

HYBRID THERMOSYPHON/PULSATING HEAT PIPE: GROUND AND MICROGRAVITY EXPERIMENTS

D. Mangini^a, M. Mameli^c, D. Fioriti^c, L. Araneo^b, S. Filippeschi^c, M. Marengo^{a,d}

^a Dept. of Engineering and Applied Sciences, University of Bergamo, Viale Marconi 5, 24044 Dalmine (BG), Italy

^b Politecnico di Milano, Dipartimento di Energia, Via Lambruschini 4A, 20158 Milano, Italy

^c Università di Pisa, DESTEC, Largo Lazzarino 2, 56122 Pisa, Italy

^d School of Computing, Engineering and Mathematics, University of Brighton, BN2 4GJ, Brighton, UK.

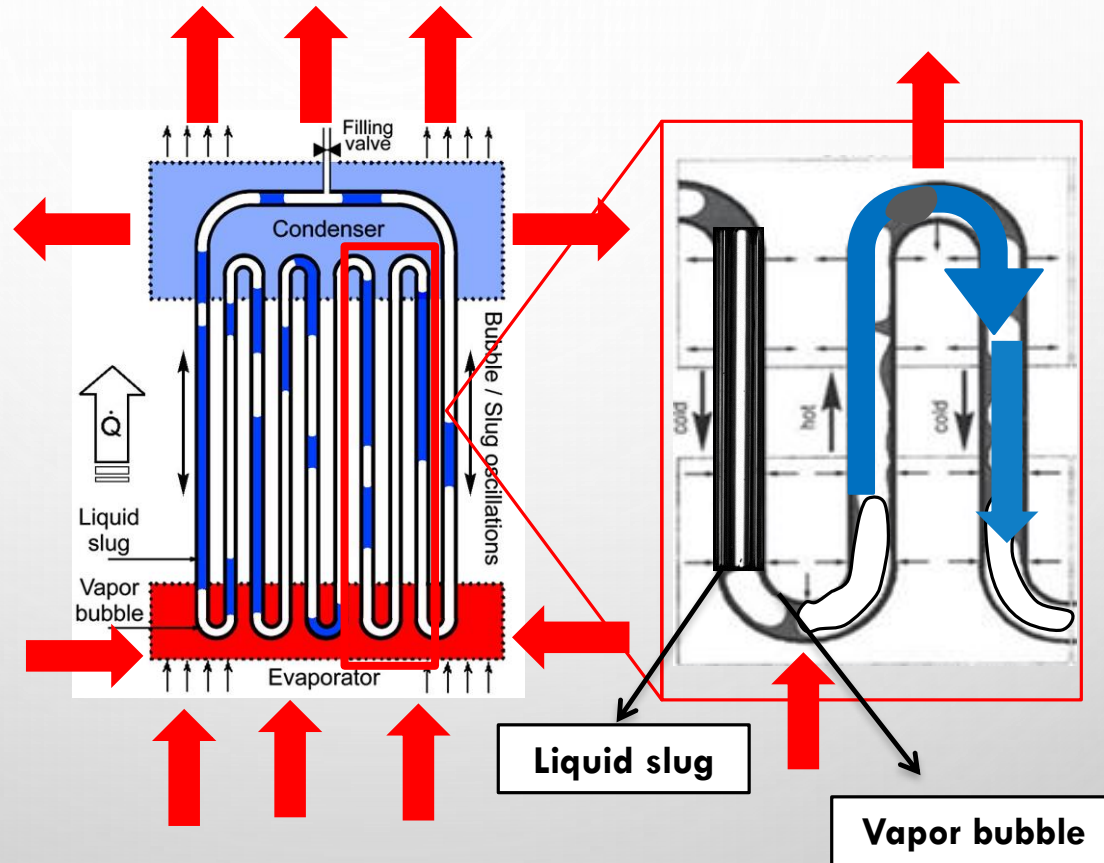


HIGHLIGHTS

- INTRODUCTION: THE HYBRID THERMOSYPHON/PHP CONCEPT
- EXPERIMENTAL APPARATUS
- RESULTS ON GROUND AND IN MICROGRAVITY

THE PULSATING HEAT PIPE

- **NO NEED FOR EXTERNAL PUMPING WORK;**
- **SIMPLE CONSTRUCTION;**
- **LOW FABRICATING COSTS;**
- **LESS SIZE AND WEIGHT DUE TO THE LOWER MASS FLOW;**
- **HIGH HEAT FLUXES.**
- **POSSIBILITY TO WORK WITHOUT GRAVITY**



INNER DIAMETER TO HAVE A SLUG/PLUG FLOW?



Inner
diameter



\dot{Q}

But if the Inner Diameter will increase too much...



SLUG/PLUG FLOW



STRATIFIED FLOW

How much is it possible to increase the Inner diameter
in order to have a Slug/Plug Flow?

THE CRITICAL DIAMETER DEPENDS BY SOME
PARAMETERS...

THE CAPILLARY LIMIT CRITERION

STATIC CRITERION

$$d_{cr,bo} \approx 2 \sqrt{\frac{\sigma}{g(\rho_l - \rho_v)}}$$

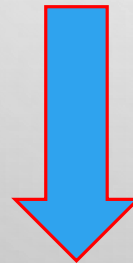
Capillary limit (Kew and Cornwell 1997)

DYNAMIC CRITERION

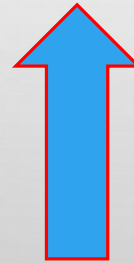
$$d_{Cr,Ga} \propto \sqrt{\frac{160\mu_l}{\rho_l U_l}} \sqrt{\frac{\sigma}{(\rho_l - \rho_v)g}}$$

(Dynamic Criterion 0-g, Baldassari et al. 2013)

