DE LA RECHERCHE À L'INDUSTRIE

INSTITUT NANOSCIENCES
ET CRYOGÉNIE

QUANTIFICATION OF HEAT FLUX IN SUPERCRITICAL HELIUM

Prepared by E.ERCOLANI A.GAUTHIER
P.GULLY JM.PONCET

Presented by E.ERCOLANI

Université
Joseph Fourier
GRENOBLE

www.cea.fr

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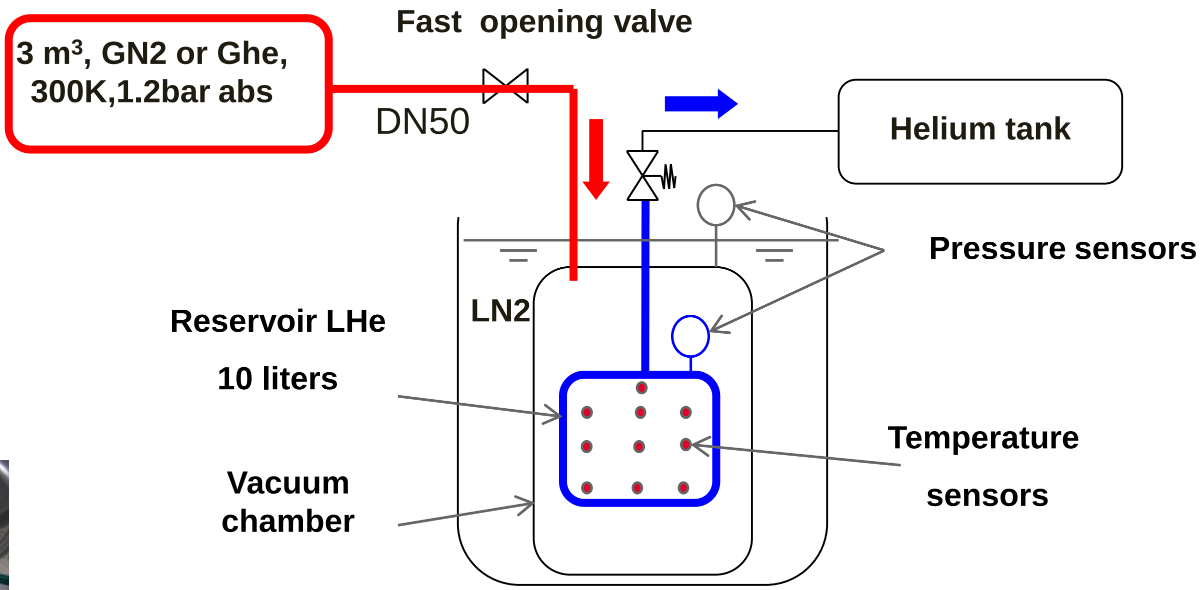
EXPERIMENTAL APPARATUS AND PROCEDURE

Reservoir LHe
without MLI

Reservoir LHe
with MLI

Poster presented at Aussois conference 2012

Super critical discharge pressure



3 m^3, GN2 or Ghe, 300K,1.2bar abs

Fast opening valve

DN50

Helium tank

Pressure sensors

LN2

Reservoir LHe

10 liters

Vacuum chamber

Temperature sensors

Test parameters:

- Initial mass inventory of the reservoir
- Nature of the gas responsible (GN_2, GHe, Air) for the loss of vacuum
- Number of layers of MLI

