Quantum Design International

SMART ENERGY CRYO-REFRIGERATOR TECHNOLOGY FOR THE NEXT GENERATION VERY LARGE ARRAY

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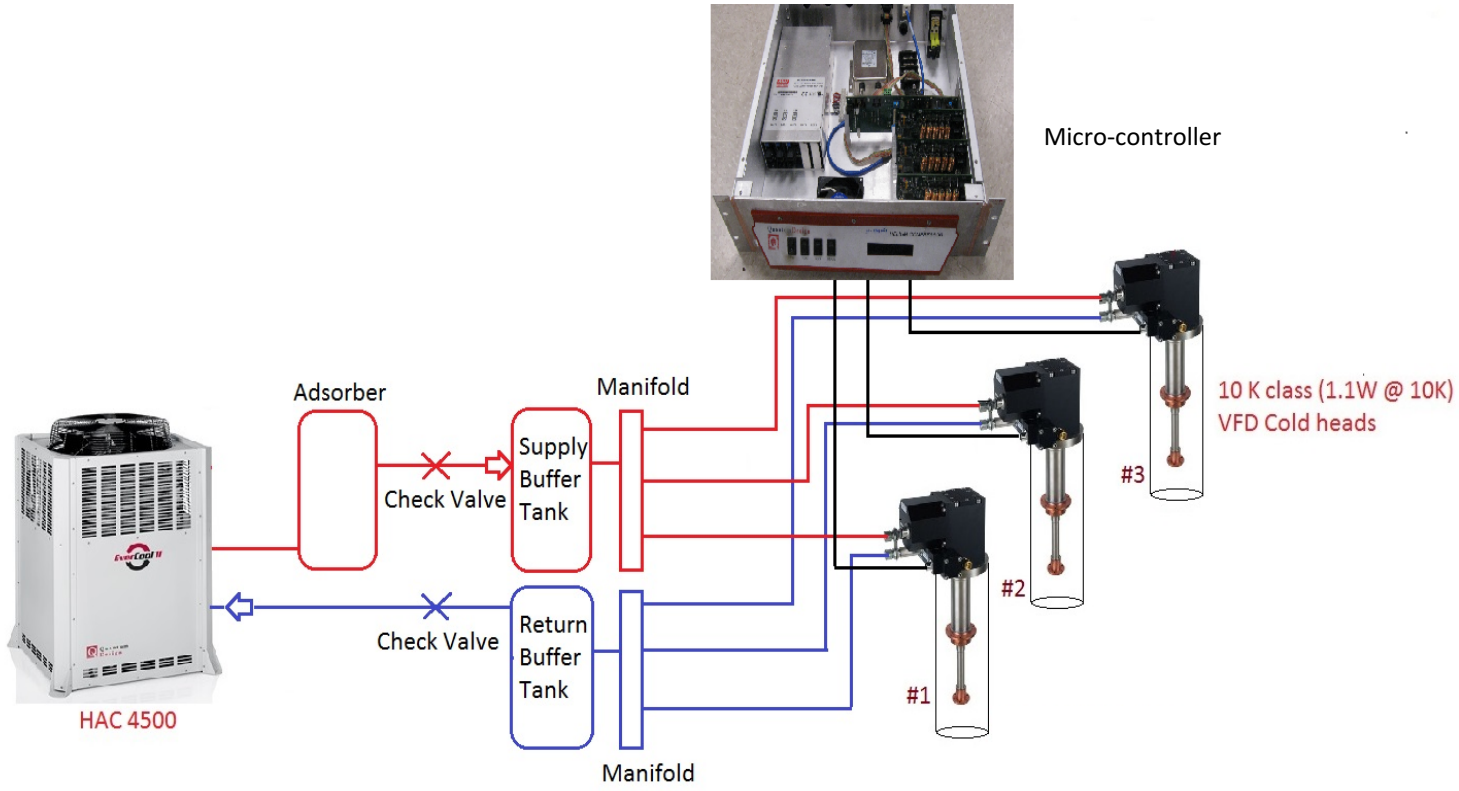
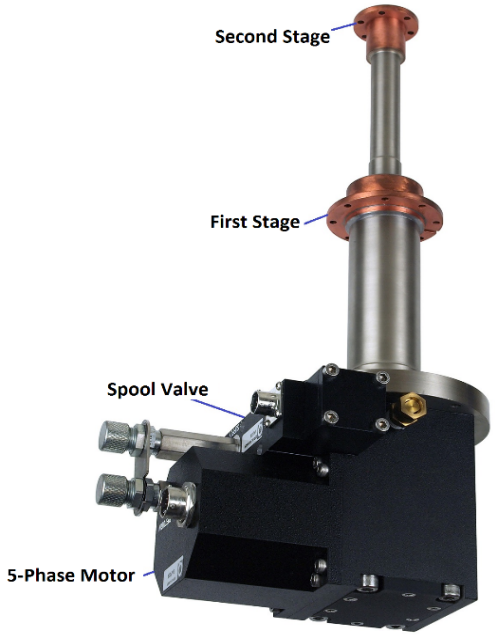
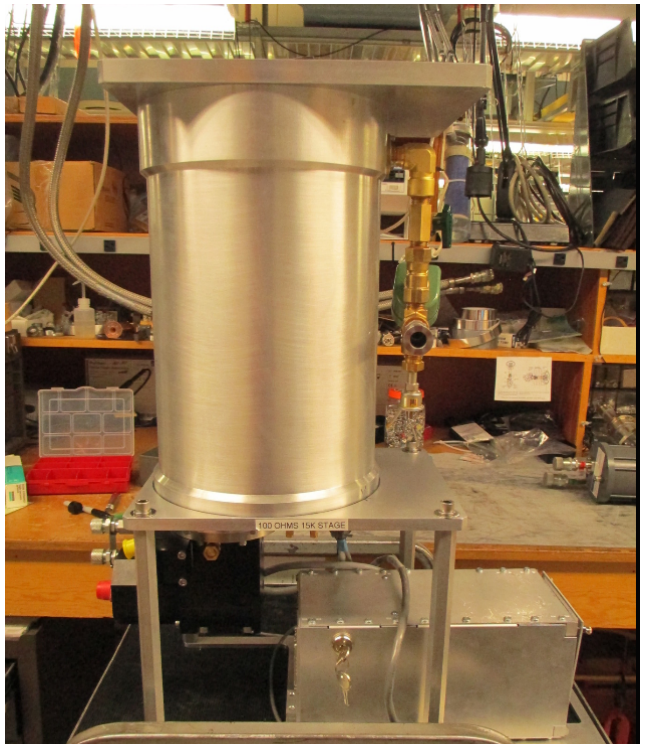
Overview of proposed architecture for the ngVLA



