Liquid Hydrogen Delivery System

M Hills (STFC, RAL)
T Bradshaw (STFC, RAL)
M Courthold (STFC, RAL)
S Ishimoto (KEK)
A Muir (STFC, DL)
I Mullacrane (STFC, DL)
S Postlethwaite (STFC, DL)
J Tarrant (STFC, RAL)
P Warburton (STFC, DL)

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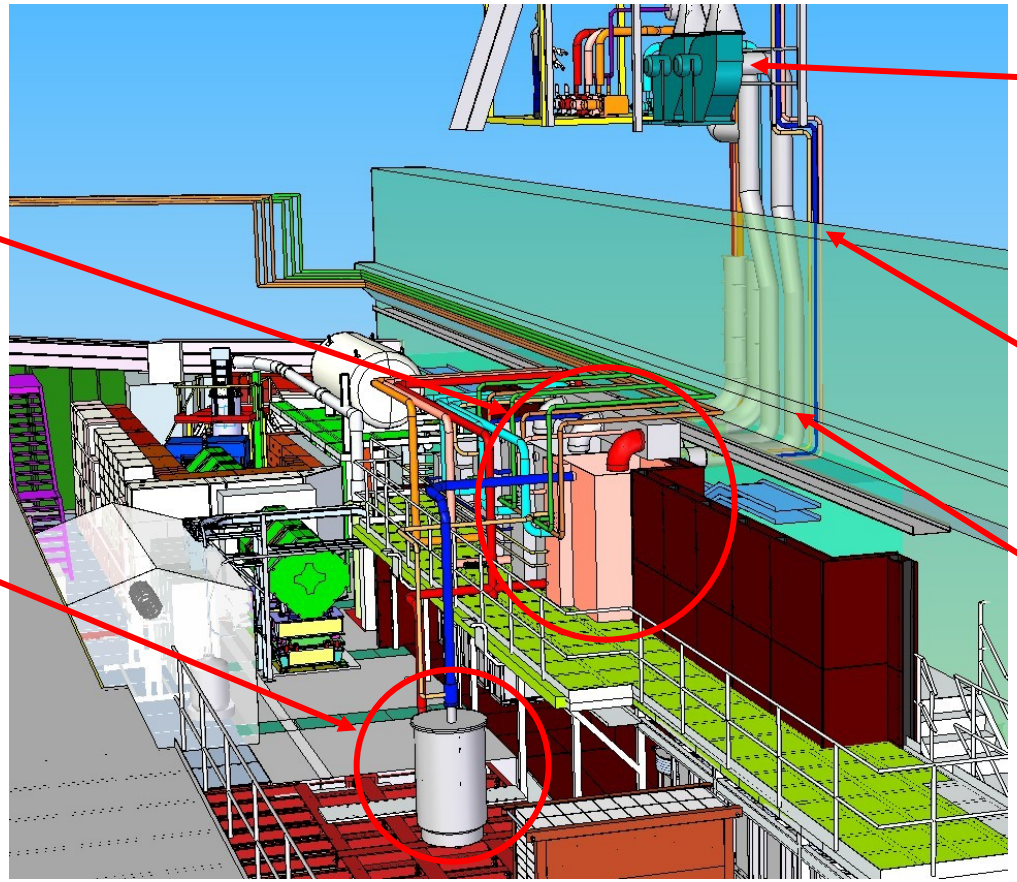
Hydrogen System



Fans

Gas Panel Enclosures

Relief lines

Test Cryostat

Ventilation ducts

Installation

- Gas Panel, Cryostat and Transfer Line delivered to the MICE Hall and installed in December 2010
- Work on services followed in early 2011
  - South mezzanine framework
  - Gas supply piping
  - Wiring to Gas Panel and Cryostat
- Something to build around for other sub-systems (vacuum, ventilation, etc.)...
- Now configured for He testing

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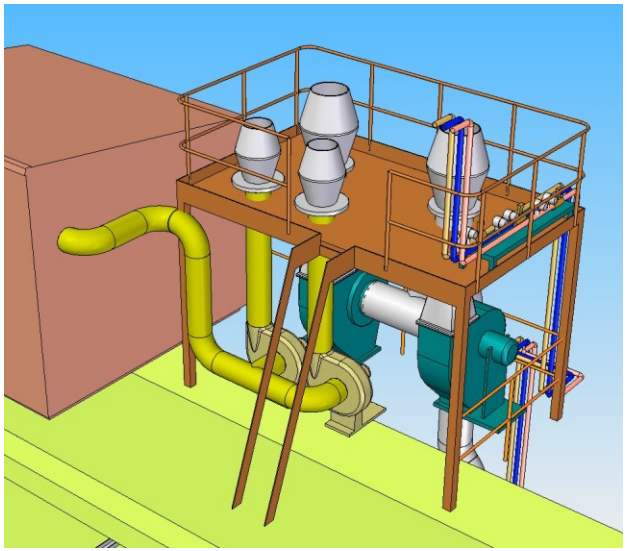
Control System
(I Mullacrane, P Warburton)

- System A controls rack and 'common' rack installed in the Hydrogen Local Control Room (HLCR)
- UPS and associated battery cabinet also installed. The batteries are rated to keep the control rack, H2 detection and ventilation system running for 2 hours (controlled vent of the system can be performed in <1hr).
- Fire safety changes to Hydrogen Local Control Room (HLCR) in hand
- Switch panels installed for vacuum pumps and fans
- All instrumentation proven
- First control sequences written

