PITTSBURGH MINING RESEARCH DIVISION

RA Ingress, Purging, and Relief Valve Testing

Tim Lutz, PE

Refuge Alternative Webinar
June 23, 2016
Pittsburgh PA

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

Outline

- Background
- NIOSH built-in-place refuge alternative
- Contamination ingress testing
- Purge testing
- Pressure relief valve testing

Advantages of BIP Refuge Alternatives

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

- Quicker and easier to prepare and operate
- Miners may not have to wait to enter while airlock is purged of CO
- Provide more space per occupant
- Eliminate 96-hour ticking clock
- Increase likelihood communication system will survive
- Better chance of surviving a secondary explosion than a tent-type mobile RA
- Order of miner arrival less important, not a problem if some miners decide to leave

Background

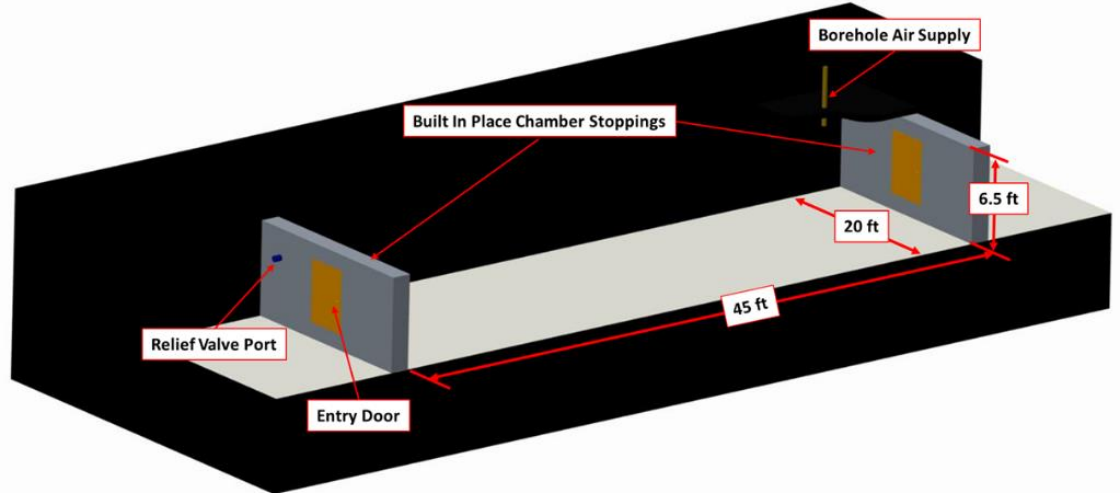
CFR specifies the following:

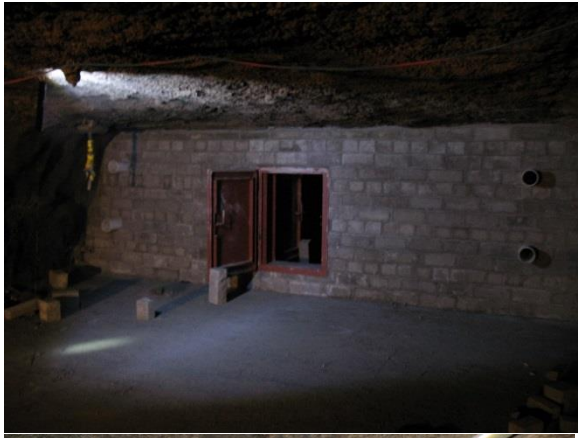
- Minimum area (15 sq ft) and airflow (12.5 CFM) per person in a built-in-place refuge alternative that uses compressed air
- Pressure inside BIP must not exceed 5” H_2O or 0.18 psi or as specified by the manufacturer
- Occupants must be capable of surviving at least 96 hours inside the refuge alternative

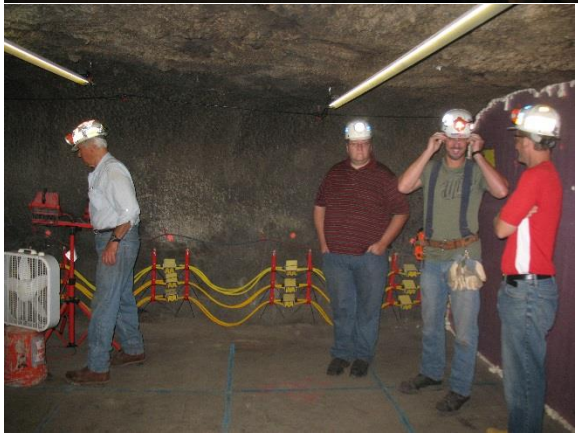
Note: CO level to be less than 25 ppm or less for no health effects

Concentration (ppm)	CO Exposure Symptoms
35	Headache and dizziness within six to eight hours of constant exposure.
100	Slight headache in two to three hours.
200	Slight headache within two to three hours; loss of judgment.
400	Frontal headache within one to two hours.
800	Dizziness, nausea, and convulsions within 45 min; insensible within 2 hours.
1,600	Headache, tachycardia, dizziness, and nausea within 20 min; death in less than 2 hours.
3,200	Headache, dizziness, and nausea in five to ten minutes. Death within 30 minutes.
6,400	Headache and dizziness in one to two minutes. Convulsions, respiratory arrest, and death in less than 20 minutes.
12,800	Unconsciousness after 2–3 breaths. Death in less than three minutes.