GD-1 cryo-refrigerator





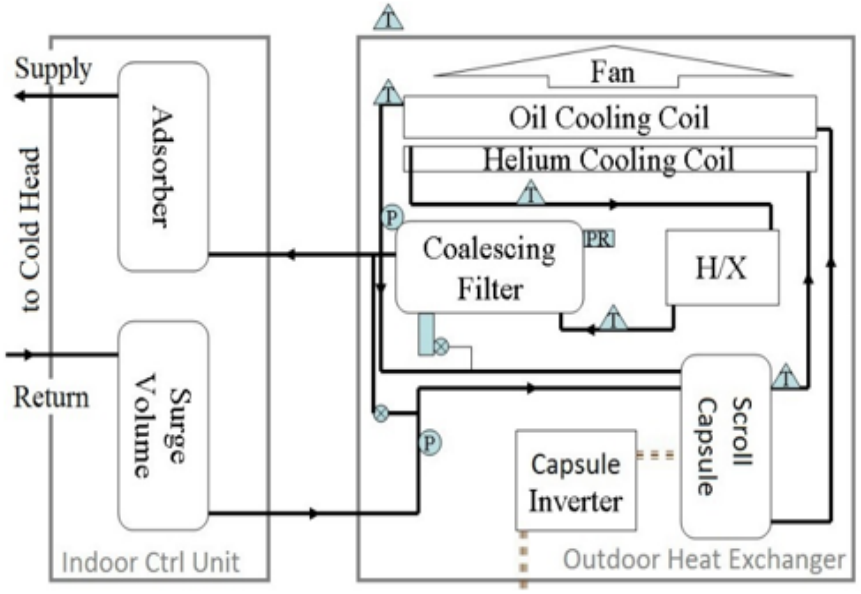
GD-1 mounted in test receiver vessel

- 2nd Stage Cooling Power: 1.1W at 10K
- 1st Stage Cooling Power: 4W at 40K
- Variable Speed: “On demand” cooling power
- Independent spool valve: heating and cooling with no heaters
- Reduced Vibration

