LHP TRANSIENT MODELLING

WITH ECOSIMPRO

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INTRODUCTION

INTRODUCTION (1)

- Loop heat pipes (LHP) are two-phase capillary heat transfer devices that are becoming very interesting for space thermal control applications because of:
  - High power transport capability
  - High temperature stability
  - Fast and strong diode action
  - Design flexibility
  - Robustness and reliability

INTRODUCTION (2)

- Important modelization efforts have been performed in order to predict thermal performances and transient behaviour of LHPs.
- LHP performances are usually obtained by using steady state calculations. The results fit quite well to experimental data.
- However, the current mathematical models do not reproduce LHP transient behaviour satisfactorily (start-ups, temperature oscillations)
- The current approach aims to catch these phenomena using the powerful ECOSIMPRO capabilities.

LHP LIBRARY

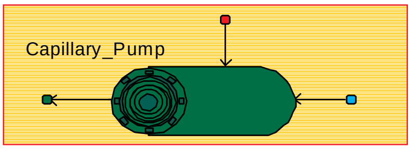
LHP LIBRARY (1)

- **General considerations:**

- This library consist of typical components that model the parts of a LHP: Capillary Pump (Evaporator Casing, Grooves and Primary Wick), Compensation Chamber, Condenser and Transport Lines.
- The working fluid is considered as a two phase fluid (homogeneous flow).
- The fluid properties are interpolated from NIST tables for real fluids.
- The capillary pressure is calculated using the Leverett's correlation that uses fluid saturation.

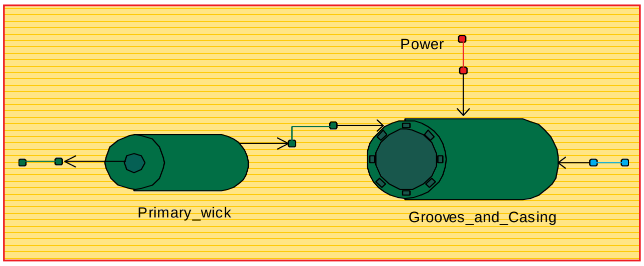
LHP LIBRARY (2)

- **Capillary Pump**



– This component is modelized using two basic components:

- *Primary wick*
- *Grooves and casing*



LHP LIBRARY (3)

- **Primary Wick:**

- This component simulates several phenomenon in a porous media.
- It is modelized by using mass and energy conservation equations in one dimension (radial) .
- The Leverett´s function *J* is calculated within the wick. Then, capillary pressure differences between wick and grooves and wick and compensation chamber can be obtained. The resulting values are introduced in the momentum equations.

LHP LIBRARY (4)

- **Grooves and Casing:**

- This component simulates the evaporator casing, the vapour grooves and the outer layer of the wick.
- The equations included in this component are mass conservation, energy conservation, momentum (including capillary pumping, head losses and height effect), fluid properties (allowing two phase mixtures) and heat transfer with walls and through the wick (effective conductivity)..

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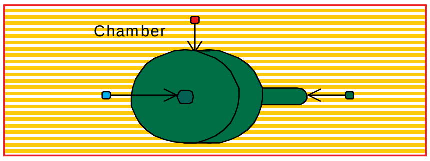
LHP LIBRARY (5)



- **Compensation Chamber:**

- This component simulates the compensation chamber and the inner layer of the wick.
- The equations included in this component are mass conservation, energy conservation, momentum (including capillary pumping, head losses and gravity effect), fluid properties (allowing two phase mixtures) and heat transfer with walls and through the wick (effective conductivity).
- The capillary pumping is calculated considering the Leverett's function in the component "wick" and assume the presence of liquid in the chamber.

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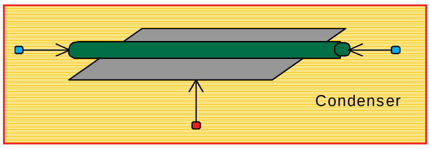
LHP LIBRARY (6)

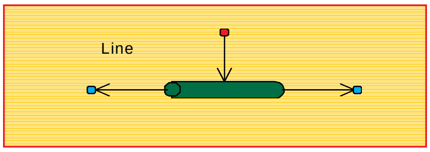


- **Condenser:**

- This component simulates the pipe circuit in a condenser. It is divided in *n* control volumes.
- The equations considered in this component are energy conservation, momentum (including fluid inertia, head losses and height effect), fluid properties (allowing two phase mixtures) and heat transfer with walls.
- The head losses and the film coefficient for heat interchange with walls are calculated using typical correlations.
- The wall energy nodes can be connected to an ambient node and/or to a sink node.