ISOCHORIC PRESSURE RISE TO ESTIMATE THE HEAT FLUX φ

Isochoric pressure rise

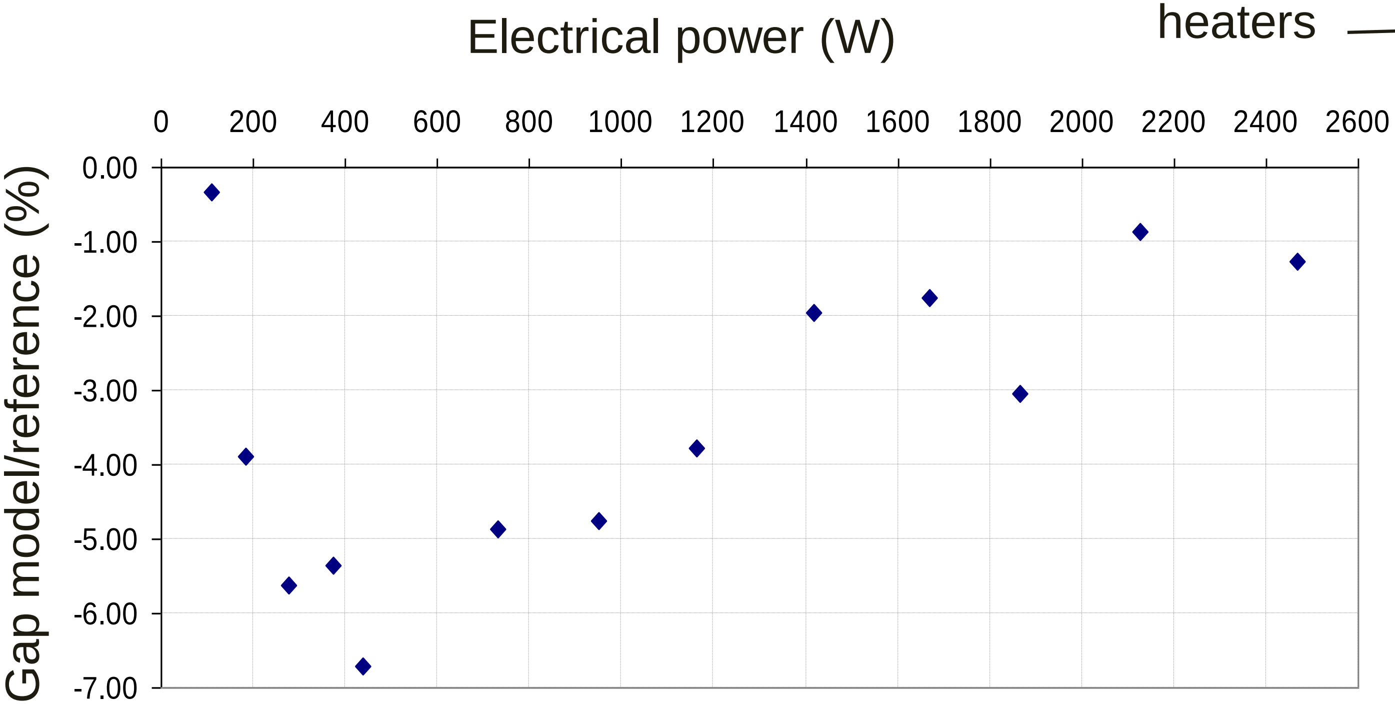
First thermodynamic law: $\Delta U = \Delta Q + \Delta \cancel{W}$

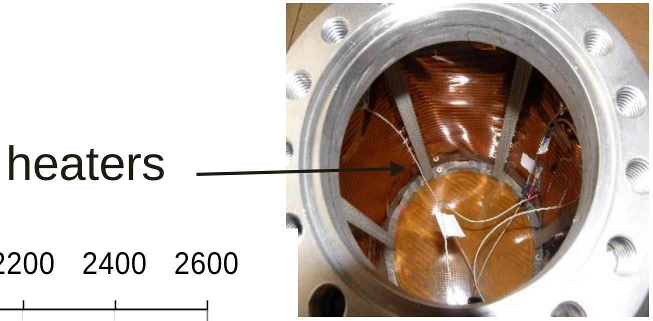
$$\varphi = \rho_i \times \frac{V}{S} \times \frac{\Delta U}{\Delta t} \qquad \Delta U = U(P_f, \rho_i) - U(P_i, \rho_i)$$

φ	heat flux in W/m2
ρ_i	initial density
V	volume of the tank
S	surface of the tank
ΔU	internal energy variation between a final and an initial time
Δt	variation of time
P_f, P_i	pressure at final and initial time

QUALIFICATION: FIRST TANK AT IMPOSED POWER

A first tank with electrical heaters has been used to qualify the instrumentation and the analysis method

