Results from NEL Cryogenic Test Facility

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Background

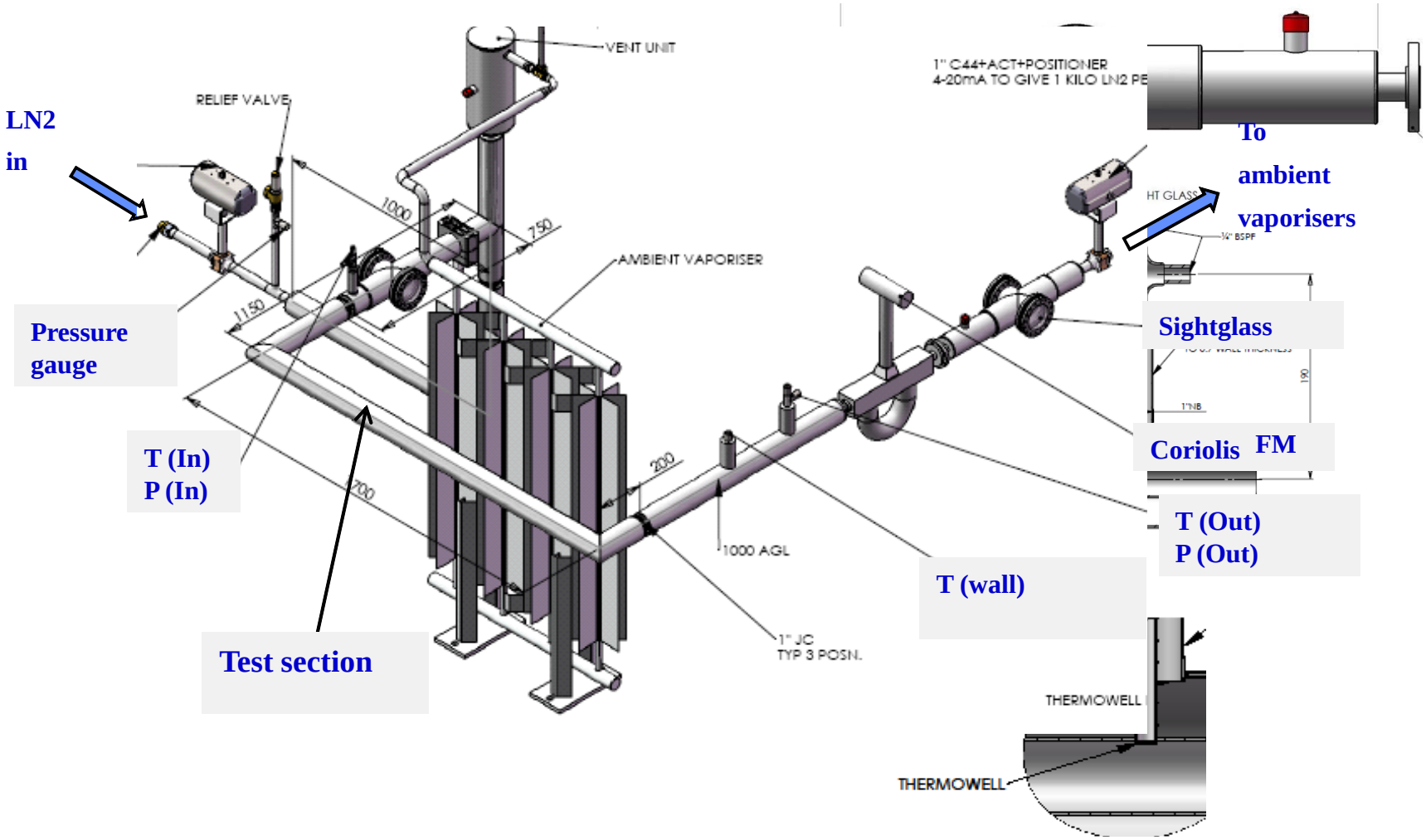
- Flowmeters have many advantages over tank gauging for LNG custody transfer measurements.
- Before flowmeters are accepted in the LNG industry calibration facilities and procedures need to be developed.
- This is a very challenging task for the pipe size and flowrates required in custody transfer applications.
- It was therefore decided to build a small scale cryogenic facility at NEL to develop expertise in the design and running of a cryogenic flow facility.

Facility Specification

- Run liquid Nitrogen (LN_2) through the test facility safely .
- Maintain single phase flow through the designated test section.
- Ability to vary the pressure and flowrate.
- The facility should have the ability to monitor and record:
  - Temperatures,
  - Pressures and
  - Flowrates

  throughout the system.