Ventilation System



- Fans and stacks installed on hall roof
- Smaller fans serve vacuum enclosure (also a Hydrogen Zone 2)
- All ductwork installed with only final welding remaining

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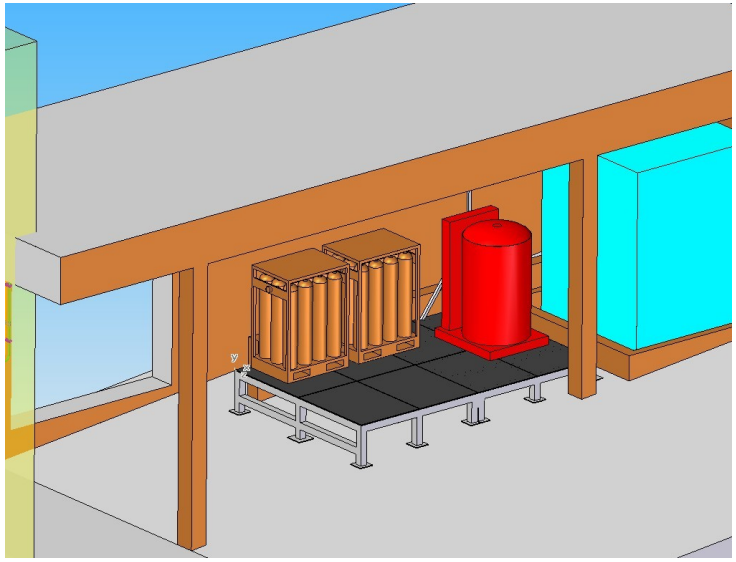
H2 Charging Station

- Hydrogen "Charging Station" (right) installed below south mezzanine
- Will provide a ventilated area for hydrogen bottles during the periods when the hydride beds are being filled
- Hydrogen bottles will only be brought into the hall during charging. This means for 1-2 days and (hopefully) once per bed.

Vacuum System

- Pump enclosure erected on hall roof
- Detail design of internal and external pipe routes complete
  - First parts delivered last month
- Enclosure ventilated by dedicated fans, which combine with spark proof heaters to maintain the enclosure within acceptable temperature limits for the pumps
  - This requires a dedicated control system which is currently on order
- Purge pump and some instrumentation already commissioned with the control system

External Helium and Nitrogen Store



- Construction underway
- Made up of 3 removable sections to accommodate future delivery of the large MICE modules
- First section is installed with other two to follow in July
- Gas panels for connection of the bottle packs have been manufacture and delivered
  - Will be fitted with second platform section
- Longer term solution for nitrogen supply (a “CryoEase” Dewar) is being investigated with ISIS

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Testing Preparations

- Cryostat vacuum system established
- Cryocooler connected and cooling water supply commissioned (some problems with running the water supply to only one compressor and with instrumentation)

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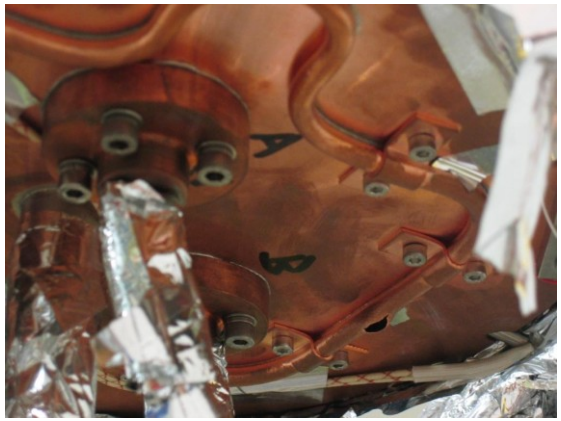
Commissioning

- First attempt at a cooldown had to be cut short due to a burst pre-cool pipe
  - This was probably due to frozen N2 in the line that expanded during a warm-up
  - Must ensure that pre-cool line is purged and evacuated before blanking off in future
- During second attempt found leaking joints and failed burst discs
  - Burst disc is still a concern as the true cause of failure has not been established



