PITTSBURGH MINING RESEARCH DIVISION

RA Heat Mitigation Systems Research

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Refuge Alternative Webinar

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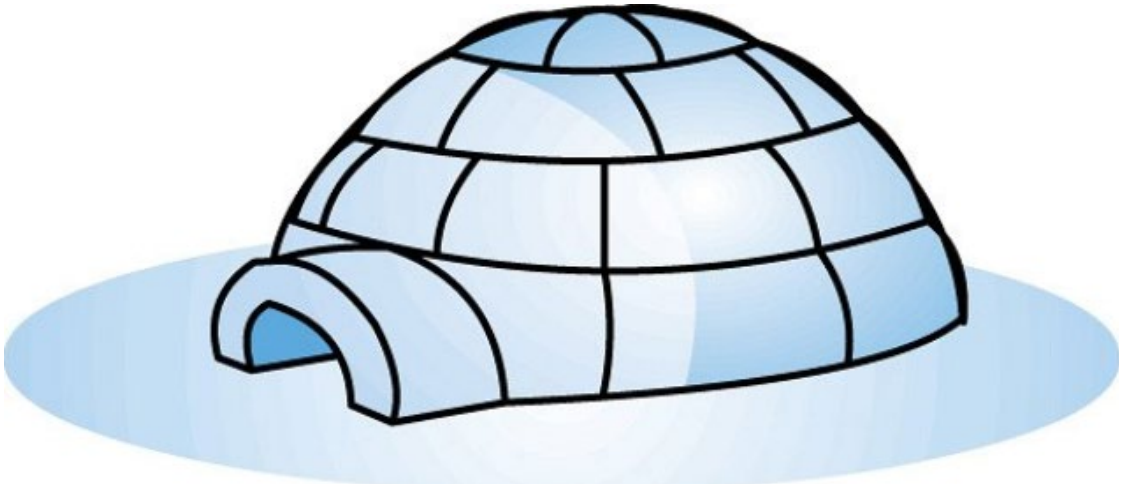
Pittsburgh, PA

DEPARTMENT OF HEALTH & HUMAN SERVICES · USA
CDC Workplace Safety and Health
NIOSH