GRAVITY FIELD



\vec{g}

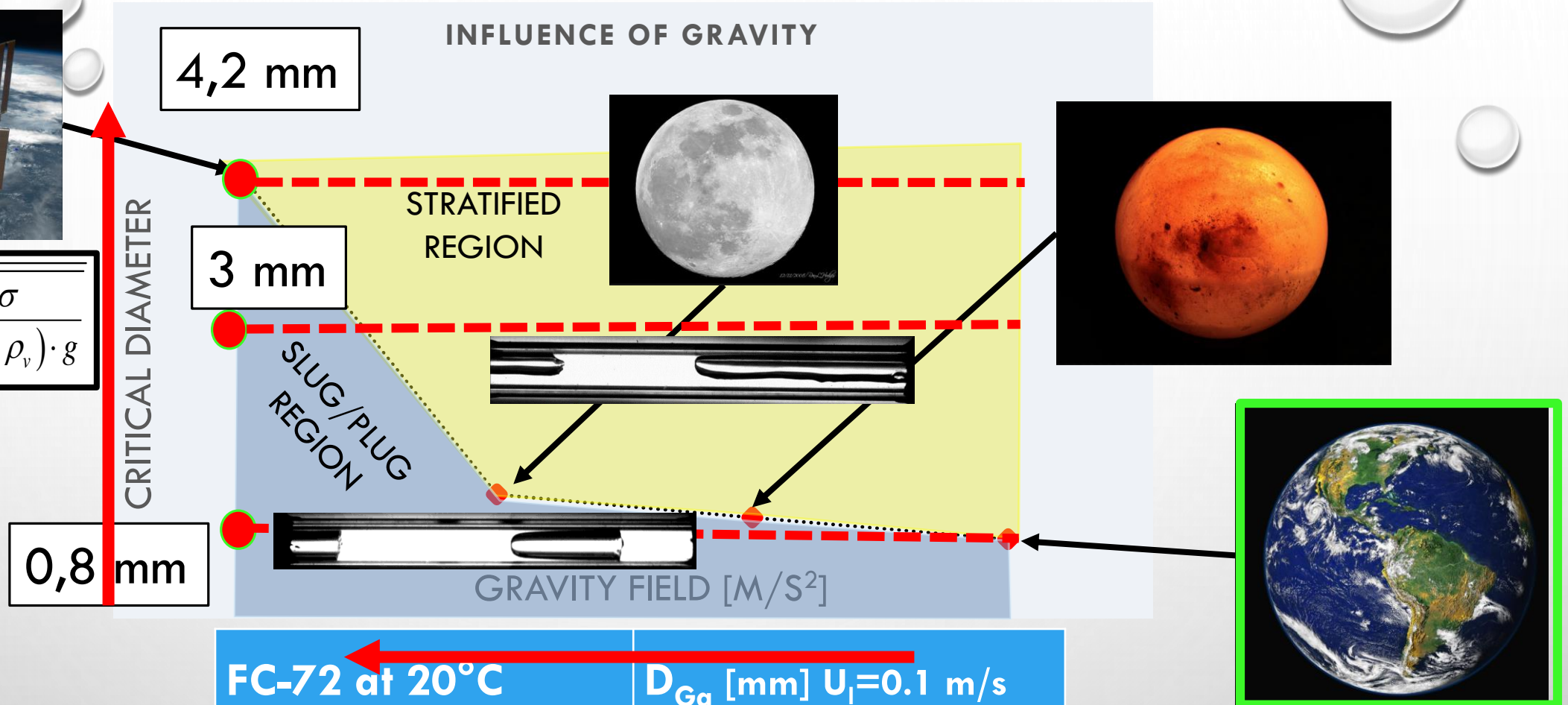


$d_{cr,bo}$

$d_{Cr,Ga}$

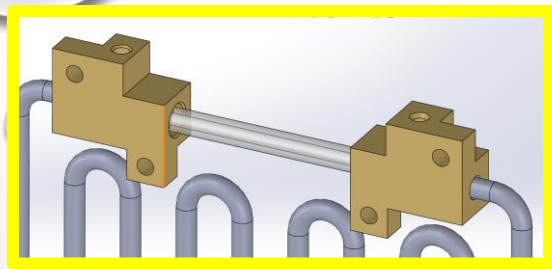


$$d_{Cr,Ga} = \sqrt{\frac{160\mu_l}{\rho_l U_l}} \sqrt{\frac{\sigma}{(\rho_l - \rho_v) \cdot g}}$$



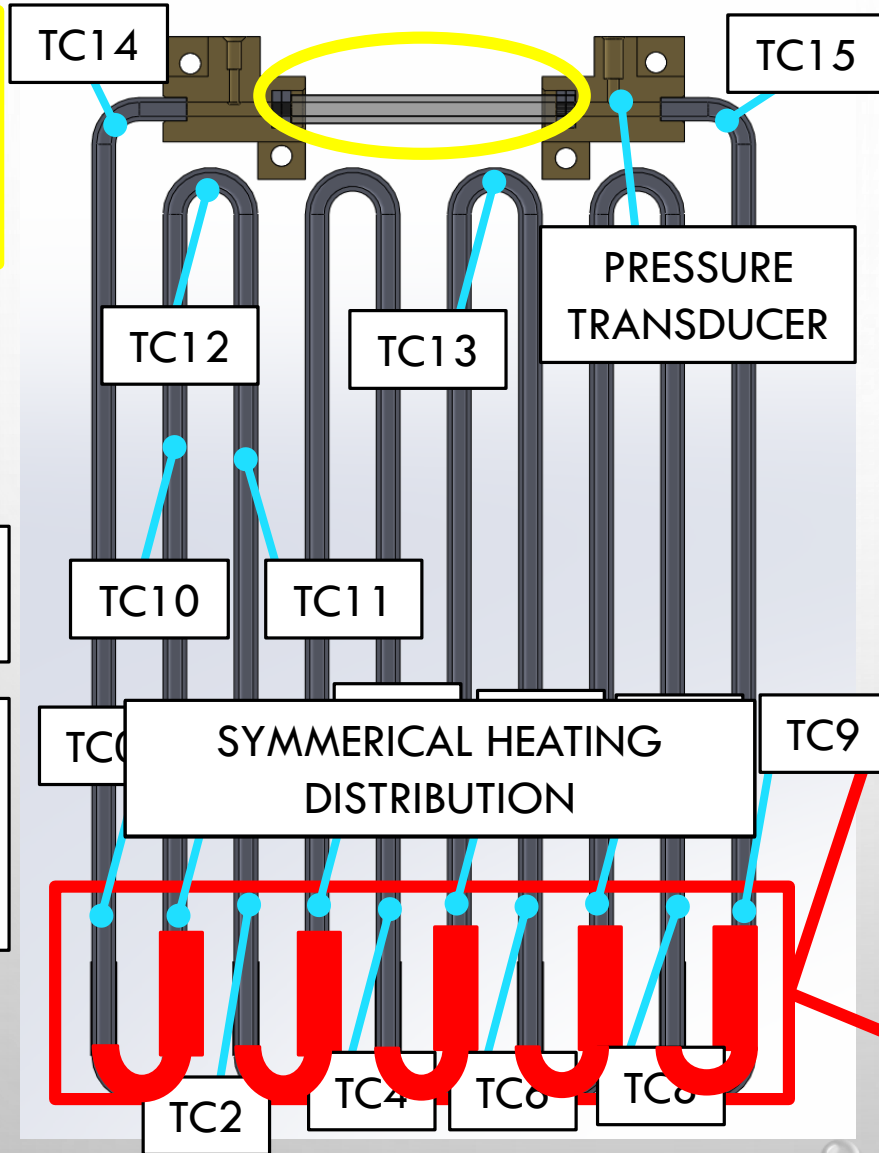
FC-72 at 20°C	D_{Ga} [mm] $U_l=0.1$ m/s
Earth gravity level: $g = 9.81$ m/s ²	0.8 mm
Microgravity: $g = 0.01$ m/s ²	4.2 mm

EXPERIMENTAL APPARATUS

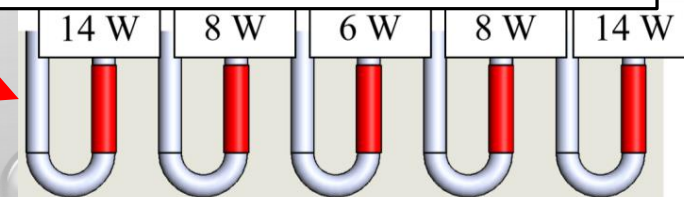


ALL THE HEATERS ARE
CONTROLLED INDIPENDENTLY

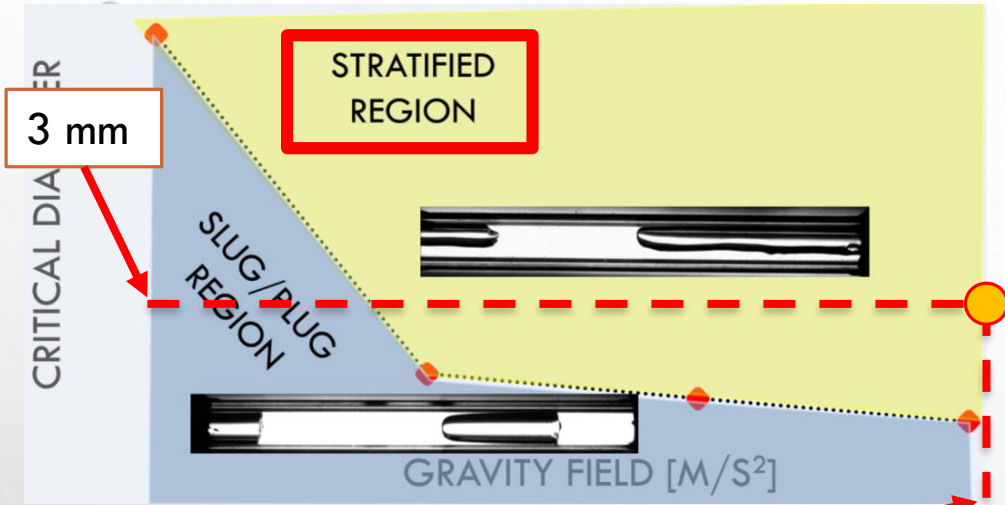
POSSIBILITY TO TEST
DIFFERENT HEATING
DISTRIBUTIONS AT THE
EVAPORATOR



- 16 T-TYPE THERMOCOUPLES.
- ALUMINUM;
- ID = 3 MM;
- OD = 5 MM;
- 5 U-TURNS EVAPORATOR ZONE;
- FLUID: FC-72, (FR = 0.5);
- AIR COOLED 20°C;



