PITTSBURGH MINING RESEARCH DIVISION

RA Heat & Humidity Update and Mine Air/Mine Strata Temperature Field Data

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Pittsburgh, PA

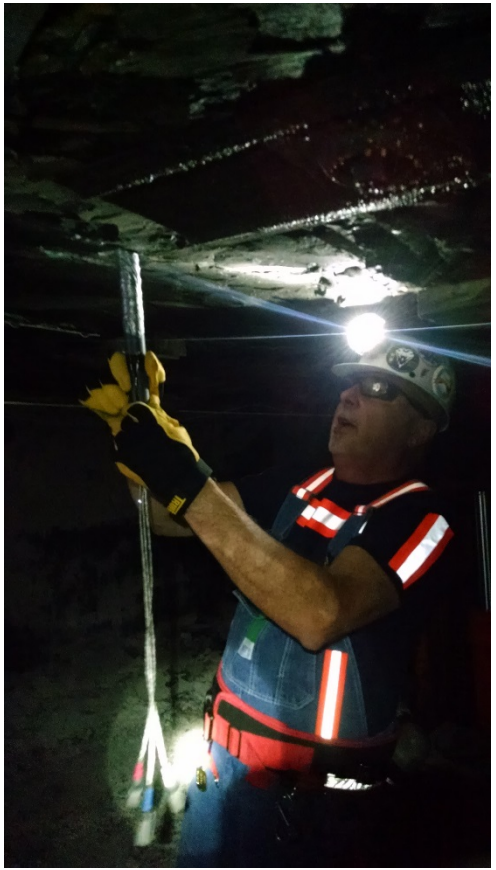
DEPARTMENT OF HEALTH & HUMAN SERVICES · USA

CDC Workplace Safety and Health

NIOSH

Outline

1. Introduction/background
2. In-mine Heat & Humidity Tests
3. Mine Air/Mine Strata Field data
4. Summary & conclusions



Heat and humidity buildup in RAs is a serious concern

- RA Regulations mandate a 96-hour duration and a 95°F apparent temperature limit
- *Heat exhaustion* occurs at body core temperatures between 98.6°F to 104°F
  - Anxiety, confusion
  - Vomiting, low blood pressure, decreased urination
  - Flushing, profuse sweating, rapid heartbeat (increased heat dissipation)

Management of Heatstroke and Heat Exhaustion. James L. Glazer, M.D., Maine Medical Center, Portland, Maine
Am Fam Physician. 2005 Jun 1;71(11):2133-2140. http://www.aafp.org/afp/2005/0601/p2133.html

Heat and humidity buildup in RAs is a serious concern

- *Heat stroke* occurs at body core temperatures above 104°F
  - Medical emergency (10% mortality rate)
  - Confusion, irritability, loss of control of body movement, seizures, coma
  - Cessation of sweating, hyperventilation, fluid accumulation in the lungs
  - Rapid breakdown of skeletal muscle tissue, blood clots
  - Heart arrhythmia, liver failure, kidney failure, shock

Management of Heatstroke and Heat Exhaustion. James L. Glazer, M.D., Maine Medical Center, Portland, Maine
Am Fam Physician. 2005 Jun 1;71(11):2133-2140. http://www.aafp.org/afp/2005/0601/p2133.html

NIOSH has performed numerous 96-hour in-mine heat and humidity tests on three mobile RAs and a built-in-place RA

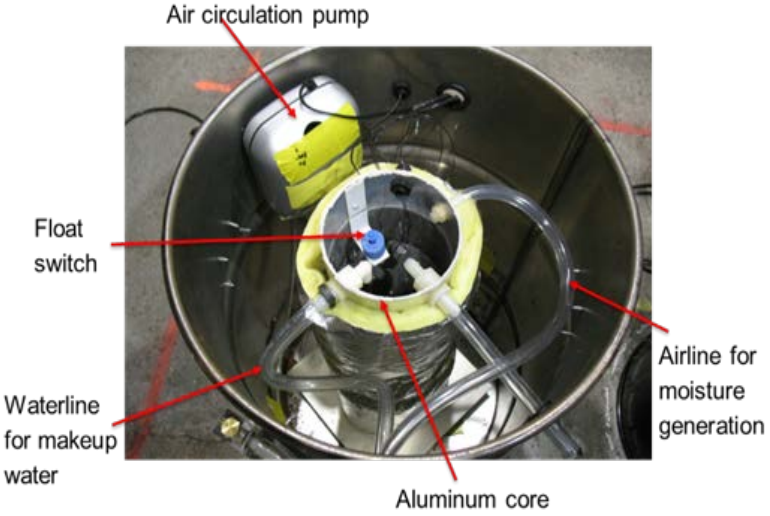
- Twenty-four 96-hour tests over the past three years[1]
  - 3 for 10-person training tent-type RA
  - 6 for 23-person tent-type RA
  - 7 for 6-person metal-type RA
  - 3 for 30-person BIP RA
  - 5 for 60-person BIP RA
- Data has been used to
  - Determine temperature rise and %RH
  - Benchmark thermal simulation models of mobile RAs
  - Identify need for heating and/or cooling of RAs
  - Support RA heat mitigation research

[1]Note: All capacities based on 15 ft^2 per miner

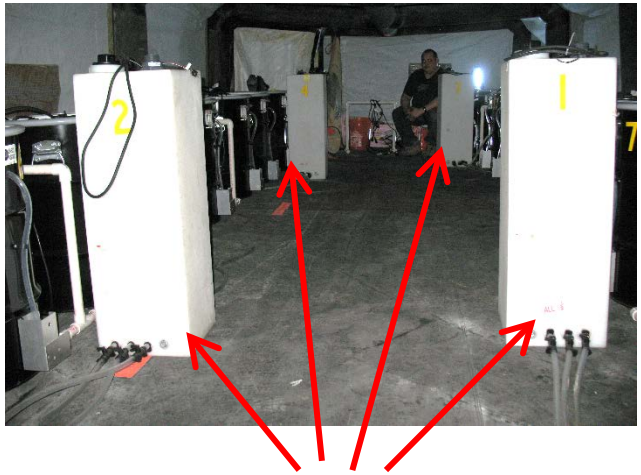
NIOSH uses consistent test methods for RA heat/humidity tests

- Automatic VARIACs to control power at desired heat input
- Simulated miners (SM) to represent miners' metabolic heat and moisture input
- Heated water tanks to represent CO_2 scrubbing system heat