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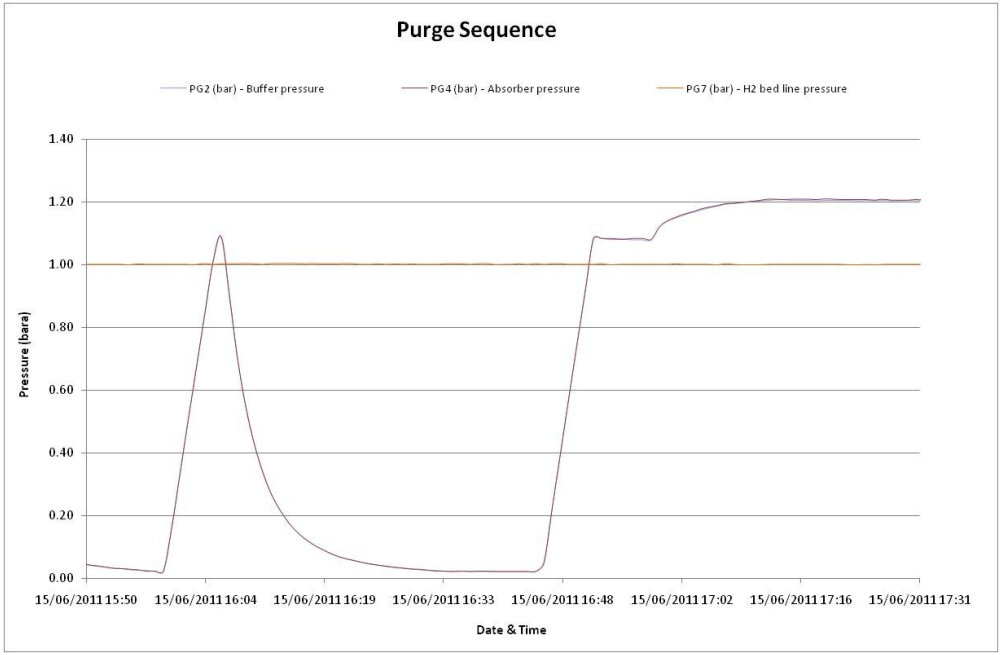
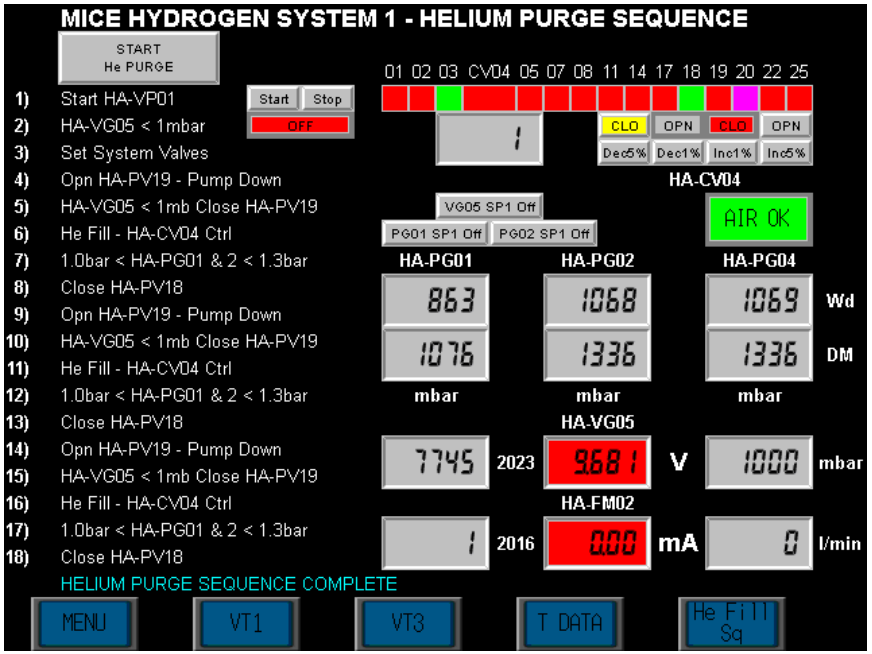
Purge Test





- Automated sequence which purges the entire system 3 times prior to operation