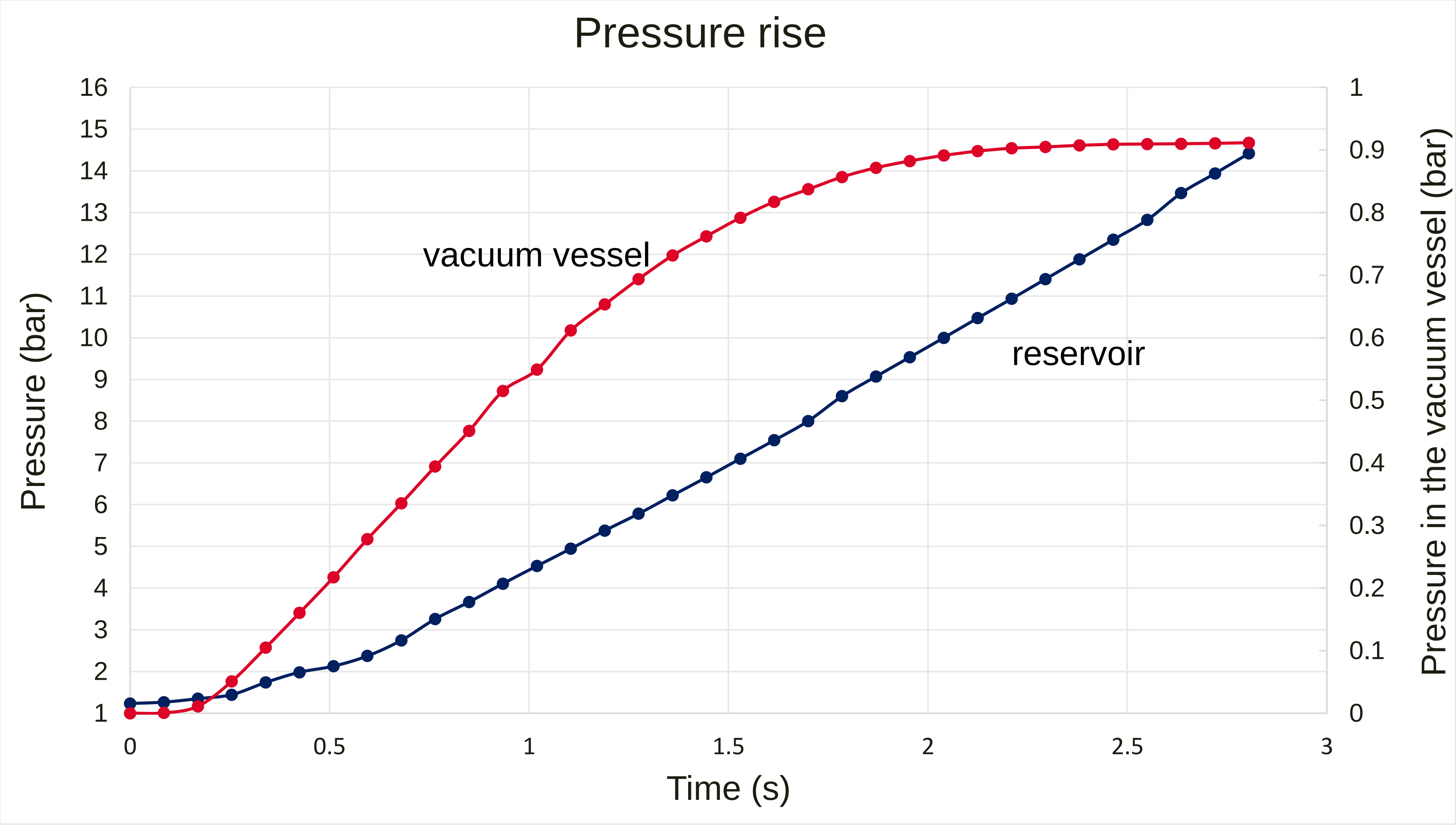




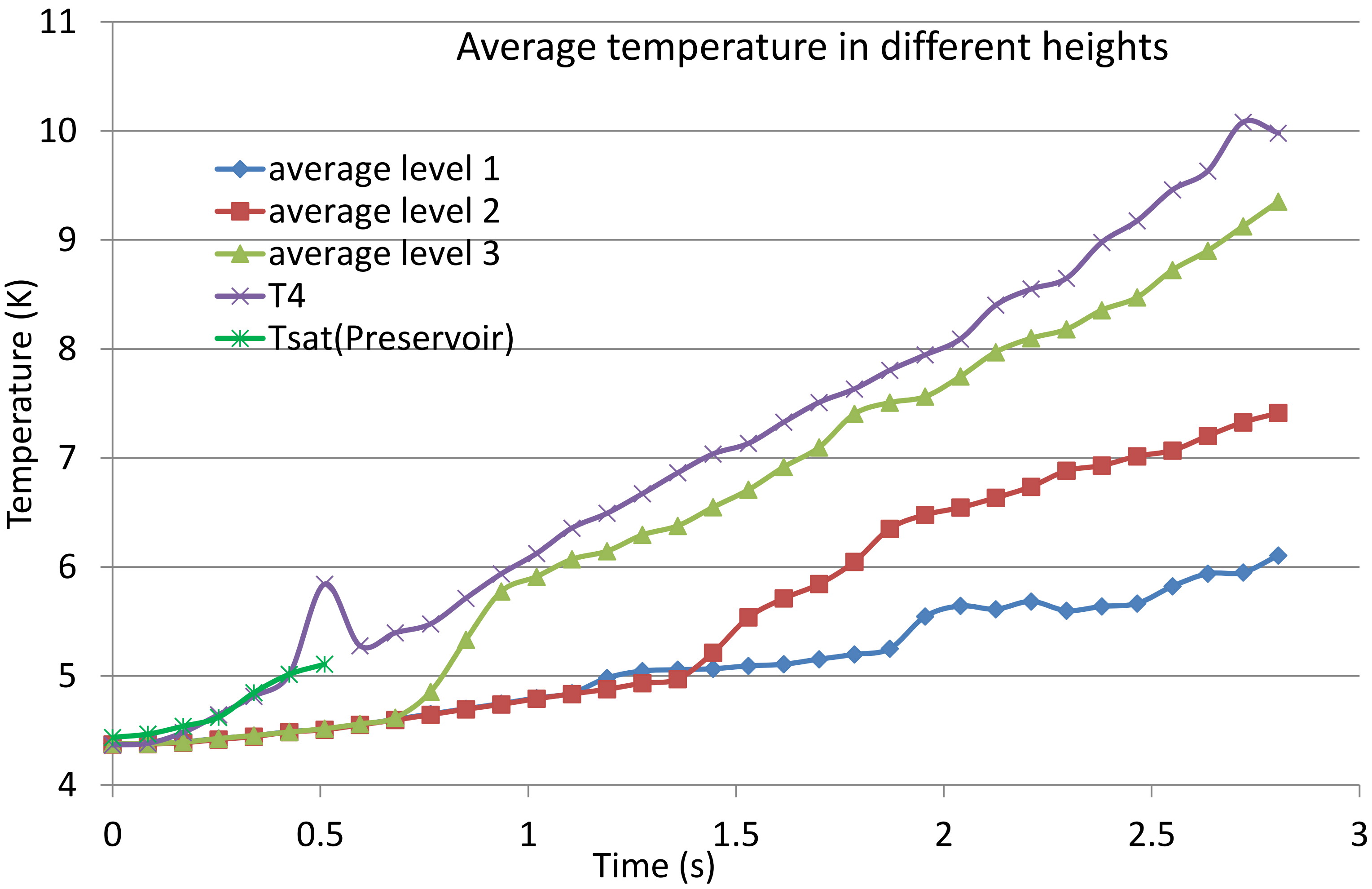
Gap: - a part of the initial mass goes to the dead volumes (0.5l)

- heat accumulation on the wall tank can not be determined precisely (response time for the temperature sensors)

