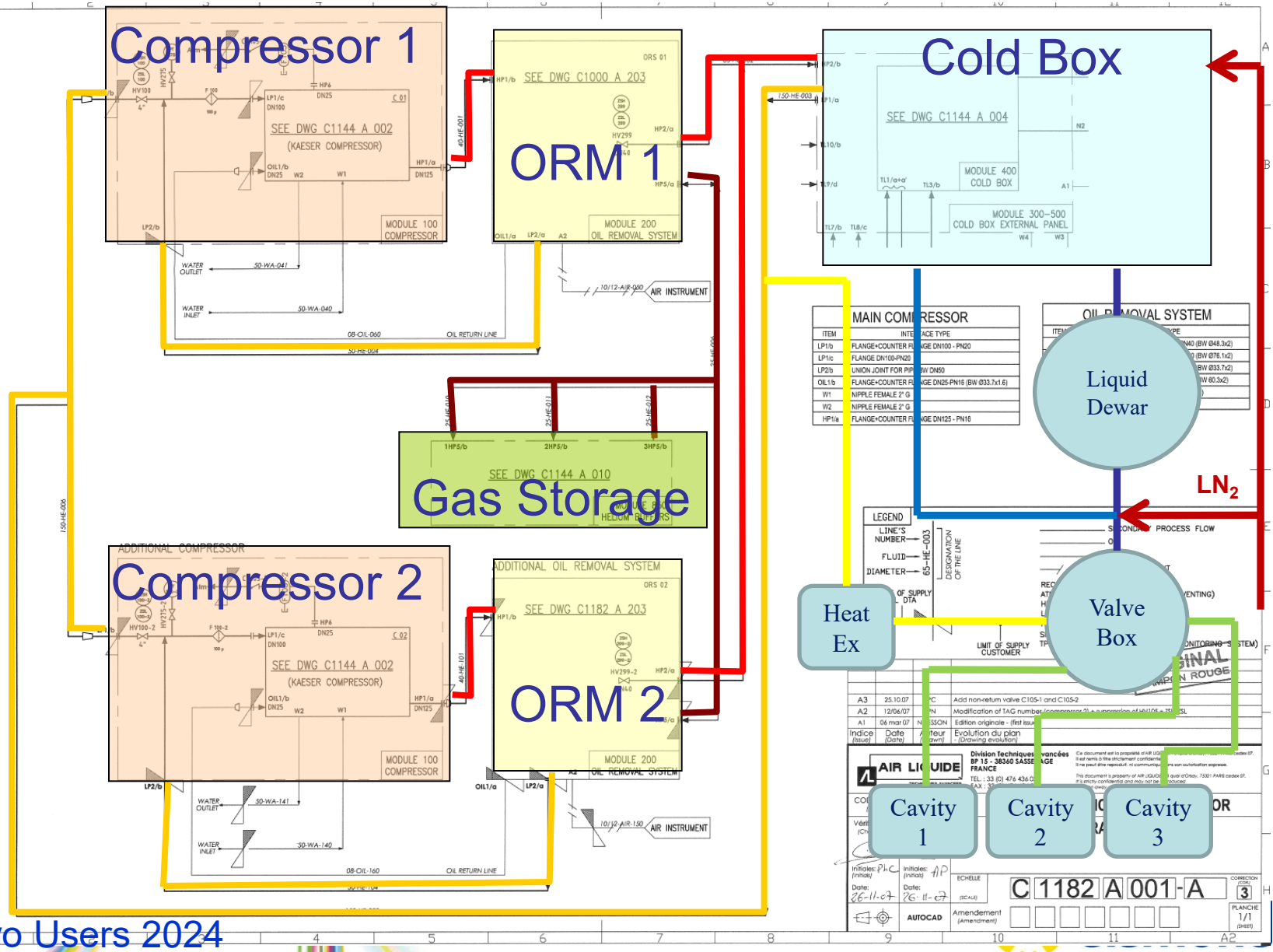


Helium Refrigeration Plant

- Air Liquide Helial 2000. Closed loop refrigerator.
- Turnkey contract.
- Originally a contracted performance of 450W.
- Design performance of 488 Watts.
- Actual final performance of 500 Watts plus 20 litres per hour.
- Diamond reliant of 24/7 operation of Helial plant.
- Plant shutdown now minimised.



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Helium Refrigeration Plant Gas Storage

- 3 vessels, 35m³ each. Total of 105m³.
- Located in the Inner Courtyard area.
- Total liquid equivalent storage of 2000 litres.
- Maximum pressure 19 barA.
- Useable volume much less (2 to 15.5 barA).
- Possible upgrade to 4th vessel.



Helium Refrigeration Compressor

- Located in dedicated room.
- Kaeser ESD 441 SFC
- Rated at 250 kW.
- Working Pressure of 14.4 Bar A.
- N₂ vaporiser added from building ring main to supply ~15m³ gas for charcoal regeneration.