Automatic VARIAC



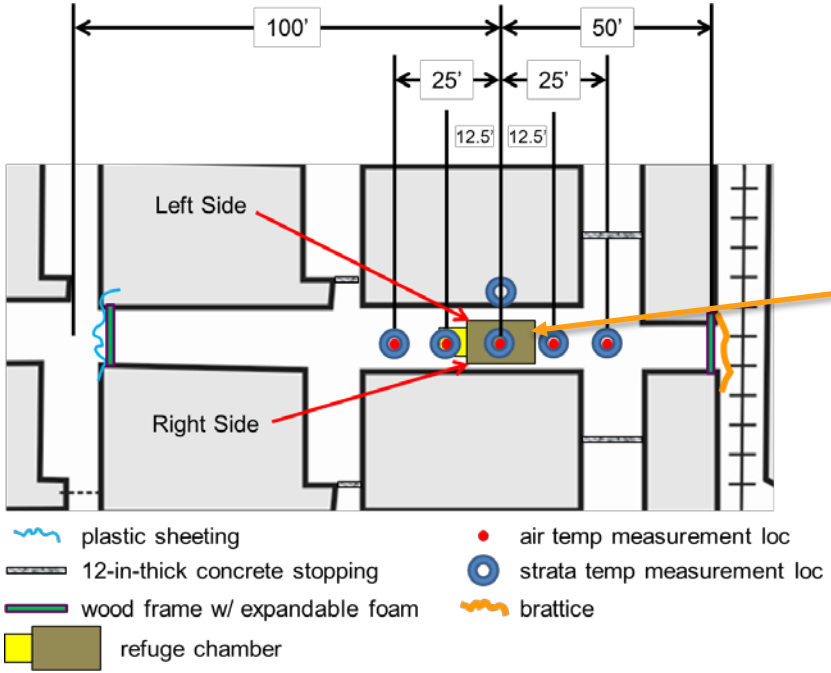
Interior view of SM

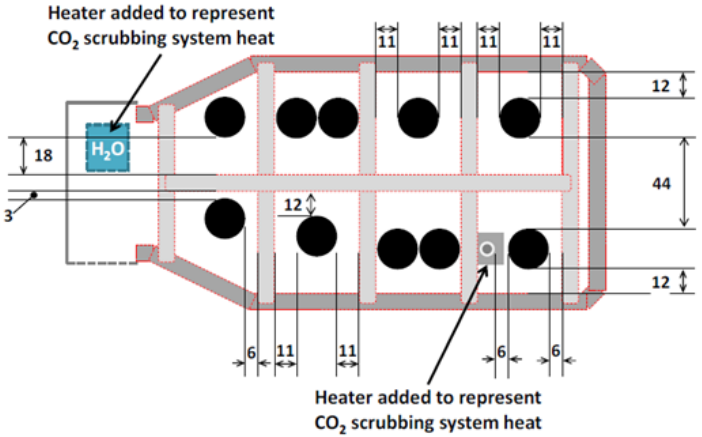


Heated water tanks

10-Person Tent-Type RA Tests (2013)

- Tests conducted by NIOSH in Safety Research Coal Mine (SRCM)





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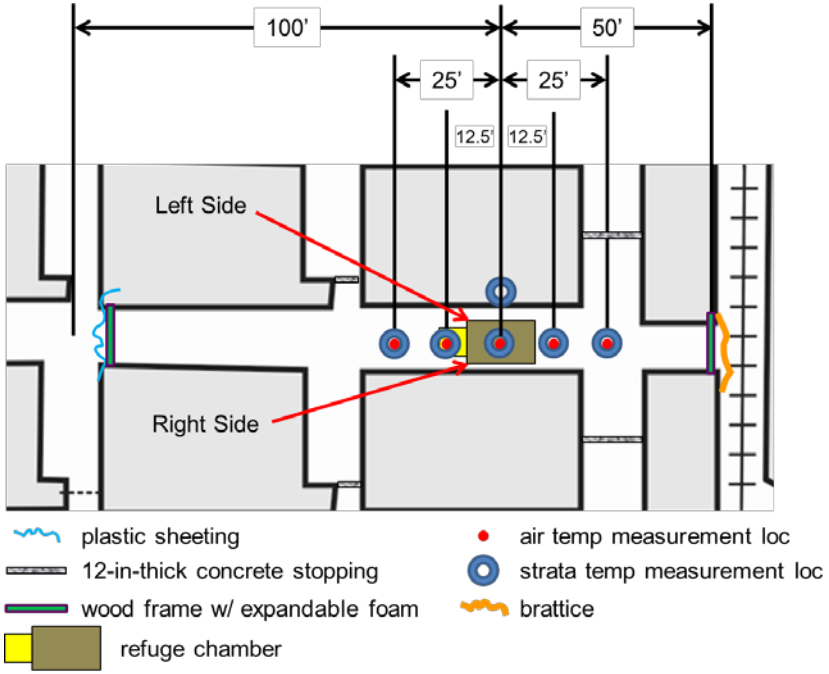
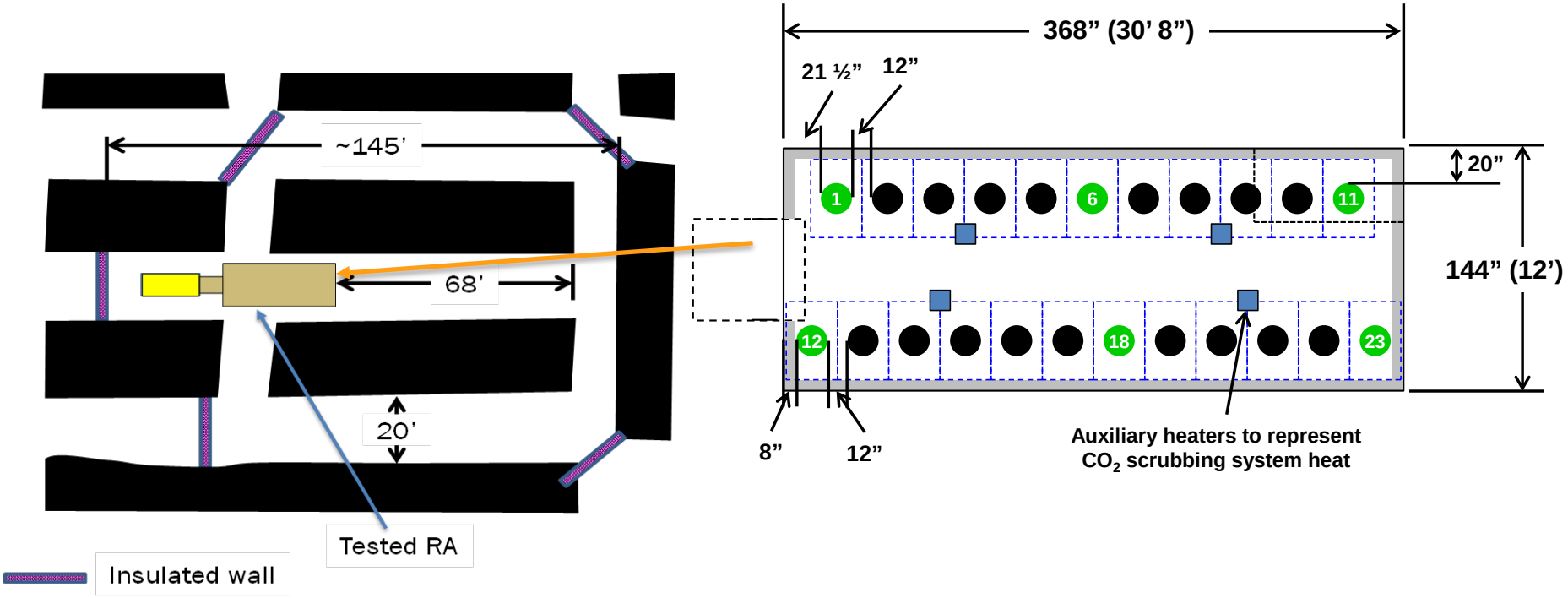


23-Person Tent-type RA Tests (2014)

- Tests conducted by NIOSH in Experimental Mine (EM)



