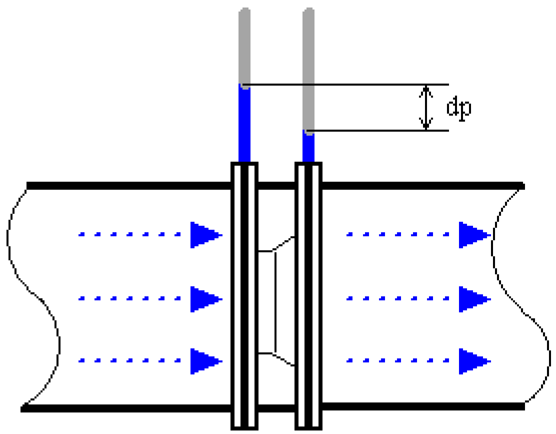
PRESLHY Workshop – Flow measurement at HSL

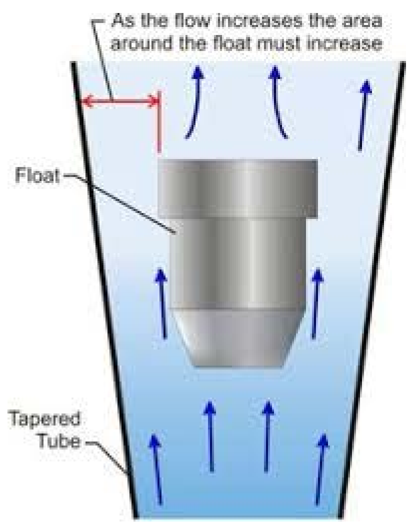
PRESLHY general assembly 08/03/2019

Pre-normative REsearch for Safe use of Liquid HYdrogen

Flow meters commonly used

- HSL commonly uses flow meters based on:
  - Coriolis
  - Thermal conductivity
  - Orifice
  - Rotameter
  - Many other types exist but these are our commonly used types



