OMSHR

Office of Mine Safety and Health Research

Update on OMSHR Refuge Alternatives Research: 2014 Heat & Humidity Research and 2015 Planned Research

Dave Yantek

Research Engineer

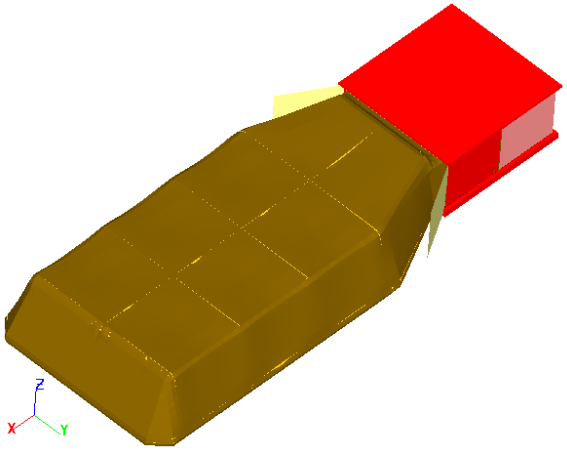
Refuge Alternatives Partnership Meeting
February 10, 2015

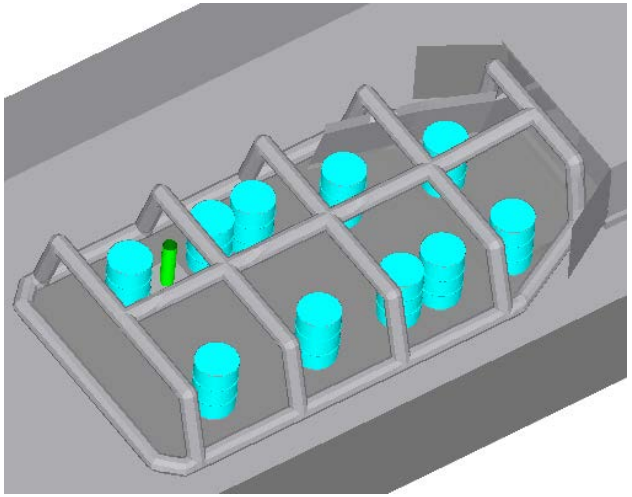
CDC Workplace Safety and Health NIOSH

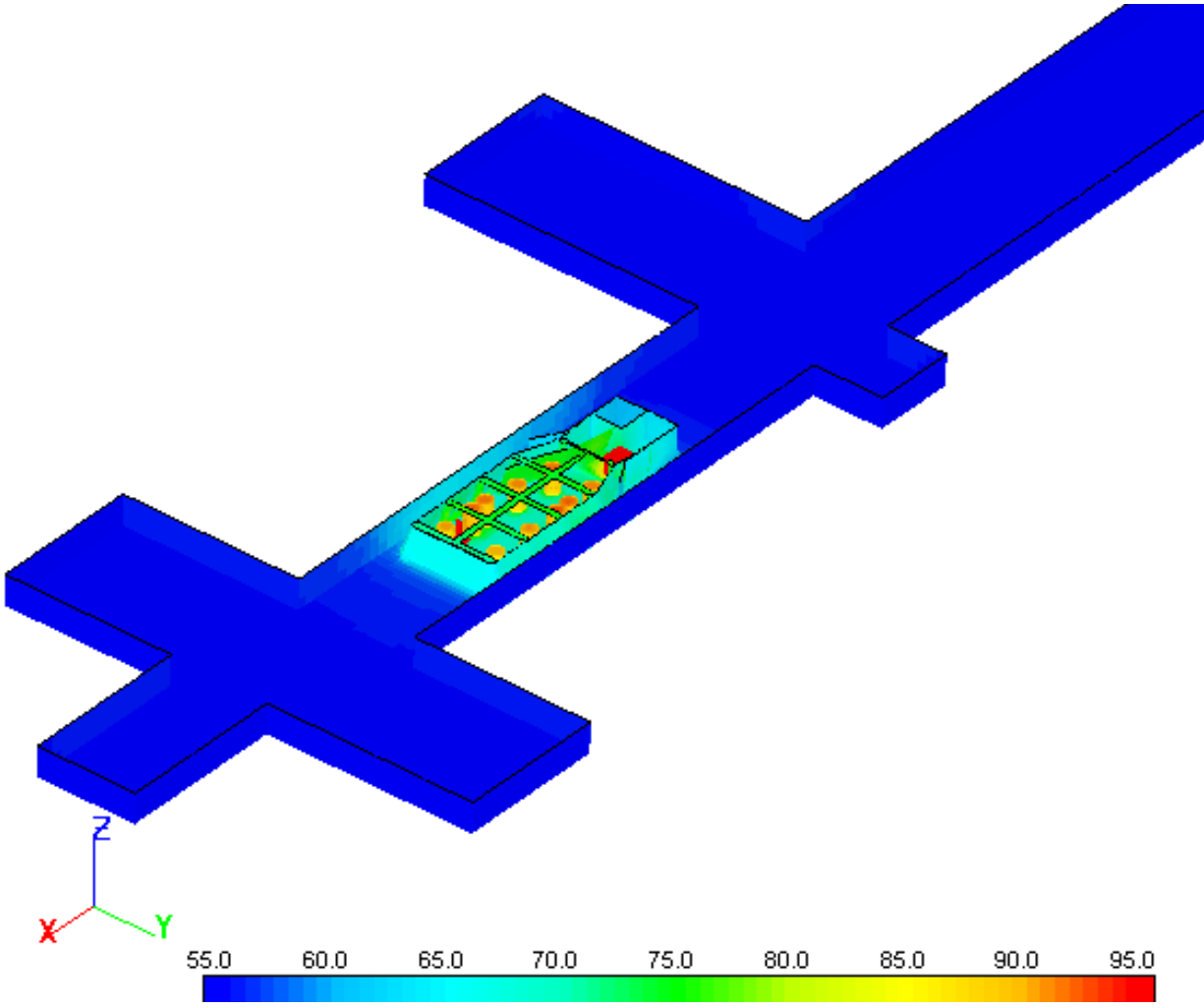
Outline

1. Thermal modeling work on 10-person mobile tent-type RA (2014)
2. Demonstration of approach for occupancy derating (2014-2015)
   - Testing
   - Simulation
   - Mine air/mine strata temperature field data
3. Mobile rigid RA heat and humidity (2015)
4. Built-in-place RA research (2015)