Design


LN2
in
Pressure
gauge
T (In)
P (In)
Test section
VENT UNIT
RELIEF VALVE
1000
750
1150
AMBIENT VAPORISER
200
700
1000 AGL
1" JC
TYP 3 POSN.
1" C44+ACT+POSITIONER
4-20mA TO GIVE 1 KILO LN2 PE
To
ambient
vaporisers
HT GLASS
14" BSPF
Sightglass
Coriolis FM
T (Out)
P (Out)
T (wall)
THERMOWELL
THERMOWELL

Design

Background

Workpackage 2 consisted of the following tasks:

1. Functionality test of 1" cryogenic facility at NEL

2. Effects of cryogenic media on flowmeter, temperature and pressure sensors

3. Installation effects on flowmeter performance

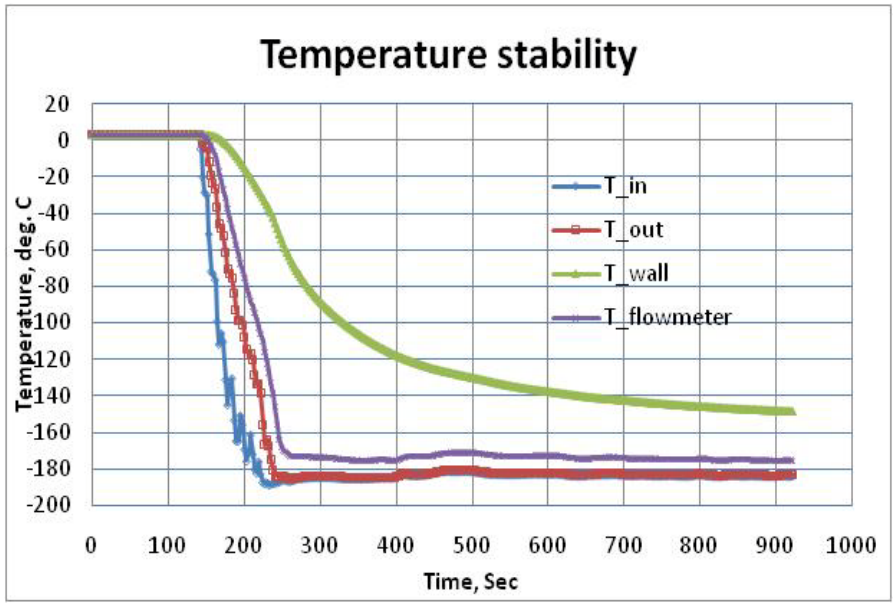
Lessons learnt from this series of tests will be used to help design a larger scale LNG calibration facility in Rotterdam

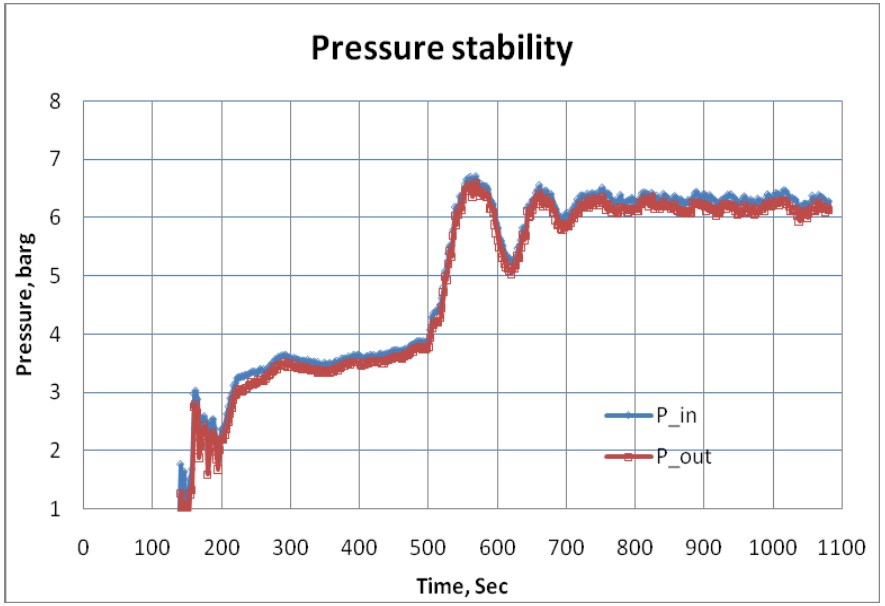
Testing Plan

- Perform safety tests including pressure, leak and blockage tests on all pipework and relief valve lines.
- Test functionality of the rig including liquid nitrogen condition, maximum flowrate and flowrate control.
- Test the stability of the instruments over a series of test points.
- Remove the insulation from the flowmeter to study the effects of insulation on flowmeter performance.