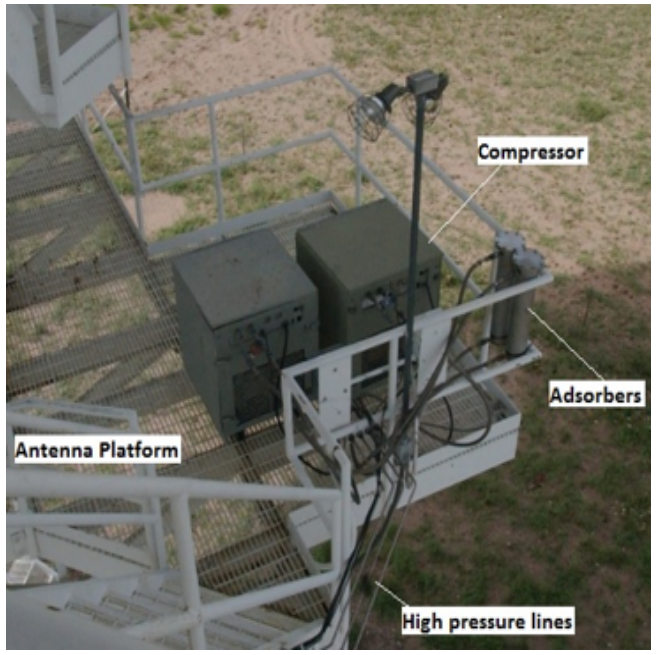
HAC 4500-LV Helium Compressor

- 200-240 VAC 3 Phase Power (50/60Hz) Input
- Variable Speed: “On demand” cooling power 2 to 8 kW real power draw
- Outdoor rated: -30 to 45 degrees C
- Environmental Coating
- “Cold Start” mode
- Integrated refrigerator for additional cooling of helium in hot weather

HAC 4500 Helium Compressor

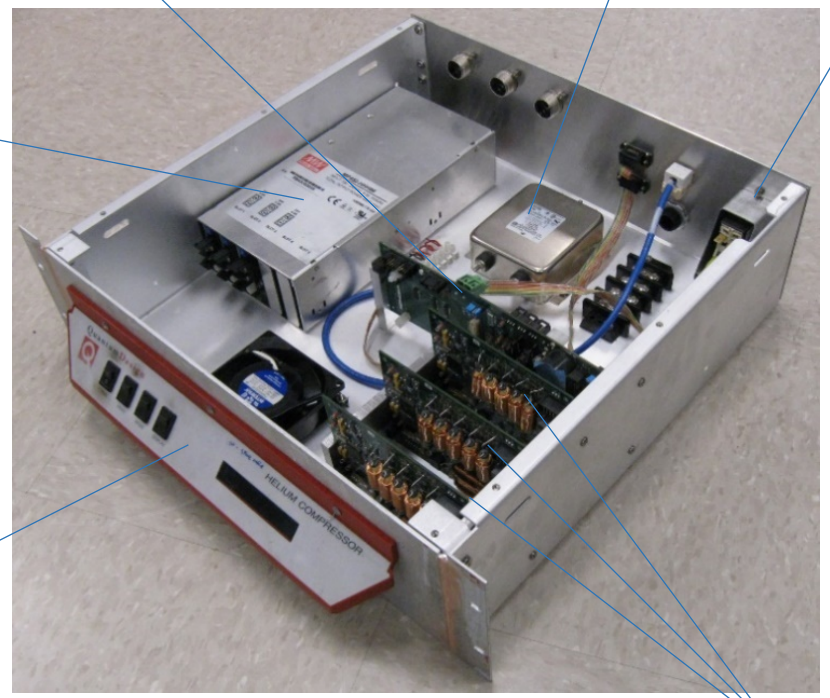


Schematic of the HAC 4500 (left). Captions T=Thermistor, P=Pressure Sensor, PR= Pressure Relief Valve, H/X Heat Exchanger.



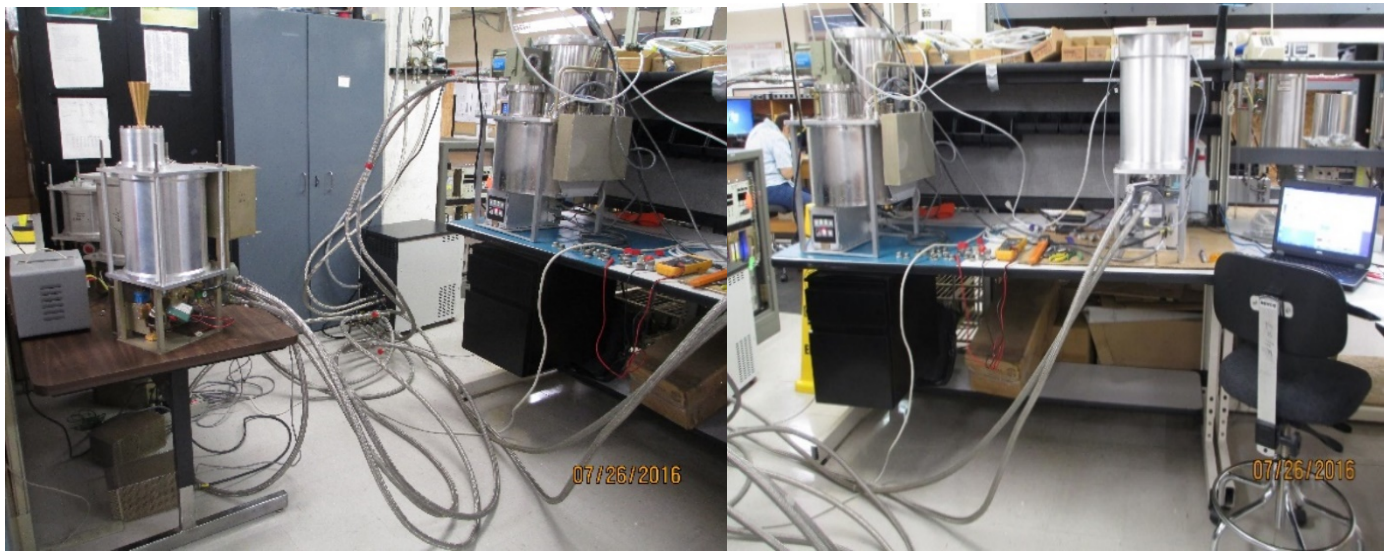
Current compressor location and configuration at the Karl Jansky Very Large Array (VLA) in New Mexico, USA.

