2nd-stage Cooling from a Cryomech PT415 Cooler at 2nd-stage Temperatures up to 300 K with Cooling on the 1st-stage from 0 to 250 W

M. A. Green[1,2], S. S, Chouhan[1], C. Wang[3] and A. F. Zeller[1]

1) Michigan State University, Berkeley CA 48824, USA
2) Lawrence Berkeley Laboratory, Berkeley CA 94720, USA
3) Cryomech Inc. Syracuse NY 13211, USA

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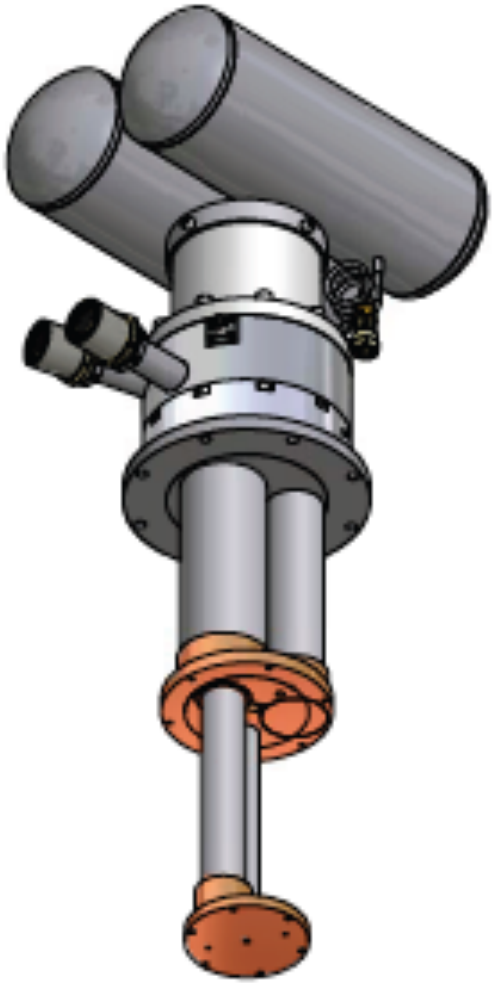
Why should one know about cooler performance over a range of temperatures?

- When one knows about the performance of a refrigerator or a liquefier, one can understand the thermal behavior of the device being cooled. This is true for any cryogenic refrigerator.

- Coolers often cool-down a device as well as keep it cold. Knowing cooler performance over a range of temperature helps predict how a cooler will cool-down a device at cryogenic temperatures.

Properties of a PT415 and PT415-RM Cooler

- The PT415 cooler is a GM pulse tube cooler that is designed to produce 1.5 W at 4.2 K on the 2nd stage while producing 40 W at 40 K on the 1st stage.
- The PT415-RM cooler is a remote motor version of the PT415 cooler. This cooler produces 90 percent of the cooling on both stages.
- Both coolers use 10.8 kW of input power at 60 Hz using a water-cooled compressor.



Cryomech PT415 Cooler

The PT415 can exist in several forms

- The PT415 cooler tested was a standard PT415 cooler that is the same as the one shown in the previous slide.
- The PT415 Cooler can be in a drop-in form that produces from 85 to 90 percent of the cooling of the standard cooler.
- The test was done in the US using 60 Hz power.

LBL Drop-in PT415 Cooler

The Test Set-up at Cryomech-1

The Test Set-up at Cryomech-2

- **All PT415 coolers are tested in a vacuum vessel. A copper shield attached to the first stage shields the MLI insulated second stage. There is MLI on the upper pulse tubes and the regenerator tube as well as outside of the copper shield.**
- **For our tests there were 100 W heaters are attached to both stages. The temperature sensors are are fully calibrated silicon diode sensors from Scientific Instruments. The temperature sensors are located on the cold head well away from the heaters.**