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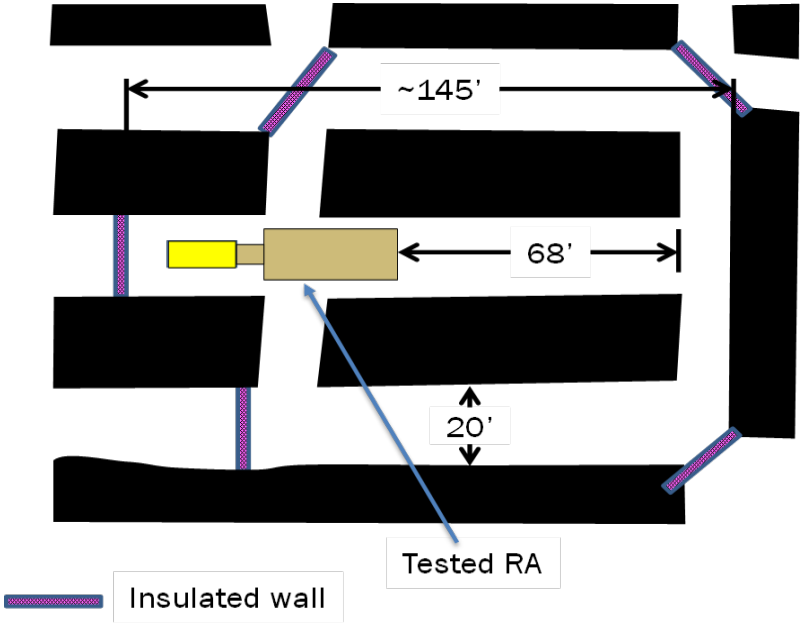

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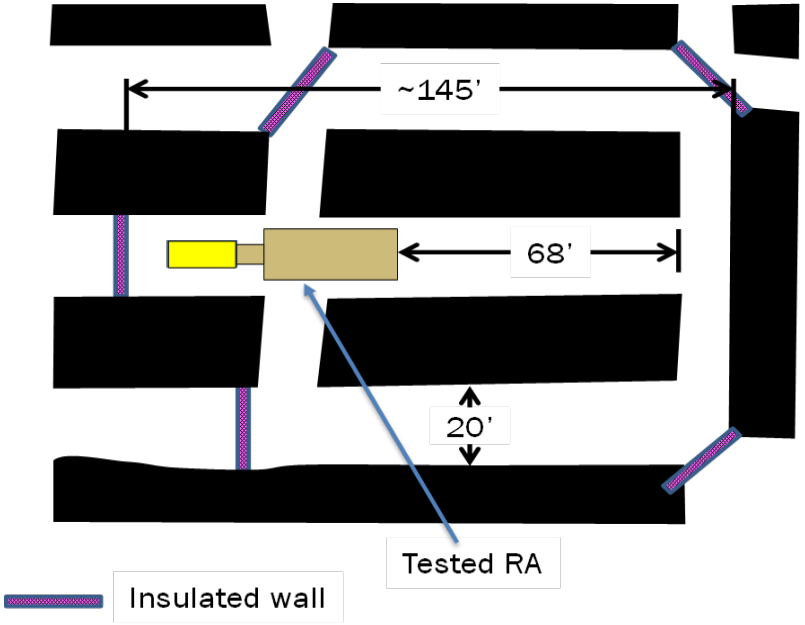
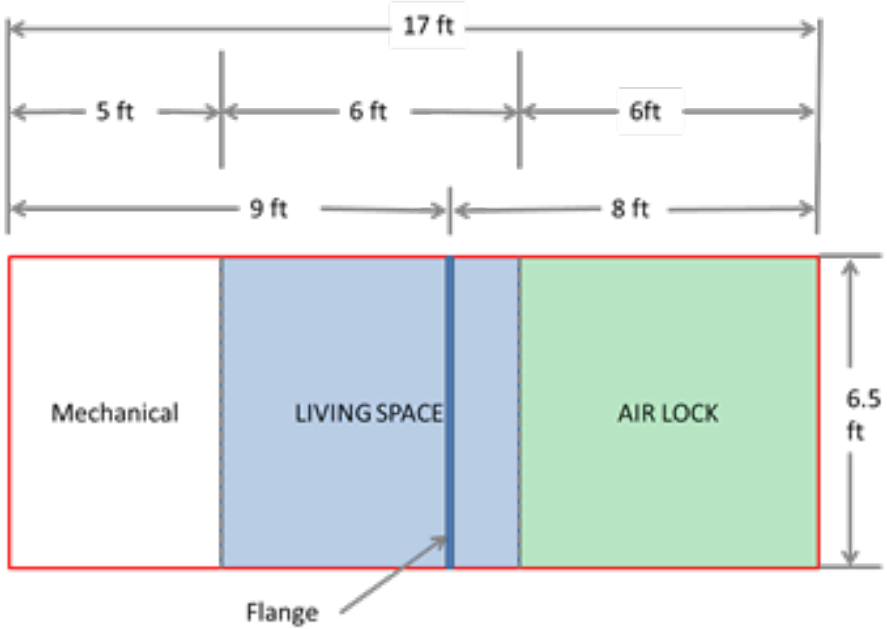


6-Person Mobile Metal-type RA Tests (2015 - Present)

- Tests conducted by NIOSH in Experimental Mine (EM)



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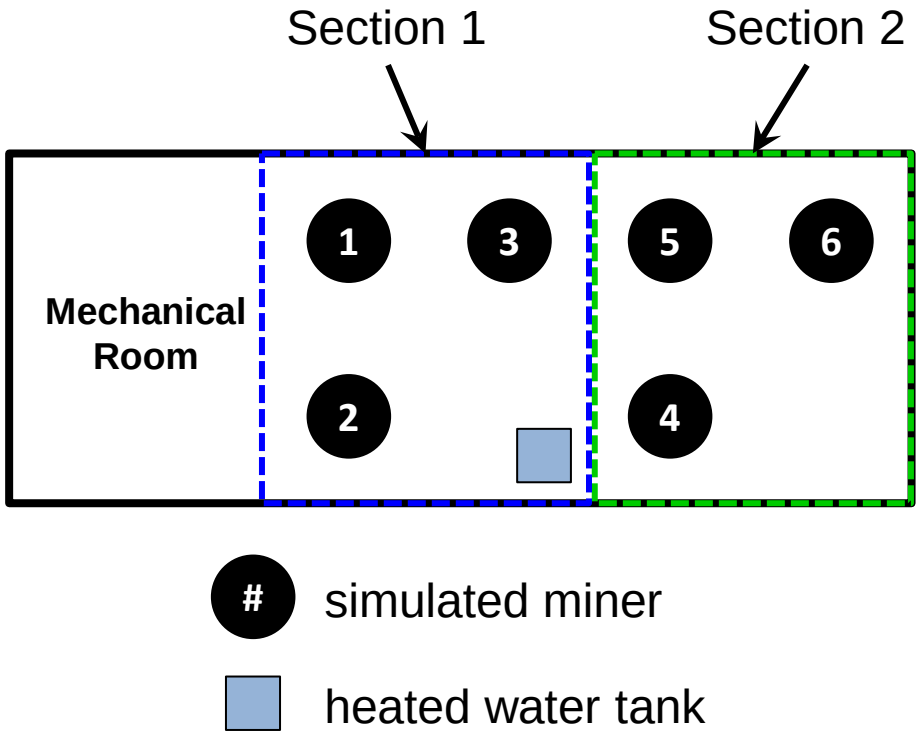