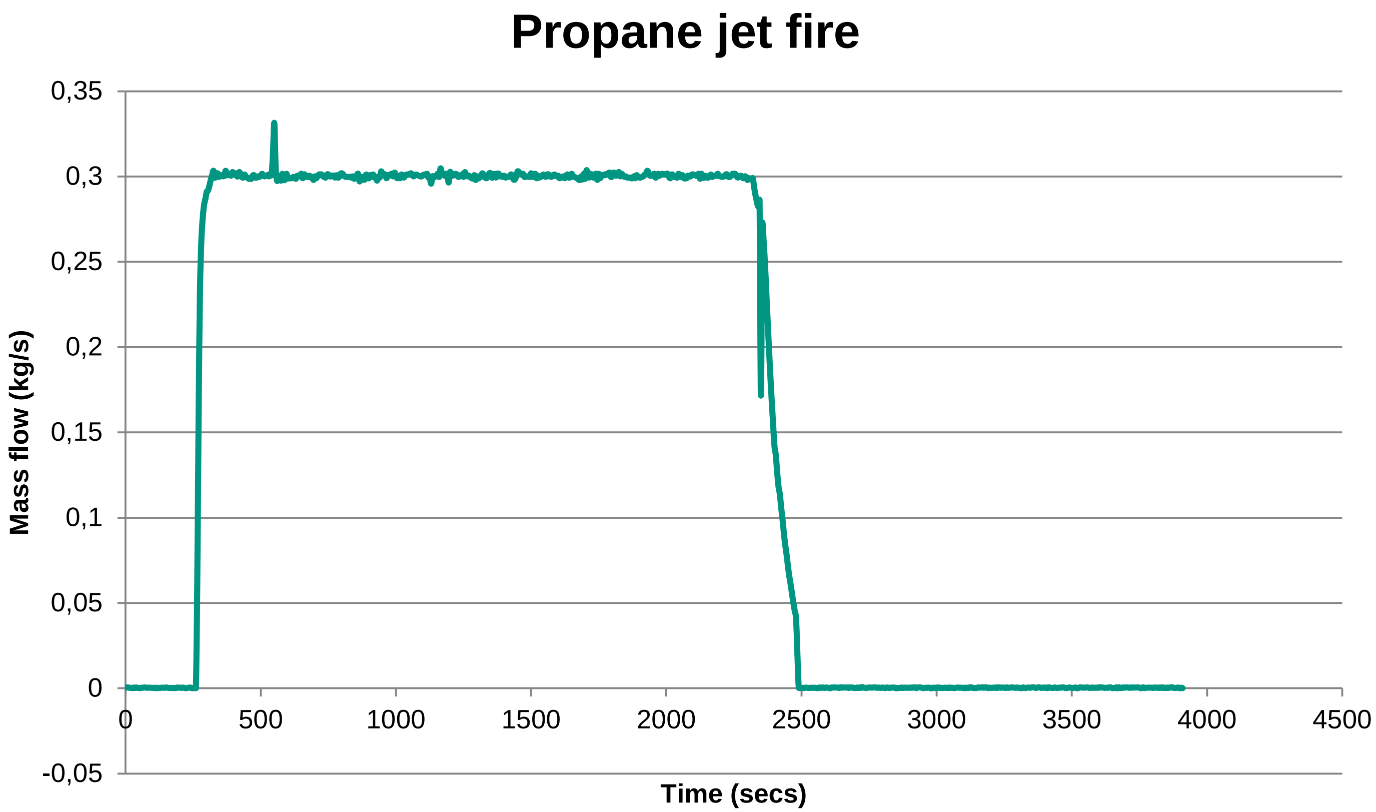


Options for cryogenics

- LIMITED!
- Only two real options as:
  - Need to minimise pressure drop
  - Minimise flashing of liquid to gas (ideally)
  - Material compatibility, extreme cold
- No currently available flow meters specified for LH_2
- Only options seem to be:
  - Coriolis
  - Orifice