LHP LIBRARY (7)

- **Lines:**



- These nodal components are used to simulate the transport lines that connect the LHP pump and the condenser.
- The equations considered in this component are energy conservation, momentum (including head losses and height effect), fluid properties (allowing two phase mixtures) and heat transfer with walls.
- The head losses and the film coefficient for heat interchange with walls are calculated using typical correlations.
- The heat exchange between the pipe and the ambient can be simulated by means of a GL (is a vector) between the thermal port of the “Line” and the ambient node.

EXAMPLES

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EXAMPLES (1)

- A real LHP model have been used as library test bench.
- Ammonia has been considered as working fluid.
- The behaviour of the loop has been checked in different conditions such as power dissipation and sink and ambient temperatures variations.

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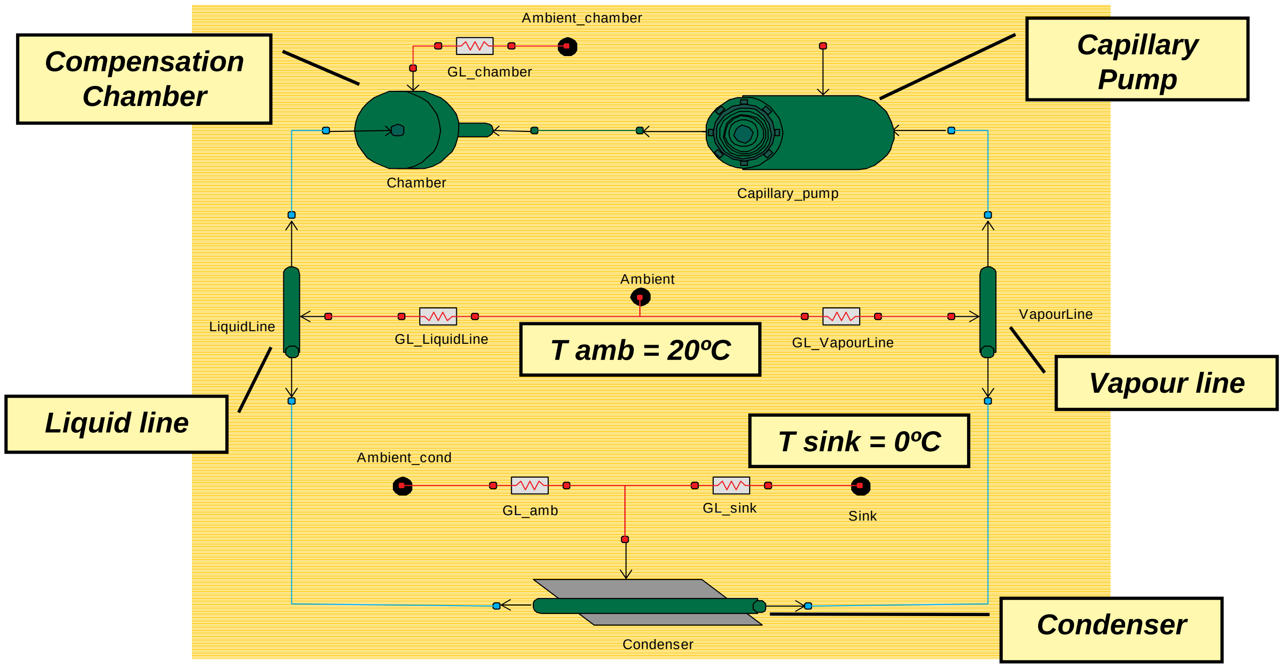
EXAMPLES (2)



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EXAMPLES (3)

- **Model data:**

Capillary Pump	
Active Length (m)	0.305
Wick Porosity	0.6000
Wick Outer Diameter (m)	0.0239
Wick Inner Diameter (m)	0.0076
Wick Thermal Conductivity (W/m-K)	25.00
Wick Permeability (m2)	6.45E-18
Wick effective pore radius	1.2000
Vapor Line	
Outer Diameter (m)	0.0048
Wall Thickness (m)	0.0007
Length (m)	1.016