Micro-controller



- 200-240 VAC 1 Phase Power (50/60Hz) Input with integrated breaker
- Standard 19” rack mount enclosure
- Multiple control interface options: CAN/CANOpen, Modbus (RS485) and RS2232
- Front Panel Control mode

Receivers connected to the indoor unit of the HAC 4500-LV compressor

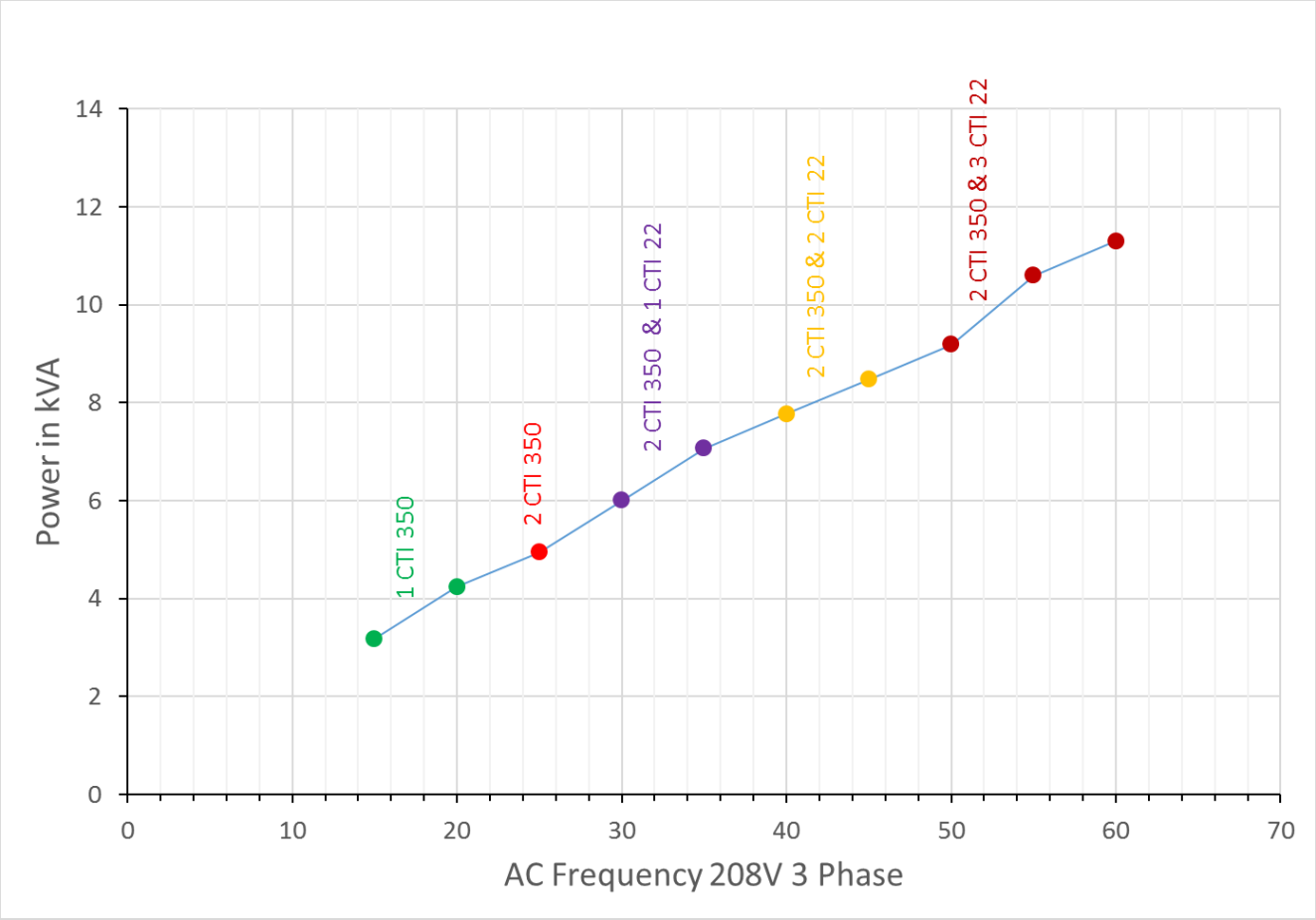


HAC 4500-LV Compressor connected to multiple receivers

- HAC-LV 4500 tested with CTI 350 and CTI 215 refrigerators
- 2nd stage temperatures remained ~20K down to reduced speed of 40Hz capsule speed