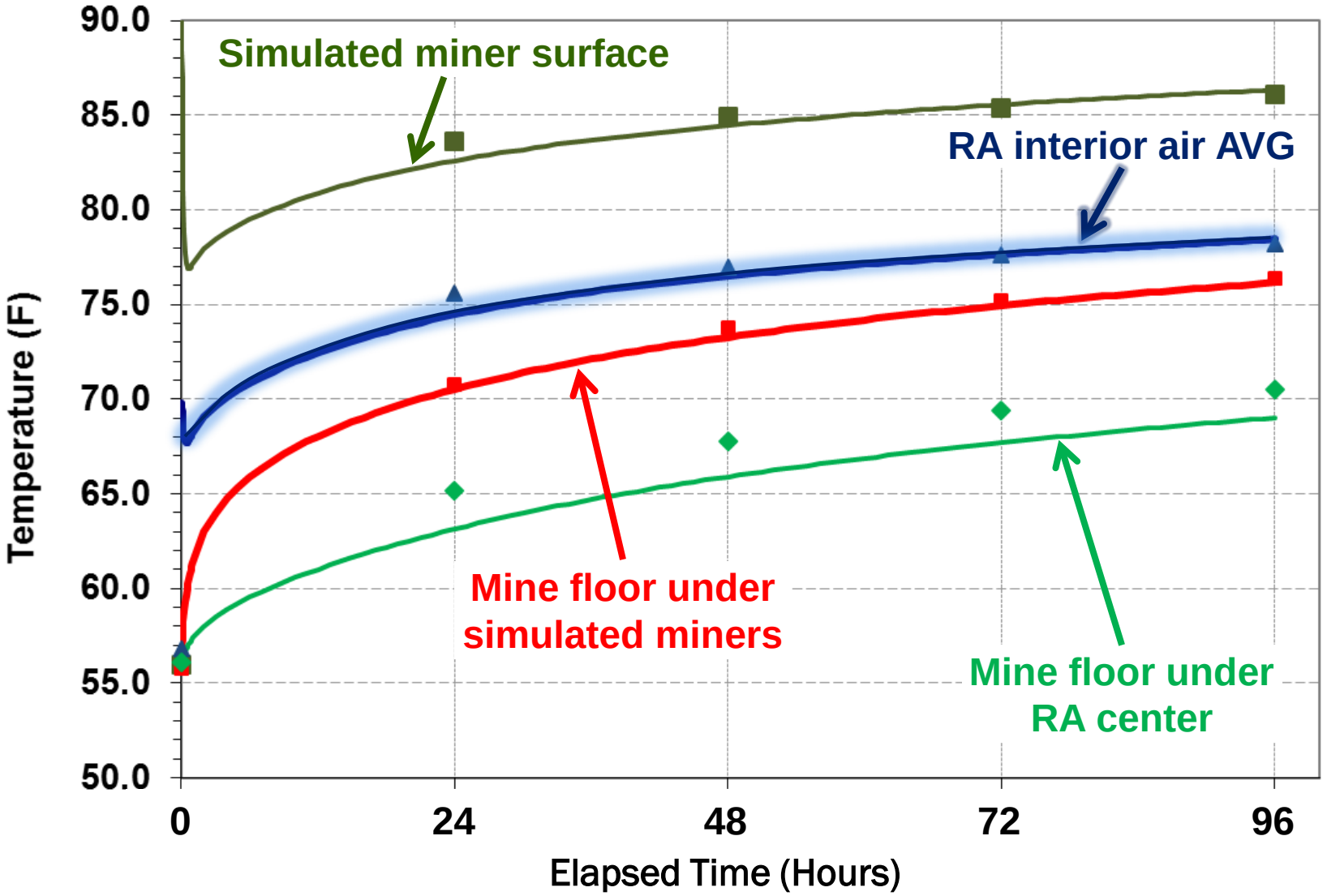
OMSHR contracted ThermoAnalytics, Inc. to develop and validate a thermal simulation model of the 10-person tent-type RA as tested in OMSHR's SRCM







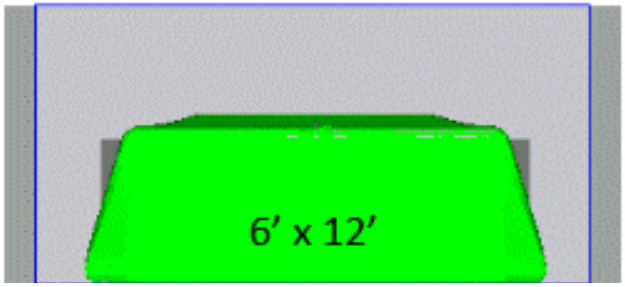
The thermal simulation model showed good agreement with the in-mine test data



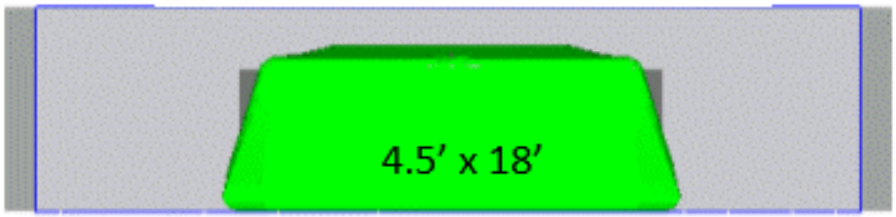
The mine dimensions of the validated model were adjusted and the model was used to examine a few concerns related to heat buildup in RAs

- Effect of the heat input variation method used during RA testing on resulting RA temperature
- Effect of initial mine air and strata temperatures on resulting RA temperature
- Ability of OMSHR simulated miners to represent real miners
- Mechanisms of heat loss for RA occupants

Original Mine Dimensions



Modified Mine Dimensions



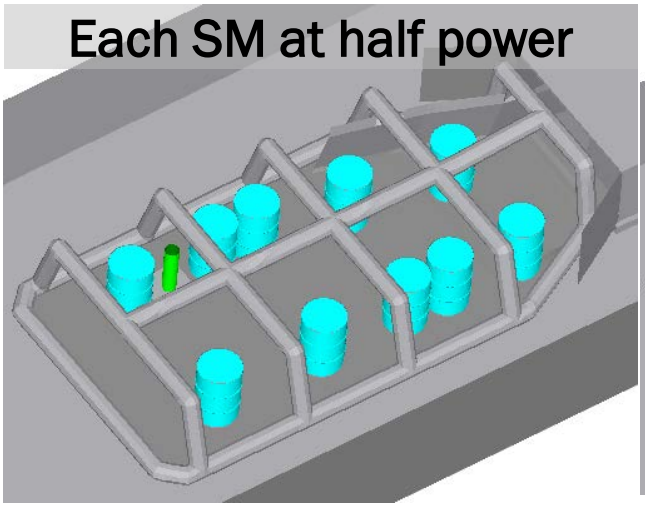
The effect of three heat variation methods were examined using the validated model