The Test Set-up at Cryomech-3

Shield attached to 1st stage

MLI Insulated 2nd stage

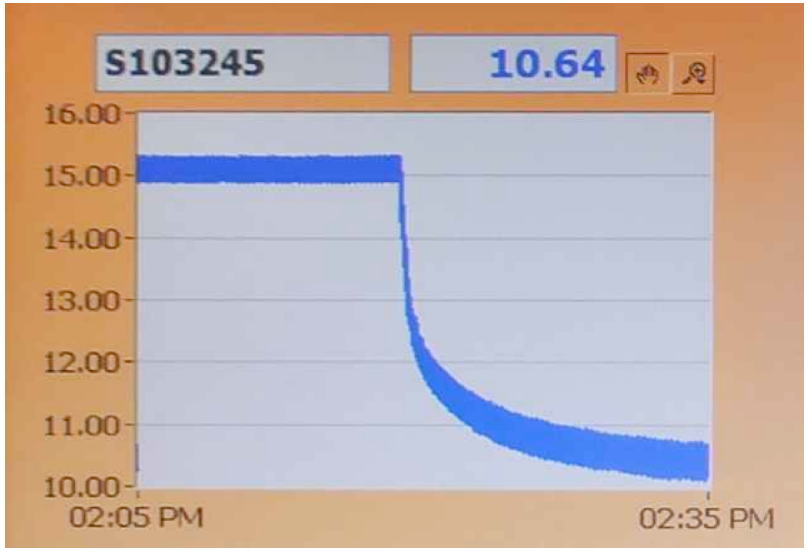
Each PT415 Cooler is Different

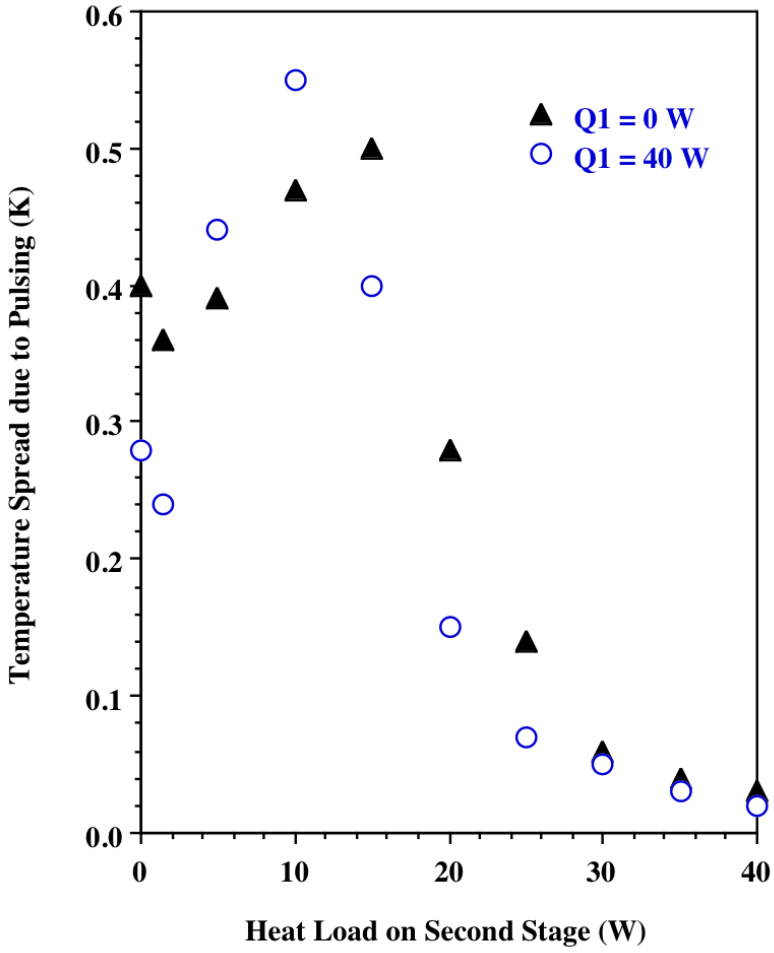
- Each PT415 cooler is measured at four operating points. Each cooler produced is slightly different from other coolers of the same type. The measured extended performance is approximately the same for all PT415 coolers.

