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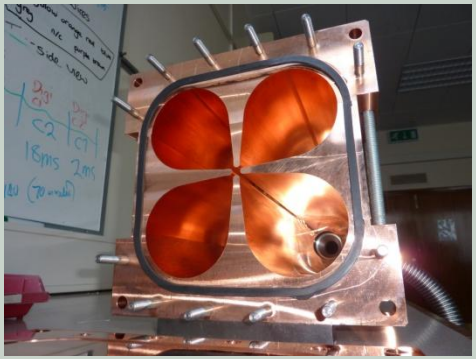
3D ‘O’ Ring Vacuum Tests – PART II

Updated 21st July 2011

by Ian Clark, Trevor Savidge & Peter Savage



This presentation is Part II

For Part I see file:

57) FETS_3D_O_RING - PART I.pdf

Summary so far....

•Vacuum tests using the 3D O ring worked well reaching pressures at the mid 10^{-6} mbar level.

•Low temperature cycling to speed up out-gassing was working well.

•At a temperature reading of just 55^{0}C the vacuum performance deteriorated and did not recover when back at room temperature.

•Failure of regular cyanoacrylate was blamed with a maximum working temperature of 82^{0}C (though there was no obvious deterioration or weakness in the 'O' ring)

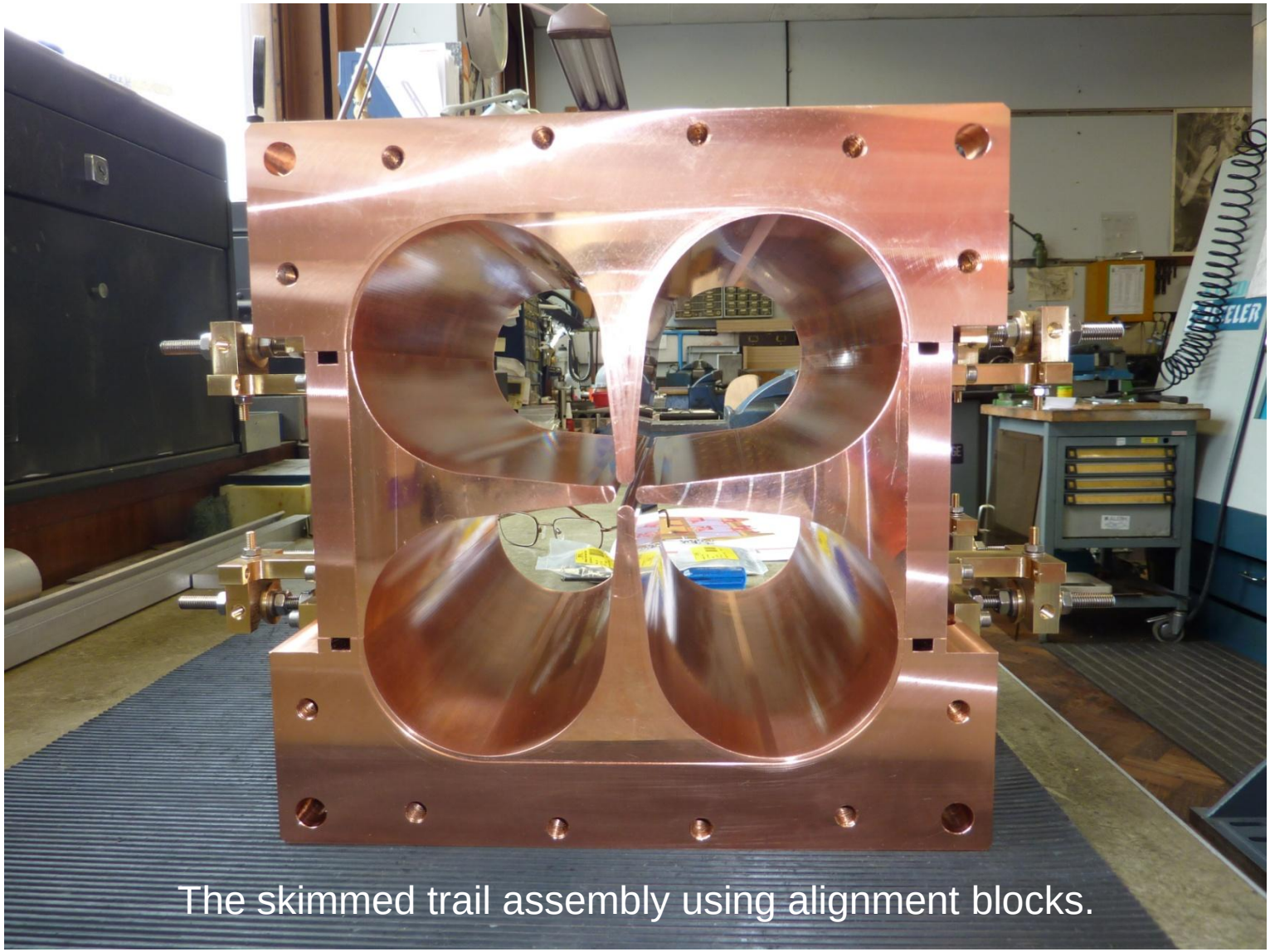
•Several weeks were spent trying to achieve strong bonds with Viton based adhesive. Eventually abandoned. Adhesive bond is weak in 'peel' making assembly handling difficult.

•Permabond 920 high temperature cyanoacrylate was purchased.

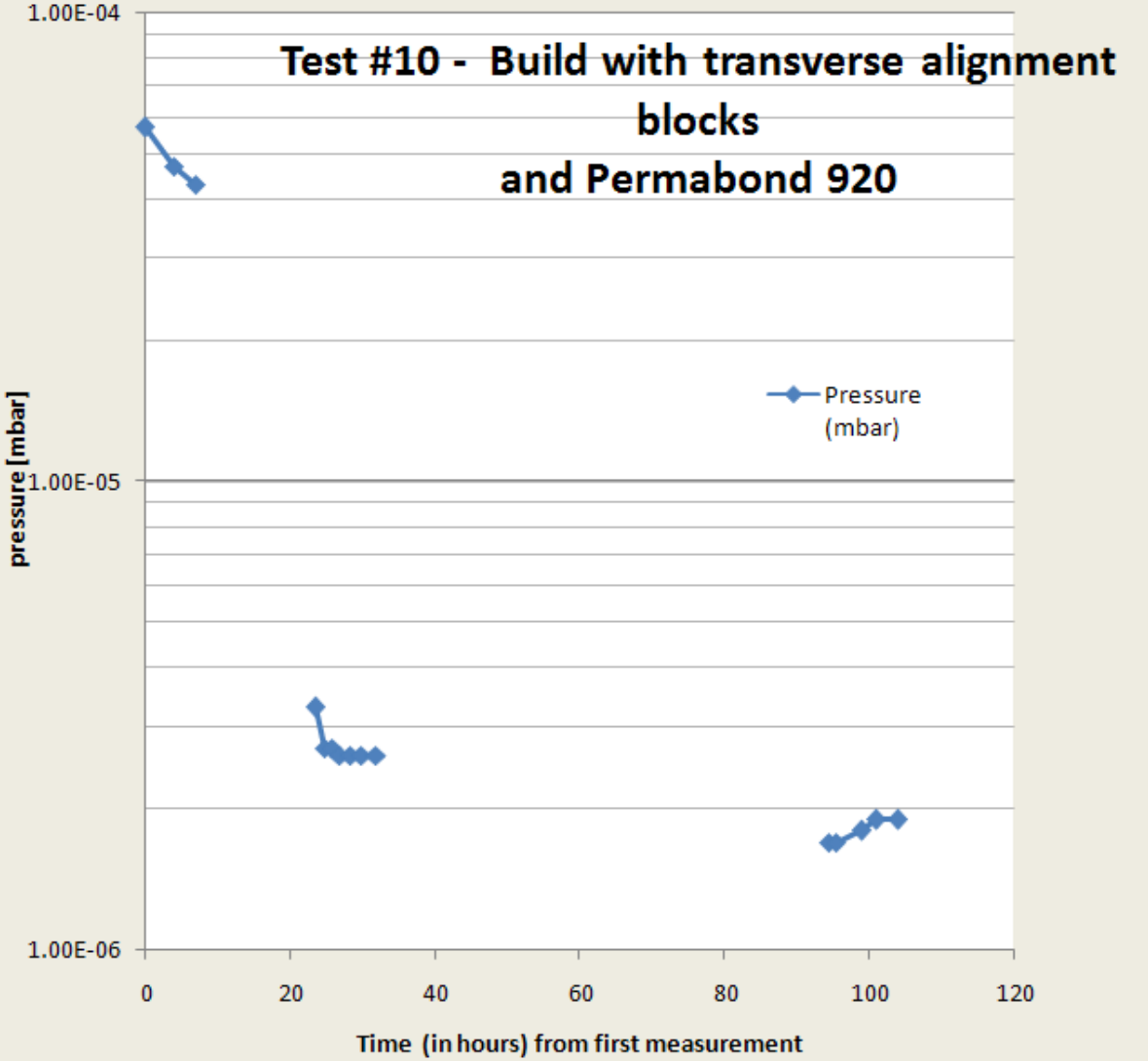
•3D O ring manufacturing jig was improved.

•Weld model end faces were skimmed to remove scratches.

•Model was rebuilt using transverse alignment blocks and latest 3D O ring.



The skimmed trail assembly using alignment blocks.



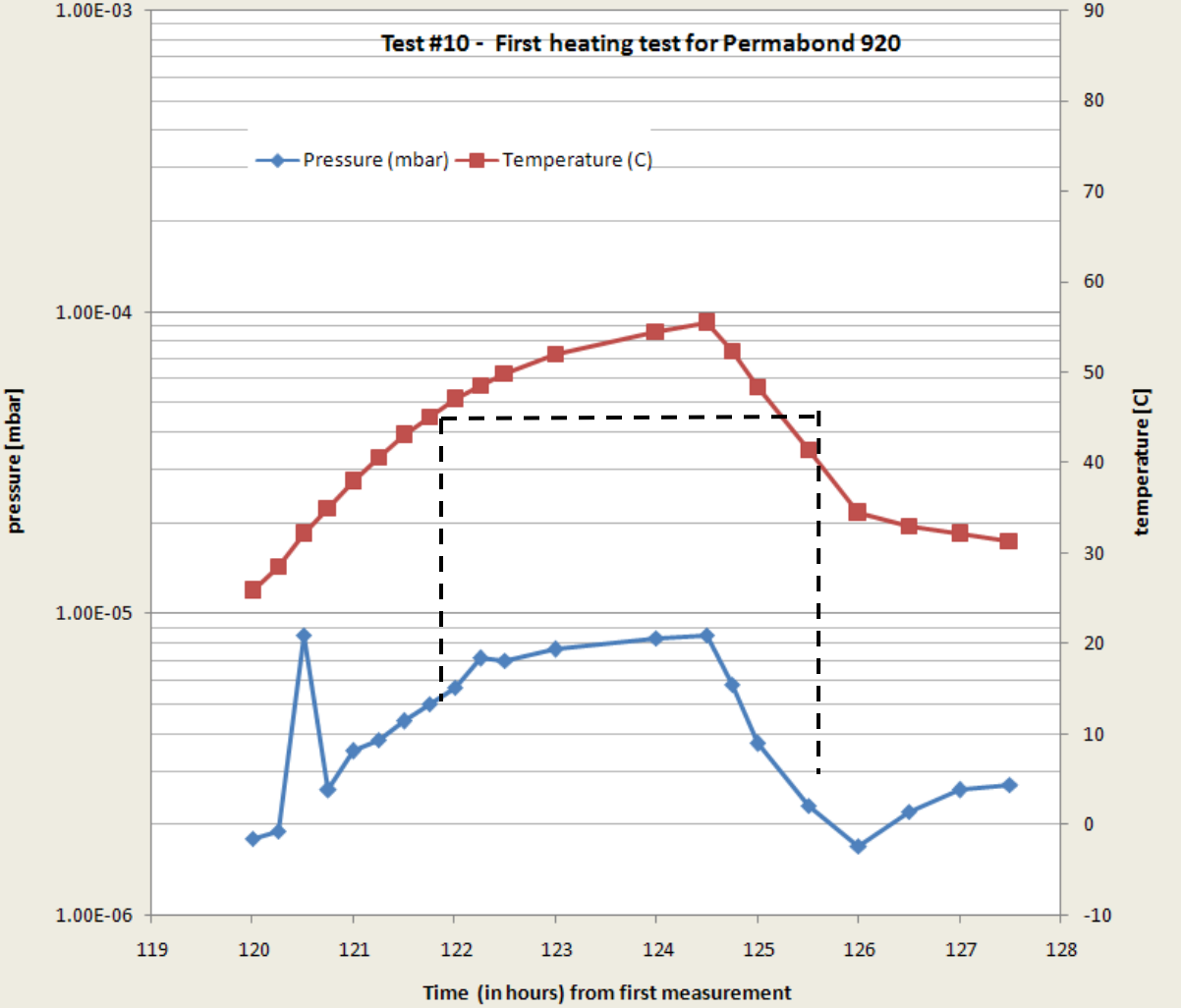
First vacuum test

Started vacuum pump on a Thursday.

By end of the day Friday the pressure was 2.6 x 10^{-6} mbar.

By Monday the pressure was 1.7 x 10^{-6} mbar.