Second Helium Compressor

- Identical machine & ORS added 2007.
 - Service intervals can be varied. Cavities do not have to be warmed up to service Compressor.
 - 8000 hrs for Compressor.
 - 15-18 months for Cold Box.
 - Manual switch over between compressors, means stopping Cold Box.
 - Capacity for a third compressor.
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Oil Removal Module

- Oil removal module (ORM).
- Two sets of two coalescence filters followed by a 400 litre charcoal adsorber.
- Charcoal changed every second service; at each oil change (16k hrs).
- Gas is managed on this module with pneumatic control valves.



Helium Cold Box

- Located in RF Hall.
- Three sets of two heat exchangers with two adsorbers (40K & 20K)
- Liquefaction only at 190 litres/hr.
- Designed performance of 488 Watts.
- Measured performance of 500 Watts plus 20 litres/hr.
- Controlled through PC Vue supervision software on PC.
- Spare PC as back up, although not required for operation.
- PLC output to EPICS (Diamond control system). All readings logged and archived.

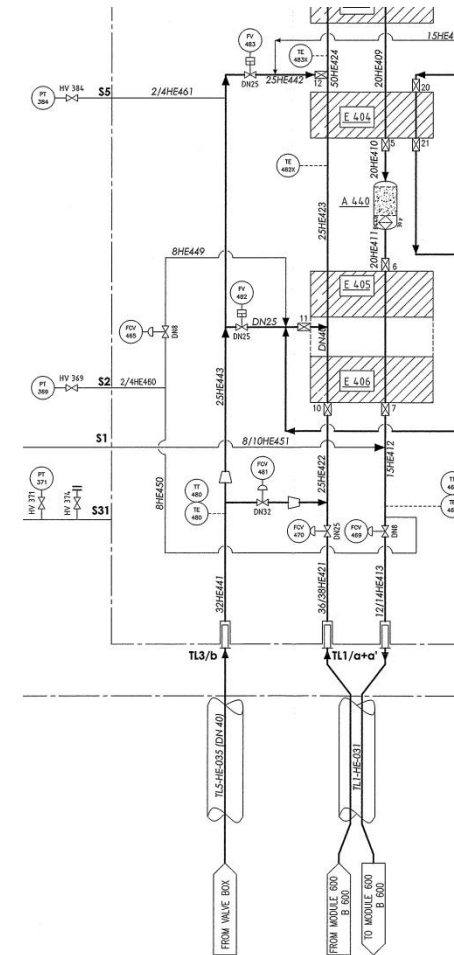




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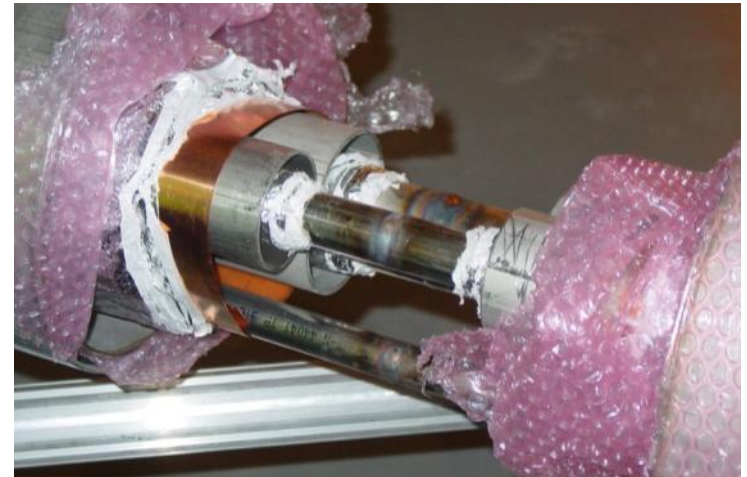
Cold Return Gas

- Heat load at 300mA beam current of 100-120 Watts per cavity.
- Plus static heat loads of ~80 Watts for the Manifold, Valve Box and Multi Channel Lines
- Cold gas is returned back to the cold box through one of 3 valves, automatically selected depending upon the gas temperature.
- Some gas bled off at the cavity to cool the RF and the beamline entries. Sent, via the Cold Box, into the compressor low pressure line.



Liquid Storage

- 2000 litre storage dewar.
- Constantly maintained at 1.3 bar A.
- Extra input available for second cold box. Now utilised for RFTF.
- Feeds MCL to Valve Box and second MCL for the RF Test Facility.



MCL to Valve Box

- Manifold to collate:
 - Liquid helium from dewar.
 - Cold gas return to cold box.
 - LN₂ from ring main supply.
 - Second gas return for second cold box, now used for Test Facility cold return.



Cavity Cryogen Management

- Valve Box with LN₂ radiation screen.
- Splits LN₂, LHe and GHe return into three multi-channel pipelines.
- Manual valve for LN₂, either fully open or fully closed.
- Pneumatic control valves for LHe level & LHe pressure control.
- Third valve (helium bypass) for warm up and cool down of cavity.



Atmospheric Heat Exchanger

- Used when warming up or cooling down cavities.
- Goes back, along 1" line to Cold Box, where it joins the low pressure line back to the compressor.



