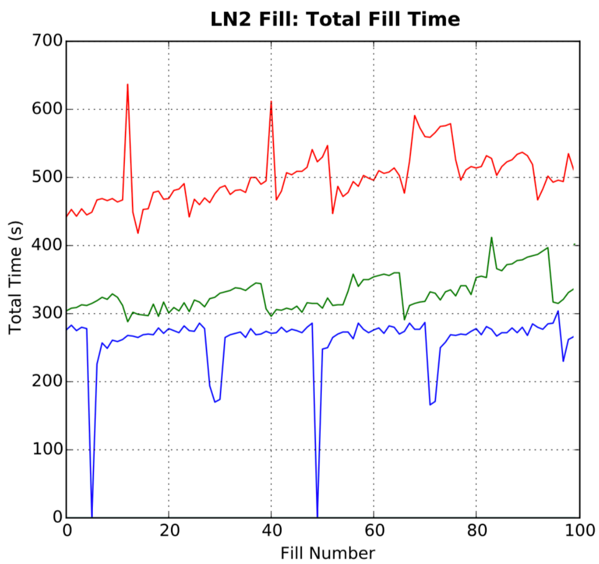
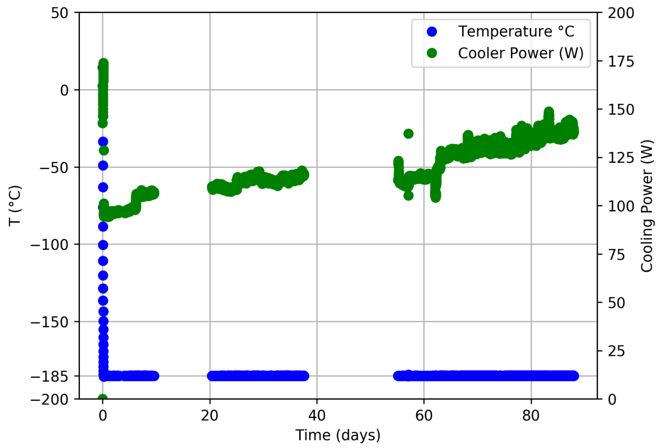
Practical 3: Managing detector vacuum systems

Section 1 – Understand the purpose of a vacuum in relation to a germanium detector and identify symptoms of a poor vacuum.

NOTE: the information given below relates only to the equipment and procedures used during this specific practical at the University of Liverpool. Always follow the instructions / guidelines for the specific equipment you are using and the environment you are working in.

A germanium detector must be cooled to cryogenic temperatures to function properly. Therefore, it need to be housed in a high vacuum to isolate it from the ambient temperature. The lower the pressure, inside the cryostat, the better the thermal isolation. The 1st plot below shows the time taken to fill three detectors with liquid nitrogen each day. Each colour corresponds to a different detector. The red and green lines can clearly be seen to increase with time. This indicates an increase in liquid nitrogen consumption for the corresponding detectors. This is a sign of the cryostat vacuum degrading with time. For a mechanically cooled detector, as the vacuum degrades, the cooler must work harder to maintain the set temperature as the vacuum degrades. This can be seen in the second plot below.





Two detector cryostats are located near the Ln2 filling station.
One of these has a good vacuum and one has a poor vacuum.
The demonstrator will fill / ask you to fill both of these with liquid nitrogen. Once the detectors have been filled. Leave them for around 30 minutes for the germanium crystal to reach a sufficiently low temperature. Notice the difference between the 2 cryostats. Identify the symptoms of a poor vacuum.

<u>Section 2. Understand different types of vacuum fittings.</u>

Different detector manufacturers use different connections between the cryostat and a vacuum system. Different cryostat designs from the same manufacturer may also require different vacuum adaptors due, to for example, physical size constrains. A variety of different adaptors are available for different detector type. Familiarise yourself with the different types of detector pumpout ports and pumpout adaptors.