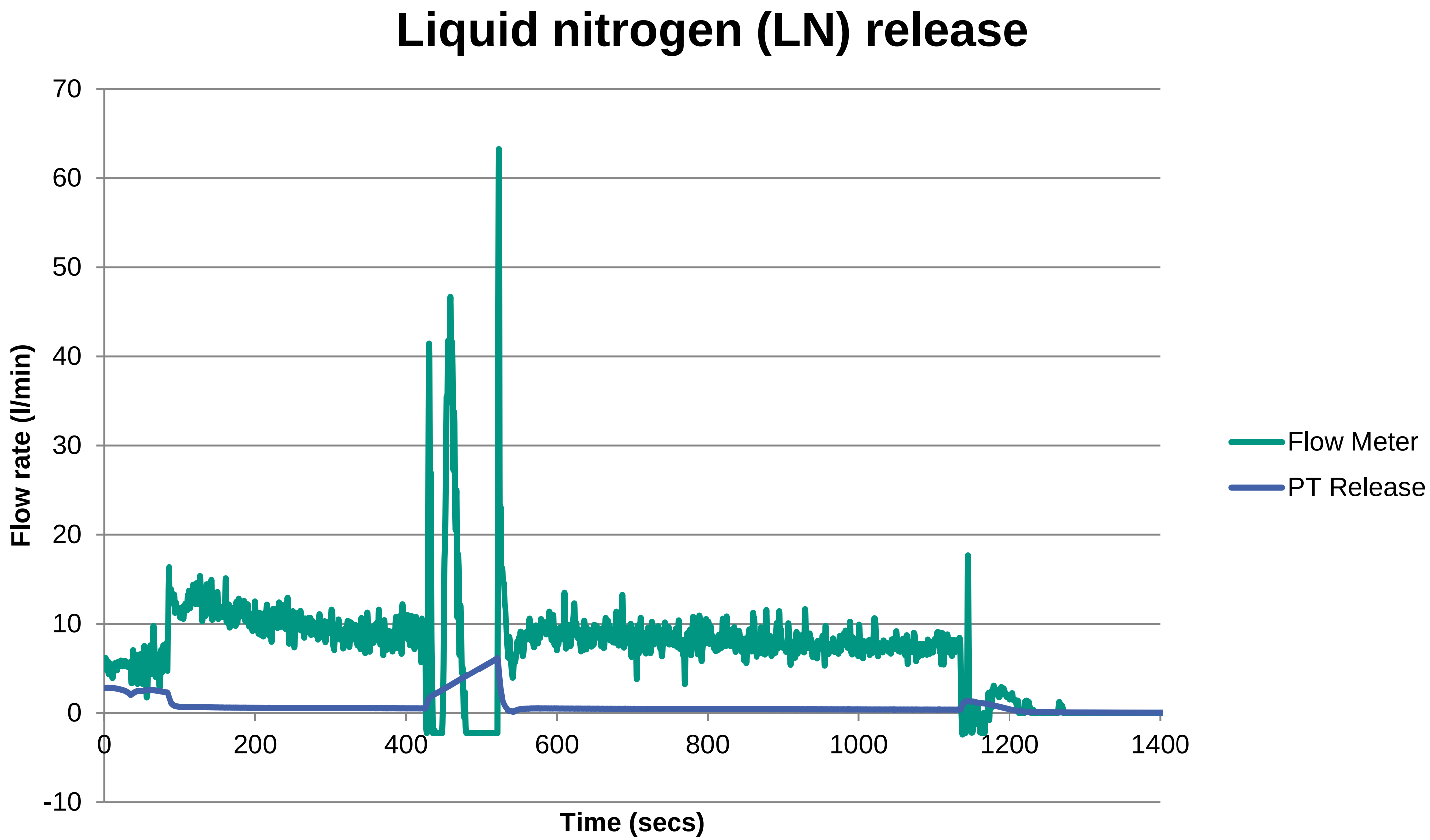
HSL coriolis experience

- Have used extensively for gaseous measurements



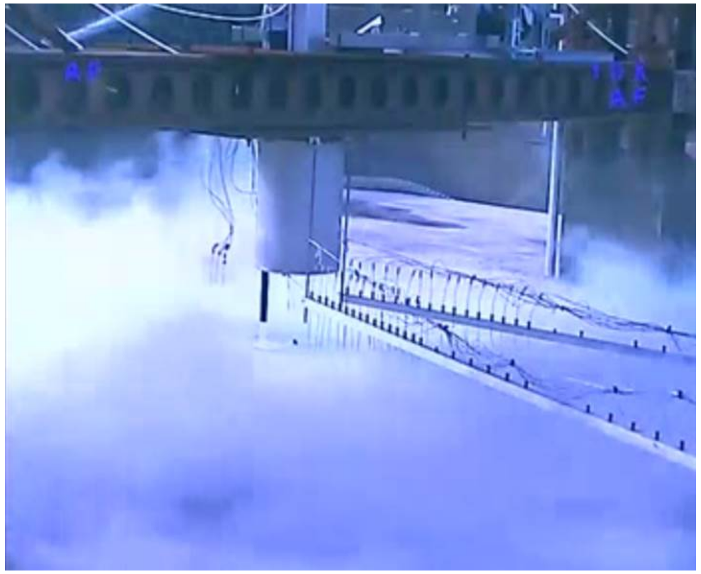
HSL coriolis experience

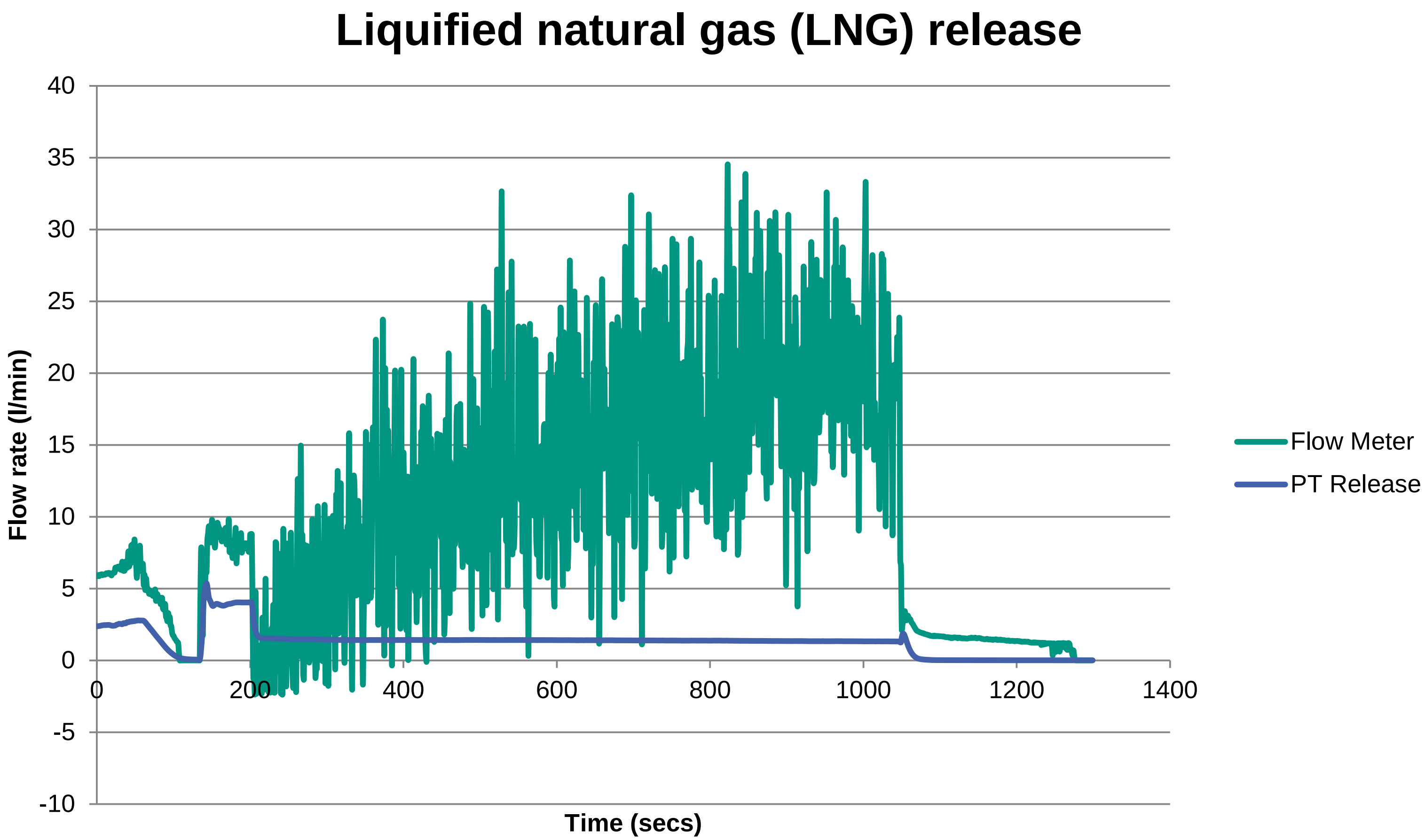
- Have used for a couple of projects for cryogenic liquid nitrogen measurements



HSL coriolis experience

- Have used for a couple of projects for cryogenic liquid natural gas measurements





Previous HSL LH2 flow measurement

- Didn't do it
- It was estimated based on information from BOC presumably of tank to tank transfers, not the same as open ended pipe
- Estimated 60 l/min (0.07 kg/s)
- Calculations using basic numerical methods and PHAST show the flow rate could have been far higher, up to 350 l/min (0.4 kg/s)
- Huge unknown is phase at release which will affect mass flow rate
- Mass flow rate key to consequence and hazard analysis