The PT415 Cooler Performance Data Curves

- Cooling from 0 to 3 W on the 2nd stage with 1st stage cooling of 0 to 84 W. This is the liquid helium range.
- Cooling from 0 to 40 W on the 2nd stage with 1st stage cooling of 0 to 50 W. This is the liquid hydrogen range.
- Cooling from 0 to 80 W on the 2nd stage with 1st stage cooling of 0 to 40 W. This is a useful temperature range
- Cooling from 0 to 140 W on the 2nd stage with 1st stage cooling of 0 to 250 W. This is the full cooling spectrum.

2nd Stage Temperature Oscillation

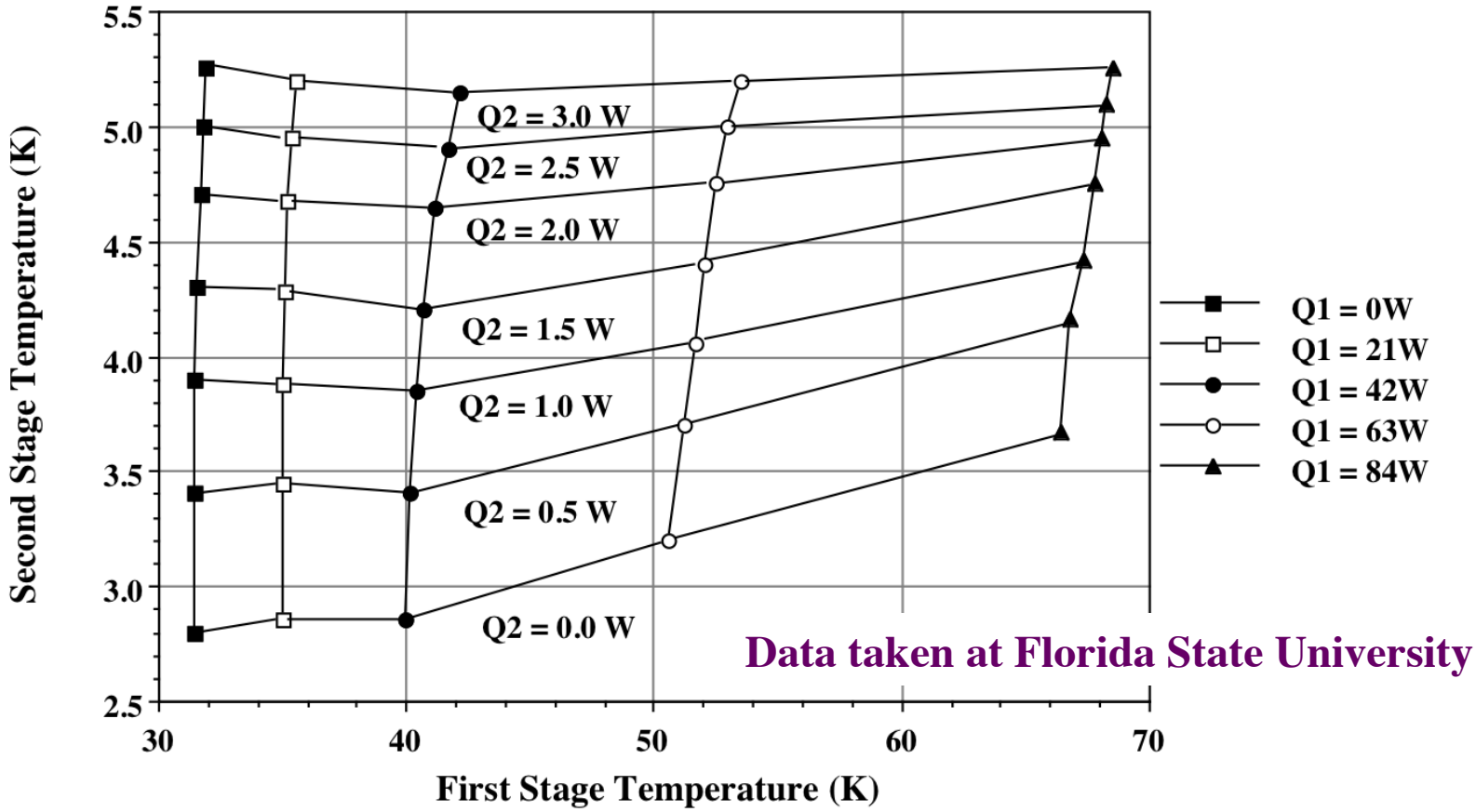




Temperature oscillations occur on both cooler stages. The oscillations are driven by the pulsing if the helium gas in the tubes. This is most seen at low temperatures in the cold heads.