Liquid Nitrogen Condition

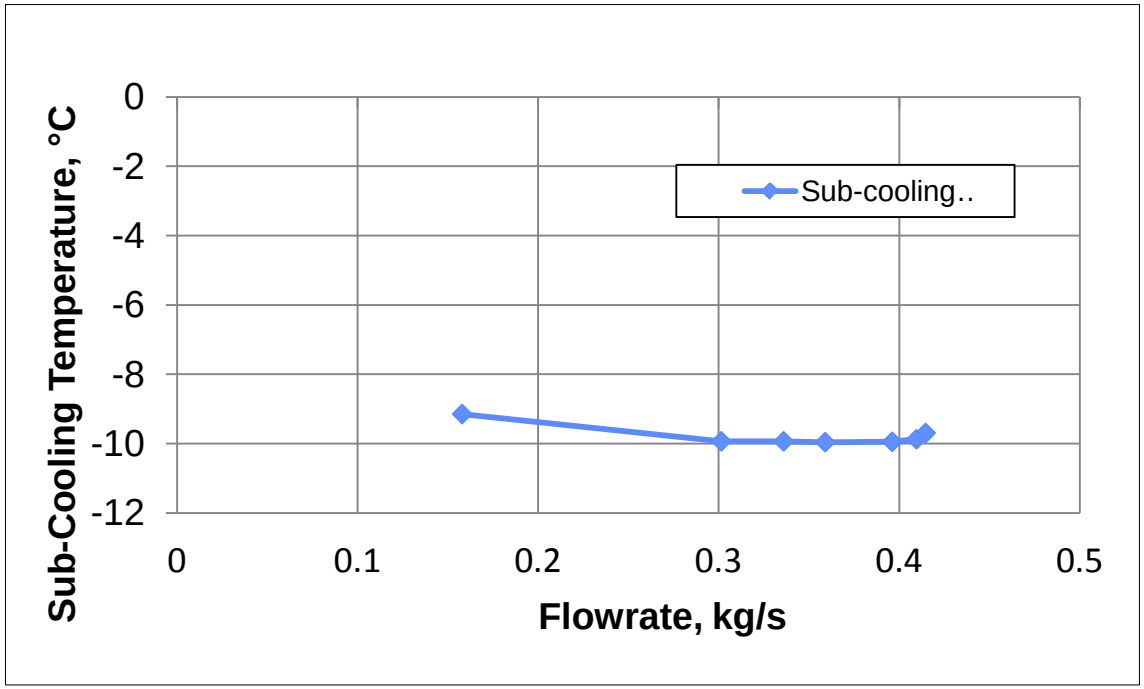
- Temperature rapidly cools to -185°C as LN_2 flows through rig..
- Wall temperature lags behind and only reaches -150°C
- Pressure Stabilises at 6 Bar





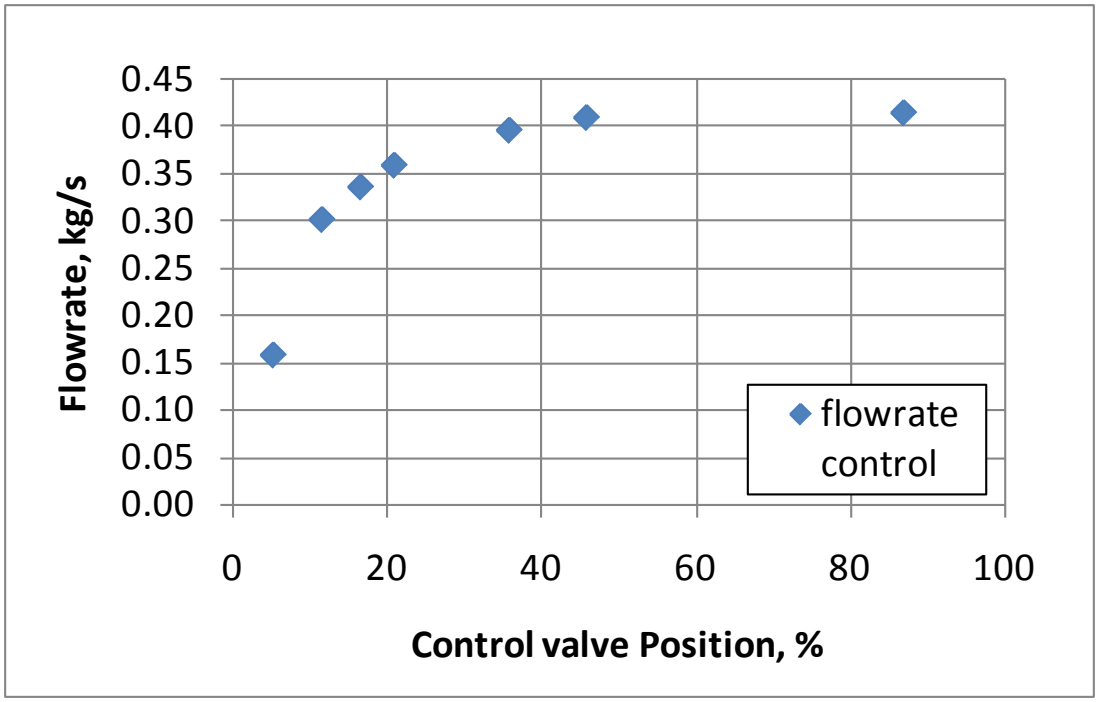
Sub-Cooling

- Subcooling is defined as the temperature of LN_2 at the centre of the pipe minus the saturation temperature at the working pressure.
- If the LN_2 is sub-cooled then no boiling will take place.