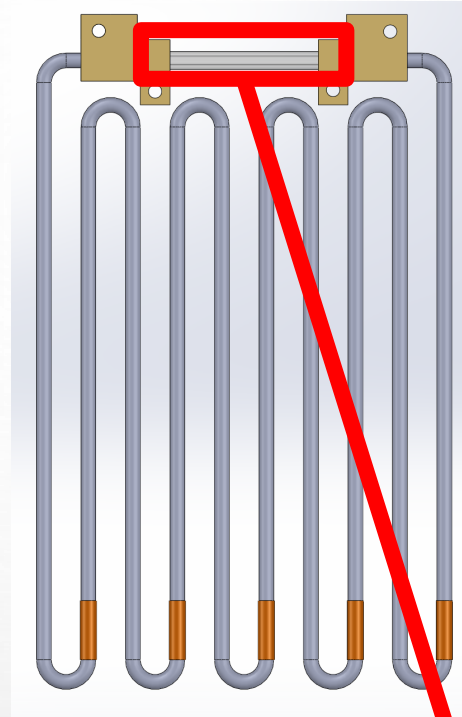
ON GROUND...



$$\vec{g}_{level} = 9.81 \text{ m/s}^2$$



vi) Stratified wavy flow



VAPOR BUBBLES THAT PASS THROUGH THE HIGHER PART



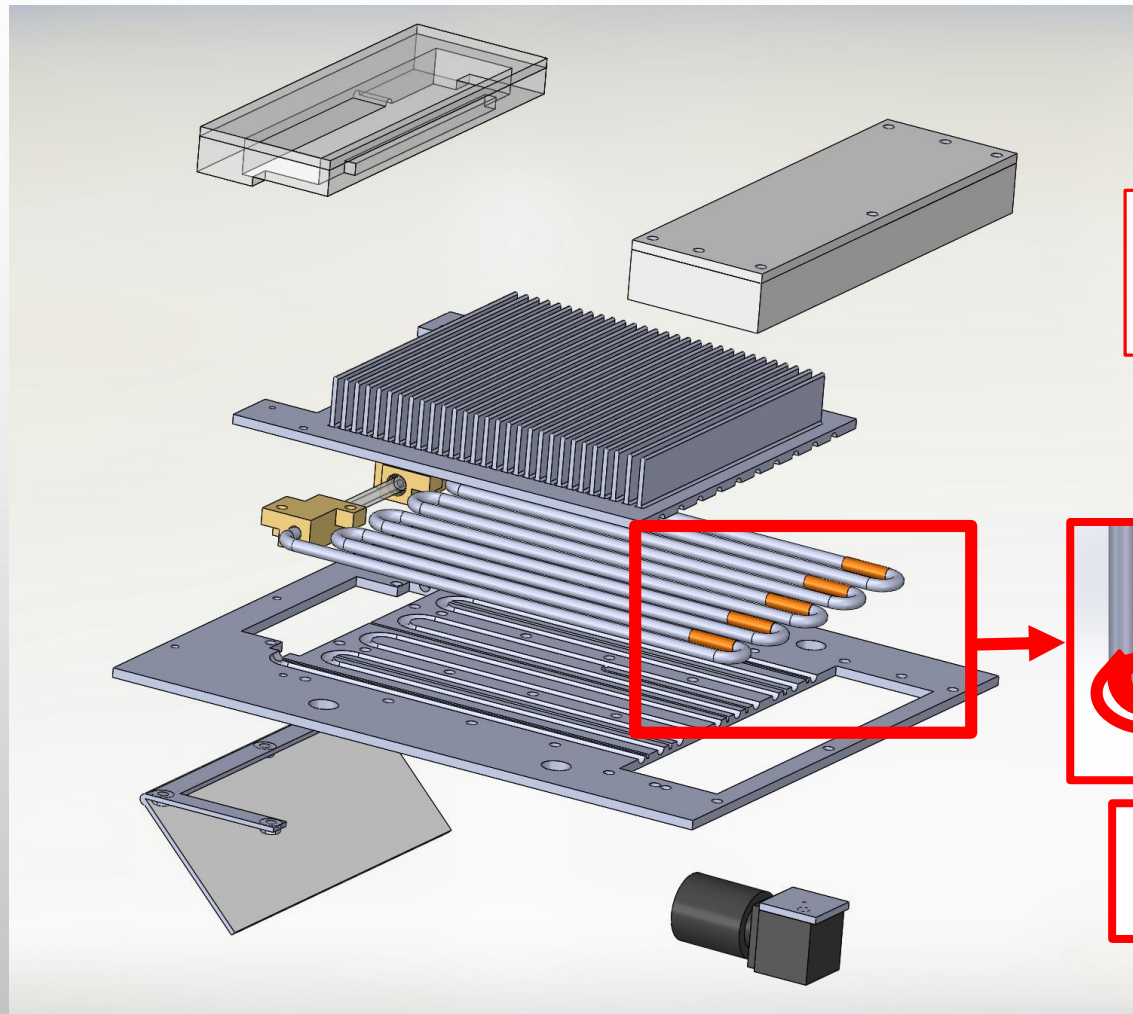
LIQUID AND VAPOR PHASE ARE STRATIFIED

LIQUID PHASE

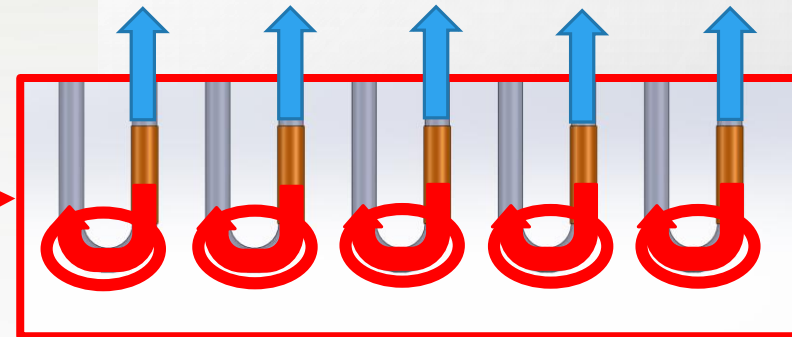
\vec{g}



EFFECT OF THE HEATER POSITIONS ON GROUND



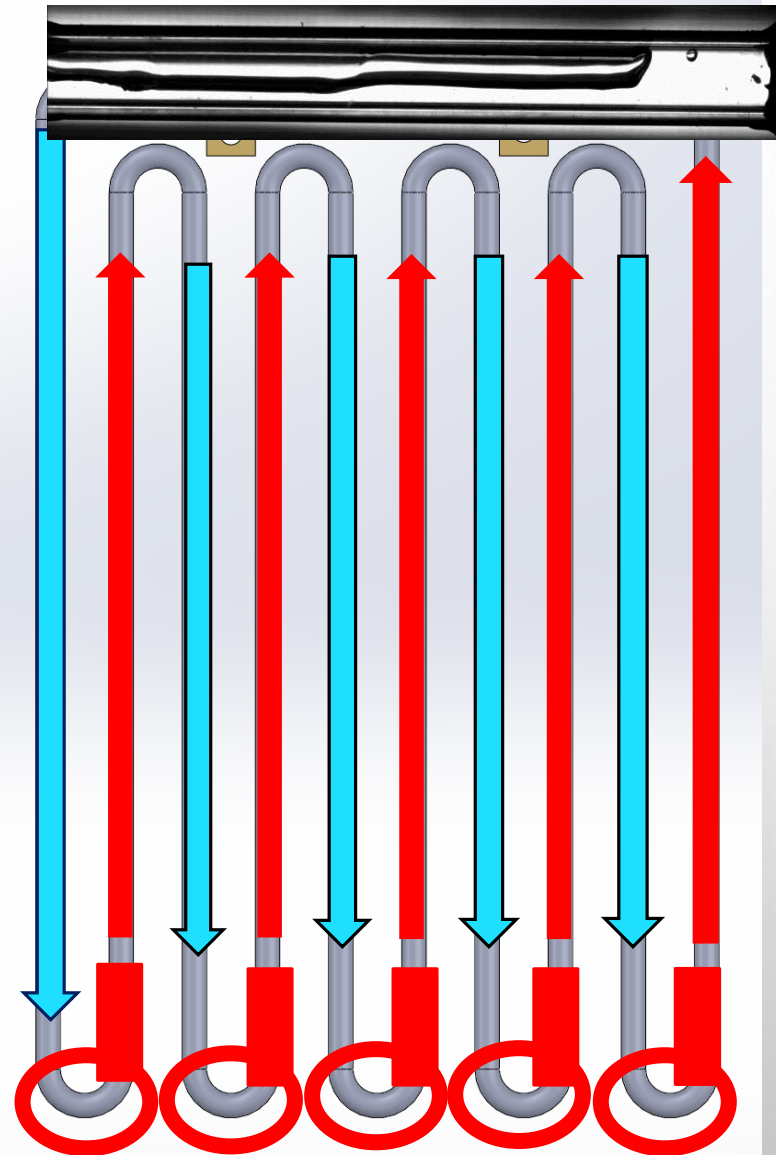
**MAIN OBJECTIVE:
STABILIZATION OF THE TWO-PHASE
FLOW IN A PREFERENTIAL DIRECTION**