Outline

1. Background/introduction
2. Overview of tested heat mitigation systems
3. Example of test results
4. Summary

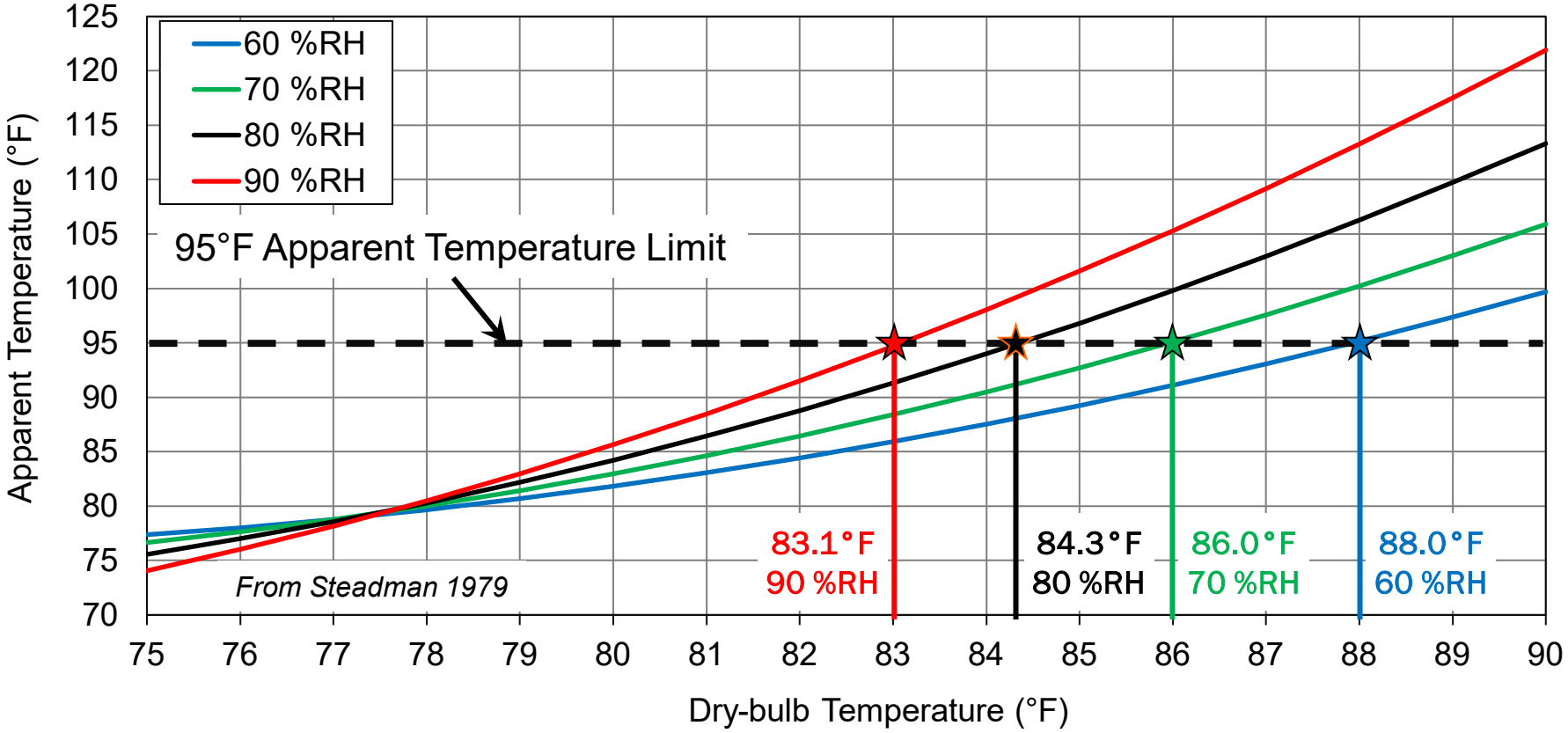


MSHA regulations limit the apparent temperature within an occupied RA to 95°F

- *Apparent temperature* is a metric used to determine the perceived temperature
- Equation is complicated, uses dry-bulb temperature and relative humidity in various combinations

$$\mathrm{HI} = c_1 + c_2 T + c_3 R + c_4 T R + c_5 T^2 + c_6 R^2 + c_7 T^2 R + c_8 T R^2 + c_9 T^2 R^2$$

Reducing either the dry-bulb temperature or the relative humidity will decrease the apparent temperature



The challenge is to develop strategies to reduce apparent temperature that meet the general requirements of 30 CFR 7.504

- Electrical components that are exposed to the mine atmosphere shall be approved as intrinsically safe
- Electrical components located inside the refuge alternative shall be either approved as intrinsically safe or approved as permissible

NIOSH tested three different systems with cooling & dehumidification capabilities

