HYBRID THERMOSYPHON/PULSATING HEAT PIPE:
GROUND AND MICROGRAVITY EXPERIMENTS

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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
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**

\[ d_{cr,bo} \approx 2 \sqrt{\frac{\sigma}{g \left( \rho_l - \rho_v \right)}} \]

Capillary limit (Kew and Cornwell 1997)

**DYNAMIC CRITERION**

\[ d_{Cr,Ga} = \sqrt{\frac{160 \mu_l}{\rho_l U_l}} \sqrt{\frac{\sigma}{\left( \rho_l - \rho_v \right) g}} \]

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

**GRAVITY FIELD**

\[ \vec{g} \]

\[ d_{cr,bo} \]

\[ d_{Cr,Ga} \]
### Critical Diameter

The critical diameter ($d_{Cr,Ga}$) is calculated using the formula:

$$d_{Cr,Ga} = \sqrt[3]{\frac{160 \mu_i \sigma}{\rho_i U_i \sqrt{\rho_i - \rho_v} \cdot g}}$$

### Influence of Gravity

- **Stratified Region**:
  - **FC-72 at 20°C**
  - **Earth gravity level**: $g = 9.81 \text{ m/s}^2$
  - **Microgravity**: $g = 0.01 \text{ m/s}^2$

<table>
<thead>
<tr>
<th>Condition</th>
<th>$D_{Ga}$ [mm]</th>
<th>$U_i = 0.1 \text{ m/s}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth gravity level</td>
<td></td>
<td>0.8 mm</td>
</tr>
<tr>
<td>Microgravity</td>
<td></td>
<td>4.2 mm</td>
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</tbody>
</table>

**GRAVITY FIELD [m/s²]**

- **4,2 mm**
- **3 mm**
- **0.8 mm**

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EXPERIMENTAL APPARATUS

- 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;

ALL THE HEATERS ARE CONTROLLED INDEPENDENTLY

POSSIBILITY TO TEST DIFFERENT HEATING DISTRIBUTIONS AT THE EVAPORATOR

14 W 8 W 6 W 8 W 14 W
ON GROUND...

\[ \vec{g}_{\text{level}} = 9.81 \, m/s^2 \]

VAPOR BUBBLES THAT PASS THROUGH THE HIGHER PART

LIQUID AND VAPOR PHASE ARE STRATIFIED

LIQUID PHASE

3 mm

GRAVITY FIELD [m/s²]

3 mm
EFFECT OF THE HEATER POSITIONS ON GROUND

The heating power is provided non-symmetrically.

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

The asymmetrical position of the heaters

MAIN GOAL: Promotion of fluid flow circulation in a preferential direction
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???

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

$\vec{g}_{\text{level}} = 0.01 \text{ m/s}^2$
IN MICROGRAVITY?

Hyper-g (1.8g)
Injection
Micro-g (±0.05g)

With a gravity field
1.8 g: Stratified flow

1g
1.5-1.8 g
0 g
1.5-1.8 g
NON-UNIFORM HEATING DISTRIBUTION IN MICROGRAVITY

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