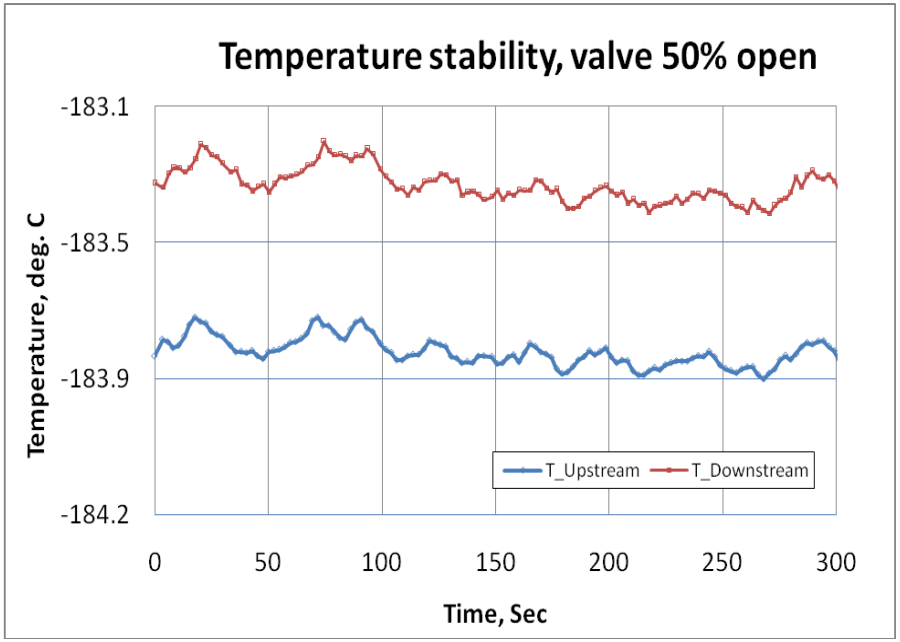
Flowrate

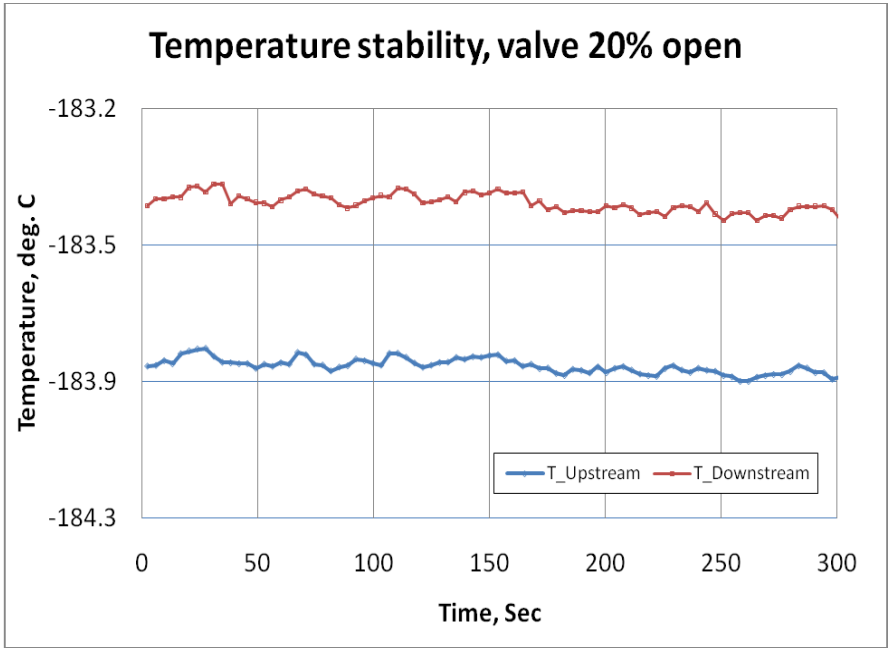
- The maximum achievable flowrate was found to be 0.40kg/s with the valve fully open
- The flowrate could be reduced using the downstream control valve.



Bulk Temperature Measurement

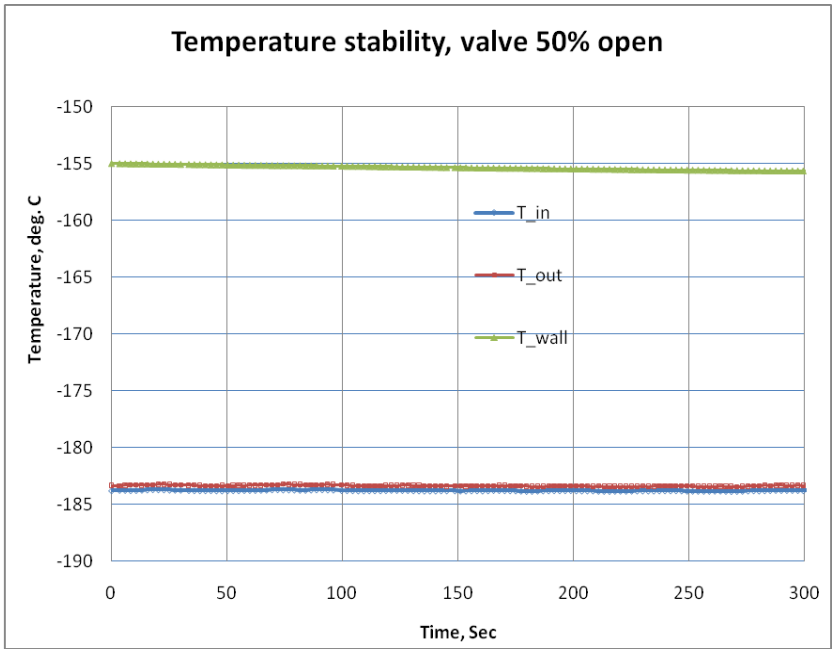
- The temperature upstream and downstream of the test section is shown below
- The temperature increases by 0.5 C between the temperature probes.