BCS Life Support
Cryogenic Air Supply

ChemBio
Borehole Air Supply

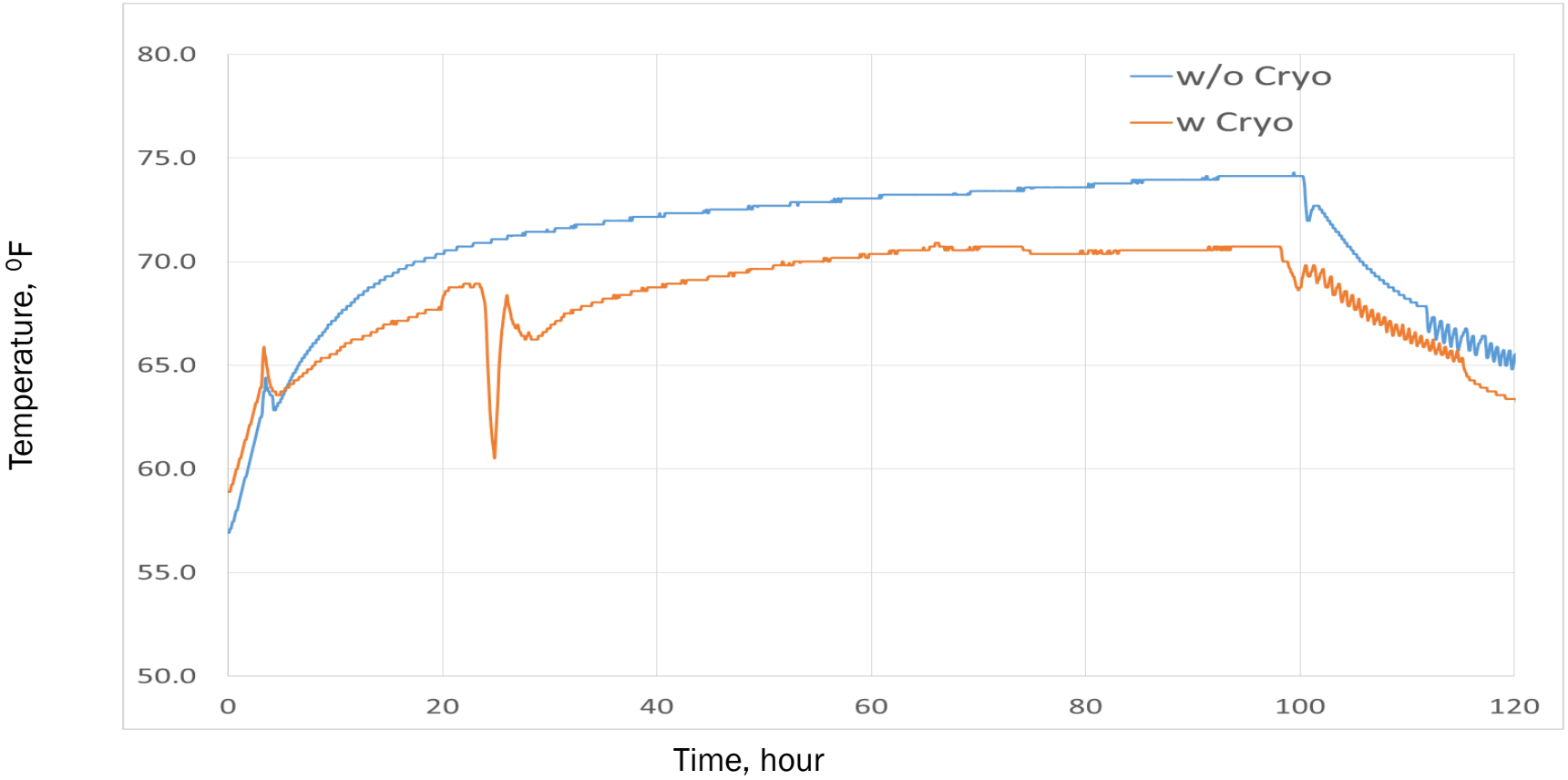
DRS Proof-of-concept
Battery-powered
Air Conditioner

NIOSH tested a cryogenic air supply system with both mobile and BIP RAs

- Cryogenic air supply can provide breathable air for miners, and provide cooling & dehumidification

23-Person Tent-Type RA w/ Cryogenic Air Supply

Temp/RH for 23-Person Tent-Type RA w/ Cryogenic Air Supply



The cryogenic air supply reduced the temperature and relative humidity within the RA, and increased the maximum initial mine temperature for RA use at full capacity

Test	Temperature Rise (°F)	Temperature (°F)	Relative Humidity (%)	Max Initial Mine Temp for Full Capacity* (°F)
w/o cryogenic air supply	17	74	94	
w/ cryogenic air supply	14	71	85	

