Simulation of Ground Heat Exchanger for Cryogenic Applications

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POLYTECHNIQUE MONTRÉAL

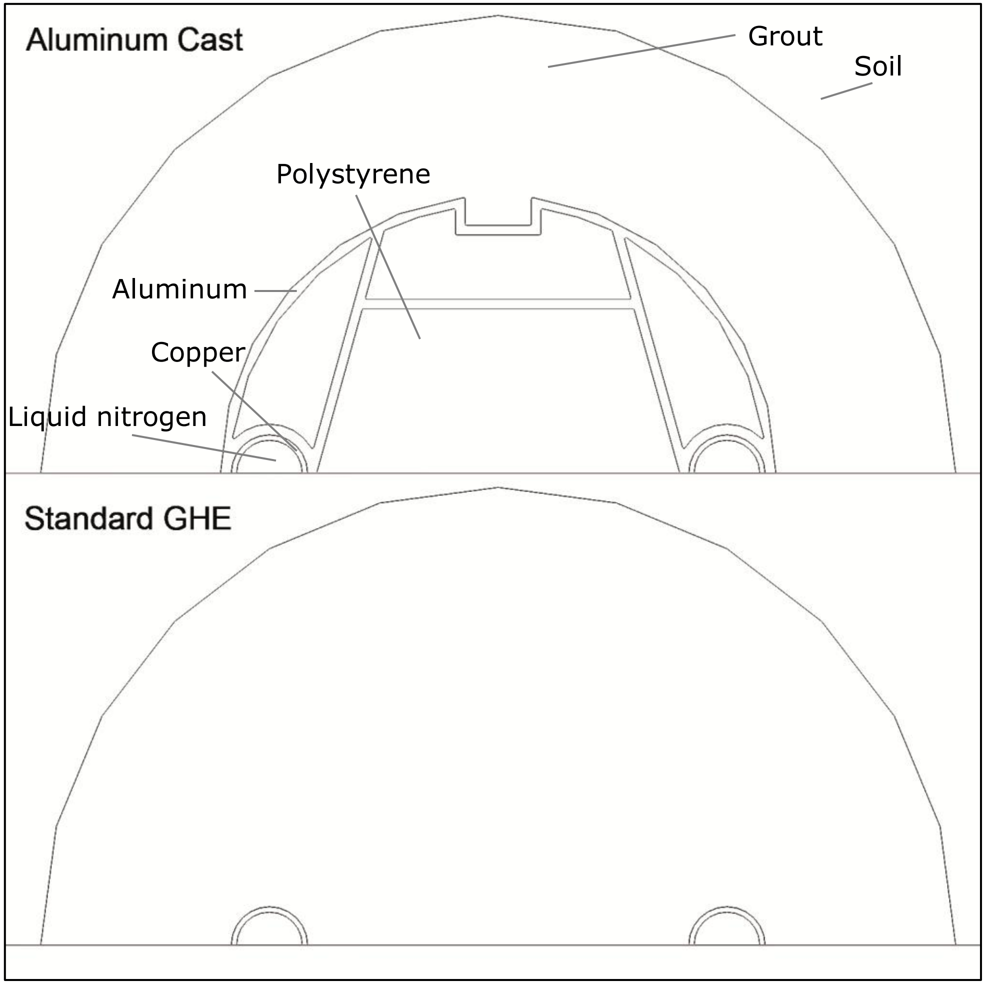
INTRODUCTION – GROUND FREEZING

- Increased mechanical properties
- Impermeable ice wall prevents water migration