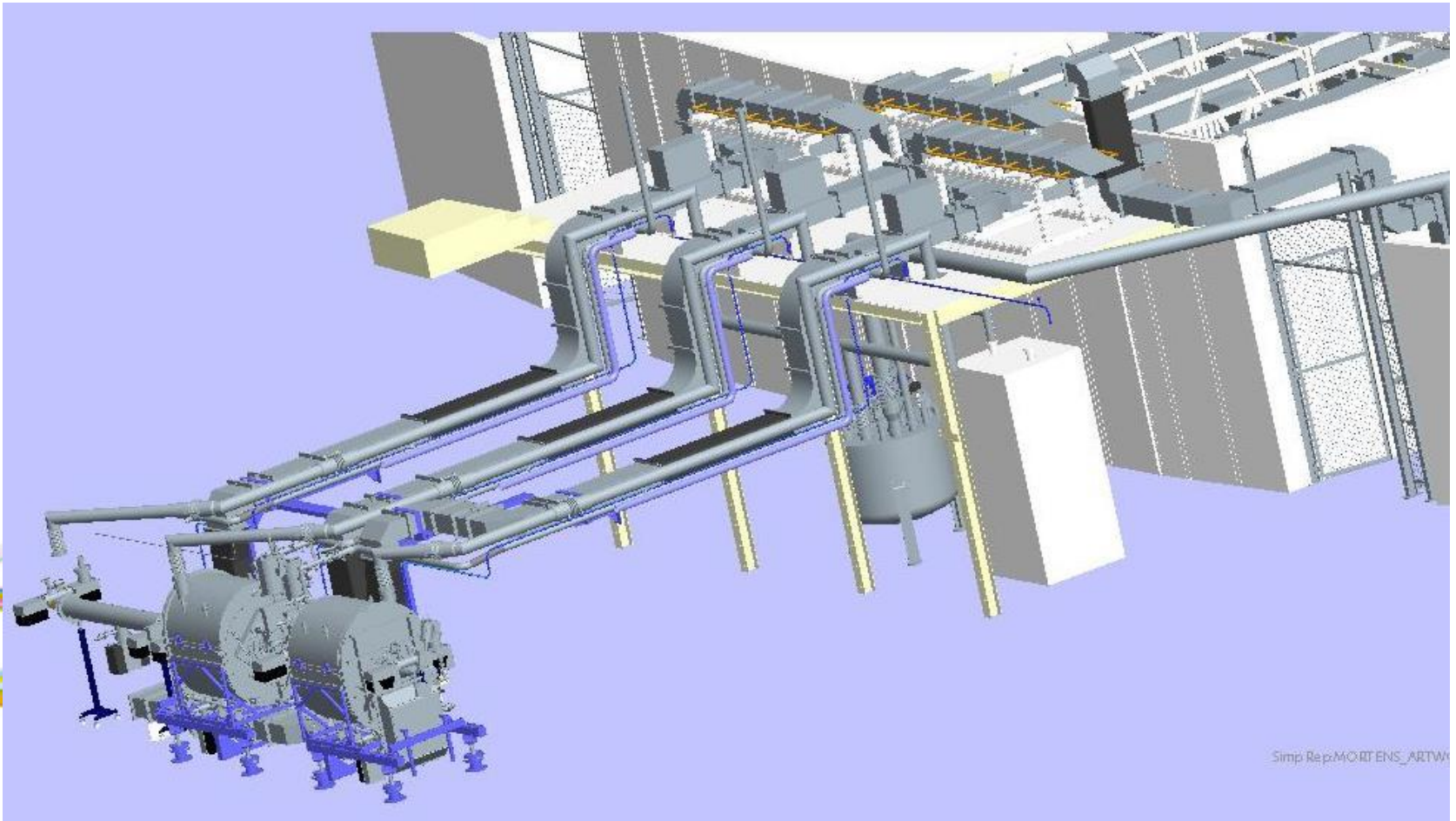
Refilling LHe

- Added in after installation to enable helium inventory to be refilled.
- Initial SIVL with pump out port and relief valve.
- Manual cryo valve to open up into heat exchanger.
- Monitored from PC.
- Enables top up whilst running.
- Prevents depressurising dewar to add liquid.

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MCLs - Valve Box to Cavities