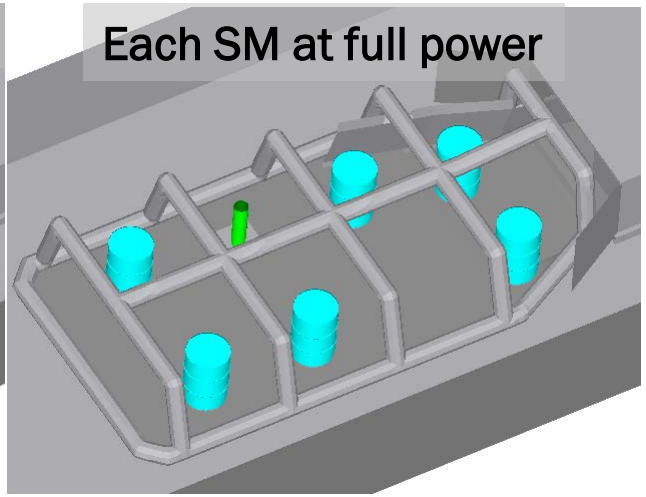
Method 1
- RA at full capacity
- Reduce power to each simulated miner
- Easiest to vary heat input (use variAC)
- Least accurate

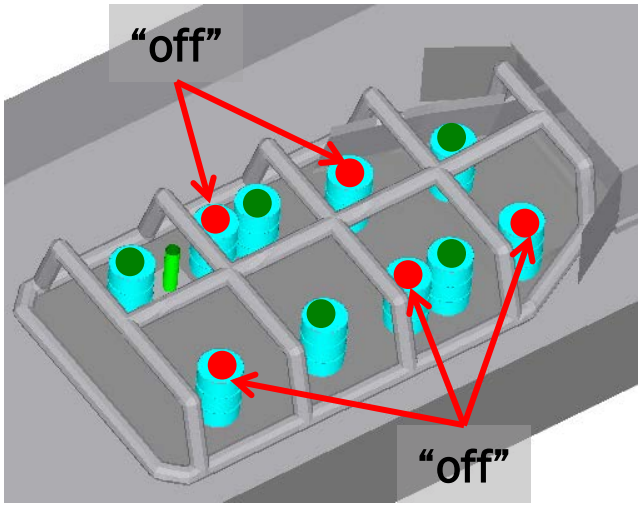
Method 2
- RA at desired capacity
- Each simulated miner provided full power
- Most time-consuming
- Most accurate

Method 3
- RA at full capacity
- Desired number of simulated miners "on"
- Remaining simulated miners "off"
- Compromise between time and accuracy

Example: 10-person RA at half capacity (5 miners)







The method of varying the heat input had minimal effect on the final dry-bulb temperature

Heat Variation Method	Final Interior Dry-bulb Temperature for Number of Simulated Miners at Initial Mine Air and Strata Temperature		
	7 Miners, 65°F	5 Miners, 70°F	3 Miners, 75°F
Method 1: Volume Knob	82.0	82.2	81.9
Method 2: Remove Non-powered Simulated Miners	82.1	82.6	82.8
Method 3: Leave Non-powered Simulated Miners	82.0	82.1	82.4

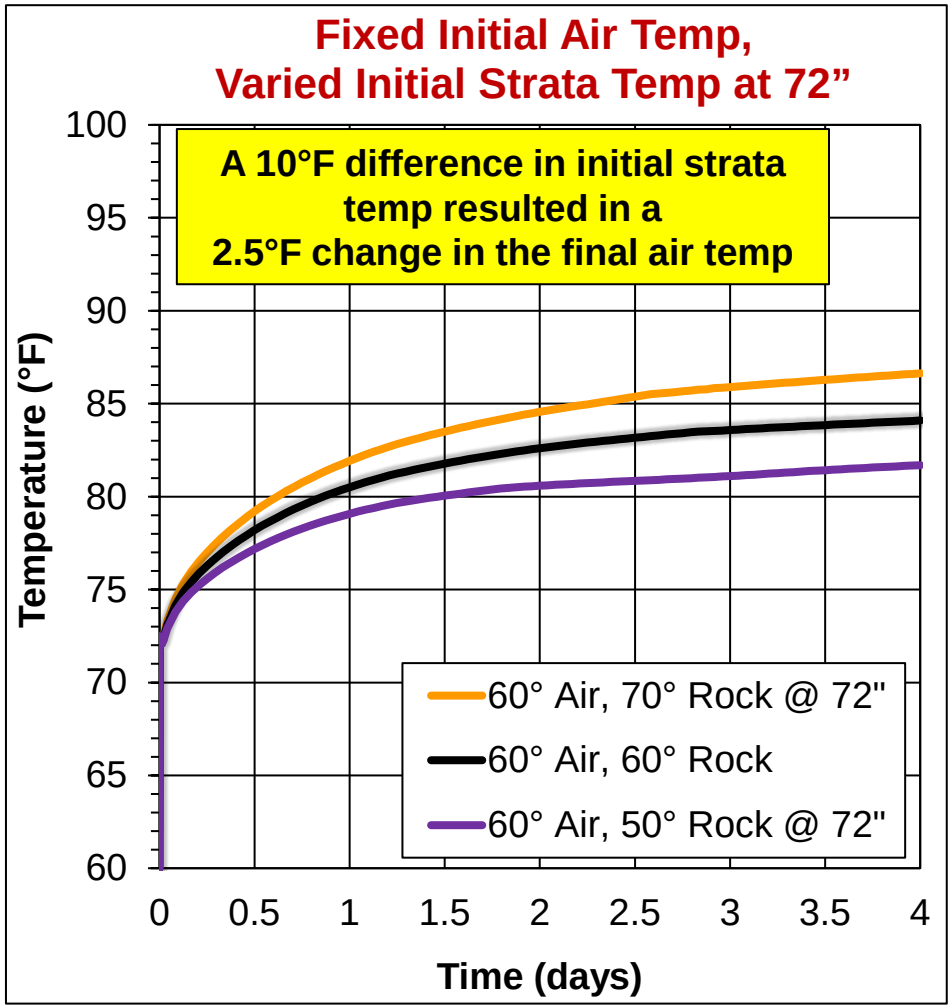
Note: Results from simulated miners with dry heat input

