

Tests of Four PT415 Coolers and the Lead Test with a Cooler

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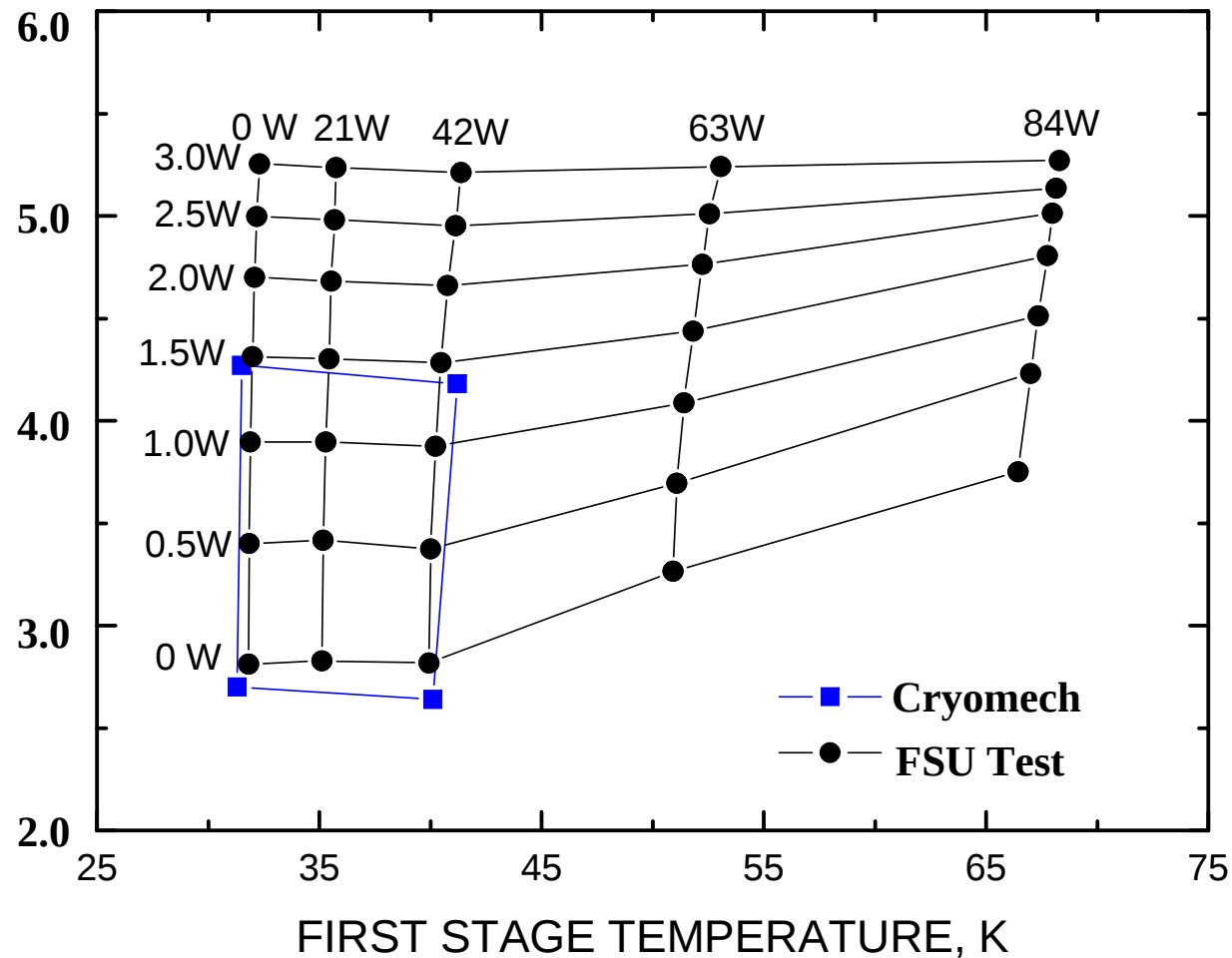
LBL Cooler Measured Performance by Cryomech

	Cooler	1 st Stage Q1 (W)	1 st Stage T1 (K)	2 nd Stage Q2 (W)	2 nd Stage T2 (K)
Charge P = 16.8 bars	A	0	29.5	0	2.50
		0	31.8	1.5	4.15
		60.0	45.0	0	2.30
		59.0	45.0	1.5	3.90
Charge P = 14.0 bars	B	0	28.0	0	2.30
		0	28.5	1.5	4.29
		42.4	42.3	0	2.35
		42.4	44.3	1.5	4.05
Charge P = 16.8 bars	C	0	31.8	0	2.50
		0	32.2	1.5	3.95
		48.8	45.0	0	2.55
		44.3	45.0	1.5	3.90
Charge P = 16.8 bars	D	0	31.3	0	2.86
		0	31.8	1.5	4.25
		42.5	41.8	0	2.78
		42.5	43.2	1.5	4.15