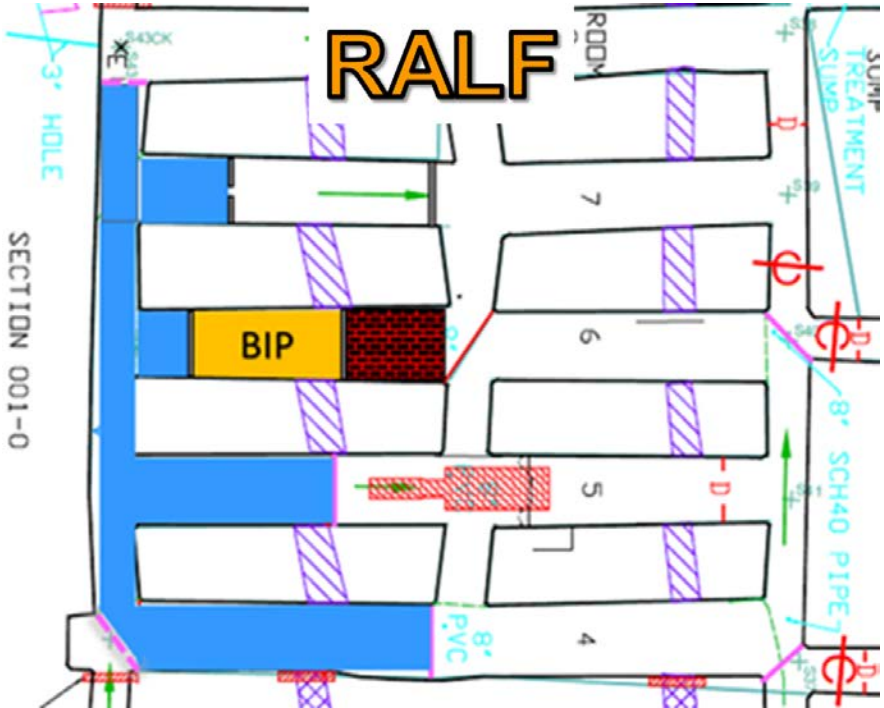
The air temperature in an occupied mobile RA will increase significantly during 96 hours

Tested RA Test Conditions and Test Location	Initial Temp (°F)	Final Temp (°F)	Temp Increase (°F)	Temp Increase per Miner (°F/person)
10-person tent-type training RA 167 watts/miner w/ moisture input Safety Research Coal Mine	58	77	19	1.9
23-person tent-type RA 144.5 watts/miner w/ moisture input Experimental Mine	57	74	17	0.74
6-person mobile RA 144.5 watts/miner w/ moisture input Experimental Mine	57	74	17	2.8

Note: (1) Capacity is based on 15 ft^2 of floor space per miner
(2) 167 watts/miner is 117 watts of metabolic heat per miner plus 50 watts/miner for LiOH CO_2 scrubber
(3) 144.5 watts/miner is 117 watts of metabolic heat per miner plus 27.5 watts/miner for soda lime CO_2 scrubber

Built-In Place (BIP) RA Tests (2015 - present)

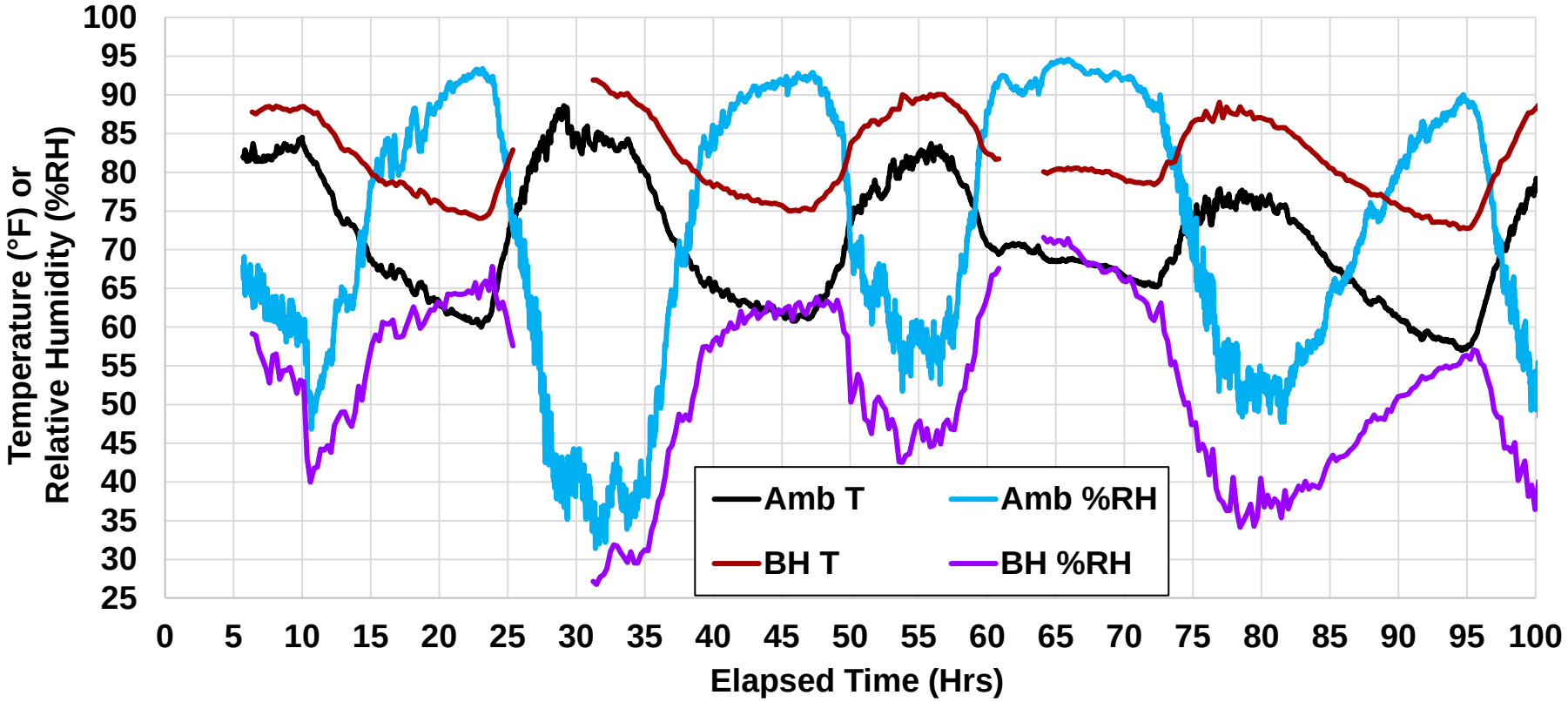
- ChemBio borehole air supply used for 60-person BIP RA testing
- Cryogenic air supply used for 30-person BIP RA testing (partitioned)



NIOSH conducted four 60-person BIP RA heat & humidity tests with both high and low outside ambient temperatures

- Nominal 775 SCFM of air (> mandated 12.5 SCFM/person)
- All tests w/ 117 W per miner, assumed CO_2 scrubbing unnecessary
- High outside temperature
  - Oct 2015: 60 simulated miners w/ air supplied at 55°F dew point
    - Outside ambient temperature of 49°F to 78°F with an average of 64°F
    - Outside relative humidity of 37 to 95 %RH with an average of 72 %RH
  - Aug 2016: 60 simulated miners w/ unconditioned air
    - Outside ambient temperature of 57°F to 89°F with an average of 71°F
    - Outside relative humidity of 31 to 95 %RH with an average of 72 %RH