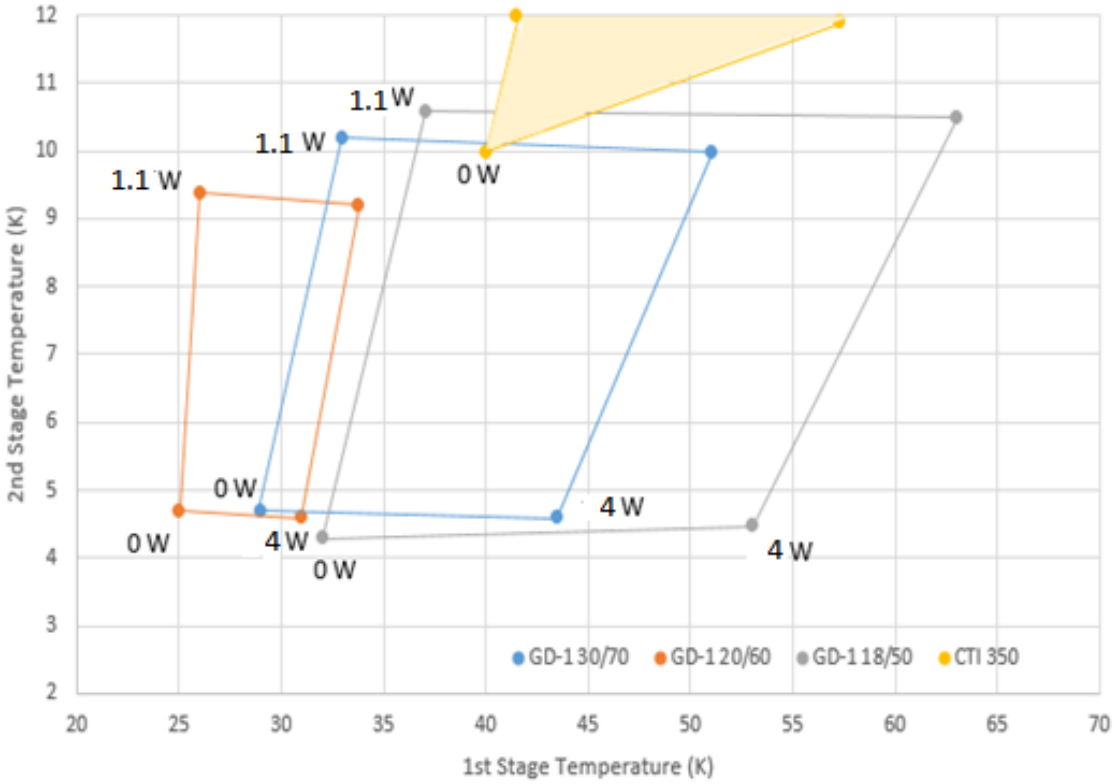
			Test Dewar		VLA S band		VLBA C band		VLBA 8 to 8.8GHz		VLBA Q band	
Frequency (Hz)	Supply Pressure (MPa)	Return Pressure (MPa)	2nd Stage	1st Stage	2nd Stage	1st Stage	2nd Stage	1st Stage	2nd Stage	1st Stage	2nd Stage	1st Stage
60	2.11	0.77	9.5	51.1	15	75.1	15.7	61.1	21.1	64.1	17.5	60.2
55	2.24	0.72	9.3	51.1	17.3	73.9	16.3	62.3	20.5	66.1	19.9	62
50	2.29	0.68	9.4	53.7	17.6	76.4	16.9	63.5	22.9	62.5	20.7	64.9
45	2.32	0.65	9.9	55	18.1	78.8	18.4	66	27.9	65.4	22	65.9
40	2.35	0.61	10.5	57.5	19.2	81.3	20.1	67.9	23.8	70.8	23.8	67.8