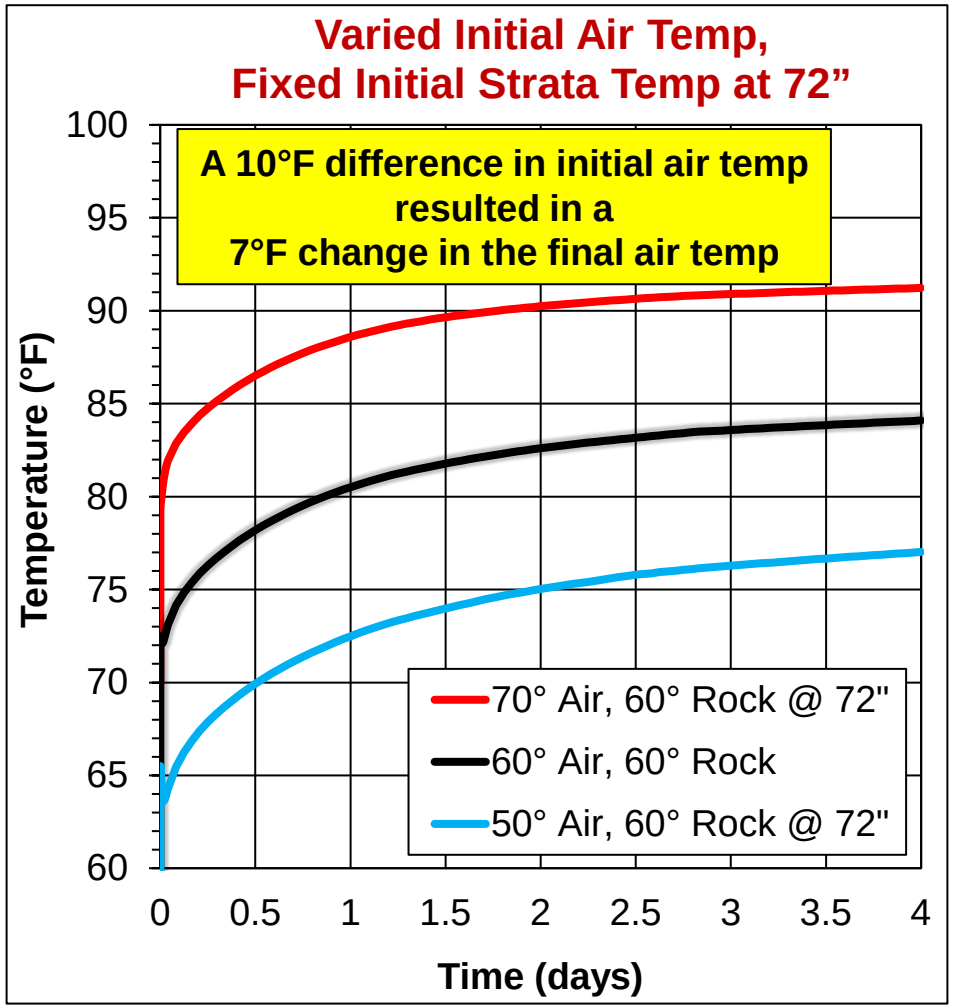
The effect of the initial mine air and strata temperatures was examined using the validated model

- In practice, mine air temperature has been used as the governing factor
- Must understand how temperature differences between mine air and mine strata influence results
- Examined results for a range of initial mine air and mine strata temperatures

Initial Mine Air Temperature (°F)	Initial Mine Strata Temperature at 6' (°F)
60 (fixed)	50, 60, 70
50, 60, 70	60 (fixed)
Note: Linear temperature gradient assumed from strata surface to 6' depth	

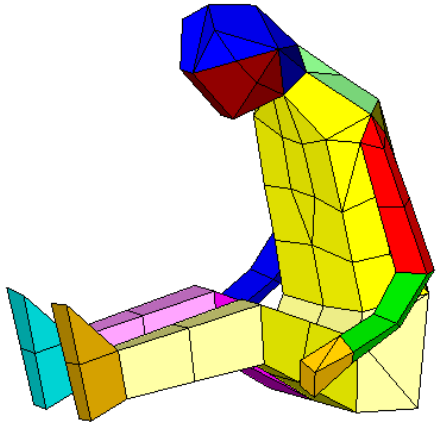
Simulations show the RA internal air temperature is affected by both the initial mine air temperature and the initial mine strata temperature

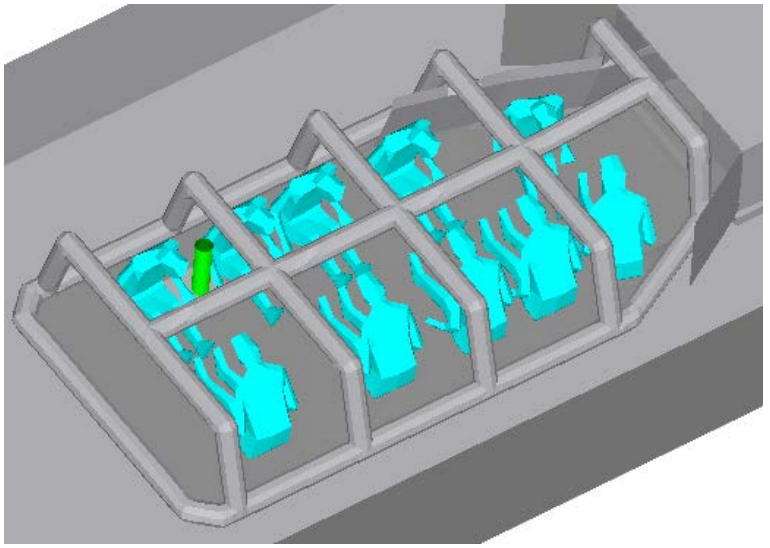




ThermoAnalytics' Human Thermoregulation Model was used to benchmark performance of OMSHR simulated miners and to examine RA occupant heat loss

- The HTM includes:
  - metabolic heating
  - shivering
  - vasomotion
  - sweating
  - respiration





For conditions that result in apparent temperatures near 95°F, the model shows simulated miners yield similar results to the "real" miners as modelled with the HTM

Heat Input	Initial Mine Air and Strata Temperatures Set to 60°F			Initial Mine Air and Strata Temperatures Set to 65°F		
	Interior Air Temp	Relative Humidity	Apparent Temp	Interior Air Temp	Relative Humidity	Apparent Temp
"Real" miners	81.5°F	87.8%	89.4°F	85.5°F	92.3%	104.7°F
Simulated miners, dry	83.6°F	NA	-	88.6°F	NA	-
Simulated miners w/ moisture	81.4°F	80.2%	87.4°F	86.1°F	80.0%	100.1°F

Note: (1) Simulated miners modeled to provide 1 L of H_20 per miner per day.