A fully occupied BIP RA w/ an unconditioned air supply could reach the apparent temp limit if the outside air temp and relative humidity are high



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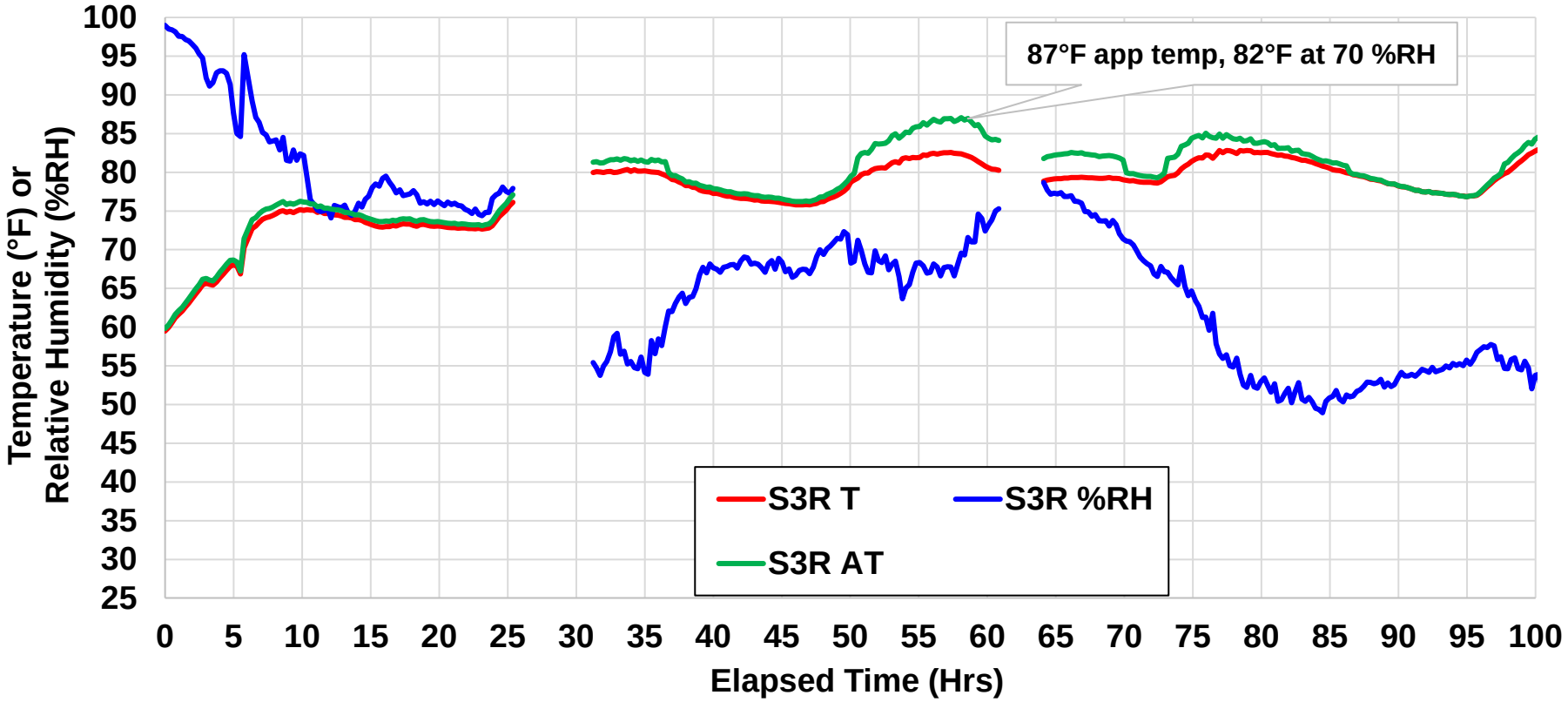


NIOSH conducted four 60-person BIP RA heat & humidity tests with both high and low outside ambient temperatures

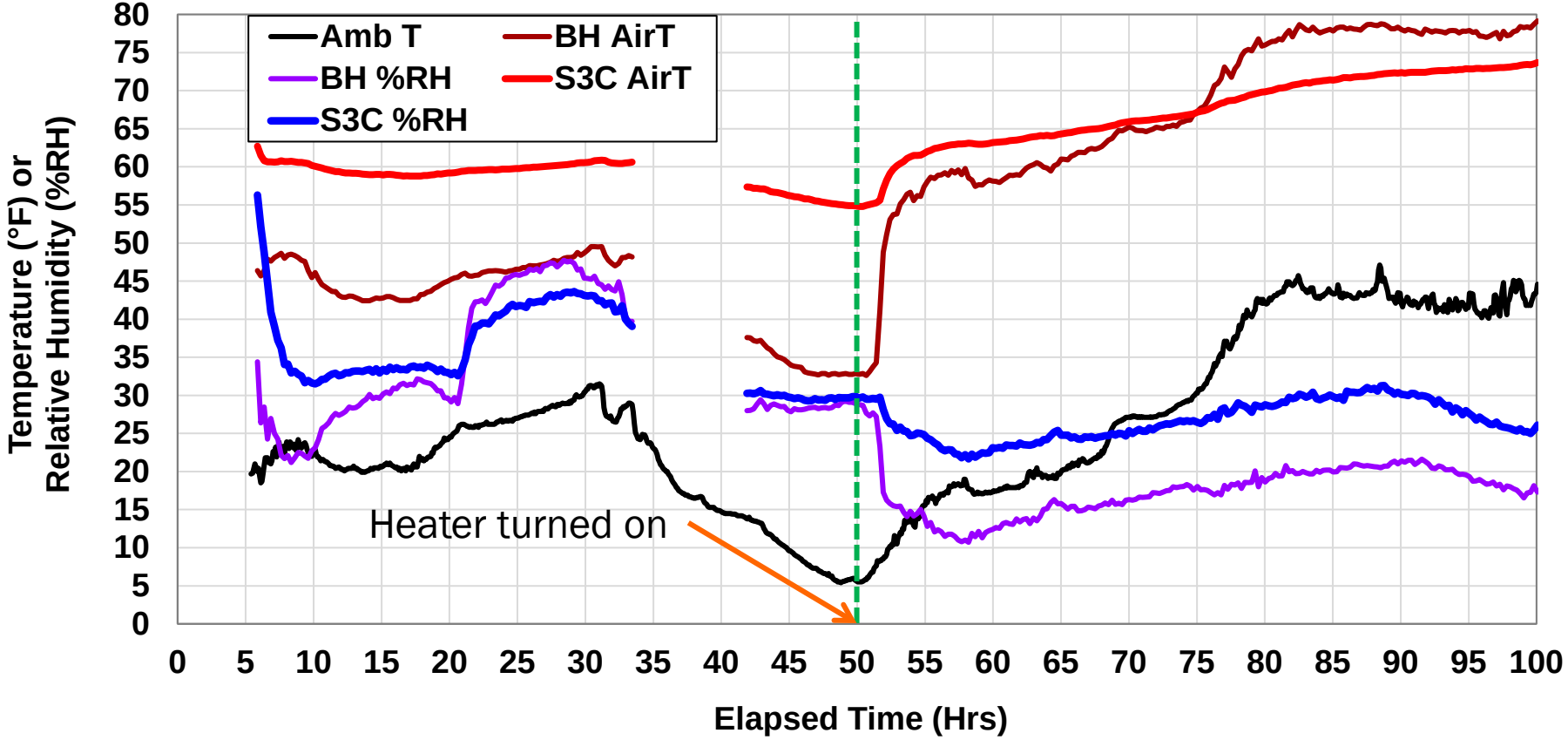
- Nominal 775 SCFM of air (> mandated 12.5 SCFM/person)
- All tests w/ 117 W per miner, assumed CO_2 scrubbing unnecessary
- Low outside temperature
  - Jan 2016: 60 simulated miners w/ uncond. air for 2 days, heated air for 2 days
    - Outside ambient temperature of 5°F to 32°F with an average of 20°F for first 2 days
    - Outside ambient temperature of 9°F to 47°F with an average of 32°F for final 2 days
  - Apr 2016: 6 simulated miners w/ unconditioned air
    - Outside ambient temperature of 23°F to 68°F with an average of 41°F