** Calculated using temperature rise values and final %RH*

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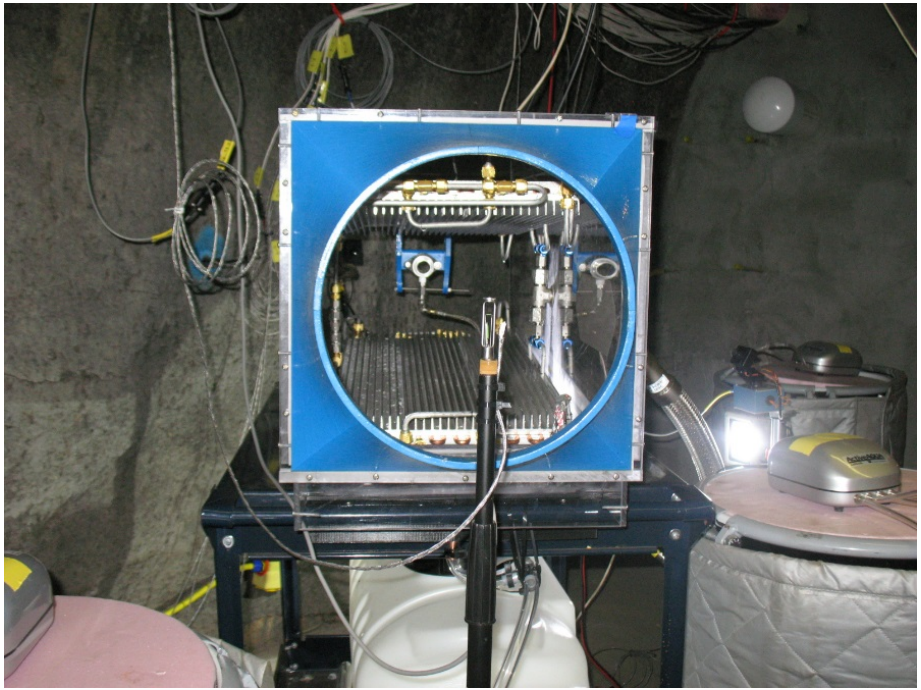
Test	Temperature Rise (°F)	Temperature (°F)	Relative Humidity (%)	Max Initial Mine Temp for Full Capacity* (°F)
w/o cryogenic air supply	17	74	94	66
w/ cryogenic air supply	14	71	85	71

