

Low Cost, Low Temperature ~~Lab~~ Shop Testing

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Need

- South Pole field trial of WT10 wind turbine for IRIS / PASSCAL
 - -83°C to -12°C
 - APRS World WT10 wind turbine
 - bearings, seals & cables
 - Web Camera
 - operation
 - Instrumentation
 - operation and accuracy

Traditional Approaches: Thermal Chamber

Pros

- Fast
- Accurate
- Able to thermal shock DUT

Cons

- Expensive
- Fragile



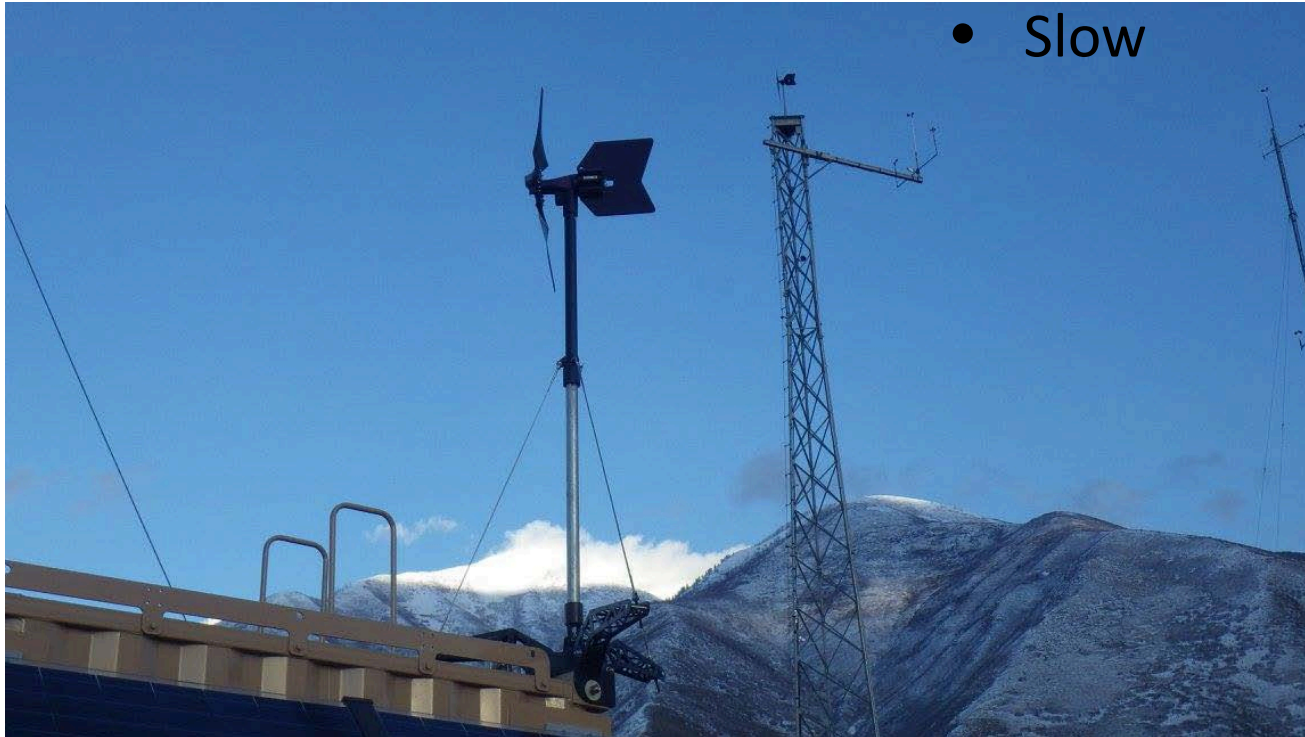
Traditional Approaches: Field Testing

Pros

- Actual conditions

Cons

- Unpredictable
- Expensive
- Slow



Traditional Approaches: Immersion (dry ice / acetone)

Pros

- Easy
- Available
- Right temperature: -78°C

Cons

- Liquid
- Solvent compatibility
- Very fast – thermal shocks



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Idea: Ultra Freezer



- Two common ranges:
 - -40°C and -85°C
- Expensive new (\$20k)
- Cheap and plentiful used (\$1k)
- 120V @ 20A or 240V @ 15A – easy!