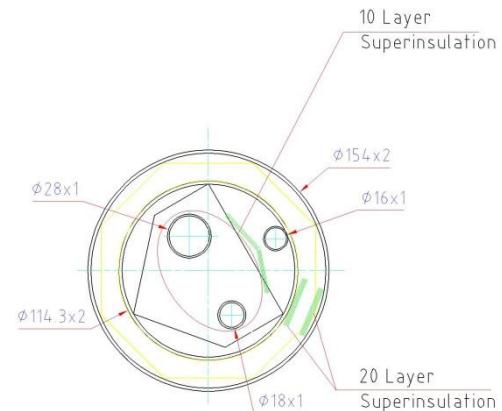
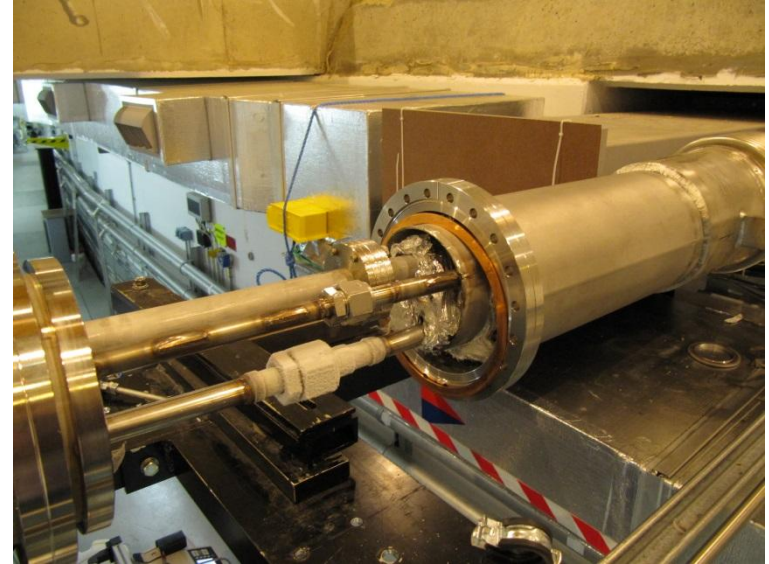
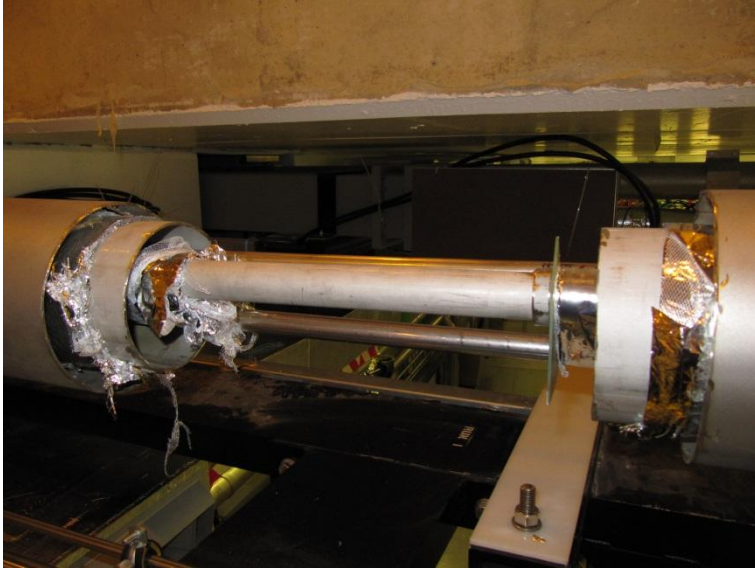


MCLs - Valve Box to Cavities

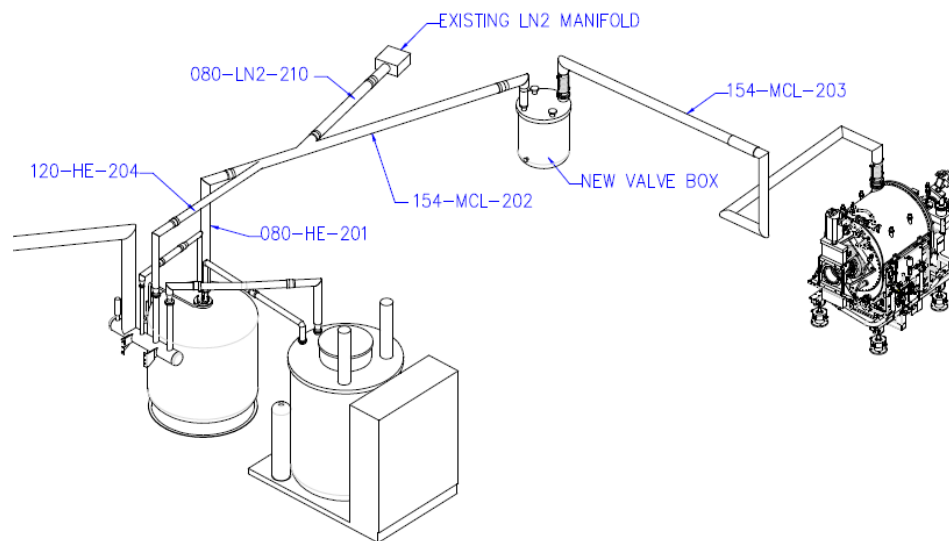
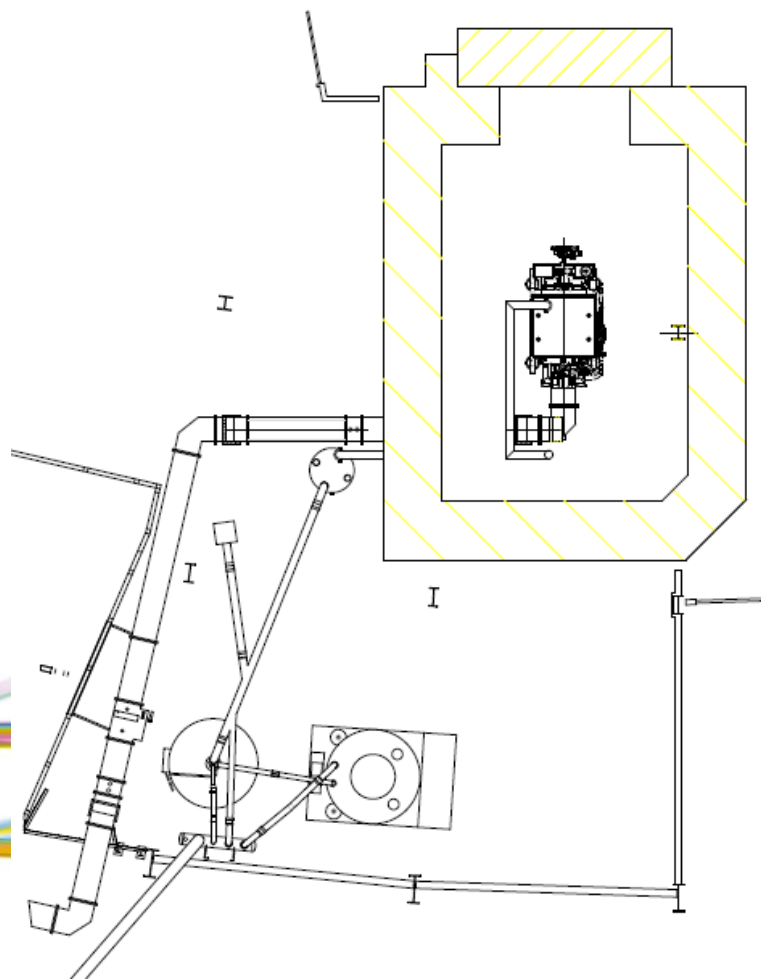
- Initially installed as one piece as finances dictated.
- Modified in 2012 to separate to help with removal & installation of cavities.