<u>Section 3. Use a He leak detector to identify a leak within a detector cryostat</u>

A helium leak detector can be used to identify the location and severity of a vacuum leak. The leak detector is attached to the cryostat vacuum port in the same way as the turbo pump system and the inbuilt pump creates a vacuum within the cryostat. The leak detector also contains a mass spectrometer that can identify and quantify the amount helium present in the gas that is being pumped out of the cryostat. By selectively releasing small amounts of helium around the cryostat and monitoring the amount of helium detected in the mass spectrometer, it is possible to identify the leak.

- Connect the leak detector to the cryostat using the appropriate pump-out adaptor.
- Ensure that the cryostat port is not opened. If the cryostat is still under any vacuum, the sudden inrush of air could damage the internals of the cryostat
- When powering up the leak detector for the first time it may be necessary to leave it to stabilise of a few minutes. When it is ready for use, the LCD display will show the ‘Ready’ message.

- Once the cryostat has been connected using the pump-out adaptor, ensure the valve on the top of the leak detector is open.
- Press the 'Test' button. The leak detectors internal roughing pump will then begin to evacuate the cryostat. Only once the pressure is down to < $1x10^{-3}$ mb will the mass spectrometer begin measuring the helium content.
- The LCD display will then show the message 'Fine Test' indicating that it is conducting a high-resolution measurement of the helium content. The red bar at the top of the screen shows the amount for helium detected. This will typically be less than $x10^{-8}$.
- Once this has stabilised to give a consistent background reading. The external helium tank can be used to release a small amount of helium around one of the possible sources of vacuum leak. These could be the endcap seal, an electrical feedthrough, a welded seam on the Dewar or a failed bond to the Dewar etc.
- It is also good practice to test the seals in the vacuum pipe connecting the cryostat to the leak detector before opening the pump-out port on the cryostat.
- As helium can defuse through materials, only a tiny amount should be used to avoid false readings.
- After releasing a small amount of helium, wait a few seconds and observe the display on the leak detector. It can take ~10 seconds for the helium to be detected.
- It is a good idea to periodically blow the area around the cryostat to disperse any residual helium to prevent any false readings.
- Once testing is over, close the regulator valve on the helium bottle to prevent unnecessary escape of gas.
- If the detector is later to be opened to atmosphere (eg. To repair a leak) the pump-out port should be left open however if no leak is detected and you wish to maintain the vacuum in the cryostat, the pump-out port should be closed.
- Press the Vent button to vent to cryostat to atmosphere.
- Remove the pump-out adaptor from the cryostat.
- The leak detector can be turned off using the rocker switch on the back of the unit. However, if the leak detector is to be used again within a small timeframe (less than about 15 minutes), it is advisable to leave it powered up to avoid having to wait through the stabilisation period.

Section 4. Setup and use of a roughing pump + turbo pump to evacuate a detector cryostat to 'full' working pressure or to vent a detector under vacuum to atmosphere

A low-pressure pumping system typically consists of 2 different pumps that are used in tandem to provide the required level of vacuum inside a detector cryostat. The first stage is a 'roughing' or 'backing' pump that is used to remove a large volume of air. Typically these are Scroll pumps which and reduce the pressure to around 10^{-2} mb or Roots-type tumps which can reduce the pressure to around 10^{-3} mb. Both the roughing pumps used during the practical are dry scroll pumps. Roughing pumps should not be oil-filled due to risk of oil feeding back into cryostat if pump fails. The second stage uses a molecular turbo pump to reduce the pressure to the levels of $10x^{-6} – 10x^{-7}$ mb. The roughing pump must be used to reduce the vacuum to ~10^{-2} mb before the turbo pump is engaged to avoid straining and potentially damaging the turbo pump.

A vacuum system may rely on two different gauge types to measure the vacuum level reliably across more than 9 orders of magnitude. The Edwards system in the practical uses an Active Pirani vacuum gauge to measure pressures down to x10^{-3} mb and a hot cathode ionization measurement system for pressures down to 10x^{-10} mb. The ionization gauge should not be used if the pressure is above 10^{-3} mb. The Agilent system uses a Pirani Inverted Magnetron Gauge. This gauge provides continuous measurement from atmosphere down to x10^{-9} mb so there is no need to switch between gauges.