Decided to perform first heating test on Tuesday.....



First heating test

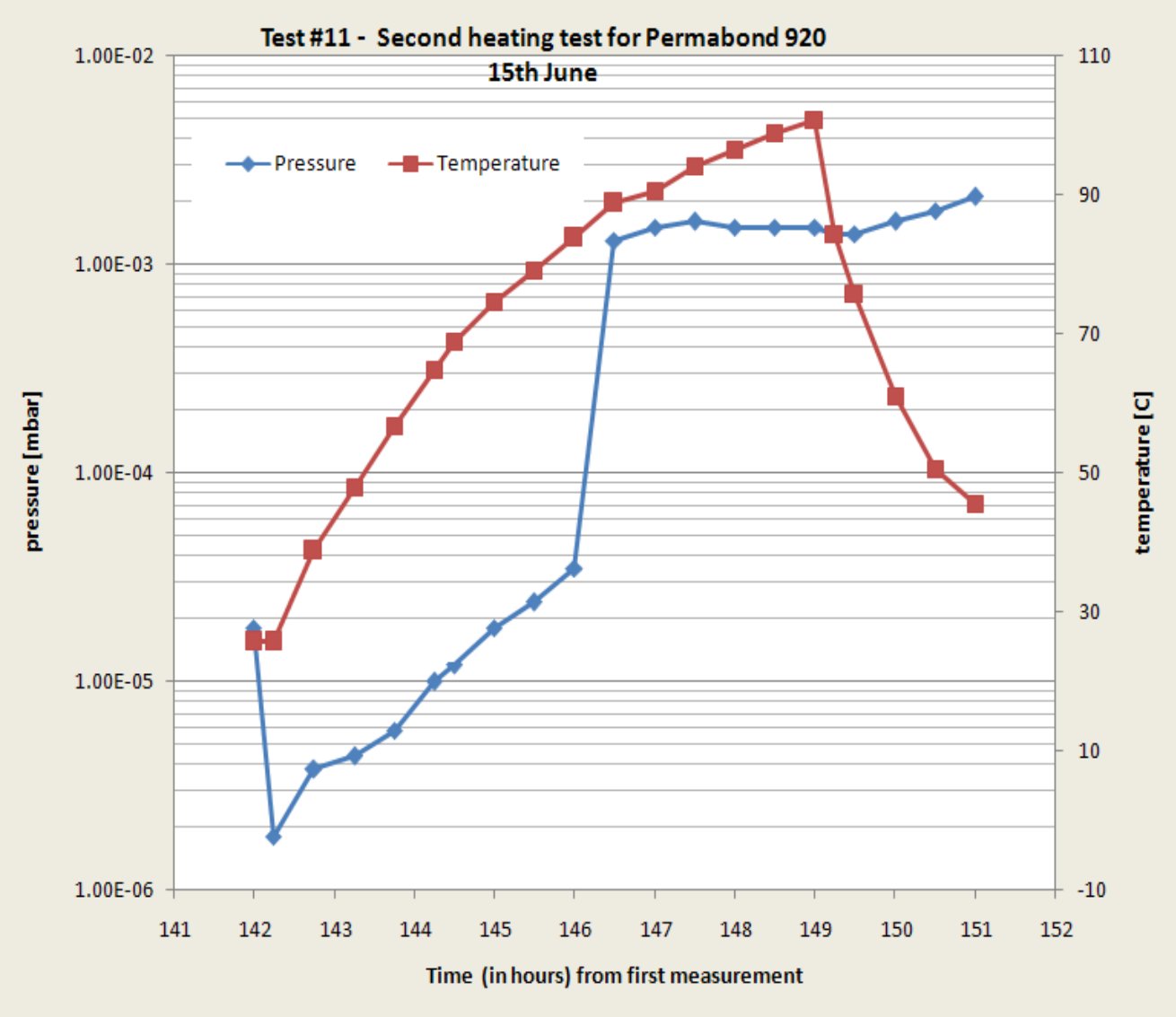
First gentle heating test.

Using one heating tape and no tin foil wrap.

Pressure rose with temperature as it should.

At 55^0C the heating was switched off.

During cool down phase the pressure was lower than at the equal temperature on the heat-up phase. Therefore the thermal cycling is doing it's job speeding up the out-gassing process.

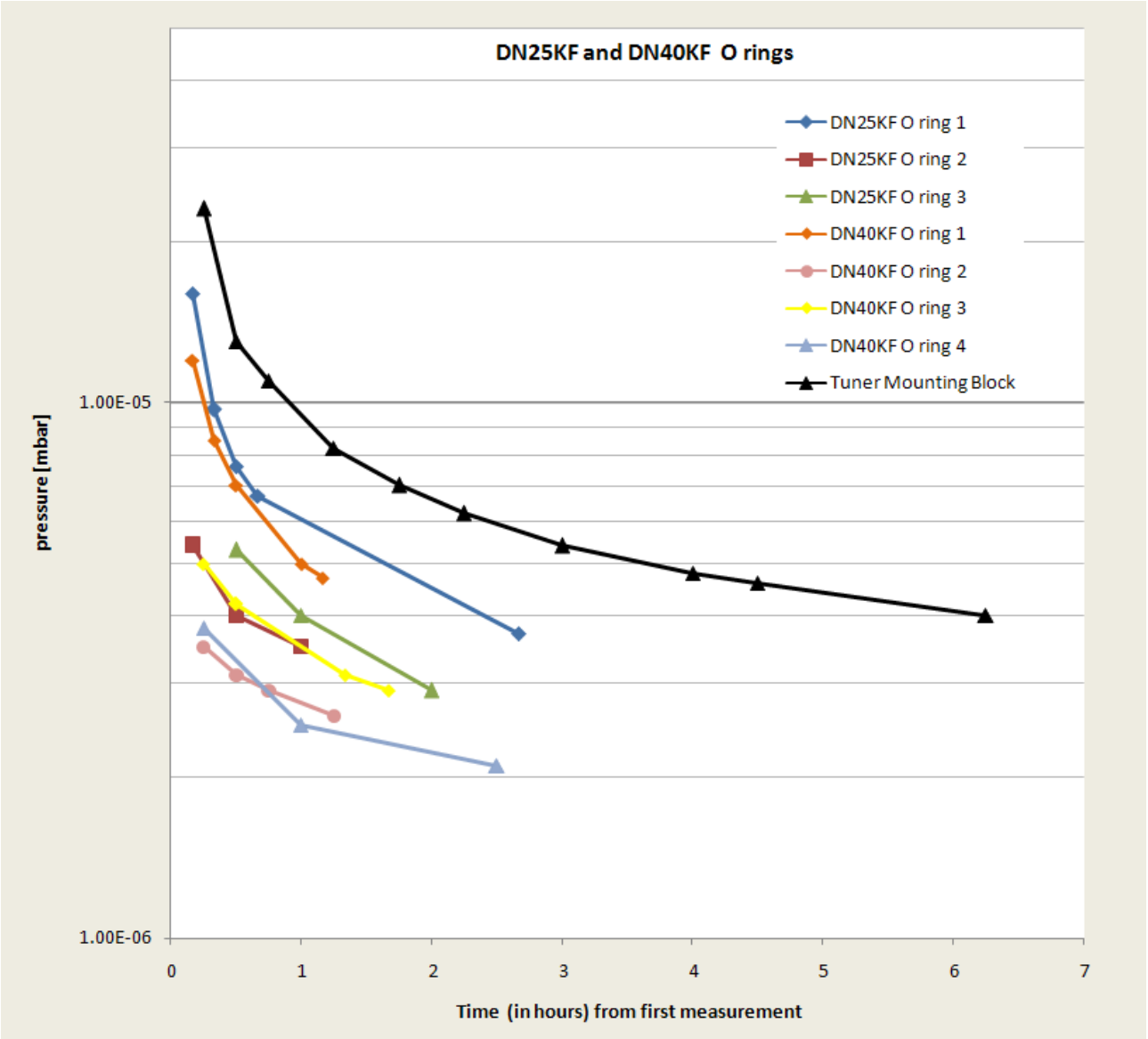


Second heating test.

Using one heating tape but this time wrapping in tin foil.

Pressure rose with temperature as it should.

At a recorded temperature of 85^{0}C the pressure suddenly increased and did not recover.



First thought:

Could it be that one of the KF25 or KF40 seals used at the end flanges is not Viton?

No. Tested all flanges individually and they all performed well reaching the low 10^{-6} region within a couple of hours.

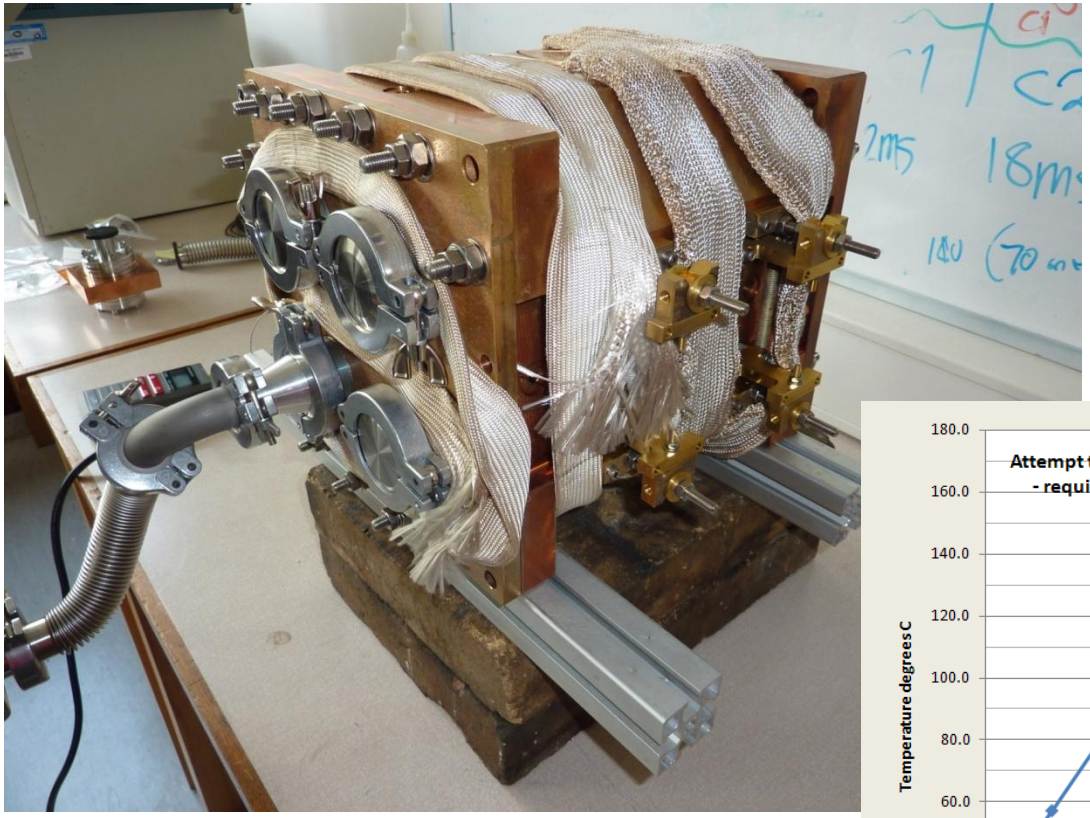
What's going on?

1. Is the copper moving and breaking the seal?
2. Is the clamping force reduced when hot?
3. Why does it not recover when cool?
4. Is the adhesive failing?
5. Is the Viton failing?
6. Do we know that the rubber is Viton?
7. Are the port seals failing – no tested individually.
8. Is the recorded temperature correct? Would it be significantly hotter inside?