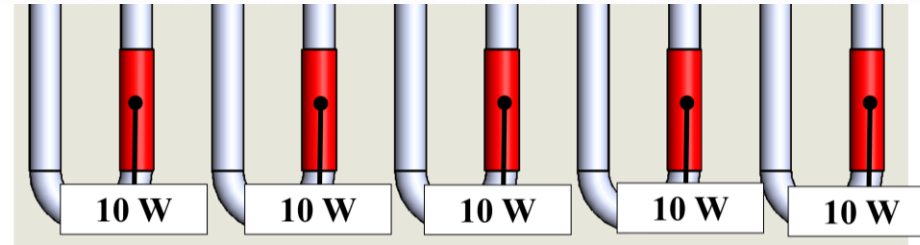
The heating power is provided non symmetrically

EFFECT ON NON-SYMMETRIC HEATING DISTRIBUTION

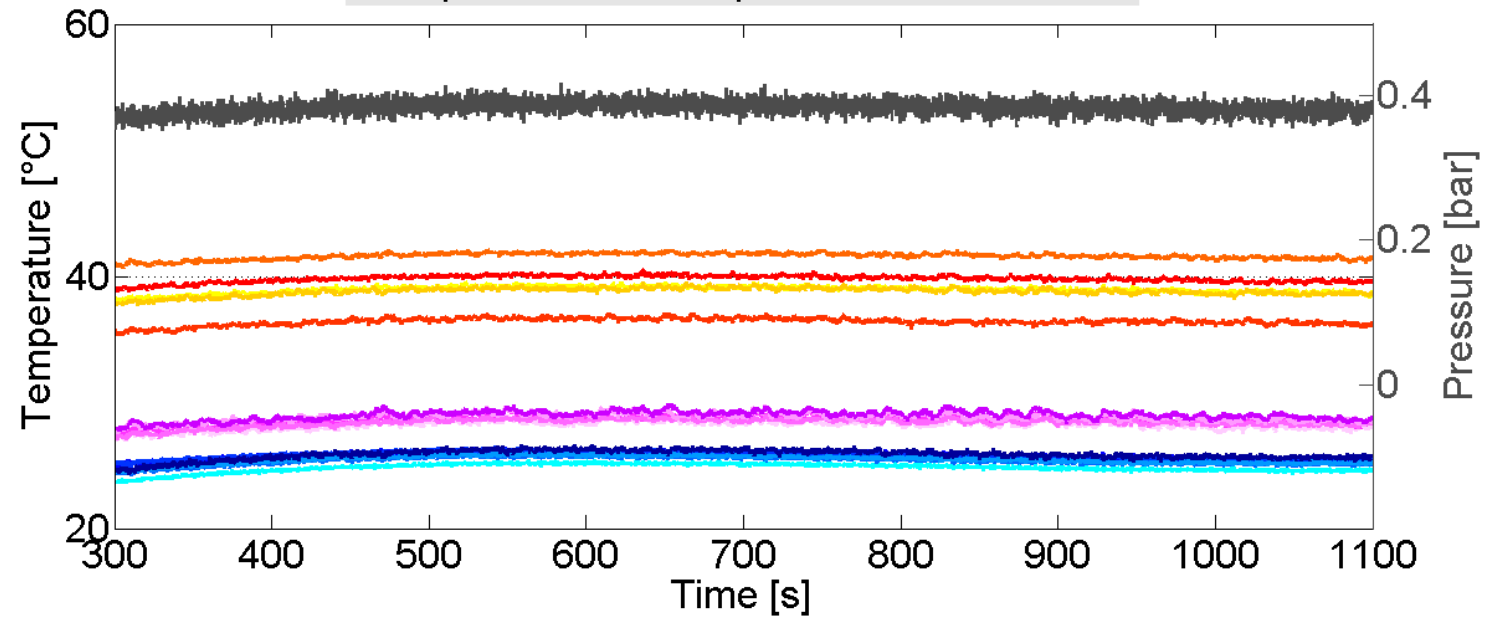
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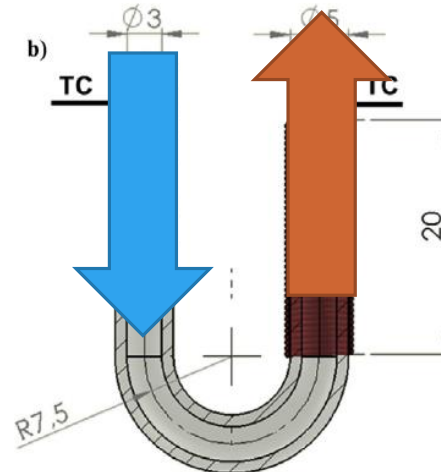
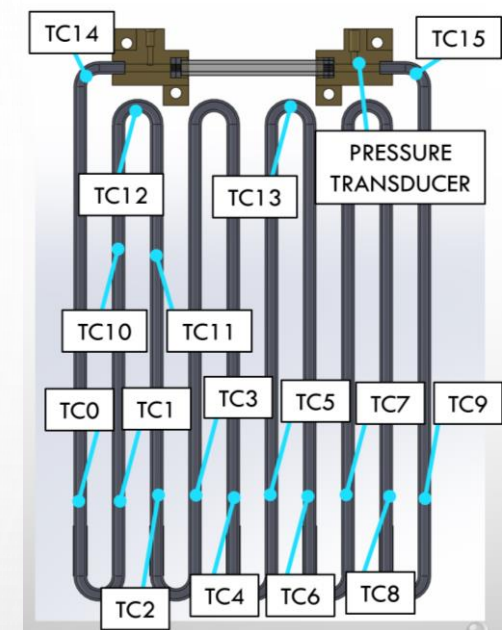
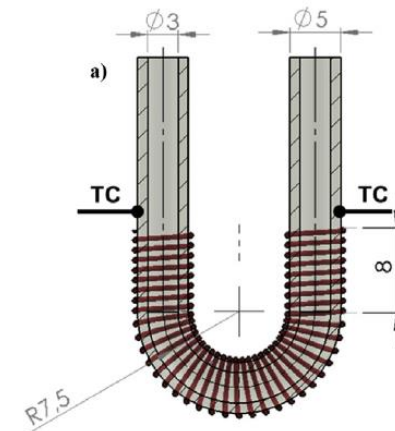
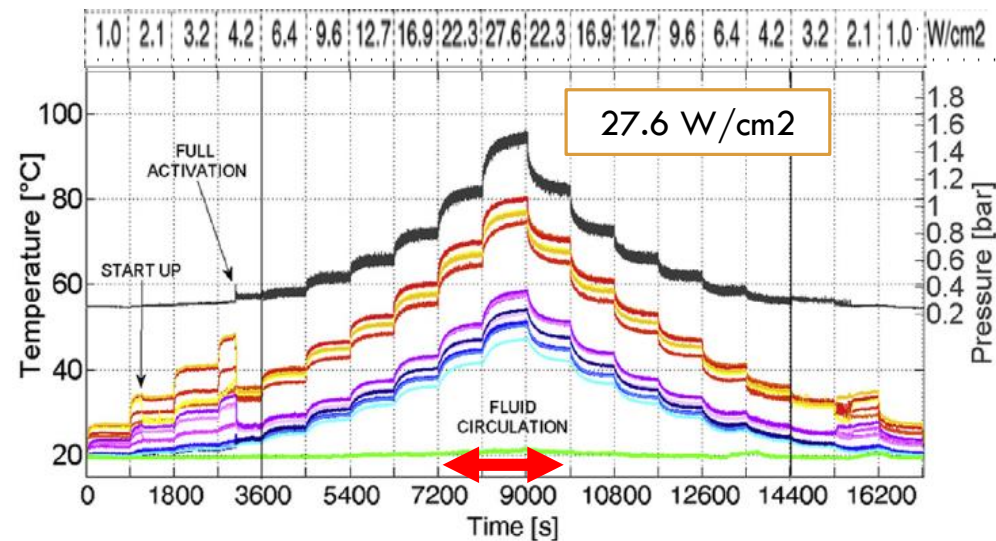
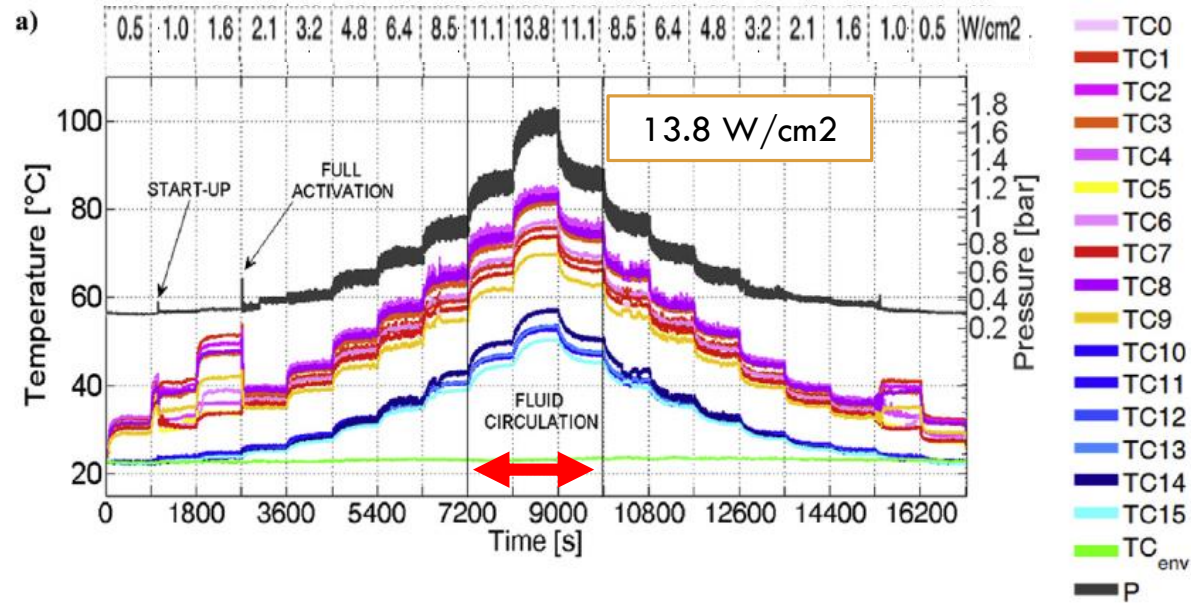
The asym



