New-generation Instruments Deserve Ultrafast Cryostats

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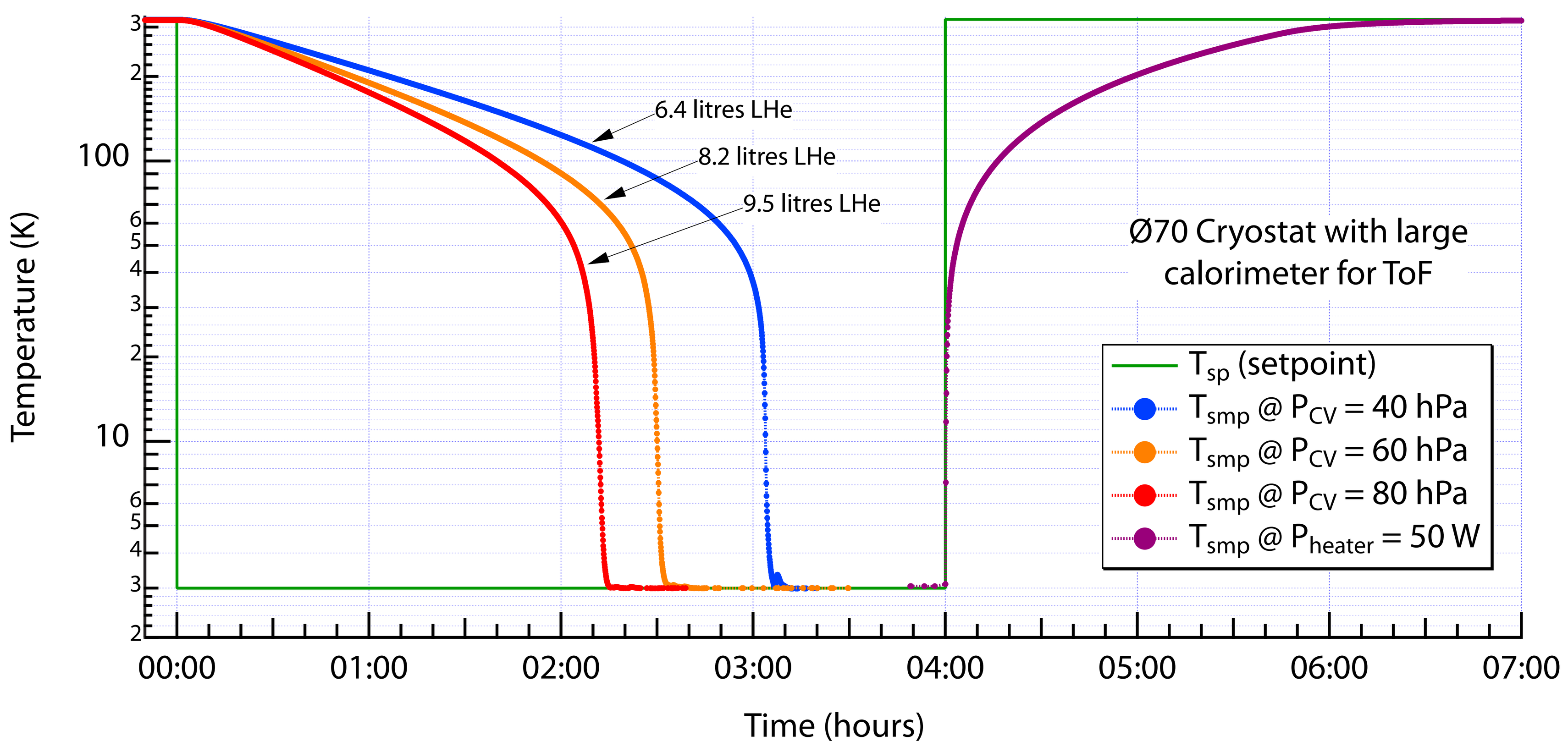
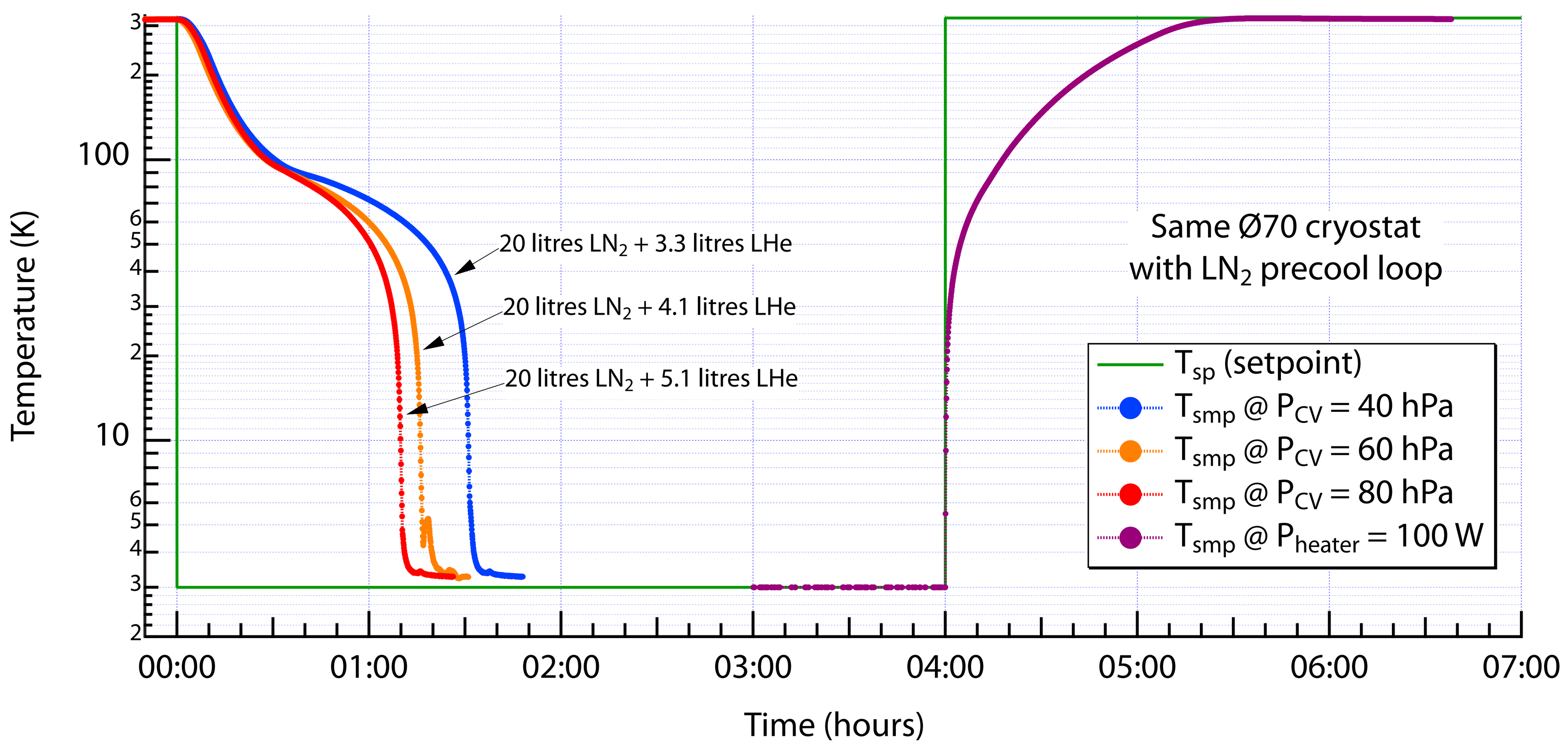
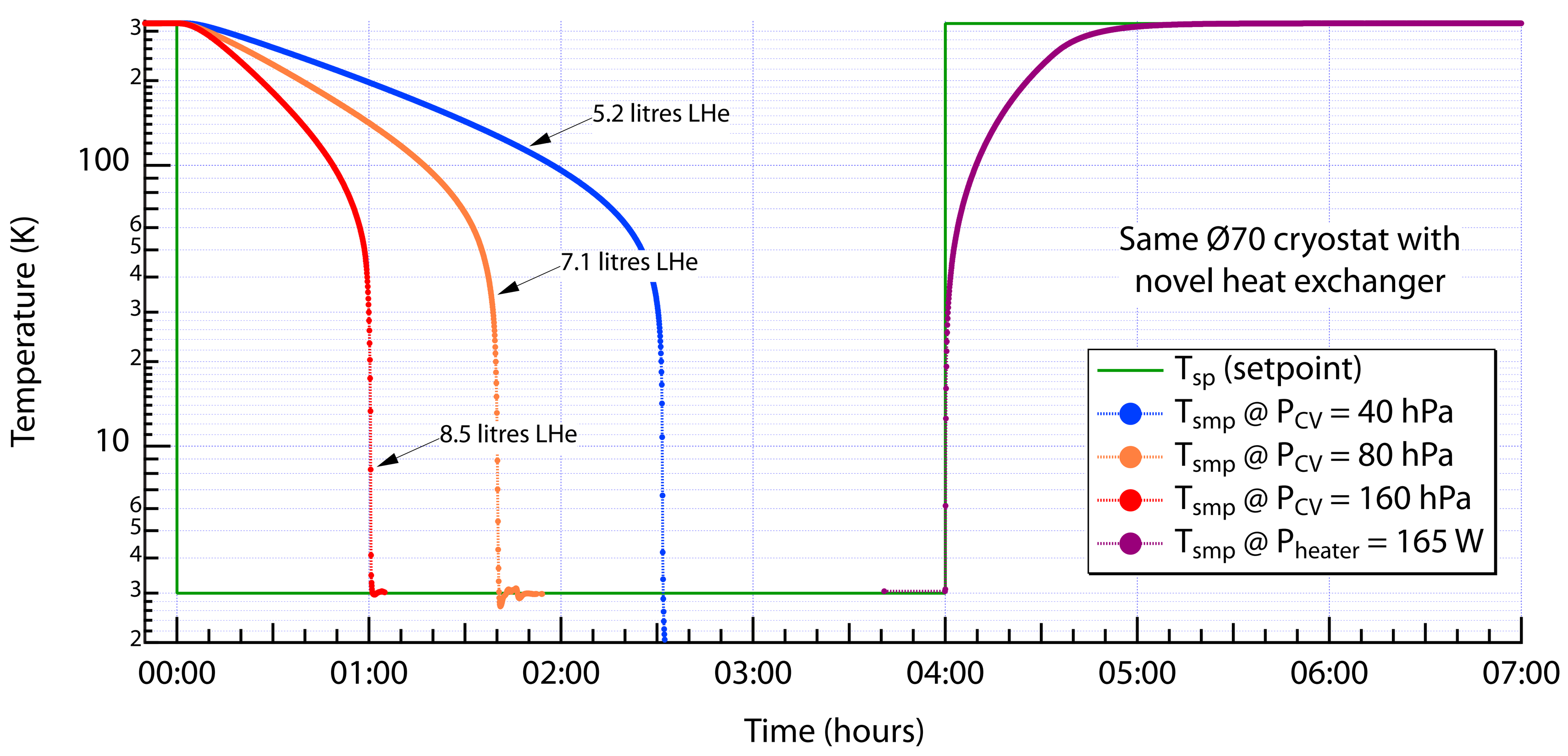
The performance of the new-generation instruments are impressive, to a point where the time required to change the sample temperature leads to unacceptable beam-time losses. Cooling a new sample down in an already cold system is quick, but changing the temperature up and down really takes long times. Of course, the cryostats must be improved without compromising the temperature stability and range.