Power study



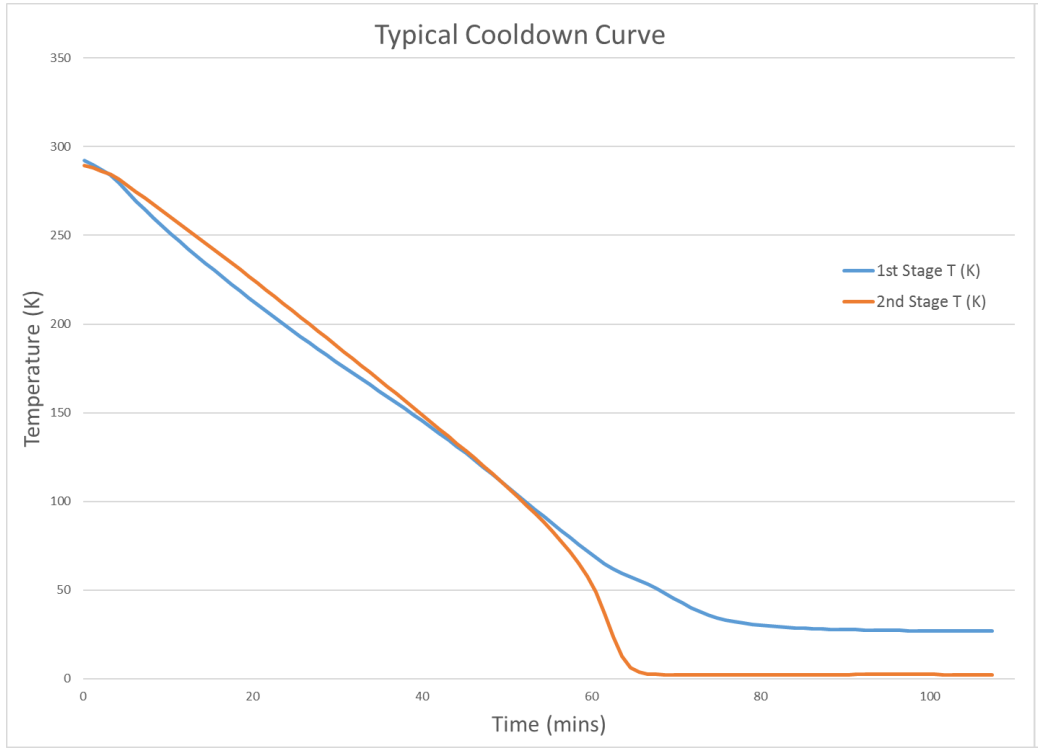
- Lower power mode for 1-2 cold heads or “stand-by” mode – electronics at 30K
- Medium power mode for 3-4 cold heads for intermediate loads – electronics at 20K
- High power mode for 5+ cold heads or “cool down” mode
- Warm up mode