Construction of the metro line 4 in Budapest ©Tunneltalk.com

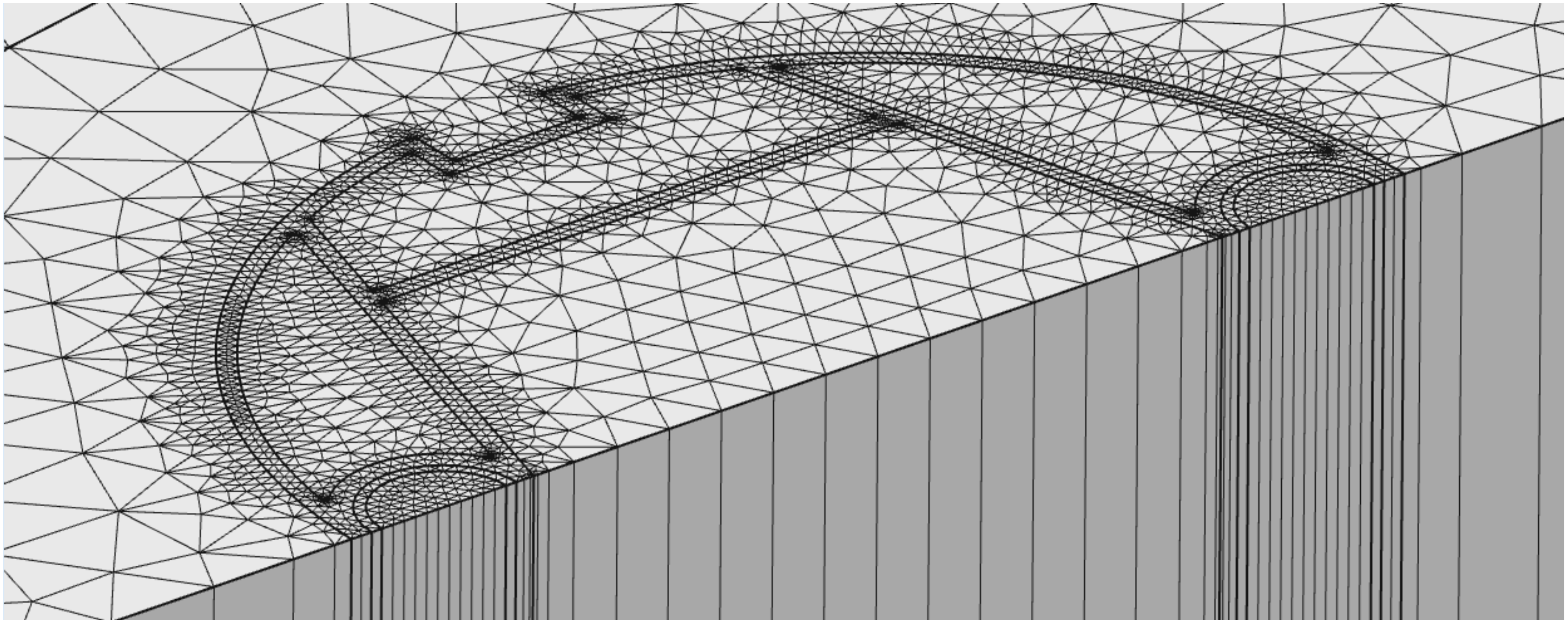
INTRODUCTION - GROUND HEAT EXCHANGER

- Reduce the time required to freeze the ground water
- Reduce the construction and operation costs of the system
- Increase the effective diameter of the geothermal well