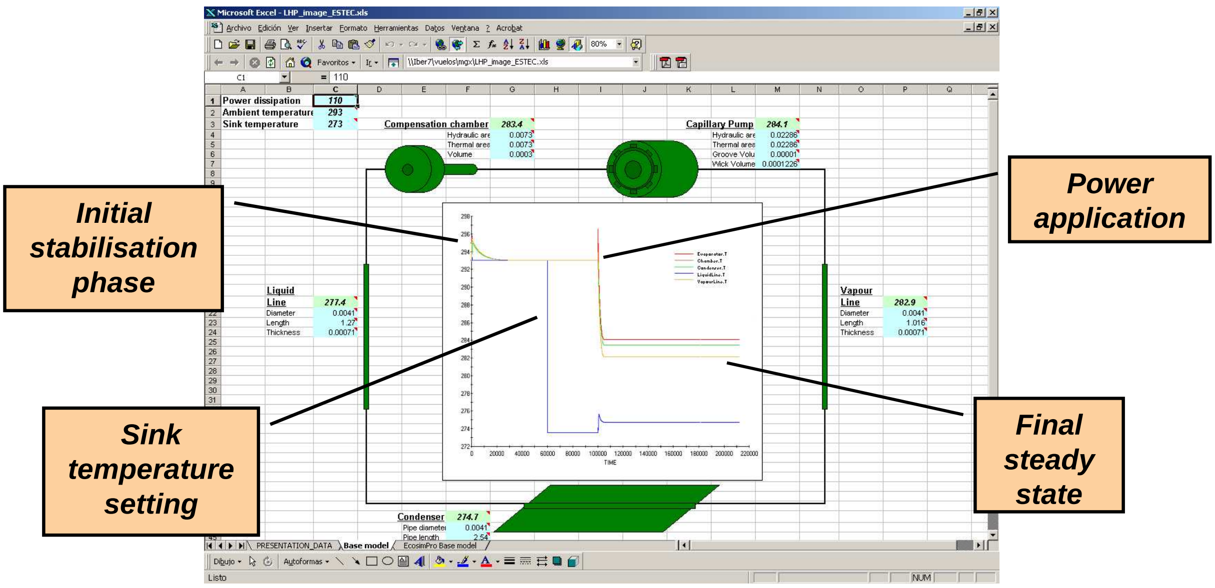
Condenser	
Outer Diameter (m)	0.0048
Wall Thickness (m)	0.0007
Length (m)	2.540
Liquid Line	
Outer Diameter (m)	0.0048
Wall Thickness (m)	0.0007
Length (m)	1.270
Compensation Chamber	
Outer Diameter (m)	0.0254
Length (m)	0.127

- **Runs data:**

  * T ambient = 20ºC , T sink = 20 / 0 ºC (applied at t=60000s)
  * Power: From 10 to 510 W (applied at t=100000s)

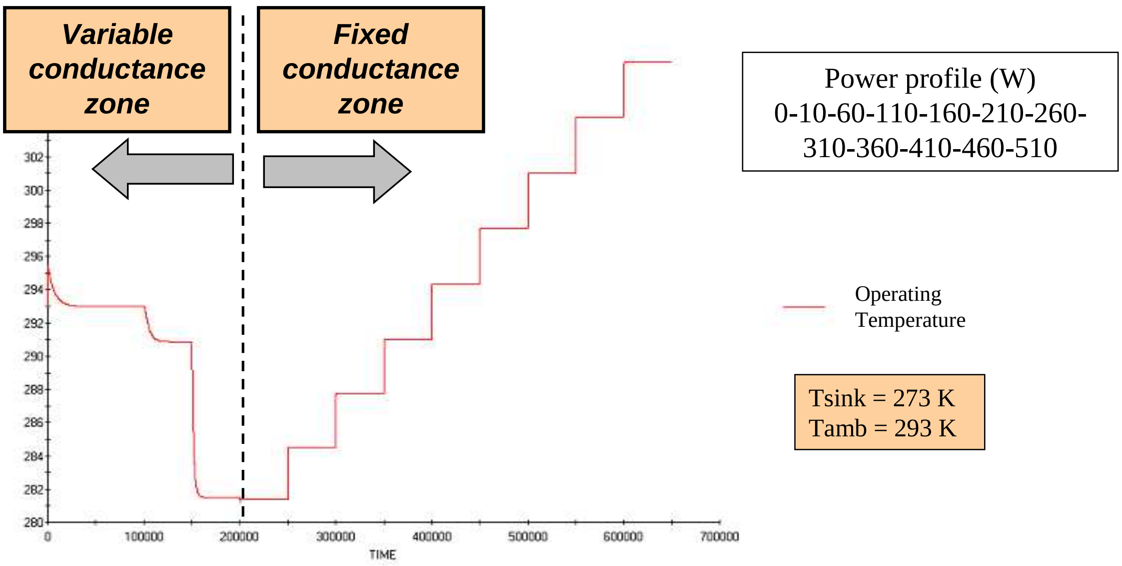
EXAMPLES (4)