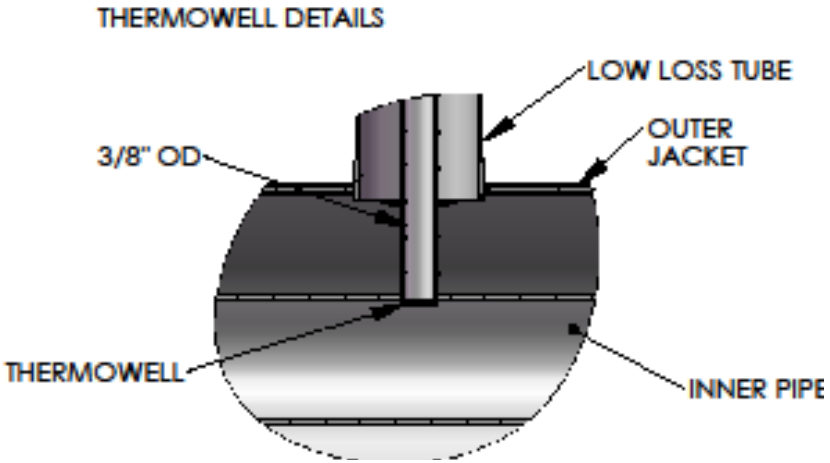




Pipe Wall Temperature

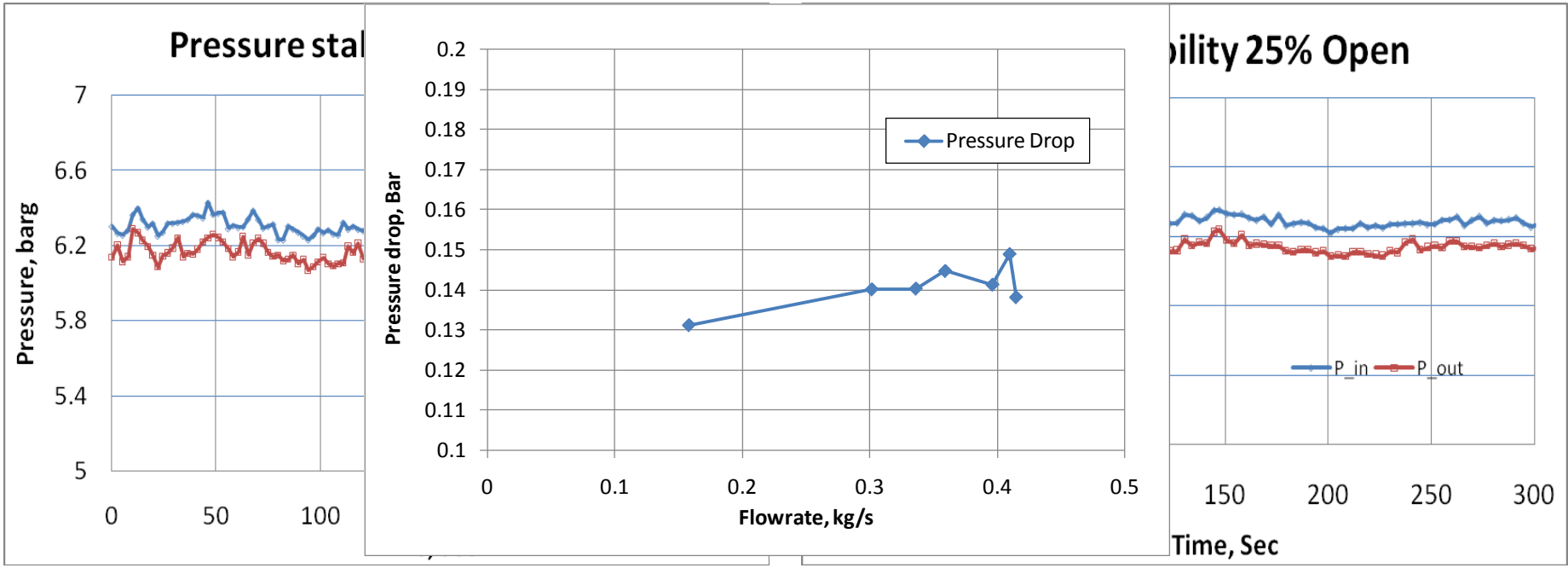
- The wall temperature was measured so the temperature gradient across the pipe could be measured.
- The wall temperature was measured to be 28°C higher than the bulk temperature
- This is thought to be too high