Ultra Freezer Pitfalls

- Often sold because they have problems
- Compressors and refrigerant are expensive
- Cascade system means that problem anywhere in system will require multiple compressors and refrigerant charges

Getting Colder: Liquid CO₂

- Sublimation point: -78.5°C
- Cheap: \$0.08 per pound
- Off the shelf controllers
- Readily available



APRS World's freezers

- Original -85°C worked for a few hours, then died
- Only -40°C freezers available given time and price constraints

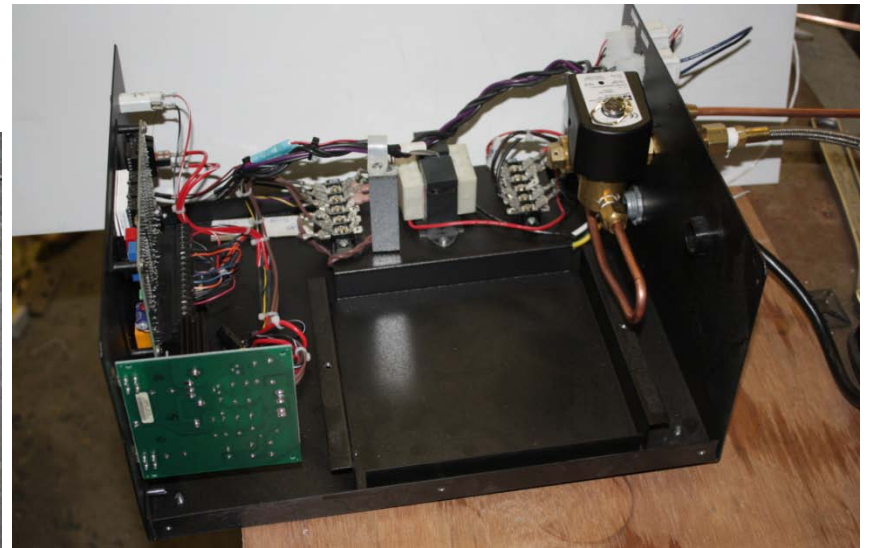
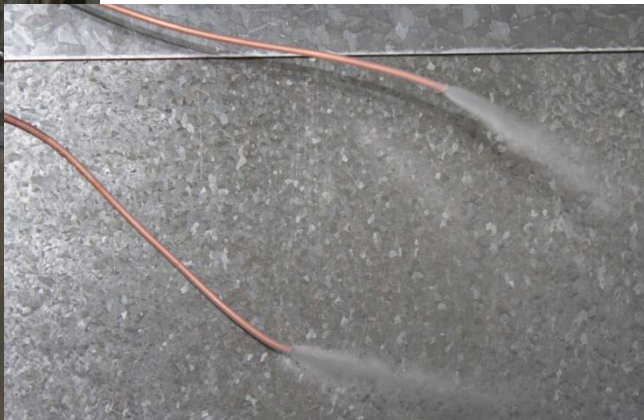
APRS World's Freezer Modifications



- So-Low -40°C Freezer
- Liquid CO₂ for sub -40°C operation
- RTD (PT100) instrumentation
- 5cm instrumentation port

APRS World's CO2 Controller Modifications

- Replaced unusual fittings with NPT
- Added solenoid indicator light
- Removed dead backup battery
- Designed and built missing CO2 discharge tube