MCLs - Valve Box to Cavities



RF Test Facility



RF Test Facility



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Reliability & Problems

- The helium plant has been very reliable.
- The large majority of Cold Box trips have been related to utility delivery (water, compressed air and power).
- Separate water plant & air compressor added in July 2010.



Reliability & Problems – Cold Restart

Restarting the Compressor can be an issue, often having to depressurise the LP line if the Compressor has tripped as well. This can take a few tries.

Problem:

The first action is to depressurise the cold box, by opening FV399 (return to compressor). This allows too much flow through to the compressor and trips the compressor LP line (PT275).

Solution:

Depressurise the internal circuits on the HP side first back to the compressor. Then open the JT bypass (FCV465) to let the return side depressurise.

Or.....

Wait until the cold box depressurises through HV386, which takes about 30 minutes.

Important to get the HP side down to < 2.5 barA, otherwise when FV399 opens, the LP line on the Compressor will trip.

Start Up from Cold

Problem:

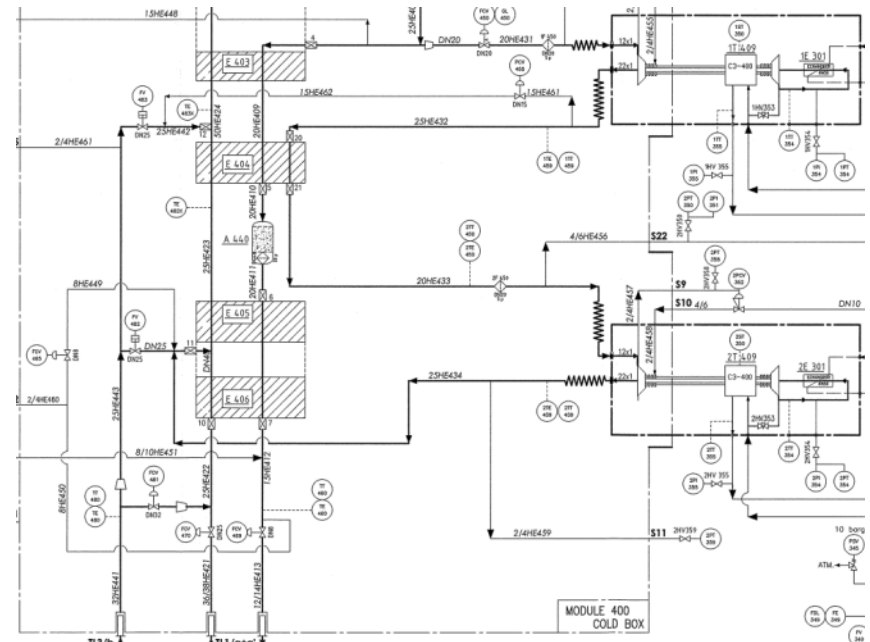
When restarting cold box at a cold temperature after a failure, cold box trips again on T2 outlet pressure too high.