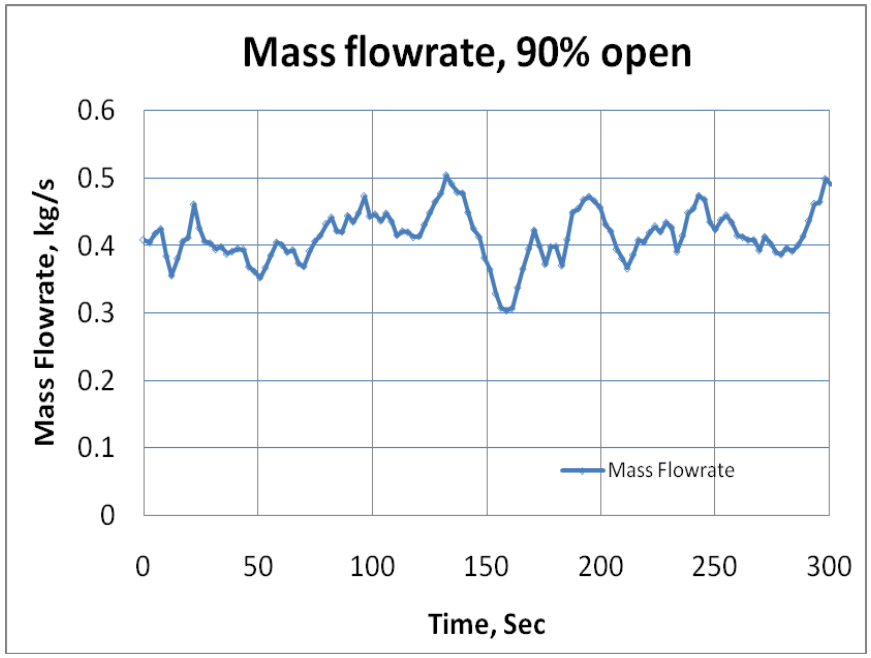
Pressure Measurement

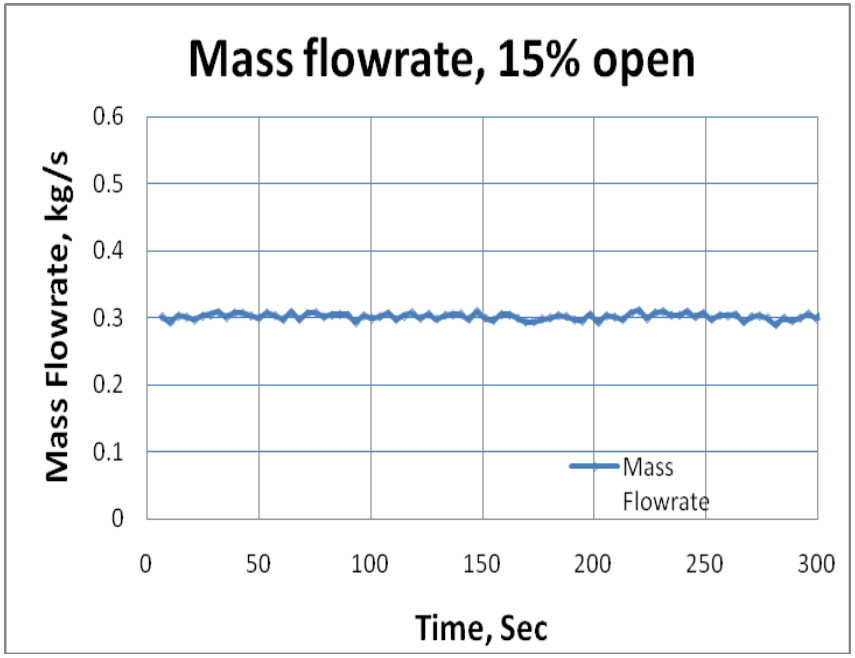
- The pressure upstream and downstream of the test section is shown below
- An average pressure drop of 0.14 bar was measured through the test section



Flowrate Measurement

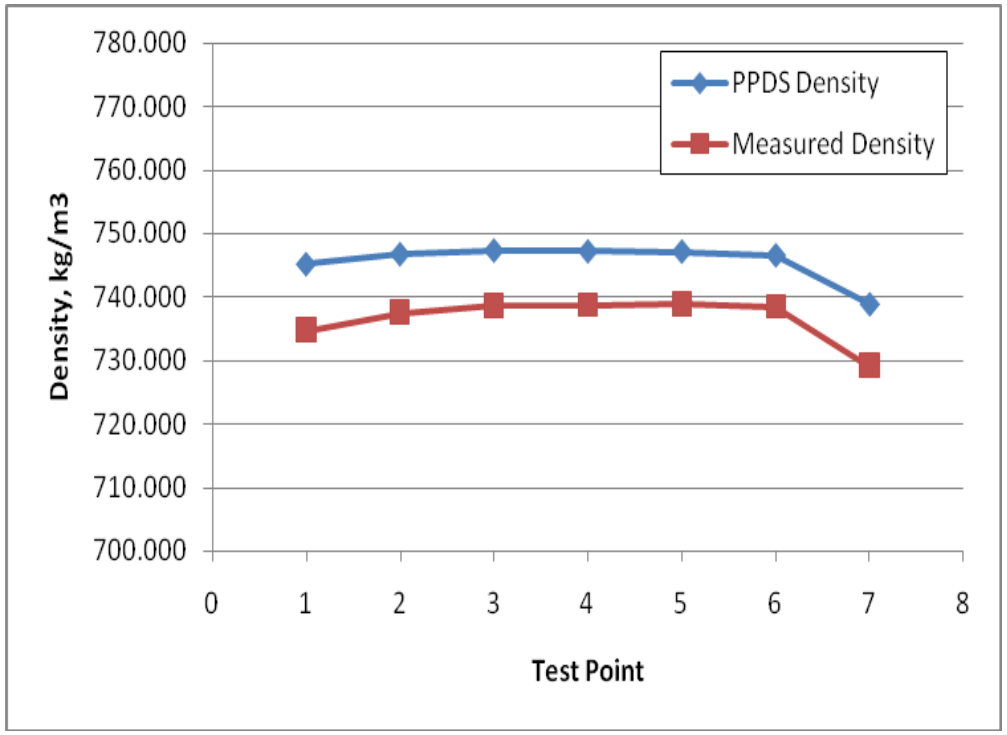
- There was large fluctuations in the flowrate but these reduced as the control valve was closed.
- It is thought that closing the control valve dampens the fluctuations due to the resistance imposed to the flow.