Temperatures and pressure UNIFORM

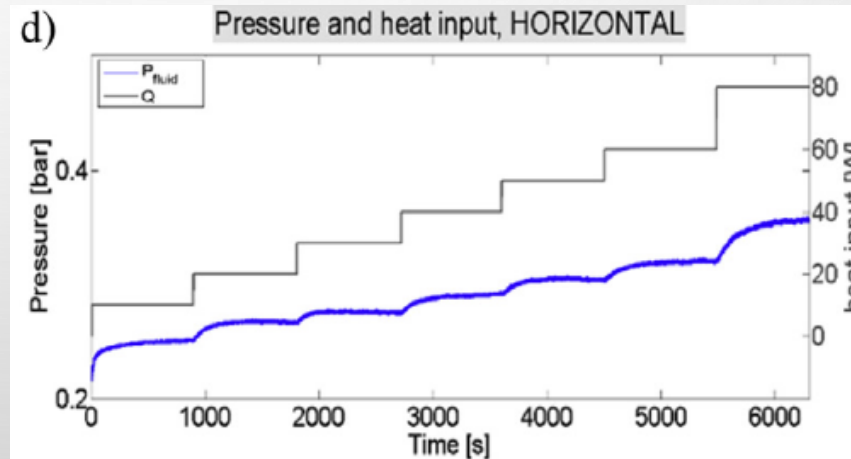
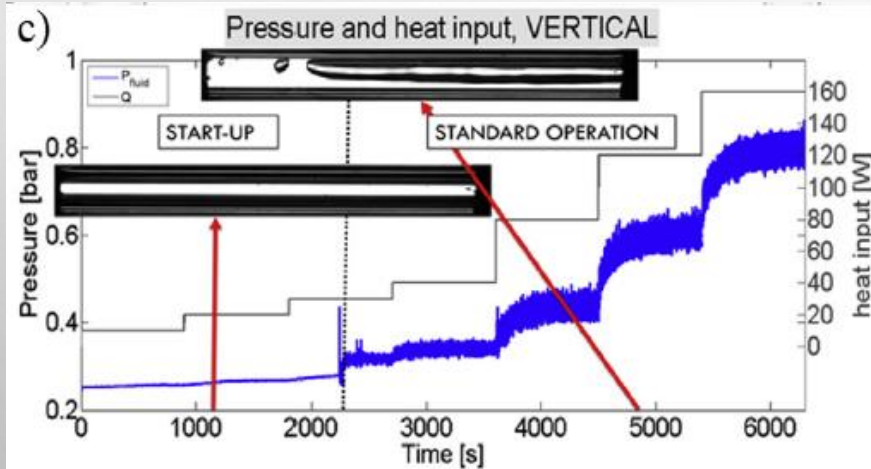
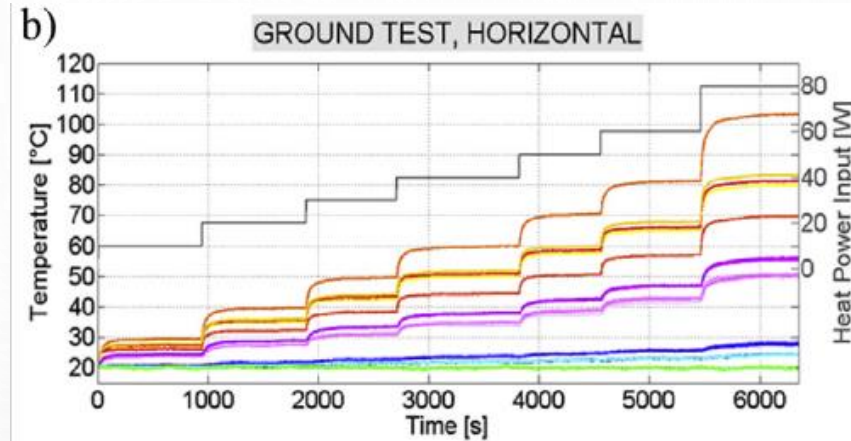
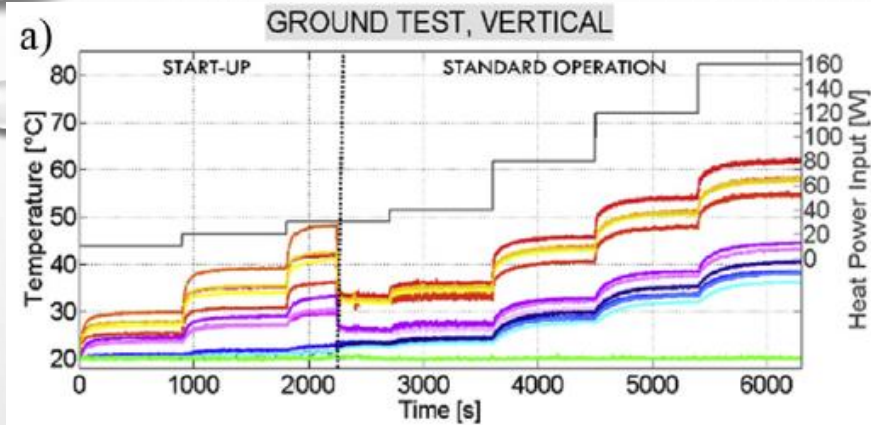