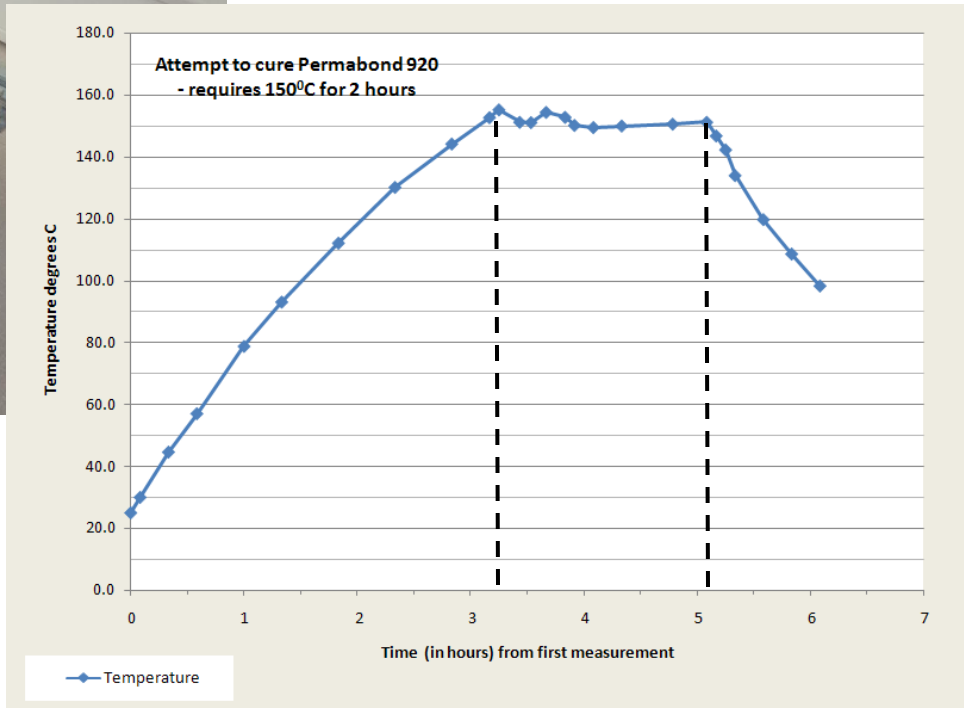
After break will try:

1. Strip and inspect.

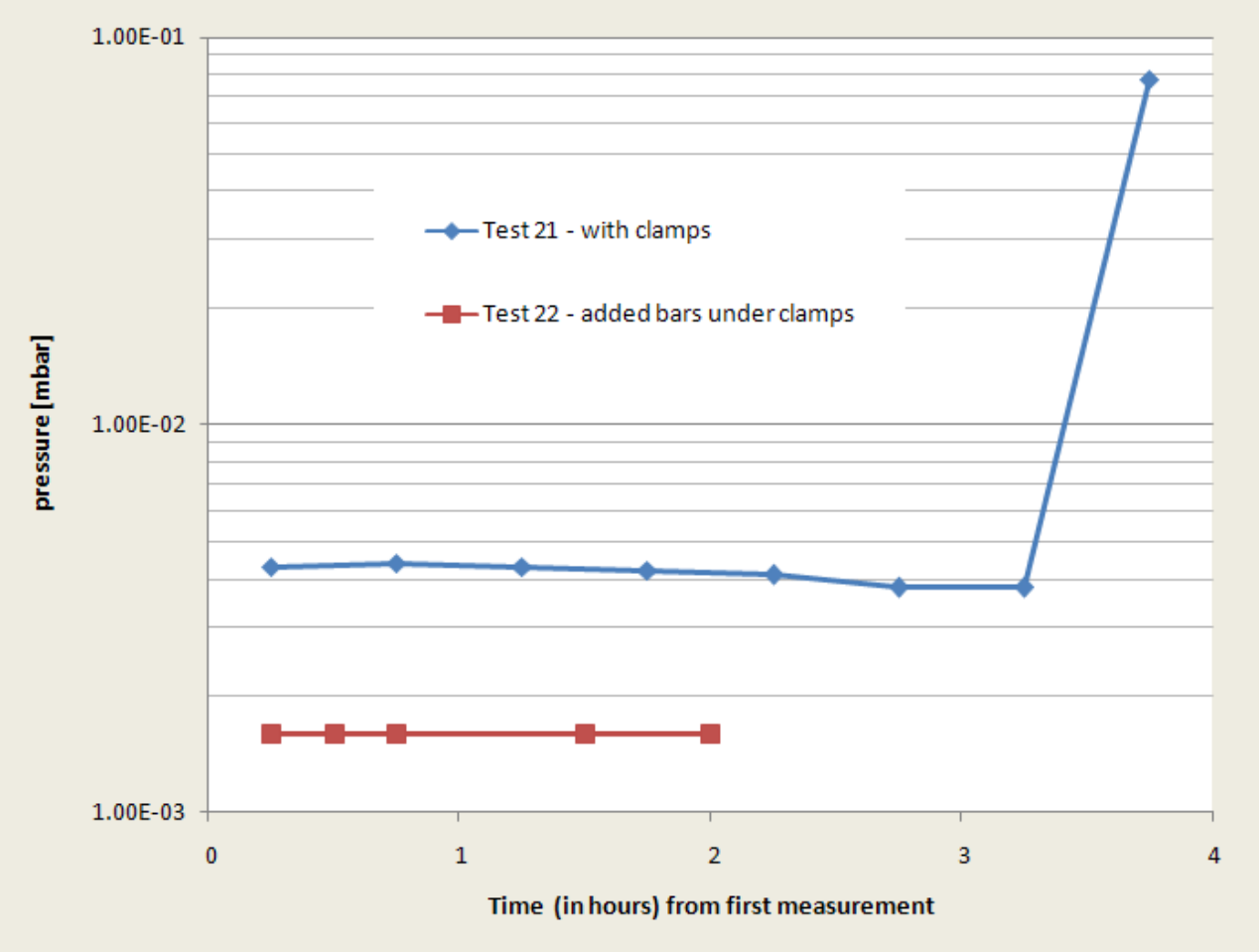
Understanding this is now the biggest priority.



The 3D ‘O’ ring was not cured to the manufacturer’s recommendation therefore leaving the ‘O’ ring in place the plan was to attempt to cure the adhesive. (Test #20)



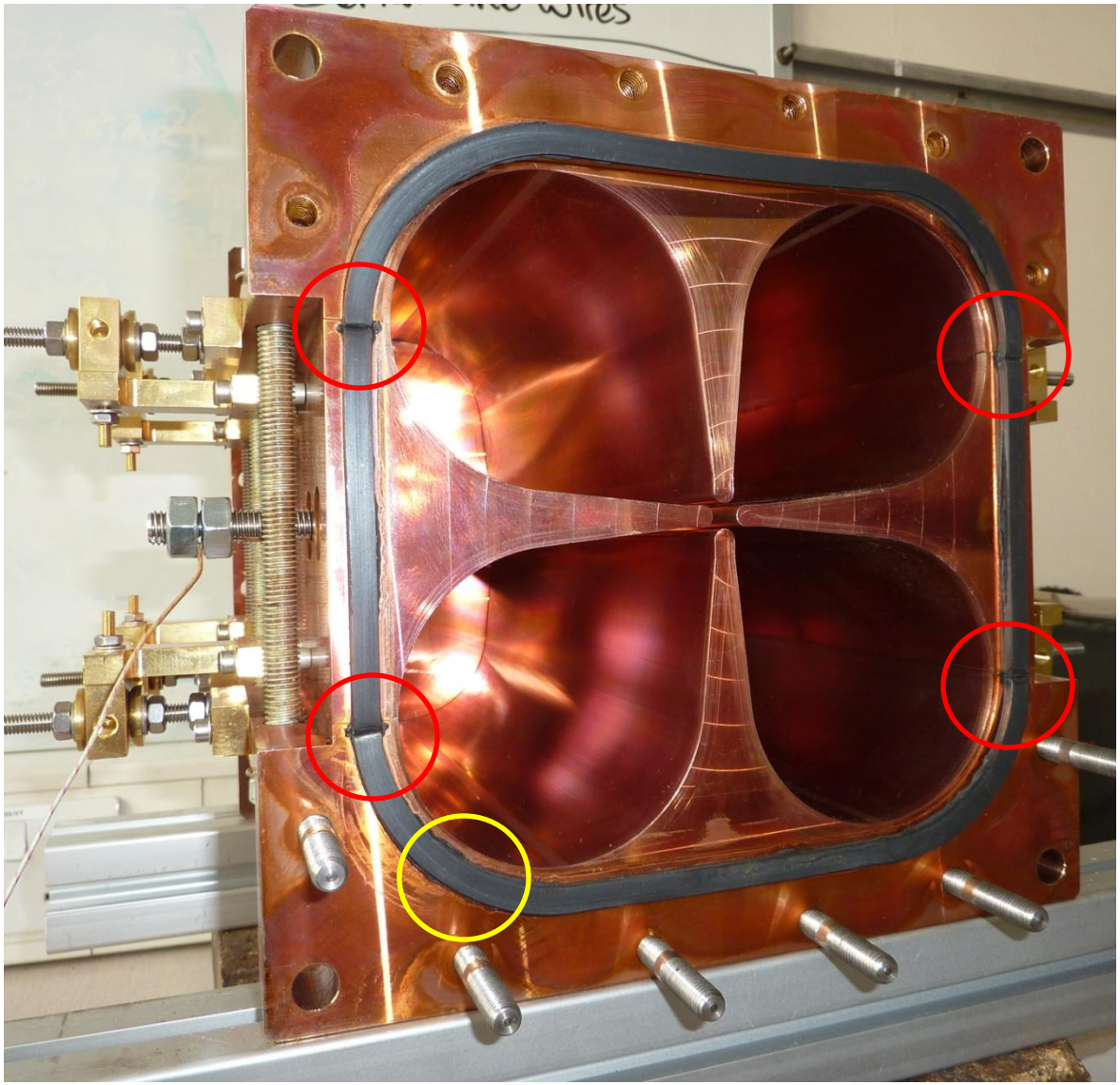
Using both heating tapes (600W total) and wrapping in tinfoil was sufficient power to reach the required 150^{0}C. This temperature was held constant for two hours by turning off one heating tape.



Vacuum testing following the attempted adhesive cure showed poor vacuum performance.

The decision was taken to open up the model and inspect the ‘O’ ring.

The result was quite a surprise.



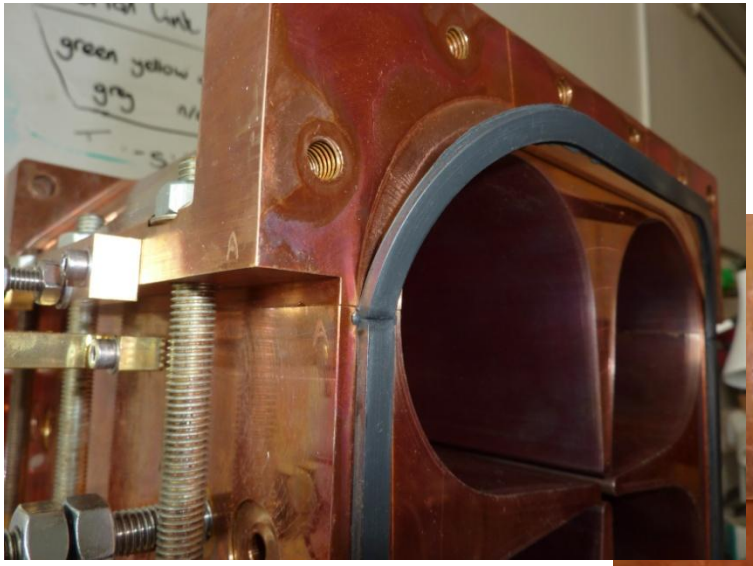
The O ring had visibly changed in 2 ways:

1) There were slots or dents at the positions where the longitudinal ‘O’ ring is bonded to the transverse ring. The slots were present at all 4 locations at both ends of the model.

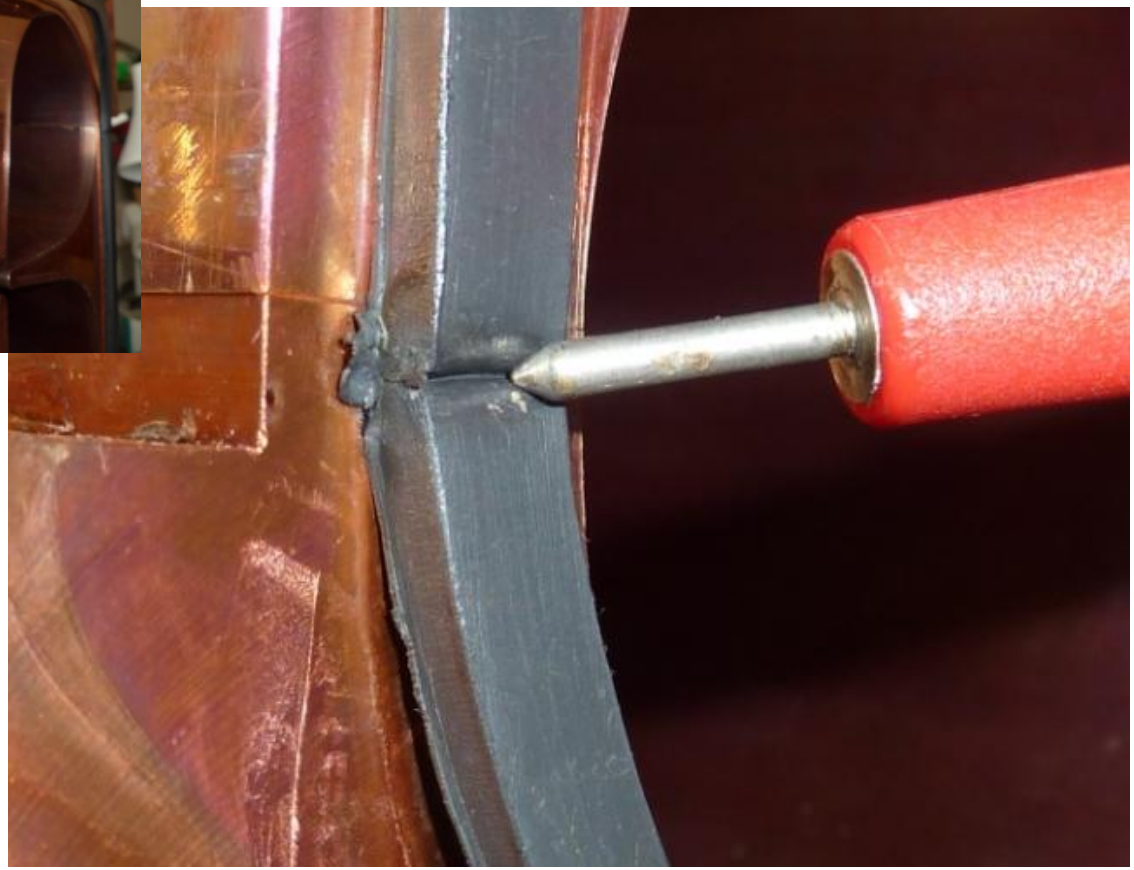
2) Flash on the edges of the inner face (bulk copper side, not flange side) of the transverse ring. Present at both ends.