Aluminum cast and standard GHE

COMSOL - GEOMETRY

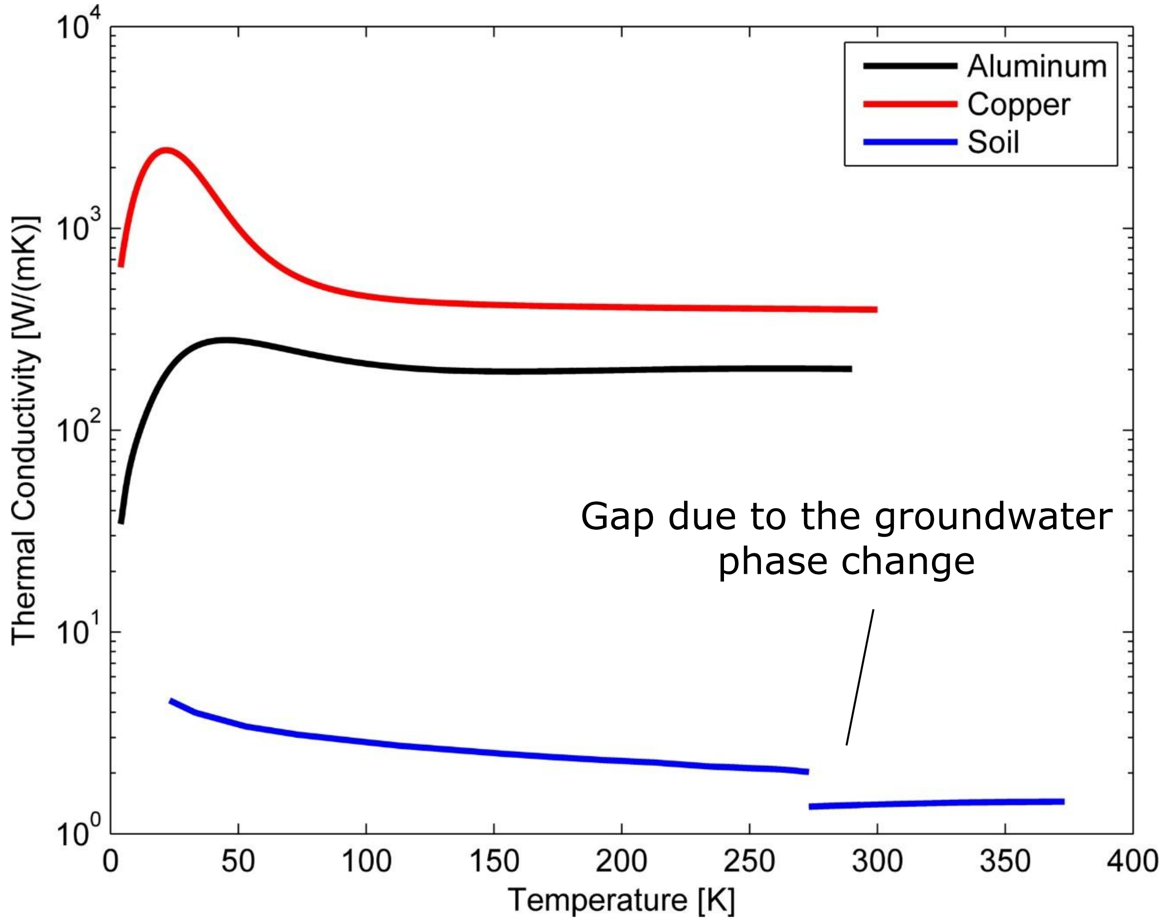


Geometry and mesh of the ground heat exchanger

Geological domain
- 20 m deep
- 5 m radius

Aluminum Cast
- 92.5 mm diameter
- 1.78 mm thick

COMSOL – MATERIAL PROPERTIES



Thermal conductivity of some materials

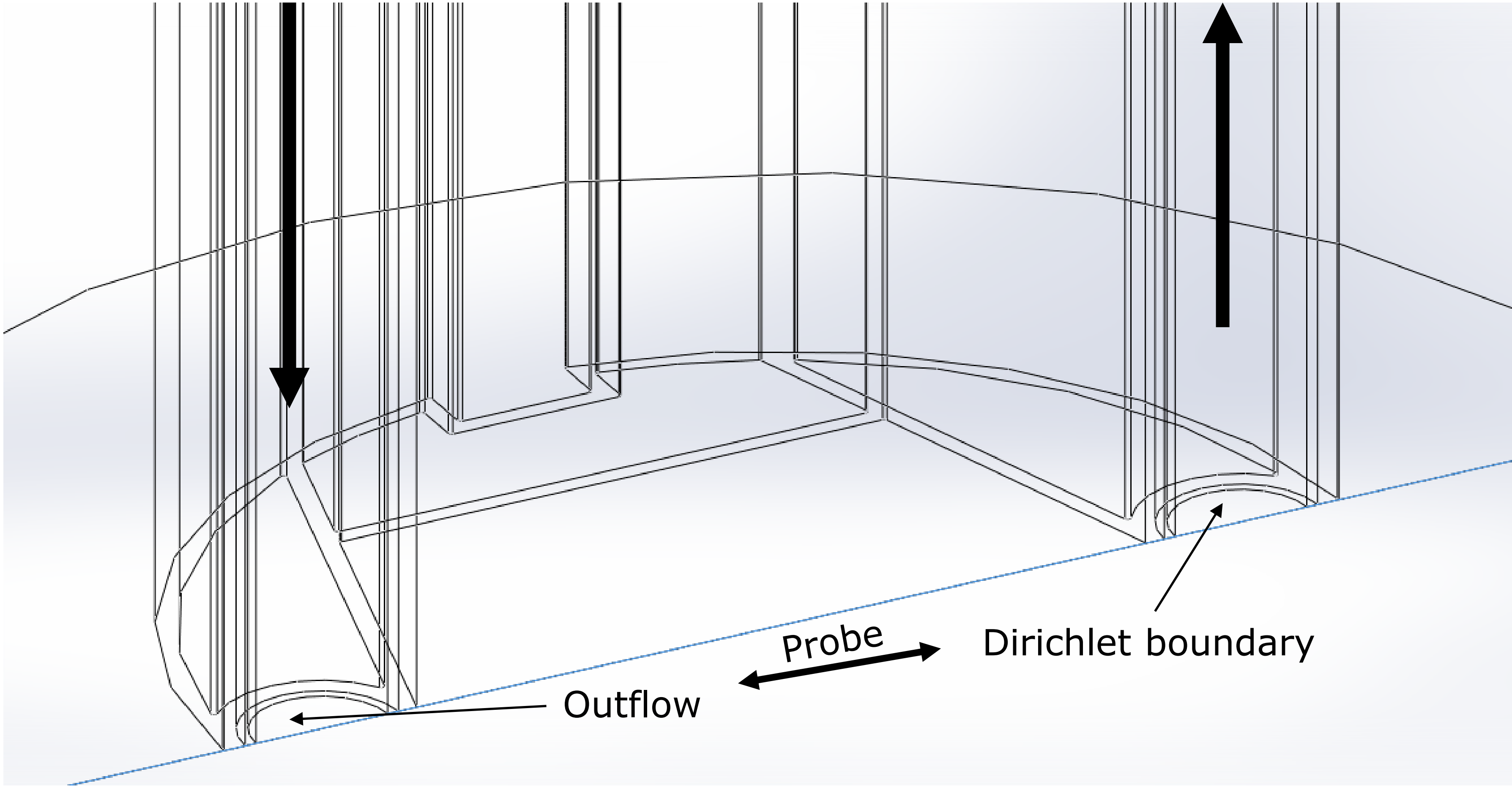
Material properties:

