ENCLOSURE D

AB79-COMM-10-4

Discussion Points/Takeaways

AB79-COMM-10-4

Topics of discussion

1. Modeling and testing should include the following considerations:
    a. Active cooling
    b. Effects of SCSRs
    c. Effect of higher ambient temperature in the mine
2. The definition of the post-accident environment needs to be investigated
3. There is a desire for more timely publication of NIOSH research findings and results.
4. There is a desire for models and modeling results to be shared with the industry to allow mine operators to reconcile NIOSH results, manufacturer claims, and MSHA findings.
5. There is a desire for a standard testing protocol for RA evaluations to allow for evaluations to be compared between mines or chamber manufacturers.
6. There is a desire for a standardized methodology for determining the ambient temperature in a mine.
7. The assumptions about metabolic heat input should be re-examined.
8. The threshold for and methods of determining apparent temperature should be re-examined
9. NIOSH and MSHA need to work together and communicate openly to ensure that the 2018 compliance deadline is met.
10. A holistic solution needs to be considered: i.e. use boreholes, compressed air lines, built in place, and mobile chambers.
11. For protected compressed air lines, discussion included:
    a. PVC should not be used due to brittle nature.
    b. Overhead and maintenance cost should be considered.
    c. Timeline of research and development needs to be consider the compliance dates.
    d. The design of a mine-wide system should be developed rather than just a single refuge chamber. Must every RA be used at one time?
    e. Post disaster survivability and utility of compressed air lines should be examined.
12. For Safe Air system, discussion included:
    a. Methods of ensuring air quality
    b. Consideration of blower system trade off of depth and hole size
    c. Feasibility/cost comparison of compressed air vs. blower systems
    d. Concerns of physical and legal access on the surface
13. For cryogenic air supply, discussion included:
    a. Need to consider maintenance, reliability and permissibility of the cryocooler
    b. How long after power is lost could the system function?
    c. The timeline for MSHA approval needs to be considered with regard to the 2018 compliance date.
    d. The availability of liquid air at the mine site needs to be addressed
14. For built in place chambers, discussion included:
    a. Do built in place chambers require airlocks and purging systems?

Takeaways from Heat & Humidity Discussion

1. Should include in modeling and testing: *
   - Active cooling
   - Effects of SCSRs
   - Effect of higher ambient temperature
   - Impact of apparent temperature standard
2. Definition of post-accident environment
3. Timely dissemination of research results
   - Publication of NIOSH publications
   - Process through which models and modeling data can be shared with all, so mine operators can interact with suppliers

Takeaways from Heat & Humidity Discussion (cont.)

4. Develop standard testing protocol for RA evaluations to allow evaluations to be compared *
5. Develop standardized method for measuring/determining mine ambient temperature (where in mine is it measured? With ventilation/power?)*
6. Consider the reasonableness of:
   - Heat load per barrel person
   - Threshold and method of calculating 95 AT *
7. Work to ensure that NIOSH/MSHA are working together with the 2018 MINER Act date in mind.

Takeaways from Compressed Air Line Discussion

1. Don't use PVC
2. Don't forget O&M of the systems
3. Think about scheduling and pacing of ongoing efforts with 2018 date in mind
4. Need to think about the design of a mine-wide system and not just for a single RA. Must system be designed for every RA to be used simultaneously?
5. Post-disaster survivability/utility of compressed air lines *
6. Need to think holistically – use boreholes, compressed air lines, BIP, mobile, etc. **
7. Agencies need to talk to each other – Dr. Wade will discuss with Joe Main and cooperation will continue at working level.

Takeaways from Safe Air System Discussion

1. Consideration of a blower system trade off of depth vs hole size
2. Feasibility/cost comparison of compressed air vs. blower systems
3. Concerns of physical/legal access on the surface (case by case, airlift unit to borehole? How do you ensure air access? Legal access from property owner? Drill after the event – with compressed air cylinders?) *
4. What happens in the event of equipment (blower) failure?

Takeaways from Cryogenic Air Supply Discussion

1. Need to consider maintenance, reliability, and permissibility
2. How long after "end of power" could the system function?
3. Consider the path to Part 7 approval
4. What about the availability of liquid air at the mine site?
5. Production of liquid air on site?
6. Application to BIP?

Takeaways from BIP RA Discussion

1. Do the San Juan RAs require an airlock or purging?
2. Clarification of what doors/stoppings are available? – MSHA website.
3. Planned NIOSH research on BIP to start next month with construction of BIP RA in Experimental Mine
4. Incorporating into mine ventilation design – ventilating into entry? (issue to mine rescue teams? does it feed fire?) Should air exhaust to surface?
5. Is built-in air supply acceptable, or do you need boreholes?

Other issues

- Communication to the surface
  - Protection
  - Secondary systems (MF, TTE) vs. Primary systems
  - Ongoing extramural NIOSH research on improving TTE (antenna design)
  - Method for miners to signal (if not talk) from inside a mobile chamber
  - Should miners enter chamber if comm is unavailable?
  - Communicating with SCSR
- Re-examine Part 7 for BIP rather than mobile chambers?
- Secondary events
  - Risk analysis
  - Standardized test method/protocol needed
- Acceptance by miners
  - Training, decision making
- CO concentration – should entire chamber be purged?
- Review volume/floor space requirements?
  - Re-examine for active cooling vs. passive cooling
- Re-examine apparent temperature methods/standards (ISO WBGT suggested)
- Opportunity for fresh perspective on issues

Priorities for Heat and Humidity

- Should include in modeling and testing: *
  - Active cooling
  - Effects of SCSRs
  - Effect of higher ambient temperature
  - Impact of apparent temperature standard
- Develop standard testing protocol for RA evaluations to allow evaluations to be compared *
- Develop standardized method for measuring/determining mine ambient temperature (where in mine is it measured? With ventilation/power?)*
- Consider the reasonableness of:
  - Heat load per barrel person
  - Threshold and method of calculating 95 AT *

Priorities for Compressed Air Line

- Post-disaster survivability/utility of compressed air lines *
- Need to think holistically – use boreholes, compressed air lines, BIP, mobile, etc. **

Priorities for Safe Air System

- Concerns of physical/legal access on the surface (case by case, airlift unit to borehole? How do you ensure air access? Legal access from property owner? Drill after the event – with compressed air cylinders?) *

Cryogenic Air Supply

- All items brought up during discussions (refer to slide 7) are being addressed through BCS Life Support LLC research and NIOSH contracts

MSHA Refuge Alternative Request For Information

- Both Reg Richards and Steve Gigliotti stated at the partnership meeting that MSHA encourages interested parties to submit comments in response to the Refuge Alternative Request For Information (RFI) that is set to close on April 2, 2014.
- Responses to the RFI do not need to be limited to the questions asked if a commenter would like to address other issues related to refuge alternatives.

http://www.msha.gov/REGSRFI.asp

NIOSH Refuge Alternatives Training

- All training materials that were at the partnership meeting can be found on the OMSHR website:

http://www.cdc.gov/niosh/mining/content/refugechambers.html

- Further information on refuge alternatives training can be obtained by contacting:

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412-386-6648
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Refuge Alternative NIOSH Contact Information

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OMSHR

Office of Mine Safety and Health Research

An Overview of OMSHR's History of Refuge Alternatives Research

Dr. RJ Matetic

Director, Division of Mining Research Operations

Refuge Alternatives Partnership Meeting
February 10, 2015

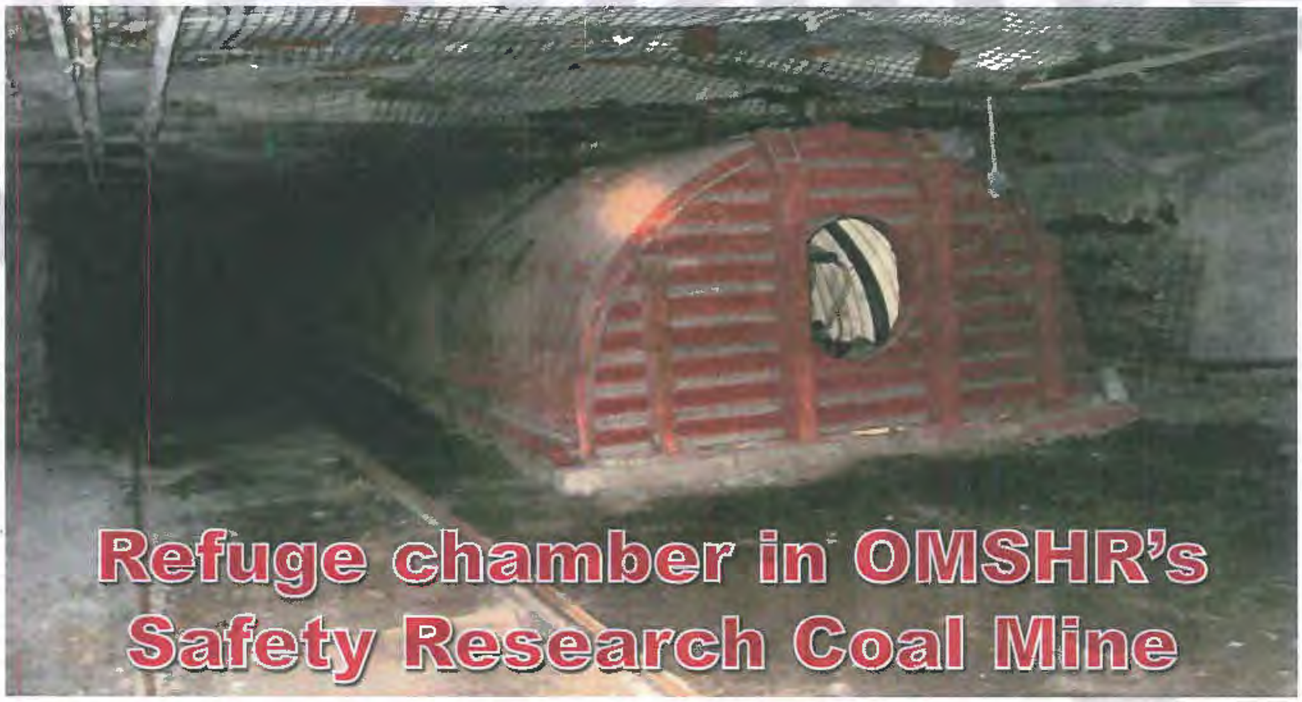
AB79-COMM-10-4

Outline

- Pre-MINER Act BOM refuge alternatives research
- MINER Act introduction
- Post-MINER Act NIOSH refuge alternatives research

The Bureau of Mines funded five major contract efforts between 1970 and 1983

- Addressed mine rescue and survival
- Examined explosion-proof bulkhead design
- Provided guidelines for rescue chambers
- Identified post survival and rescue research needs



In 2006, three mine tragedies occurred and the MINER Act was passed

- January 2: an explosion occurred at Sago Mine
  - 12 miners killed; 1 miner survived
- January 19: a belt fire occurred at Alma Mine
  - 2 miners killed; 10 miners escaped
- May 16: the Mine Improvement and New Emergency Response (MINER) Act was introduced
- May 20: an explosion occurred at Darby Mine
  - 5 miners killed; 1 miner injured
- May 24: Senate unanimously passed the MINER Act
- June 7: House passed the MINER Act by a vote of 381–37
- June 15: President George W. Bush signed the MINER Act into law

The MINER act included two RA-related mandates for NIOSH:

- "NIOSH shall provide for the conduct of research, including field tests, concerning the utility, practicality, survivability, and cost of various refuge alternatives in an underground coal environment"
- "No later than 18 months after the date of enactment of this Act, NIOSH shall prepare and submit to the Secretary of Labor, the Secretary of Health and Human Services, the Committee on Health, Education, Labor, and Pensions of the Senate, and the Committee on Education and the Workforce of the House of Representatives a report concerning the results of the research conducted"
  - Completed December 2007

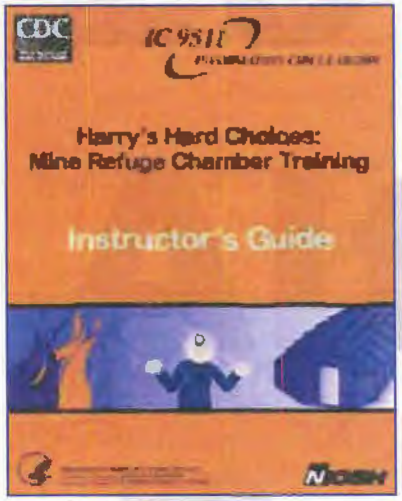
Since the MINER Act was passed, NIOSH has conducted numerous research activities on refuge alternatives

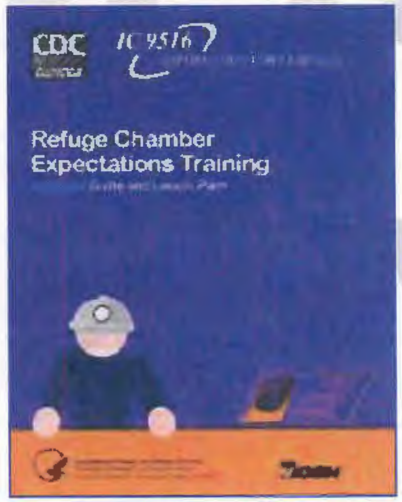
- NIOSH/MSHA Working Group
- Refuge alternatives contract (Foster-Miller)
- Mine curtain survivability system contract (Battelle)
- Explosive forces, debris fields, and anchoring
- Thermal analyses (Raytheon, NASA, O'Donnell, ThermoAnalytics)
- Refuge chamber moving issues
- Best practices world-wide
- Cost estimates
- Location guidance
- Survivability evaluations
- Training issues
- Purging, heat and humidity

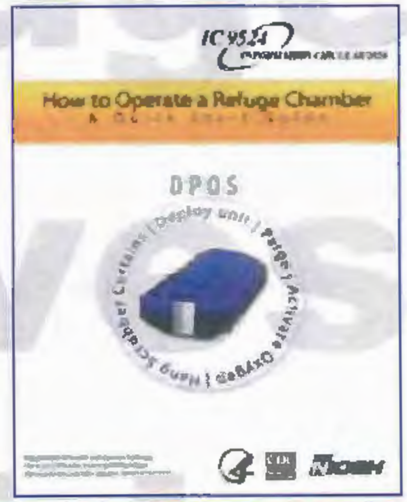
Survivability performance evaluations that examined CO_2 scrubbing, O_2 supply, and heat and humidity over 96 hours were conducted on WV-approved chambers at Lake Lynn Laboratory

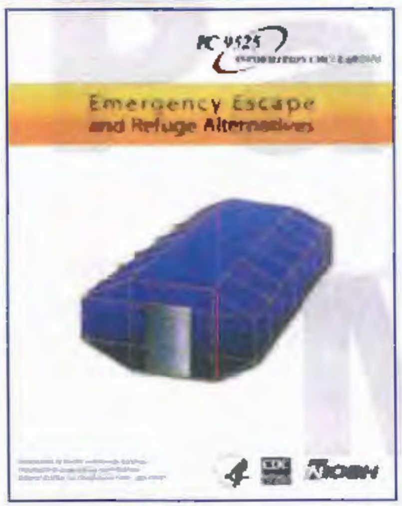
NIOSH has developed extensive refuge alternative training materials

- http://www.cdc.gov/niosh/mining/topics/RefugeChambers.html
- http://www.cdc.gov/niosh/mining/content/refugechambers.html



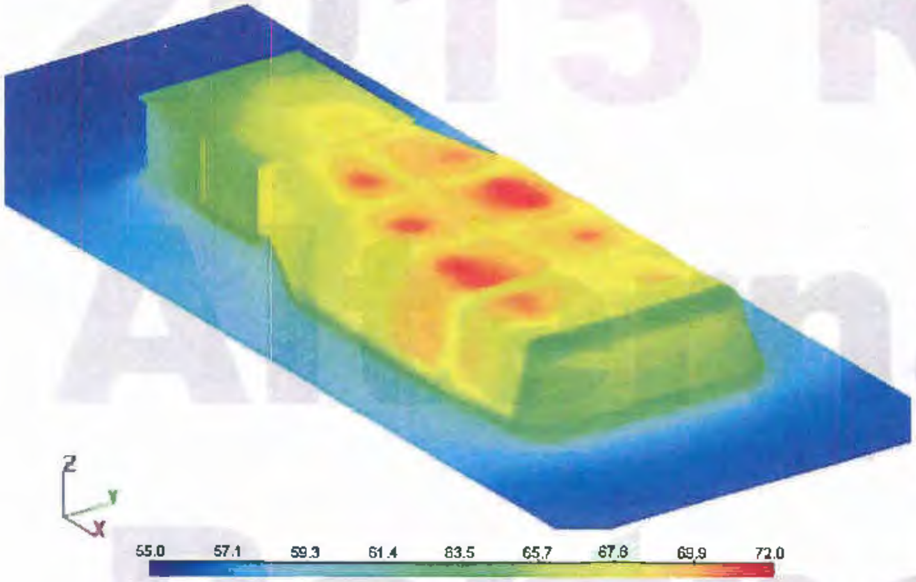






NIOSH continues to perform RA-related research

Heat & Humidity



Built-in-place

OMSHR

Office of Mine Safety and Health Research

Questions?

Refuge Alternatives Partnership Meeting
February 10, 2015

CDC Workplace Safety and Health NIOSH

OMSHR

Office of Mine Safety and Health Research

Overview of Prior OMSHR Refuge Alternatives Research on Purging, Heat & Humidity, and Built-in-place

Dave Yantek

Research Engineer

Refuge Alternatives Partnership Meeting
February 10, 2015

CDC Workplace Safety and Health NIOSH

Outline

1. Overview of RAs types in use
2. Prior OMSHR research on mobile RA purging
3. Prior OMSHR research on mobile RA heat and humidity
4. Prior OMSHR research on built-in-place RAs

Tent-Type Mobile RA

- Inflatable tent contained within a rigid metal box
- Miners deploy the tent and stay primarily in the tent
- Provide oxygen via compressed oxygen cylinders
- Largest holds up to 36 miners
- Roughly 1,400 tent-type RAs in US coal mines

Rigid Mobile RA

- Rigid metal structure
- Miners enter the steel box and stay in the steel enclosure
- Provide oxygen via compressed oxygen cylinders
- Generally hold fewer miners because of their size limitation
- About 300 rigid mobile RAs in US coal mines

Built-in-Place RA

- Permanent structures
- All BIP RAs in the US are outby the face
- All BIP RAs in the US use boreholes to provide breathable air
- Can be sized to accommodate large number of miners
- Approximately 30 BIP RAs in US coal mines

Prior OMSHR Research on Mobile RA Purging

MSHA Regulations relevant to purging (30 CFR 7.501 to 7.510 and 30 CFR 75.106)

- Require maximum of 10 minutes to deploy and 20 minutes to enter
- Original regs required ability to purge airlock from 400 ppm CO to 25 ppm CO for all groups of entering miners in less than 20 minutes

OMSHR mobile RA purging research focused on two questions:

- How much time is needed to enter through airlocks?
- Can purging systems reduce the CO concentration to safe levels in the allotted time?

Prior OMSHR Research on Mobile RA Purging

OMSHR purging research to address these concerns consisted of the following:

- Reviewing data on post-disaster CO concentrations in mines
- Measuring the time required to enter RA airlocks
- Evaluating the ability of purging systems to reduce CO concentrations in airlocks in the allotted time
- Determining the concentration of contaminated mine air that could result from miners entering an airlock

Prior OMSHR Research On Mobile RA Purging

SF_6 testing to determine amount of contaminated air that could enter an airlock

Key Findings from Prior OMSHR Research On Mobile RA Purging

- Small size of door opening and airlock may prevent miners from entering main chamber within the 20-minute time limit
- Current portable RA purging systems are able to reduce CO concentrations as designed
- The airlock CO concentration could reach up to 60% of the ambient mine air CO concentration as miners enter the RA
  - 10,000 ppm CO outside RA would result in 6,000 ppm CO in airlock

Testing and results discussed in *RI 9694: Investigation of Purging and Airlock Contamination of Mobile Refuge Alternatives*

Prior OMSHR Research on Mobile RA Heat and Humidity

MSHA Regulations relevant to RA heat and humidity (30 CFR 7.501 to 7.510 and 30 CFR 75.106)

- Maintain an apparent temperature (AT) of less than 95°F
- Provide breathable air, food, water, etc. 96 hours
- Provide carbon dioxide scrubbing (generates heat)
- Provide minimum floor space of 15 ft^2 per occupant
- Provide minimum volume of 30 - 60 ft^3 per miner (based on mine height)

OMSHR mobile RA heat and humidity research focused on several questions:

- Do mine air and strata temps change due to heat from an occupied RA?
- Does the test facility significantly affect the internal AT?
- At what mine temp could the interior AT of an occupied RA reach 95°F?
- What occupancy derating might be necessary to prevent an RA from reaching the 95°F AT limit?

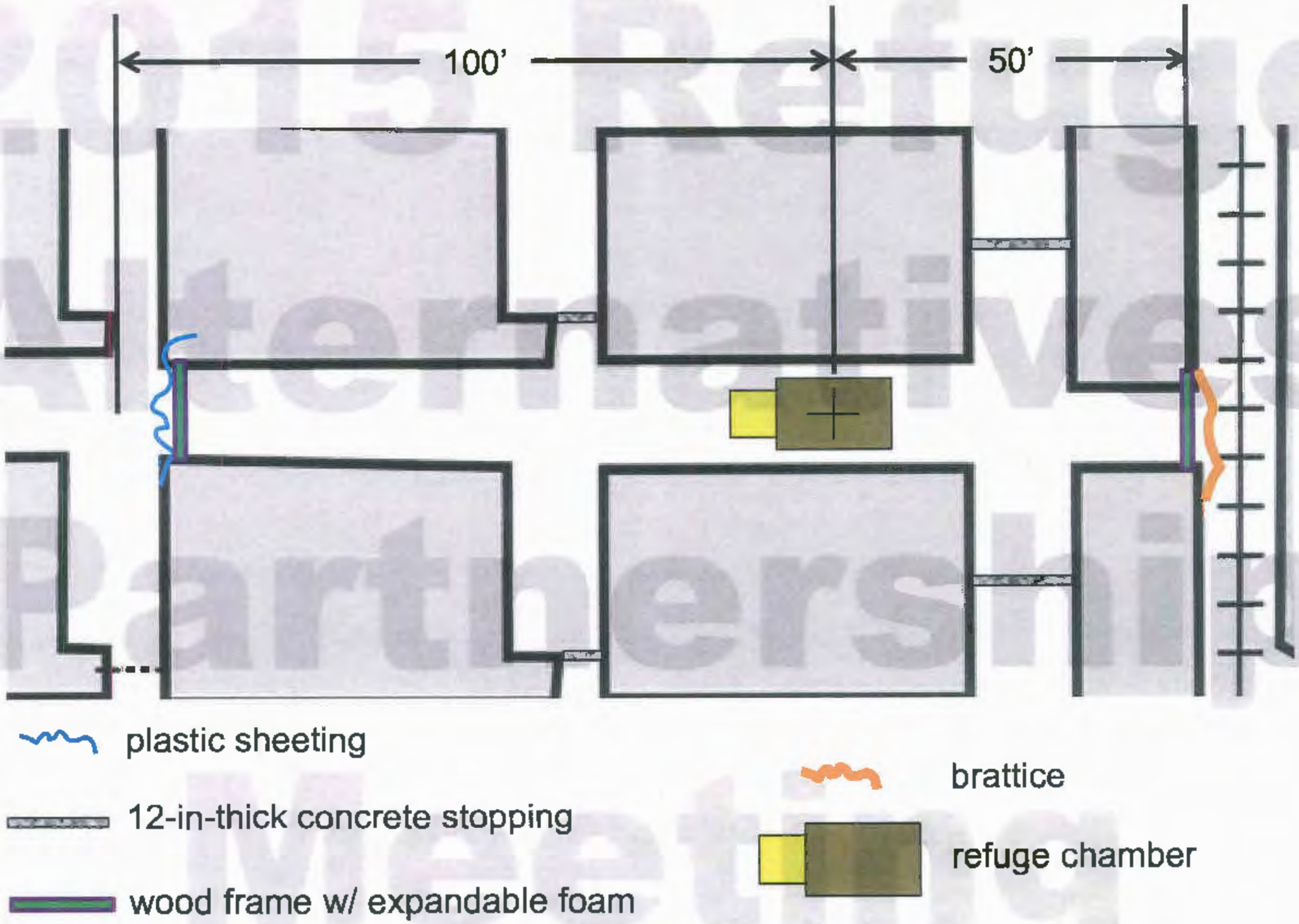
Prior OMSHR Research on Mobile RA Heat and Humidity