Hypothermia may be a concern at low temperatures

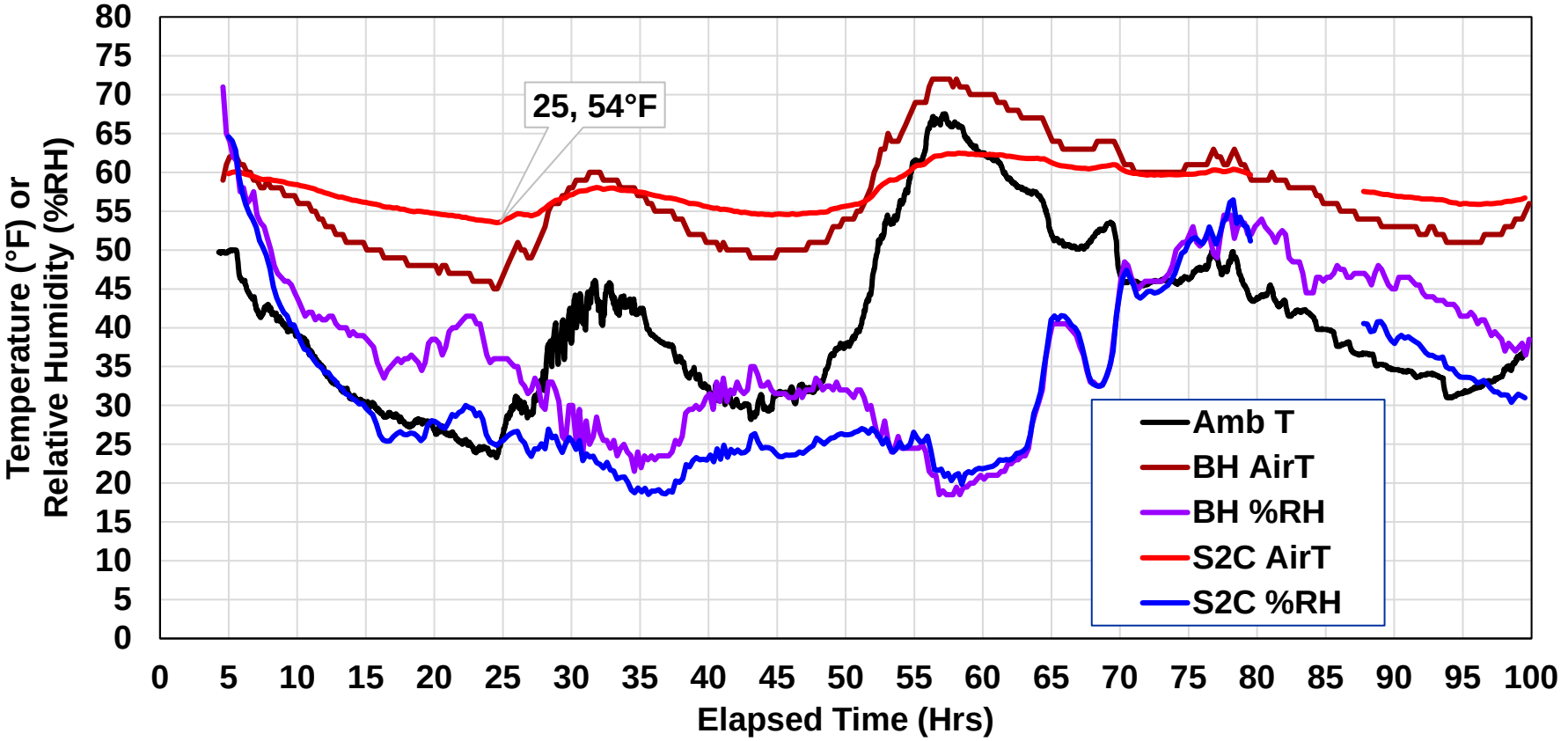
- Occurs when the body loses heat faster than it produces heat
- Caused by exposure to cold air, water, wind, or rain
  - Temperatures of 50°F or higher in wet and windy weather
  - Temperatures of 60°F to 70°F in water
- Emergency condition that can quickly lead to unconsciousness and death if heat loss continues

http://www.webmd.com/first-aid/tc/hypothermia-and-cold-temperature-exposure-topic-overview

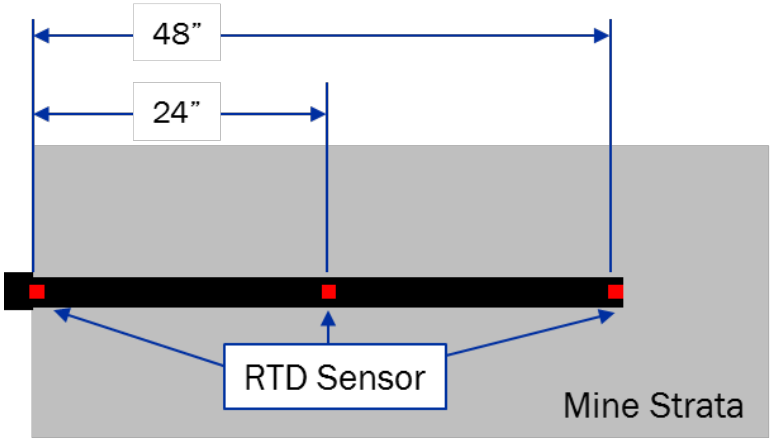
Low temperatures inside a fully occupied BIP RA could be a concern if the outside air temperature is low



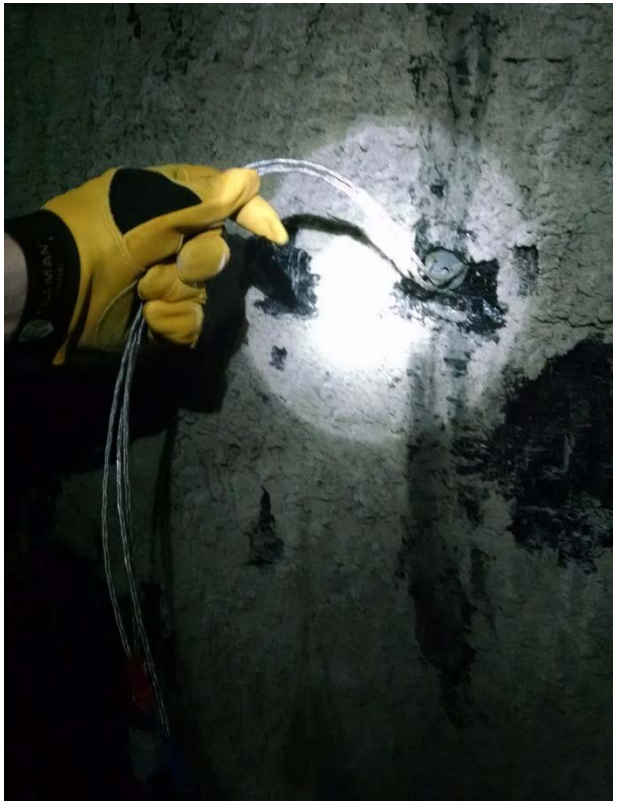
Low temperatures inside a *less-than-fully occupied* BIP RA could be a concern if the outside air temperature is low