The procedure for venting a detector under vacuum to atmosphere, for example to allow repair is detailed below.

- Connect the pump to the appropriate pump-out adaptor
- Keep the vacuum port on the cryostat closed
- Ensure all connections in the vacuum pipe are tight and closed
- Open the valve on top of the turbo pump
- Make sure the low-pressure gauge is off
- The pump-out port on the cryostat should remain closed at this point.
- Turn on the roughing pump using physical switch at the rear of the unit
- Wait for pressure to drop to < x10^{-2} mb
- Turn on turbo pump using the controller
- Wait for pressure to drop below 1x10^{-3} mb then turn on low pressure vacuum gauge
- Pressure should drop to x10^{-6} mb.
- Slowly open the pump-out port on cryostat
- Pressure will increase significantly if the cryostat vacuum is poor.
- Once the pressure between the cryostat and the pump has equalised, the turbo pump can be switched off.
- Once the turbo pump has stopped and the pressure has risen to ~10x^{-3} mb, the roughing pump can be stopped.
- The vacuum system can then be vented to atmospheric pressure.

If pumping a detector that is known to be at atmosphere, for example the detector has just been repaired, the procedure is as follows

- Connect the pump to the appropriate pump-out adaptor
- Keep the vacuum port on the cryostat closed
- Ensure all connections in the vacuum pipe are tight and closed
- Open the valve on top of the turbo pump
- Make sure the low-pressure gauge is switched off
- The pump-out port should be opened at this point.
- Turn on the roughing pump using the physical switch at the rear of the unit
- Wait for the pressure to drop to < x10^{-2} mb
- Turn on the turbo pump using the controller
- Wait for the pressure to drop below 1x10^{-3} mb then turn on the low-pressure vacuum gauge

- The pressure should eventually drop to x10^{-6} mb. This may take several hours depending on how long the detector has been at atmosphere, if any work has been done inside the cryostat, etc.
- The detector should be left on the pump long enough to remove any outgassing that may be ongoing – pressure will continue to decrease. Due to the time constraints of this practical, discuss with them demonstrator at what point to proceed.
- When satisfied that the pressure is steady and at its minimum, close the pump-out port on the cryostat.
- Turn off the turbo pump and allow it to spin down. This can take many minutes.
- Turn off the low-pressure gauge before the pressure reaches x10^{-3} mb.
- Once the turbo pump has stopped spinning, turn off the backing pump.
- Slowly open the relief value at the base of the turbo pump to vent to atmosphere.

<u>Section 5. Investigate the internal components of a detector cryostat</u>

There are two Ortec germanium detectors on benched in the middle of the lab.
These can be disassembled to study the components of a detector + cryostat

- Remove the cross-head screws on the bottom of the preamp housing
- Slide the preamp cover off over the endcap to reveal the preamp and HV filter.
- Remove the 2 hex-bolts in the two semi-circular base
- Remove the 2 semi-circular sections taking care of the cables passing through and the LED
- Loosen The 2 flat-head screws securing the HV filter. The can be undone with your finger once they are untightened.
- Pull the HV filter back towards the Dewar to disconnect it from the HV feedthrough pin.
- There are 2, round, 4-pin connectors connecting the preamp to the feedthrough.
- Locate the connector with only 2 wires attached. This is the PT100 (temperature dependent resistance) Note the rotation of this connector (which pins are connected to which wires) and lift the connector from the feedthrough pins.
- Locate and remove the 2 hex bolts securing the preamp board to the cryostat
- Note the position of the round 4-pin connector (which pins are connected to which wires) and lift the connector from the feedthrough pins.
- Remove the preamp.
- Identify the vacuum port
- Identify the 3 clamps fixing the endcap onto the cryostat.
- Loosen the 3 small hex-bolts on each clamp and remove the clamps.
- The endcap should now be free and can be slid forwards and off over the germanium crystal. Be careful not to strike the detector whilst removing the end cap.
- Identify the components inside the endcap.