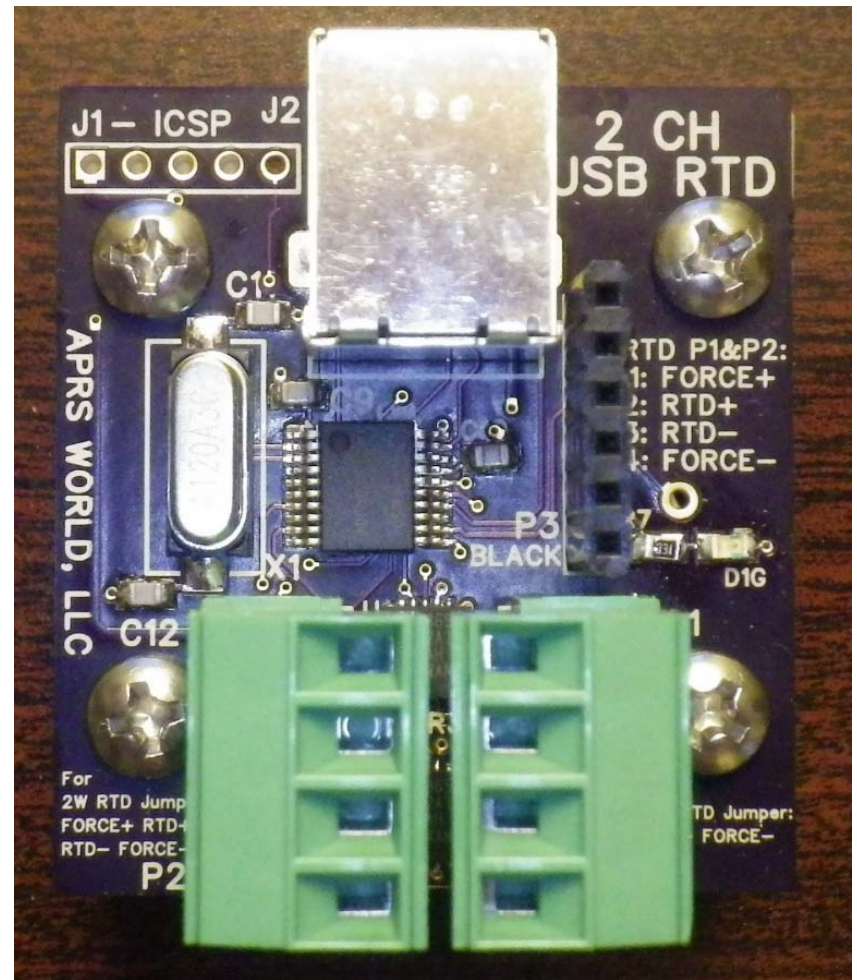
RTD Temperature Instrumentation: ThermokLogger-RTD

- 4 x PT100 or PT1000 RTD 4-wire inputs
- 2 x programmable solid state relay outputs
- SD card logging
- Real time clock
- LCD display
- Optional wireless modems
- RS-232 port



RTD Temperature Instrumentation: ThermokUSB-RTD2

- 2 x PT100 or PT1000 RTD 4-wire inputs
- USB interface
- Modbus or streaming ASCII
- Small (4 x 4.5cm)
- DIN rail mountable
- Open Source
 - hardware
 - firmware
 - software