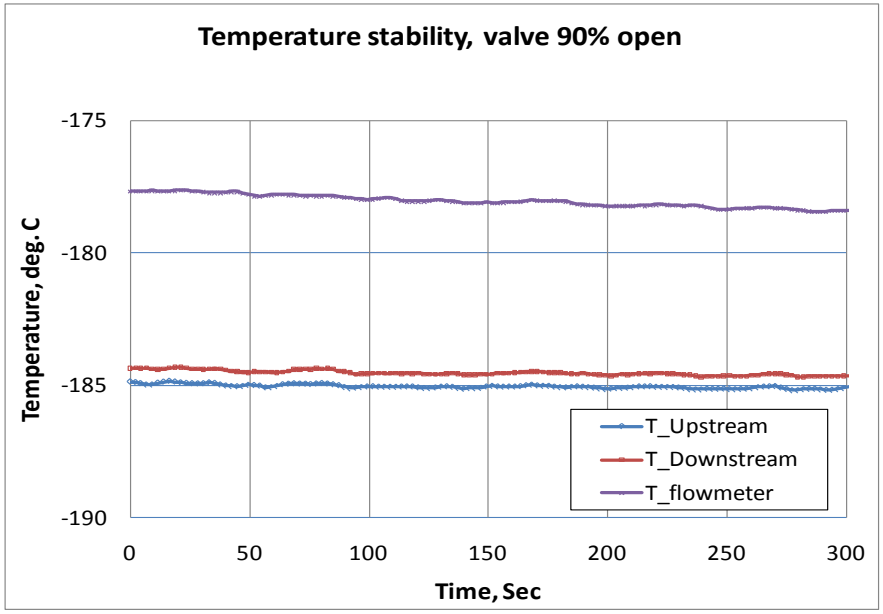
Density Measurement

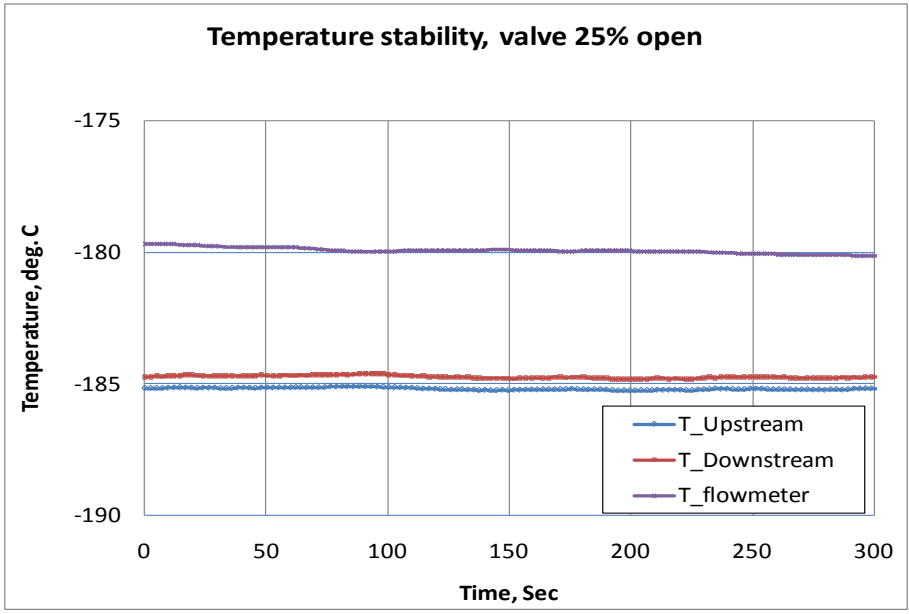
- The Coriolis density measurement was compared to the density calculated with physical properties data service (PPDS).
- Agreement was within 1.4%.



Flowmeter Temperature Measurement

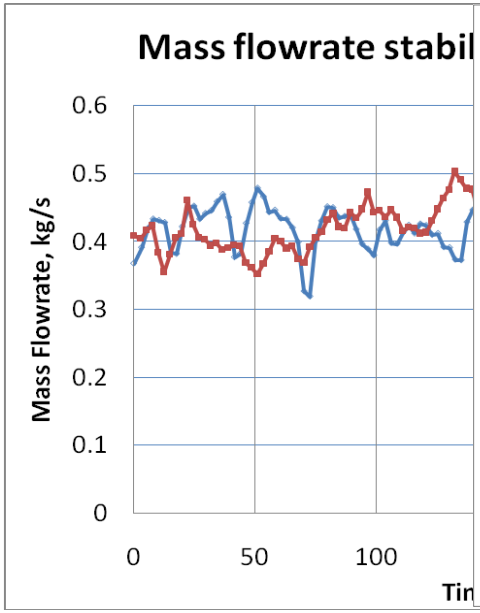
- The flowmeter temperature took longer to stabilise than the bulk flow measurement and stabilises about 5°C higher.
- This is reasonable as the flowmeter measures the temperature at the tube wall and not the bulk temperature.