TEST IN VERTICAL ORIENTATION



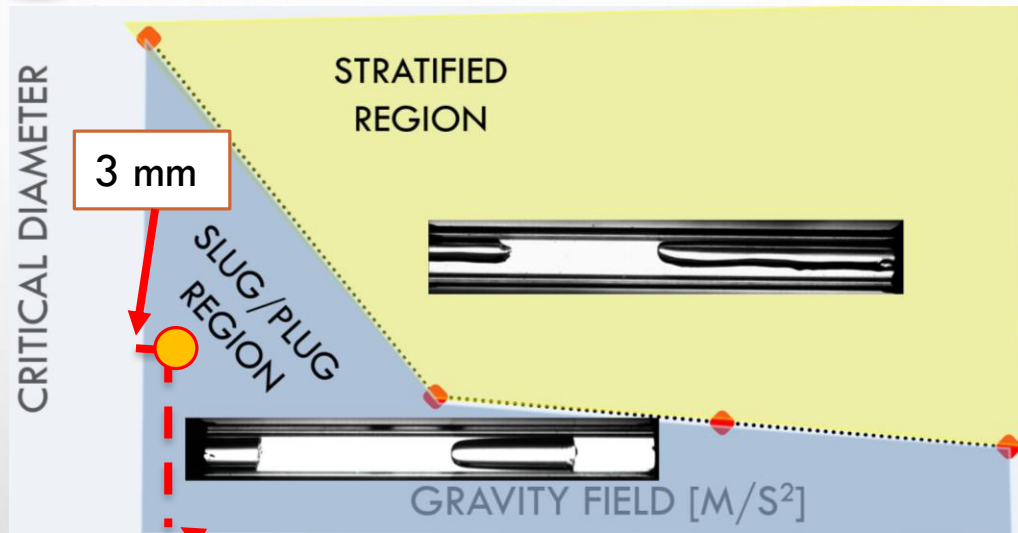
The non-symmetric heating distribution, improving the flow motion in a preferential direction, allows to dissipate higher global heat fluxes

AND HORIZONTALLY ON GROUND?



BEING A LOOP
THERMOSYPHON ON
GROUND, THE DEVICE
DOES NOT WORK
WHEN HORIZONTALLY
PLACED!

IN MICROGRAVITY...



DOES THE DEVICE BECOME A PULSATING HEAT PIPE IN MICROGRAVITY?

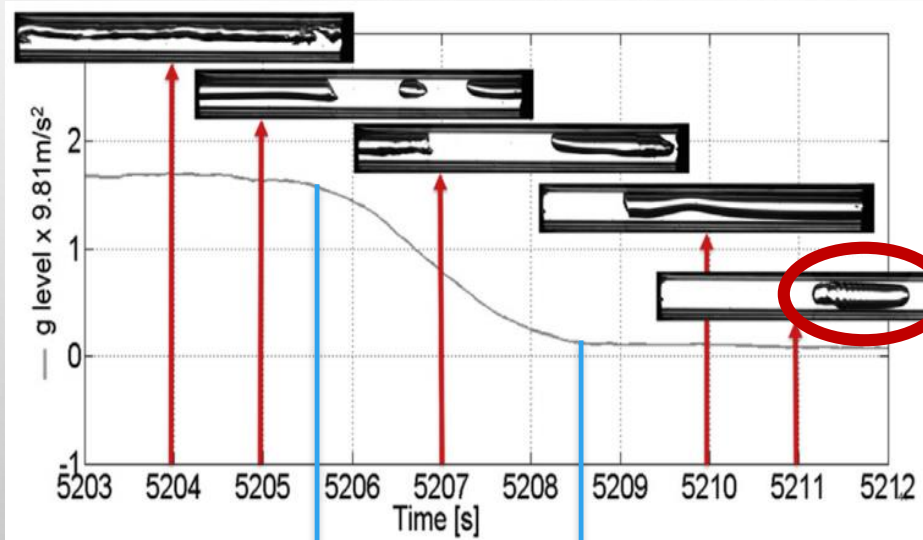
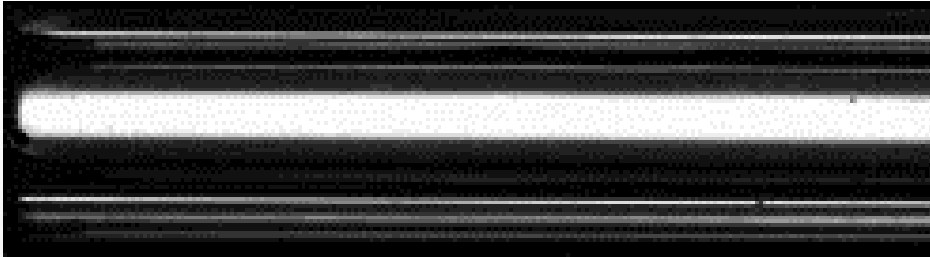
DOES THE DEVICE WORKS IN MICROGRAVITY CONDITIONS???

$$\overrightarrow{g_{level}} = 0.01 \text{ m/s}^2$$



The device was tested during the 61° and 63° ESA Parabolic Flight Campaign

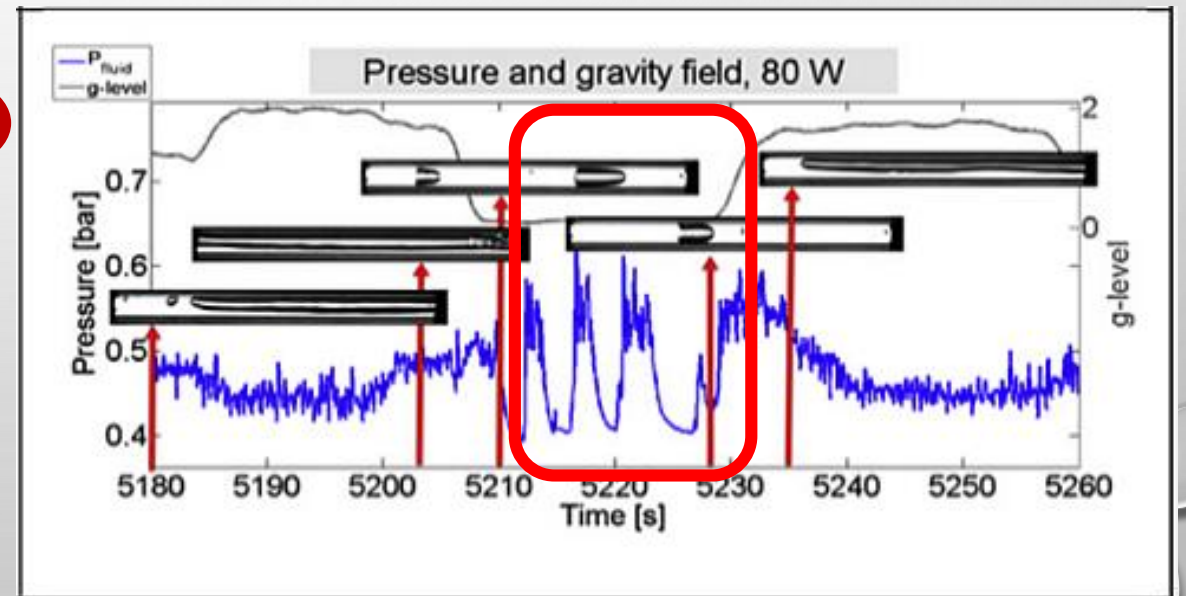
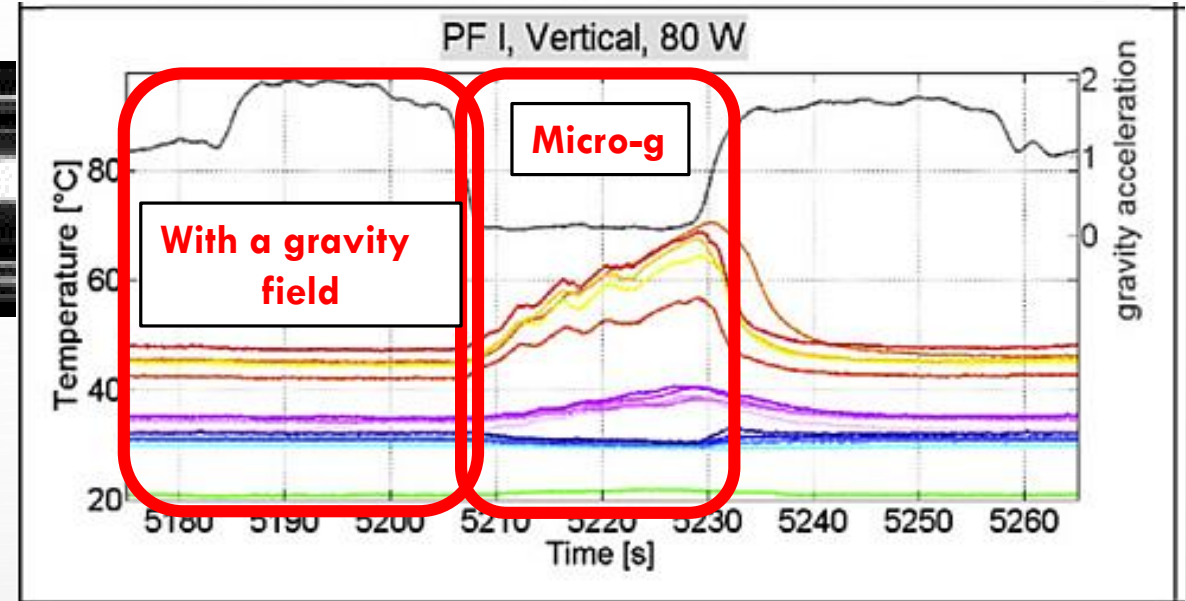
IN MICROGRAVITY?