NIOSH characterized mine air and strata temperatures to understand their effects on RA heat and humidity



RTD thermometer



RTD probe in rib

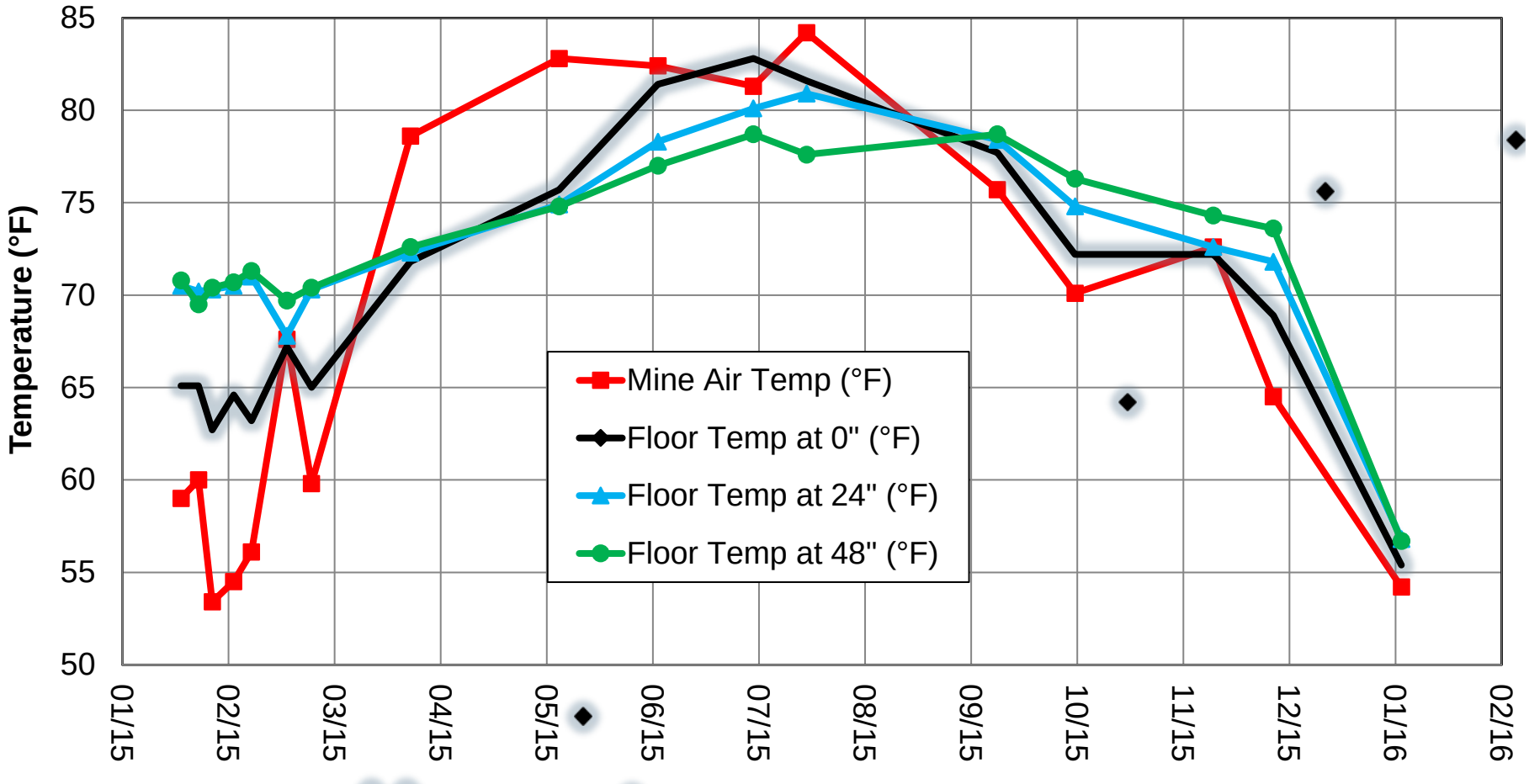
Mine temperature measurements were taken at 5 underground coal mines across the United States

Mine	Strata Composition		
	Floor	Ribs	Roof
Mine 1 (300' depth)	Sandstone, Shale	Bituminous Coal and Fireclay	Shale, Fireclay, Bituminous Coal, Sandstone Composite
Mine 1 (1,000' depth)	Shale	Bituminous Coal/Shale composite	Bituminous Coal, Shale
Mine 2	Mudstone	Bituminous Coal	Bituminous Coal, Shale, Mudstone
Mine 3	Bituminous Coal	Shotcrete, Bituminous Coal and mudstone	Sandstone, Bituminous Coal
Mine 4	Shale	Bituminous Coal and Shale	Shale
Mine 5	Claystone, Sandstone	Bituminous Coal	Shale