At ILL, we recover in average 95% of He and a litre of liquid helium costs about 4.2 €. Knowing that the cost of latency is roughly 50 €/h (averaged staff cost including taxes), it is reasonnable to spend up to 50/4.2≈12 litres to save an hour. So we thought that we could minimise beamtime losses by opening the cold-valve…

But increasing the He flow does not reduce the cool-down time that much! There is an intrinsinc limit. In the case of the large tail cryostat of IN5, this limit is of about 2 hours as shown on the first graph.

So we proposed to add a CryoBooster at the bottom of the calorimeter: a copper ring integrating a liquid nitrogen precool loop and a Thermocoax heater.

When cooling the sample down, liquid nitrogen is automatically injected into the base of the calorimeter until the regulation temperature reaches about 80 K. And when heating up, the Thermocoax brings heat in concert with the heater of the exchanger. As shown on the second graph, a gain factor of ≈2 was reached in time and He consumption. Great!

But the prototype remained too fragile and risky to be used at a user facility: the precool-loop must be evacuated below 80 K and must remain tight enough to avoid N_2/air cryopumping. If not, the loop is destroyed when heating up the sample. So we abandoned this solution.

We then decided to study the intrinsinc limitation of the heat exchanger and realised from calculations and tests that only 30% of the enthalpy is exploited at 80 hPa in the studied Ø70 Orange cryostat (large tail).

We studied different heat exchangers and found ways to improve the efficiency significantly (by 33% at 80 hPa). Users usually set the cold-valve to 40 hPa and wait 3 hours whilst boiling 6.4 litres of LHe (and coffees). With the new heat exchanger and 8.5 litres of liquid He, the system is cooled down in 1h: **3x faster with only 33% more liquid He**.

In a similar way, we modified the heat exchanger of a standard Ø49 mm top-loading Orange cryostat. The performances are summarised in the graph below.

With this new Orange, the cool-down is performed in 22 min with 3.2 litres of liquid He i.e. **3x faster with only 33% more liquid He**.
This cryostat is also 2x faster than a standard Orange set to 80 hPa (same consumption).
Heating up the temperature is also 2x quicker for both cryostats.

PS: These tests were performed with an old 40 m³/h oil pump and slighlty better performances are obtained with a 100 m³/h dry pump.

The regulation/sample temperatures were easily stabilised and this solution does not necessitate the replacement of other components like the cold-valve.