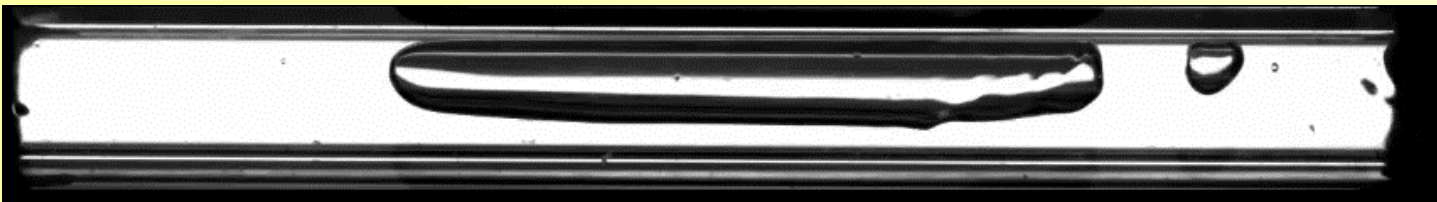


Hyper-g
(1.8g)

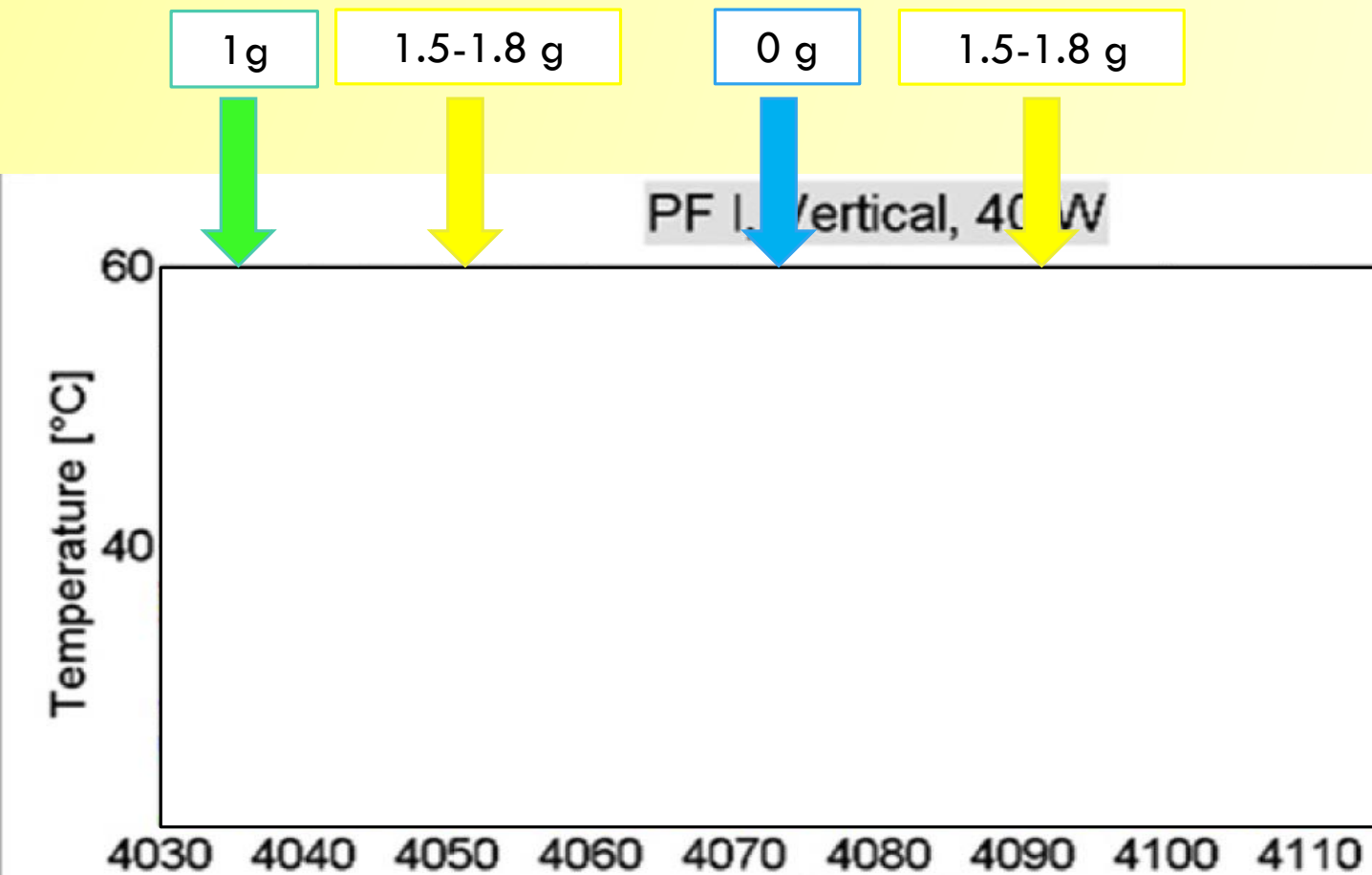
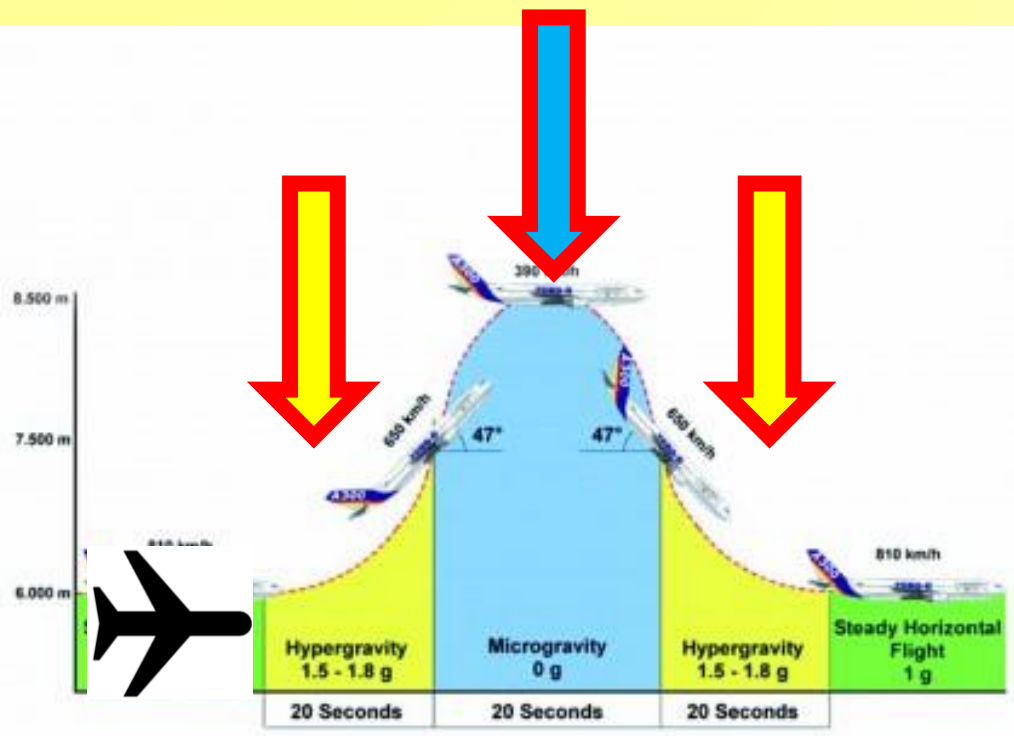
Injection