** Calculated using temperature rise values and final %RH*

30-Person BIP RA w/ Cryogenic Air Supply

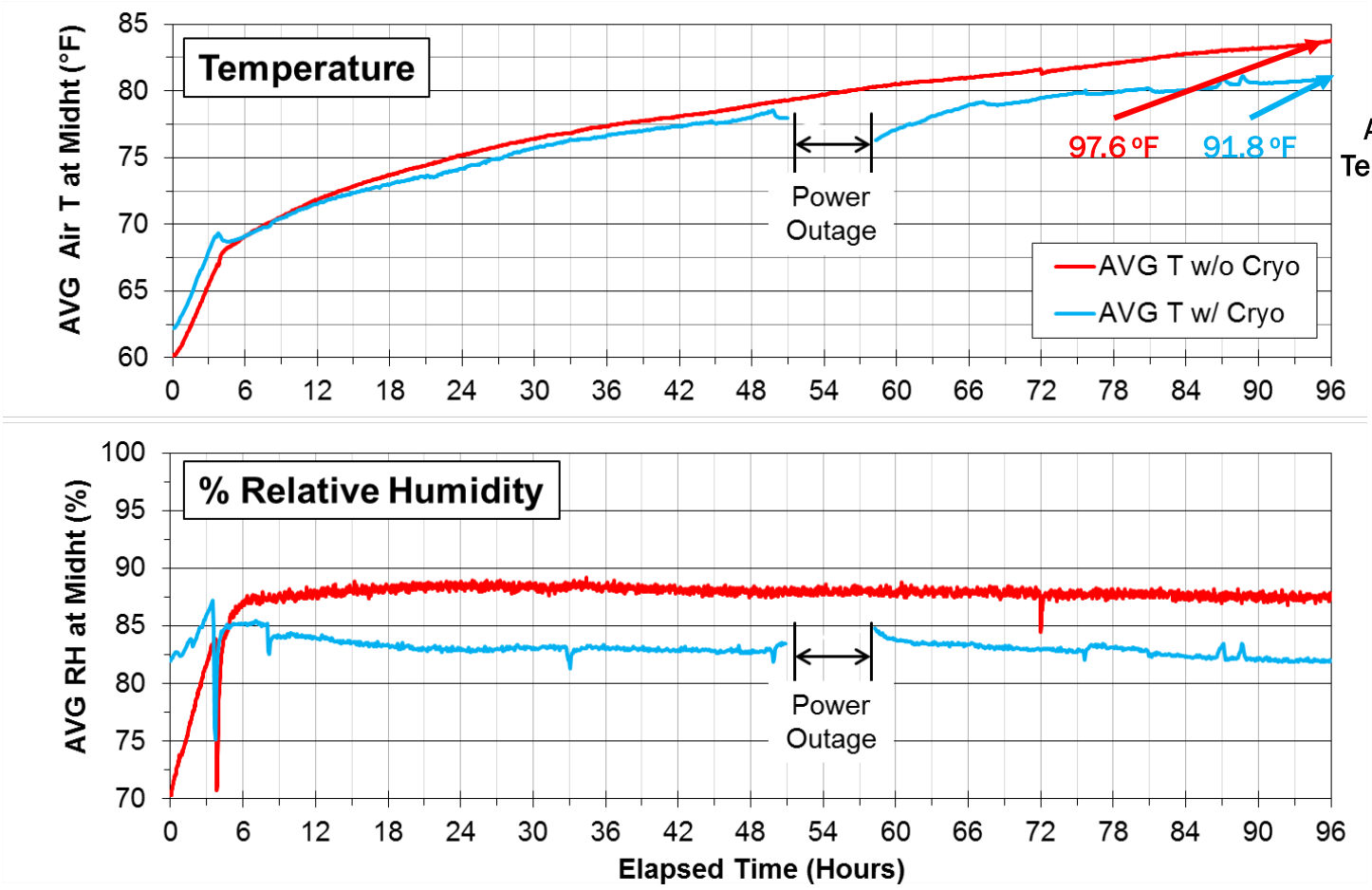


30-Person BIP RA Tests (2015 - present)

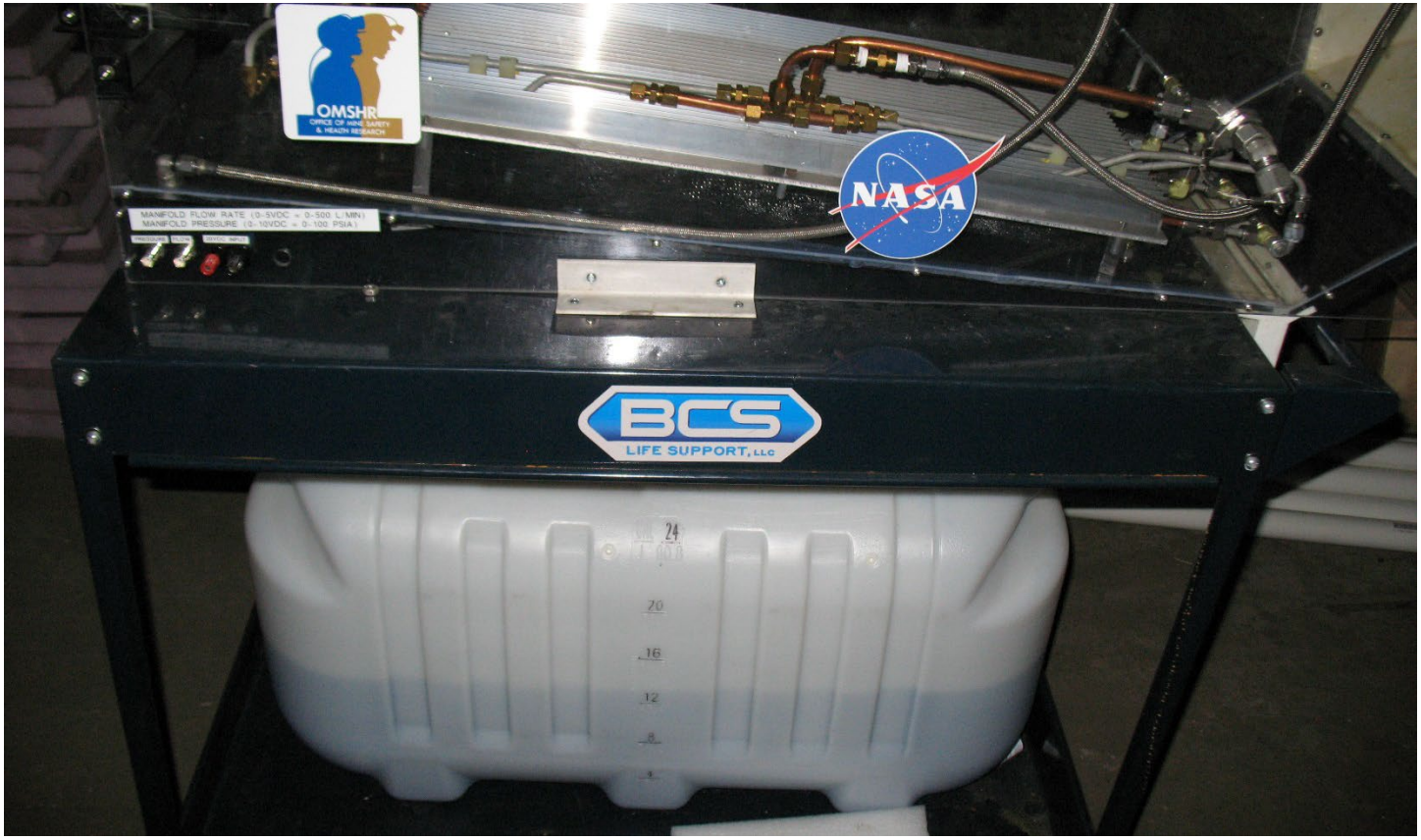
- 60-person BIP RA partitioned using 2-in-thick Styrofoam attached to both sides of a wood-frame wall
- Used to examine BIP RA w/o borehole or compressed air supply and to test cryogenic air supply