- 96-hour tests using a 10-man tent-type training RA

High bay, dry

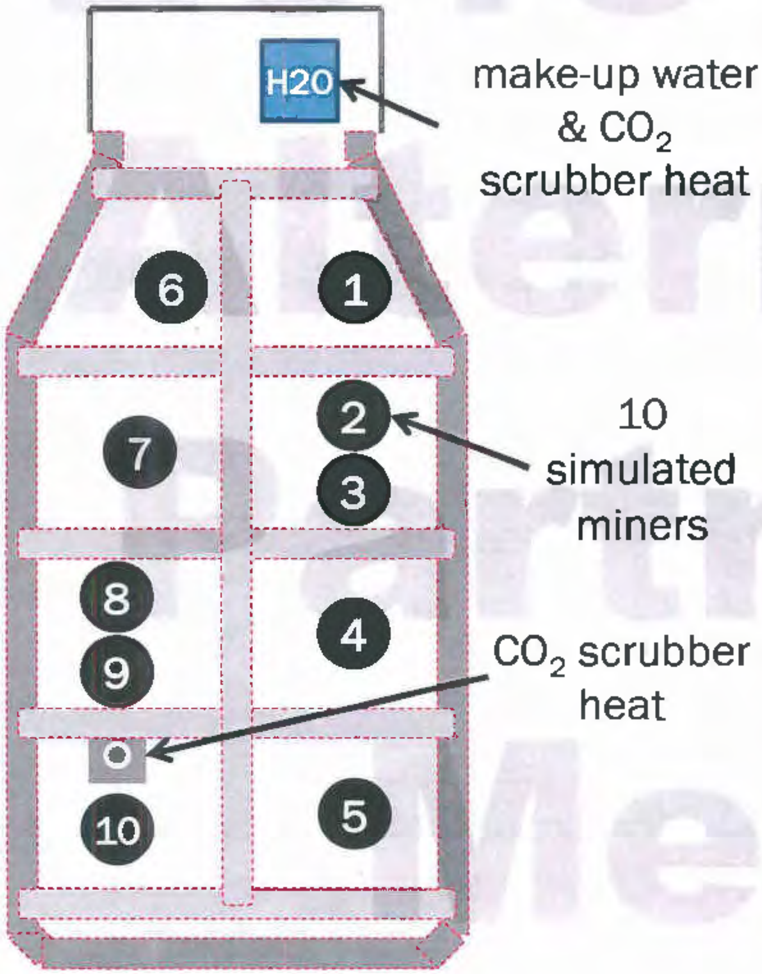
Safety Research Coal Mine, dry & wet

Test Area in OMSHR SRCM



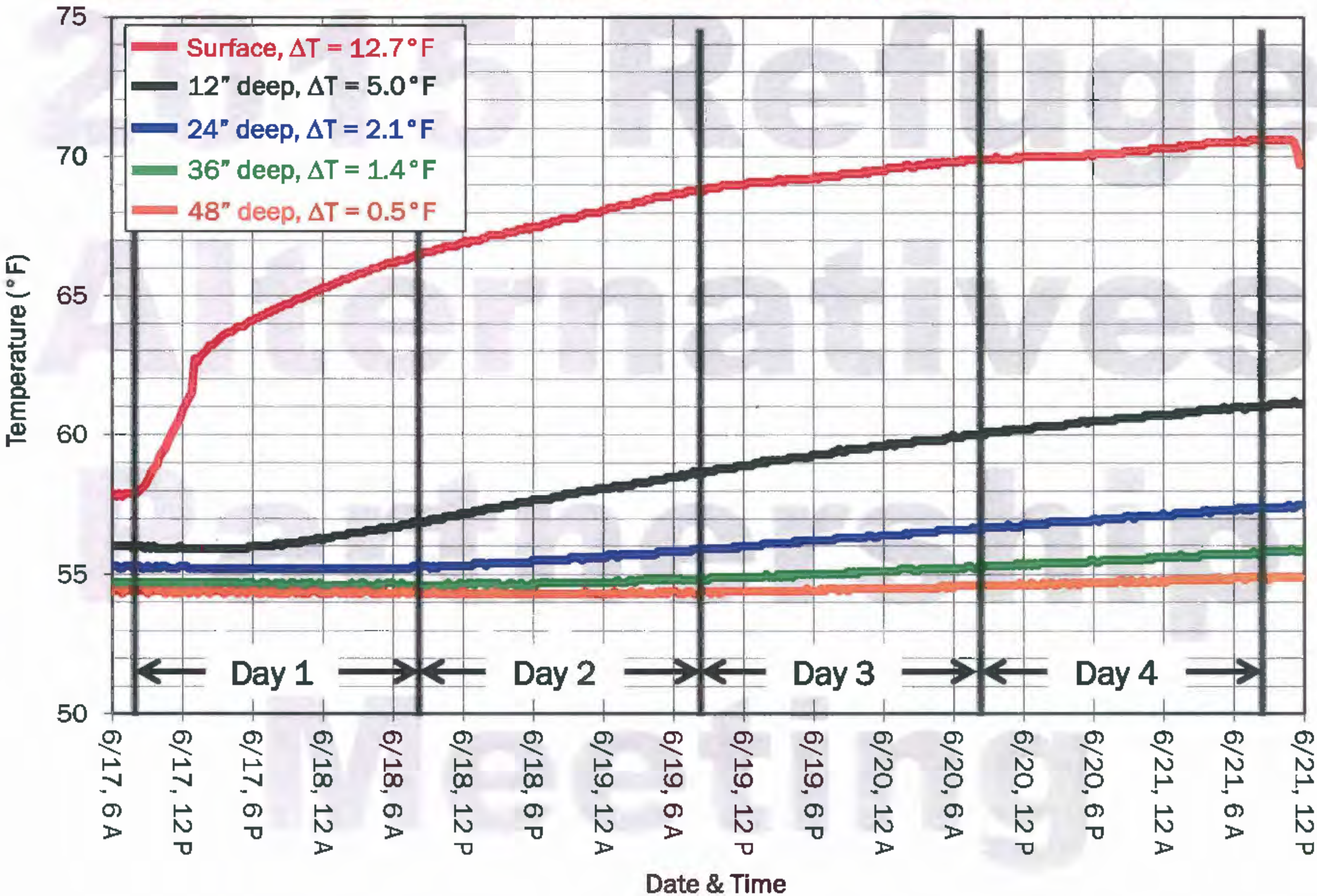
Prior OMSHR Research on Mobile RA Heat and Humidity

- Total heat input of 1670 watts (167 watts/miner) to represent metabolic heat and CO_2 scrubber heat (LiOH)



Prior OMSHR Research on Mobile RA Heat and Humidity

Mine Floor Strata Temperatures Measured Under Tent (Wet SRCM Tests)



Prior OMSHR Research on Mobile RA Heat and Humidity

Apparent Temperature Results from Wet SRCM Tests

- The internal air temperature increased by 22°F and the interior reached 93 %RH
- This temperature increase and %RH would yield the following apparent temperatures as a function of the initial mine ambient temperature

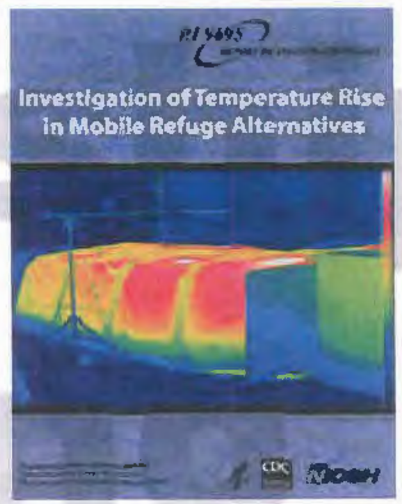
Mine Ambient Temperature (°F)	RA Interior Temperature (°F)	RA Apparent Temperature (°F)
55	77	79
60	82	94
61	83	97
65	87	113

These results are specific to this particular RA, but show the potential for problems

Key Findings from Prior OMSHR Research On Mobile RA Heat and Humidity

- Mine strata temperatures increase over the entire 96-hour duration
- RA heat testing must be done in a facility that mimics an actual mine, or the mine temperature increase must be accounted for by other means
- At initial mine ambient temperatures ≥60°F, the tested, fully occupied RA would exceed 95°F AT and derating would be necessary
- Significant wall and roof condensation and water pooling on the floor occurred during testing

Testing and results discussed in *RI 9695: Investigation of Temperature Rise in Mobile Refuge Alternatives*



Prior OMSHR Research on BIP RAs

MSHA Regulations that present challenges for BIP RAs (30 CFR 7.501 to 7.510 and 30 CFR 75.106)

- Must be within 1,000 ft of each working face and spaced within 1-hour travel distance in outby locations
- Must withstand a blast overpressure of 15 psi for 0.2 seconds and remain airtight
- Must provide 12.5 cfm (750 ft^3/hr) of breathable air or 1.32 ft^3/hr of oxygen per occupant

OMSHR BIP RA research focused on several areas:

- Potential advantages/disadvantages of BIP RAs
- Distance from the working face
- Stopping design criteria to meet 15-psi requirement
- Existing air delivery systems

Prior OMSHR Research on BIP RAs

Potential Advantages of BIP Refuge Alternatives

(Assuming the use of protected compressed air line or borehole)

- Quicker and easier to prepare and operate; no tent to roll out, fewer valves to open, no O_2 controls, may not require CO_2 scrubber
- Miners may not have to wait to enter while airlock is purged of CO
- Order of miner arrival may be less important, not a problem if some miners decide to leave
- May increase chances of communication system survival
- May eliminate heat and humidity issues
- Better chance of surviving a secondary explosion than a tent-type mobile RA
- May eliminate 96-hour ticking clock
- Provide more space per occupant; may reduce psychological & physiological stress

Prior OMSHR Research on BIP RAs

Potential Disadvantages of BIP Refuge Alternatives

- Must be economically viable, must be inexpensive enough to abandon or use reusable stopping/door system
- Not practical to keep within 1000 feet of the face
- Economical stopping & door systems that meet the 15-psi criteria must be developed
- Air delivery systems that meet the 15-psi criteria must be developed


Prior OMSHR Research on BIP RAs

OMSHR-conducted analyses to examine RA-to-face distance

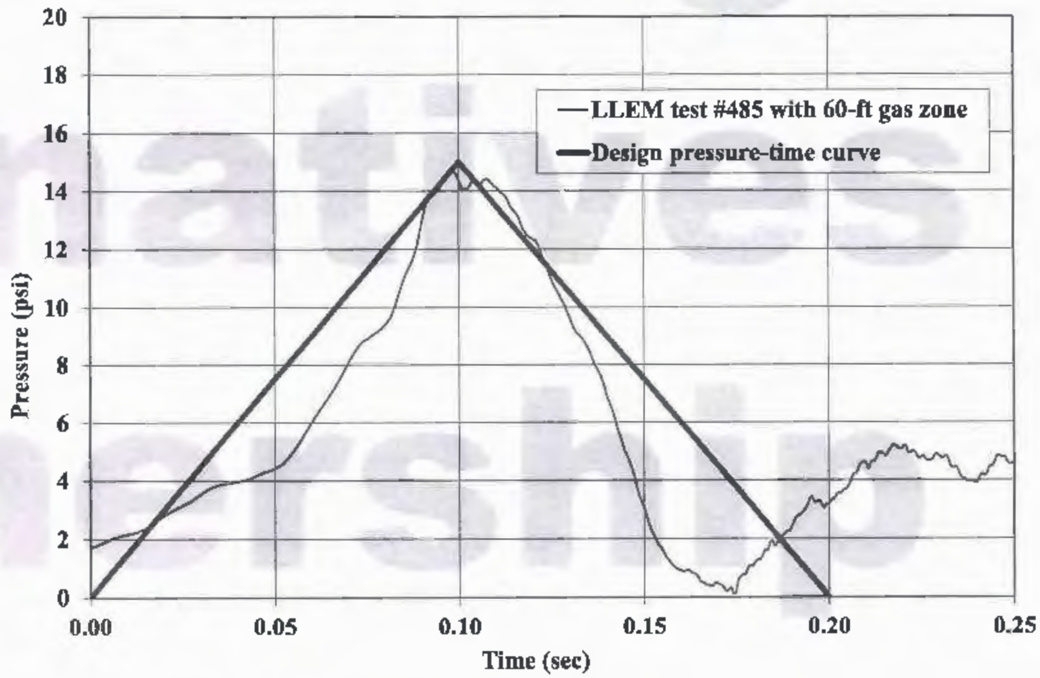
Entry Height	Approach 1: Based on mandated SCSR storage cache locations	Approach 2: Based on worst-case SCSR usage times	Approach 3: Based on NIOSH and BOM established travel times and escape probabilities	OMSHR-concluded maximum RA-to-face distance
< 40 inches	2,200 feet	2,640 feet	NA	2,000 feet
40 to 50 inches	3,300 feet	3,960 feet	NA	3,000 feet
50 to 65 inches	4,400 feet	5,280 feet	6,000 feet	4,000 feet
> 65 inches	5,700 feet	6,480 feet	6,500–7,000 feet	5,000 feet

RAs can be located more than 1,000 feet from the working face, and the distance depends on mine height

Prior OMSHR Research on BIP RAs

RA Stopping/Door System Designs

- To date, only two stopping/door system designs have been approved
- To facilitate the approval process, OMSHR has:
  - Reaffirmed its recommended design pressure-time curve of 15 psi over 0.2 seconds
  - Provided design guidelines for submitting BIP RA stopping/door systems for MSHA approval
  - Design guidelines were adapted from MSHA guidelines for coal mine seal design applications
  - Provided a detailed example of a stopping/door system that meets the 15-psi criteria (including all structural design calculations)



Prior OMSHR Research on BIP RAs

Breathable air delivery systems

- Most BIP RA advantages disappear without a reliable supply of breathable air
- Possible solutions include
  - Borehole to surface
  - Protected compressed air line
- Research is needed in this area

Key Findings from Prior OMSHR Research on BIP RAs

- BIP RAs offer many potential advantages over mobile RAs, but hurdles exist to make them a practical solution
- RAs can be located more than 1000 feet from the working face, and the distance depends on mine height
- Stopping/door system design guideline and example provided

BIP RAs discussed in detail in pending
Report of Investigations
expected to be published Spring 2015

OMSHR

Office of Mine Safety and Health Research

Questions?

Refuge Alternatives Partnership Meeting
February 10, 2015

CDC Workplace Safety and Health NIOSH

OMSHR

Office of Mine Safety and Health Research

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

Dave Yantek

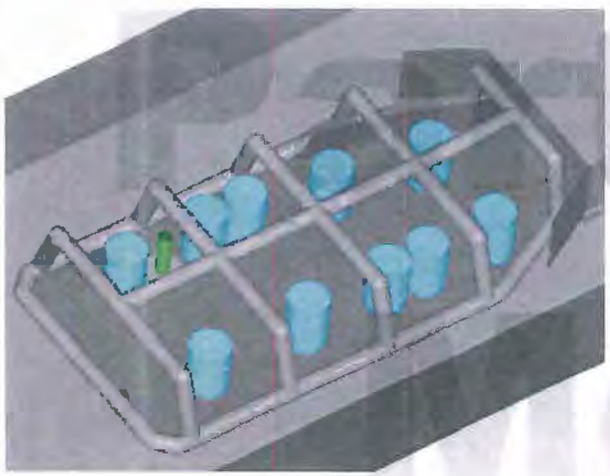
Research Engineer

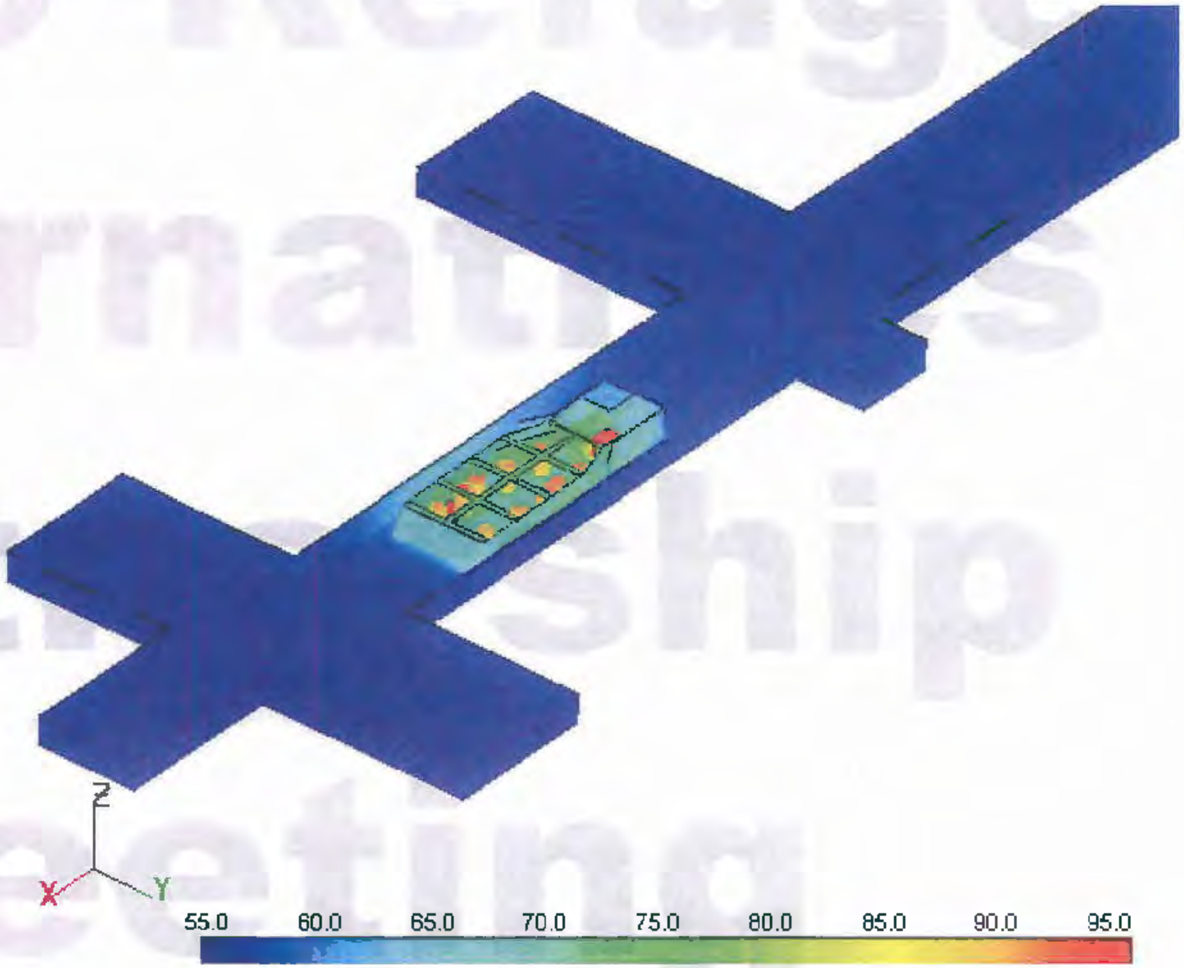
Refuge Alternatives Partnership Meeting
February 10, 2015

Outline

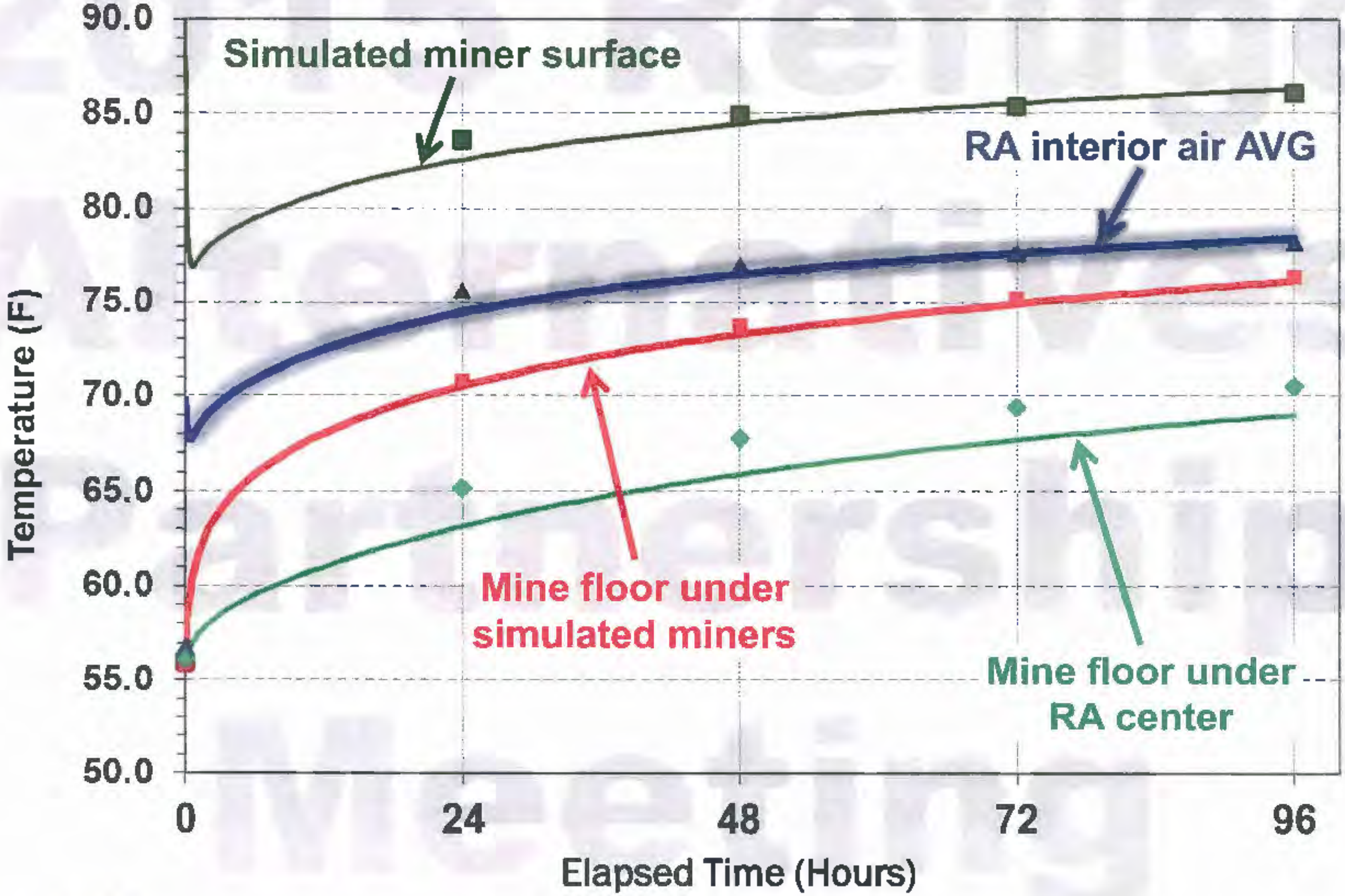
1. Thermal modeling work on 10-person mobile tent-type RA (2014)
2. Demonstration of approach for occupancy derating (2014-2015)
   - Testing
   - Simulation
   - Mine air/mine strata temperature field data
3. Mobile rigid RA heat and humidity (2015)
4. Built-in-place RA research (2015)

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





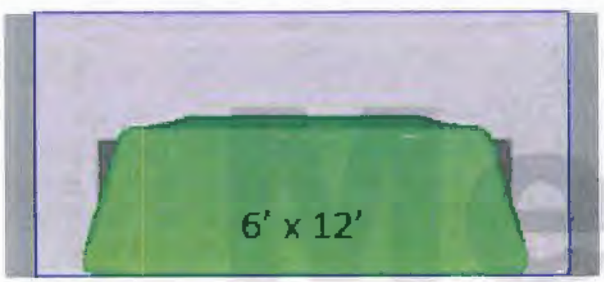
The thermal simulation model showed good agreement with the in-mine test data



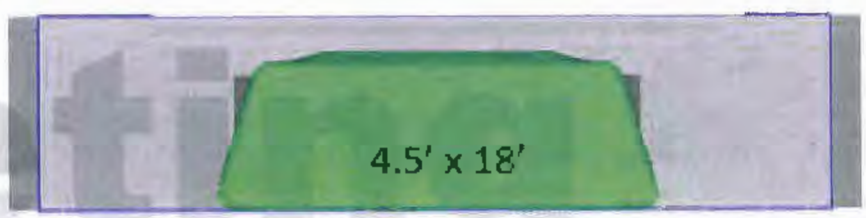
The mine dimensions of the validated model were adjusted and the model was used to examine a few concerns related to heat buildup in RAs

- 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



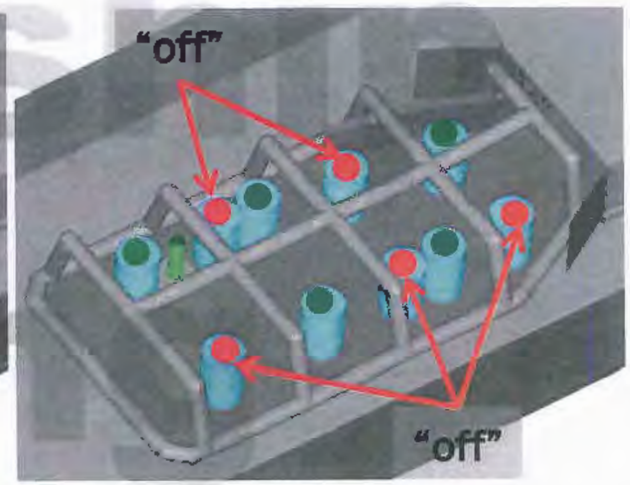
The effect of three heat variation methods were examined using the validated model

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

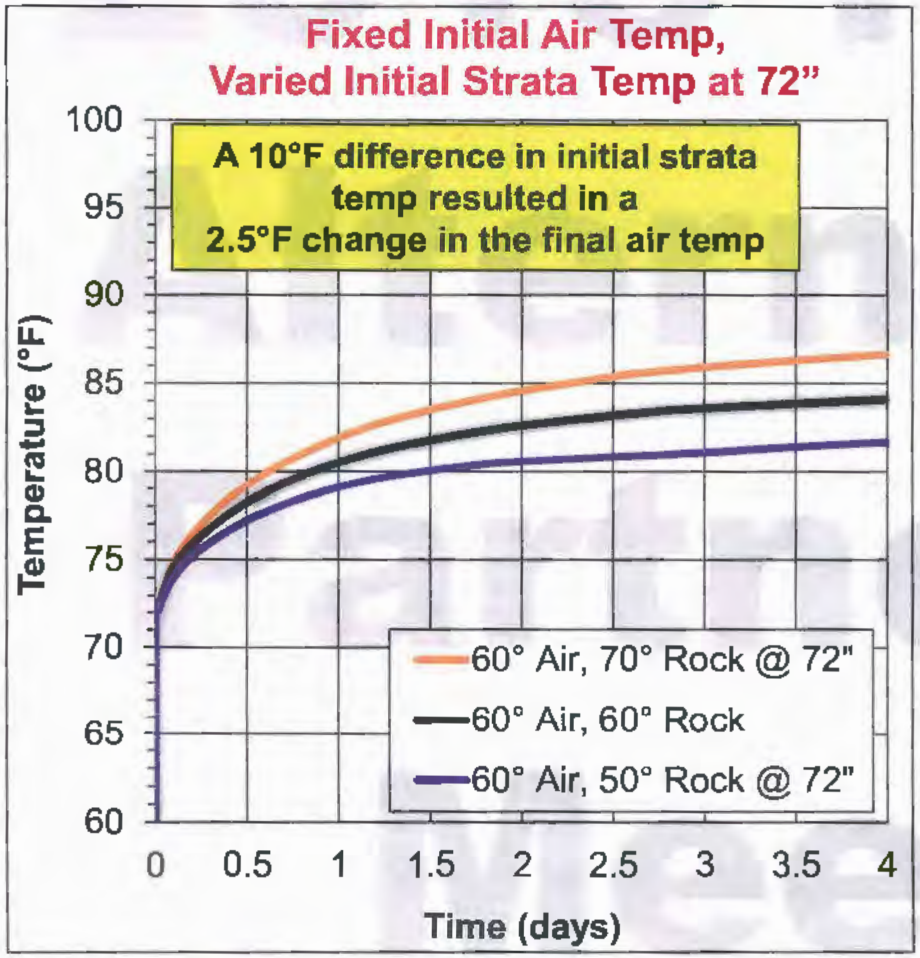
Note: Results from simulated miners with dry heat input