- Thermal conductivity
- Heat Capacity
- Density

Thermal properties are temperature dependant

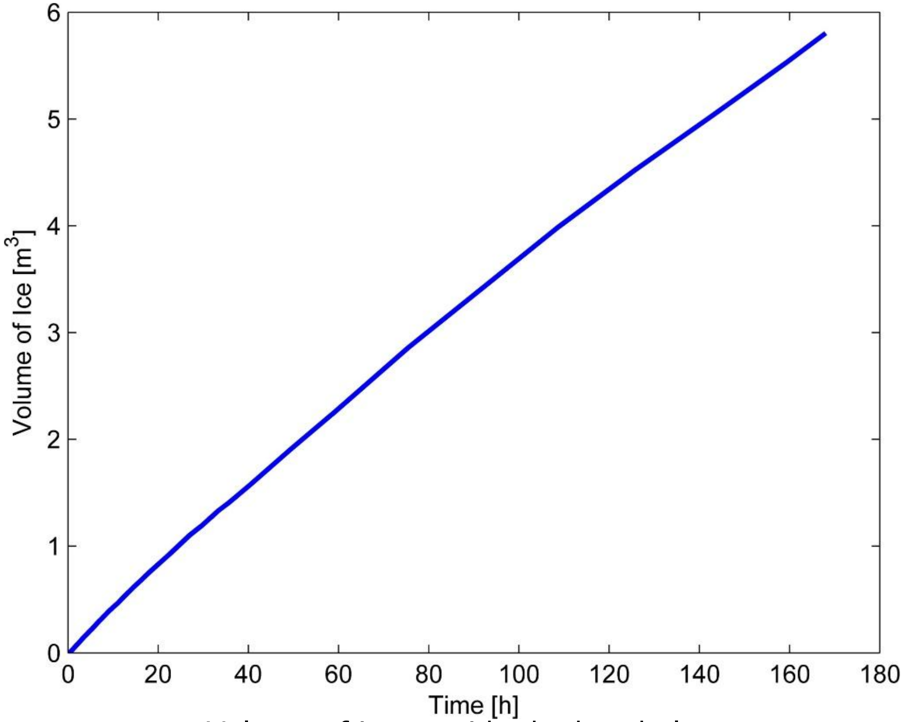
COMSOL – INITIAL AND BOUNDARY CONDITIONS

- Dirichlet condition (10°C) at r=5m
- Perfect insulation on the symmetry and surface
- Heat flux from the bottom ($60 \times 10^{-3} W/m^2$)
- Liquid nitrogen is entering at 77K (-196.15°C)
- Turbulent flow is simulated by increasing thermal conductivity in the horizontal plane