Extended PT-415 Cooler Performance

2nd Stage T (K)

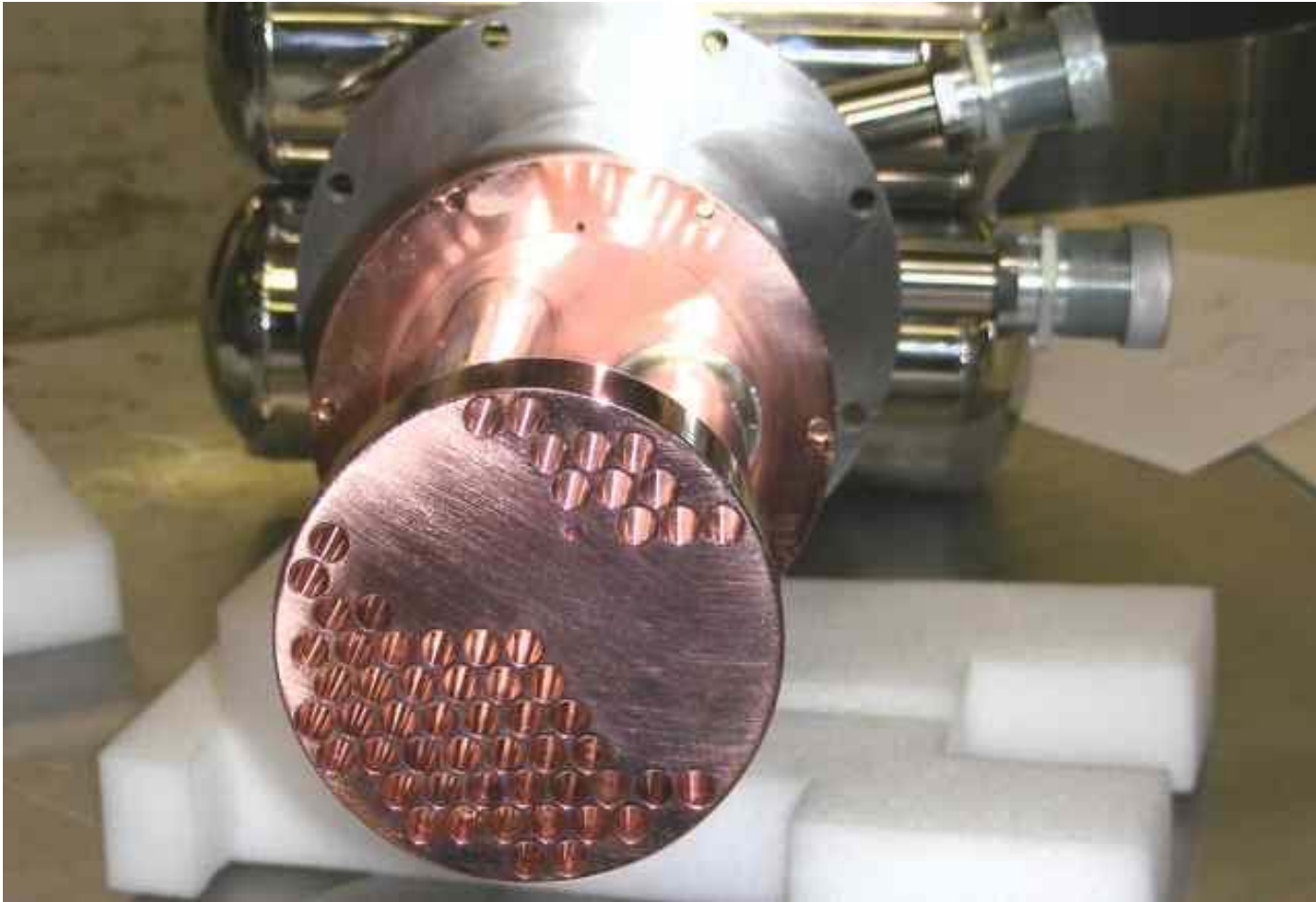
Experimental data from FSU and Cryomech



Cooler Experiment's Original Purpose

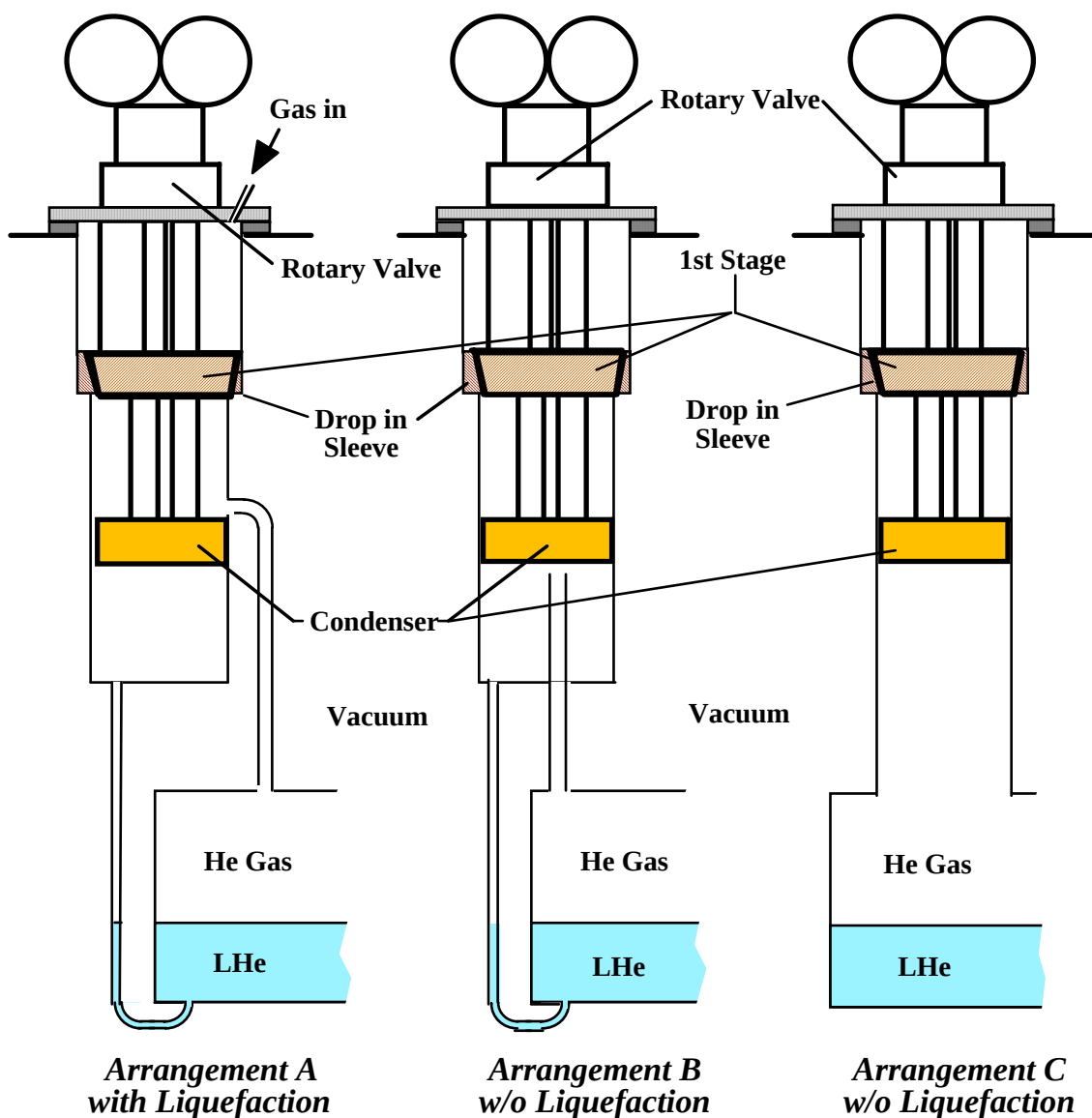
- Confirm that the PT-415 cooler will work as a re-condenser in the drop in configuration. Measure the extra heat leak that comes from this method of mounting the cooler in this way.
- Measure the performance of the PT-415 cooler in the magnet configuration over a temperature range from about 3 K to about 5 K.
- To measure the ΔT across the joint that connects the shield to the cooler first stage.
- Demonstrate that the PT-415 cooler will liquefy helium.

PT415 Cooler Condenser on LBL Coolers



The simple condenser above has a vertical area of 0.042 m².