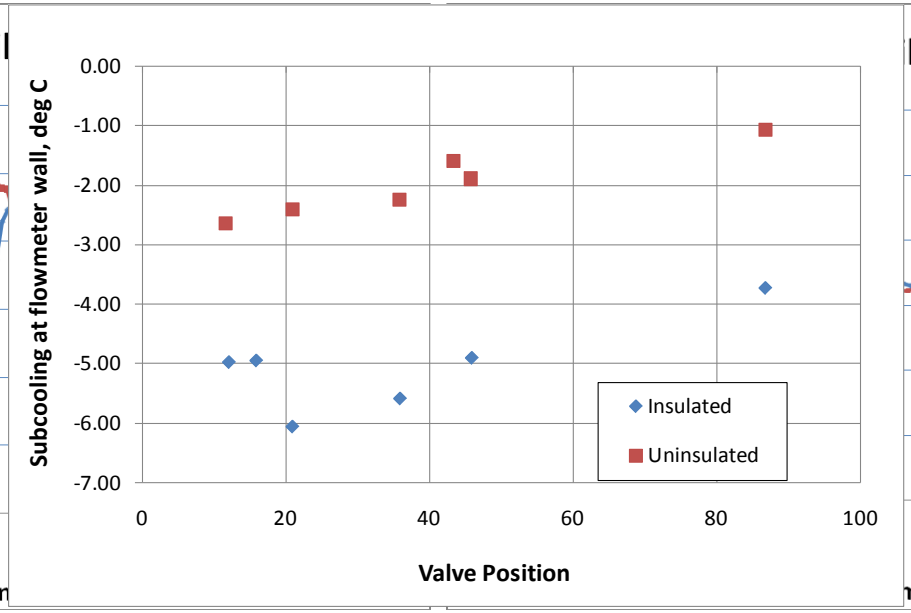


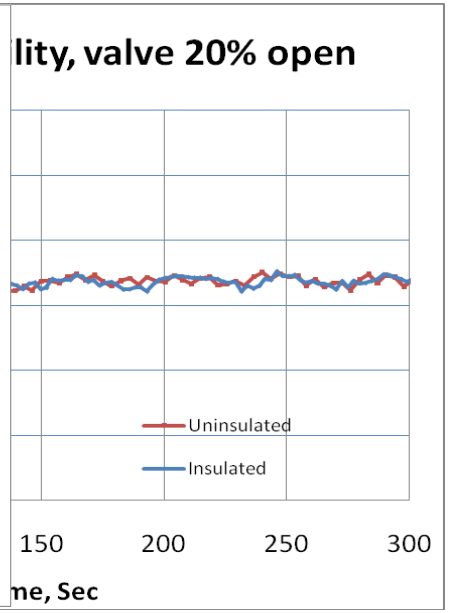


Effect of Insulation

- The flowrate and flowrate stability were unaffected by the removal of insulation in these tests.
- However the amount of sub-cooling at the flowmeter tube walls reduced by 3 °C when the insulation was removed.







Lessons Learnt - Cooling

- Sub-cooling of around 10 °C was achieved with these tests due to sub-cooling in the storage tank and vacuum insulation.
- A temperature rise of 0.5 °C through the facility was caused mainly by un-insulated flanged sections.
- A recirculation facility is likely to require a cooling system to avoid boiling.
- Effort should be made to minimise un-insulated flanged sections in a larger scale facility.

Lessons Learnt - Control

- It was shown that flowrate could be controlled effectively with a downstream control valve.
- Flowrate fluctuations could be reduced by regulating the back pressure with the control valve.
- Pressure fluctuations will affect flow stability so careful design is needed to ensure pressure stability in a larger scale facility.

Lessons Learnt - Instruments

- The pressure transmitters followed the same patterns and showed the pressure drop from the upstream to downstream measurements.
- The temperature transmitters followed the patterns and showed a temperature rise from the upstream to downstream measurement.
- The wall PRT reading was thought to be too high and modifications should be made to the design in a larger scale facility.
- Both the wall and flowmeter temperature measurements took longer to stabilise than the bulk temperature measurements.
- This should be considered if temperature corrections are being made at the flowmeter

Lessons Learnt - Flowmeter

- The Coriolis flowmeter operated well in the cryogenic conditions and it is thought that the measured fluctuations were genuine flow fluctuations.
- The density measurement agreed well with the reading from PPDS.
- Removal of the insulation reduced the amount of sub-cooling at the Coriolis tube wall by 3°C.
- It is important that any reference meter in a larger scale facility is well insulated to avoid boiling at the pipe walls which could lead to errors.

Any Questions?