Journal of
Fundamentals of Renewable Energy
and Applications

Misale, J Fundam Renewable Energy Appl 2015, 6:1
DOI: 10.4172/2090-4541.1000e105

Editorial Open Access

Heat Transfer and Energy

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Rec date: Nov 26, 2015; **Acc date:** Nov 28, 2015; **Pub date:** Nov 30, 2015

Editorial

In particular, the first research activities were developed in the fields of the cooling of electronic equipment either by air natural convection or by direct immersion cooling of electronic components by dielectric fluids. For the former subject a simple formula was developed to evaluate the vents area as function of several parameters such as the power transferred to the air, friction losses in the vents, shape and size of the vents, distance between vents [1]. About latter research activity, at the DIME-TEC Labs were performed a lot of experimental campaigns, analyzing different pool boiling aspects such as dielectric fluid properties, working pressure, surface geometries (plain or finned) and surface confinements [2-4].

Figure 1: Experimental setup.

At the beginning of the 2000, my research activity was dedicated to passive technologies applied in several engineering applications such as nuclear power plant, geothermal systems, and solar collectors. In all these applications, the heat is convoy by natural circulation. In a natural circulation systems, fluid circulation starts automatically following the activation of the heat source under the influence of a body force field like gravity. With both the source and sink conditions maintained constant, a steady circulation is expected to be achieved. The fluid circulation is the result of buoyancy forces, which are the result of the density differences thermally induced by the heat transport from the source to the sink. Usually, the heat sink is located above the source to promote natural circulation. The primary function of a natural circulation loop (NCL) is that to convoy heat from a heat source to a sink. The main advantage of a natural circulation system is that no fluid moving machinery is needed, making the system less prone to failures and reducing the maintenance and operating costs. The motive force for the flow is generated within the loop simply because of the presence of the heat source and the heat sink.

At DIME-TEC Labs several experimental facilities were designed and were constructed. A picture of one of this apparatus is shown in (Figure 1). The NCL consists of a lower heater and an upper cooler. Usually the secondary fluid at the cooler is tap water, but in my case a cryostat was employed to control the temperature at the cooler. The cooler temperature can range between -10°C up to 30°C.

The experimental activities are focused to better understand the thermos-hydraulic behaviour of the NCLs. These thermal systems show different behaviors: stable (steady temperature difference across the heat sinks) or unstable (amplification of the oscillations of the temperature differences across the heat sinks and flow reversals).

In (Figure 2) the typical unstable behaviours are depicted:

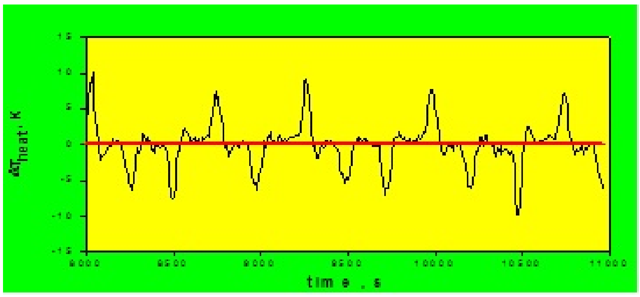


Figure 2: Temperature difference at the heater (Unstable behaviour).

Obviously, the latter behaviour must be avoid to appear because it vanished the advantage to use NC to convoy heat in a thermal system.

Different technologies can be used to avoid the appearance of an unstable behavior:

a) Insert localised pressure drops in the circuit [5]

b) Control the temperature of the secondary fluid at the cooler [6]

The presence of a significant localized pressure drops in the circuit increase the friction losses, but on the contrary, increases at the same time the average temperature fluid (Figure 3).

Citation: Misale M (2015) Heat Transfer and Energy. J Fundam Renewable Energy Appl 6: e105. doi:10.4172/2090-4541.1000e105

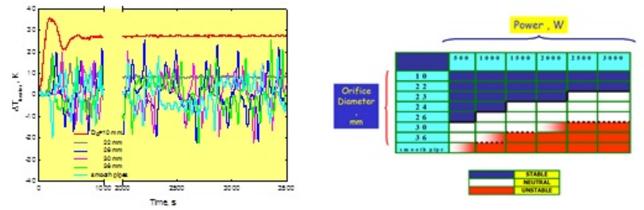
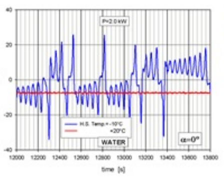


Figure 3: Comparison between tests with smooth pipes and pipes with orifices.

As an example in (Figure 4) is shown how the temperature of the heat sink can stabilise the NCL behaviour.



WATER	HEAT SINK TEMPERATURE [°C]				
Power [kW]	-10	0	10	20	30
0.5	S	US	US	US	US
1	US	US	US	US	US
1.5	US	US	US	US	US
2	US	US	US	S	S
2.5	US	US	S	S	US

Figure 4: Dependency of system stability on heat sink temperature and heat flux (S = Stable, US = Un Stable).

A new aspect that, in the last years was investigated is the NC in miniloops. These thermal systems are characterized by few millimeters of ID. The reduced size of the ID causes always-stable behaviour because the friction losses are higher than buoyancy forces [7]. At DIME-TEC Labs, were designed and were constructed several NC miniloop varying both ID value and aspect ratio. In the case of stable behaviour could be interesting employ different fluids during the experiments. In particular, new kind of fluids called "nanofluid" are widely studied at DIME-TEC Labs [8]. Nanofluid is the name conceived by Argonne National Laboratories to describe a fluid in which nanometer-size particles are suspended in a base fluid [9]. In particular, for practical application of nanofluids will be necessary to deeper understand the sedimentation problems during the life of the thermal systems. As example some picture of nanofluid sedimentation are reported below (Figure 5):

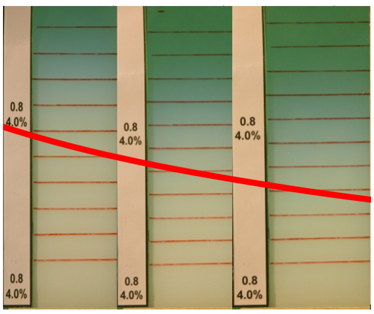


Figure 5: Al_2O_3 sedimentation.

The main open questions in the study of single-phase NCLs are:

The instrumentation should be able to measure the velocity and the temperature of the fluid without disturbance on the measurements:

Magnetic flow meter

Ultrasound Pulsed Doppler Velocimetry

Liquid crystal.

The thermo-hydraulic behaviour of a single-phase natural circulation loop depends on:

Interaction between the fluid properties and material utilised to construct the loop (pipe material).

Thermal performance of complex loop:

Heaters and coolers displacement and numbers.

Horizontal parallel channels (new nuclear reactors).

Thermal performance of mini-loop.

Stability map able to take into account the pipe materials, loop inclination.

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