- Demonstrates:
  - PLC programming
  - Pressure and temperature instrumentation
  - Purge pump operation

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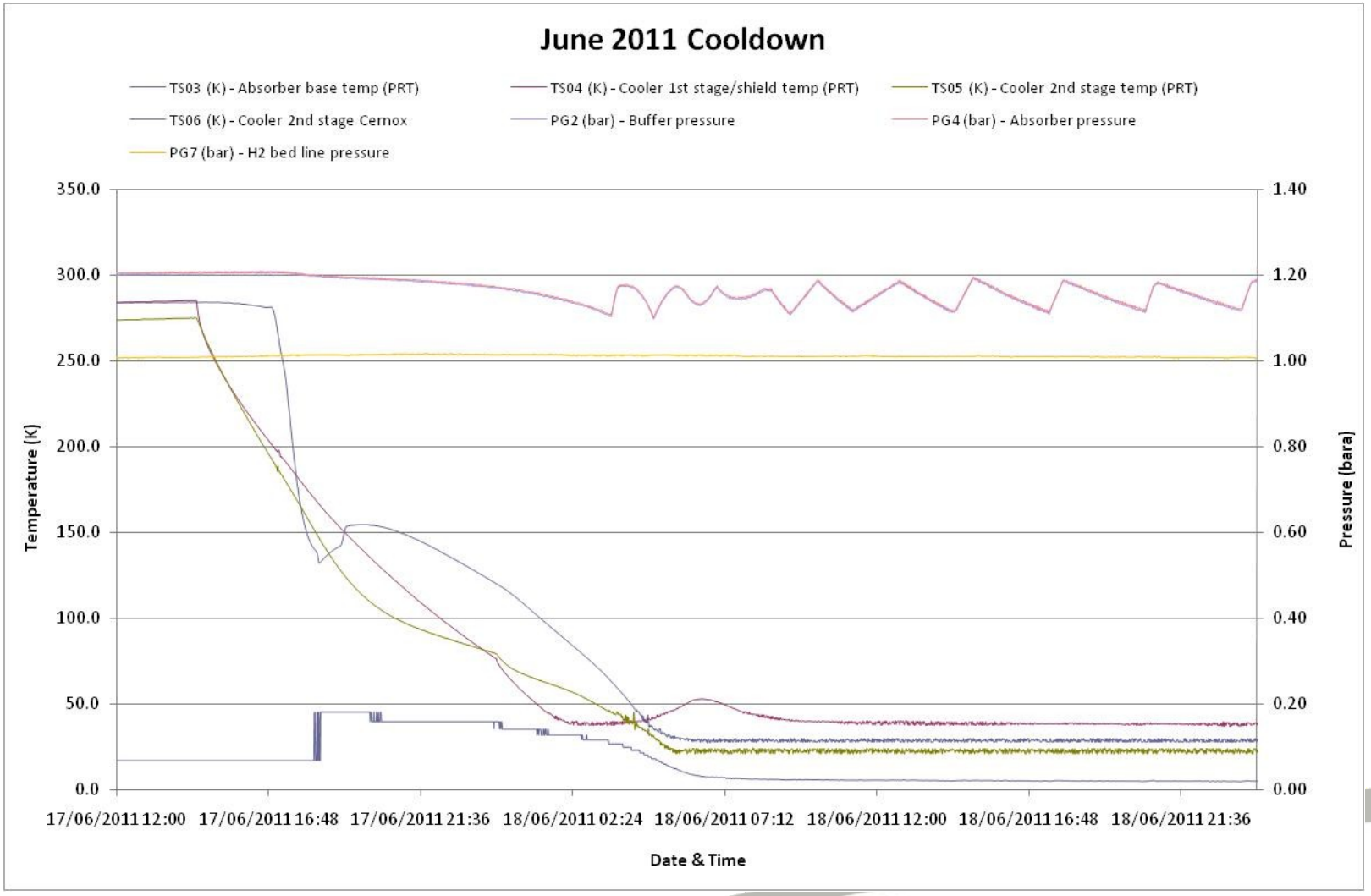
Cooldown