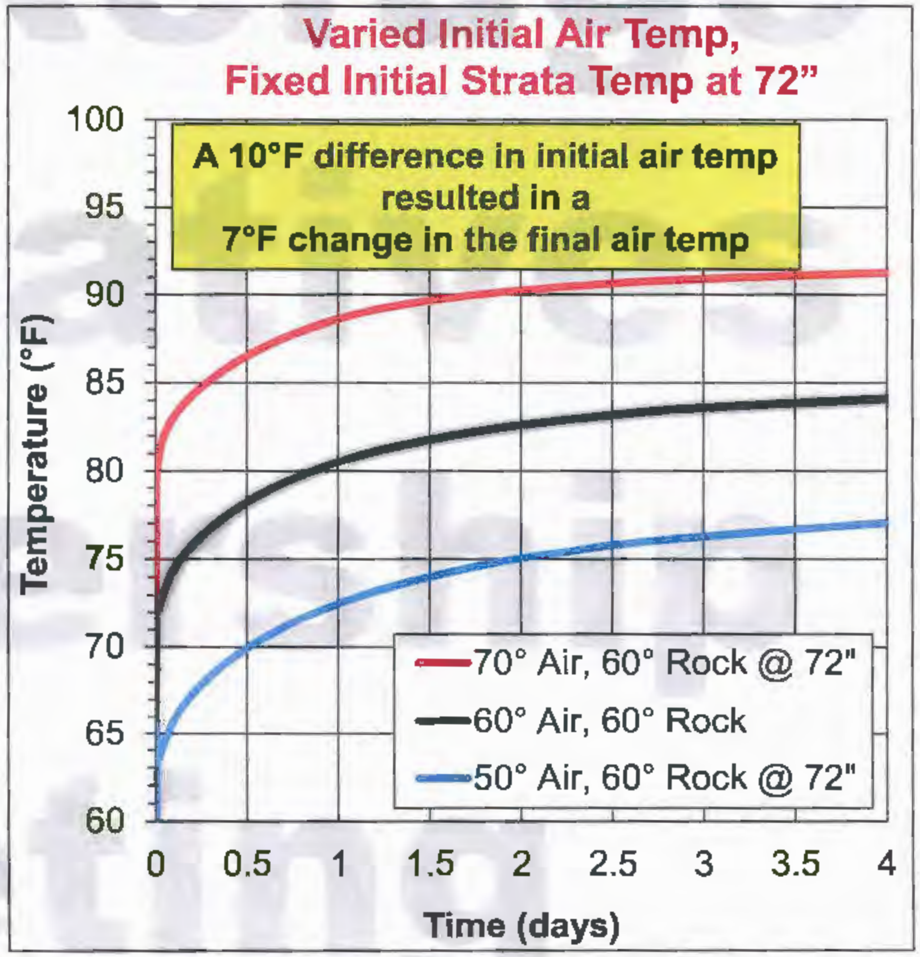
The effect of the initial mine air and strata temperatures was examined using the validated model

- 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	

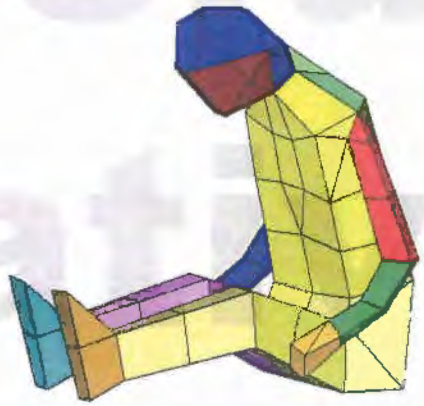
Simulations show the RA internal air temperature is affected by both the initial mine air temperature and the initial mine strata temperature

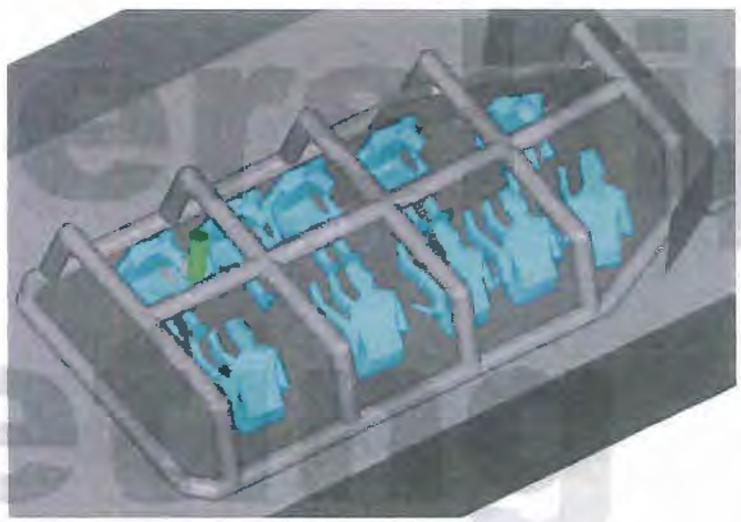




ThermoAnalytics' Human Thermoregulation Model was used to benchmark performance of OMSHR simulated miners and to examine RA occupant heat loss

- 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_2O per miner per day.

(2) “Real” miners averaged ~1.8 L of H_2O per miner per day for final AT of 95 °F.

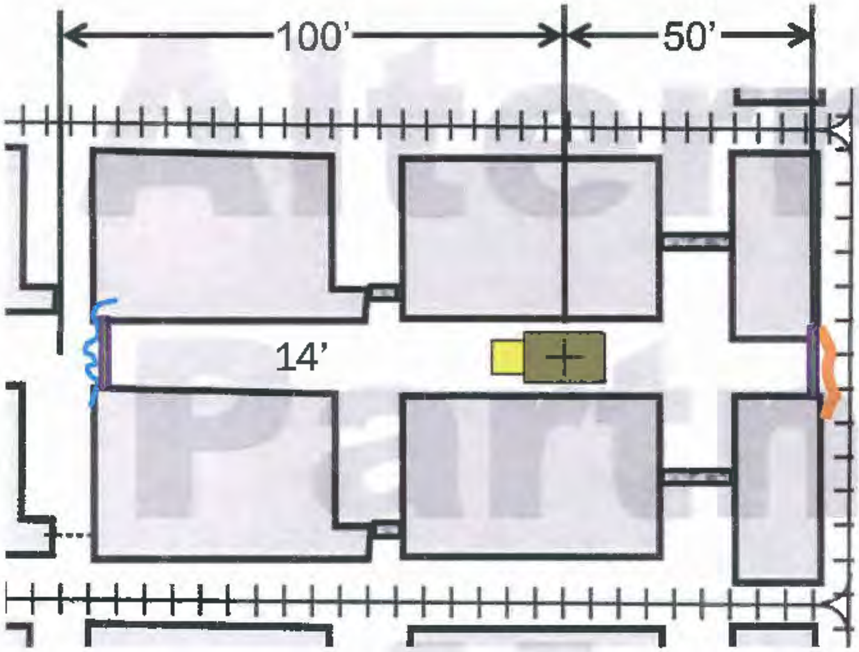
In 2014, OMSHR began an effort to demonstrate an approach to determine occupancy derating for RAs that uses test data combined with thermal simulation

- 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

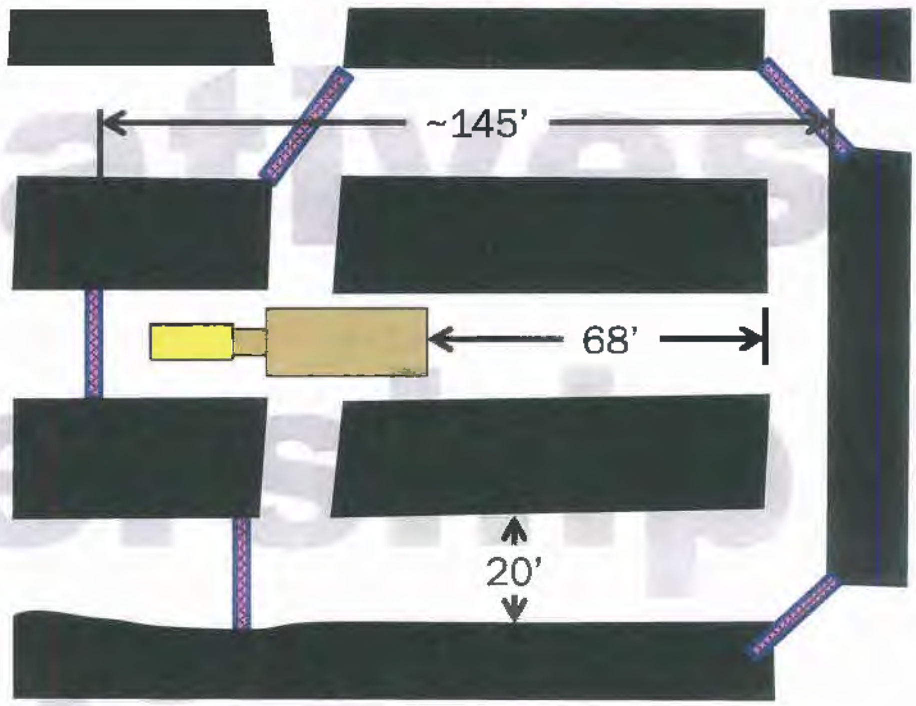
OMSHR simulated miners were modified to increase moisture generation (latent heat) to ~1.8 L/day in conditions of 80°F and 80 to 85 %RH

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)

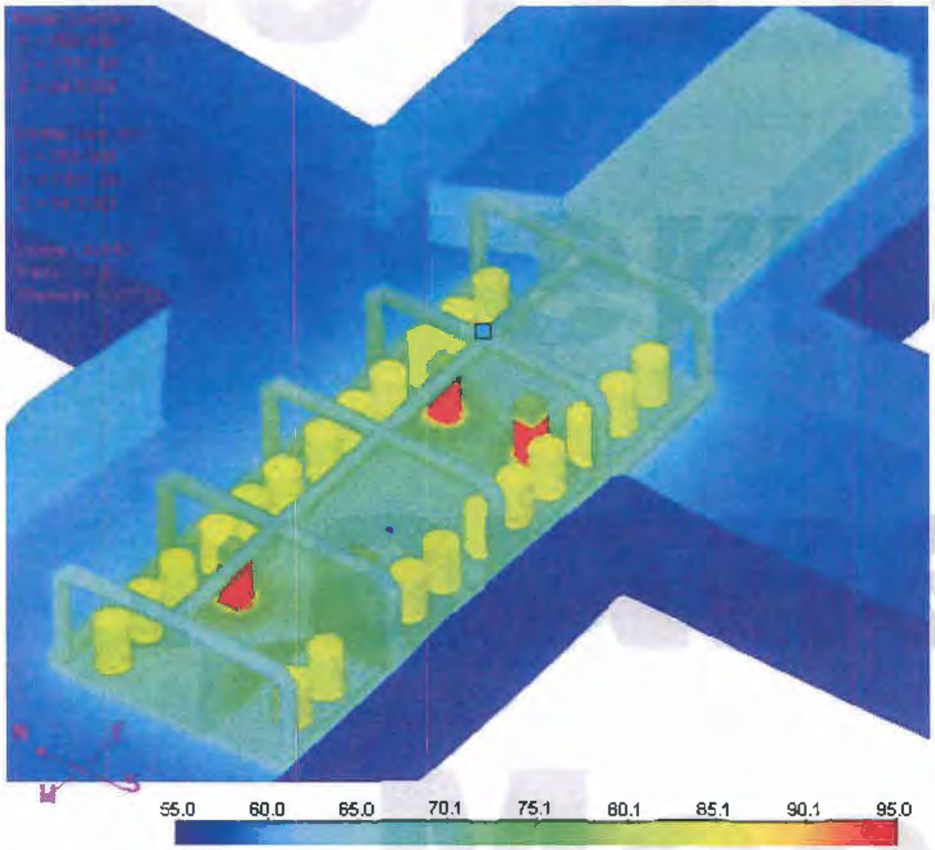
Six in-mine heat and humidity tests were conducted from over four months from 8/2014 through 12/2014

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 :

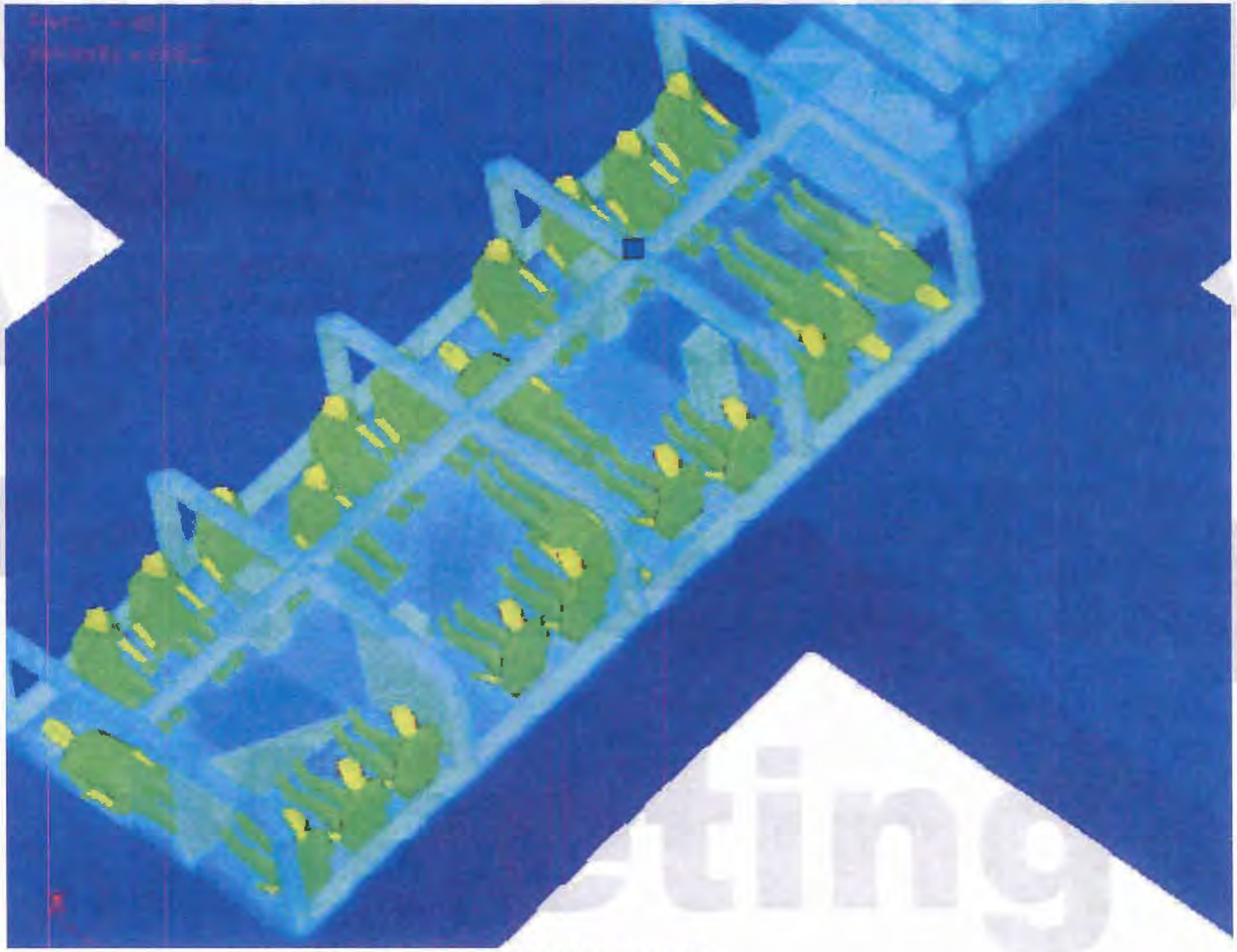
- For the baseline 23-person test, the RA air temperature increased from 57°F to 74°F (17°F), and the RH reached 94%
- The RA air temperature increased by 17°F for the 23-person "wet" test and 19°F for the 23-person "dry" test
- Preheating the mine air by 5°F had no effect on either the RA air temperature 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

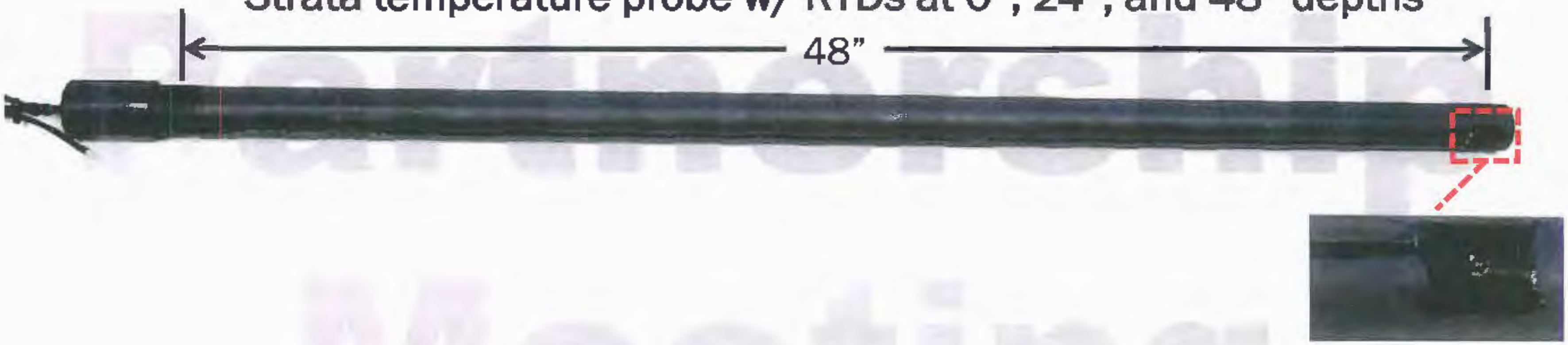
The validated thermal simulation model will be used to determine the derated capacity and to further examine the performance of the OMSHR-developed simulated miners



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.

Strata temperature probe w/ RTDs at 0", 24", and 48" depths



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

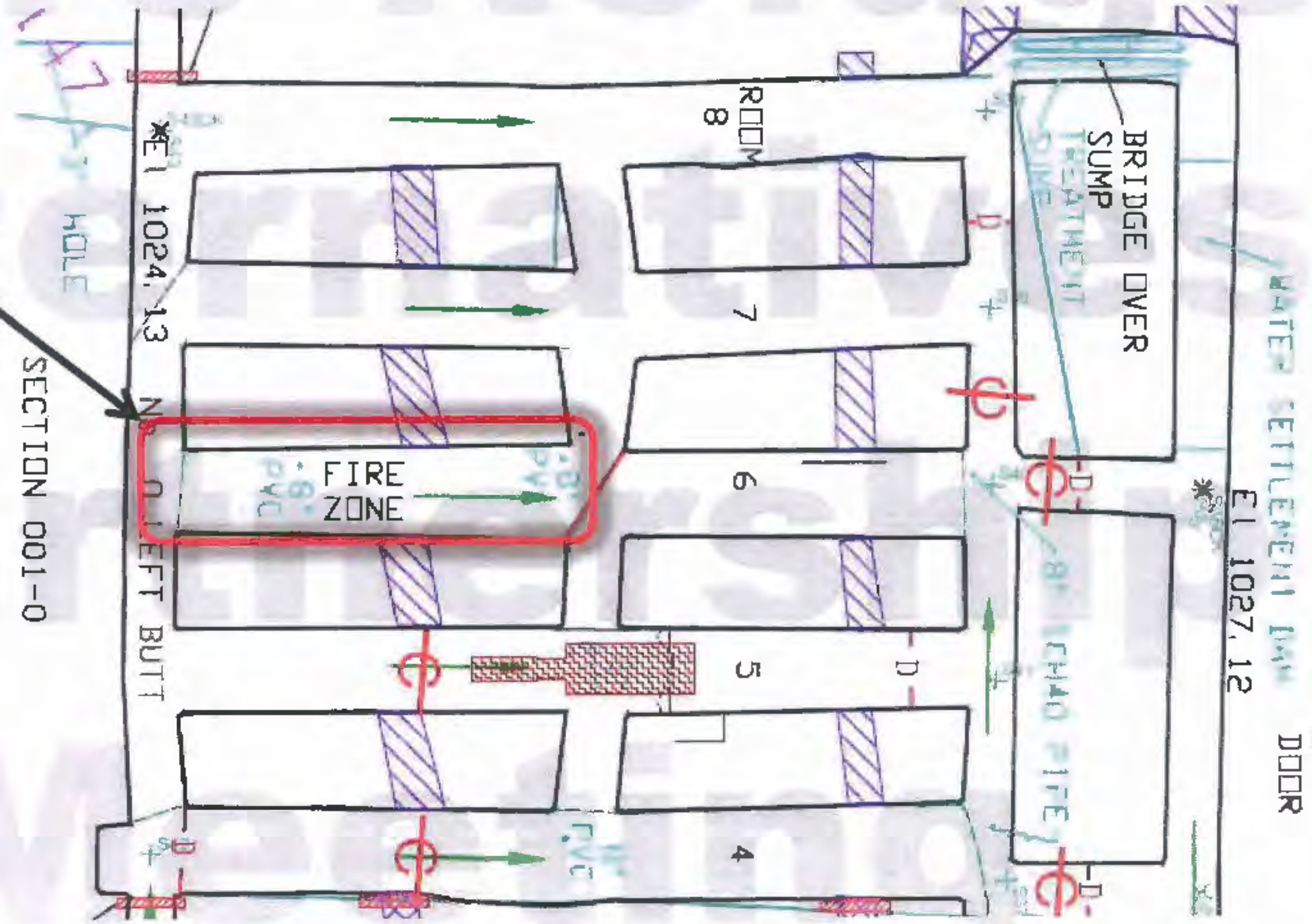
Additional mines sites desired

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

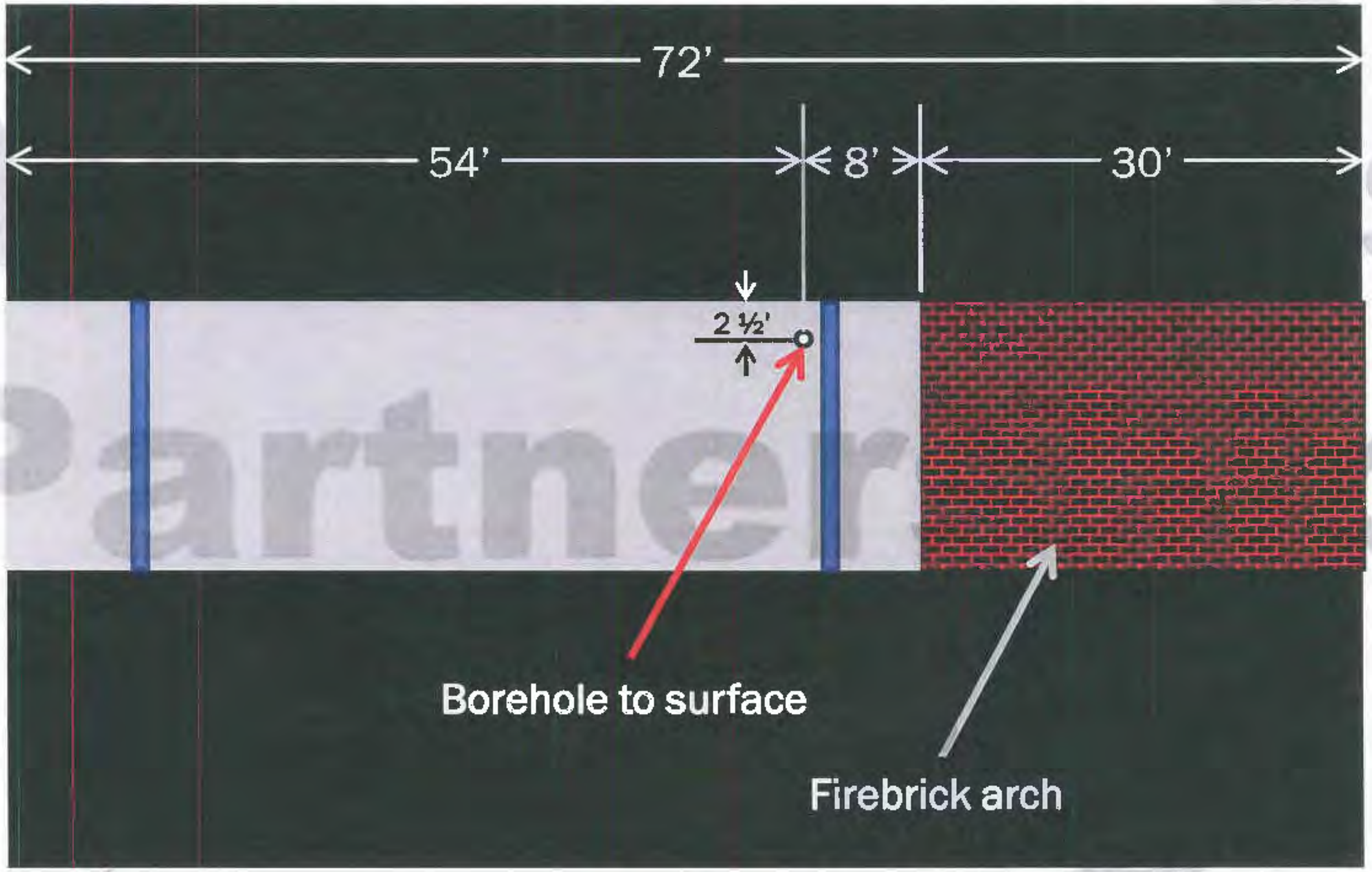
- Conduct in-mine heat and humidity testing
- Develop validated thermal simulation model
- Investigate occupancy derating

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

"Design and Construction Considerations for a Protected Compressed Air Line to a Refuge Alternative"

PI - Jhon Silva, (Assistant Professor)
Co-PI - Braden Lusk, (Associate Professor)

NIOSH Refuge Alternatives Partnership (RAP) Meeting – Tuesday, February 10, 2015
Pittsburgh, PA

Objective:

This proposed work will explore, in a practical way through laboratory tests, design and construction considerations regarding compressed air lines to a refuge alternative including but not limited to; materials, bending, crushing, tensile and other strength requirements, anchoring systems, protection of the compressed air lines and drainage.