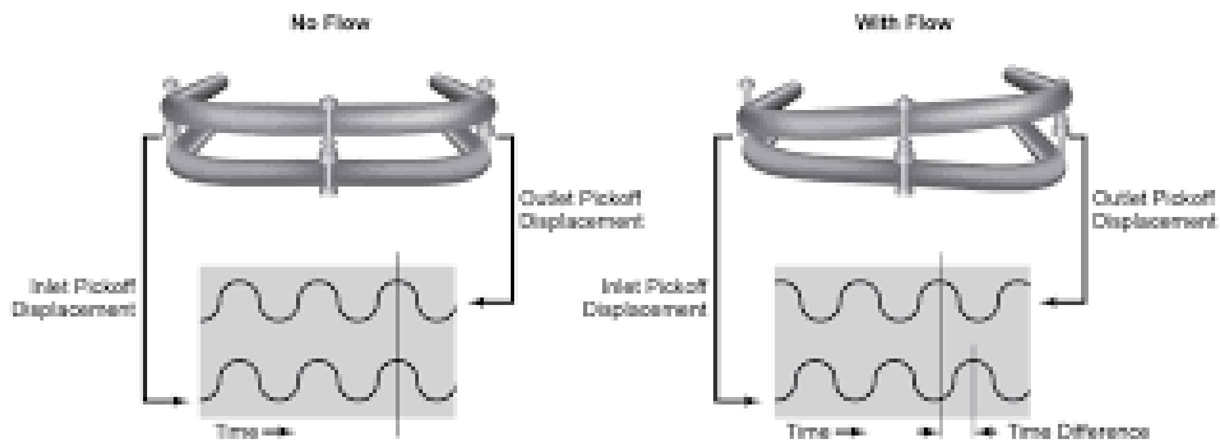
HSL coriolis experience

- LN and LNG are relatively ‘easy’ as off the shelf products exist, i.e. >-200°C
  - Multi phase causes a problem, as can be seen in previous graphs
- Problems which must be overcome:
  - Current flow meters use PT100’s which do not operate reliably below -200°C approximately
  - Air inside the sealed unit will freeze and affect the electronics
  - Thermal cycling affecting small gauge wiring

	Oxygen	Nitrogen	Hydrogen
Boiling point (°C)	-183	-196	-253
Melting point (°C)	-219	-210	-259