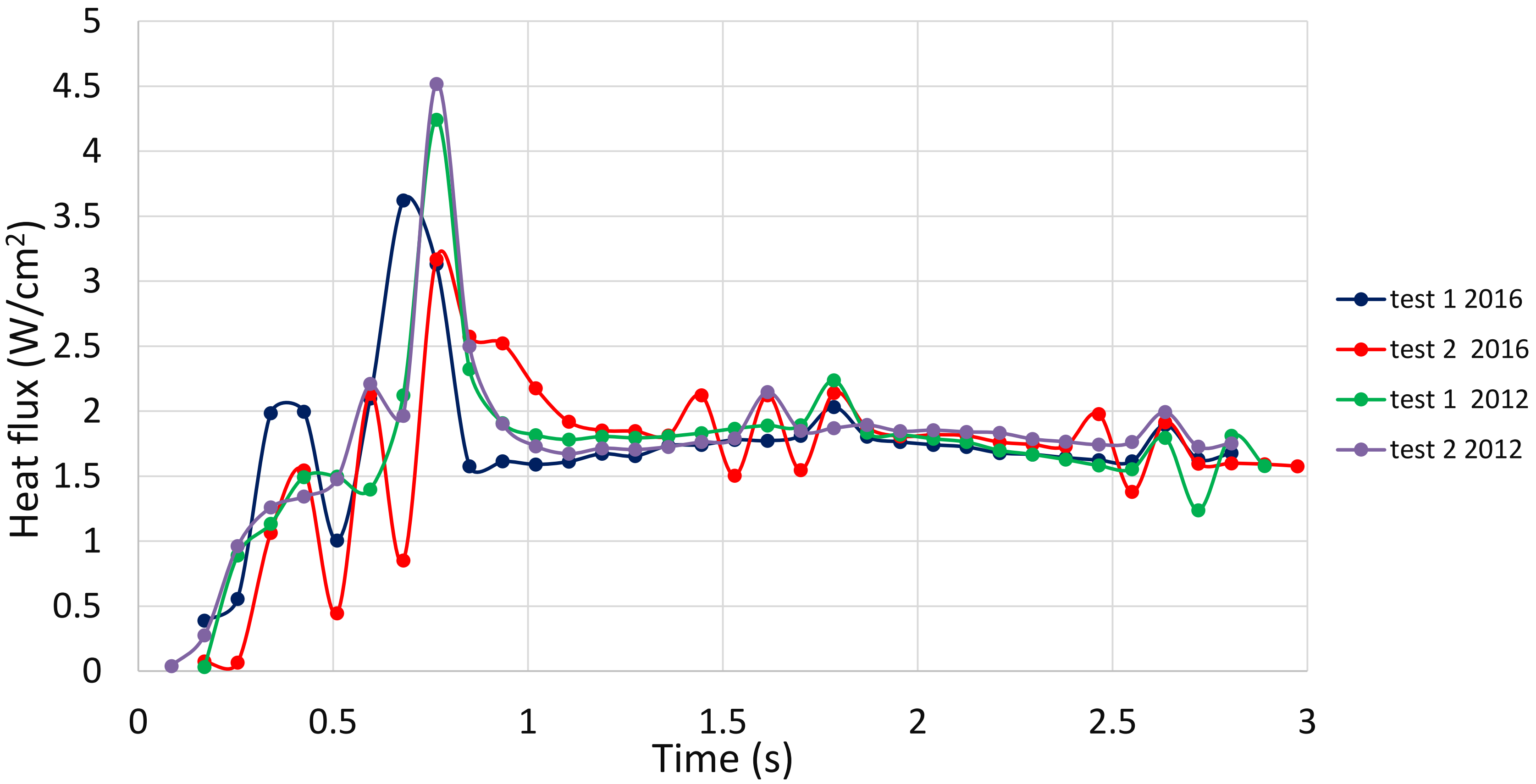
PRESSURE RISE OF THE RESERVOIR AND VACUUM VESSEL: LOSS OF VACUUM VESSEL WITH GN_2