Considering the two features individually.....

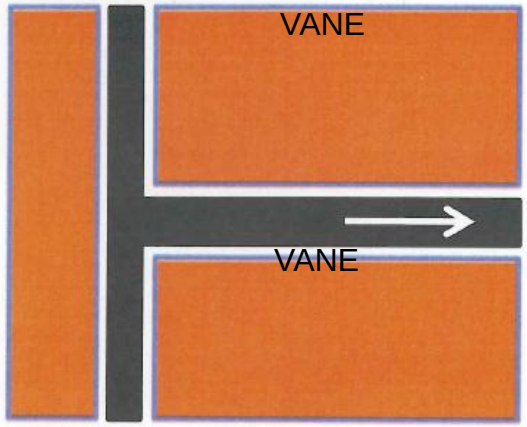
1) Dents



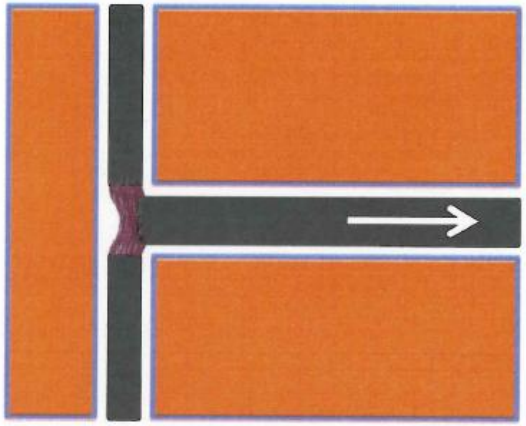
Centre line of dent does not coincide with joint interface because the longitudinal slot is only present in one vane.

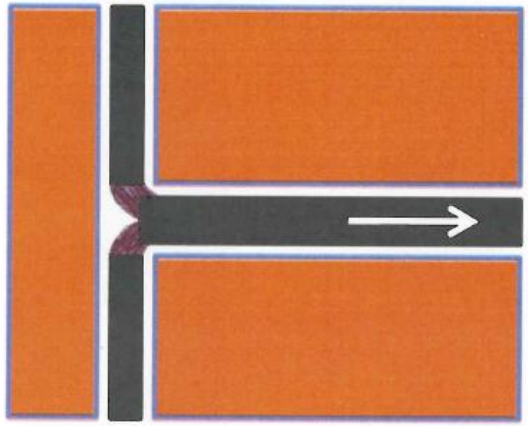


A possible explanation for the dents.



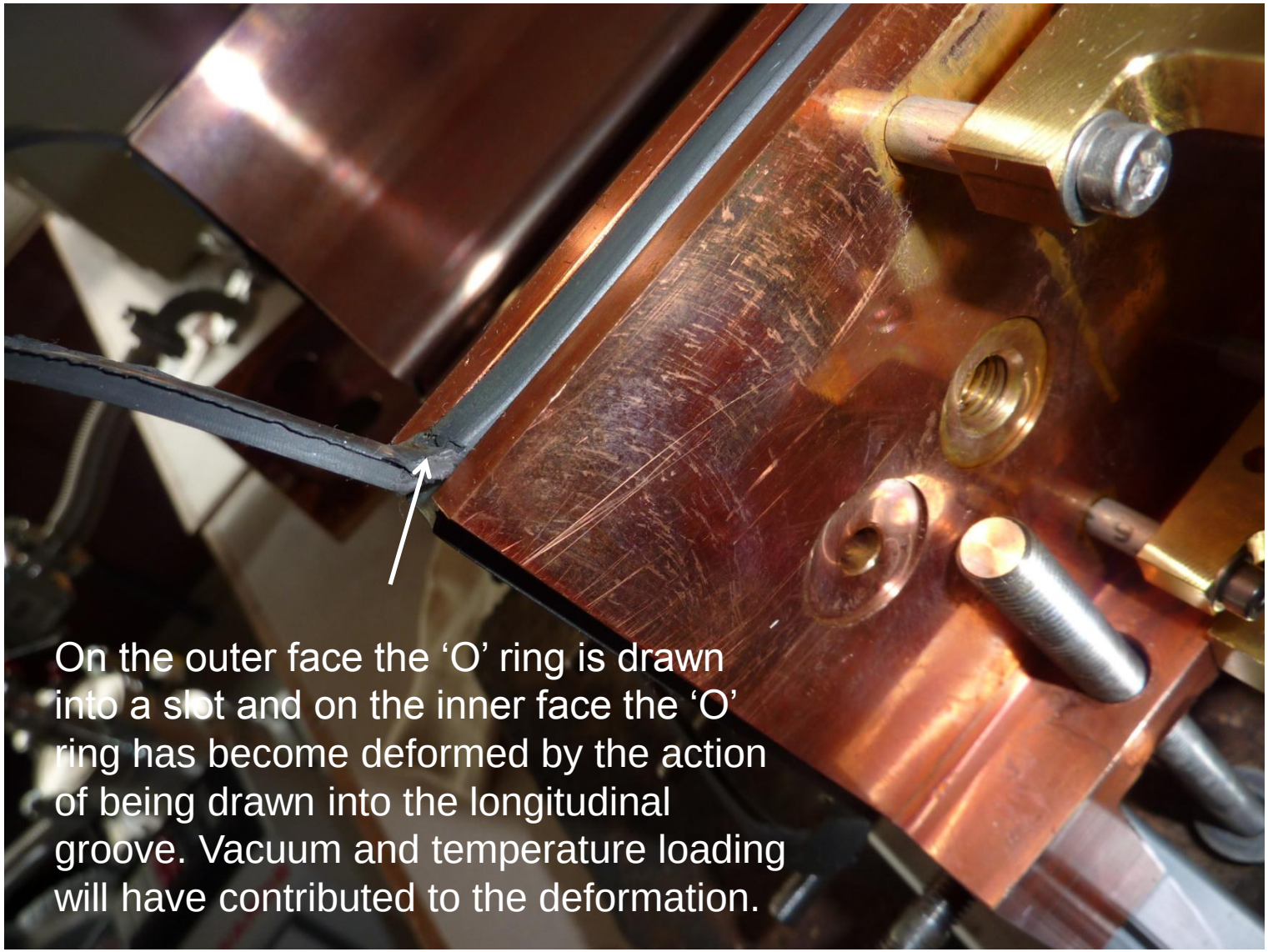
For this 3D ‘O’ ring build the longitudinal ‘O’ rings were cut short at 245mm instead of 250mm. The idea was to counter the length increase due to compression and to pull the transverse ring onto the end faces which assists the fitting of the end flanges. However this results in a tension at the adhesive joint region.



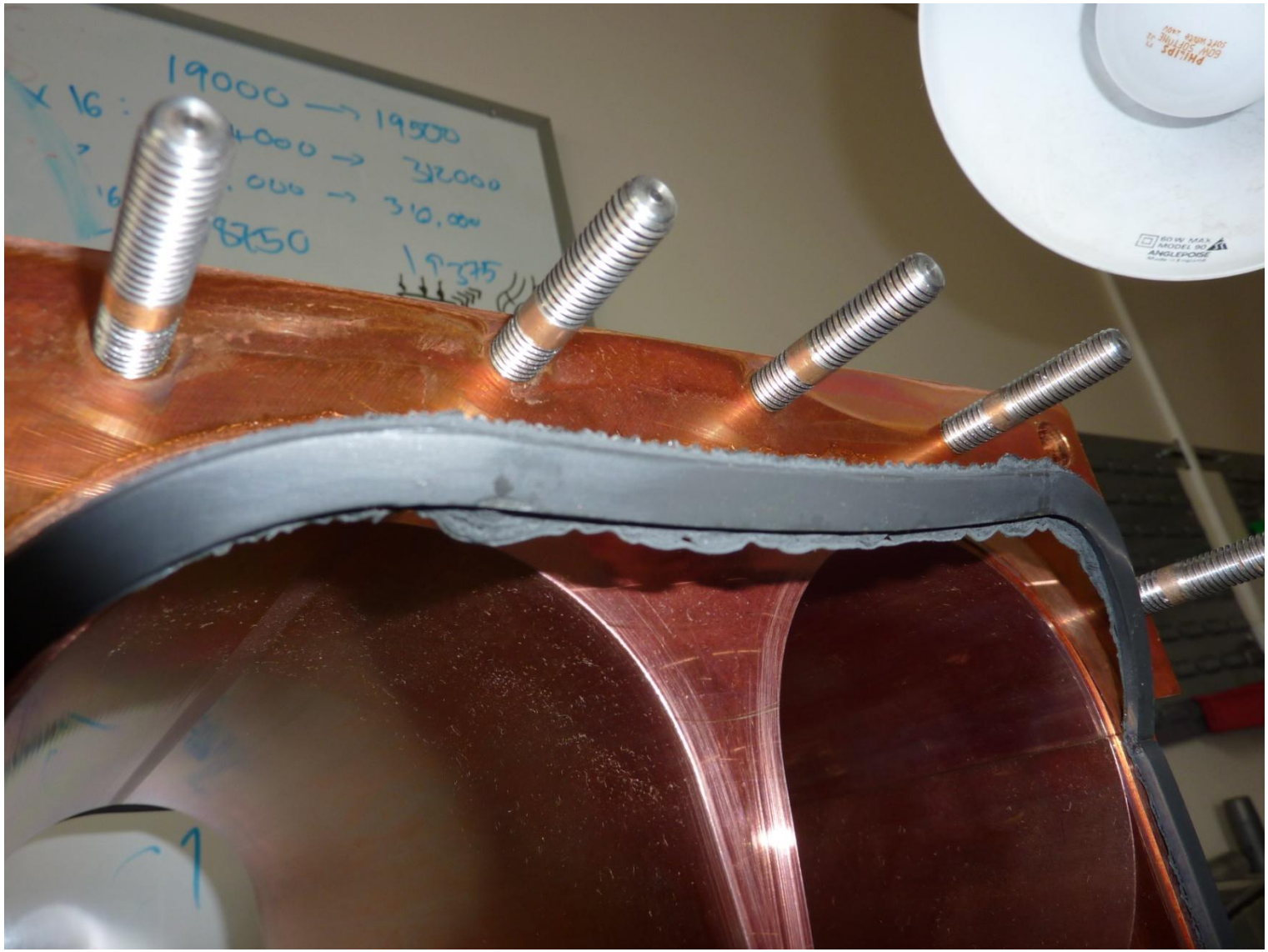


It is imagined that due to the tension, heat and vacuum over time the ‘O’ ring is drawn down into the square slot for the longitudinal ‘O’ ring.

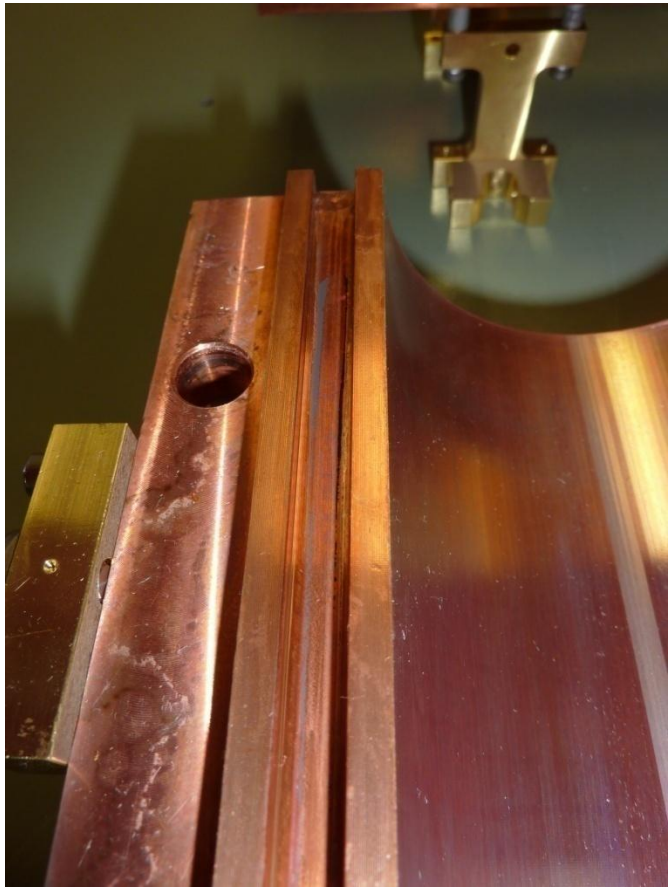
This will have caused the vacuum leak. This behaviour has not been seen before with the full length longitudinal ‘O’ rings.