- **Transient phenomena: Fixed power run**



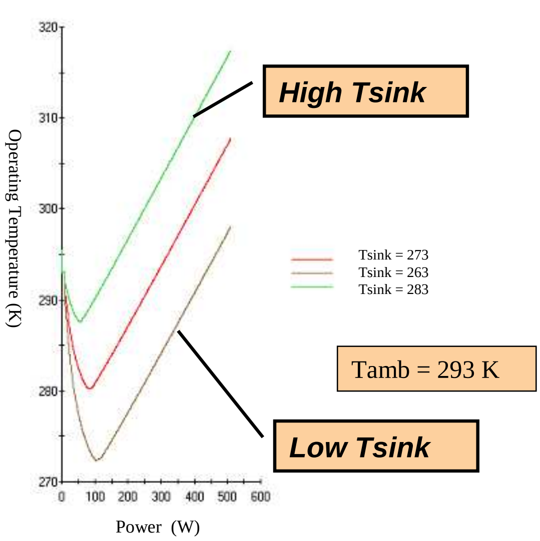
EXAMPLES (5)

- **LHP performance: T_vs_TIME plot**

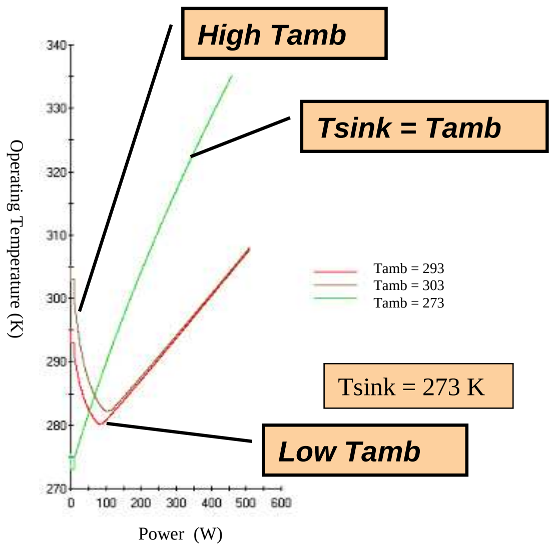


EXAMPLES (6)

- Variation of Sink Temperature: T_vs_Power plot



- Variation of Ambient Temperature: T_vs_Power plot



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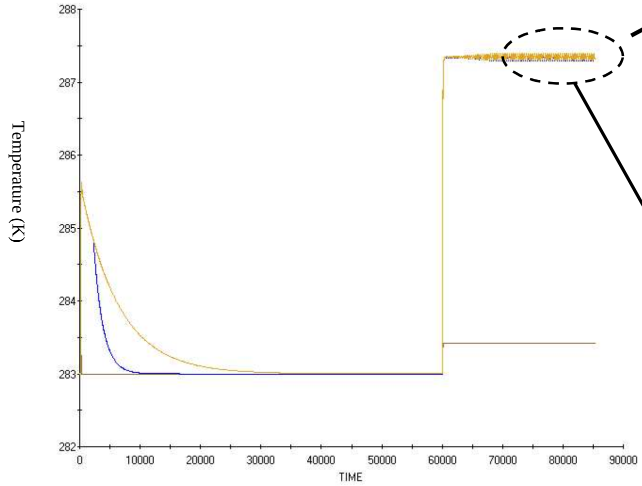
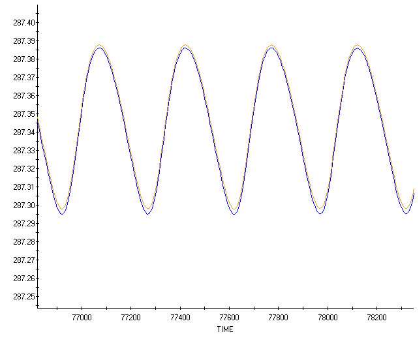
EXAMPLES (7)