Bearing Friction Testing

- 12-volt cordless drill with drive adapter for WTAPRS



- DC power / energy meter



- Lower power to turn turbine at given RPM => less bearing losses



Instrumentation Port

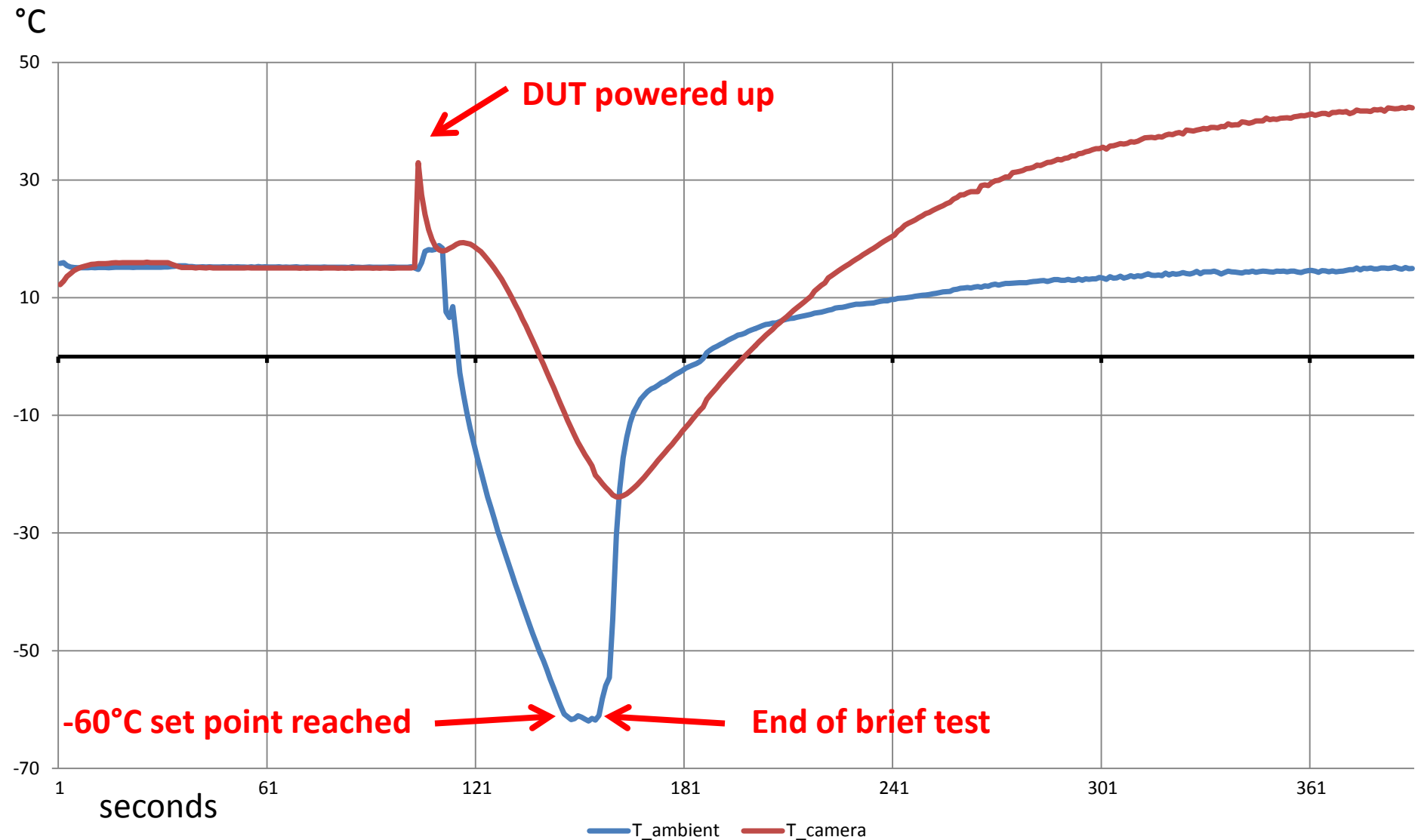


- 2" SCH 40 Stainless Pipe
- SCH 80 polypropylene pipe cap when not in use
- Also provides CO₂ vent
- Almost a disaster when installing
 - MFG instructions wrong!