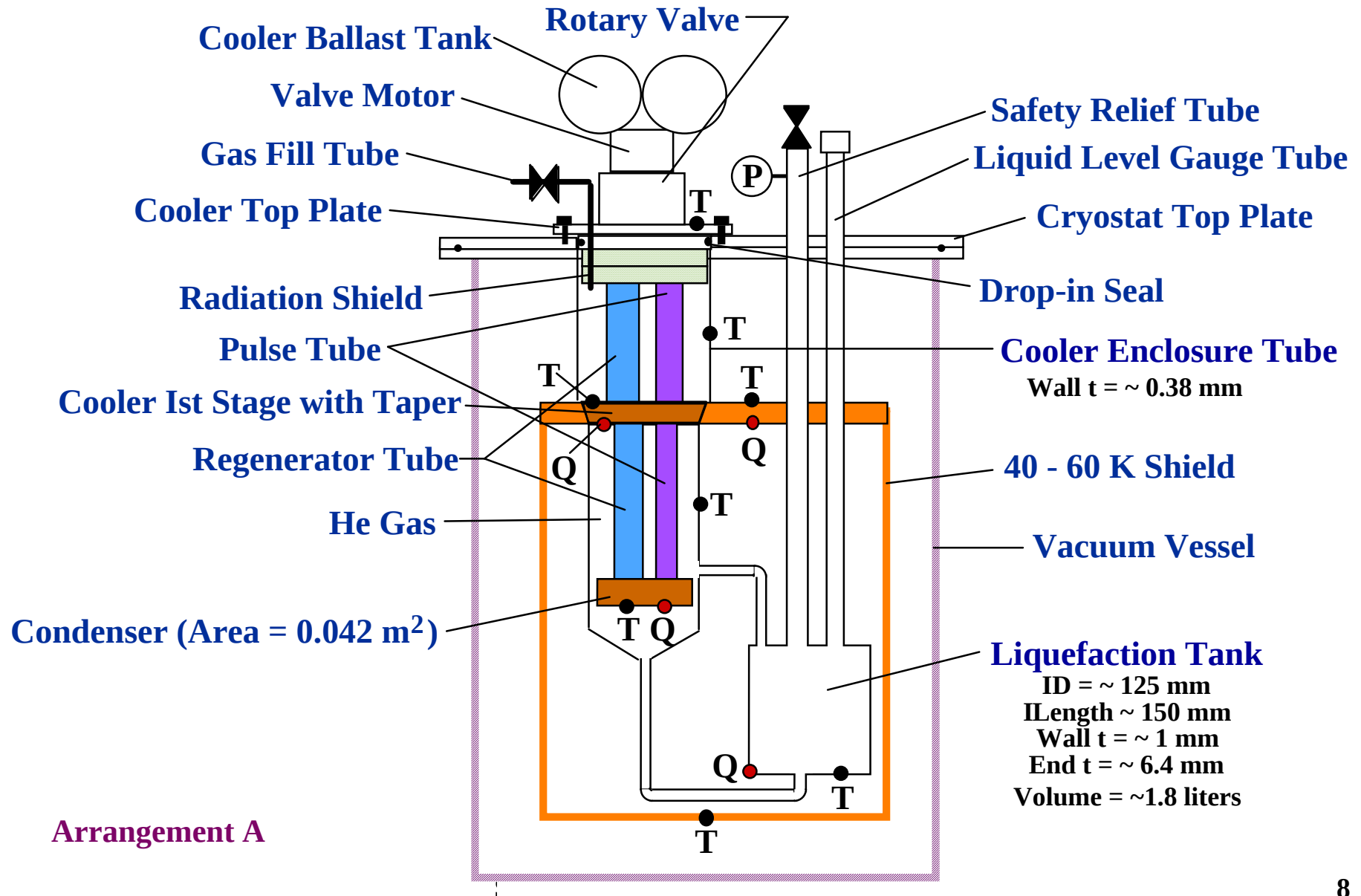
Three PT415 Cooler Experiment Configurations



1st Cooler Test with Arrangement A

Arrangement A is theoretically the best way to cool a magnet. This configuration permits the cooler to cool down the cold mass, and it also permits helium liquefaction. We intended to use this configuration on the magnets.