TEMPERATURE RISE INSIDE THE TANK

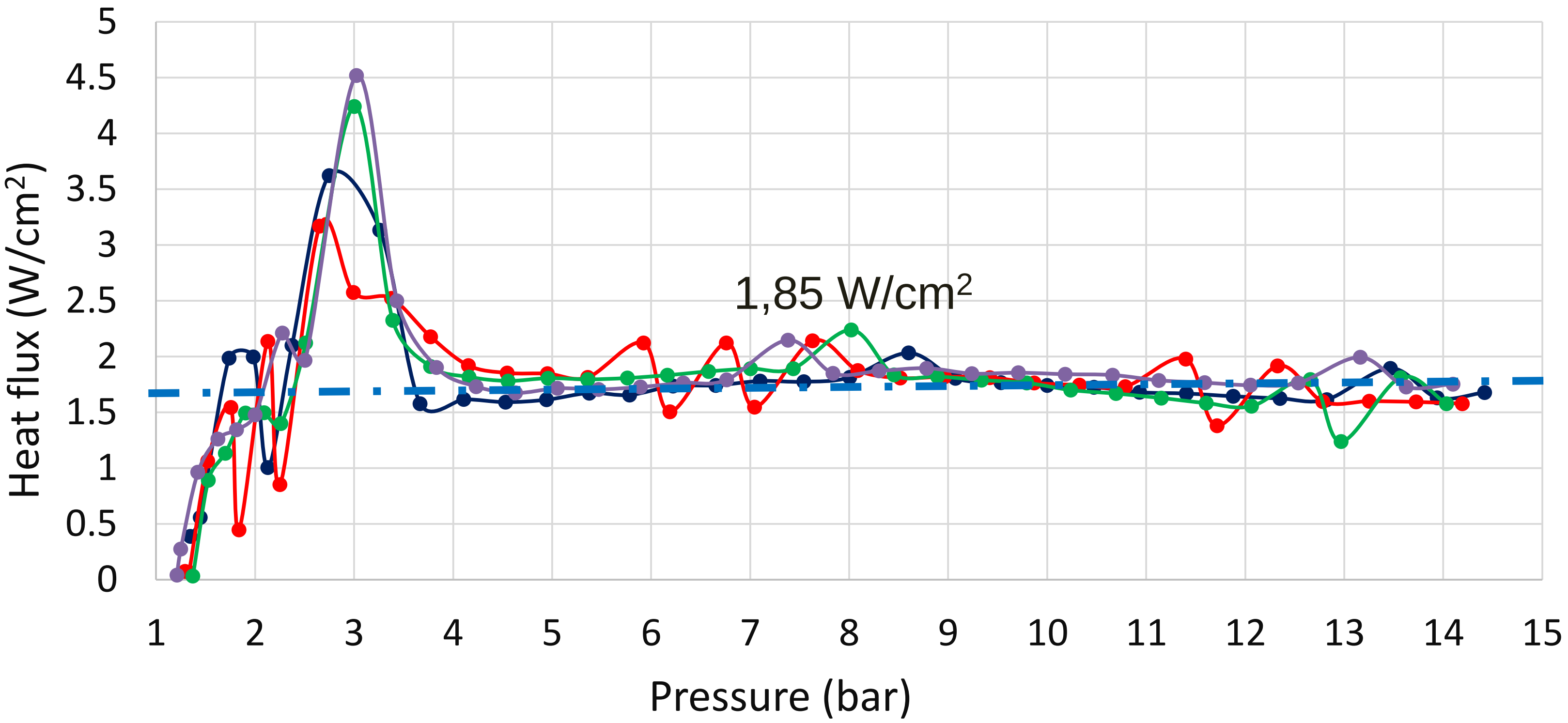


HEAT FLUX RECEIVED BY THE LIQUID



- Peak of heat flux at the first moments < 1s: nucleate and film boiling inside the tank
- After the heat flux remains constant: free convection inside the tank