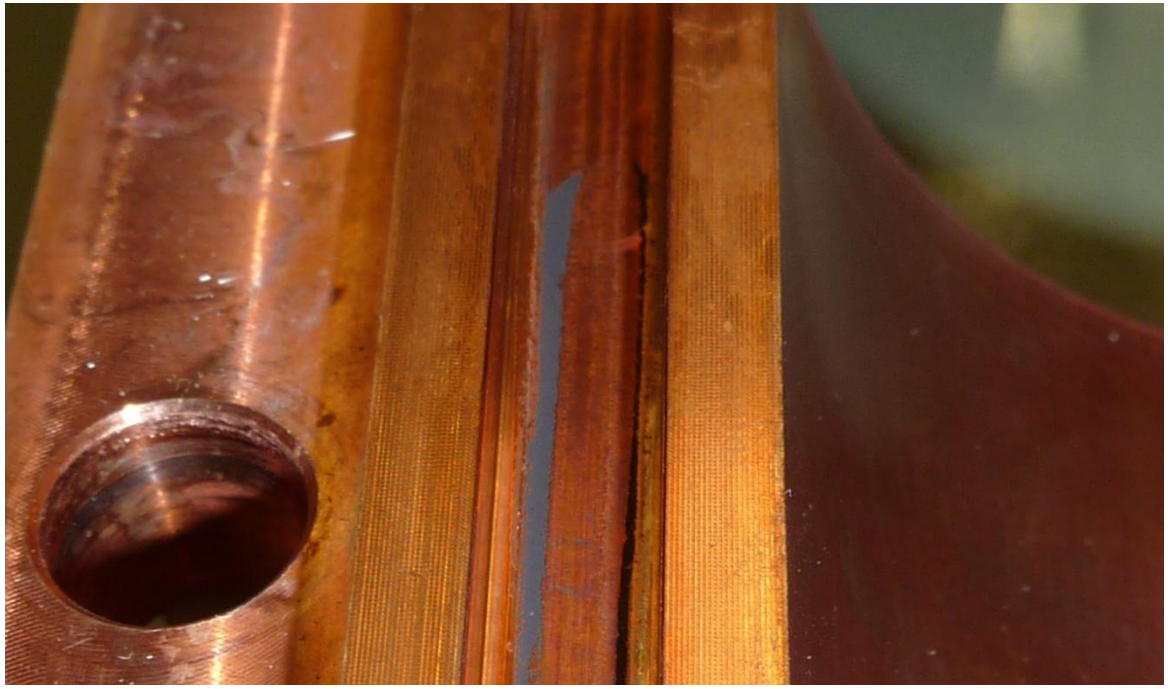

On the outer face the ‘O’ ring is drawn into a slot and on the inner face the ‘O’ ring has become deformed by the action of being drawn into the longitudinal groove. Vacuum and temperature loading will have contributed to the deformation.

2) Flash


19000 → 19500
PHILIPS
ANGLEPOISE

Observation - rubber has been deposited on the weld test model.





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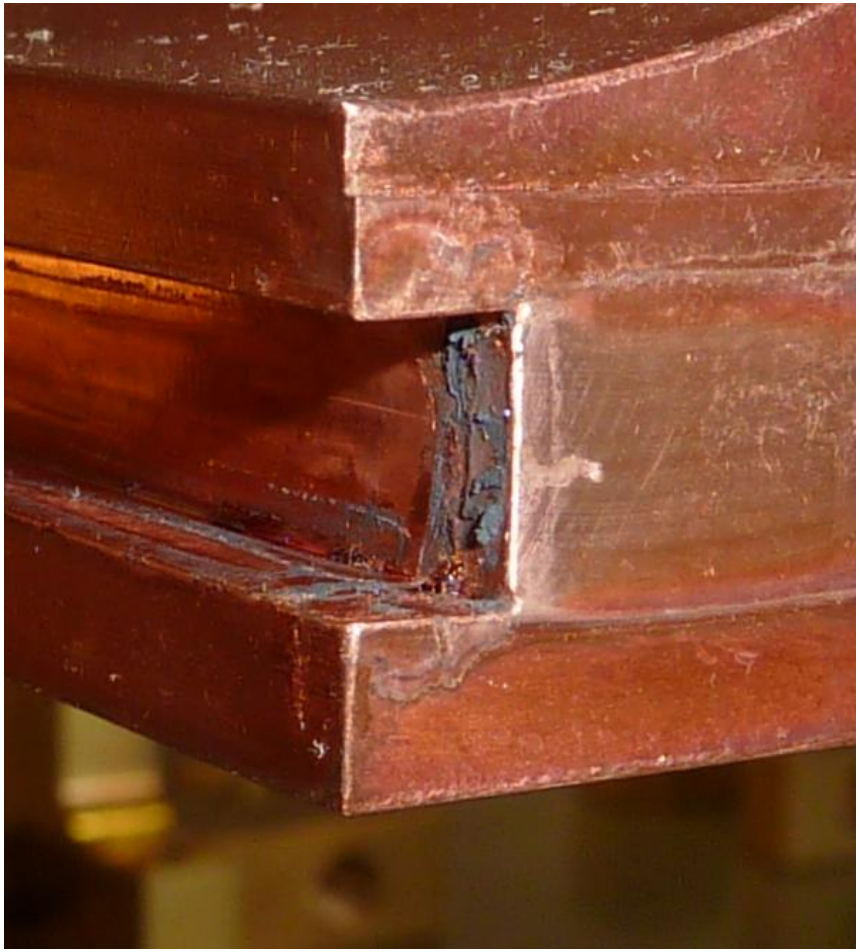


Conclusions

Dents

•The dents must be prevented because they will cause a vacuum leak.
•This behaviour has not been seen before using the full length longitudinal 'O' rings and so should be easy to cure.

Flash

•Do not know the cause.
•Is the temperature measurement reliable?
•Is it a feature of square profile 'O' ring?
•Does it matter? – it would probably still have maintained a vacuum seal.

General comments

•Neither features have been observed before.
•Temperatures of 150^0C have not been used before.
•Not clear whether curing the 'O' ring after vacuum testing would have worked.
•Some basic tests will be performed (while waiting for more transverse 'O' rings to be delivered) to help to understand these features.

Plan

•Build a new 3D O ring using full length longitudinal ‘O’ rings and Permabond 920.
•Cure the adhesive to the manufacturers specification.
•Re-test vacuum performance with heat applied.

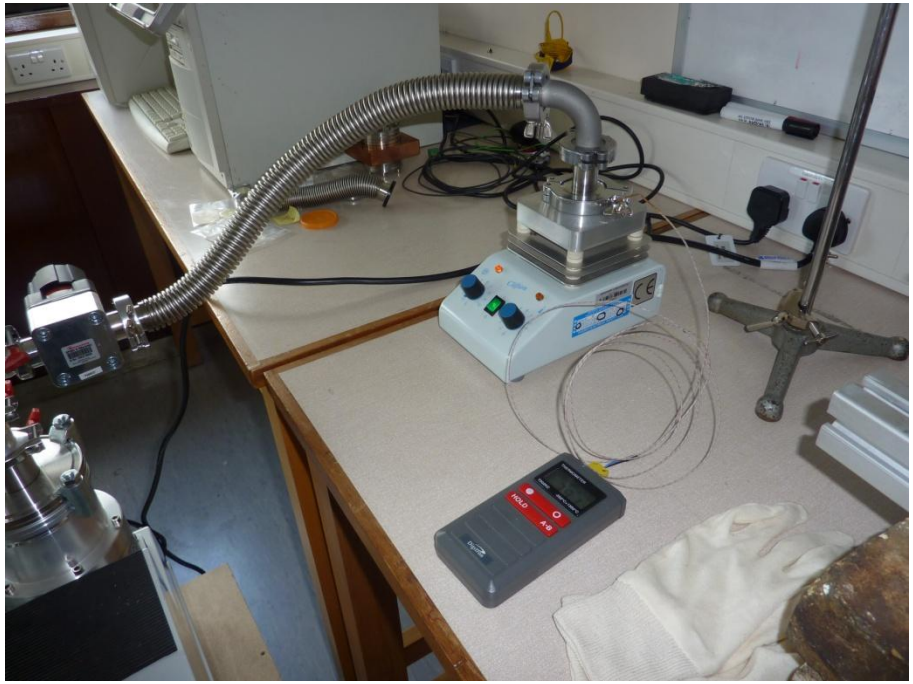
While waiting for new transverse rings to be delivered make use of the borrowed pumping rig to perform three simple tests:

Test 23: Using a standard off the shelf Viton DN40KF ‘O’ ring. Pump down and heat to 150^0C. Resulting data will be used as the benchmark against which to compare the results from tests 24 and 25.

Test 24: Using the same ‘O’ ring from Test 23 but now sliced and re-bonded using Permabond 920, cured for 2 hours at 150^0C. Pump down and heat to 150^0C.

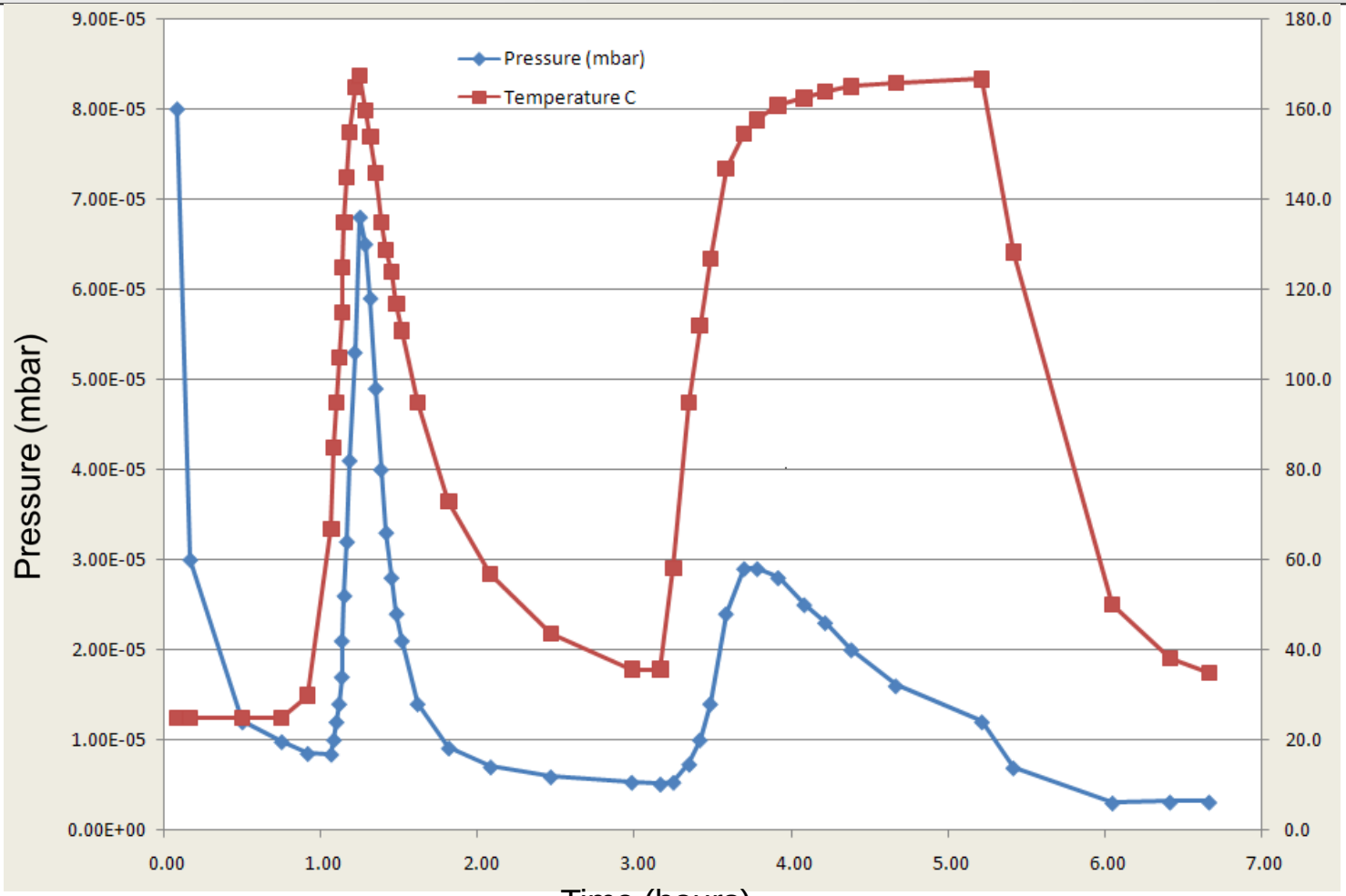
Test 25: Again using the same ‘O’ ring from Test 23 - sliced and re-bonded using Permabond 920 but this time left uncured. Pump down to low pressures in the low 10^{-6} range and then attempt an in-place cure. Observe pressure during cure cycle.

The apparatus used to perform the 3 simple tests.....