Topics:

1. Surface Compressor Station Considerations and Air Delivery Limits

2. Protected Compressed Air Line Considerations:
   Materials
   Strength parameters
   (Mechanical-Dynamical-Environmental)

3. Anchoring

4. Procedures for extending and purging line

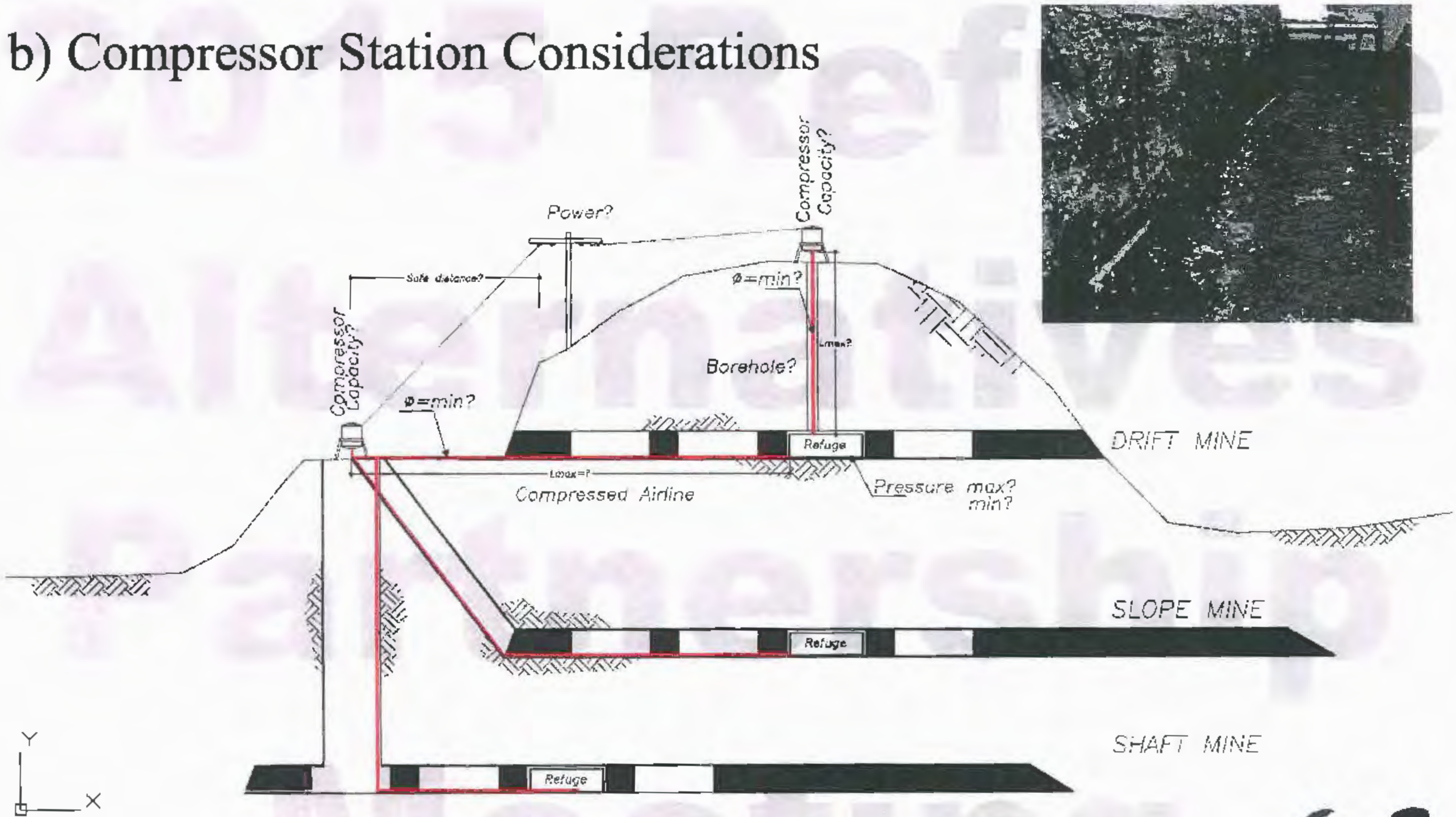
NIOSH

UK

2015 Refuge Alternatives Partnership Meeting

Surface Compressor Station Considerations and Air Delivery Limits

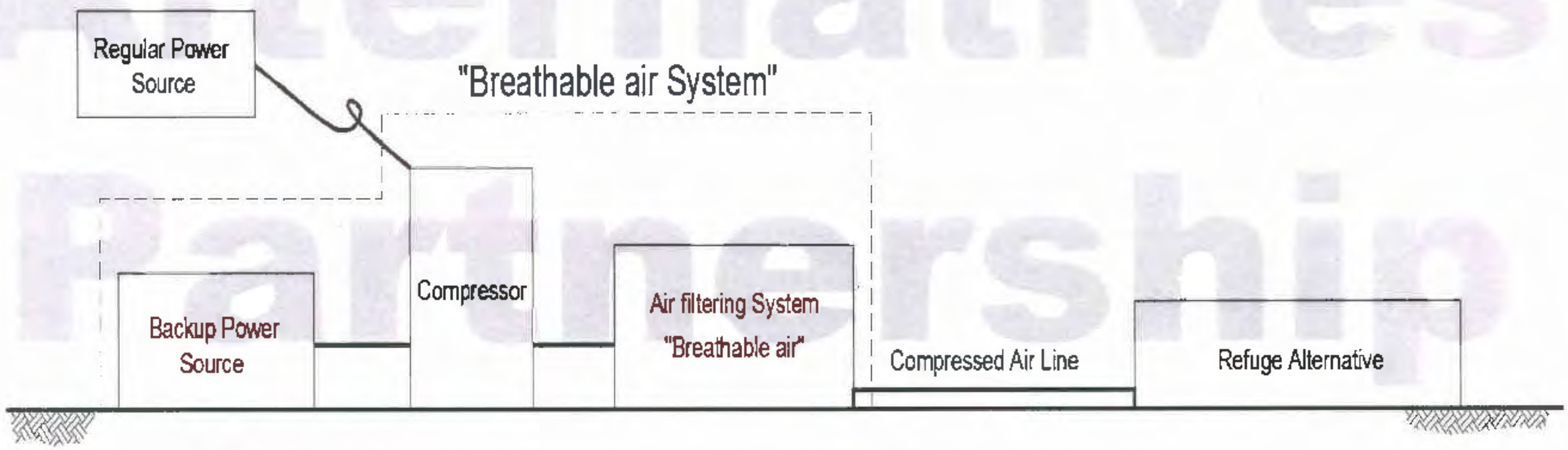
b) Compressor Station Considerations



Overview

Field visits:

- Hubble 07 underground coal mine (Pike County)
- Inspiration Mine



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Regular Power Source
Breathable air System
Fan of the mine
Compressed air line


Regular power source
Mine Fan
Breathable air system

NIOSH

UK

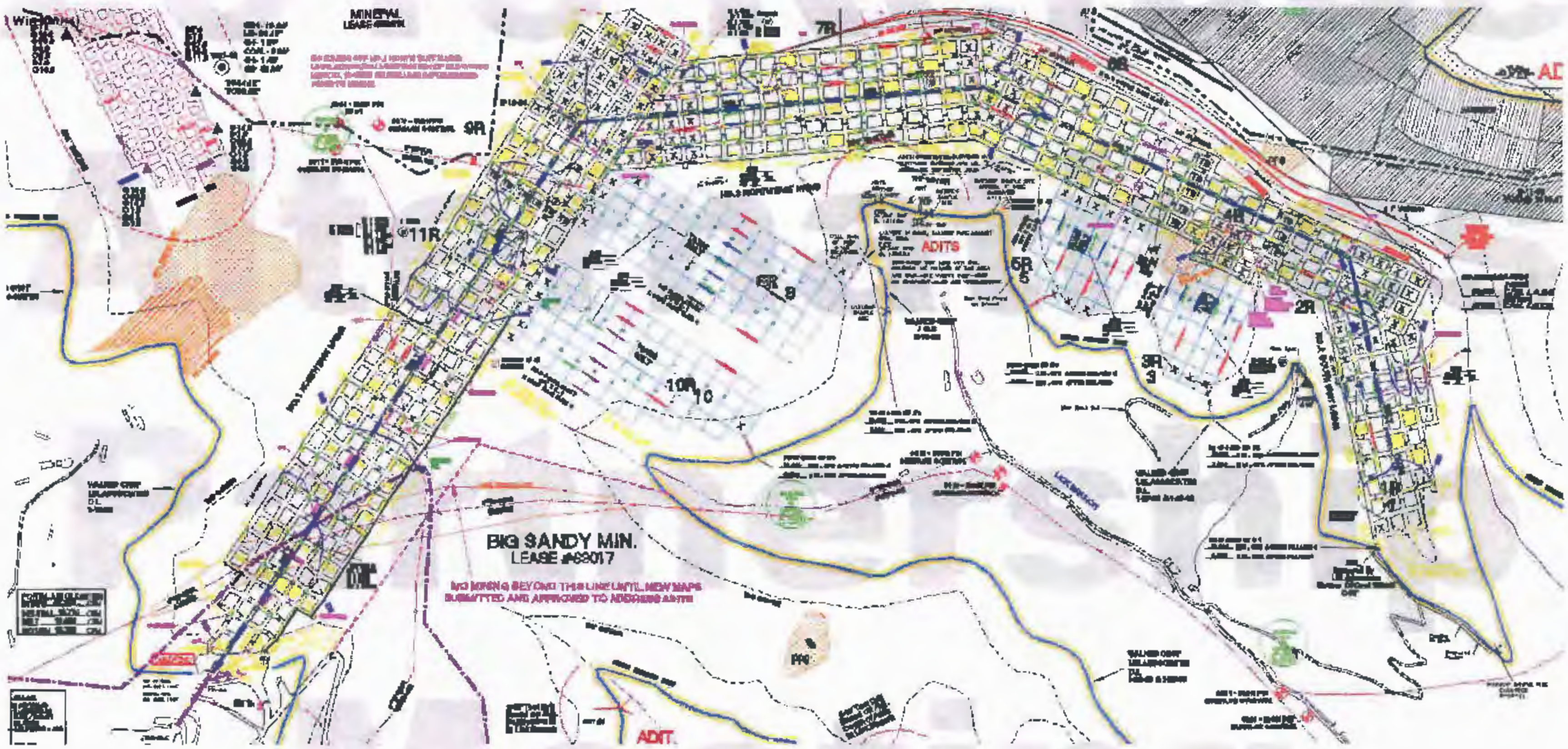
Flames burn out of control from a ventilation shaft at the Pike River Mine Photo: EPA

To date conclusions:

Separate the regular air system from the mine to the compressed air, it is recommended to have at least 100 to 200ft distance from the mine fan to the breathable air system.

The location for the breathable air system should be done in an area geotechnical stable. It is necessary to perform all slope stability analysis to avoid any failure of the ground were the system is located. Among the analysis, it is recommended to perform conventional kinematic analyses and limit equilibrium analyses. In all cases the factor of safety should be minimum of 1.5.

Hubble 07 underground coal mine (Pike County)



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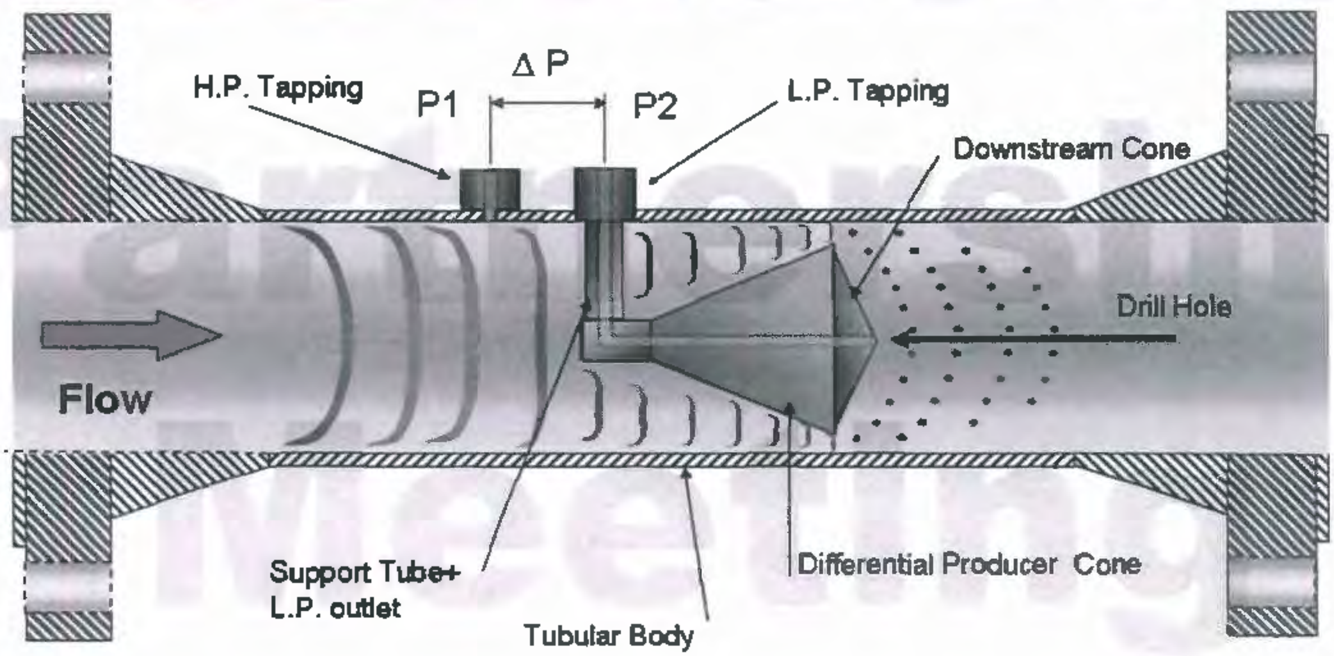
UK

Hubble 07 underground coal mine (Pike County)

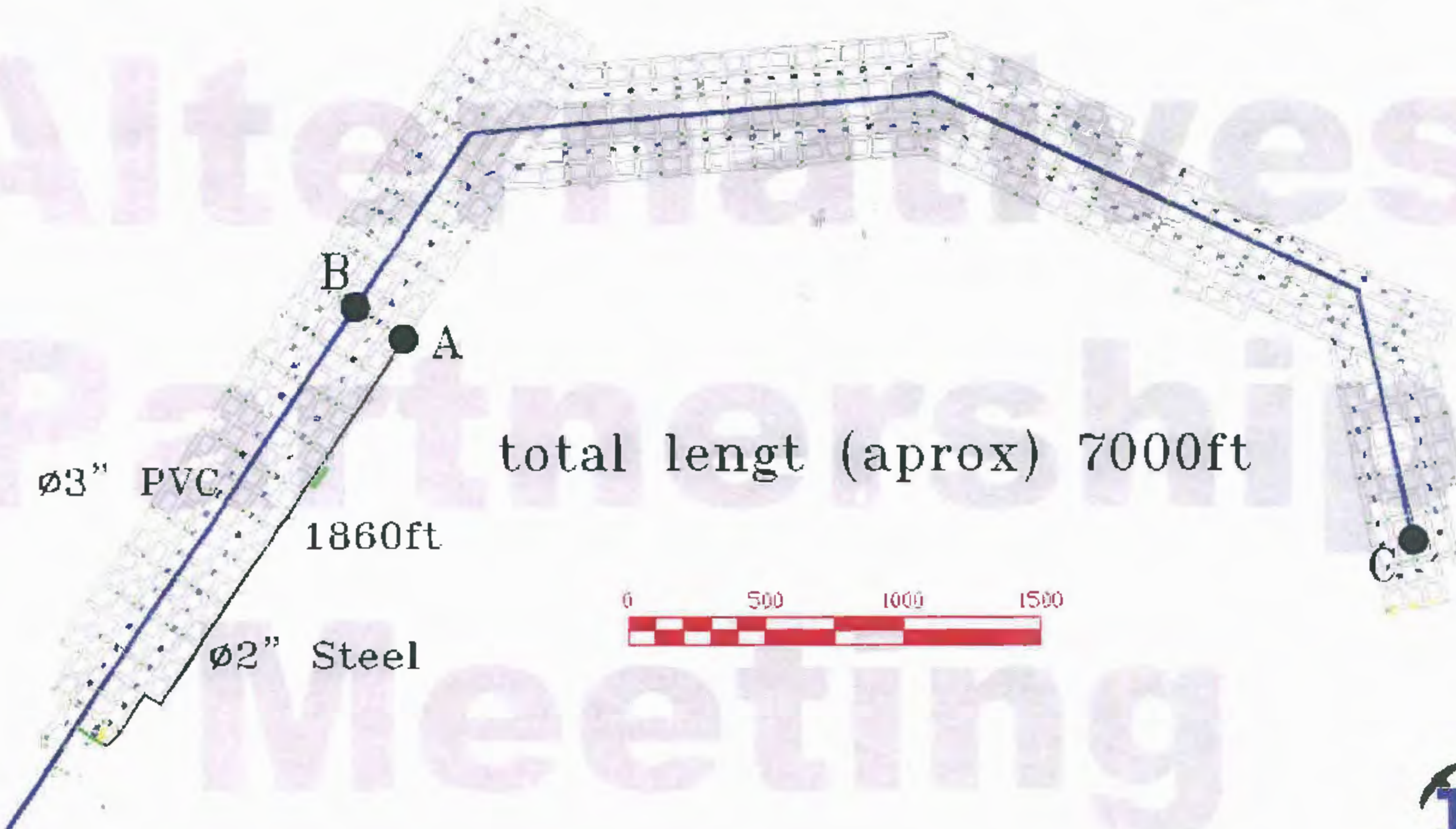
Pressure drop????
Flow????

Differential Pressure Cone Meter

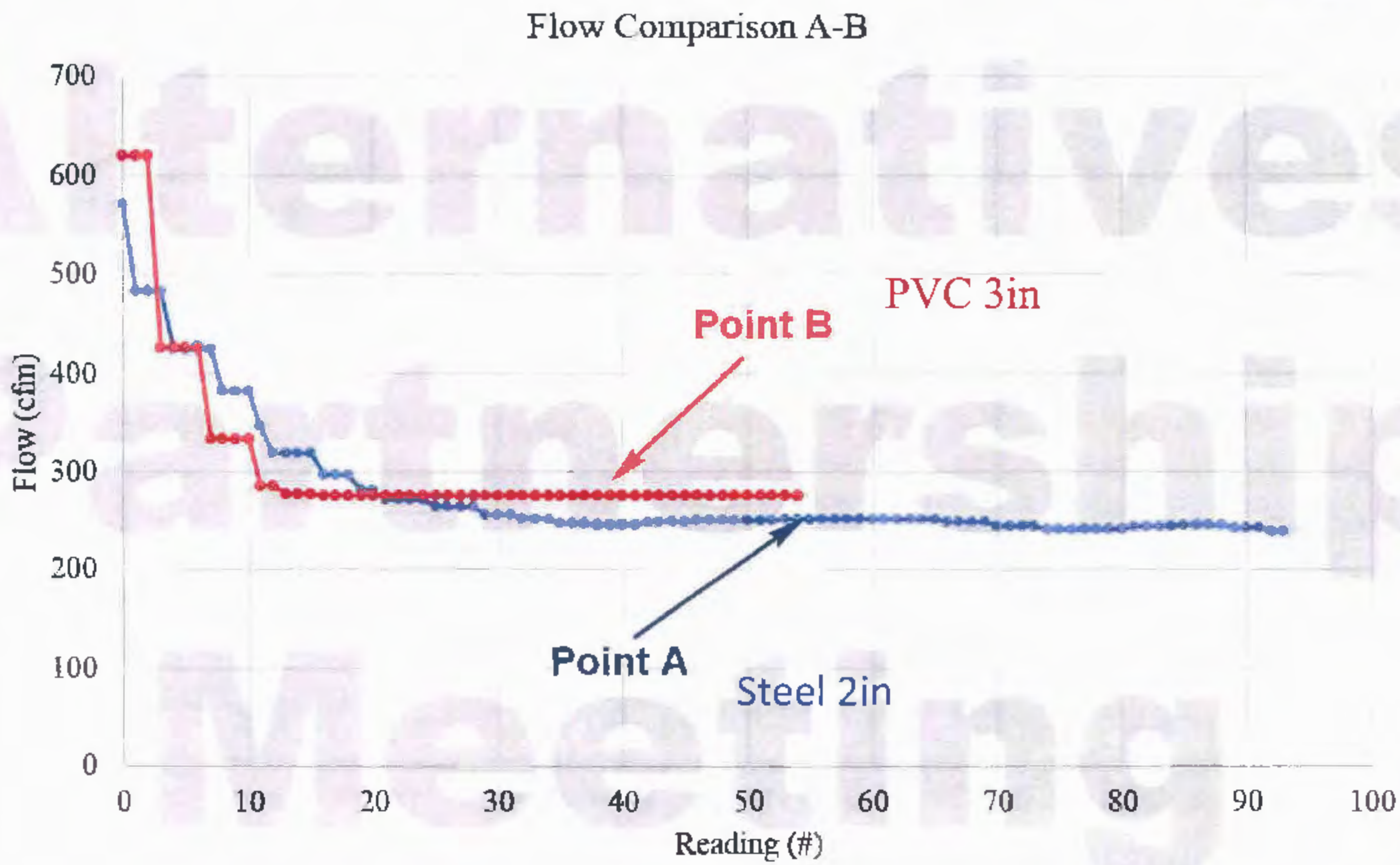


Hubble 07 underground coal mine (Pike County)
Pressure drop????
Flow????

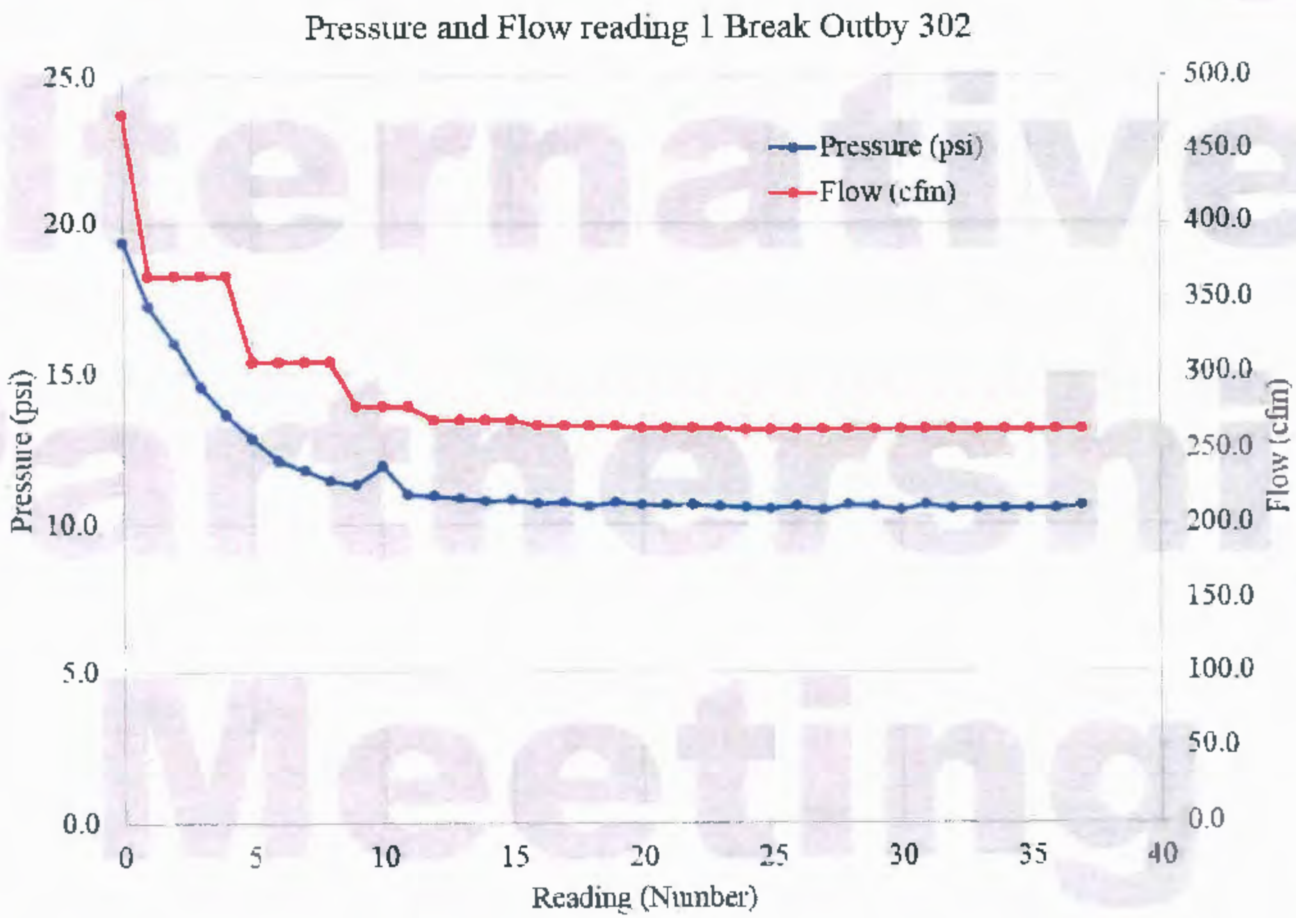
Hubble 07 underground coal mine (Pike County)
Pressure drop????
Flow????