Solution:

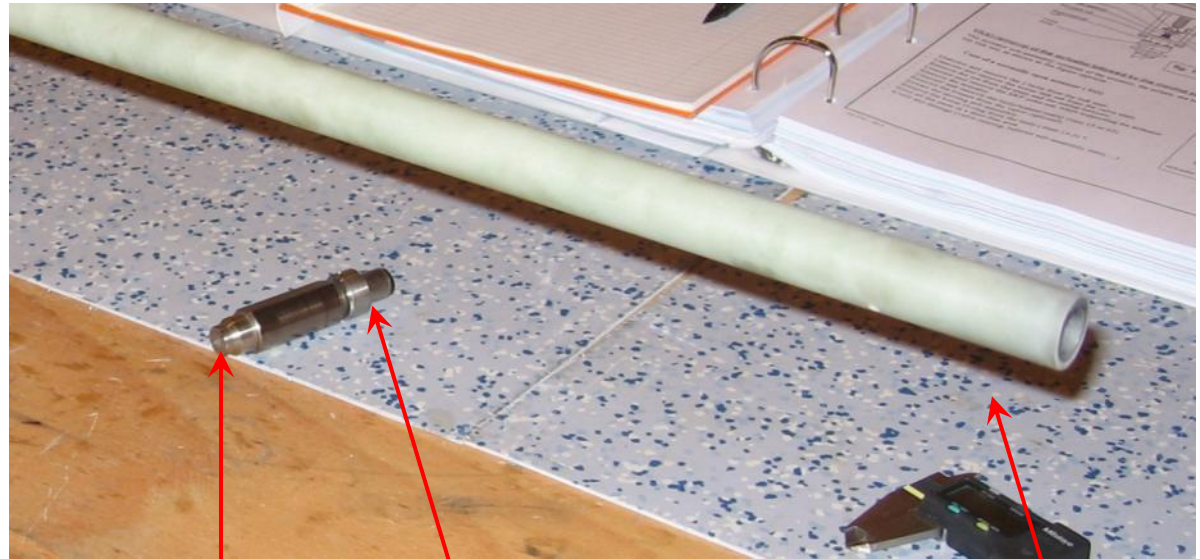
At beginning of restart, manually reduce the turbine attenuation (ATM) to 0.85.

FCV465 (JT bypass) high point reset
from 65% to 50%.

When additional compressor added, ATLP introduced. ATLP looks at the PT275 and attenuates the turbines when the LP rises.



FV410 Breakage (March 09)



Valve
seal

Aluminium end cap that
should be attached to the
end of the GRP rod.

End of GRP
extension
rod

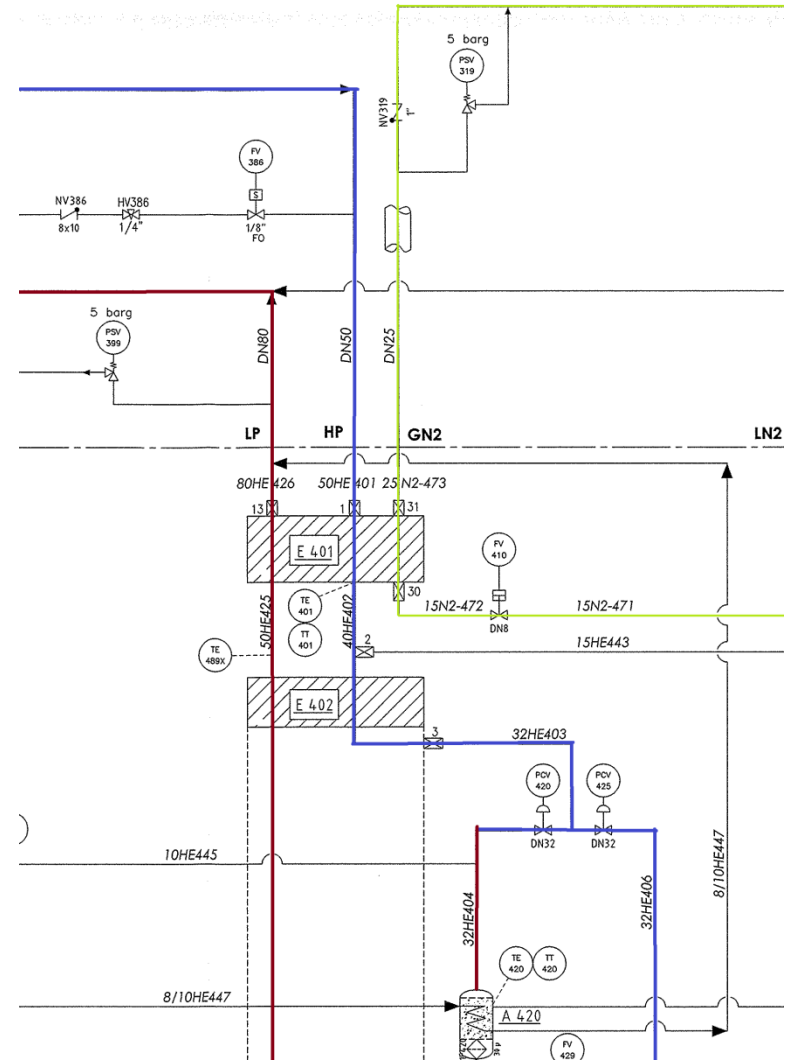


Damaged
bellows

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Reliability & Problems

- Contamination.....!!!
- Three instances of contamination within the Cold Box.
- Initially seen as a rising temperature of TT401 and TT319 dipping below 270K.
- Consistently monitor TT319 to look for an indication of