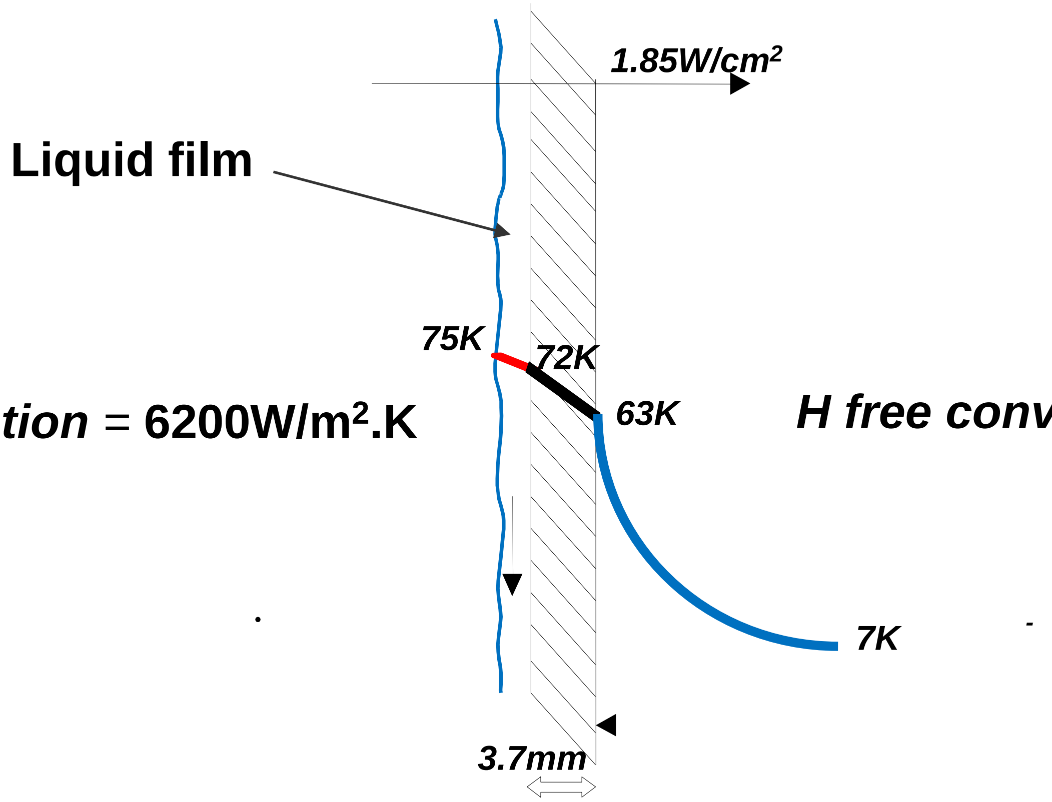
HEAT FLUX RECEIVED BY THE LIQUID



- Delay of peak nucleate/film boiling in comparison with the pressure at the first moments (Be careful with a safety device calculated at pressure close to 3 bars…)

- Constant heat flux 1.85 W/cm^2 , steady state outside the tank? ⇨ no variation of the thickness film condensation, free convection inside the tank.

ESTIMATION OF THE AVERAGE TRANSFER COEFFICIENTS



Hcondensation **= 6200W/m².K**

H free convection = 330W/m².K

Hwall = 1945W/m².K

- Heat flux limited by free convection inside the tank

- High condensation coefficient because super heated gas, strong interfacial friction between the vapor and the liquid film, turbulent flow ⟹ very low film thickness (0.025mm)

LOSS OF VACCUM VESSEL WITH GHE AND AIR

- ☐ GHe

heat flux: 0.15 W/cm^2, the heat flux is limited by free convection inside the vacuum vessel (h = 30 W/m^2.K to compare to 6200 W/m^2.K by condensation)

- ☐ AIR (one test)

heat flux: 2 W/cm^2, close to the value obtained with GN_2

HEAT FLUX WITH MUTI LAYER INSULATION

☐ Currently, no reproducible values have been obtained, we have to continue to work on this point…

☐ The value depends strongly on the way to install MLI on the reservoir !

☐ Question: is it relevant to measure /give some values…..?
(way to install the MLI, types of MLI….)

Reservoir LHe
with MLI

PAST RESULTS OF A BRUTAL LOSS OF VACCUM WITH GN$_2$, HEAT FLUX FOR AN UNINSULATED HE RESERVOIR

Experimentators	Intial conditions	Final conditions	Geometry tank	Filling rate	Heat Flux
Lehman 1980	1bar 4.2K	1bar 4.2K	Ø=0.3m L=1m 70 liters	50%	3.8 W/cm^2
Harrison 2001	23mbar 1.9K	11bar 6K	Ø=0.2m L=0.4m 12 liters	90%	3W/cm^2
Van Sciver 2015	1bar 4.2K	1bar 4.2K	Not mentioned	Not mentioned	2.5W/cm^2

- Difference between Lehman and Van Sciver in sub-critical condition
- Difference between Harrison and CEA in super-critical condition

⇨

Different designs cryostat, different geometry of reservoirs and different analysis methods may lead to different results… BE CAREFUL

CONCLUSION

☐ A heat flux of 1.85 W/cm^2 has been measured with our facility in super critical condition with a brutal loss of vacuum (GN$_2$).
Value to compare with Harrison (3W/cm^2)…….

☐ Heat flux is limited by the free convection coefficient inside the tank (except for GHe break of vacuum)

☐ Future work:

- Heat flux with MLI…..
- It will be interesting to compare the heat transfer condensation coefficient with bibliographic correlations.