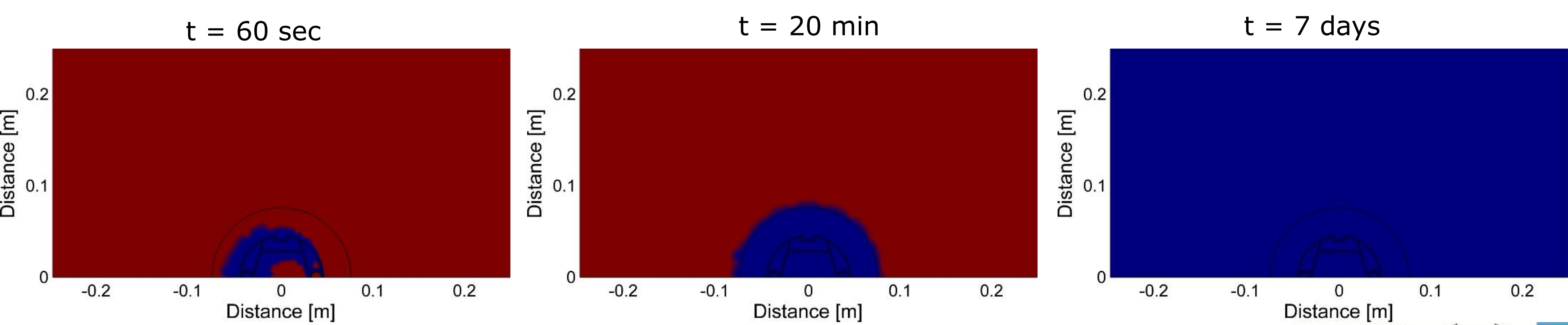
Boundary condition to simulate the U loop

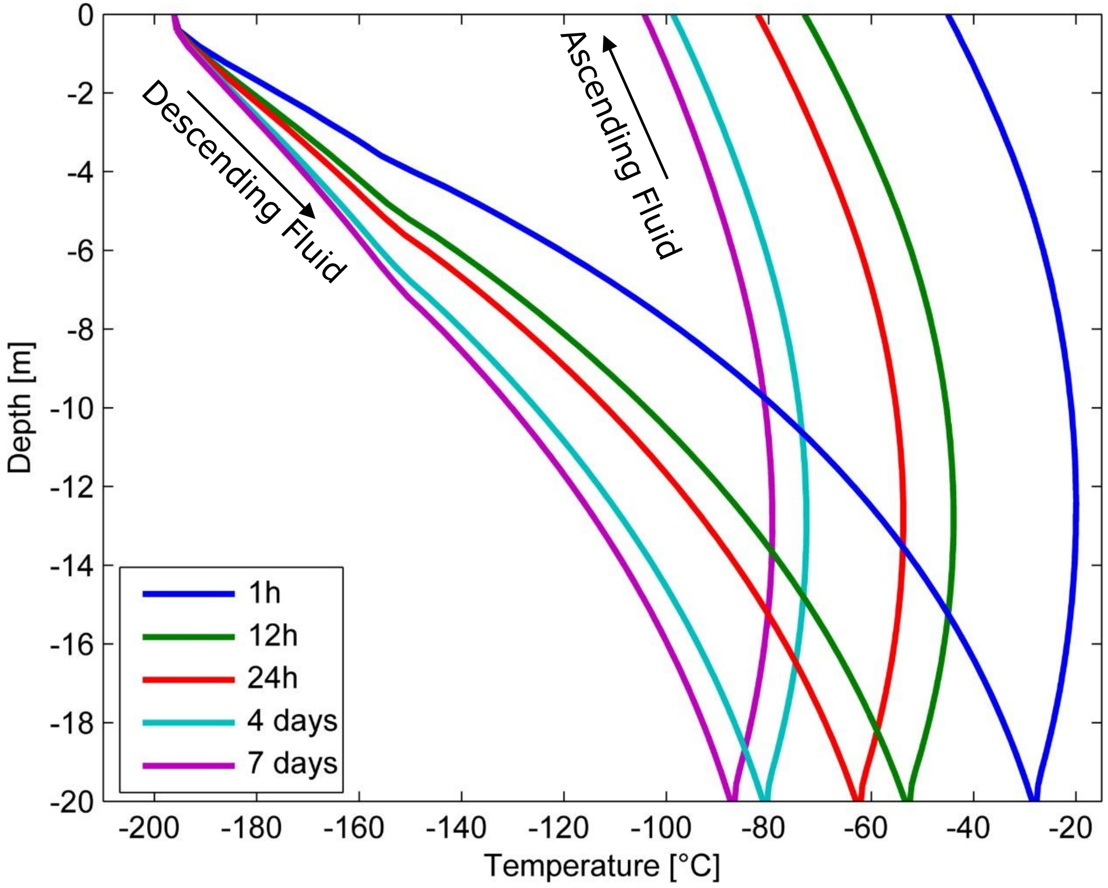
RESULTS – ICE FORMATION



Volume of ice outside the borehole

- Ice lens increase the thermal conductivity of the soil
- After 7 days, 5.8m^3 of ice outside the borehole is created