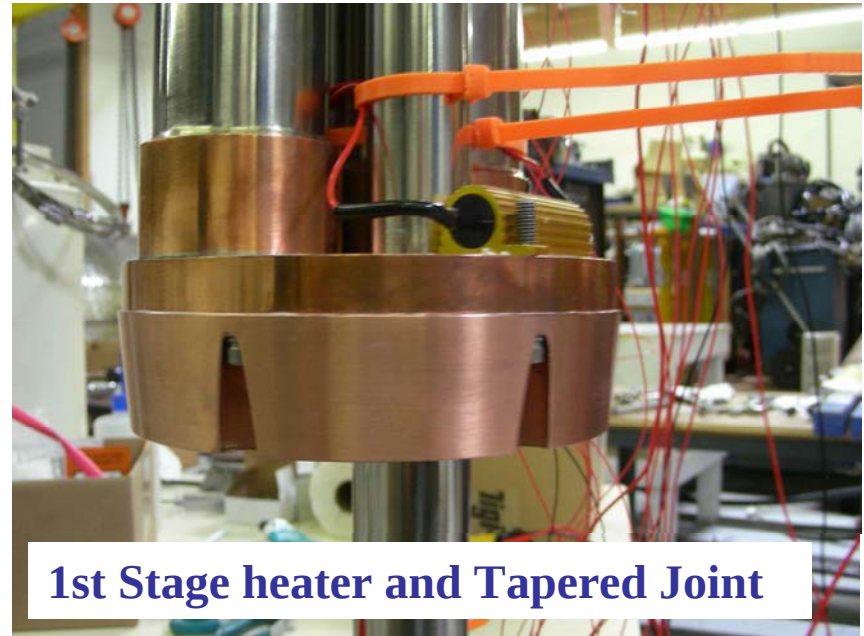
First Cooler Experiment Schematic



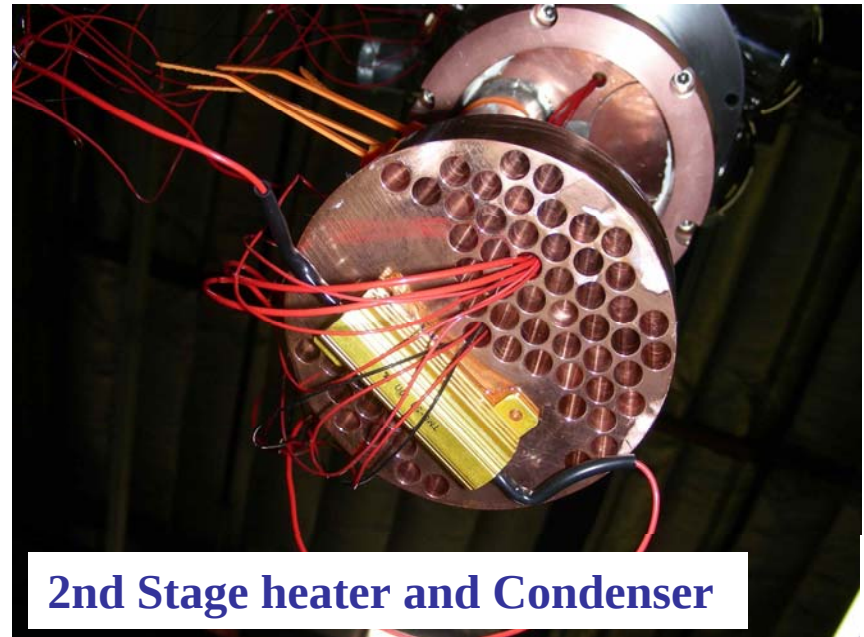
First PT-415 Drop-in Cooler Test Photos 1



PT-415 Drop-in Cooler



1st Stage heater and Tapered Joint



2nd Stage heater and Condenser

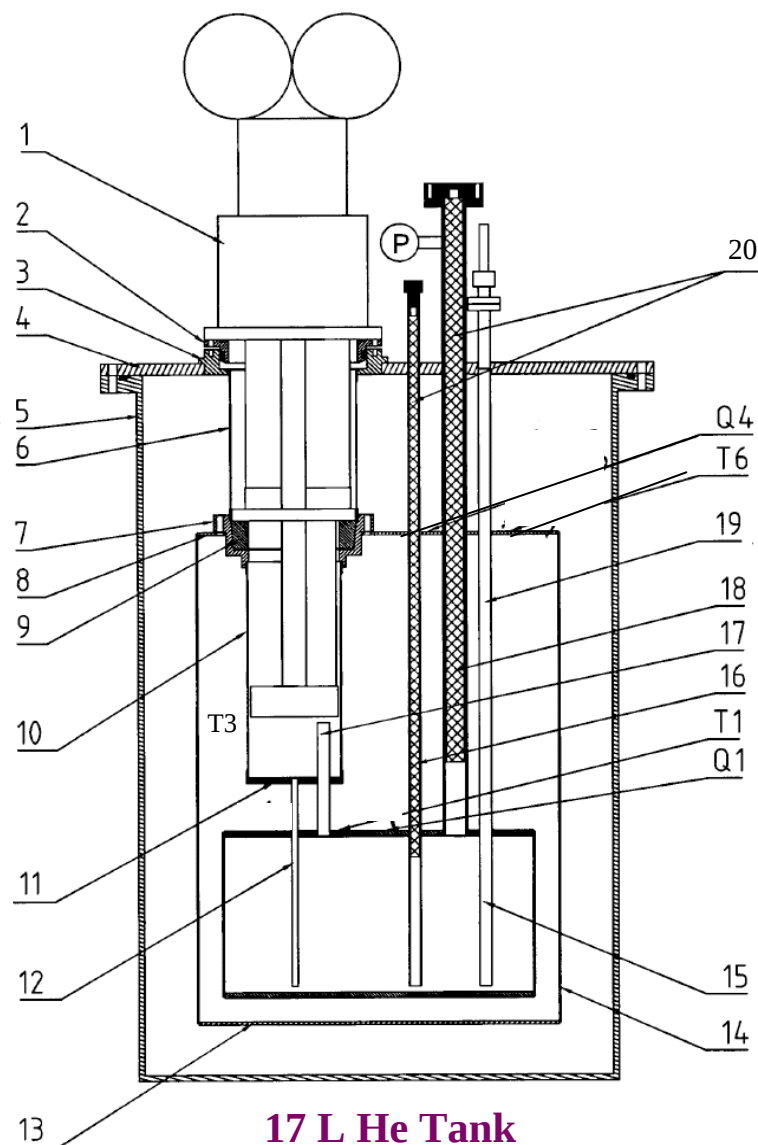
Results from the First Cooler Test

- Helium liquefaction (up to 0.25 L/hr) from 300 K gas was demonstrated. This was done without a heat exchanger on the first stage of the cooler.
- Helium re-condensation was demonstrated with the liquid cryostat half full for heat loads up to 0.6 W. The 2nd-stage heat leak was ~ 0.9 W versus an expected 0.2 W.
- The first-stage heat leak appeared to be excessive (~ 8 W versus a calculated 2 W).
- All of the temperatures measured by the Cernox sensors were incorrect.