(2) "Real" miners averaged ~1.8 L of H_20 per miner per day for final AT of 95°F.

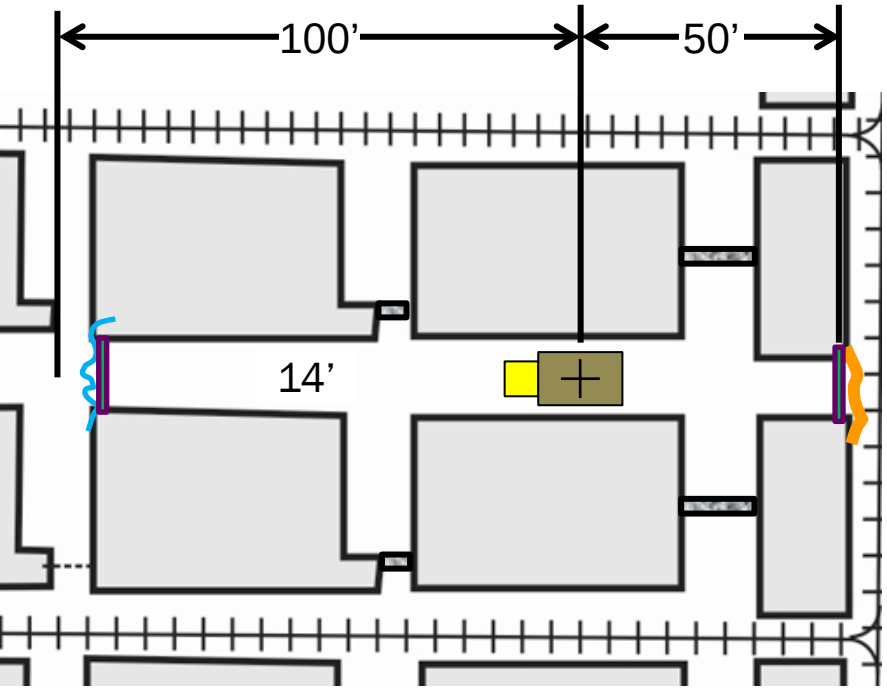
In 2014, OMSHR began an effort to demonstrate an approach to determine occupancy derating for RAs that uses test data combined with thermal simulation

- Tested a production, 23-person (15 ft^2/miner) tent-type RA in OMSHR Experimental Mine
- Contracted ThermoAnalytics, Inc. to develop a validated thermal simulation model of 23-person RA as tested in OMSHR Experimental Mine
- Validated model will be used to determine number of miners that cause RA to reach 95°F AT for
  - A range of mine air and mine strata temperatures using strata composition of Experimental Mine
  - Measured mine air and mine strata temperatures and strata composition from real mines

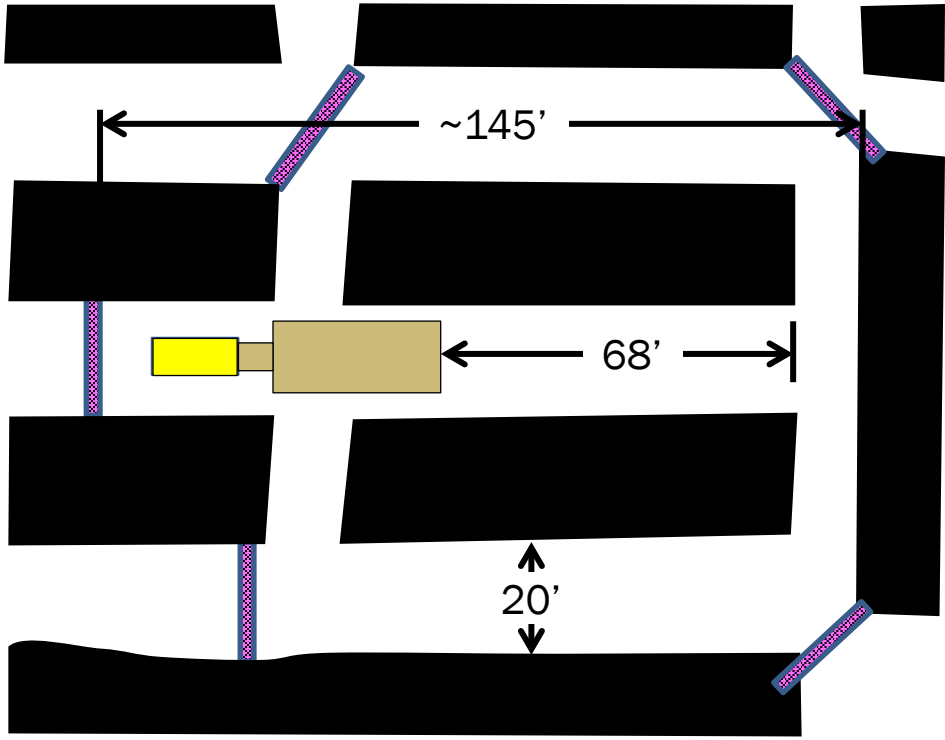
OMSHR simulated miners were modified to increase moisture generation (latent heat) to ~1.8 L/day in conditions of 80°F and 80 to 85 %RH

Test area for 2014 tests more similar to real RA installations than 2013 tests

2013 Test Area in Safety Research Coal Mine



2014 Test Area in Experimental Mine



Automatic VARIACs were used to control the power (heat input) delivered by the simulated miners

- VARIACs set to deliver total of 144.5 W/SM
  - 117 W/SM for metabolic heat
  - 27.5 W/SM for CO_2 scrubber heat (soda lime)

Note: Previous tests used 167 W/SM; 117 W/SM for metabolic heat and 50 W/SM for CO_2 scrubber heat)