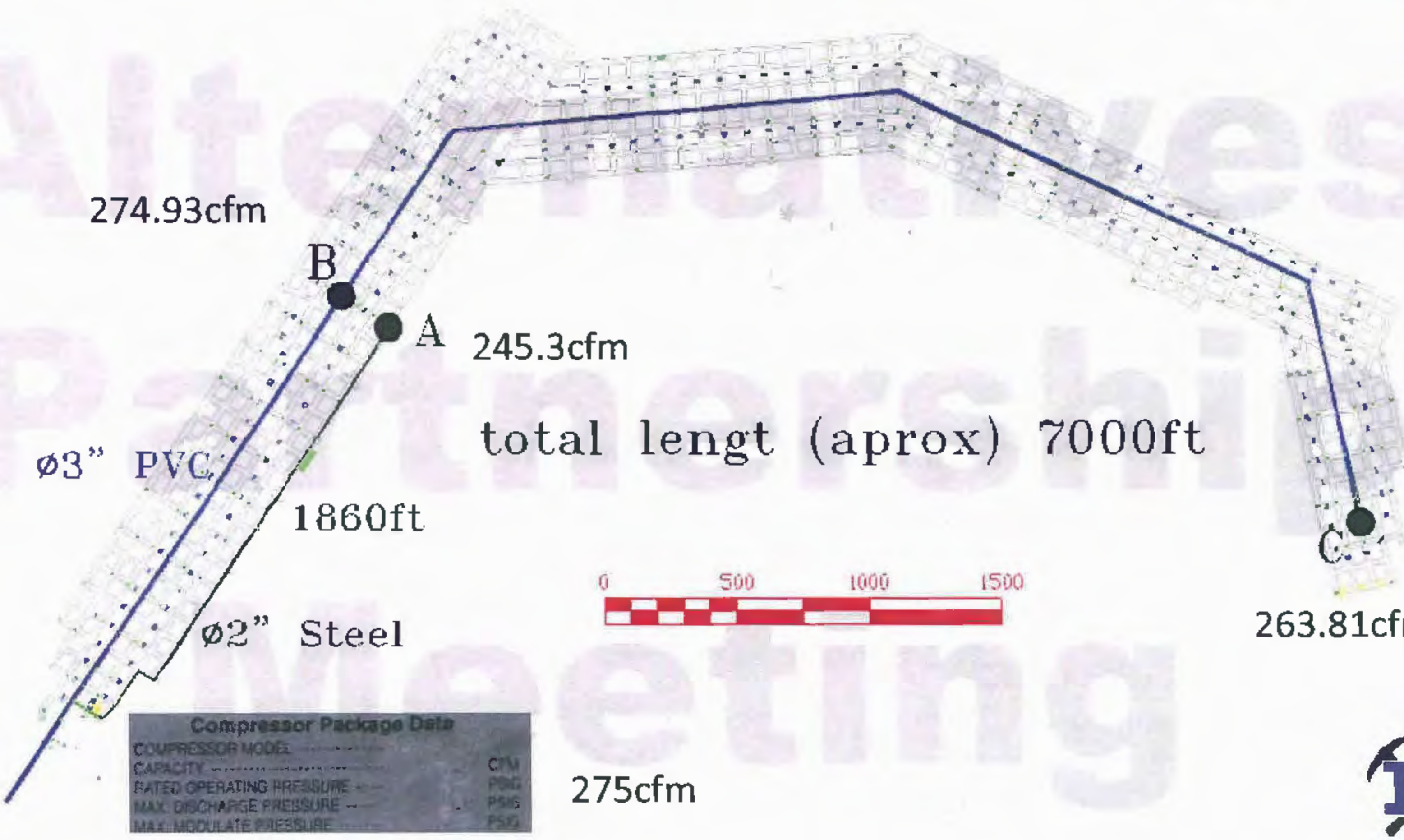
Hubble 07 underground coal mine (Pike County)
Pressure drop????
Flow????



Hubble 07 underground coal mine (Pike County)
Pressure drop????
Flow????



Hubble 07 underground coal mine (Pike County)
Pressure drop????
Flow????



Protected Compressed Air Line Considerations:

Materials

Strength parameters

(Mechanical-Dynamical-Environmental)

Pipe samples:
Non-Metal Pipe — commonly called "plastic" pipe has been offered for many years as compressed air piping.

Metal Pipe - can be black iron, stainless steel, copper, aluminum, etc. with proper thermal and pressure characteristics.

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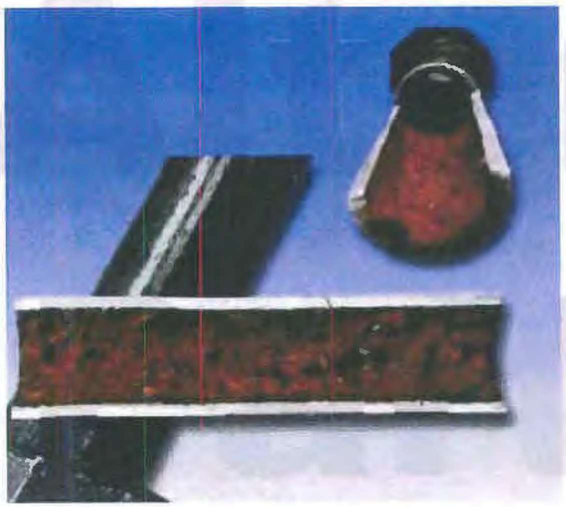
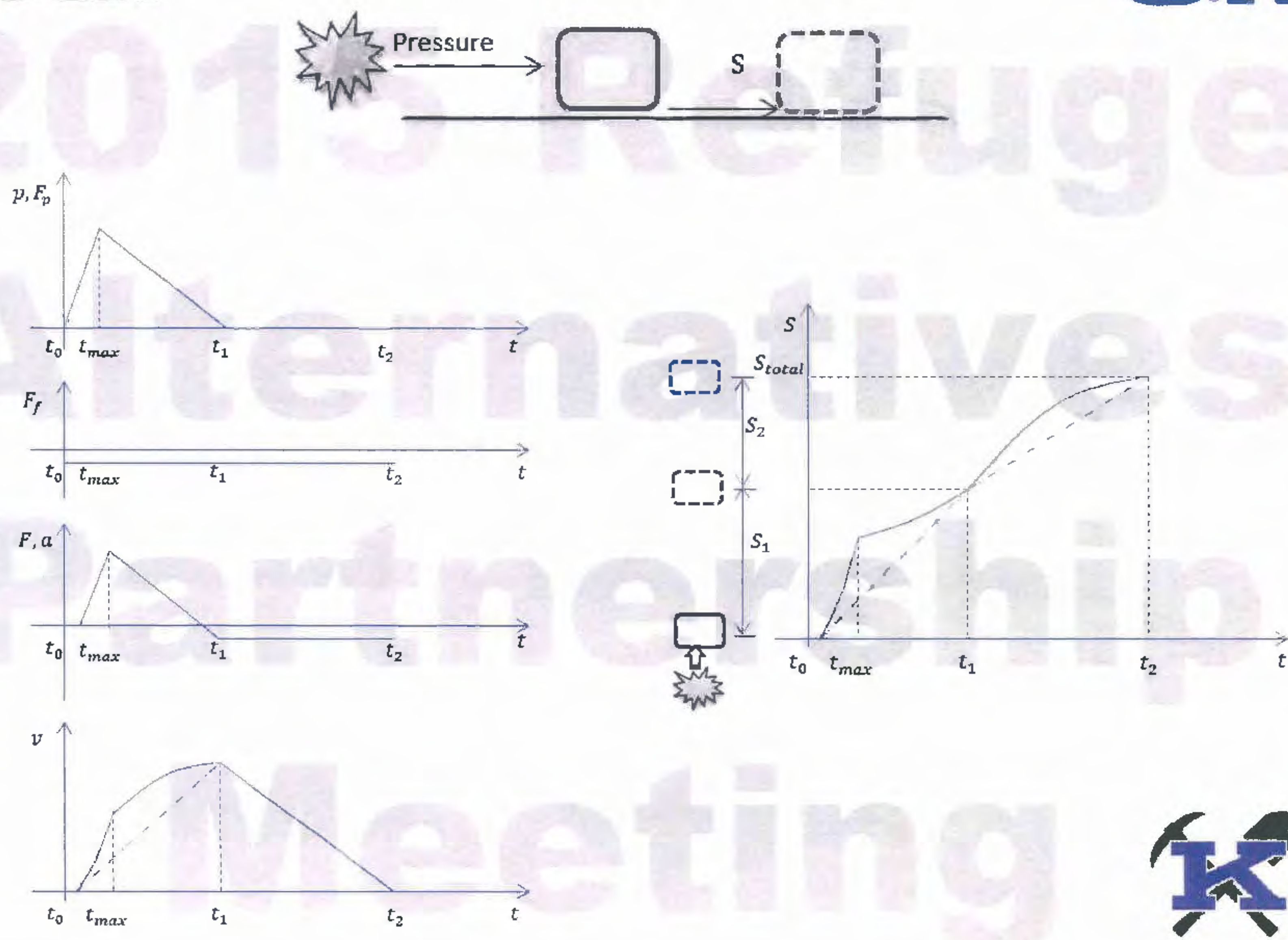
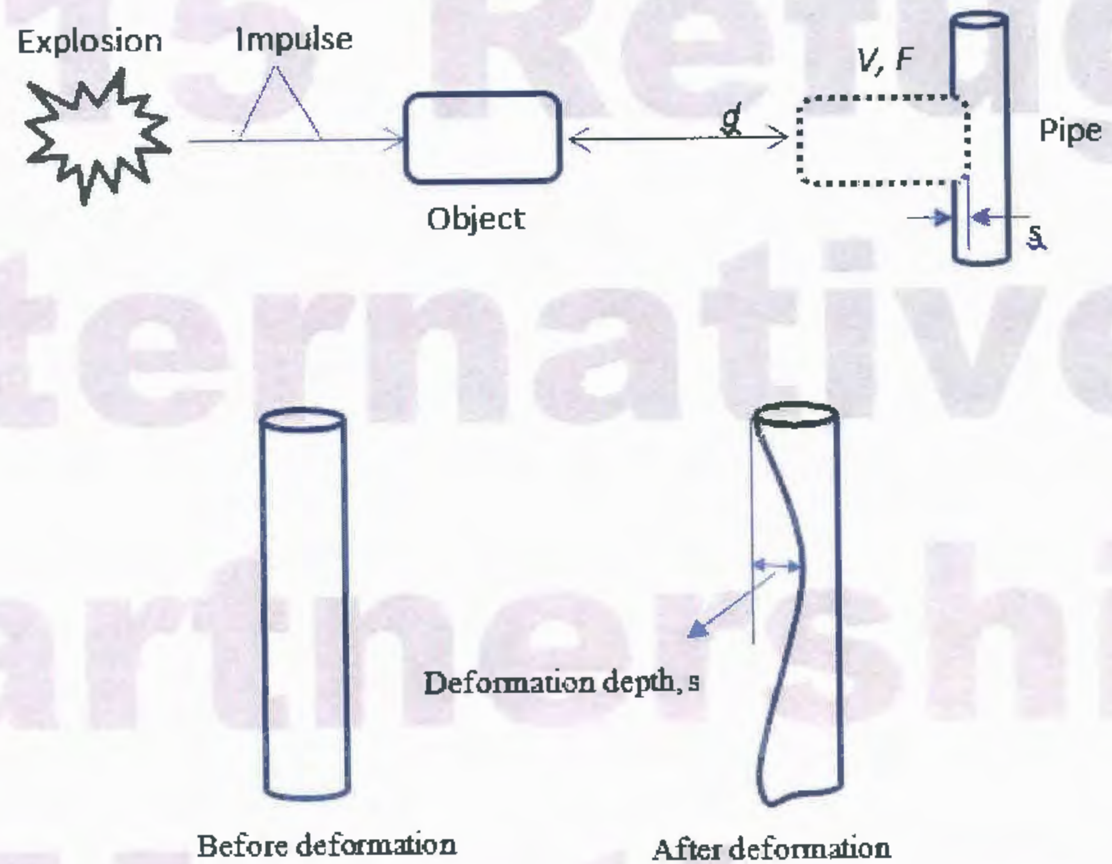
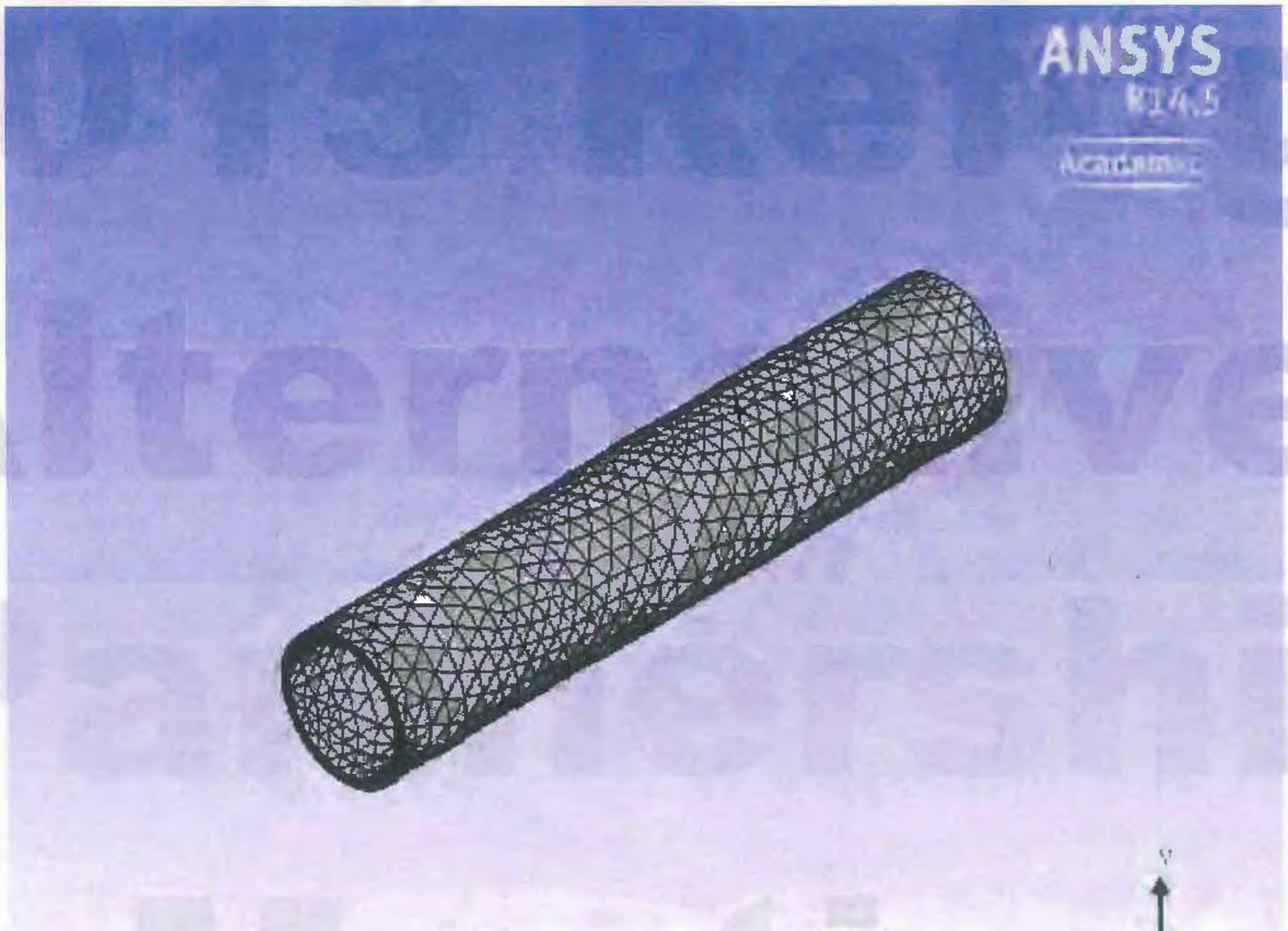



Explosion
Pressure
S
p, F_p
F_f
F, a
v
t_0
t_{max}
t_1
t_2
t
S
S_{total}
S_2
S_1

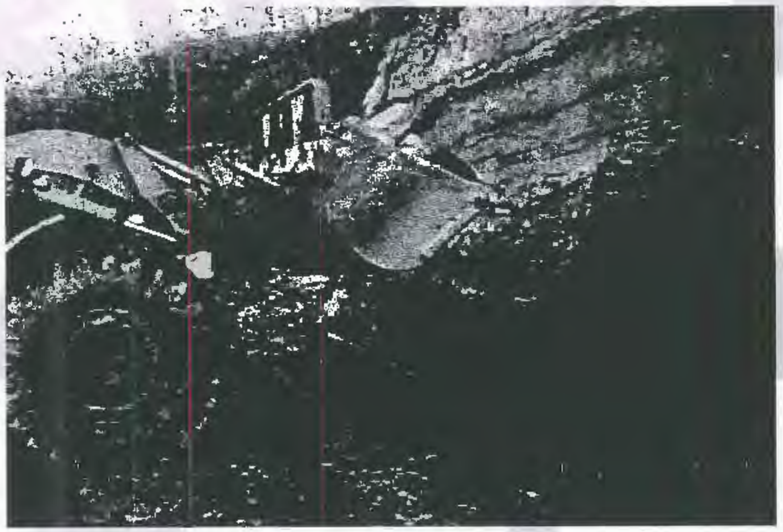

Explosion
Impulse
Object
d
V, F
Pipe
s
Deformation depth, s
Before deformation
After deformation

Refuge Alternatives


ANSYS
R14.5
Academic
0.000
0.200
0.400 (m)
Y
Z
X

NIOSH

Materials Properties



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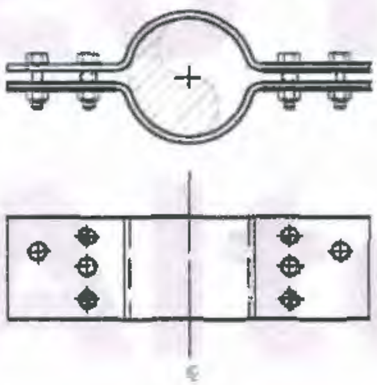
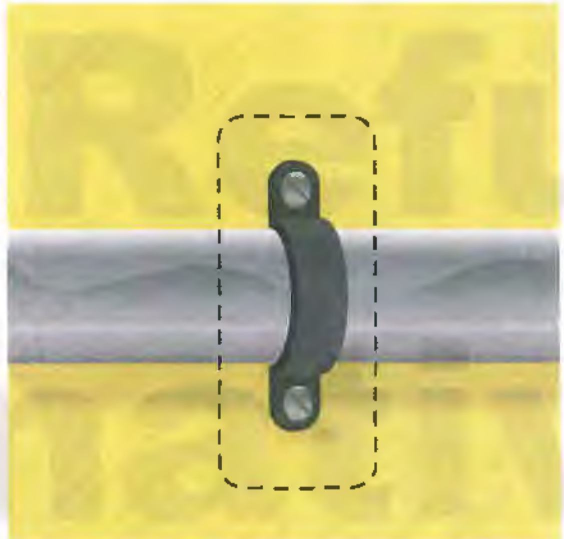
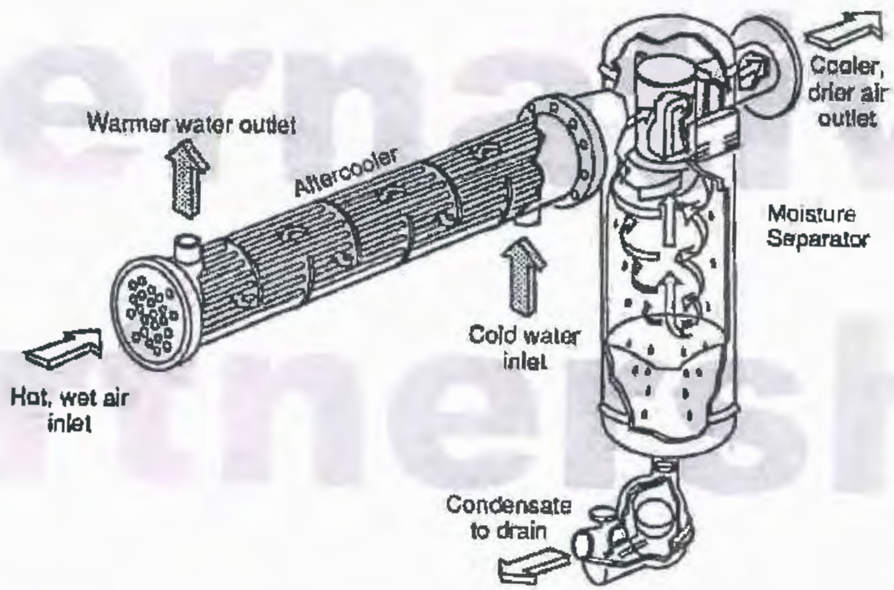
Anchoring





Purging lines



Underground Mining Equipment

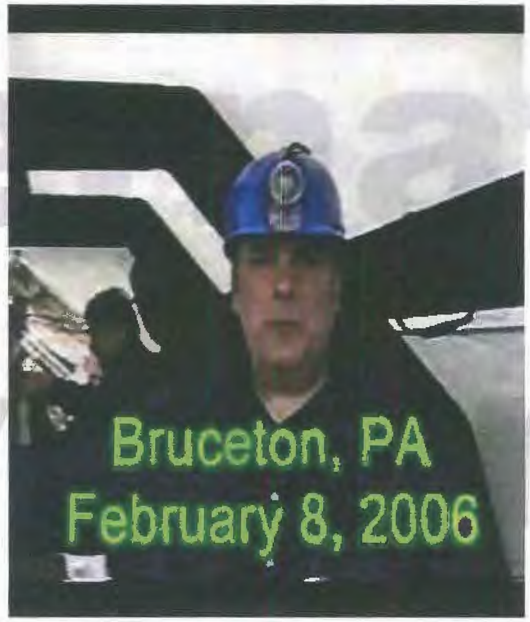
The Total loaded weight is the sum of operating weight and carry capacity. Those which don't have operating weight are not takend account into total weight. Part of them have dimensions of tires and chain, even ground pressure. Some machins with lower weight have higher ground pressure. But the pressure on the air pipes may not just be the same to the ground pressure.

Mining Methods	Type	Model	Dimensions(ft)			Weight(tn)			Ground Contact (Tire,track. etc)	Ground Pressure(psi)	Cutting Profile(ft)	
			Length	Width	Height	Operating weight(Empty Load)	Carry Capacity(tn)	Total loaded weight			Cutting width	Cutting height
longwall systems	CST Drive System(right/left-angle drive system)	CST30	7.5	3.9	3.0	6.4		6.4	Maybe L*W			
		CST45	9.1	4.2	3.5	10.8		10.8				
		CST65	9.6	5.0	3.5	12.0		12.0				
	Roof Support System						support up to 1929 tons	/	Not provided			
	shearers	EL2000	45.1	40.6	20.5	77.0		77.0	Not provided			71-177
		EL3000	49.9	44.6	27	116.0		116.0				98-217
		EL4000	54.8	52.8	41.3	154.0		154.0				158-276
	Roof Support Carriers	SH620	31.2	9.3			22.0	/	tire			
		SH630	35.7	9.5			36.0	/				
		SH650	38.3	9.9			50.0	/				
		SH680	45.3	11.3			88.0	/				
		SH640D	30.2	8.7			44.0	/				
		SH660D	33.0	10.2			60.0	/				
		SH660HD	33.0	10.2			66.0	/				
		SH150	15.4	12.7			55.0	/				

NIOSH Refuge Workshop
10 February 2015

Thermal Control in Mine Refuges

Ed Roscioli



Initial shelter demonstration at Bruceton Experimental Coal Mine near Pittsburg, PA USA, February, 2006, one month after the Sago Mine Accident in West Virginia.

Not So Easy

- ChemBio started looking at chemical and biological protection issues in 2004.
- Protection from toxic atmospheres turned out to be the easy part.
- Ensuring that those who take refuge can maintain a safe environment internally, turned out to be the problem.
- While the problems associated with providing oxygen and removing carbon dioxide have been solved, another problem still exists.

ChemBio SHELTER, Inc.

Temperature - Many Roads Traveled

- The companies and agencies involved have explored many solutions to maintaining internal temperature levels.
- Air conditioning in RA's requires batteries and permissible components which adds to cost
- Compressed gas expansion presents volume challenges for the quantities needed for an extended occupancy.
- Liquid gases are being tested and cost and efficiency is being determined.
- Pre-frozen ice has been explored along with the duration and quantity issues it requires.
- Endothermic chemicals may offer hope, as well as materials that promote nucleation of water vapor on the walls

ChamBio SHELTER Inc

ChemBio "BoreHole" Blower

- In 2009 ChemBio started experimenting with what we called the "Borehole Blower" which was essentially a blower driven by a diesel engine
- This unit delivered 1,450 CFM of air at 1 psi down boreholes to BIPRA's below
- At 12.5 CFM/person it would support up to 116 people
- This unit (along with a back-up) could be permanently attached to the borehole or stored in a warehouse, and in the case of an emergency, could be transported to the borehole and start producing air within 30 minutes

ChemBio SHELTER, Inc.

ChemBio Borehole Blower

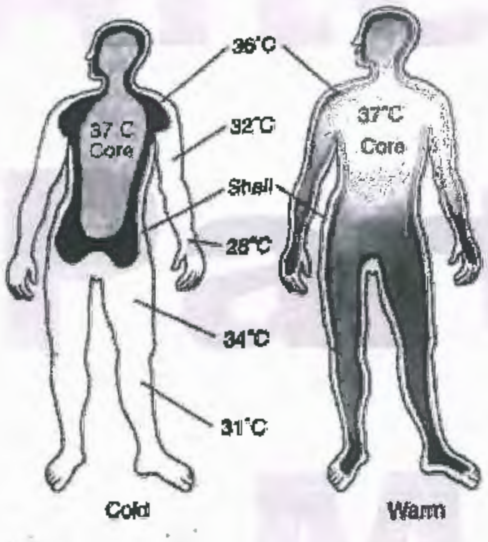
- This unit worked very well but the following issues existed:
  - Blowing extreme ambient outside air temperatures of 100° F plus the inherent heat produced by the blower presented heat problems in the refuge alternative
  - We had no way of controlling the humidity
  - In extreme cold outside ambient conditions such as 0° F hypothermia could become a concern

ChemBio SHELTER, Inc

So Back to the Basics

- We decided to step back and reexamine the research that defined the thermal injury threshold to see if we had missed something.

