Projection of cryogenic fluids: a comparison between liquid nitrogen and liquid carbon dioxide

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Experimental set-up, Projection of cryogenic fluids onto a heated copper target

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This study aims at providing Air Liquide's business teams with reliable data on the heat transfers involved when cryogenic fluids are propelled onto a hot surface. Indeed, for cryo-tooling applications, where cryogenic fluids replace oil emulsions to lubricate and cool the machined area, heat transfer between the cooling fluid and the heated area is a key parameter.

An experimental study has been performed to compare the cooling power of Liquid Nitrogen (LIN) and Liquid Carbon Dioxide (LCO$_2$). LIN and LCO$_2$ were projected vertically through a nozzle towards a heated surface.

The influence of two key parameters was studied:

- the nozzle-to-surface distance,
- the fluid mass flow rate.

The operating conditions are derived from industrial settings. The heated target is made of copper (130mm diameter, 20mm thick) and maintained at 150°C with heating cartridges, while electrical power is recorded. The nozzle orifice is of 1mm diameter. Piping systems are identical for both fluids. LIN (LCO$_2$) storage is at 10 bar rel (20 bar rel).

- The **influence of the nozzle-to-surface** distance does not seem to induce significant changes in the cooling power. For each fluid, no clear difference between 1, 2 and 3cm is observed in the frame of our experimental uncertainties.

- The **fluid mass flow rate** has been computed from the mass variation of the storage. In this case, for a fixed flow rate, we observe that LCO_2 outperforms LIN. However, heat losses related to vaporization inside the piping system are more important for LIN than for LCO_2. Therefore, a dedicated experimental system was set-up to measure the fluid flow rate directly at the nozzle. When fluid flow rates through the nozzle are considered, we evidence that **LIN and LCO_2 present almost identical cooling powers**.

- The study also sheds light on a **critical flow rate**, above which the cooling power seems to stay identical even if the flow rate increases.