Results: Test Setup

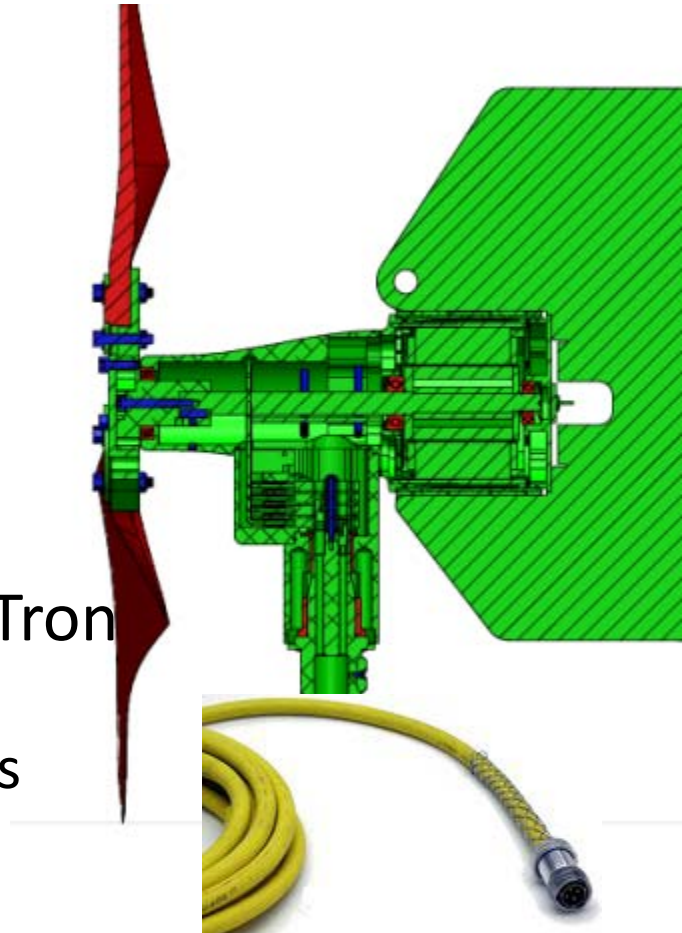
- < \$2000 able to obtain South Pole cold
- Fast ramps down with CO₂
- Slow ramps with refrigeration
- Stable
- Good remote monitoring

CO₂ and Refrigeration Fast Ramp



Results: WT10 / WT14

- Bearings
 - Molykote 33 grease works great!
 - Standard low drag seals are okay
 - No short term ball clearance issues
- Drop (output) cable “Carol Super Vu-Tron Supreme”
 - not bendable at “winter” temperatures
 - installable at “summer” temperatures
- Blades (glass filled nylon)
 - gets stiffer as it gets colder
 - good!
 - field tested in Antarctica



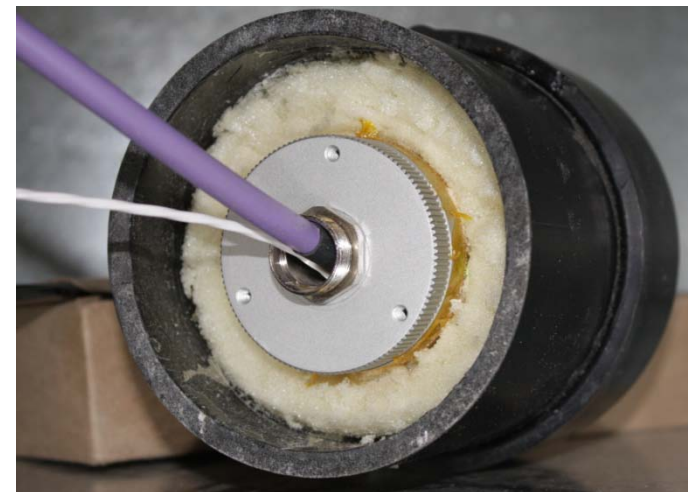
Results: Pelican Cooler

- 2 watts waste heat keeps cooler interior 20°C above outdoor ambient
- Not bad for \$250 MSRP COTS!



Results: IP Camera

- Vivotek IP8364 rated to -20°C
- Mechanical IR cut filter expected to be a problem
- Polyurethane insulated ABS sleeve developed
- Camera interior stays $\sim 30^{\circ}\text{C}$ above ambient



Results: Pi Camera / Weather Station

- IP Camera
- Weather Station
- Wireless or 802.15.4 POE
- ~1 watts
- IP67 enclosure
- Linux based
- Open source
- Wide DC input voltage



Questions and Comments?



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Information on our products:
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