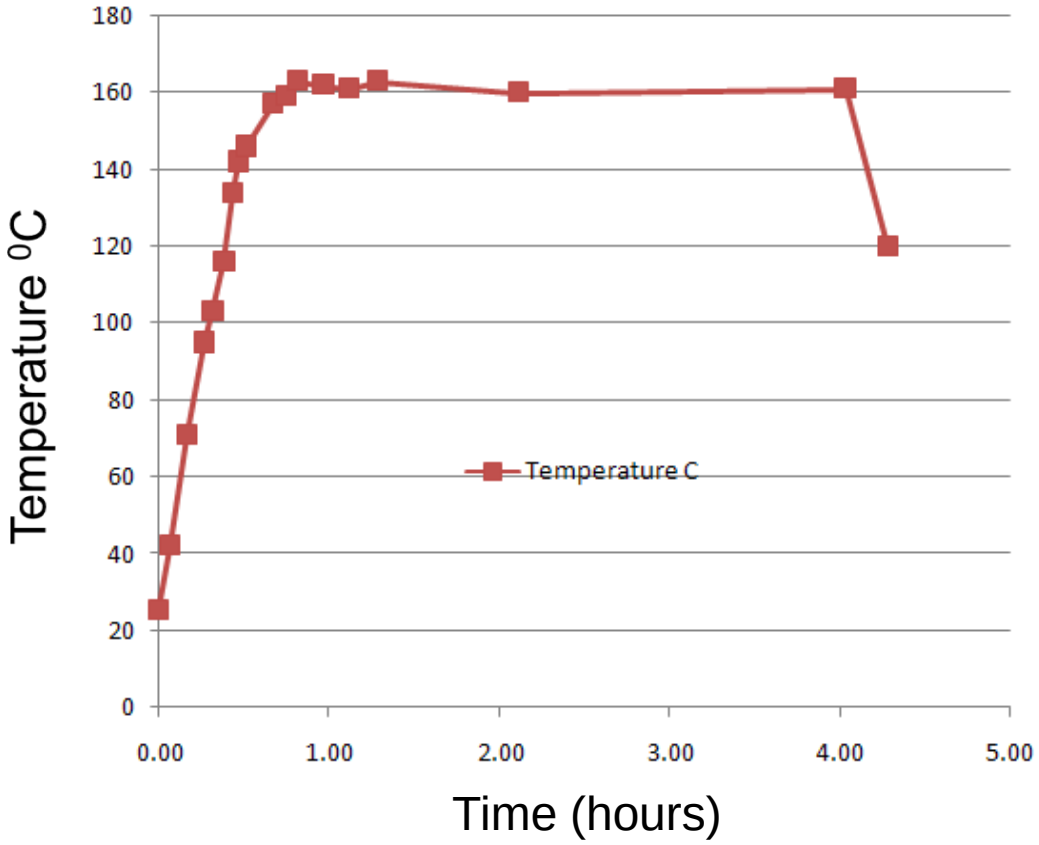


The heater set to power level 4 will take the ‘O’ ring under test to just over 150^0C.

Test # 23

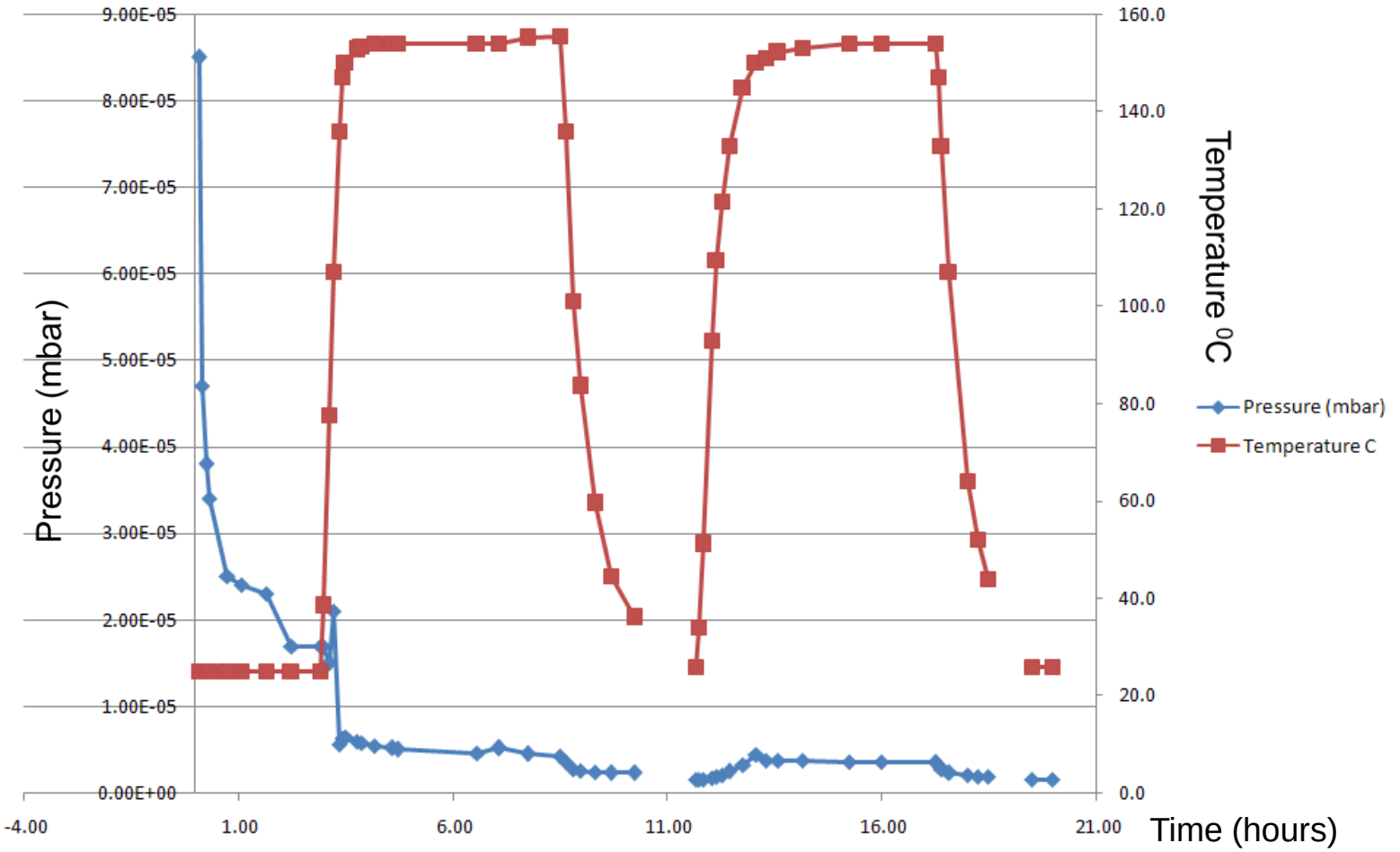


The 'O' ring was heated to 150^{0}C and then immediately cooled followed by heating again to 150^{0}C and holding there for two hours. During the high temperature period the pressure initially rose and then began to fall as expected. This test is the benchmark for tests 24 and 25.



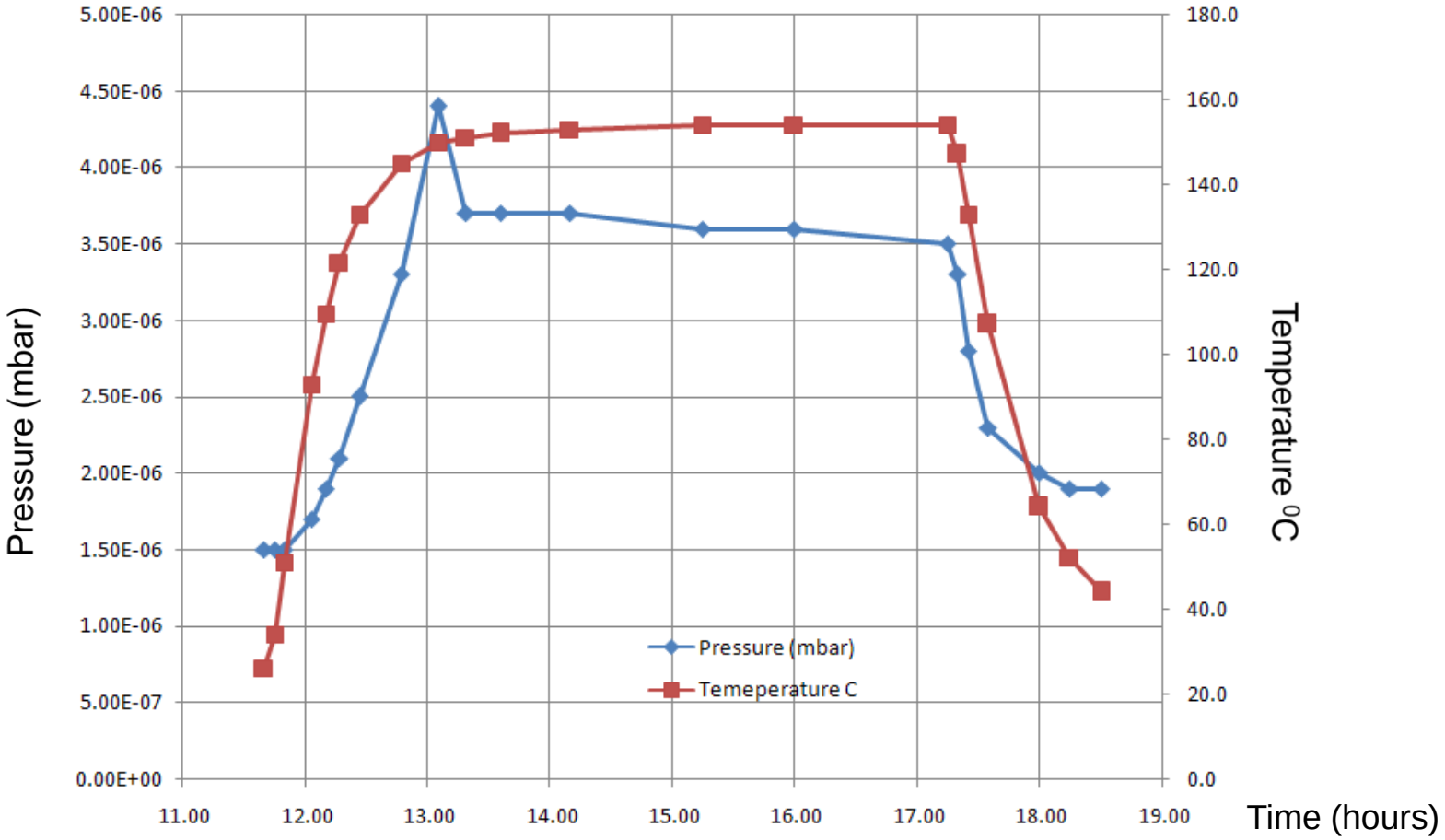
Adhesive cure cycle for the ‘O’ ring to be used inTest # 24.
The ‘O’ ring was placed in an aluminium holder and heated on the hot plate at 160^0C for 3 hours.

Test # 24



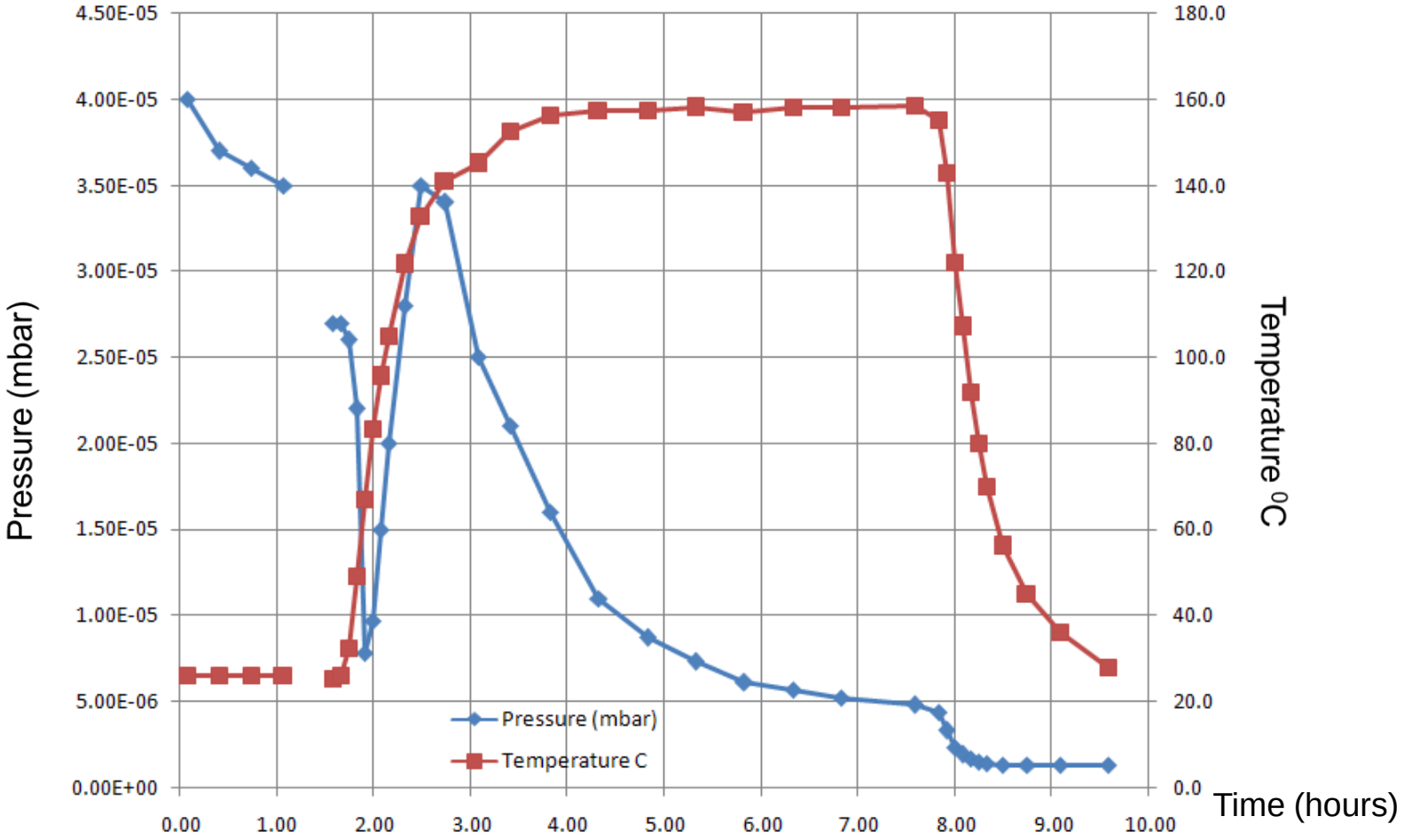
The bonded (and cured) 'O' ring was heated to 150^{0}C and held there for approximately five hours. The test was repeated after a weekend of vacuum without heat (the time axis has been modified for ease of seeing the graphs). The bonded 'O' ring shows good vacuum performance.