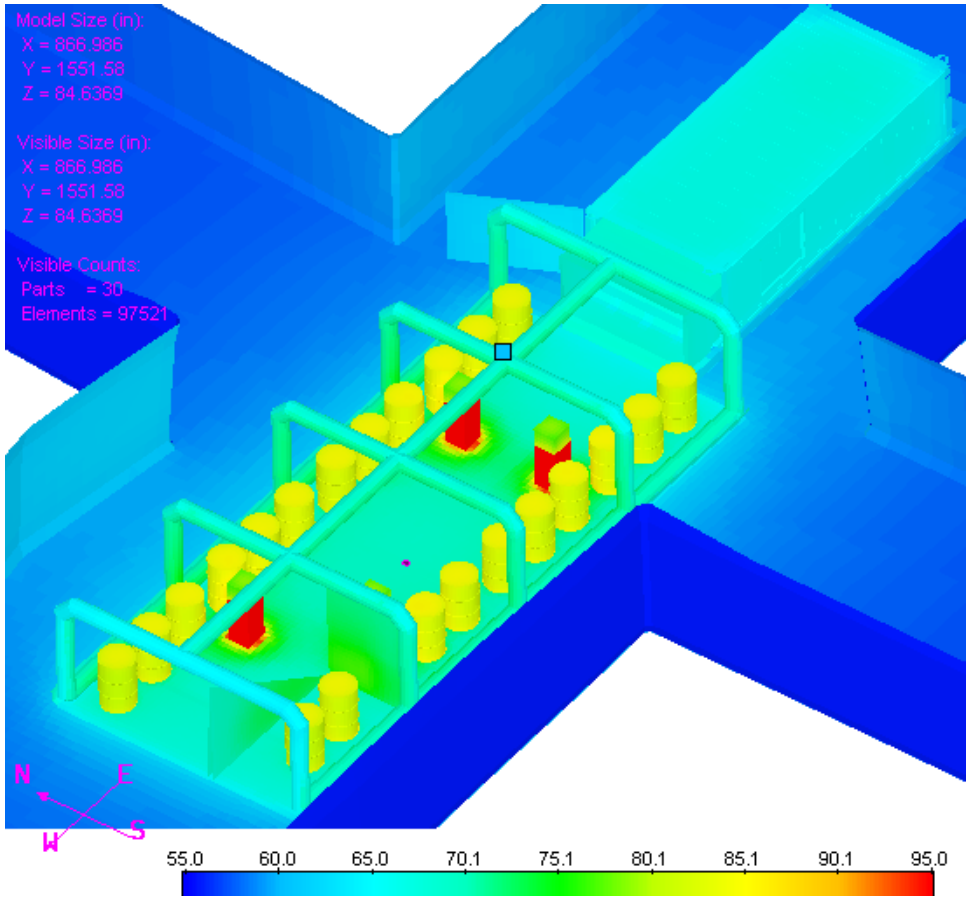
Six in-mine heat and humidity tests were conducted from over four months from 8/2014 through 12/2014

Test	Test Condition	# of SMs	Total Heat Input (W)
1	Full capacity (15 ft^2/miner), mine at "natural" temperature, w/moisture	23	3324
2	Full capacity (15 ft^2/miner), mine at "natural" temperature, dry	23	3324
3	Full capacity (15 ft^2/miner), mine temperature elevated, w/ moisture	23	3324
4	Full capacity (15 ft^2/miner), mine at "natural" temperature, w/moisture, w/ 2600 CFM fresh air	23	3324
5	Full capacity (15 ft^2/miner), mine at "natural" temperature, w/moisture, cryogenic air supply	23	3324
6	"As sold" capacity, mine at "natural" temperature, w/moisture	30	4335

With these test conditions, the preliminary heat and humidity results from the 2014 testing indicate that :

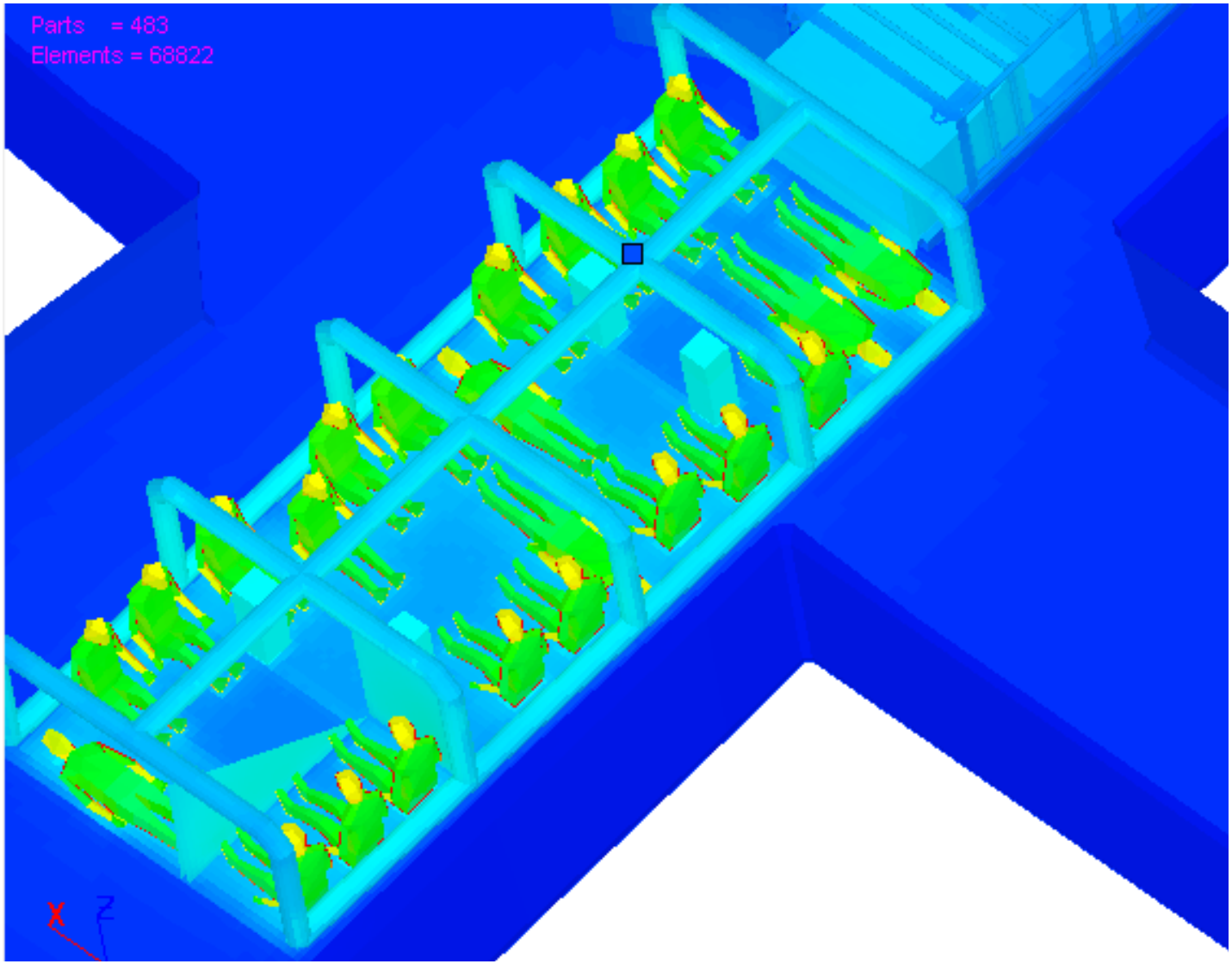
- For the baseline 23-person test, the RA air temperature increased from 57°F to 74°F (17°F), and the RH reached 94%
- The RA air temperature increased by 17°F for the 23-person "wet" test and 19°F for the 23-person "dry" test
- Preheating the mine air by 5°F had no effect on either the RA air temperature rise or final RH
- Providing 2600 CFM of fresh air had little effect on the RA air temperature rise (-0.2°F) or the RH (-1 %)
- For the 30-person test, the RA air temperature increased from 58°F to 80°F (22°F), and the RH reached 91%
- The temperature rise per SM was 0.74°F/SM for the 23-person test and 0.73°F/SM for the 30-person test