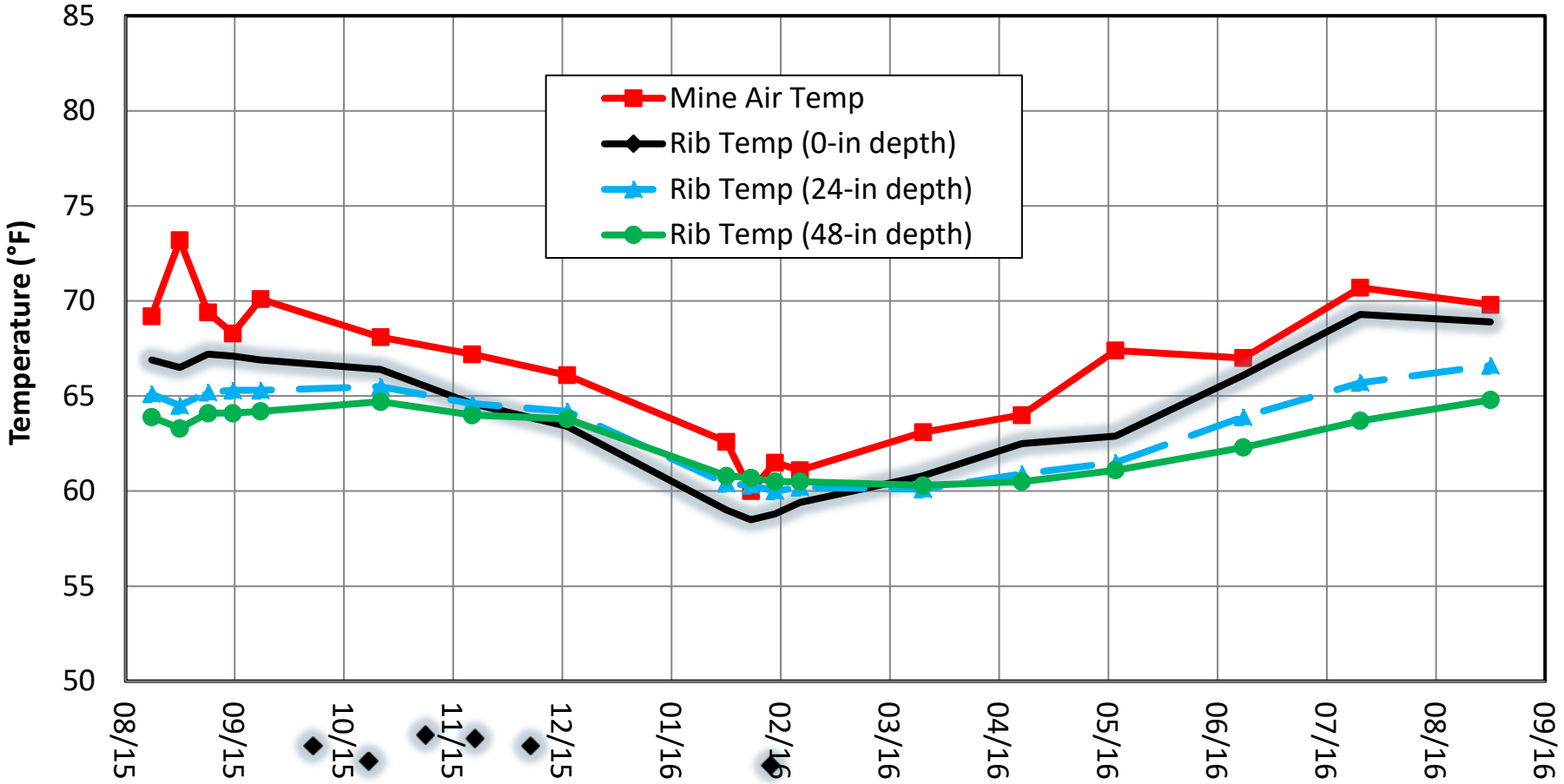
Temperatures varied widely from mine-to-mine, and within a mine

Mine	Value	Mine Air Temp (°F)	Strata temperature at depth (°F)		
			0"	24"	48"
Mine 1 (300' depth)	max.	63	61	60	60
	min.	58	56	58	58
Mine 1 (1,000' depth)	max.	66	63	63	63
	min.	65	61	62	62
Mine 2	max.	66	65	66	66
	min.	51	50	53	61
Mine 3	max.	60	64	57	55
	min.	46	44	51	55
Mine 4	max.	81	83	81	79
	min.	54	55	57	57
Mine 5	max.	71	69	66	64
	min.	60	59	60	61

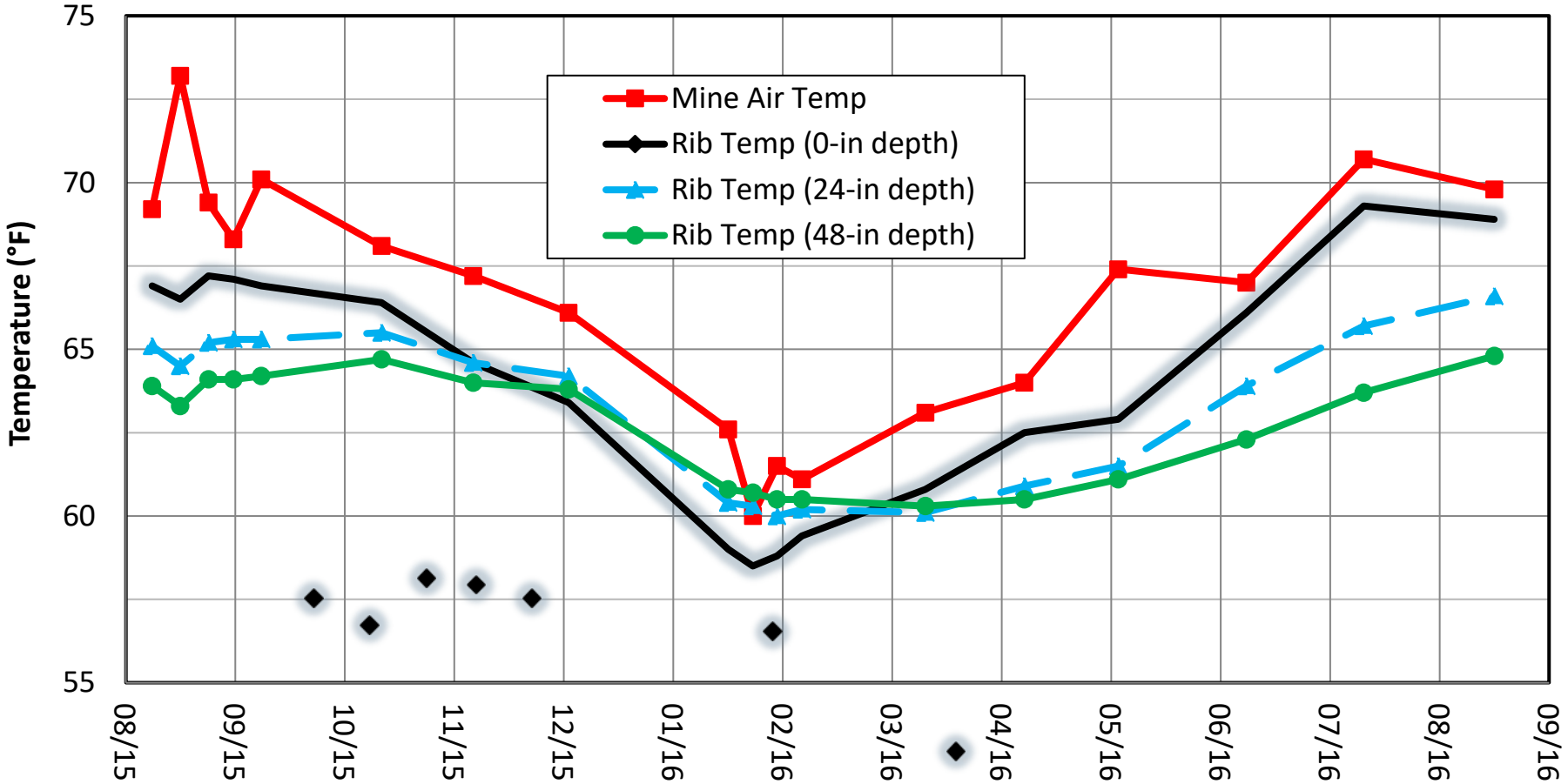
Mine 4 mine air and strata temperatures for one year



Mine 5 mine air and strata temperatures for one year



Mine 5 mine air and strata temperatures for one year



Summary & Conclusions

- If the outside ambient temperature/relative humidity are high, conditions in a BIP RA with an unconditioned borehole air supply could exceed the apparent temperature limit
- If the outside ambient temperature is low, hypothermia may be a concern for BIP RAs without a heated air supply
- BIP RA temperature/relative humidity depend on *BIP RA specific* outside air temperature/relative humidity, air flow, free space/volume per miner, depth, strata temperatures, and strata composition
- Mine air/strata temperatures vary from geographically from mine-to-mine, and seasonally within a mine
- Actual mine air/strata temperatures should be used in assessment of RA occupancy

Questions?

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