Reliability & Problems

- Temporary fix.....
- To continue running, without warming up cavities.
- Heat guns with control placed at nitrogen exit of E401.
- TT319 disconnected.
Reconnected to spare sensor and positioned further up exhaust line.
- Longest run like this was 16 weeks.
- Trap contaminants in Cold Box, then release to atmosphere.



Reliability & Problems - PT275 Instability

PT275 usual position

PT275



On installation of additional compressor

New bellows

PT275

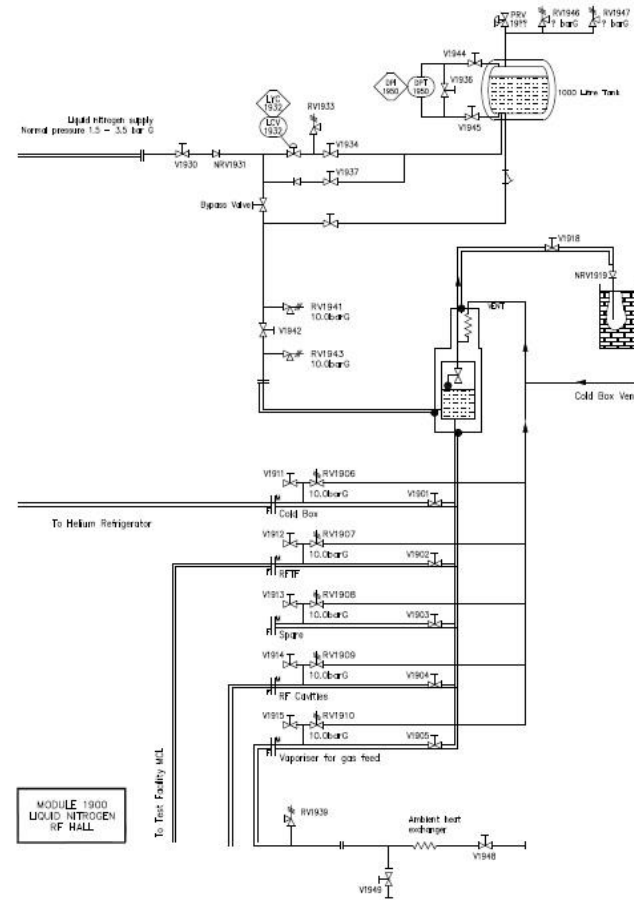


After moving from original location to prove theory.

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Liquid Nitrogen

- DLS ring main of LN₂ SIVL pipework.
- Branch off to feed 1000 L tank near RF Hall.
- Fed into RF Hall through phase separator.
- In RF Hall, manifold with five outputs:
 - 1) RF Cavities.
 - 2) Helium Plant.
 - 3) Gas generation.
 - 4) RF Test Facility.
 - 5) Spare, used for decanting.