Test	Start Date	End Date	BP Heat Input (W)	CO_2 scrubber heat input (W)	Nominal Total Heat Input (W)	Conditions	Purpose
1	10/26/2015	10/30/2015	117	27.5	4335	w/ Cryogenic air supply flowing cryogen @ 13.5 liters/hour	Demonstrate ability of cryogenic air supply to reduce heat/humidity
2	12/7/2015	12/11/2015	117	27.5	4335	Baseline w/ moisture input	Provide baseline conditions for comparison to Cryogenic air supply test
3	4/25/2016	4/29/2015	117	27.5	4335	Baseline dry test	

Temp/RH for 30-Person BIP RA w/ Cryogenic Air Supply



The cryogenic air supply captures moisture from the air, this is a potential source of drinking water



60-Person BIP RA w/ Borehole Air Supply

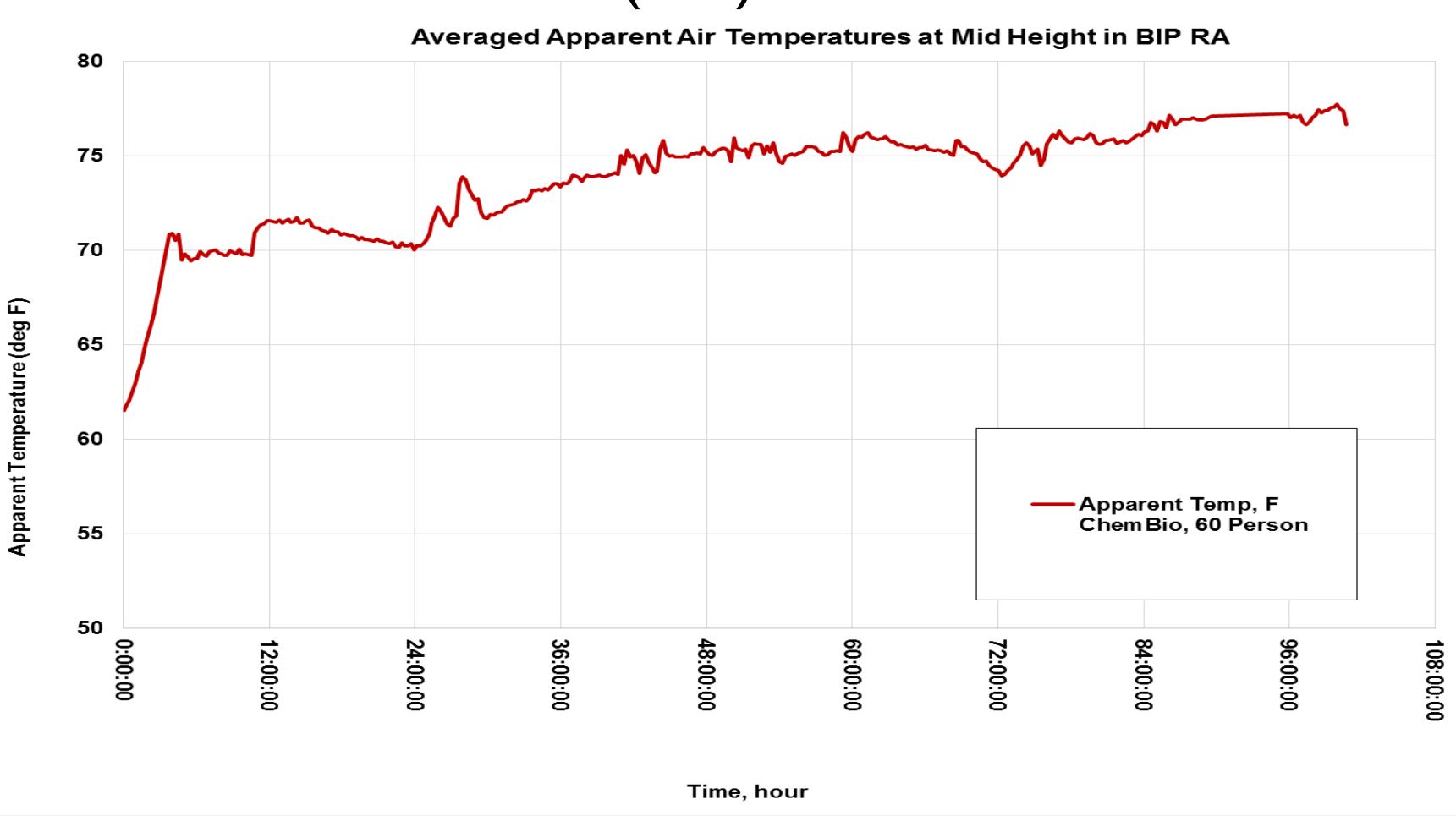
- Borehole air supply delivering 55°F dew point air at 750 to 800 CFM