Test # 24



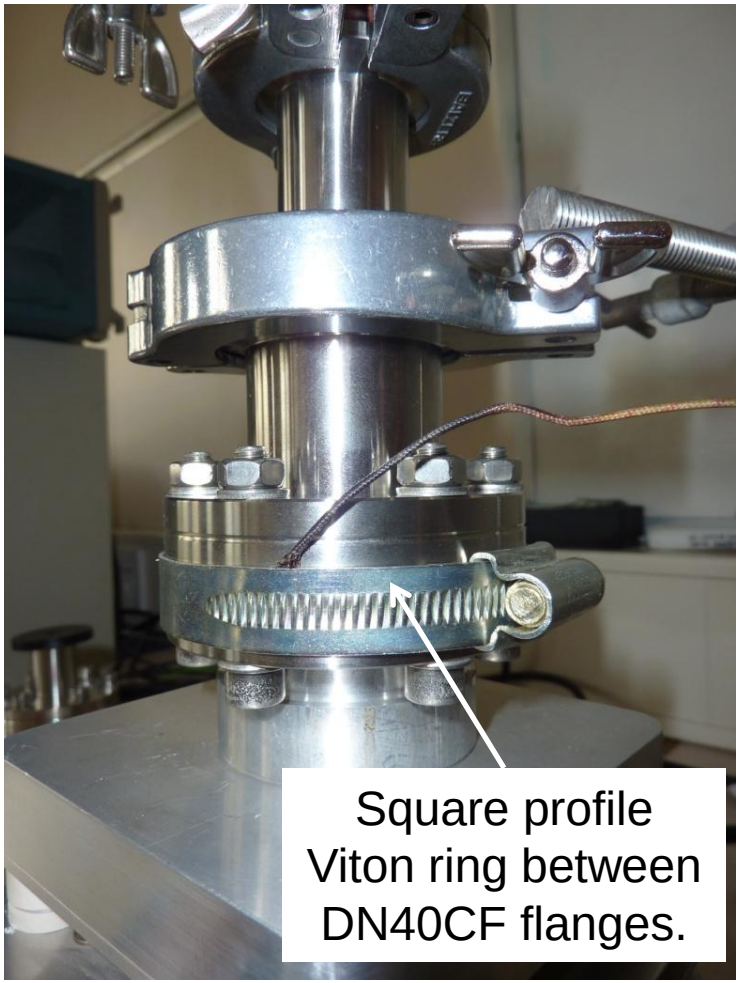
Showing just the second heating cycle for Test# 24.
During the high temperature phase the pressure initially rose and then begun to fall as the out-gassing decreased. Finally the pressure begun to fall rapidly with falling temperature.

Test # 25

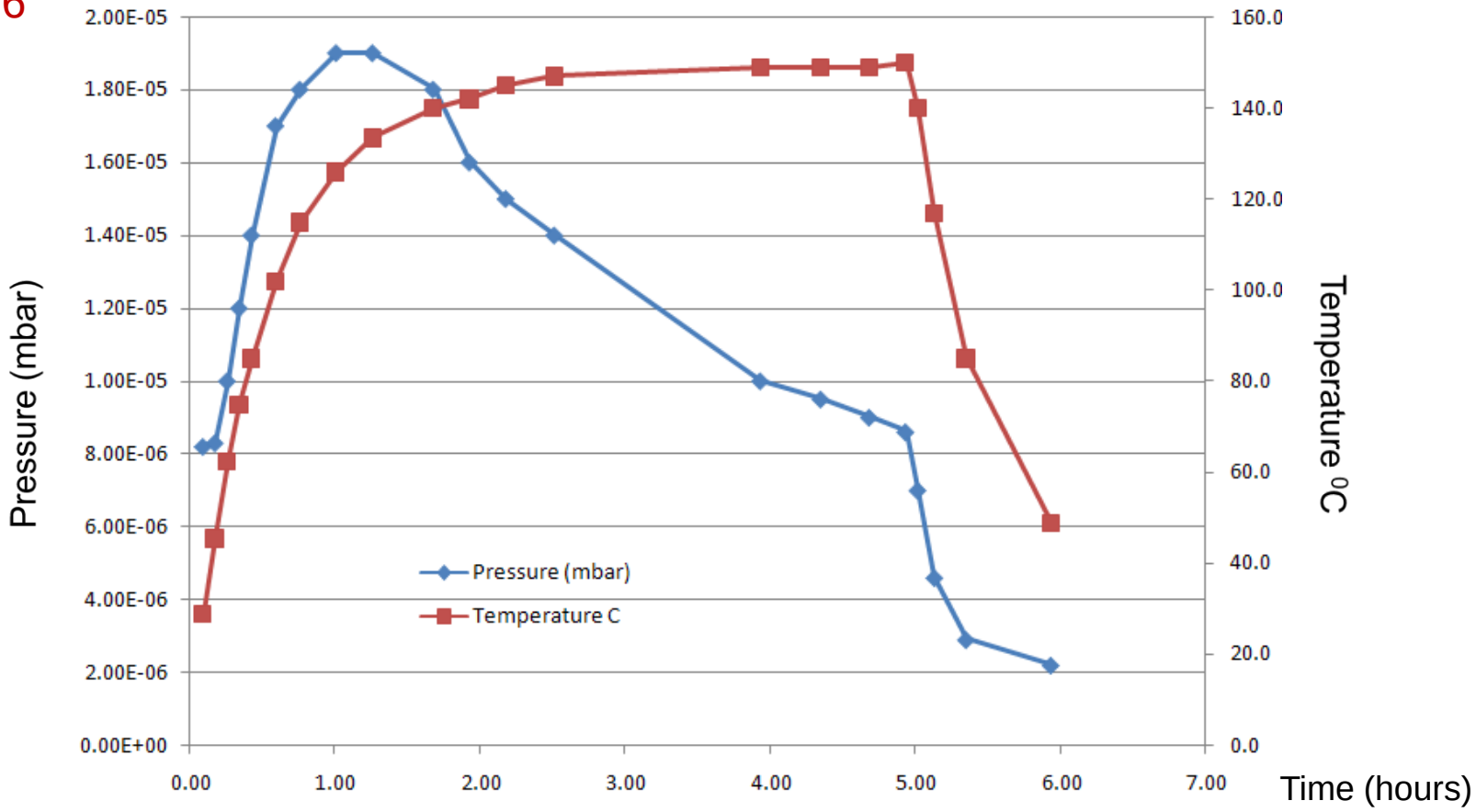


The 'O' ring will have been cured in place by the thermal cycle. The vacuum performance appears to be consistent with that of the cured O ring (test # 24) and that of the complete O ring (test # 23). I cannot explain the sudden pressure drop during the heating up phase. Note that the initial pumping at 0 to 1 hour was in reality15 hours prior to the heating cycle.

Test #26 – Attempt to re-create the ‘flash’ seen on the 3D ‘O’ ring transverse sections. Using a standard DN40CF square profile Viton ring. Heated and vacuum pumped in similar conditions to those for the 3D ‘O’ ring.
QN: Is the flash caused by the square profile ring?



Test # 26



The ‘O’ ring flanges were heated to 150^{0}C and held at that temperature for approximately 3 hours.

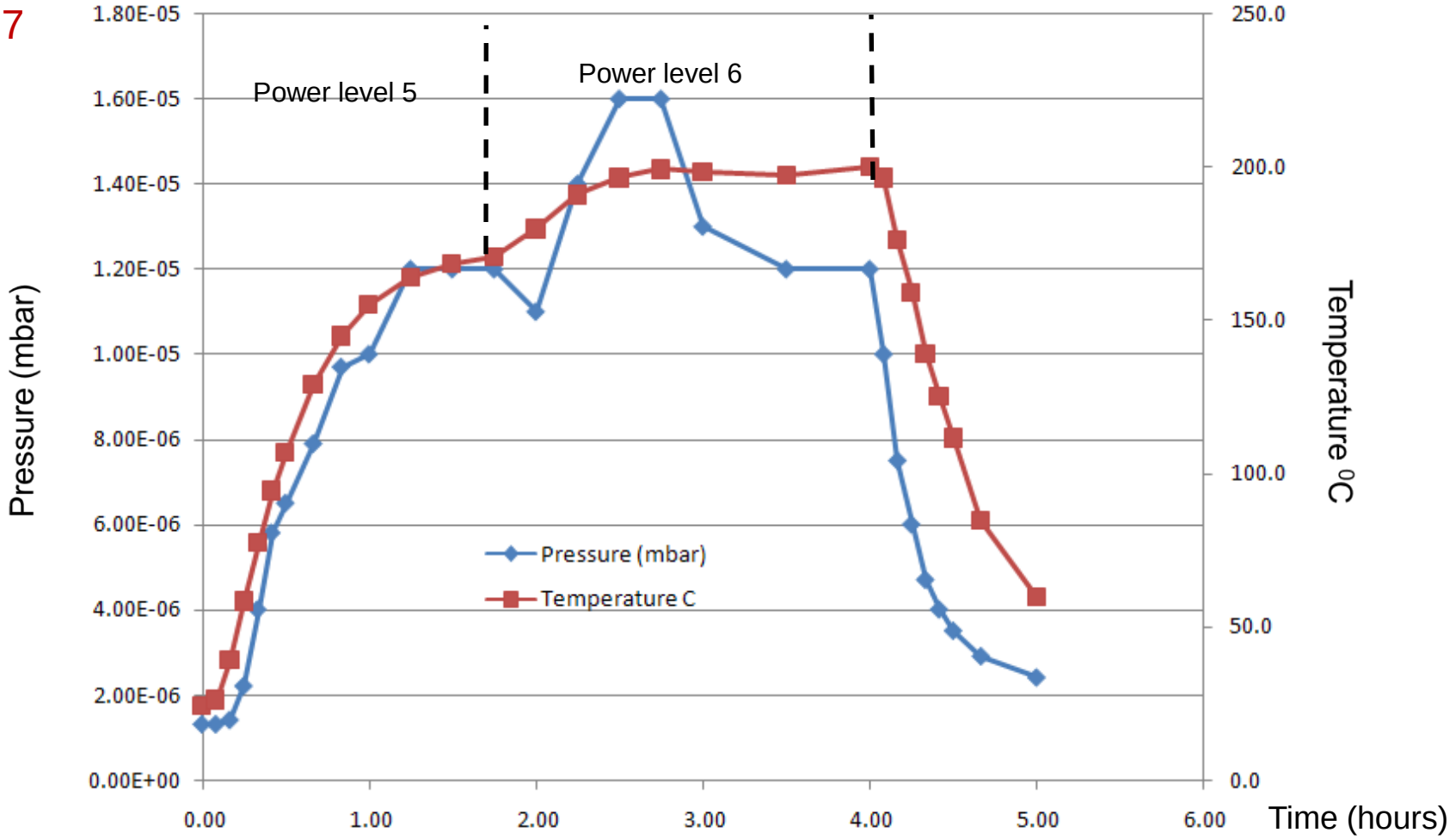
Test #26.....

Opening up the DN40CF flanges revealed that the square profile Viton ring showed no signs of ‘flash’.