2nd Cooler Test with Arrangement B

Arrangement B was the cooler arrangement used for Magnet 1. This arrangement was easier to manufacture, and it was less subject to damage during installation.

Second Cooler Experiment Test Setup



- 1.PT415 Cooler
- 2.Cooler Adaptor
- 3.300 K Sleeve Flange
- 4.Cryostat Top Plate
- 5.Cryostat Vacuum Vessel
- 6.Cooler Sleeve-1
- 7.Copper Sleeve Flange
- 8.Copper 60 K Shield Top Plate
- 9.First Stage Adaptor
- 10.Cooler Sleeve-2
- 11.Cooler Sleeve-2 Bottom Plate
- 12.Liquid Helium Tube to Tank
- 13.Copper 60 K Bottom Plate
- 14.Copper 60 K Enclosure Tube
- 15.4.2 Liquid Helium Can
- 16.Helium Gas Tube to Condenser
- 17.Helium Vent Tube to 300 K
- 18.Liquid Helium Fill Tube
- 19.Liquid Level Gauge Tube
- 20.Thermal Acoustic Oscillation Plug

Q1 and Q4 are Heaters, T1, T3 and T6 are Temperature Sensors.

The thermal acoustic oscillation plugs were used during some of the tests. It was clear that thermal acoustic oscillations were a problem at times during the tests. The temperature sensor on the helium can was moved to various positions on the helium can.

Arrangement B

Results of the Second Experiment

- Three radiation shields were put between the cooler 1st and 2nd stages. The shields didn't help or hinder re-condensation.
- Conductive grease was put on the tapered copper part on 1st stage to reduce ΔT between the shield and the cooler 1st stage. The grease reduced the ΔT to the 1st stage of the cooler.
- The first time the experiment was run, there was an added heat leak. A thermal acoustic oscillation plug was installed. As a result, four PT-415 coolers were tested successfully, with re-condensation with ~ 1.3 W put onto the helium tank.

Some Test Results on One Cooler with Grease

Cooler	2 nd Stage Q (W)	2 nd Stage T (K)	1 st Stage Q (W)	1 st Stage T (K)
B	0.4	3.46	0	31.5
B	0.4	3.44	55	56.7
B	1.10	3.99	55	56.9
B	1.15	4.01	55	56.9
B	1.20	4.04	55	56.9
B	1.25	4.11	55	57.1



From He Vapor Pressure

From Pt Resistance
Sensor

2nd Stage Condenser

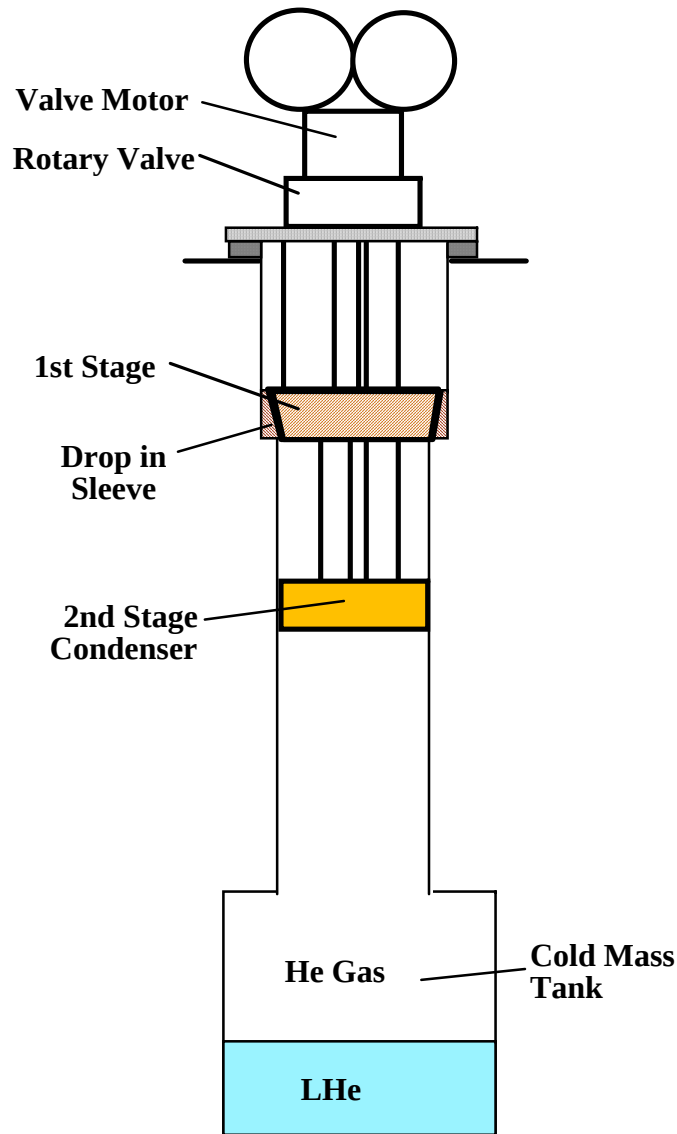
MLI Shield Plate

Conducting Grease to Reduce ΔT

3rd Cooler Test with Arrangement C

Arrangement C avoids the trap that resulted in the helium pipe blockage that prevented helium circulation to the cold mass in the first magnet. This cooling configuration is used on MRI magnets.