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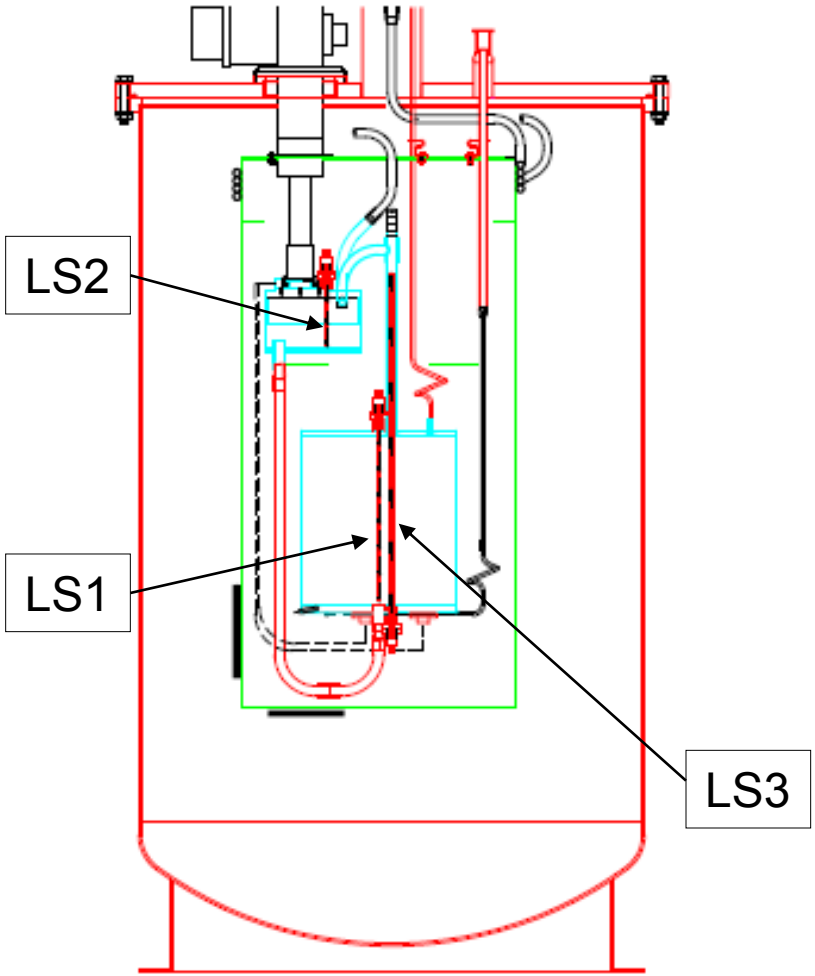
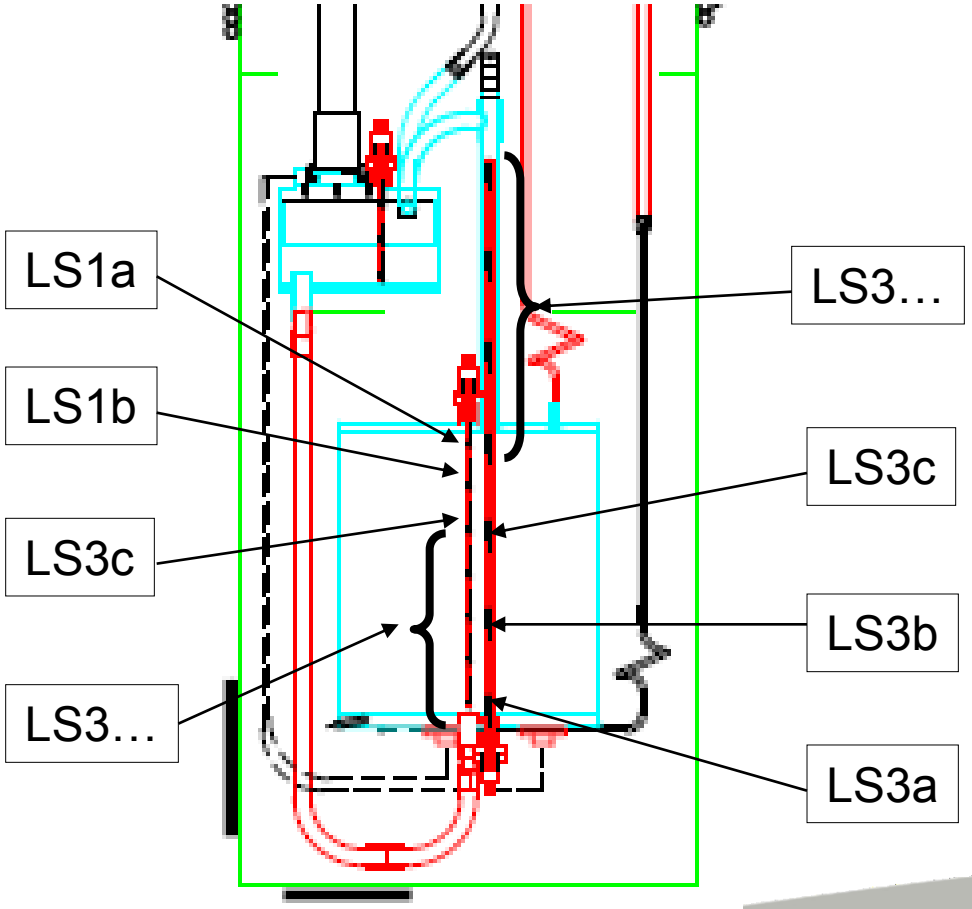
Level Sensors