The thermal simulation model has been built, and validation and updating are underway



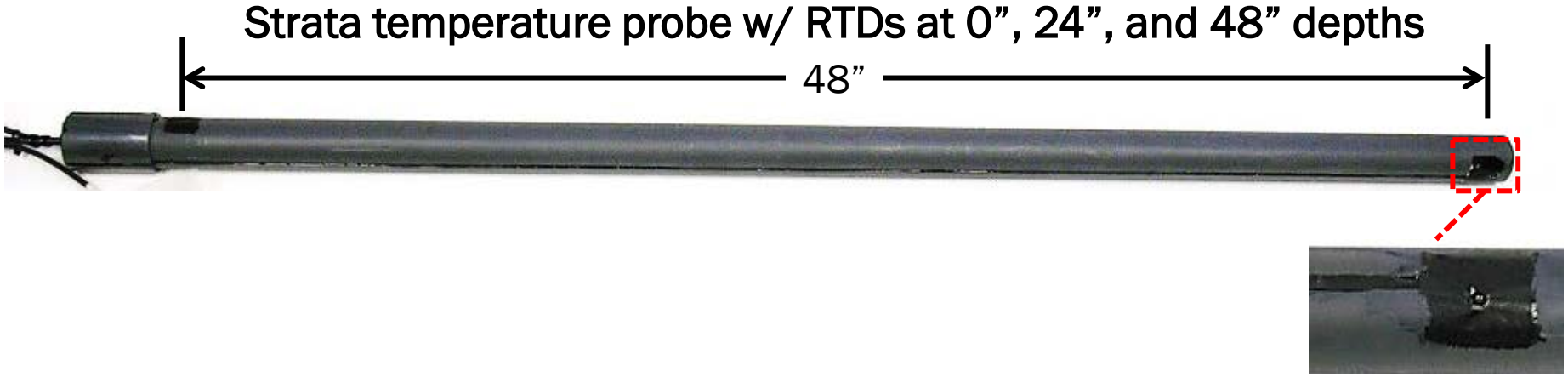
- The model predicted the average RA air temperature to within 1°F
- The model predicted the mine strata surface temperatures to within 2°F
- To improve the model, core samples will be sent for material property testing

The validated thermal simulation model will be used to determine the derated capacity and to further examine the performance of the OMSHR-developed simulated miners



Mine air and strata temperature data is being collected at mines across the US

- Examine temperature variations due to location, mine depth, and/or mine geology
- Use measured temperatures with mine strata composition to examine variation of RA capacity with season, geographic location, etc.



Five mines across the US have agreed to support this effort; probes are currently installed in four of the five mines