However, it should be noted that there are some differences between this test and the 3D ‘O’ ring:

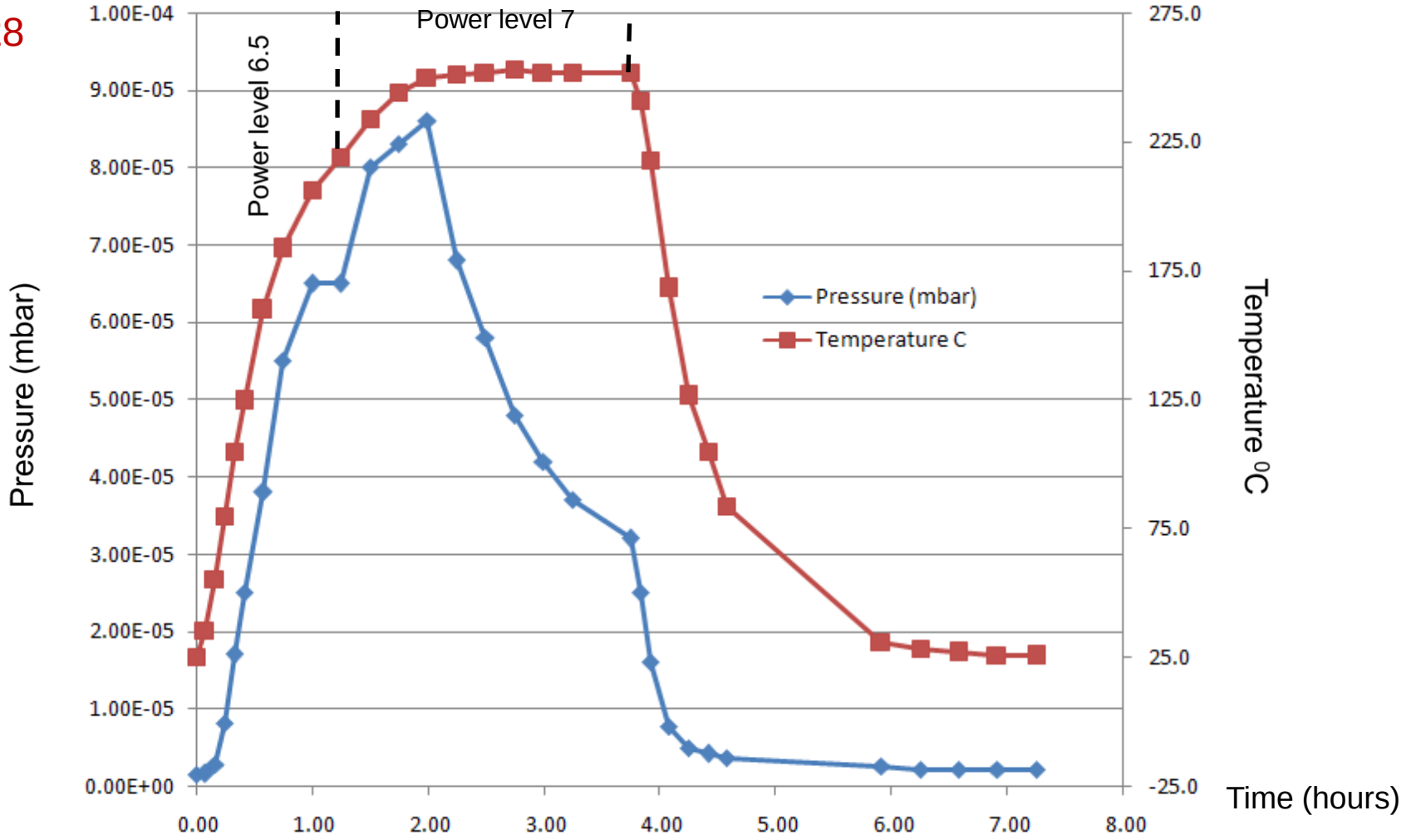
•The groove is present in both flanges and therefore the rubber ring square edges are constrained.
•The ring is smaller (there is less rubber).
•This system is stiffer with more clamping per unit area i.e. less chance for creep of rubber between mating faces.

Test # 27



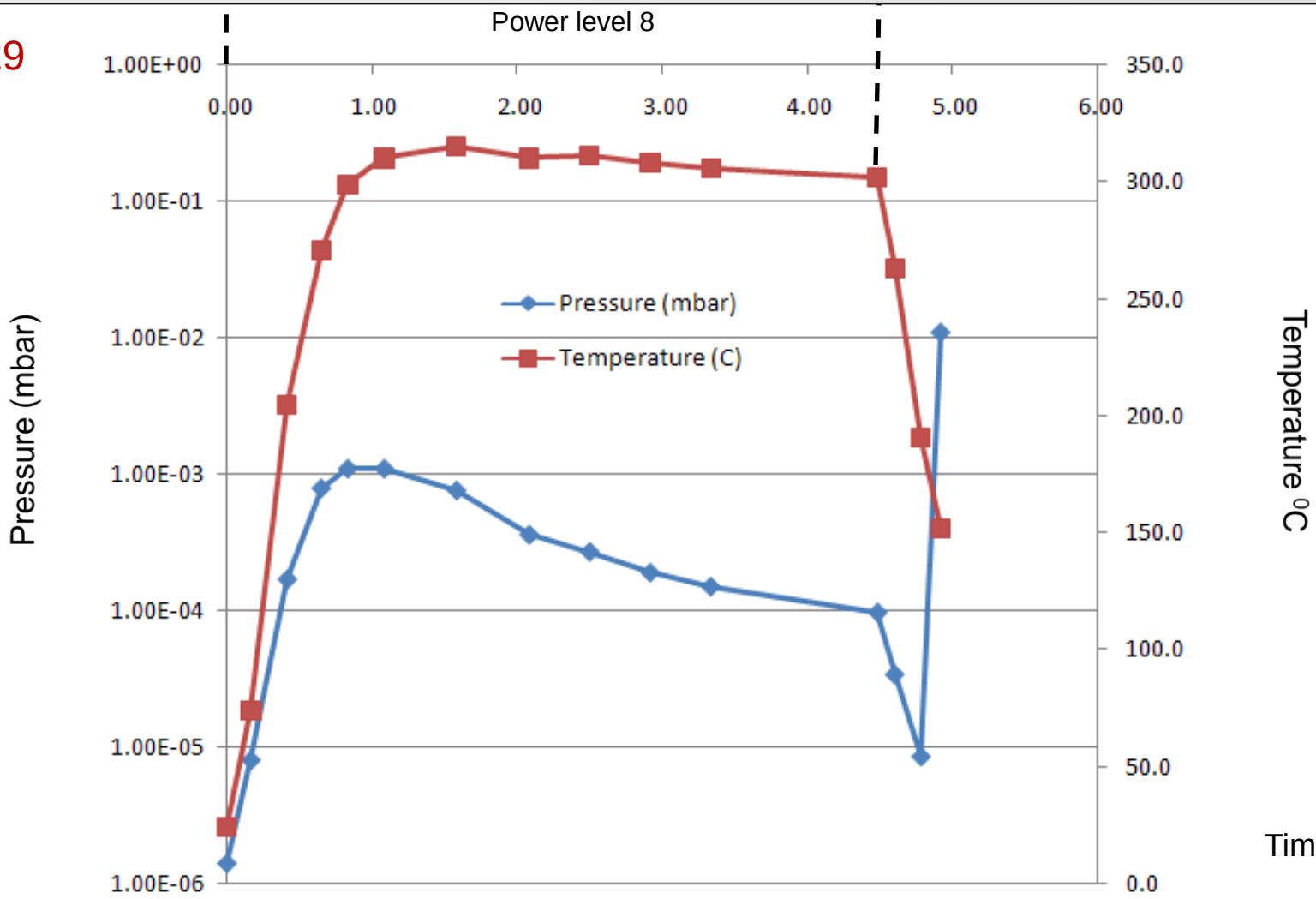
A repeat of test 26 but this time taking the system up to 200^{0}C and holding.
The Viton ring showed no visible signs of 'flash'.
This test demonstrates that the out-gassing rate increases, and then plateaus before decreasing with time at a given temperature. Raising the temperature repeats the cycle.

Test # 28

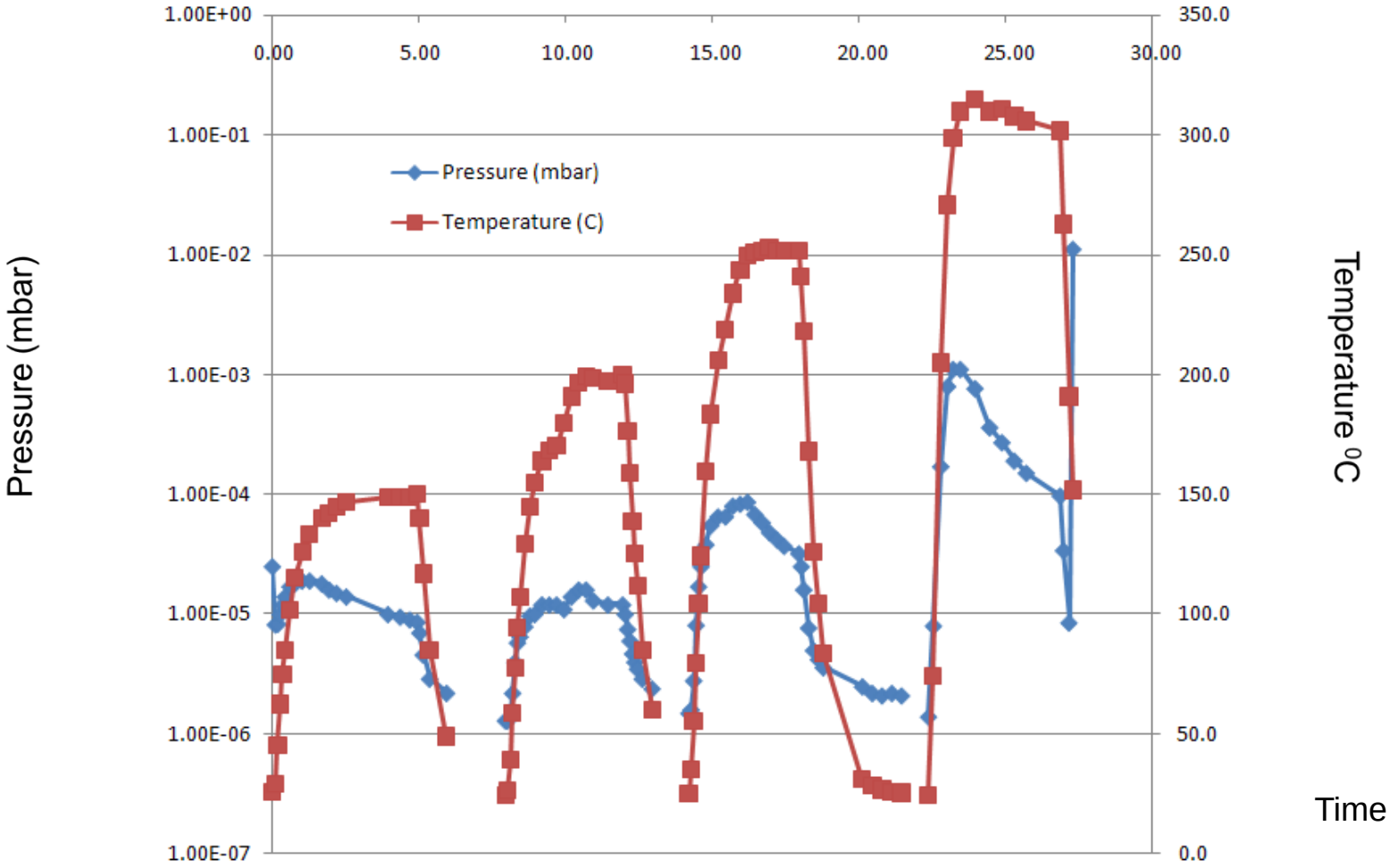


A repeat of test 26 but this time taking the system up to 250^{0}C and holding.
The Viton ring showed no visible signs of ‘flash’.

Test # 29



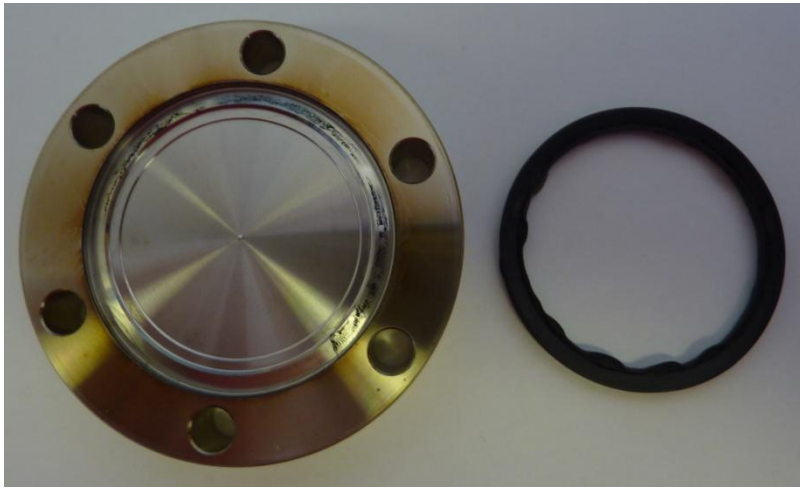
A repeat of test 26 but this time taking the system up to 300^{0}C and holding. During the cool down the seal began to fail.



Results shown consecutively for tests 26 through to 29 which correspond to temperatures of 150^{0}C, 200^{0}C, 250^{0}C and 300^{0}C.

Test #29.....

Opening up the DN40CF flanges revealed that the stainless steel is discoloured and the ‘O’ ring has started to deteriorate. The ‘O’ ring was lightly stuck to the stainless steel and after peeling it off some rubber was left behind.



Conclusions

•I believe that the cause of the 'O' ring dents is due to using short longitudinal 'O' rings.
•I believe that the dents will have caused a vacuum leak.
•Tests 23, 24 and 25 show that bonding and curing the 'O' ring before vacuum pumping or bonding the 'O' ring, then pumping and then curing in-place seem to have little affect on the vacuum performance.
•Test 26, 27 and 28 showed that at 150^0C, 200^0C, 250^0C there was no reduction of vacuum performance and no 'O' ring degradation. Test 29 at 300^0C led to a vacuum leak, a damaged 'O' ring and rubber being deposited onto the stainless steel surfaces.

What next?

•New transverse Viton rings have arrived at Imperial.
•Weld test model has been cleaned to remove deposited rubber.
•Longitudinal 'O' rings lengths will revert to 250mm long.
•New 3D 'O' rings will be bonded and cured in an oven.
•Weld test model will be reassembled.
•Vacuum testing with heat will be repeated.
•Hope to have result by end of next week.
•Vulcanising will be our fall-back option and is being investigated by Alberto.
•Transport is booked to return the RAL pumping rig on 3rd August.

More soon.....