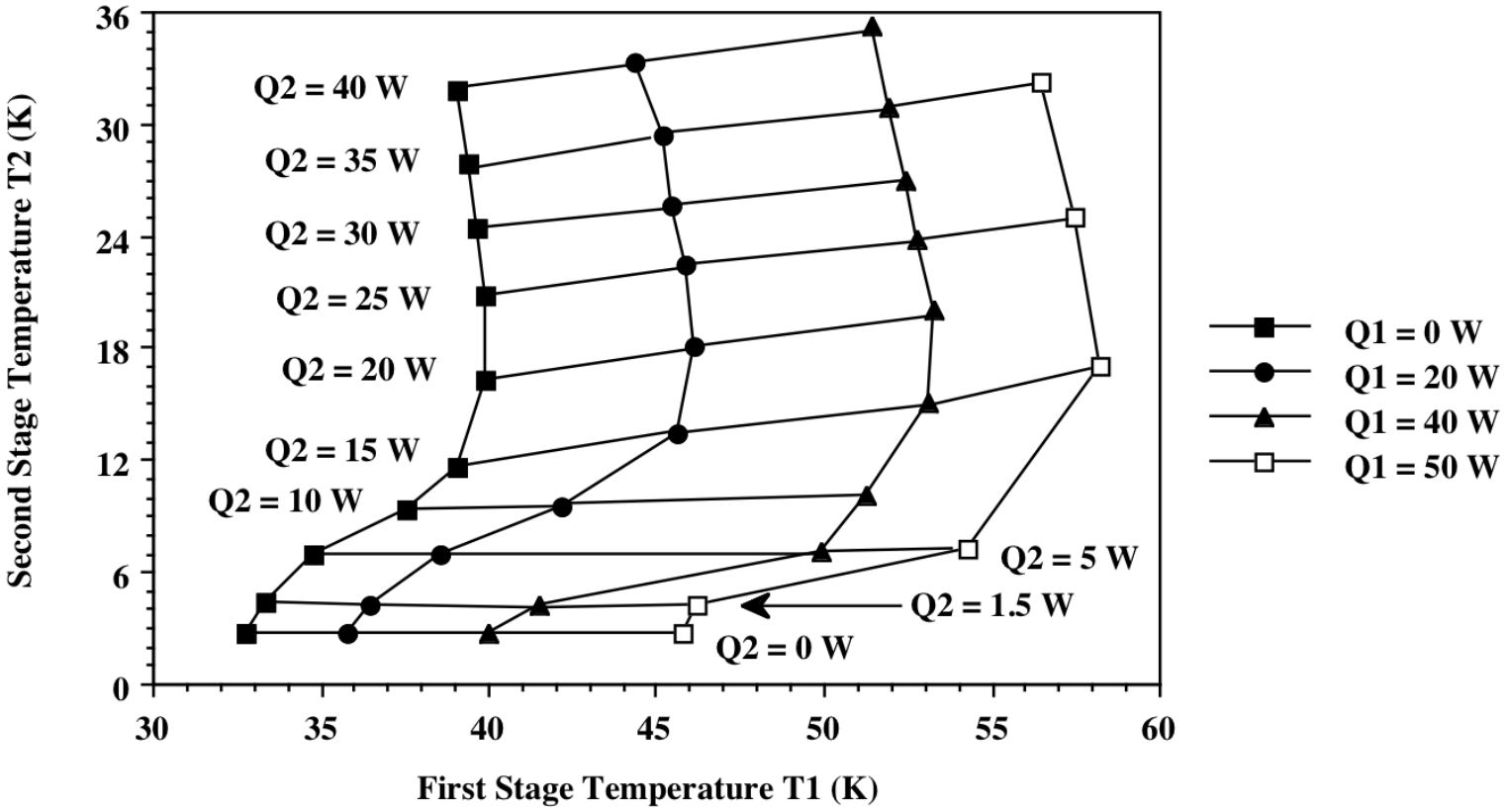
Data taken at Cryomech June 2015

PT415 2nd stage Cooing in the LHe Range



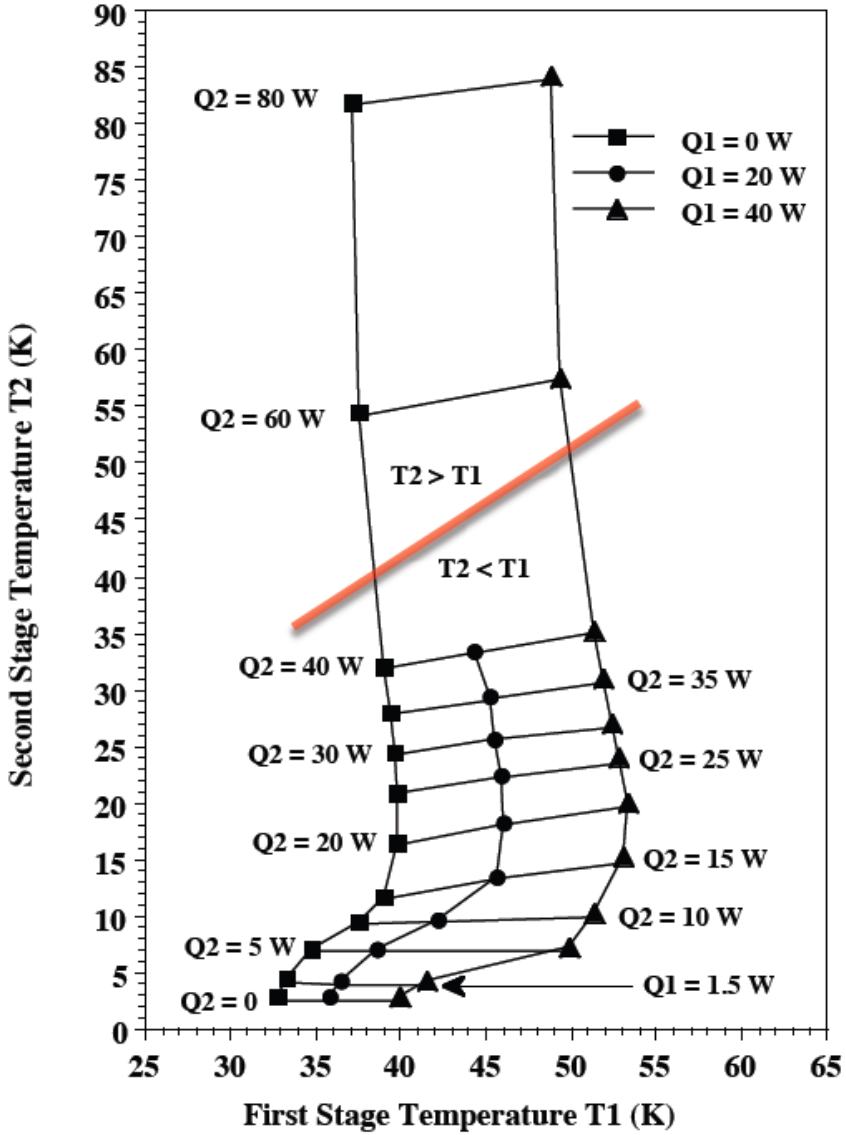
Choi Y S, et al, "Helium-liquefaction by cryocoolers for high field magnet cooling," *Proceedings of the International Cryocooler Conference* **ICC-14** (2006).