Human Thermal Regulatory System

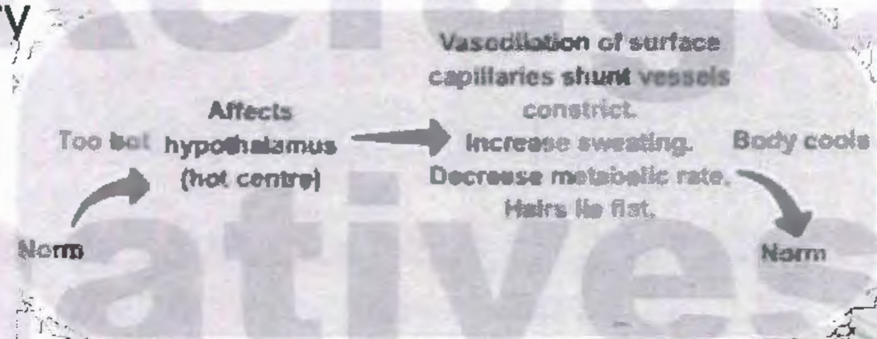


- Human body can maintain a core temperature of 36.6 C (97.9 F) to 38.2°C (100.8 F), even when ambient temperature is 30.0 C (86 F) to 54.4°C (130 F).
- It is the core temperature that results in thermal injury.
- So how does the body maintain it across such a wide range?

ChamBio SHELTER, Inc.

Keeping Your Cool

- A complex thermoregulatory control system modifies
  - heart rates,
  - metabolic rates, and
  - sweat rates



- The body is divided into an inner core and cooler shell.
- All heat leaving the body must pass through this shell except that lost through respiration.
- Core body temperature varies slightly from one site to another in the body, however, all are similar to the central blood temperature and tend to change together.

Not All Equal

- Evaporation of sweat is the critical heat transfer factor for maintaining the core temperature in the temperature range encountered in a refuge.
- Evaporation works to maintain skin temperature at a level that supports the transfer of metabolic heat by blood convection to the surface
- As the skin temperature approaches the blood temperature the stored heat increases, thus the core temperature increases.
- Evaporative heat loss is primarily dependent upon the difference in vapor pressure of the water on the skin and vapor pressure in the air.

ChamBio SHELTER, Inc

New Objective

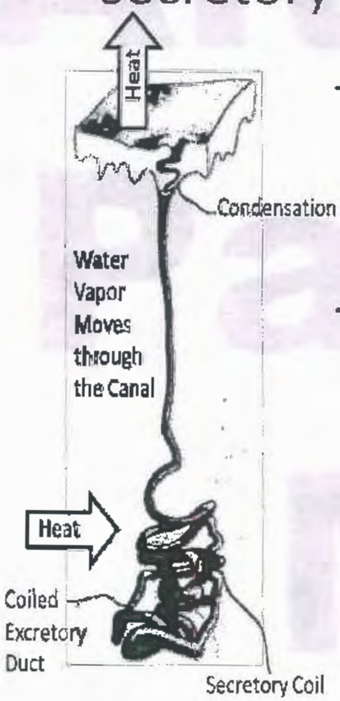
- Sweat evaporative cooling efficiency (η_{sw}) , defined as the ratio between evaporative rate and the sweat rate, decreases as humidity increases.
- If ambient water vapor pressure increases, the percentage of wetted skin increases and a portion of the sweat will be lost to dripping or absorption in clothing, with the effect of lowering the evaporative cooling efficiency.

Objective: Reduce vapor pressure in the air

- If the vapor pressure of the air is too high the body cannot sweat, even though the air temperature may be lower than the core, hyperthermia can still occur

~~Don't~~ Sweat It

- Secreted water vapor is moved to the skin surface by about 2,500,000 sweat ducts.
- Blood on its way to the skin remains at core temperature then, after transferring heat to the secretory coil, returns at skin temperature.



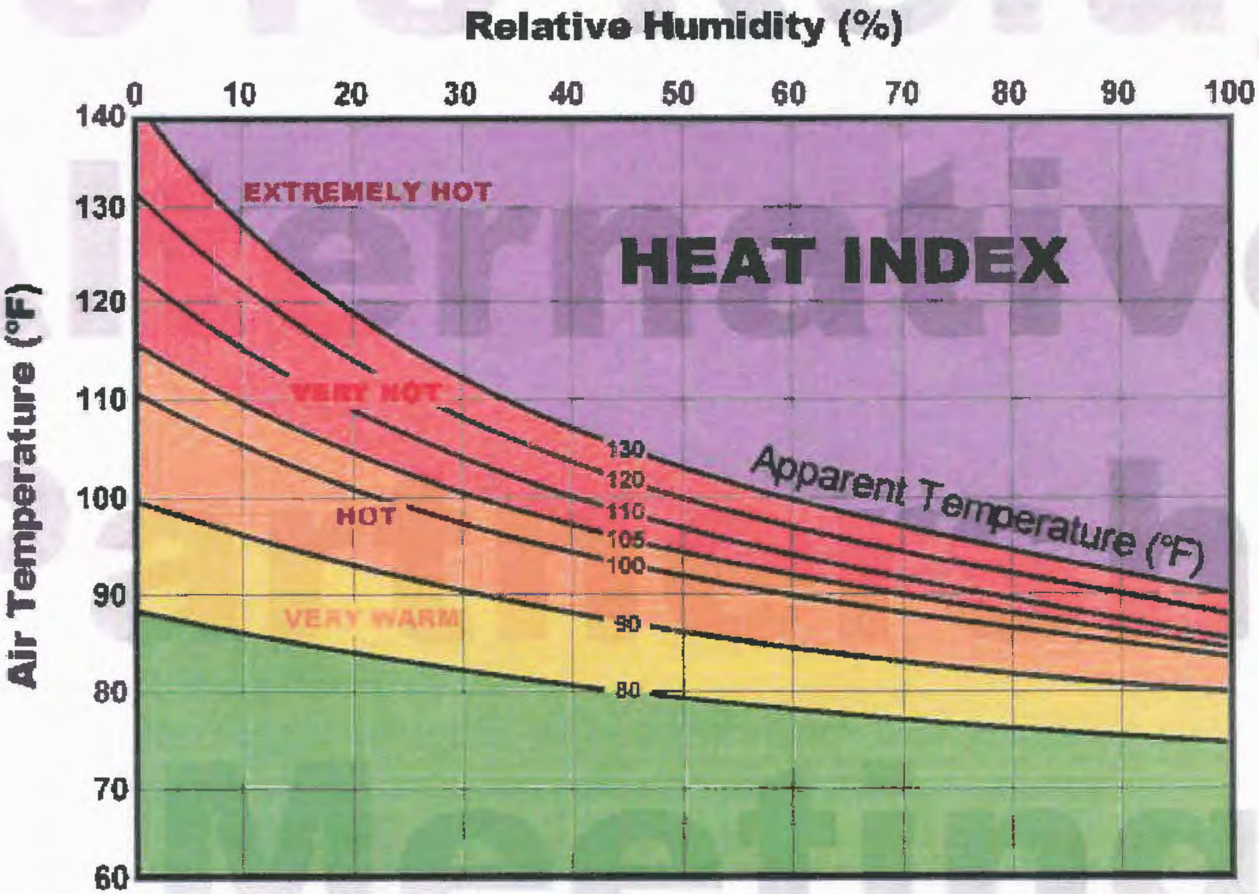
  - Vapor condenses at the surface where latent heat of condensation is transferred to the epidermal tissue and the air.
  - If saturated vapor pressure of water at skin temperature is less than the ambient vapor pressure of water in the air, then the sweat will evaporate, yielding cooling to the skin surface, thus enhancing transfer of core heat to the environment.

ChemBio SHELTER Inc.

Not Cool

- Simply cooling the skin elicits a sensible effect but does not impact core temperature.
- 1°C reduction in skin temperature elicits only a $1/9^{th}$ change in core temperature.
- If the skin temperature is lowered too rapidly, the flow of blood to the skin is actually reduced as the body anticipates a cold environment and begins restricting limb veins.
- The ultimate goal of sweating is evaporation, which depends on the ambient vapor pressure and not the body.

HEAT INDEX



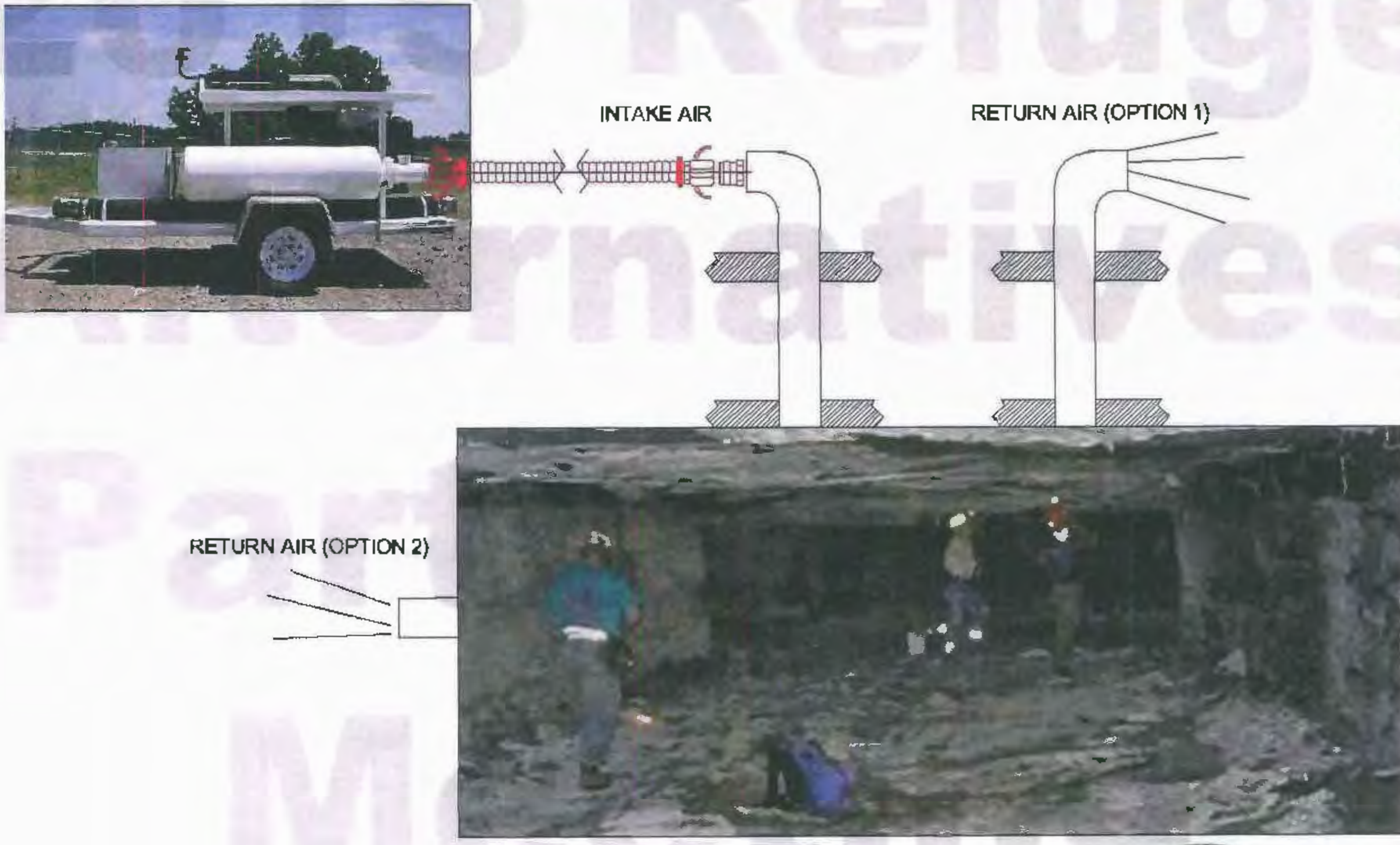
ChamBio SHELTER, Inc.

CHEMBIO "SAFE AIR" DELIVERY SYSTEM

- As a result of our findings in the "Human Thermal Regulatory System", ChemBio pivoted and developed the "Safe Air" Delivery System in 2012 and are involved in the MSHA approval process
- 1,250 CFM of filtered air is de-humidified and cooled or heated and then delivered through the blower, down the borehole and into the RA.
- By integrating "Hot Gas Reheat Technology" into the refrigeration circuit, the "Safe Air Unit" can maintain a temperature of 72° F while keeping the dew point below 55° F.
- At a mine demonstration with an ambient of 72° F and a relative humidity of 86%, the "Safe Air Unit" was removing a little over 6 gallons of water per hour
- At another test site, with an outside ambient of 18° F, the "Safe Air" unit was able to heat 1,250 CFM of air to 86° F
- We are experiencing about .18 psi per 100 feet at 1,200 CFM through a 6" borehole

ChemBio SHELTER, Inc.

"SAFE AIR" SETUP

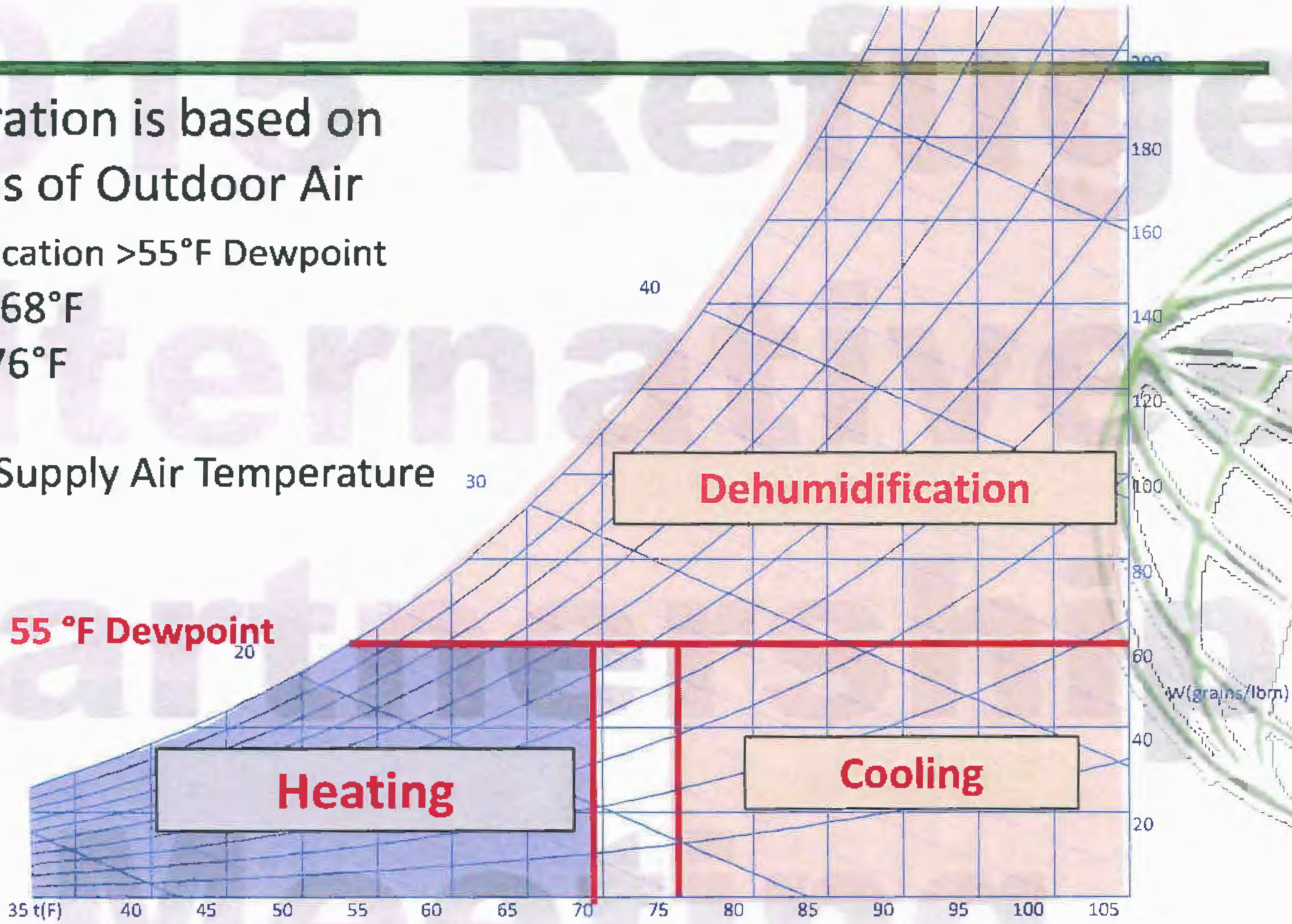


Unit Operation

Unit Operation is based on Conditions of Outdoor Air

- Dehumidification >55°F Dewpoint
- Heating < 68°F
- Cooling >76°F

Adjustable Supply Air Temperature



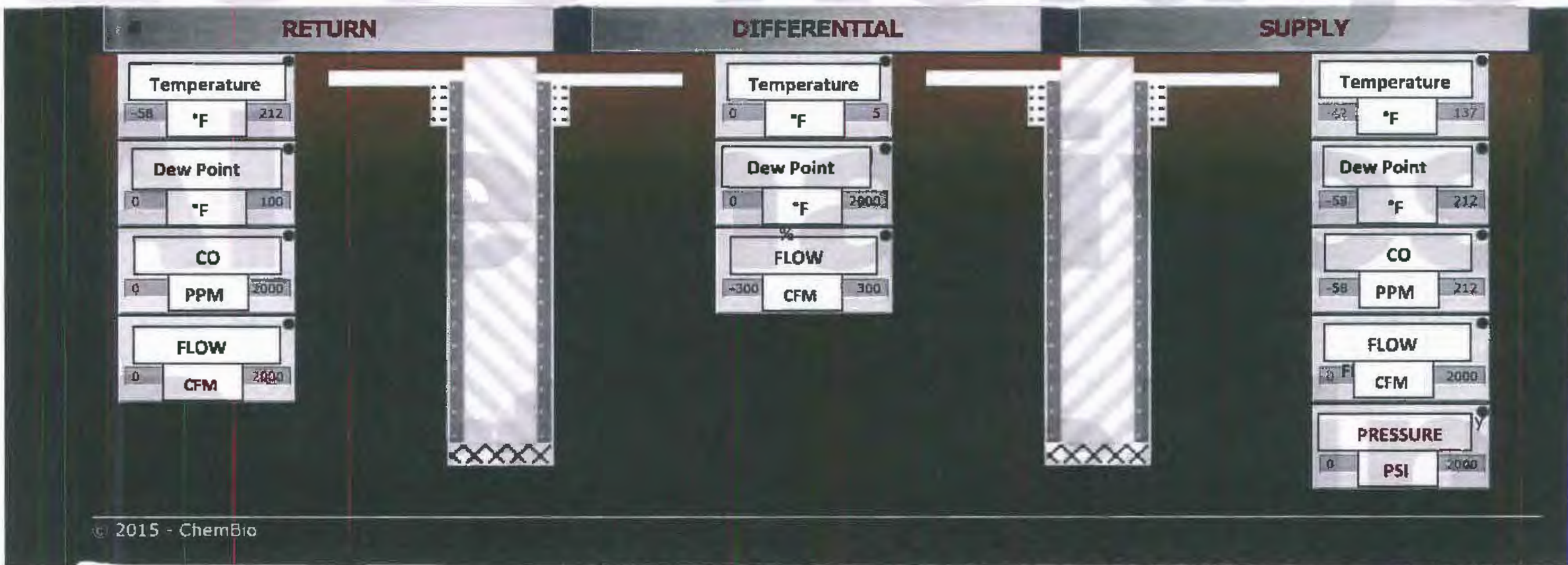
Dew point		Human perception[1]	Relative humidity at 32 °C (90 °F)
Over 26 °C	Over 80 °F	Severely high. Even deadly for asthma related illnesses	65% and higher
24–26 °C	75–80 °F	Extremely uncomfortable, fairly oppressive	62%
21–24 °C	70–74 °F	Very humid, quite uncomfortable	52–60%
18–21 °C	65–69 °F	Somewhat uncomfortable for most people at upper edge	44–52%
16–18 °C	60–64 °F	OK for most, but all perceive the humidity at upper edge	37–46%
13–16 °C	55–59 °F	Comfortable	38–41%
10–12 °C	50–54 °F	Very comfortable	31–37%
Under 10 °C	Under 50 °F	A bit dry for some	30% and lower

"Safe Air" Computer Monitoring System

– The "Safe Air" unit is equipped with a computer that is continuously monitoring the intake air and return air. The following functions can be displayed on the computer screen:
  – Intake and Return CFM
  – Intake and Return temperature
  – Intake and Return Dew Point (with calculated Humidity)
  – Intake line pressure
  – Intake and Return CO monitoring
  – Additional sensors can be added as required

ChemBio SHELTER Inc

"Safe Air" Computer Controlled Display



"Safe Air" Configurations

- The "Safe Air" system can be used in a multitude of configurations:
  - The intake air can be delivered down the borehole, into a BIP RA or mobile refuge and discharged into the mine entry
  - A dual borehole system has been tested in which air is delivered down one borehole into the RA and exits through a 2nd borehole that is drilled into the RA
    - The advantages to the 2nd borehole is that the RA can be ventilated easily when the RA is not in use
    - No air is discharged into the mine which could lower methane to an explosive limit thus aiding in a secondary explosion
    - The 2nd borehole allows assures those topside of the conditions below and eliminates intrinsically safe sensors below

ChamBio SHELTER Inc

DUAL AND SINGLE BOREHOLE SETUP

CheraBio SHELTER Inc.

AIR, COMMUNICATION & SUPPLY DELIVERY

ChemBio SHELTER Inc.

"Safe Air Advantages"

- The "Safe Air" system is electrically driven and can operate off utility power or a generator
- The unit can provide air for an unlimited amount of time
- The "Safe Air" blower system does not introduce hydrocarbons into the air
- Food, water, and medical supplies can be transferred to the miners if needed
- Communication can be integrated into the borehole
- 5 year expiration dates are only limited to consumables
- A patented connection to mobile RA's could be attached pre-event with the elimination of oxygen, air and CO2 scrubbing
- Post even patented connections are available for mobile RA's as well

ChamBio SHELTER, Inc.

Its not the Heat!!!!!

"It's not the heat, it's the humidity."

CharmBio SHELTER Inc

BCS LIFE SUPPORT LLC

NASA

John F. Kennedy Space Center

Mine Test of a Cryogenic Refuge Alternative Supply System (CryoRASS)

OMSHR
OFFICE OF MINE SAFETY
& HEALTH RESEARCH
cdc.gov/niosh/mining
National Institute for Occupational Safety and Health
NIOSH

Donald Doerr, Ed Blalock, and David Bush

LABTECH Inc., BCS Life Support LLC, and NASA

10 February 2015

Refuge Alternatives Partnership Meeting

L.A.B
LIQUID AIR BREATHING TECHNOLOGY

This effort is completed as part of CDC Inter-Agency Agreement (IAA/SAA):-
CDC Agreement No: 12FED1213259, NASA SAA No: KCA-4357

Why use liquid air?

- Provide a new technology method for air storage
- Store more air in less space to reduce size & weight
- Store air at lower pressure to improve safety
- Provide heat stress relief to improve comfort & survivability – reduce temperature and humidity

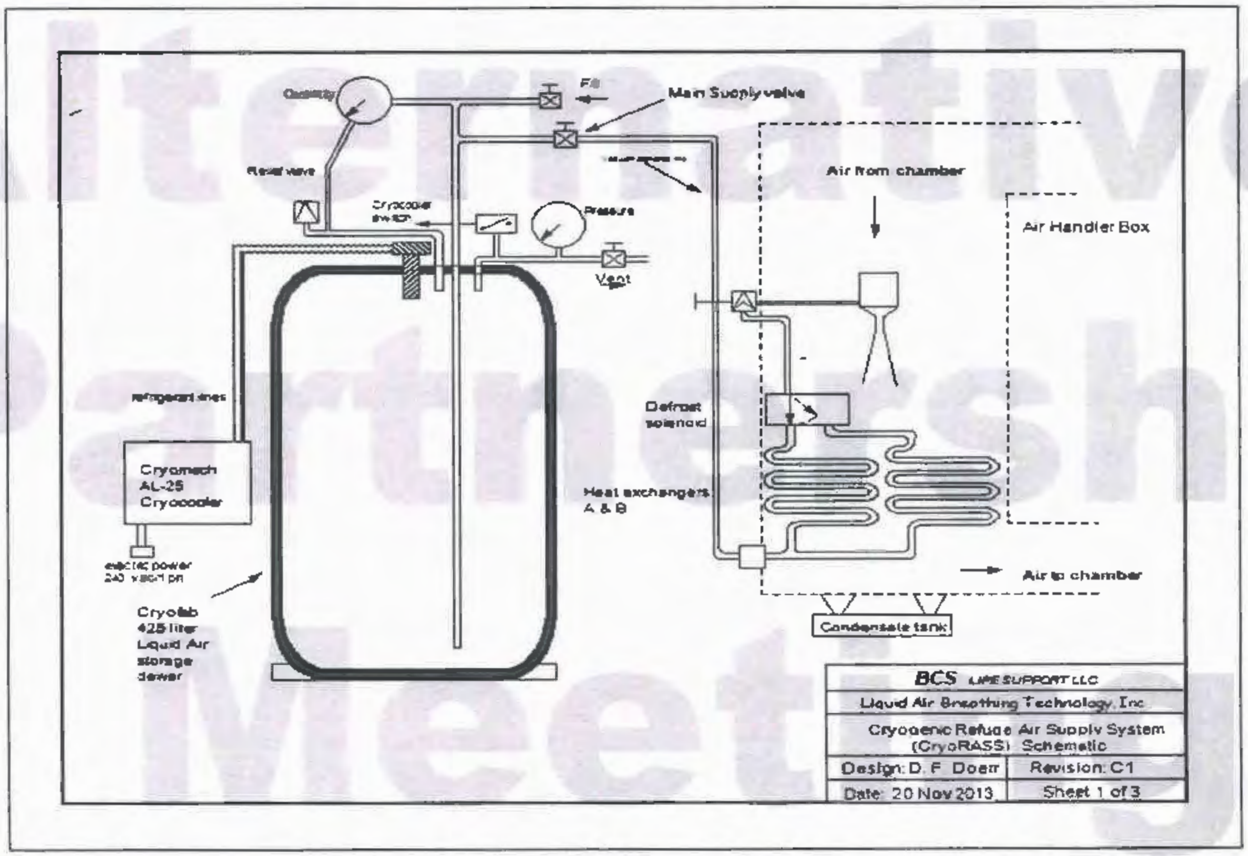
Basic Design considerations

John F. Kennedy Space Center

- Store 96 hours of air supply in liquid form
  - Use 2 x 425 liter + 300 liter dewars for a 23 man chamber
- Preserve quantity and composition of liquid air
  - Use cryocooler to overcome heat leak during long term storage
    - Assume electrical power until emergency
    - Assume no electrical power during emergency
- Simple activation by first miner to enter (1 pull)
- Provide air at 5X oxygen quantity (1.32 ft^3/hr/person)
- Provide cooling for heat stress relief
- Provide dehumidification for heat stress relief
- Provide air circulation within refuge
- Provide partial CO_2 flushing

Basic schematic

John F. Kennedy Space Center



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Sustainability of Liquid Air

NASA

John F. Kennedy Space Center

- Liquid air composition and quantity can be maintained with use of cryocooler
  - Instrumented studies for 6 months show no change
  - Cryocooler for 425 liter dewar requires 7.2 amp/240VAC
- For this test, all three dewars filled on 6 November
- Dewars shipped on 10/11 November – 300 liter cryocooler damaged
- Dewars in mine 12 November – 2 cryocoolers operating (425's)
- Test started 17 November with 300 liter
  - 11 days after fill
  - 7 days after cryocooler failed
- Dewar is self pressurizing with buildup loop, regulator controls pressure at 75 psi

First 96 hour test of CryoRASS

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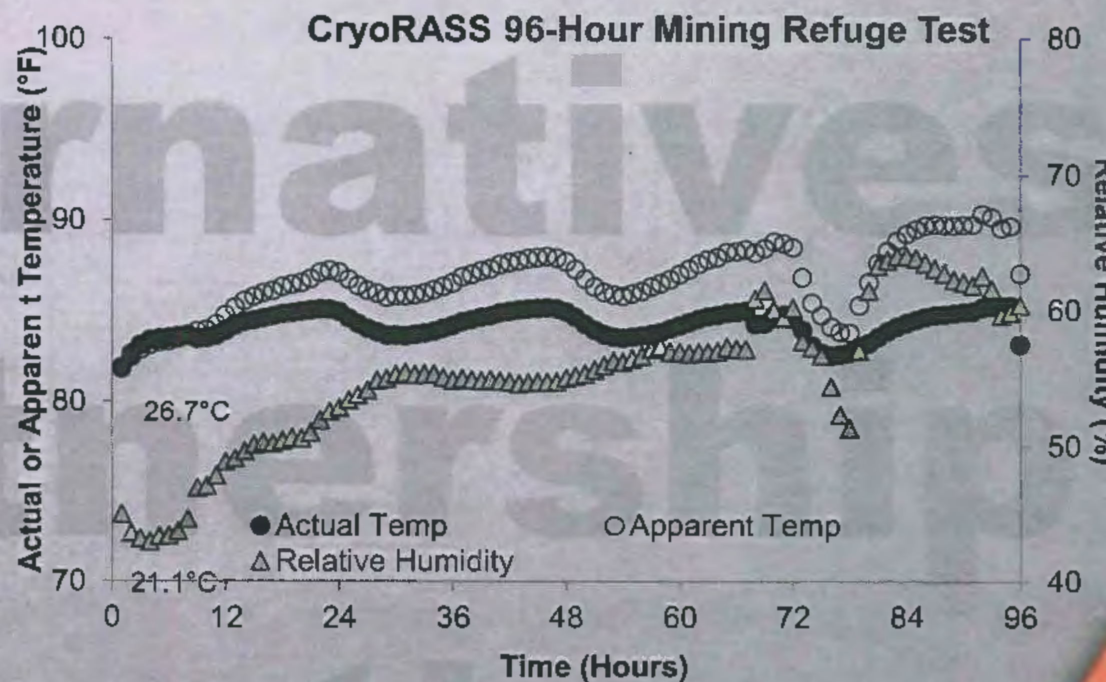

Trinity Refuge Alternative - 10 person

How much liquid air for 23 person inflatable refuge?