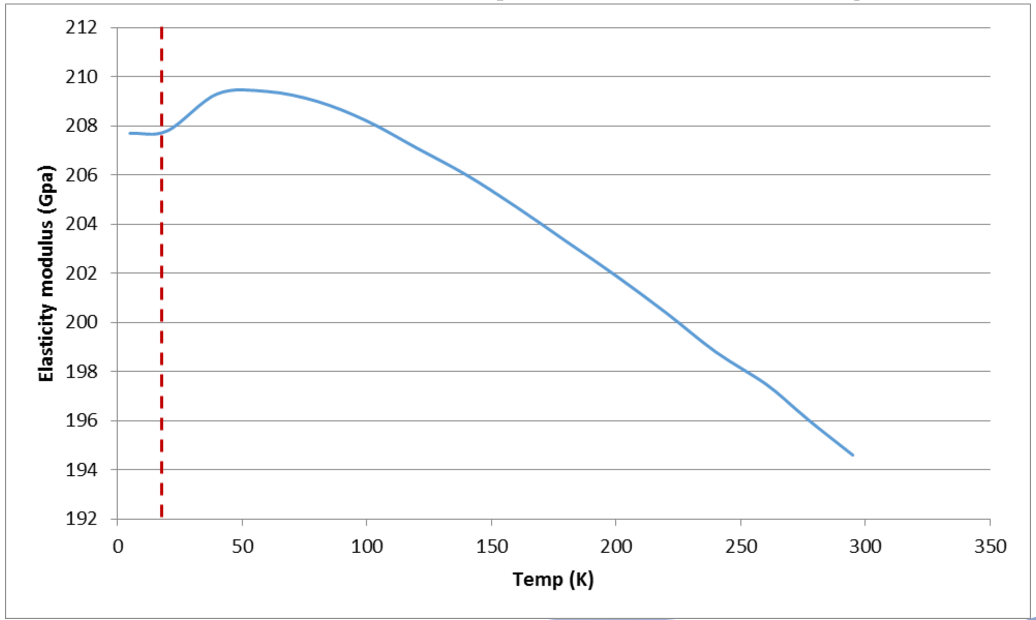
Coriolis operation

- Coriolis meters work independently of density, unlike other flow measurement techniques
- The flow is passed through tubes which are vibrated at the systems resonant frequency
- Flow through the tube induces a force which is translated to a phase shift
- Phase shift is proportional to mass flow rate



Coriolis operation

- Coriolis meters use temperature to compensate for changes in the flow tube materials modulus of elasticity
- The density is calculated from the change in resonant frequency and by knowing the modulus of elasticity of the flow tube
- As the PT100 will not work, a fixed modulus of elasticity will be chosen to suit equilibrium conditions: -253°C (LH2 boiling point)



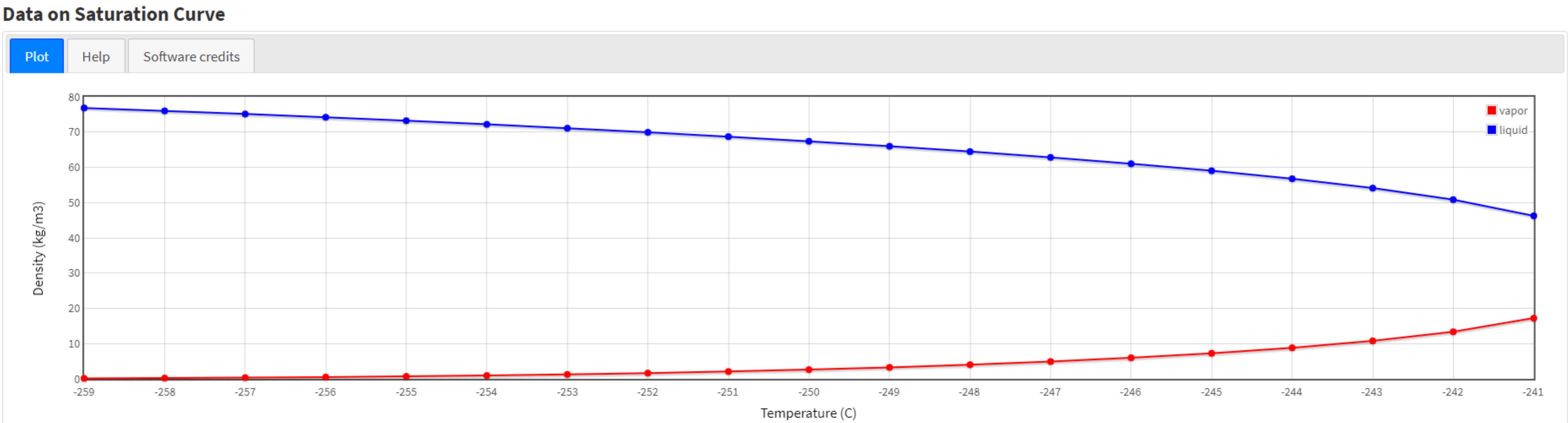
Coriolis operation

- Using this fixed elasticity modulus, a mass flow rate can be measured, estimated accuracy ±3% full scale (full scale is 350 l/min)
- The casing will be evacuated to eliminate air freezing issue and help reduce heat losses
- The internal wiring is to be improved to reduce thermal cycling issues

- This appears to be new ground for liquid hydrogen but not new for liquid helium: *de Jonge T., Development of a mass flowmeter based on the Coriolis acceleration for liquid, supercritical and superfluid helium, LHC division CERN*