Cooler Arrangement for the 3rd Test



Arrangement C

This test was driven by the problems with magnet 1. This arrangement eliminates the trap that can become clogged with dirt and ice.

The helium condenser is inside of a 120 mm diameter tube that feeds liquid helium directly into the helium tank. The He gas comes from the manifold up the wall of the 120 mm tube to the condenser.

A temperature sensors was installed on the 1st stage of the cooler to measure ΔT across the joint.

Results of the Third Cooler Test

- For the first time a direct measurement of the ΔT across the joint was made. The measured ΔT across the joint was 0.5 K, when there was high conductivity grease in the joint and the heat transferred across the joint was 50 W. When there was no grease in the joint the ΔT was about 3 K for the same heat load.
- The measurements were made with only one cooler, but this allowed the vendor to make the modifications to magnet 2.

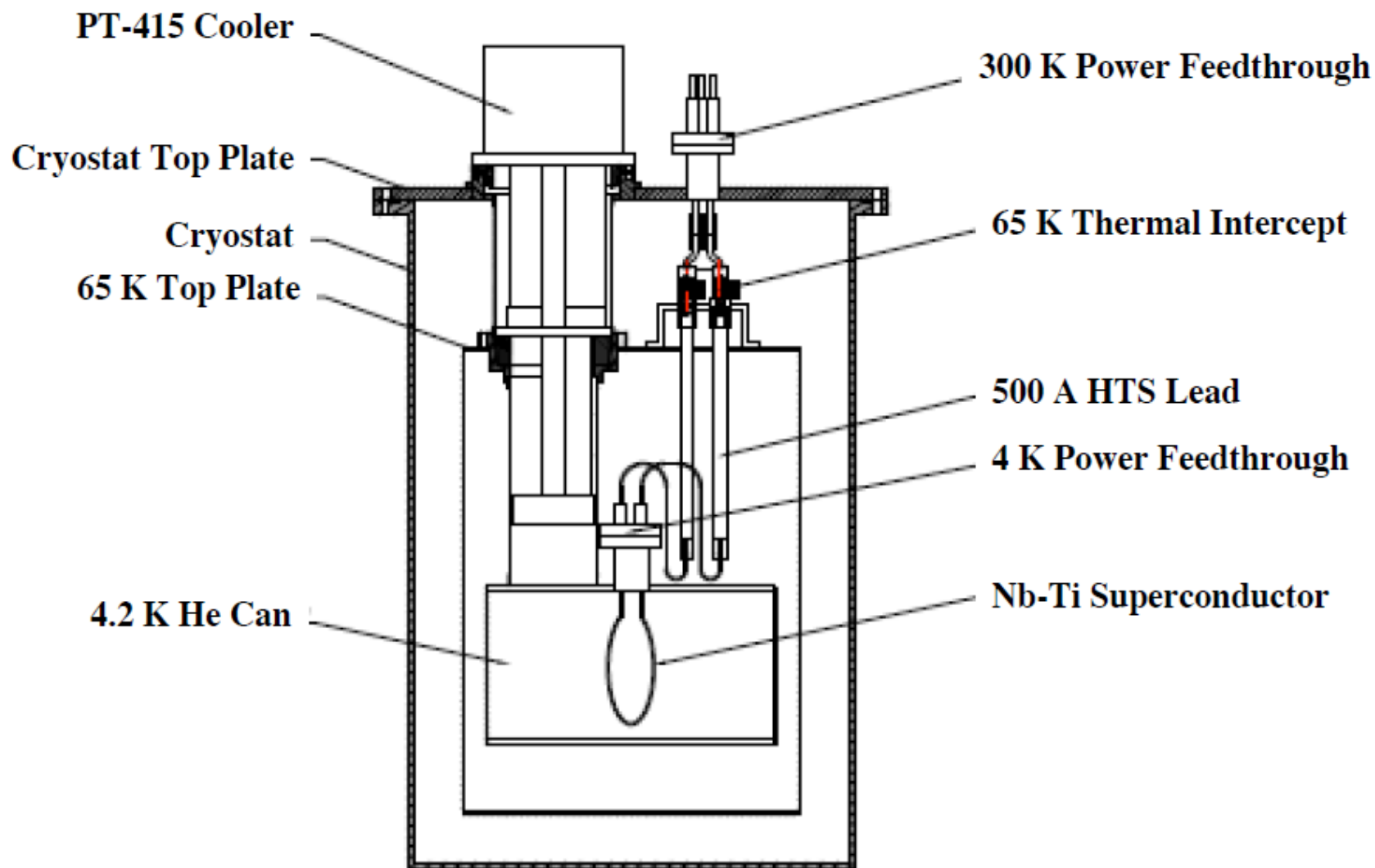
Cooler and Lead Test

This test uses arrangement C. The test will measure the heat leak down the Cu leads directly. In addition, the test will provide more information about the ΔT across the joint between the first stage and the shield ring.