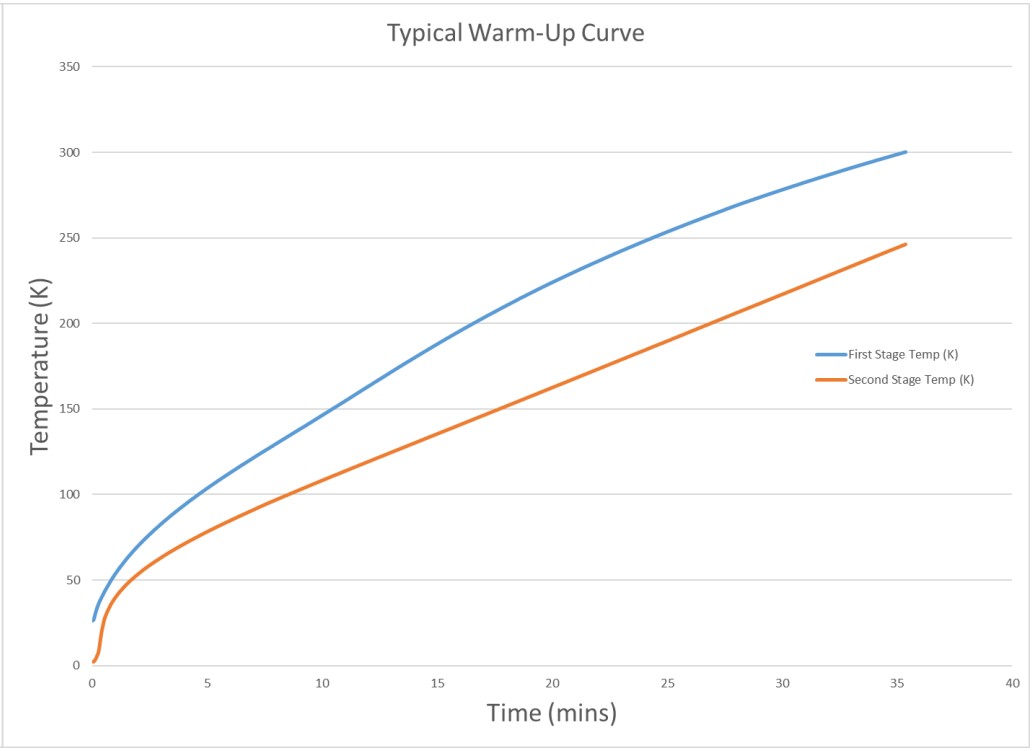
GD-1 Variable speed features



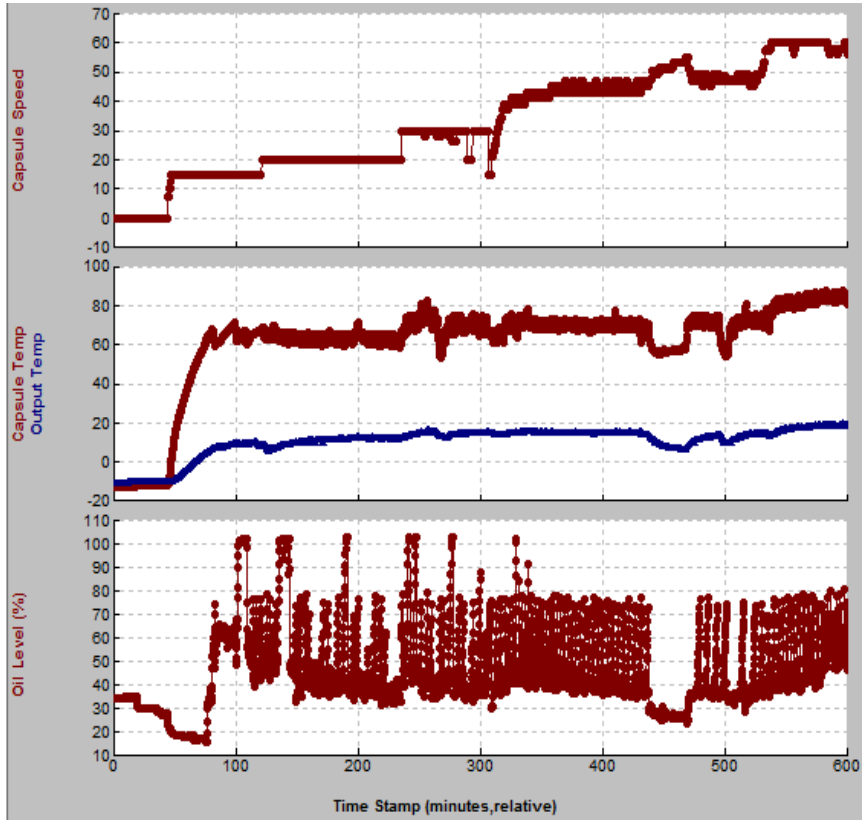
- 9 to 11K 2nd stage temperature with 1.1W heat load
- 30K to 60K 1st stage temperature with 4W head load
- Phase delay allows rapid warmup and possible temperature control without heaters