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- MSHA requirement = 1.32 ft^3 oxygen/ hour/person
  - X5 = 6.6 ft^3/hr since O_2 is ~20% component of air
  - for 23 miners = 152 ft^3/hr
  - for 96 hours = 14,575 ft^3 (total)
  - gaseous flow rate = 4300 liters/hr = 72 liters/minute (minimum)(2.5 SCFM)

- Volumetric expansion ration for liquid to gaseous air = 728 : 1
  - total liquid required = 20 ft^3 or 566 liters
  - → minimum flow to air handler = 72 liters/minute (gaseous)(2.5 SCFM)
    - to provide maximum duration (165 hr)

- CryoRASS storage for this test = 425 CryoRASS + 425 CryoASFS + 300 ZL
  - For 96 hours, can flow (1150 x 728) = 837,200 liters gaseous (29,600 ft^3)
  - → maximum flow rate (for 96 hr) = 145 liters/minute (5.1 SCFM)
    - to provide maximum cooling and dehumidification

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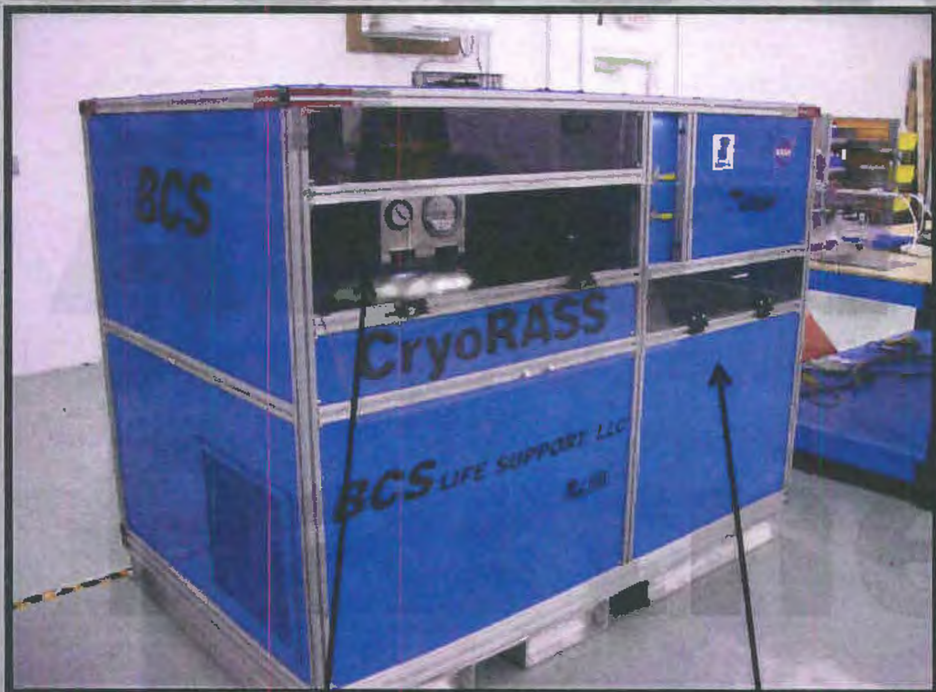
CryoRASS Prototype 1

NASA

John F. Kennedy Space Center



Cryocooler behind panel

Liquid Air 425 liter dewar

Air Handler box
with duct work

How was CryoRASS tested?

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Test plan for CryoRASS in Experimental Mine

- Commercially available, inflatable Refuge chamber
- Instrument for temperatures, pressure, humidity
- Use "barrel person" simulator to generate heat and water vapor
  - Add 494 BTU/person
  - Add 1.3 liter water /person/day
- Conduct 96 (continuous) hour test
- Isolate chamber in cross-cut with insulated walls
- Digitally record all data
- Test conducted by Pittsburgh OMSHR personnel
- BCS/LABtech support on site for operation of CryoRASS

Instrumentation diagram

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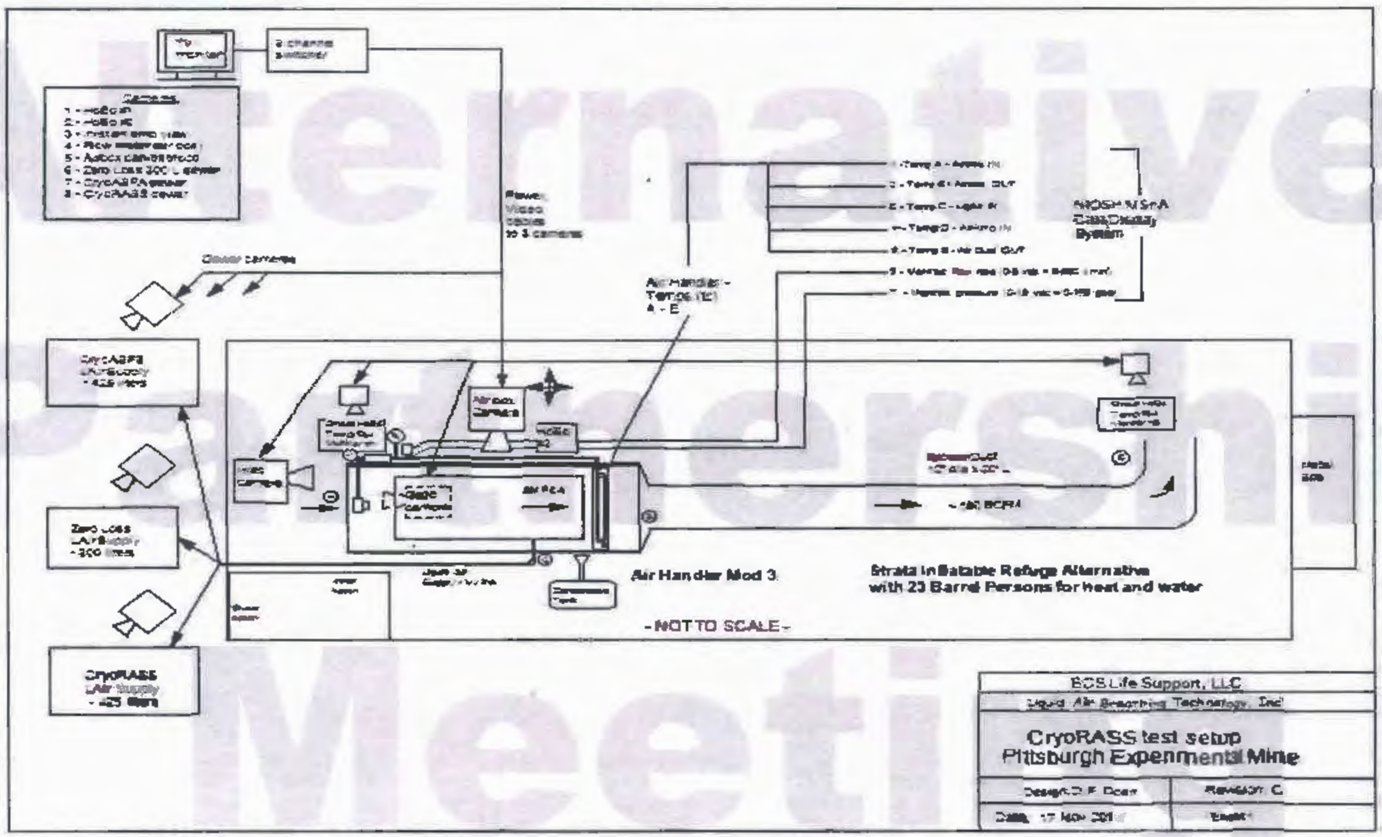

Refuge chamber interior

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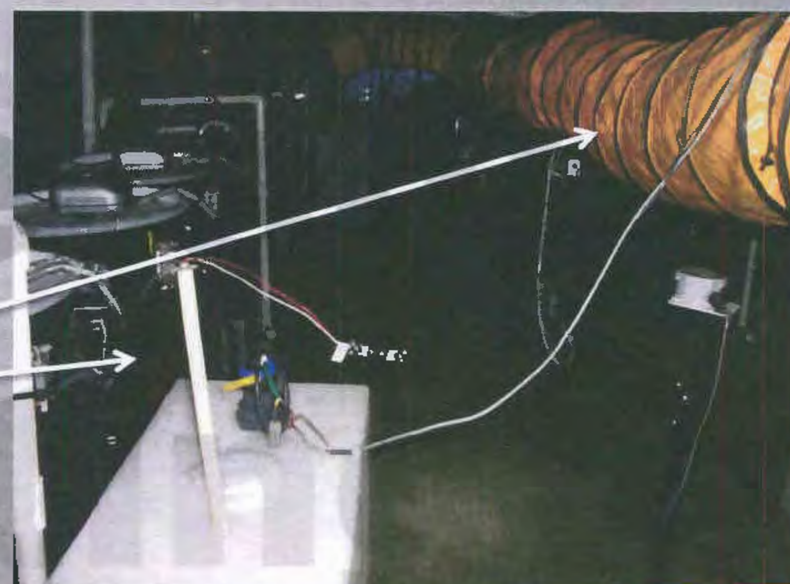
Air Handler Box
- liquid air input from bottom



Air duct from air handler (right)
Note "barrel persons" (left)

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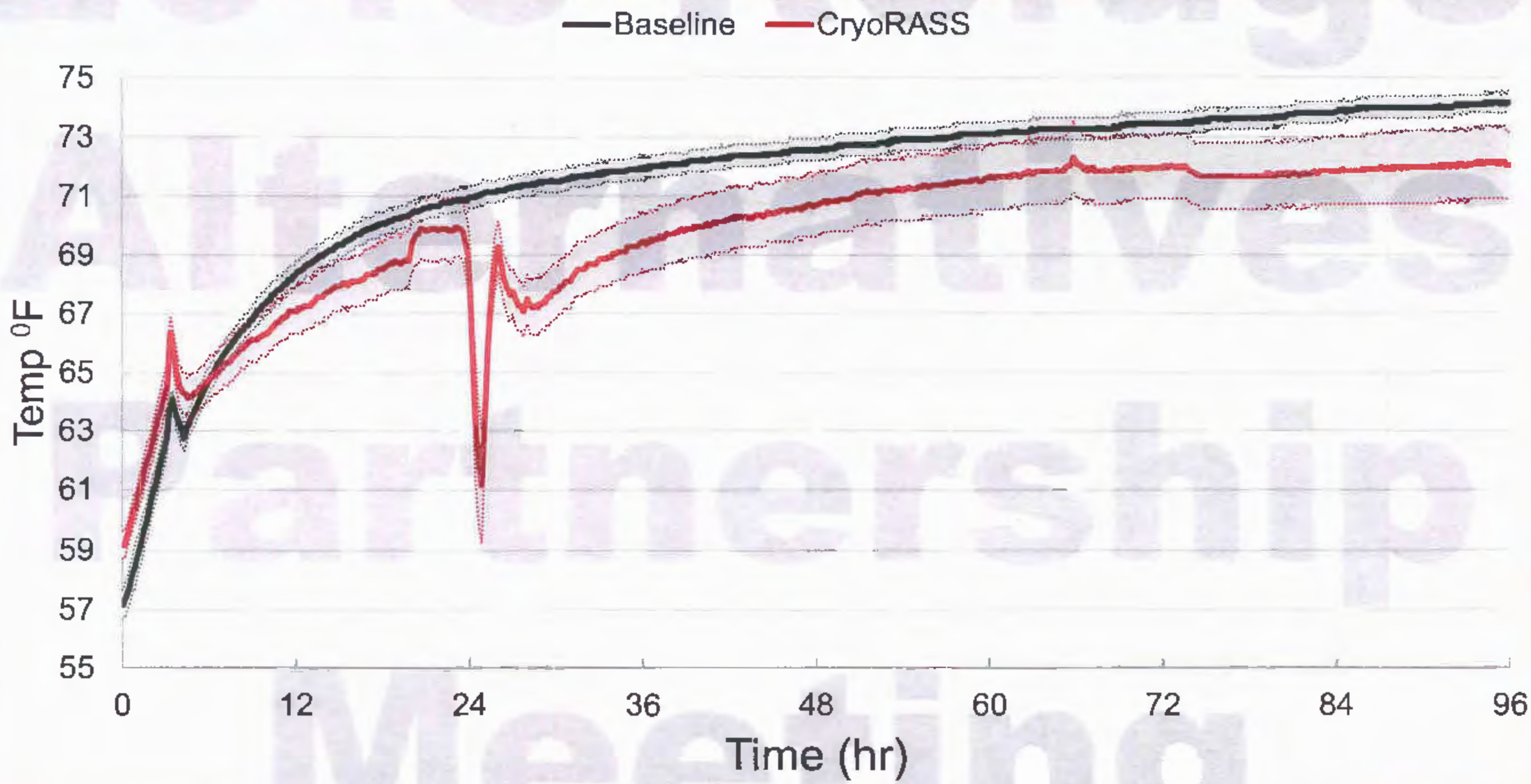
Testing of CryoRASS

John F. Kennedy Space Center

RASS connected to 23 man inflatable chamber

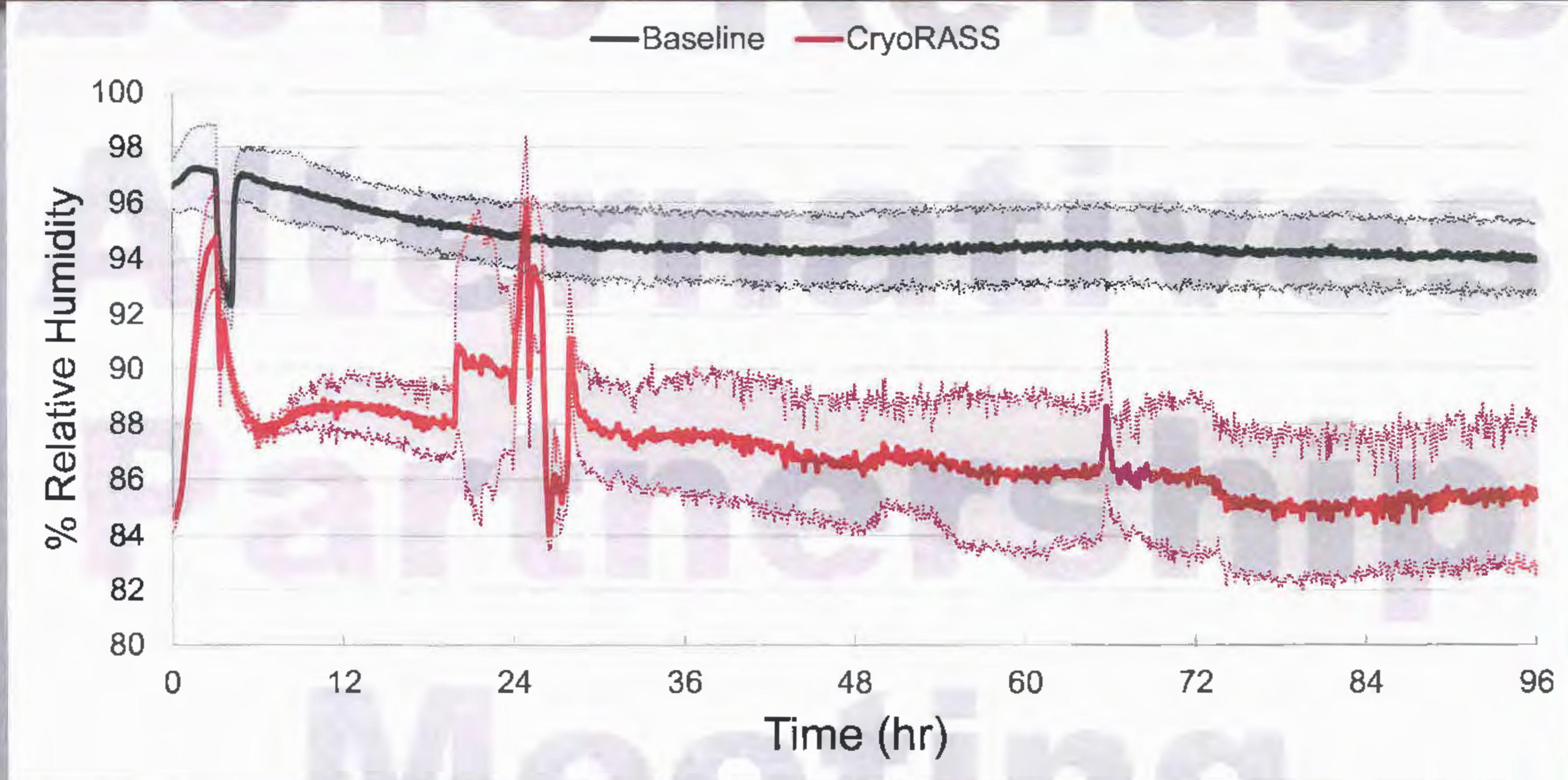
Test Instrumentation & video monitoring

Air Temperature



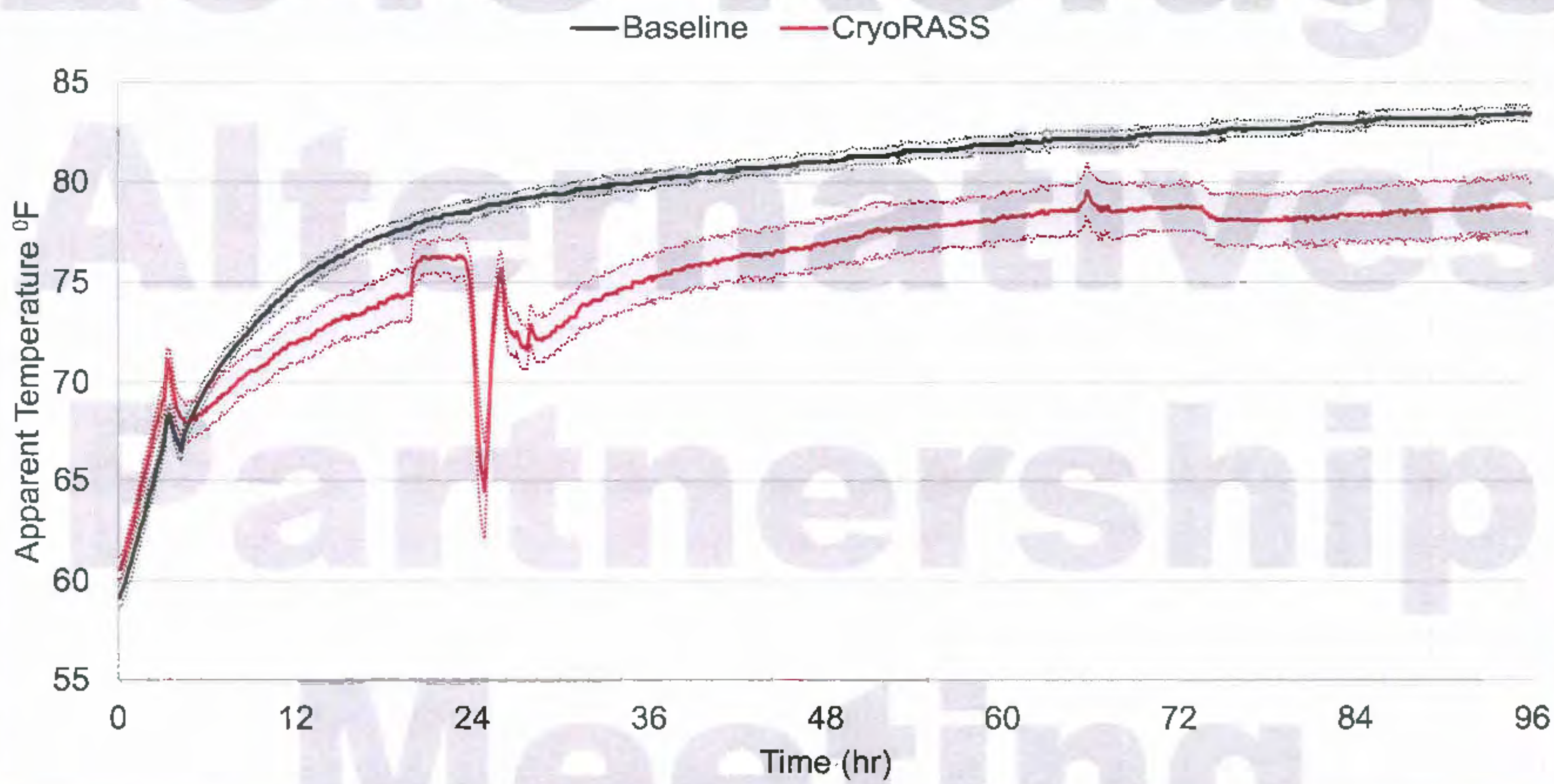
Plotted is the average and standard deviations of three temperature readings inside the refuge chamber (Front, middle, end) for each test. The data was collected at 1sample/20 sec and re-sampled post-test 1 sample/ 5 minutes.

Relative Humidity



Plotted is the average and standard deviations of three Humidity readings inside the refuge chamber (Front, middle, end) for each test. The data was collected at 1sample/20 sec and re-sampled post-test 1 sample/ 5 minutes.

Apparent Temperature



Plotted is the apparent temperature calculated by using the Wet Globe Bulb Temp approximation. The average and standard deviations of Three Humidity/Temperature readings inside the refuge chamber (Front, middle, end) was used for the WGBT calculation.

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Test Results Summary

NASA

John F. Kennedy Space Center

- Actual (dry bulb) temperatures were marginally lower (- 3° F)

- Considerable humidity removed (~ 11 gal + ~ 1 gal frost + 3.4 gal expelled out through relief valve and/or leaks)
    - RH down to 85%
    - RH down to 76% at duct outlet

- Apparent temperature reduction:
    - Baseline: 74°F, 94% RH = 83.1°F Apparent
    - CryoRASS: 73°F, 85% RH = 77.2°F Apparent
    - **Overall apparent temperature reduction: 6°F**

- No effort was made to model or control CO_2

Conclusion

John F. Kennedy Space Center

- This test proved concept feasibility and prototype design
- CryoRASS system creates refuge air circulation (~ 150 SCFM)
- Since 140 liters/min (5.1 SCFM) added, then140 l/m (w/water vapor + CO_2) expelled
- Temperature and humidity reduced
- Heat stress relief provided (6°F apparent temp reduction)
- Safety enhanced (low pressure air source)
- Air source space & weight requirement decreased
- Although not specifically tested here, increased airflow will purge CO_2, reducing the CO_2 levels in the chamber, thus reducing the need for CO_2 scrubbing. Since CO_2 scrubbing is a significant exothermic reaction, any reduction in the CO_2 concentration will result in additional heat savings.

Entry Observations

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Note dry
floor in tent 2 & 3

Air handler, cold plate
and condensate tank

Partially dry
floor in tent 1

What's next?