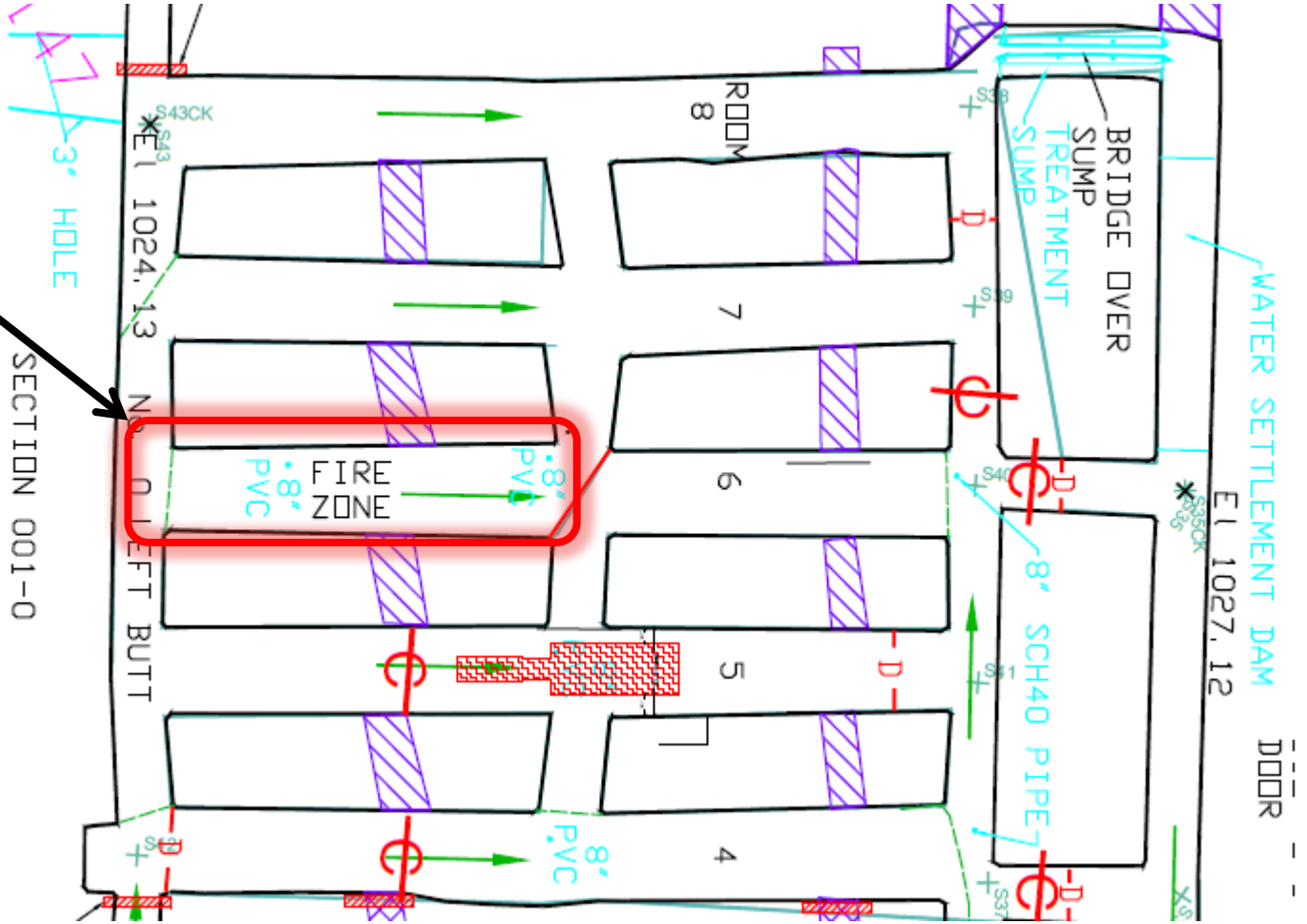
Additional mines sites desired

In 2015, OMSHR plans to conduct in-mine heat and humidity research on a 6-person rigid RA following the 2014 test protocol

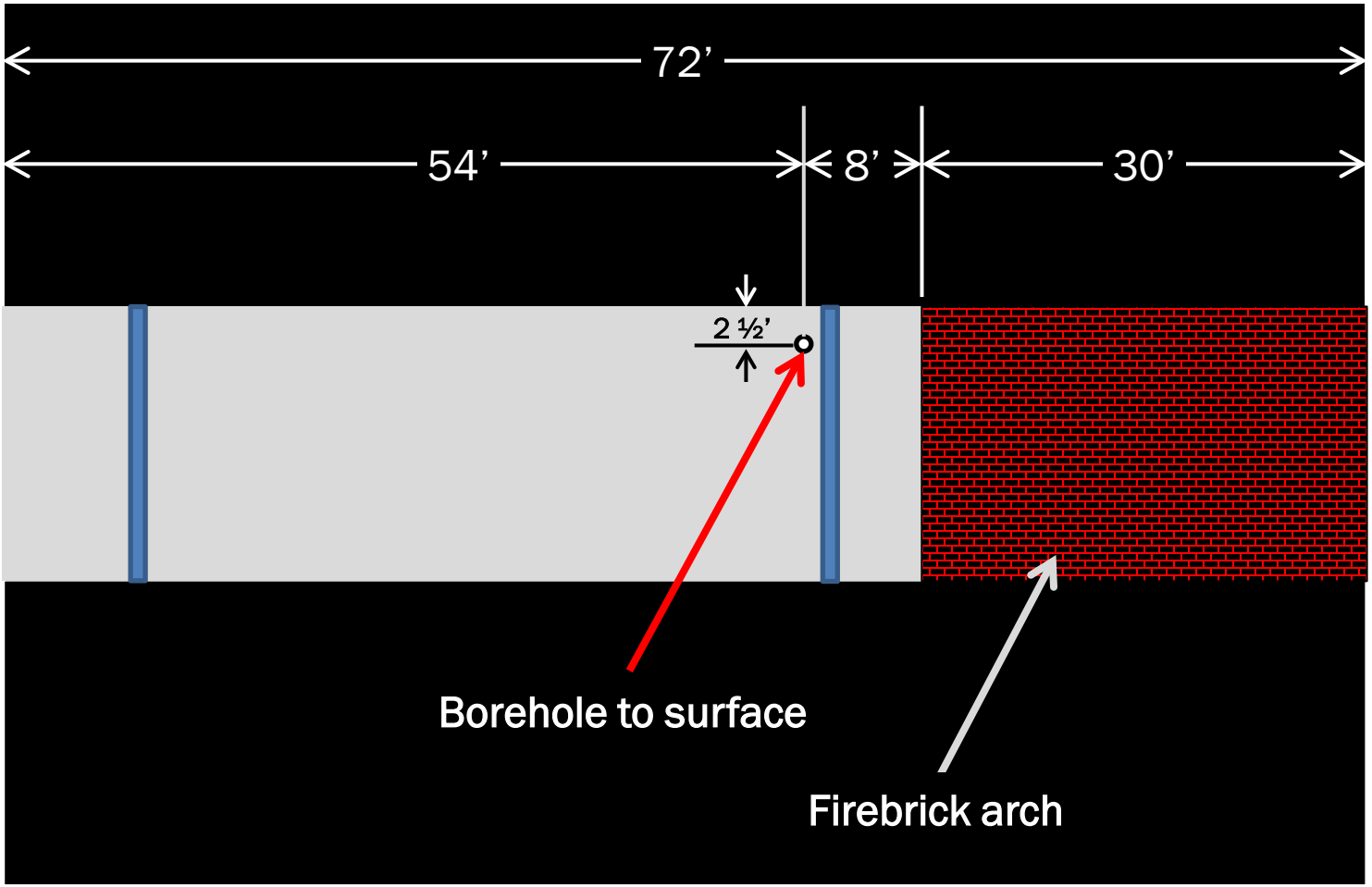
- Conduct in-mine heat and humidity testing
- Develop validated thermal simulation model
- Investigate occupancy derating

OMSHR also plans to construct a BIP RA in its Experimental Mine in 2015 to examine air delivery, purging, and heat and humidity

Planned BIP RA Location



OMSHR plans to conduct purging tests to examine ingress of contaminated air, and heat testing to examine apparent temperature following previously used protocols



OMSHR

Office of Mine Safety and Health Research

Questions?

Refuge Alternatives Partnership Meeting
February 10, 2015