Liquid Nitrogen

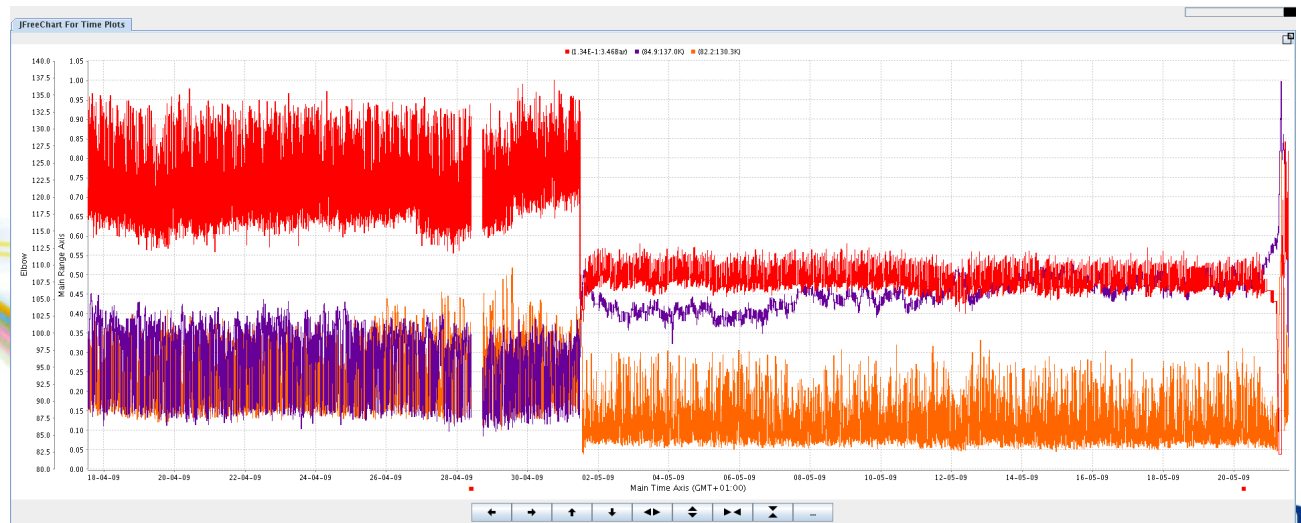


Liquid Nitrogen – Pressure Stability

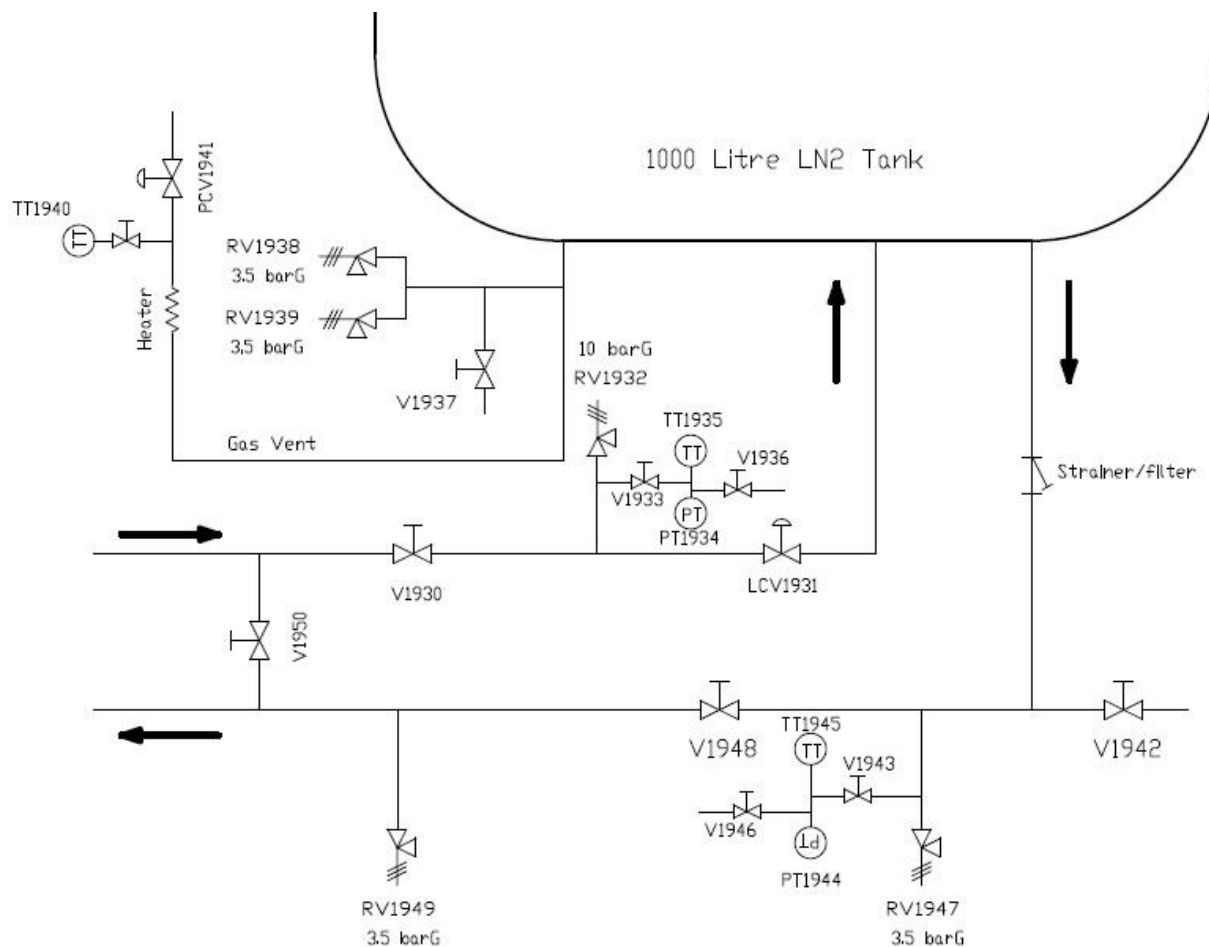
- LN₂ system designed to deliver at constant 2 barG. Maintained by relief devices on bulk storage vessels.
- Large pressure swings observed from 1.4 barG to more than 3.5 barG.
- Initially fitted relief devices which kept lifting.
- Fix: to re-engineer the 1000 L tank to act as a phase separator.
- Result:
- To keep LN₂ delivery pressure to 1.5 ± 0.1 barG.
- Protect the cavities from any high pressure events and stop the relief valves opening so much.
- To minimise cavity tuner movement.

Cavity 1 & 2
“Elbow Near”
temperature
variation before
and after
operation of
1000L tank

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Liquid Nitrogen



Liquid Nitrogen



Thank you for your attention.
Are there any questions
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