PT415 2nd stage Cooing in the LH_2 Range



Data taken at Cryomech June 2015

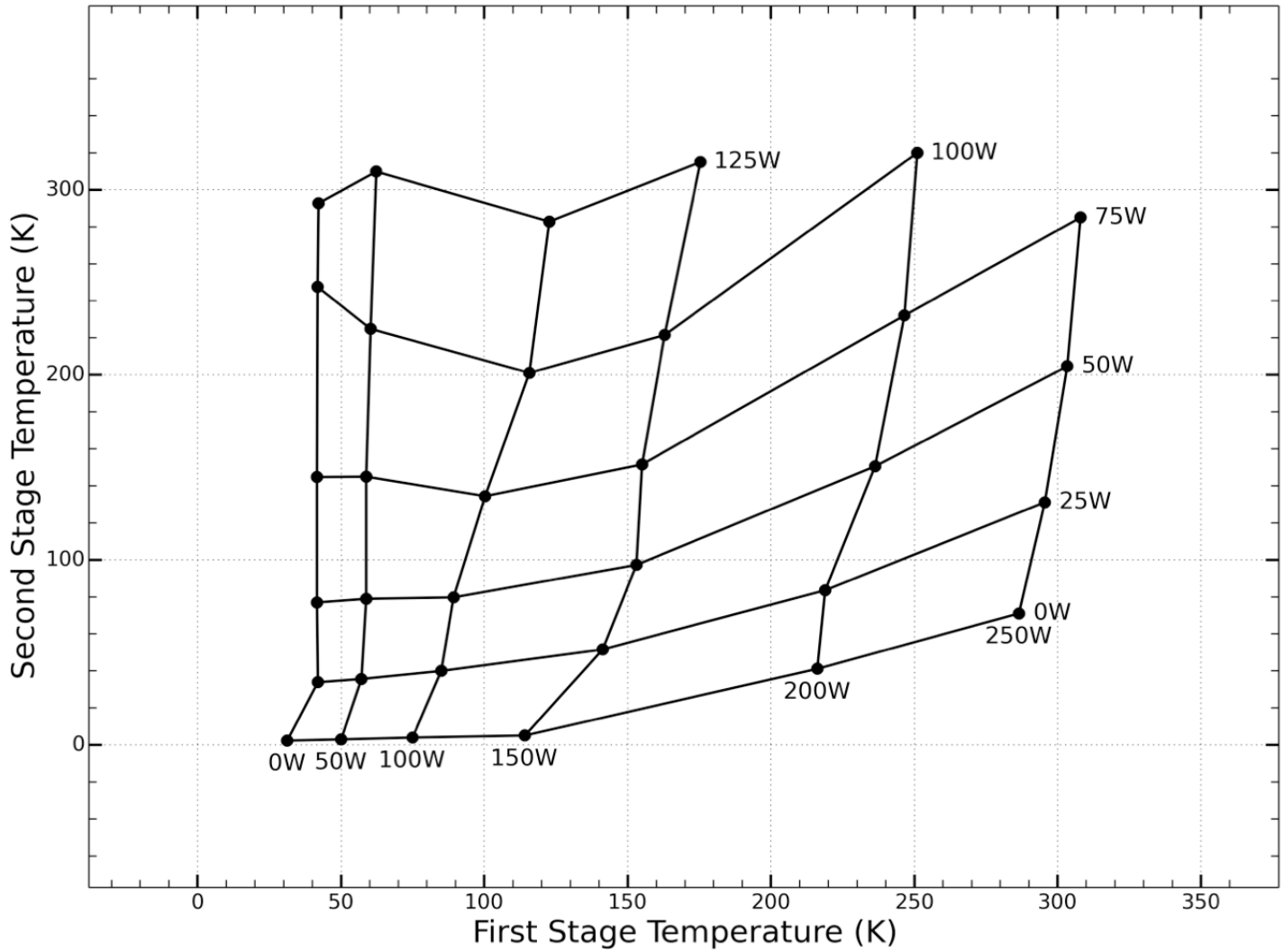
PT415 2nd stage Cooing in an extended Range