surface

underground

underground

60-Person Built-In Place (BIP) RA Test



Battery-powered A/C System for 6-Person Metal-Type RA

Hole cut for A/C condenser fan

Battery-Powered A/C System in 6-Person Metal-Type RA

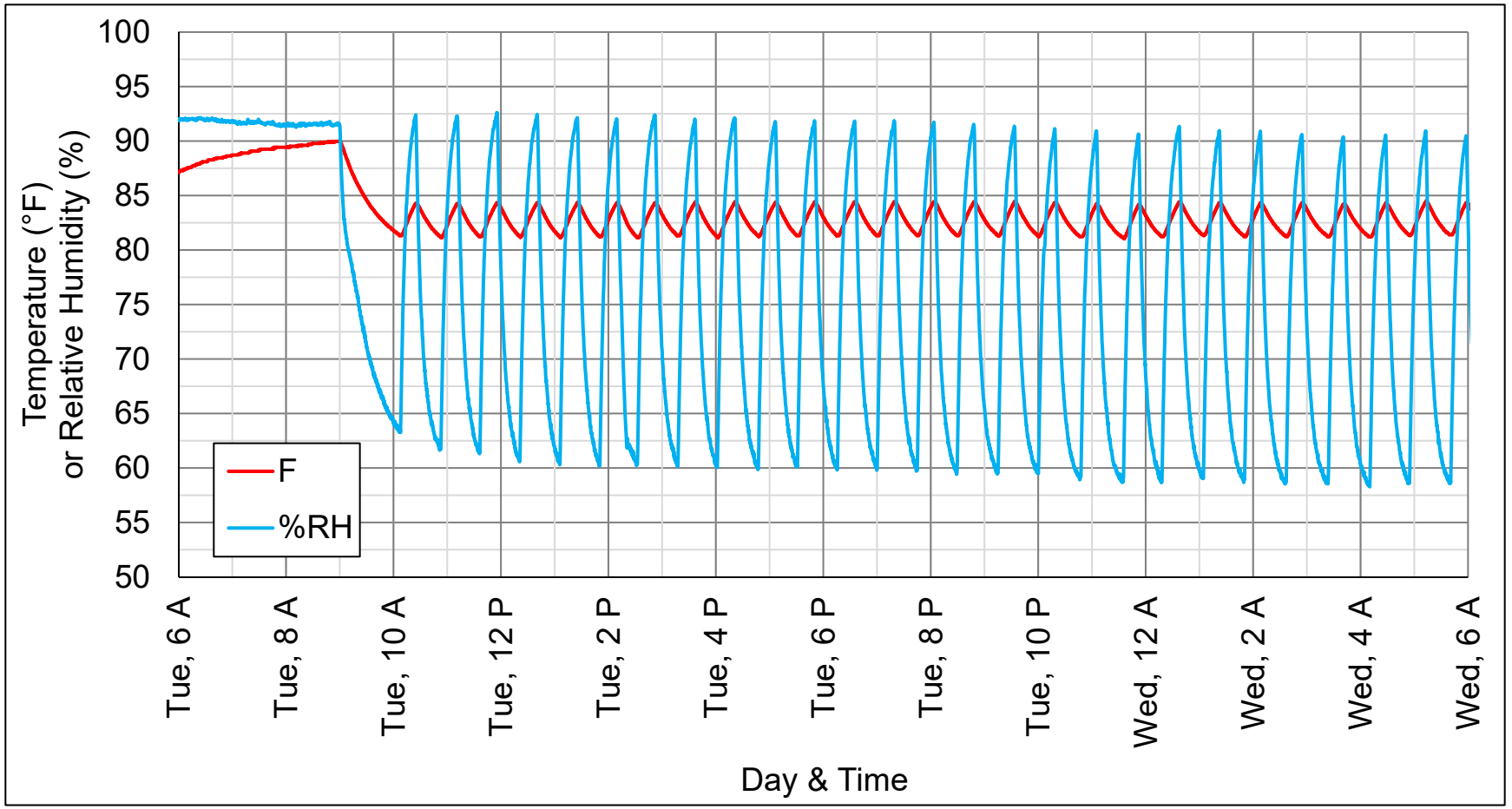
Battery Bank

Evaporator

Natural Mine Temp vs Preheated Mine

- Mine preheated to roughly 85°F at condenser inlet
- Enclosed space around the RA using Styrofoam walls
- Used 14 x 1500 W heaters to heat mine air

Test Results for Proof-of-Concept A/C System, Mine Air Preheated



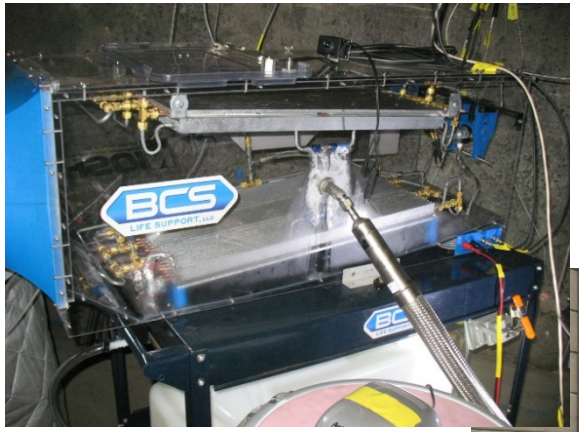
Summary for RA Heat Mitigation

- Cryogenic air supply for both BIP and mobile RA
  - BIP RA w/ and w/o Cryogenic
  - Mobile RA w/ and w/o Cryogenic
- Borehole air supply w/ 60-person BIP RA, 750 to 800 CFM airflow
  - 55°F dew point
  - Heated air for part, unconditioned air for part
  - Unconditioned air
- Battery powered A/C for mobile RA
  - 65 °F natural mine air temp
  - 85 °F preheated mine air temp

Future Work on RA Heat Mitigation

- Further research & development of cryogenic air supply, borehole air supply, and battery-powered A/C system
- Proof-of-concept testing of phase change materials and ice cooling

Questions?



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