- **Oscillations: Temperatures plot**

Power: 65 W
Tsink = Tamb = 283 K





High frequency oscillations:
Period ~ 350s / Amplitude < 1 K

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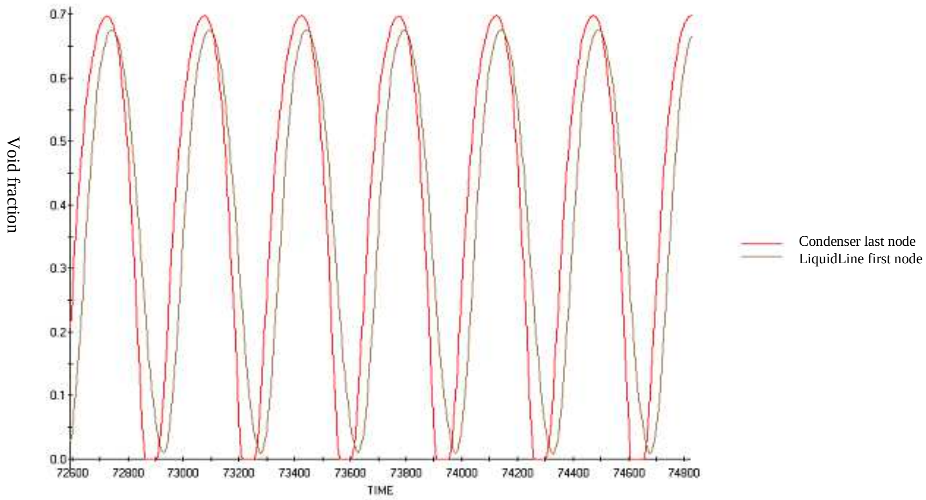
EXAMPLES (8)

- **Oscillations: Void fractions plot**



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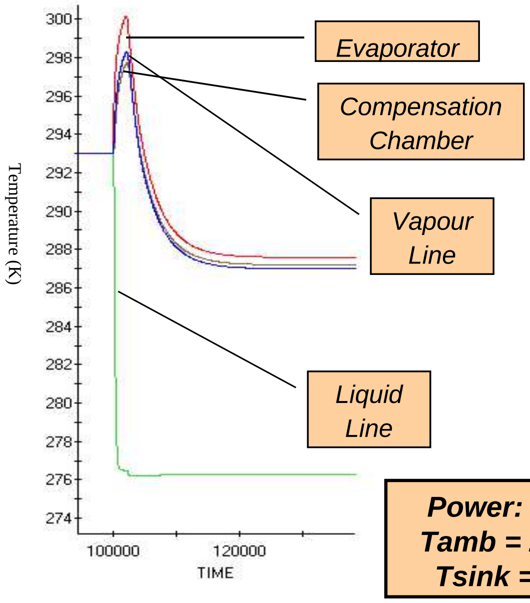
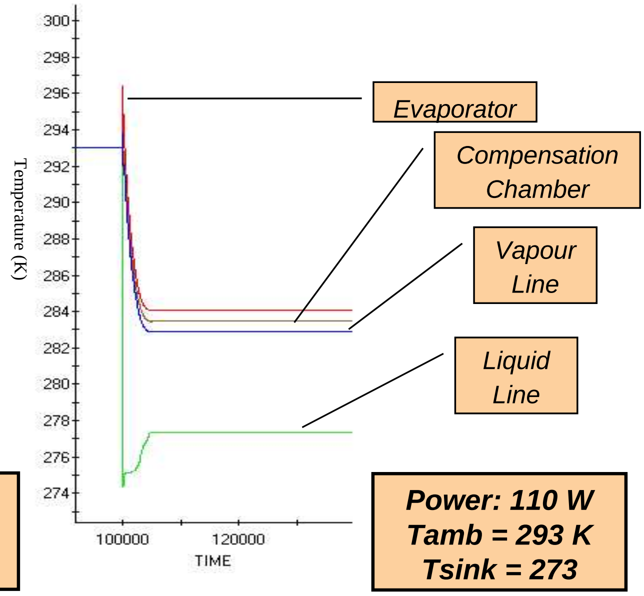
EXAMPLES (9)

- **Transient phenomena: Start - up**



Power: 60 W
Tamb = 293 K
Tsink = 273



Power: 110 W
Tamb = 293 K
Tsink = 273

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FUTURE IMPROVEMENTS

FUTURE IMPROVEMENTS

- Implementation of the secondary loop to improve the determination of heat leak to catch the superheat precisely.
- To perform additional validation of the model
- Several nodes at the primary wick are already implemented to determine the fluid distribution. Some refinement are under development.
- To improve the correlations for two-phase flow.
- Friendly user interface.