- This is an important range of temperatures when cooling-down a magnet.
- Note the temperature of the 1st stage can be lower than the temperature of the 2nd stage. This inversion occurs frequently when a magnet is cooled down from room temperature to below 35 K

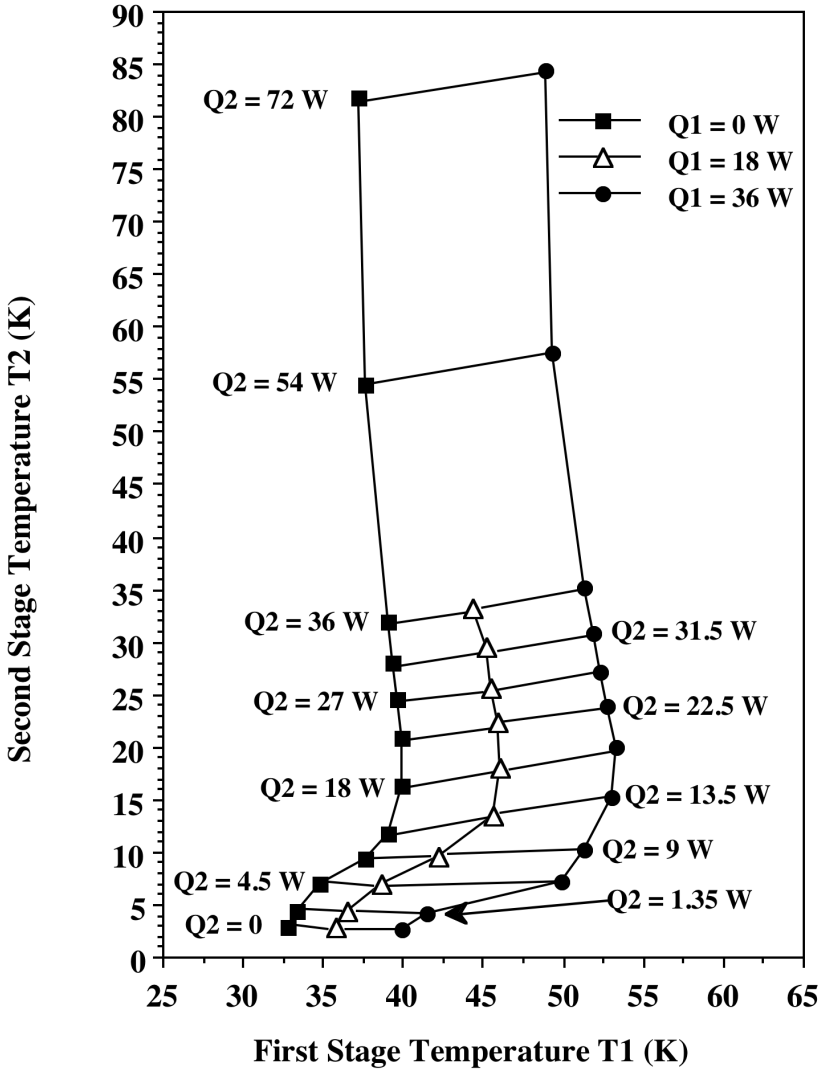
Data taken at Cryomech June 2015

PT415 Cooing over the full range both stages

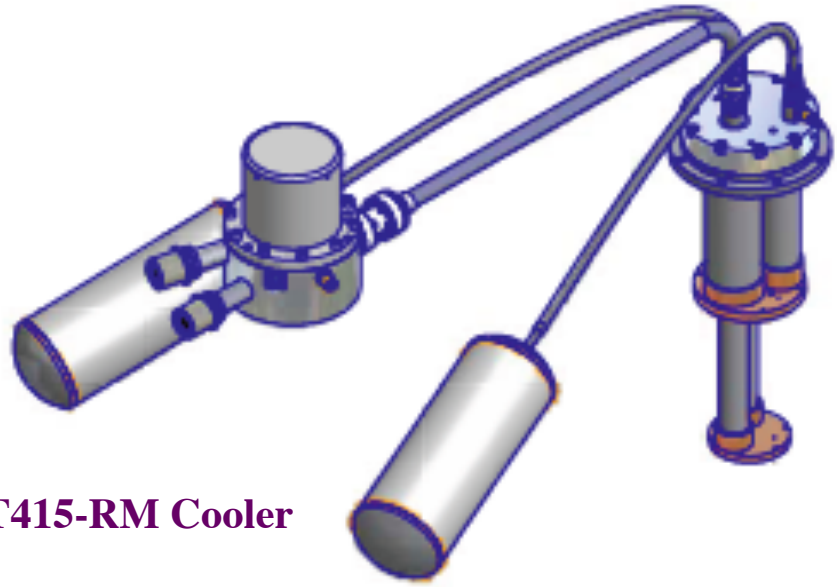


Data taken at Cryomech in 2006

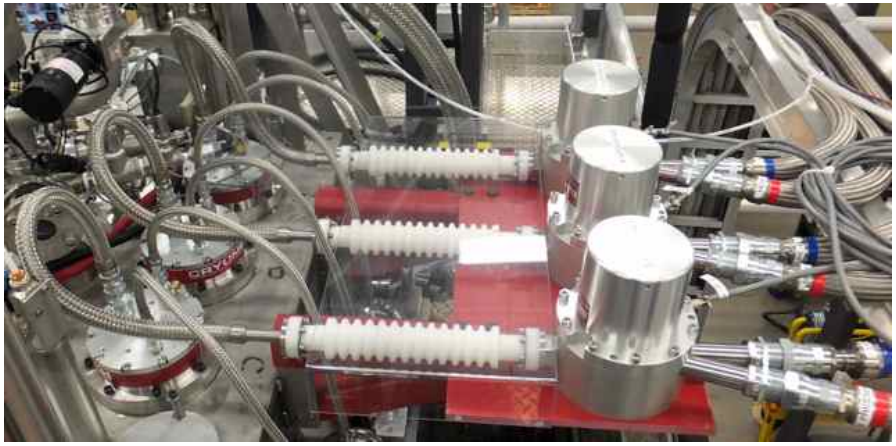
Cooling Parameters for a PT415-RM Cooler



PT415-RM Cooler Extended Performance



PT415-RM Cooler



Three PT415-RM Coolers at MSU

Some Conclusions

- **The performance of a PT415 cooler is different from its cousin the PT410 cooler. The differences are primarily in the higher temperature part of the cool-down spectrum.**
- **The FSU measurements appear to be quite good when compared to other people's measurements of the PT415 cooler.**
- **There is enough data to predict how the PT415 cooler will behave as a hydrogen cooler.**
- **The extended curves up to 90 K on the 2^{nd} stage are a good predictor of cooler performance when cooling-down a superconducting magnet**