- Strong heat absorption in the downward pipe
- Intensive heat loss in the 2nd half of the upward pipe

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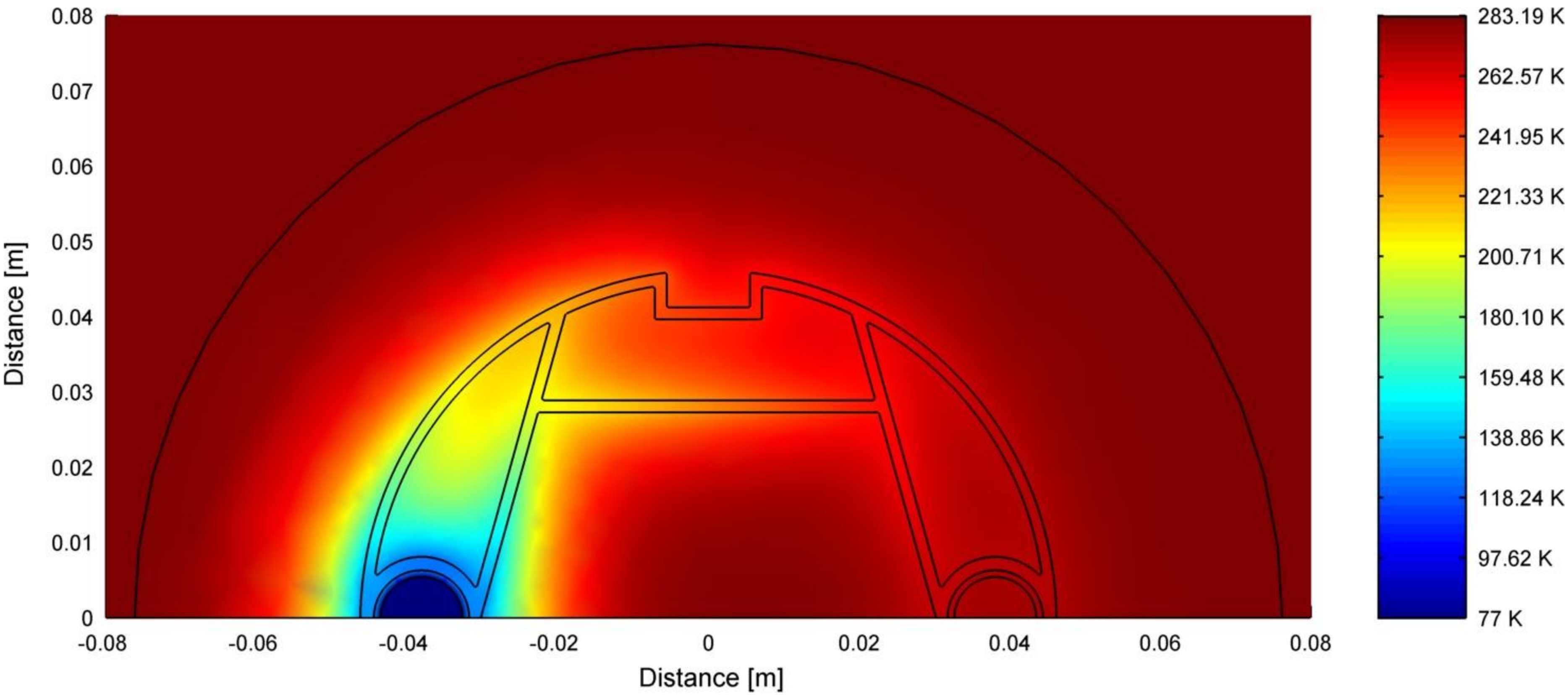
LE GÉNIE EN PREMIÈRE CLASSE

RESULTS – THERMAL SHORT-CIRCUIT



Thermal short-circuit after 60 sec at z=0

Aluminum is the preferred path for the thermal short-circuit

- The current design has important thermal short-circuit
- 2nd design is already existing and is ready to be implemented into Comsol Multiphysics
- Novel designs help to reduce the operation time and cost

QUESTIONS