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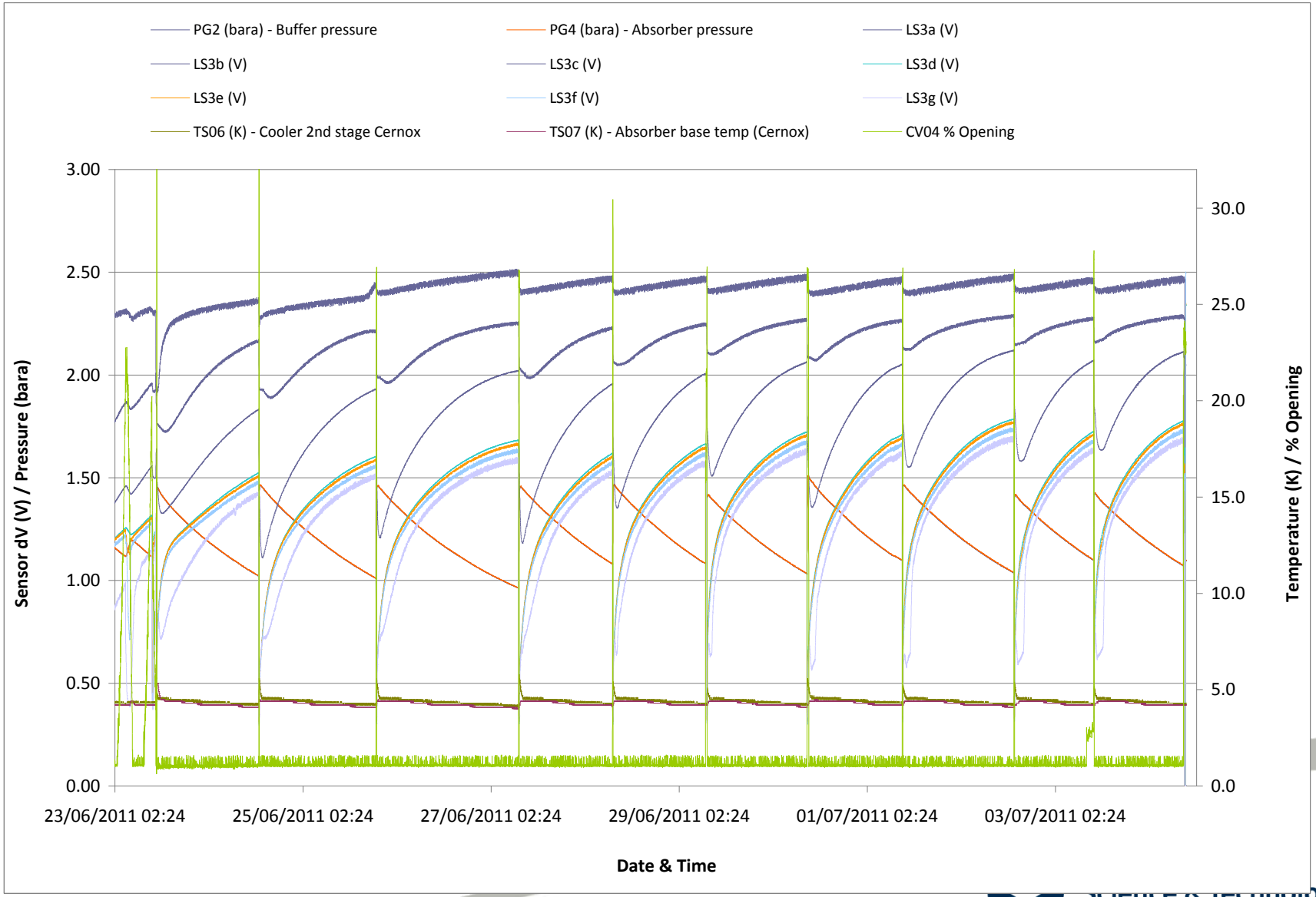
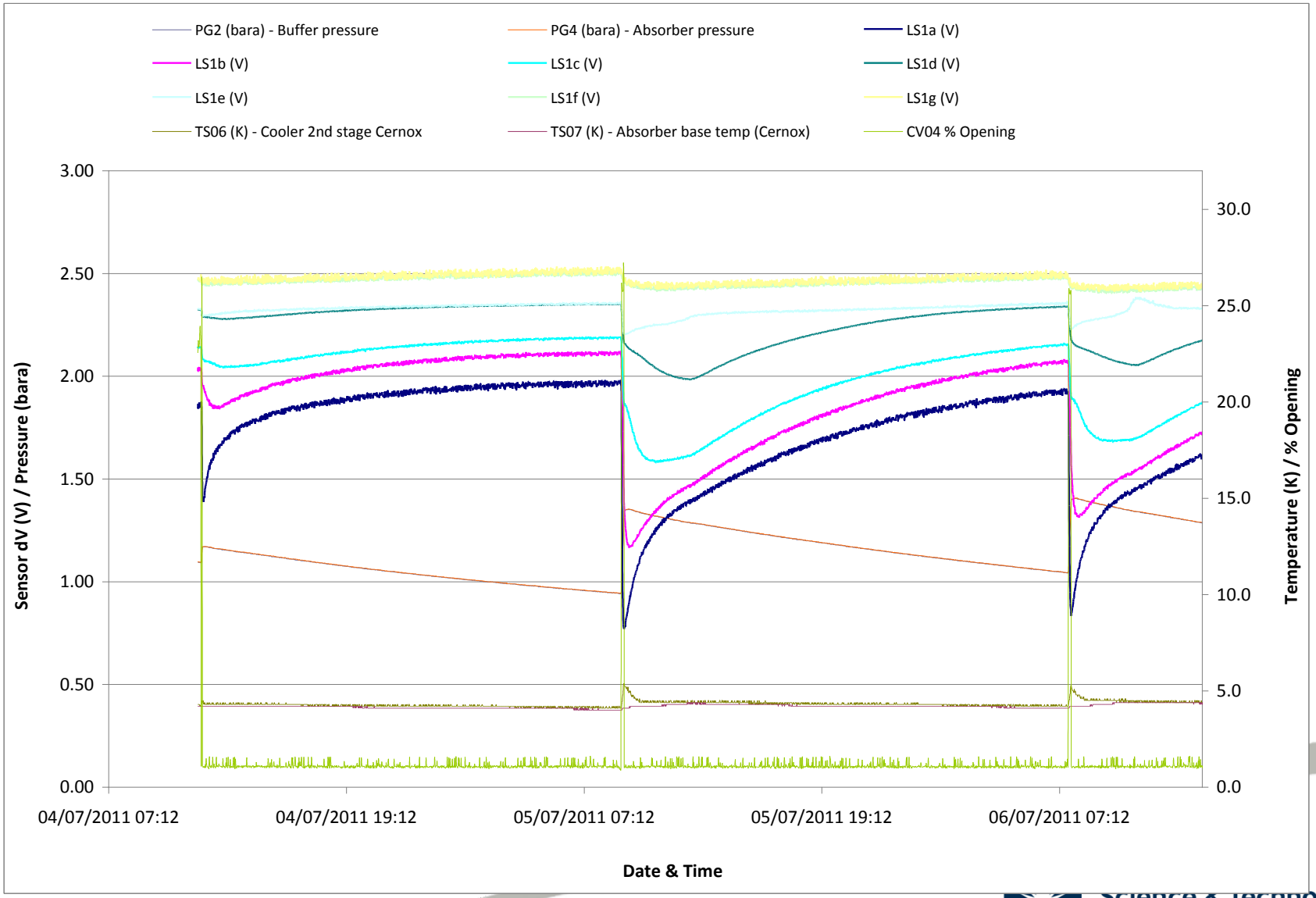
LS3 History