CryoRASS Prototype #2 will:

- Add second cold plate to air handler box
- Change to1000 liter horizontal dewar (low seam mines)
- Ruggedize construction to comply with MSHA
- Larger, ruggedized cryocooler
- Design to fit existing inflatable, hard chambers, and "built in place"
    - Options
        - Stand alone CryoRASS connected to inflatable, hard refuge, or built in place
        - Fit CryoRASS components into inflatable's storage box
        - Fit CryoRASS components into airlock of hard refuge
- Include Air Curtain at entryway vs. purge (next page)

Air Curtain in place of Purge

John F. Kennedy Space Center

Video clip of air curtain

Vent tubes

Measuring air flow from air curtain

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Questions?

John F. Kennedy Space Center

Built-In-Place Refuge Alternatives – (BIP-RA)
San Juan Coal Company

David Hales
Health & Safety Manager
February 10, 2015

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New Mexico Coal

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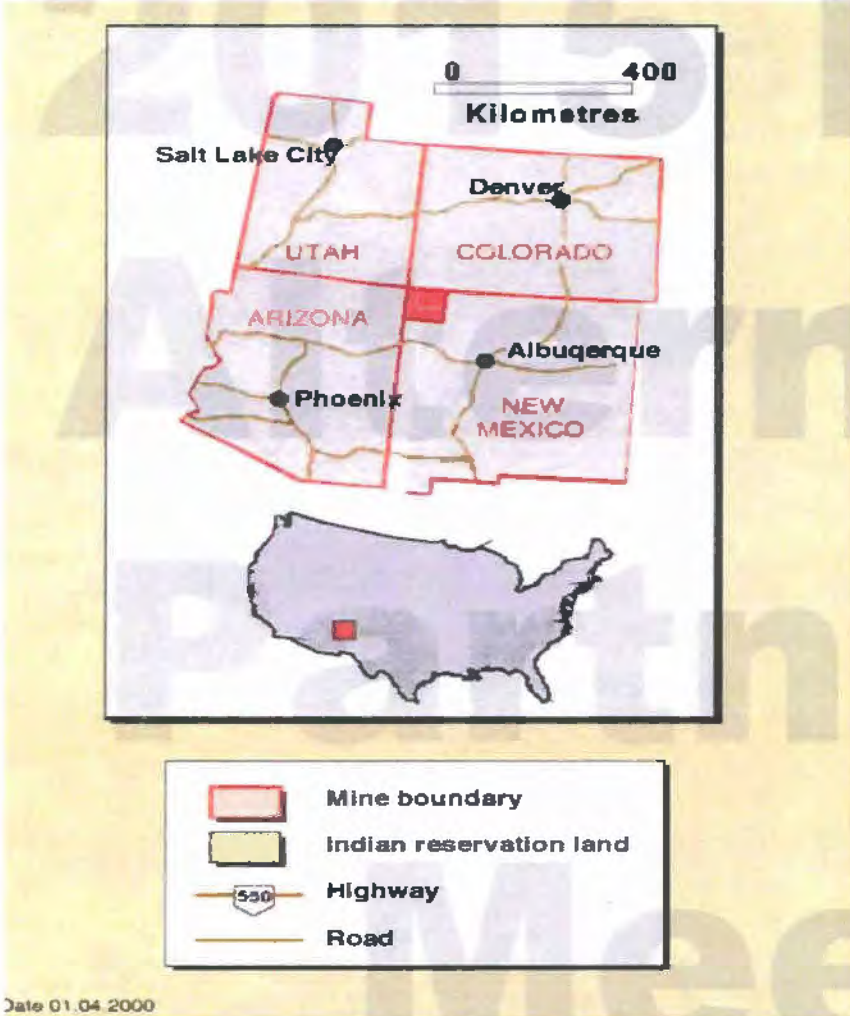

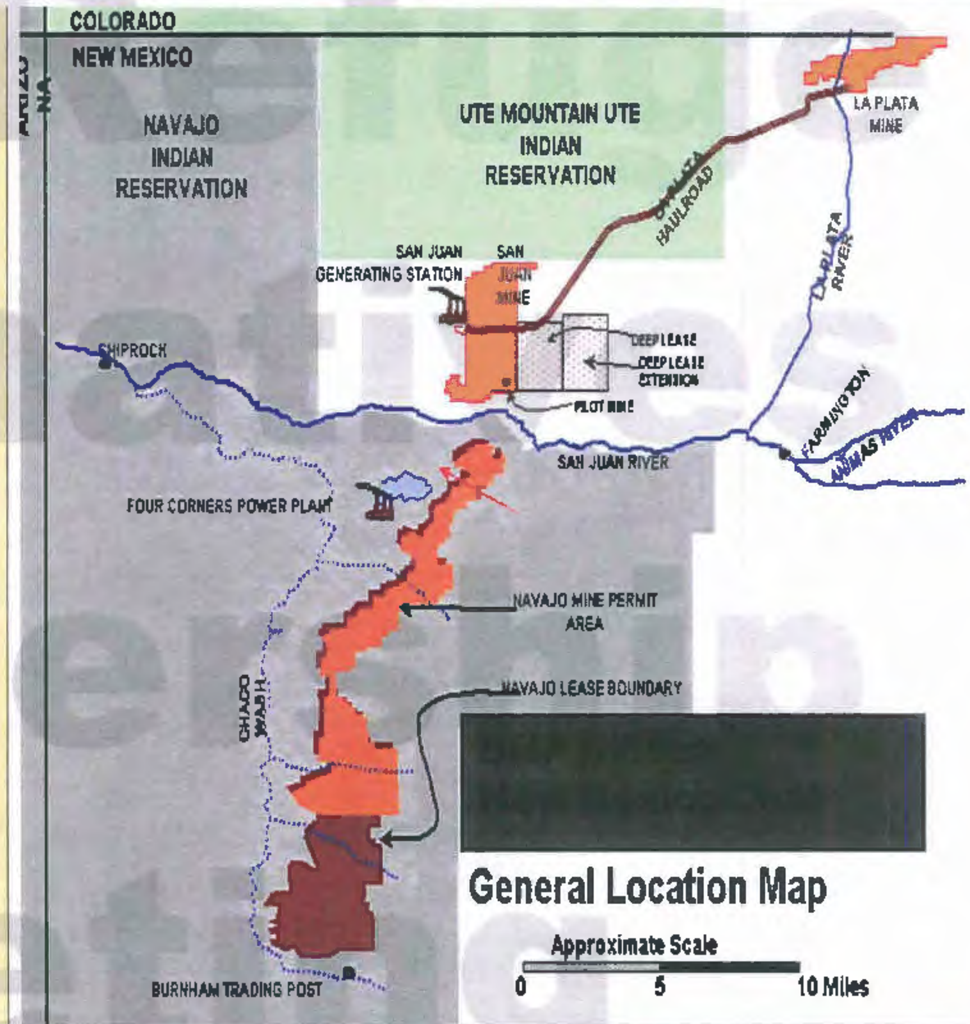

BIP RA History at San Juan Mine

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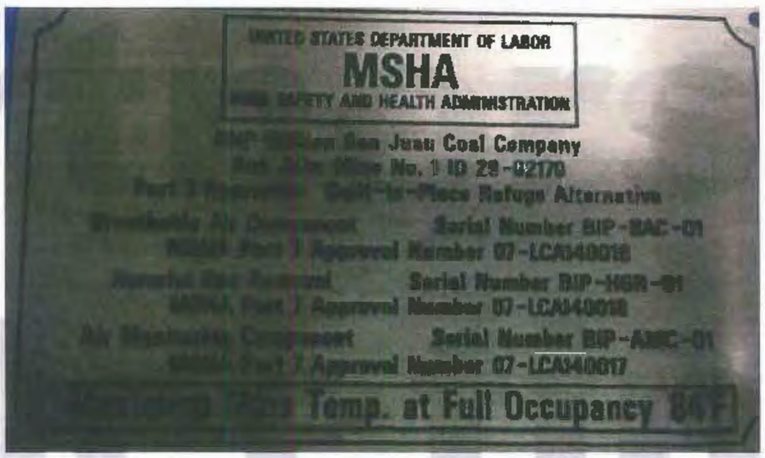
- First installation, March 2006
- Incorporated into the MSHA Approved Emergency Response Plan, April 2007
- Structure was certified as exceeding the 15 psi strength requirements in 2009.
- Structure and Door were certified as exceeding the 15 psi strength requirements in 2010.
- Part 7 Approval was achieved in 2014.
- Continue to install at 6000 foot intervals.



Major Driver for this Decision

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Time To Increase CO_2 Levels From Normal To Fatal
Barricading Volumes and Equivalent Number of Crosscuts

No. Of Miners	Time (Hrs)	Vol (ft3)	No. Of 203 XC's
1	1	3505	0.96
	4	14018	1.05
	12	42054	1.28
	24	84109	1.63
	48	**168218**	**2.34**
	72	252327	3.04
	96	336436	3.74
	120	420545	4.44
	144	504653	5.14
	168	588762	5.84
	192	672871	6.54
	216	756980	7.24
	240	841089	7.94

Barricading Space Required

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Time To Increase CO_2 Levels From Normal To Fatal
Barricading Volumes and Equivalent Number of Crosscuts

No. Of Miners	Time (Hrs)	Vol (ft3)	No. Of 203 XC's
12	1	42054	1.28
	4	168218	2.34
	12	504653	5.14
	24	1009307	9.34
	48	**2018614**	**17.76**
	72	3027921	26.17
	96	4037228	34.58
	120	5046535	42.99
	144	6055841	51.40
	168	7065148	59.81
	192	8074455	68.22
	216	9083762	76.63
	240	10093069	85.04

Typical Construction Details

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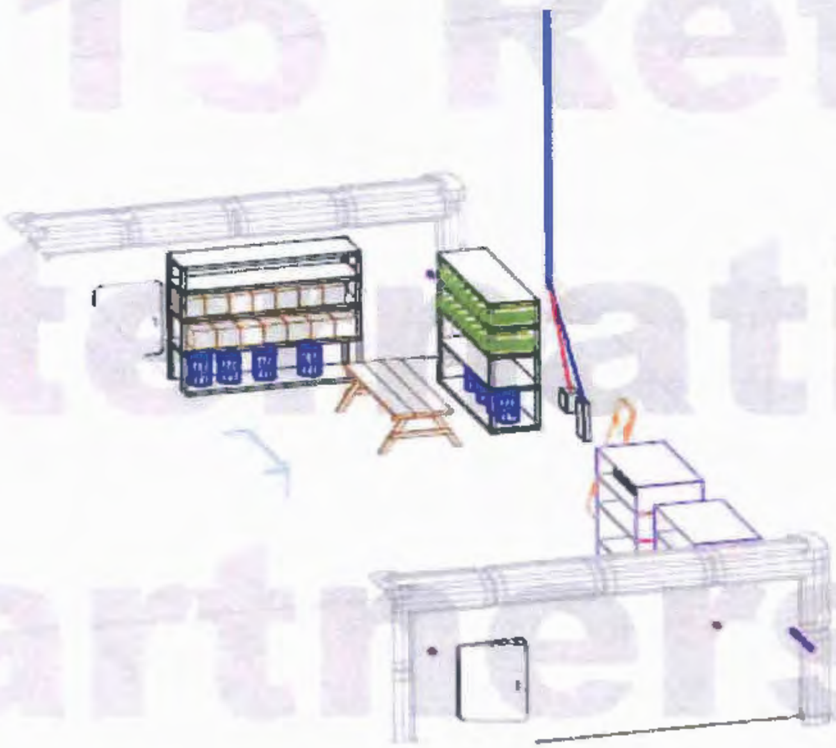
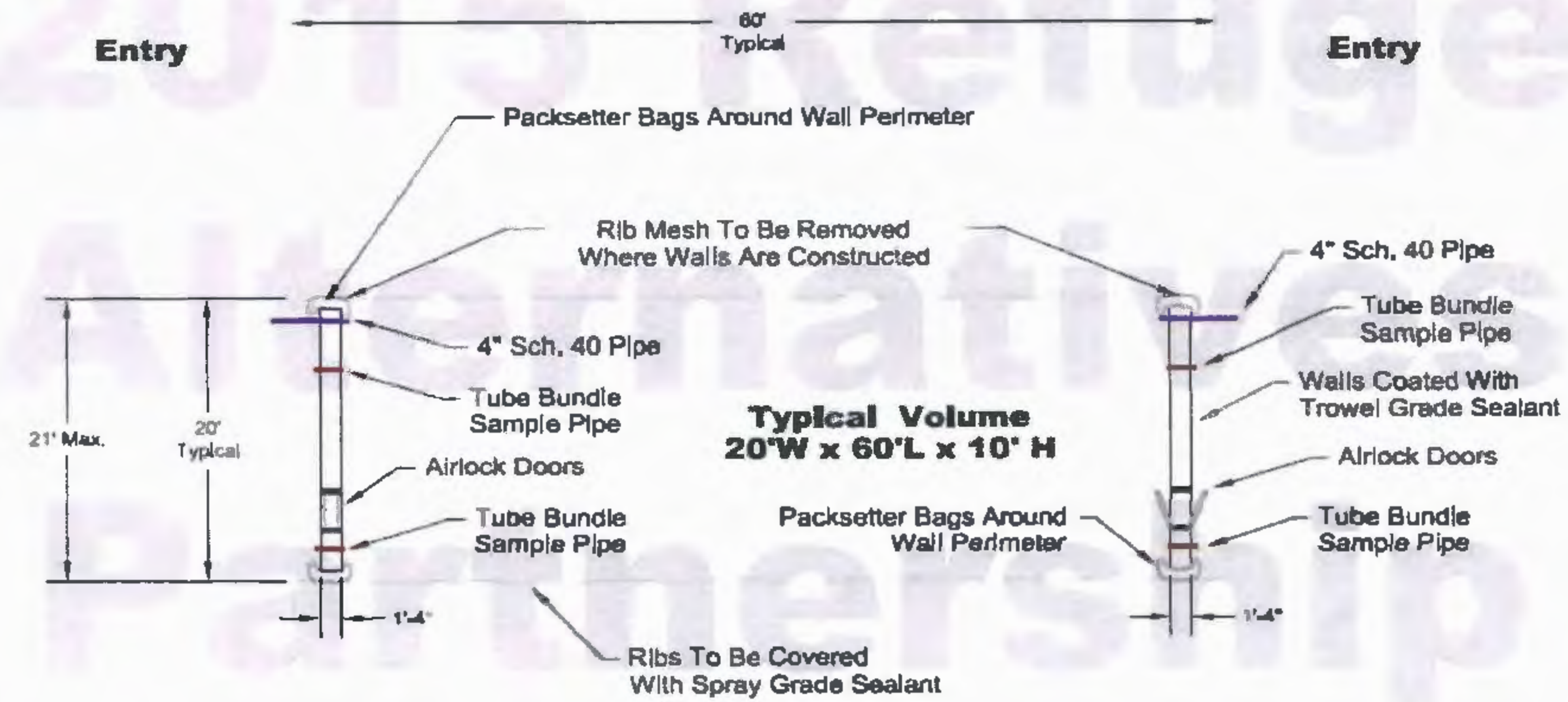


Typical Construction Description



Roof Support Will Be Per The MSHA Approved Roof Control Plan. Supplemental Rib Support Will Be Evaluated On A Site-Specific Basis, But Will Typically Consist Of Chain Link Or Mesh With Rock Props.

Typical Stopping Wall Construction Will Be As Per A Mitchell-Barrett Wall - Dry Stacked Solid Concrete Block Layed In A Transverse Pattern. Hitching Is Not Required. A Pilaster Will Be Utilized As Required On A Site-Specific Basis. Overall Chamber Design Will Be Evaluated On A Site-Specific Basis.

Maintenance of Atmosphere

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- Large vent pipe is open during normal operations, closed during actual use.
- Equipped with a check valve to prevent air reversing through the pipe.
- Dual sampling ports for sampling the mine atmosphere outside the RA.
- A second vent pipe is equipped with a pressure relief valve.

Interior View of An Early Version

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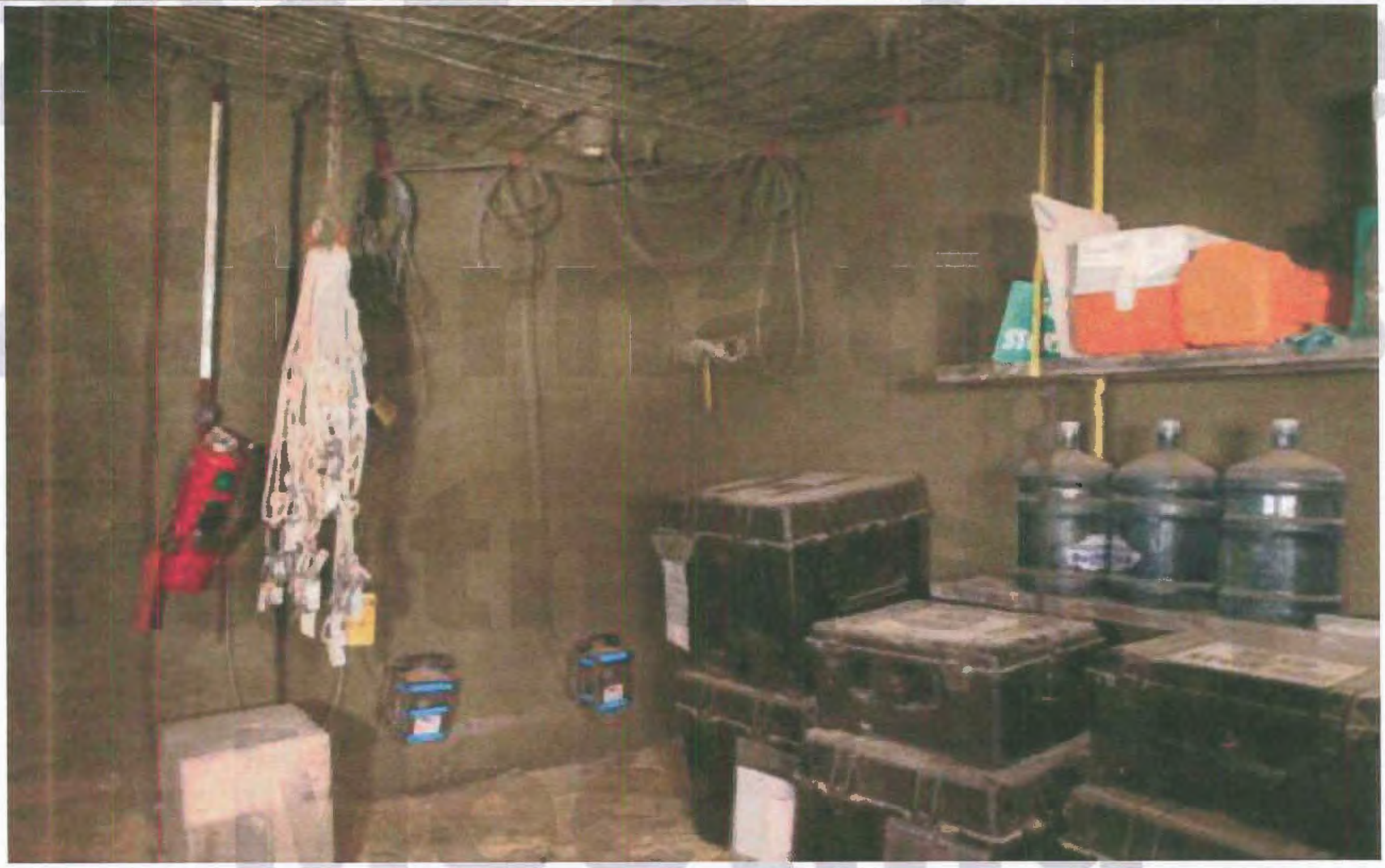

Interior Photo of Current Installation

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- Supply containers with tamper-evident seals.
- Improved storage shelving.

Underground Supplies List

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Supply Materials	Quantity	
	Gateroad	Mains/Submains
10'X25' brattice	10	15
Fire extinguisher	1	1
Pager phone	2	2
Picnic tables, folding	2	4
Industrial Scientific MX6 Refuge Chamber Kit	1	1
Simplex roof jacks	4	4
Wool blankets	15	30
Trauma kit/O2 & stretcher	1/shelter	1/shelter
Eye wash station with 2 bottles of saline	1	2
Built in urinal	1	1
Bag toilet & bags	1	1
Biohazard containers with bags	2	4
Paper coveralls	4	8
water (clean up, wash, toilet, etc.)	30 gal	60
water in individual 4.22 oz. containers (5 yr life)	640	1280
Dried foods, 5 yr life, (44 # 9 cans of assorted dried fruit & 99 energy bars)	1 set	2 set
Cots	4	4
MSHA Approved portable lights - (Streamlight or Equiv)	2	2

Surface Component Typical Layout

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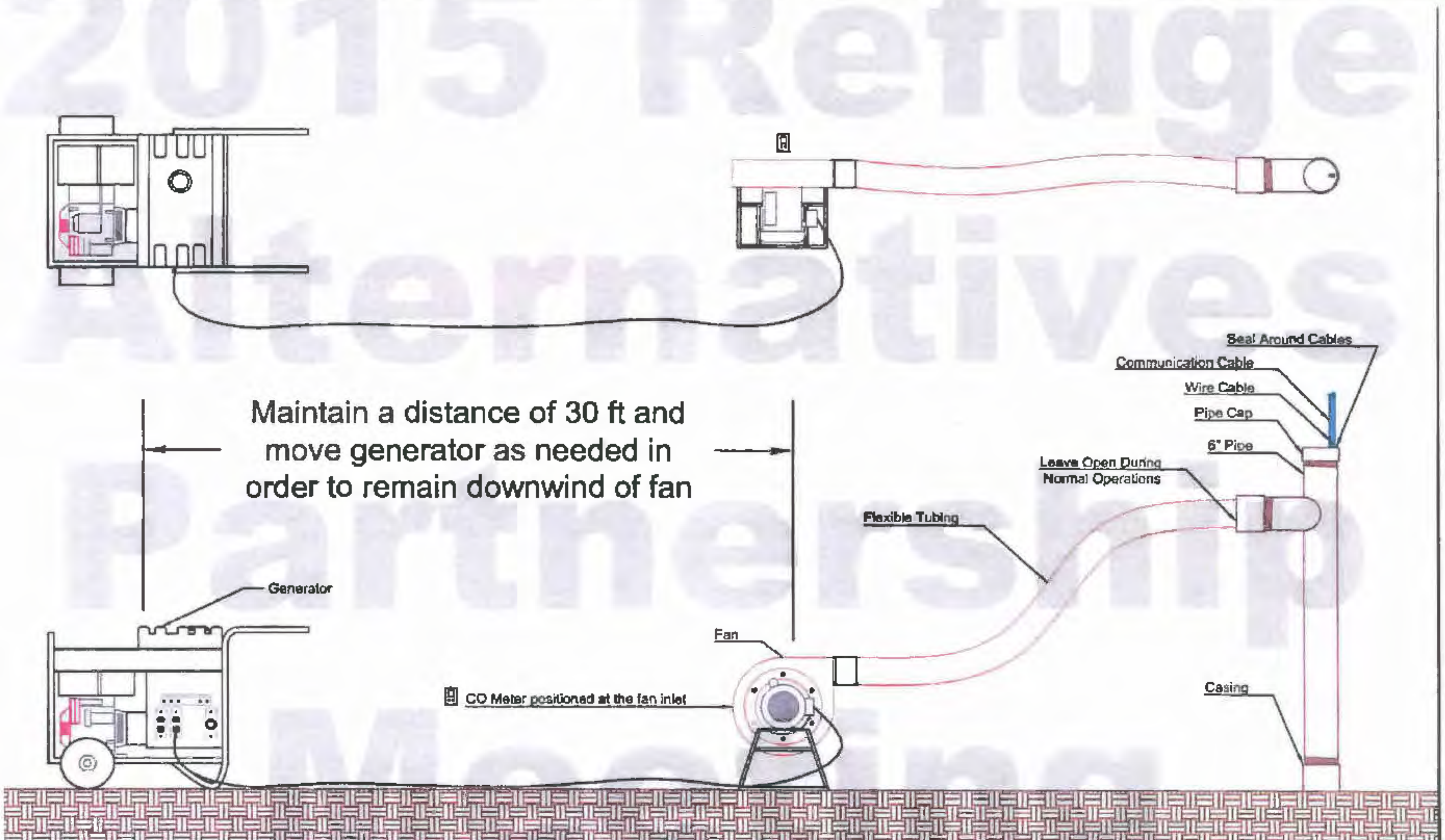

Typical Surface Borehole Site

Borehole Support Trailers

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- Borehole **Support** Trailers
- Stored at a central & secure location
- Equipment examined and tested on a regular basis.

Trailer Materials	Quantity	
	Gateroad	East Mains
Generator	1/borehole	1/borehole
Carbon Monoxide Detector set to alarm at 10 PPM	1/borehole	1/borehole
Fans	1/borehole	1/borehole
Ventilation hose/tubing	1/borehole	1/borehole
Lighting	1/borehole	1/borehole

Borehole Support Equipment

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Ventilation Survey Data – Part 7 Application

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BIP RA Location	Wall to Wall Length (ft)	Floor to Roof Height (ft)	Rib to Rib Width (ft)	Ambient Noise Level (db)	Ambient Noise Level with Fan (db)	Ambient Inside Temperature (F)	Ambient Surface Temperature (F)	CFM W/O Aux Fan (Adjusted)	CFM W/ Aux Fan (Adjusted)
EM XC 35	44.5	10	18.75	52.2	62	64	99	78	270
EM XC 72	31.5	10	18.05	55	61	64	79.7	191	468
EM XC 107	53	10	19	48	54	71	99	78	397
WSM XC 1	68.1	8	18	61	63	65	86.6	174	374
GR-400 XC 24	35.5	11.3	21	40.2	47.8	66	96.3	110	321
GR-401 XC 22	66.5	9.5	18.3	48	50	67	95.4	110	302
GR-401 XC 48	78.5	9.4	22.3	38.2	48.1	72	93.1	302	480
GR-402 XC 16	66.5	10	18	45	50.3	66	93.2	220	480
GR-402 XC 42	61.8	9.5	19.8	34	58	66	89.5	302	499

Key Points

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- Major ventilation changes can impact RA ventilation and its performance.
- Regular inspections of ventilation, supplies and RA conditions are necessary.
- Exhausting ventilation fan maintains fresh air flow continuously. Borehole fans enhance that ventilation volume.

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