GD-1 cool down and warm up



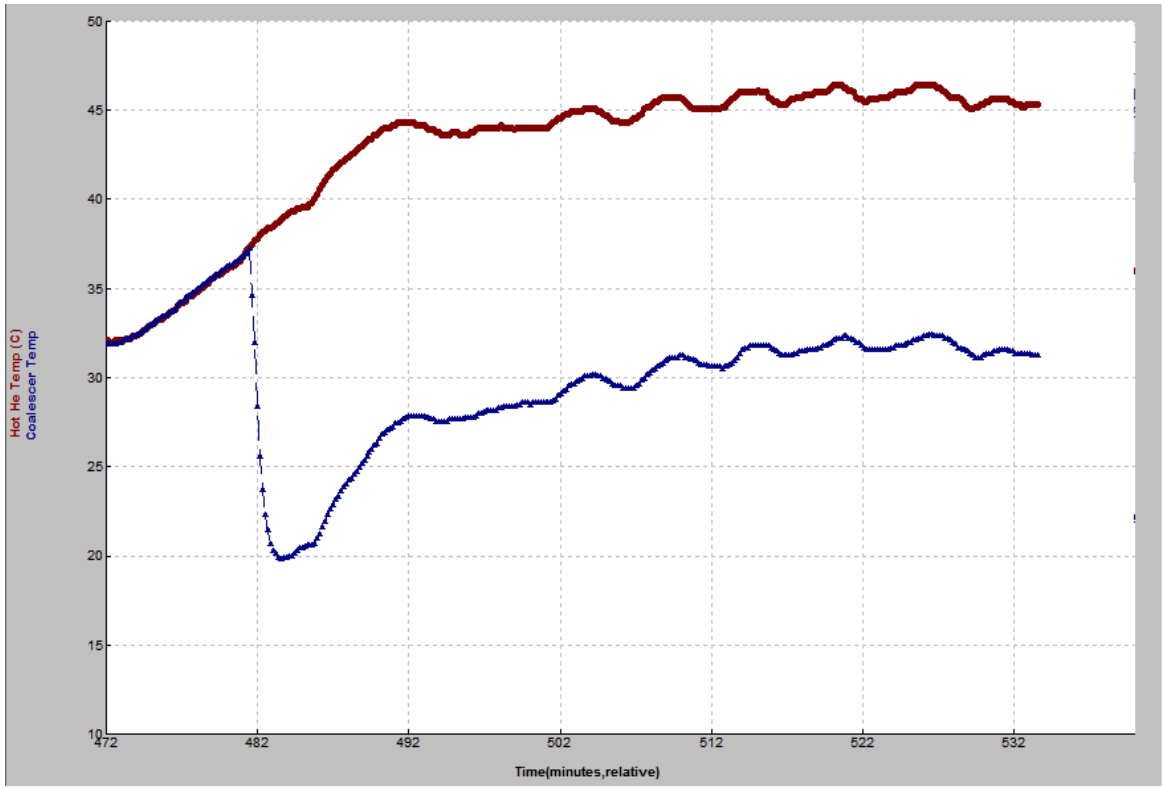


Slow start



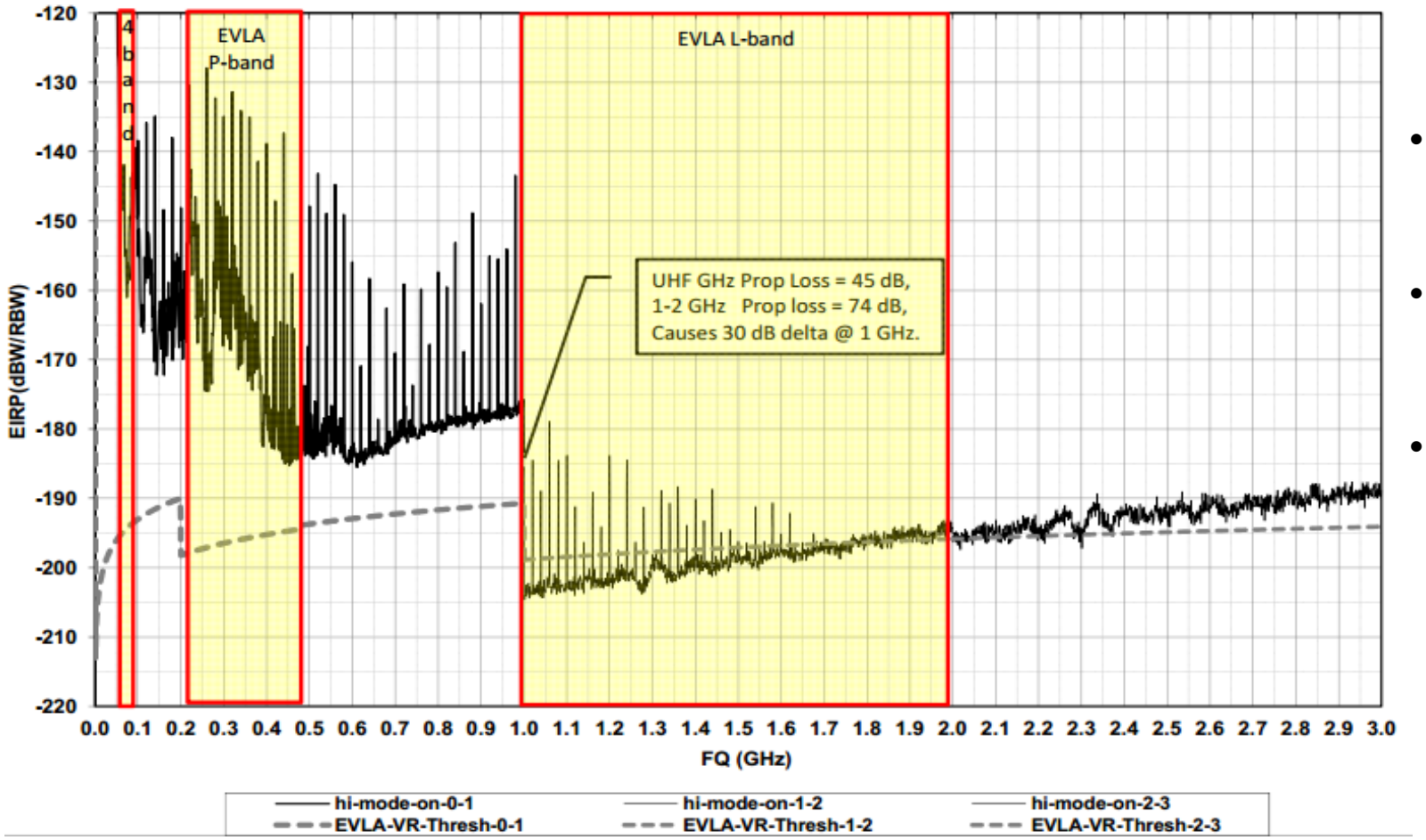
- A slow ramp from 15 to 60 Hz capsule allows oil to warm up gradually
- Oil circulation monitored with a capacitive level sensor
- No external heaters needed

Extended Ambient Temperature Range



- Integrated refrigeration system (R134a) to cool helium to head to <35° C
- Adapting code reduces capsule speed for operation above 45° C
- Also adapts for max supply and min return pressures and electronics bay temperature

RFI



- Radiated emissions of HAC 4500 (shown) and HAC 900-GD1 tested in RF Chamber
- Peaks as much as 60dB above threshold in P-band and 20dB in the L-band.
- Need shielding to reduce noise on HAC4500 <1.5GHz and GD1 <3.0 GHz

Conclusions

- Initial feasibility studies have shown promising results for QD cryo-refrigerator technology with the ngVLA
- Variable speed technology offers significant power savings over older technology
- Compressor is ruggedized for extreme operating conditions
- Further effort needed to better shield the control and drive electronics to meet emissions requirements