PG2 (bara) - Buffer pressure
PG4 (bara) - Absorber pressure
LS3a (V)
LS3b (V)
LS3c (V)
LS3d (V)
LS3e (V)
LS3f (V)
LS3g (V)
TS06 (K) - Cooler 2nd stage Cernox
TS07 (K) - Absorber base temp (Cernox)
CV04 % Opening
Sensor dV (V) / Pressure (bara)
Temperature (K) / % Opening
3.00
2.50
2.00
1.50
1.00
0.50
0.00
30.0
25.0
20.0
15.0
10.0
5.0
0.0
23/06/2011 02:24
25/06/2011 02:24
27/06/2011 02:24
29/06/2011 02:24
01/07/2011 02:24
03/07/2011 02:24
Date & Time

LS1 History


PG2 (bara) - Buffer pressure
PG4 (bara) - Absorber pressure
LS1a (V)
LS1b (V)
LS1c (V)
LS1d (V)
LS1e (V)
LS1f (V)
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3.00
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0.50
0.00
30.0
25.0
20.0
15.0
10.0
5.0
0.0
04/07/2011 07:12
04/07/2011 19:12
05/07/2011 07:12
05/07/2011 19:12
06/07/2011 07:12
Date & Time

Testing Status

- Cryostat is stable at 4K
- Some helium liquefaction, but rate difficult to quantify at this stage
- Will run the test as long as possible before EMR running prevents hall access
  - Confirm long term stability
  - Give water system an extended test
  - Investigate level sensor performance more fully
  - Collect other data to estimate liquefaction rate
  - Test warm-up sequence

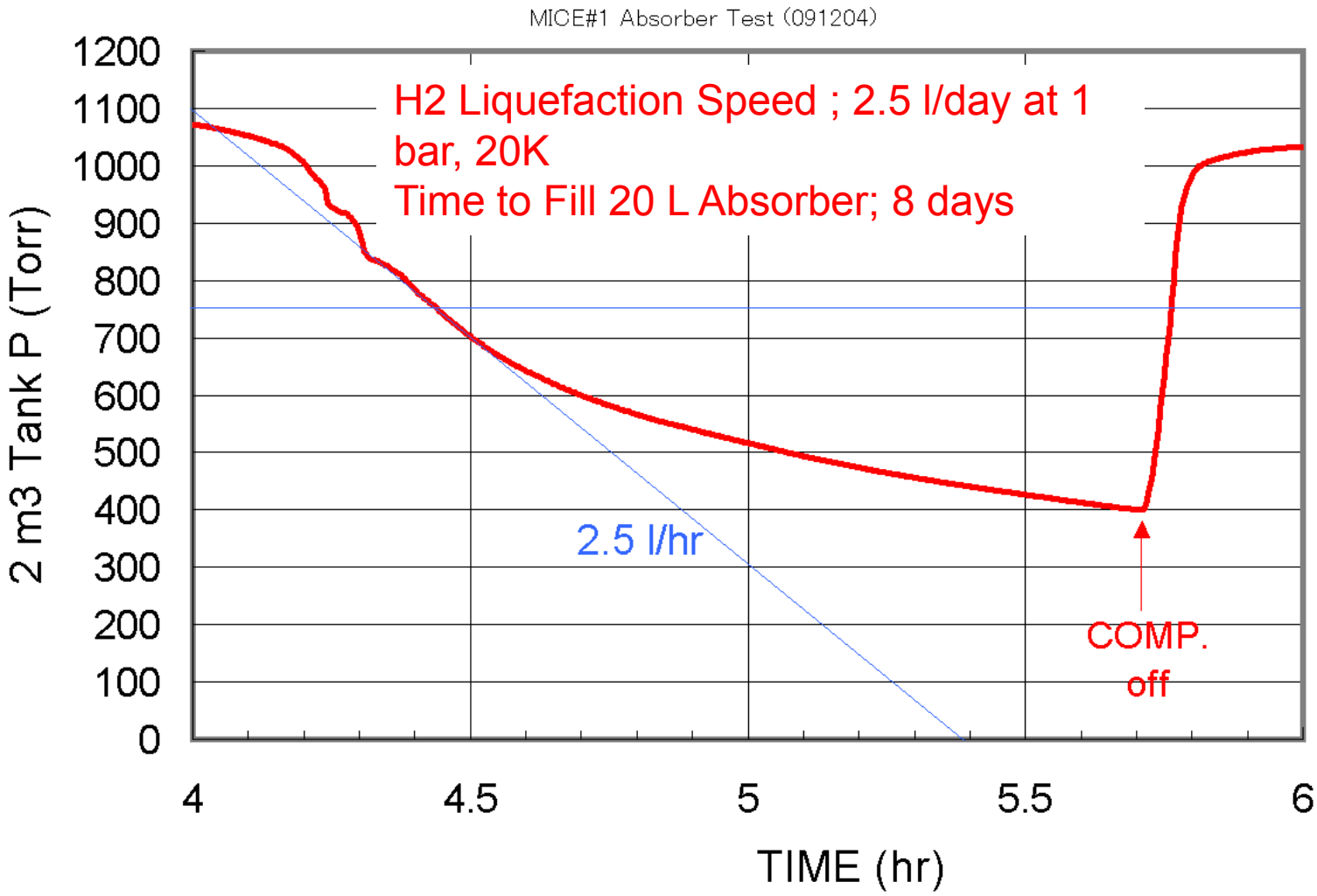
Safety

- UPS case agreed within the project and system now installed
- Ventilation system and all fans have been shown to comply with DSEAR (confirmed with external consultation)
- IEC61508 compliance being developed with help of a specialist company (Functional Safety Consultancy Ltd)
- Discussions on pre-operation safety review continuing with ISIS and it is converging on an appropriate format and membership
  - Work on this has been held back at the expense of the recent test programme, but the focus will shift back in the next month
- Safety principles have been well established for some time, but it is important that the detail of their implementation is approved

The Absorbers

- 1st Absorber has been delivered to RAL
- 2nd is ready to cooling down after final set-up.
- But, no-crane, broken shutters and limited electric power, because of the East Japan Earthquake/Tsunami/Fukushima.
- The recovery schedule of crane and shutters and electric power are not yet announced from KEK. ~ months?