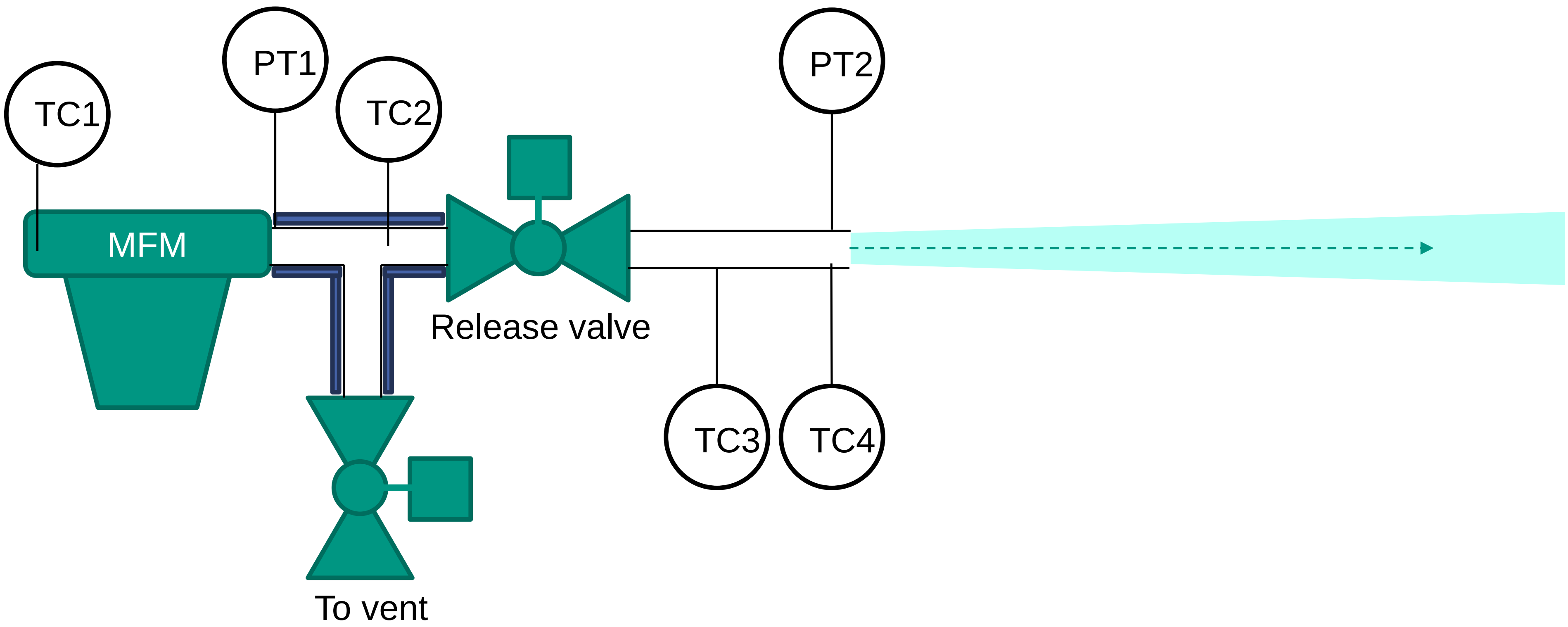
Coriolis operation HSL changes

- The plan is to make our own measurement of temperature in and out of the flow meter (can’t do inside) using type T thermocouples
- If we log frequency then we should be able to compensate for any elasticity changes and get more accurate flow measurements and actual density measurements (resonant frequency is a function of density)
- Drive gain (power) will also be logged to help infer gas quality, the more power the meter requires, the more gas is present in the meter



Another option

- The release system has an inbuilt orifice plate, the release valve
- An assessment of mass flow should be possible as:
  - The valve has a known CV
  - Temperature is measured before and after valve
  - Pressure is measured before and after the valve
- Always risky making two measurements of the same thing!



Acknowledgements

The research leading to these results was financially supported by the PRESLHY project, which has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 779613. The HSL work programme acknowledges funding from its sponsors Shell, Lloyd's and Equinor.