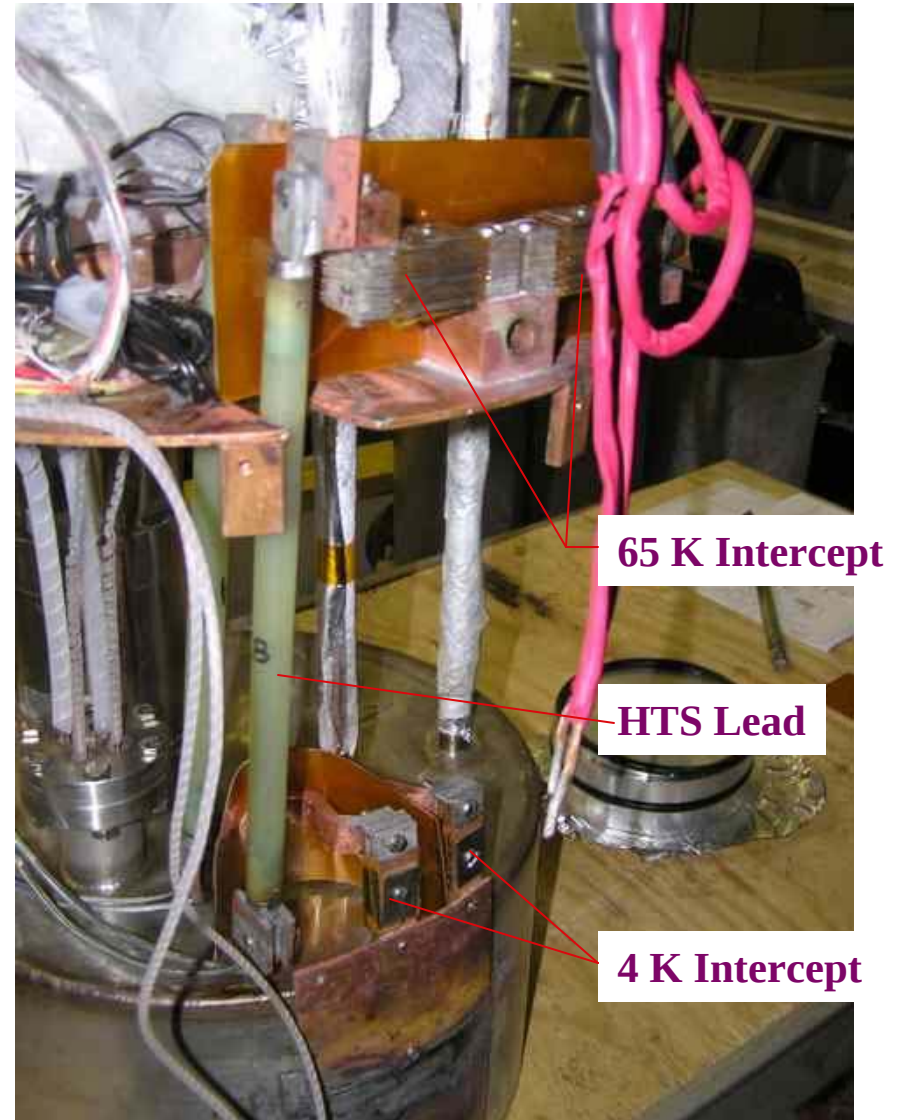
Purpose of the Lead and Cooler Test

- The primary purpose of the test is to measure the heat flow through the Cu leads that are connected to 500 A HTS leads. The heat flow will be measured for currents from 0 to 300 A. The voltage drop across the copper lead will also be measured.
- In addition there will be further measurements of the ΔT from the shield ring to the cooler first stage. The cooler should be removed and reinstalled a couple of times to find out how reliable the joint is.
- A measurement of the ΔT across the 65 K thermal intercept will also be done.

Schematic of the Cooler and Lead Test



Photos of the Lead Test with a Cooler



Cooler Test Observations to Date

- Once thermal acoustic heat leaks were eliminated, the coolers had no trouble re-condensing the helium boil off gas at ~ 1.3 W at 1.1 bar.
- The conductive grease reduced the ΔT between the shield and the 1st stage. The grease makes it difficult to remove the cooler while things are cold, but we won't remove the cooler while it is cold.
- Since ΔT is proportional to the heat going into the shield, we should work hard to reduce the 1st stage heat loads.