Micro-g
($\pm 0.05 \text{g}$)

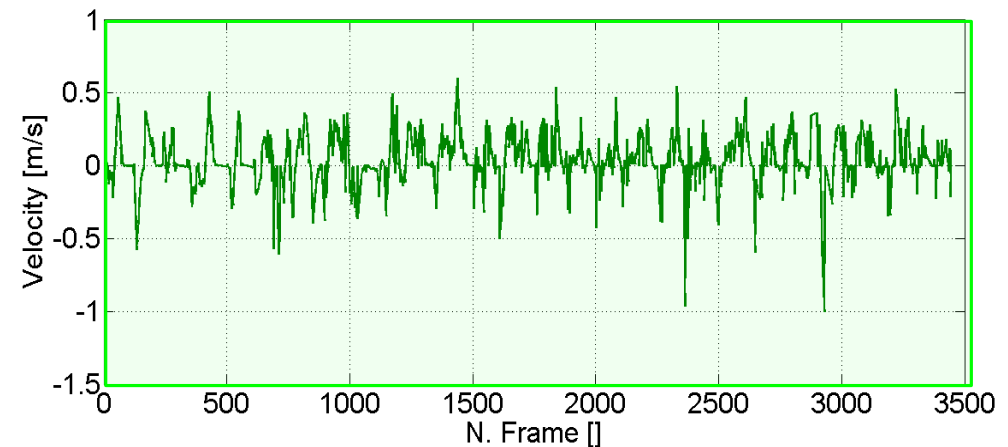
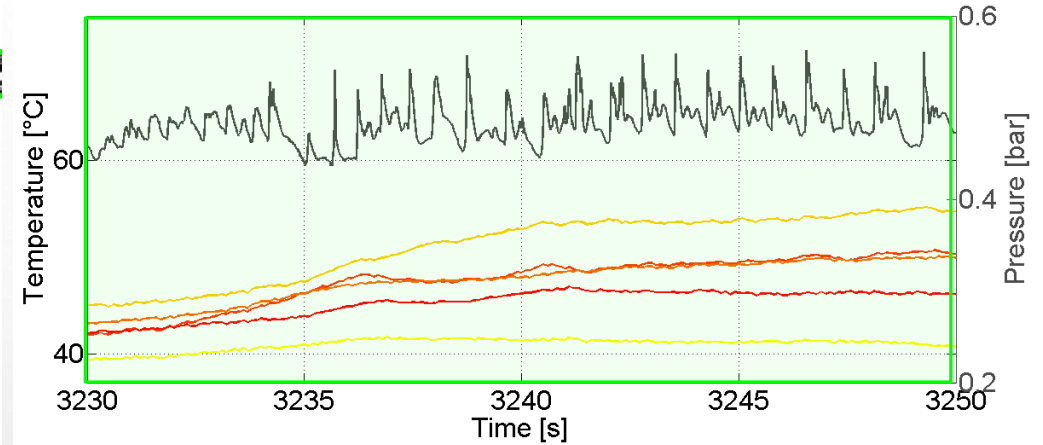
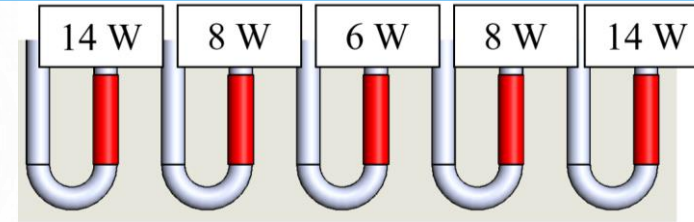
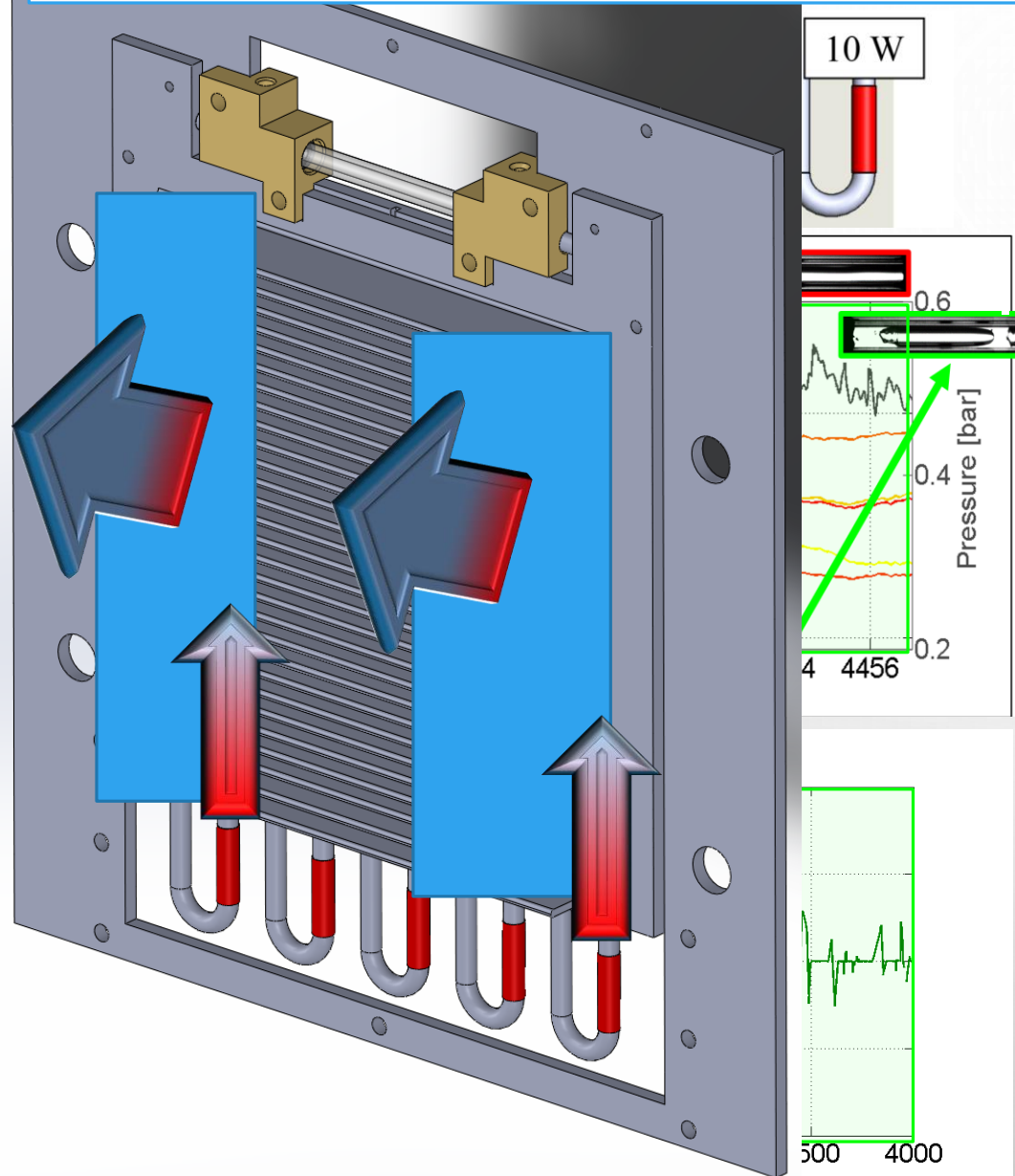




1.8 g: Stratified flow



NON-UNIFORM HEATING DISTRIBUTION IN MICROGRAVITY



THANK YOU FOR YOUR KIND ATTENTION!!!



Daniele Mangini
University of Bergamo
daniele.mangini@unibg.it



Davide Fioriti
University of Pisa, Italy



Dott. Mauro Mameli
University of Pisa, Italy



Prof. Lucio Araneo
Polytechnic of Milano, Italy



Prof. Sauro Filipeschi
University of Pisa, Italy



Prof. Marco Marengo
University of Brighton, UK