Hydrogen Liquefaction



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STEP IV Running Thoughts

- Absorber cooldown time: 1 day with LN2 pre-cool (both for KEK Absorber and R&D system)
- Helium liquefaction should be possible, but will take many days (exact time TBC)
- Filling from an LHe Dewar will require removal of the hydrogen transfer line
- Hydrogen liquefaction is reasonable (8 days?)
- Hydride Bed absorption and desorption rates from testing at the manufacturer: 50L/min
  - Absorber fill is limited by cryogenic power
  - Absorber empty will be approx 350min (~6hrs)
  - BUT, 50L/min was the limit of the manufacturer's measuring equipment

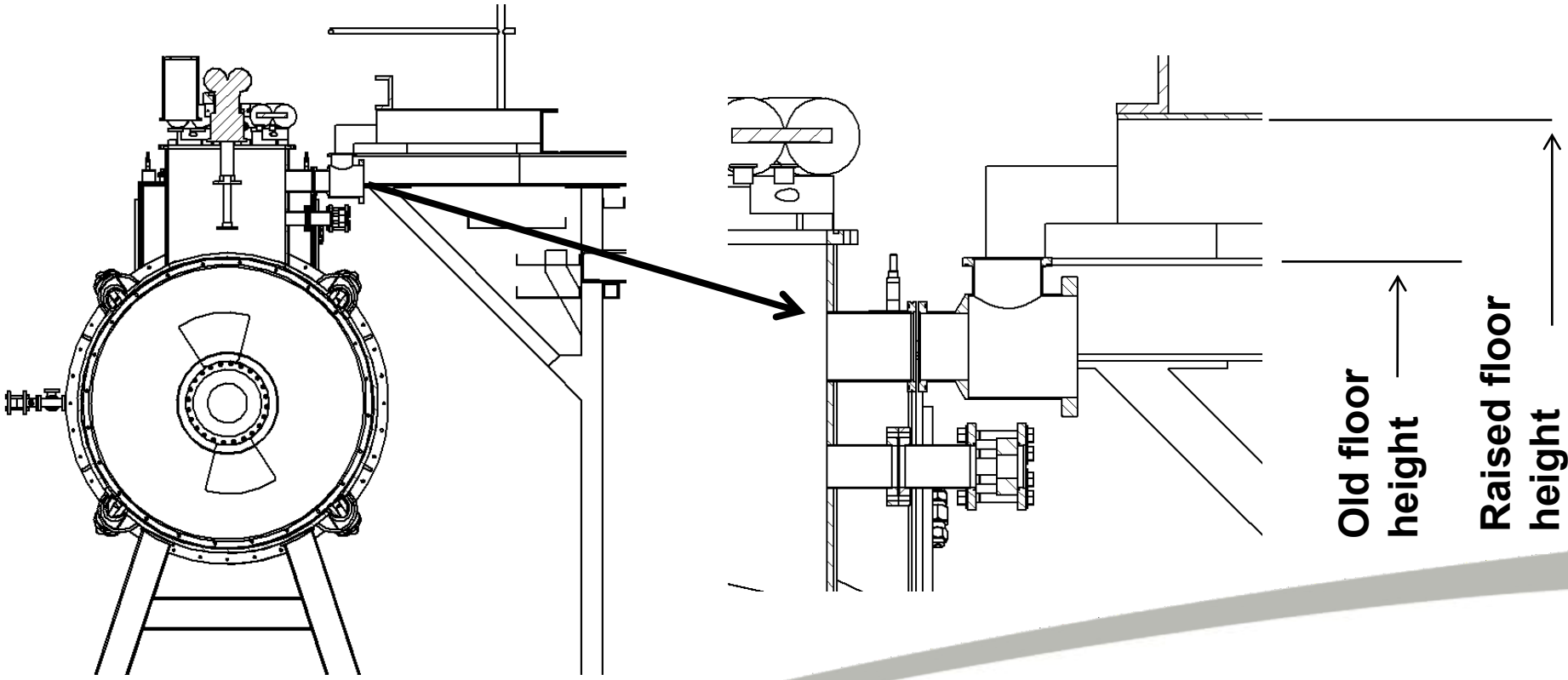
Confirming these things is what the Hydrogen R&D is all about…

Towards AFC#1 and STEPIV

- Final hurdle for System A is to commission it with the first AFC module
- Good links with Tesla and the AFC team, but this will become more crucial as the AFC progress
  - Sufficient engineering effort must be devoted to it to avoid problems later
- Current plan is to commission the absorber with the AFC, but this depends on the AFC schedule.
  - If the AFC is delayed it may be useful to reconfigure the test cryostat for absorber testing
- It is currently envisaged to relocate the Gas Panel Enclosure to the East end of the mezzanine for STEPIV
- New transfer lines and vacuum pipes need to be manufactured and installed for the AFC, and these must be compatible with the later installations
  - Mezzanine modifications currently being designed
  - Need to consider a helium fill from a Dewar

AFC Integration (J Tarrant)

- Working with Jason to identify the clashes
- Lots of detail design to be done – raise lines, make ends flexible, etc.



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Milestones

Milestone	Date
Helium R&D testing complete	July 2011
Safety Review passed	August 2011
Hall infrastructure and installation complete	September 2011
Hydrogen R&D complete	December 2011
Manufacture of items for AFC adaption complete	November 2011
AFC Commissioning complete	April/May 2012

Summary and forward look

- Installation of the Hydrogen Delivery System infrastructure is well advanced and progressing well
- Testing of the system with helium is underway with promising results
- First absorber has been delivered to RAL
- Primary absorber windows are ready for shipping after QA
- Aim to complete R&D with hydrogen by the end of 2011, depending on EMR running
- Planning for STEPIV is significantly dependent on the AFC schedule and closer working with Tesla will be important in the coming months
- Research into the hydride beds for Systems B&C should begin as soon as possible

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