NIOSH Built-In-Place (BIP) Refuge Alternative (RA) Research Area

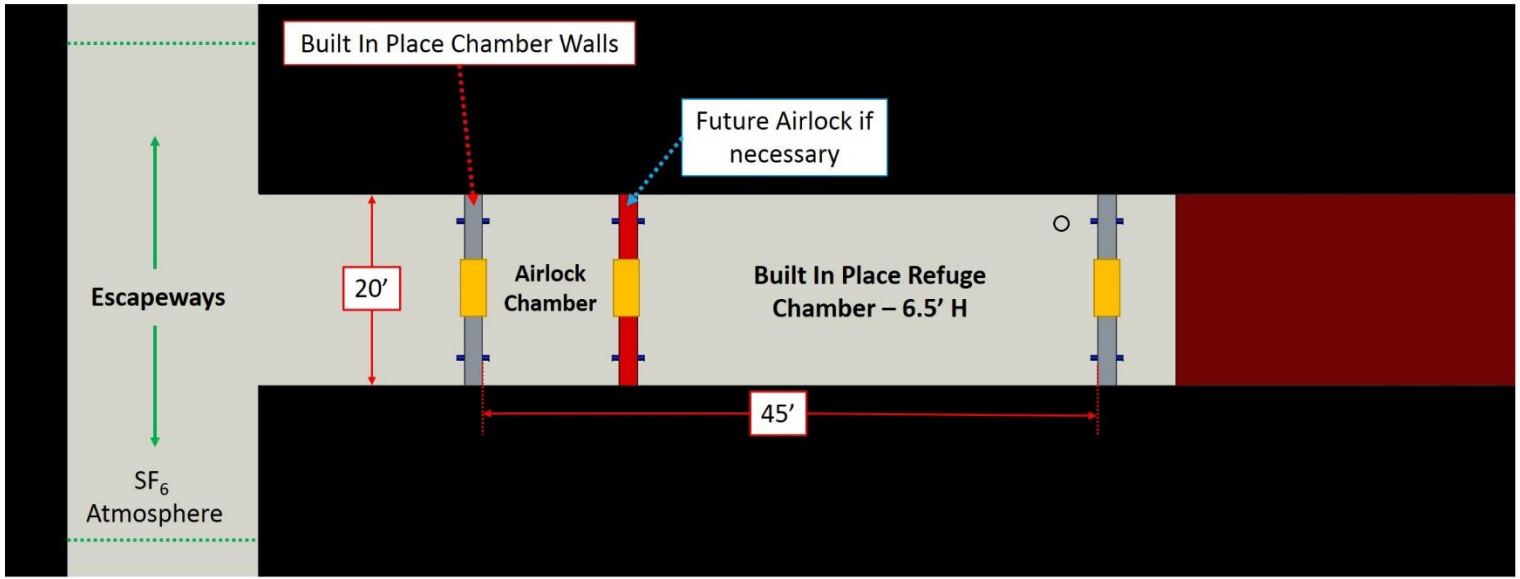






Contamination Ingress Testing

Refuge Chamber

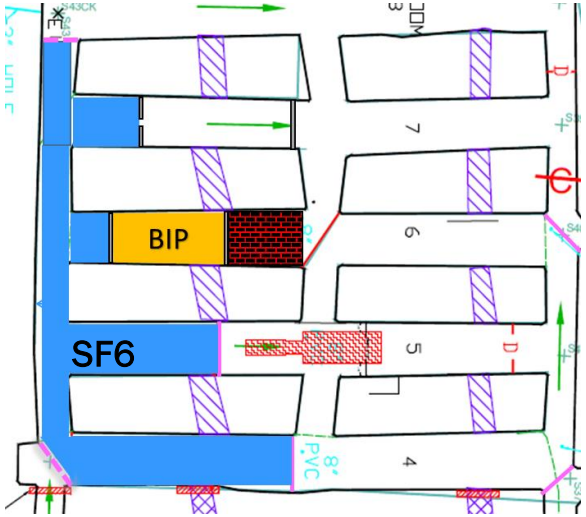


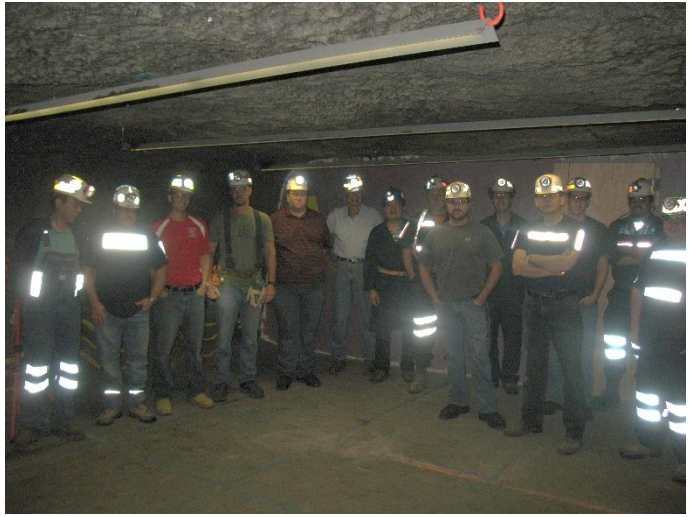
Legend

- Doors 30"W x 46"H
- Relief Valves / Instrumentation Piping
- Borehole Air Supply

Contamination Ingress Testing in BIP RA

NIOSH is performing contamination ingress research to determine the concentration of CO that would exist in a BIP RA due to miners entering after a catastrophic event.





Contamination Ingress Testing Procedure

- Introduce SF_6 into sealed outside area of BIP (blue area), mix with fans and take samples at prescribed intervals
  - SF_6 at low concentrations acts similar to other gases (CO) and is safe for human exposure
- Once stabilized to ensure uniform concentration of 150-200 ppb, bring all human subjects into SF_6 area and then all enter the BIP RA
- Close door to BIP, take samples inside and outside BIP RA

Contamination Ingress Testing Results

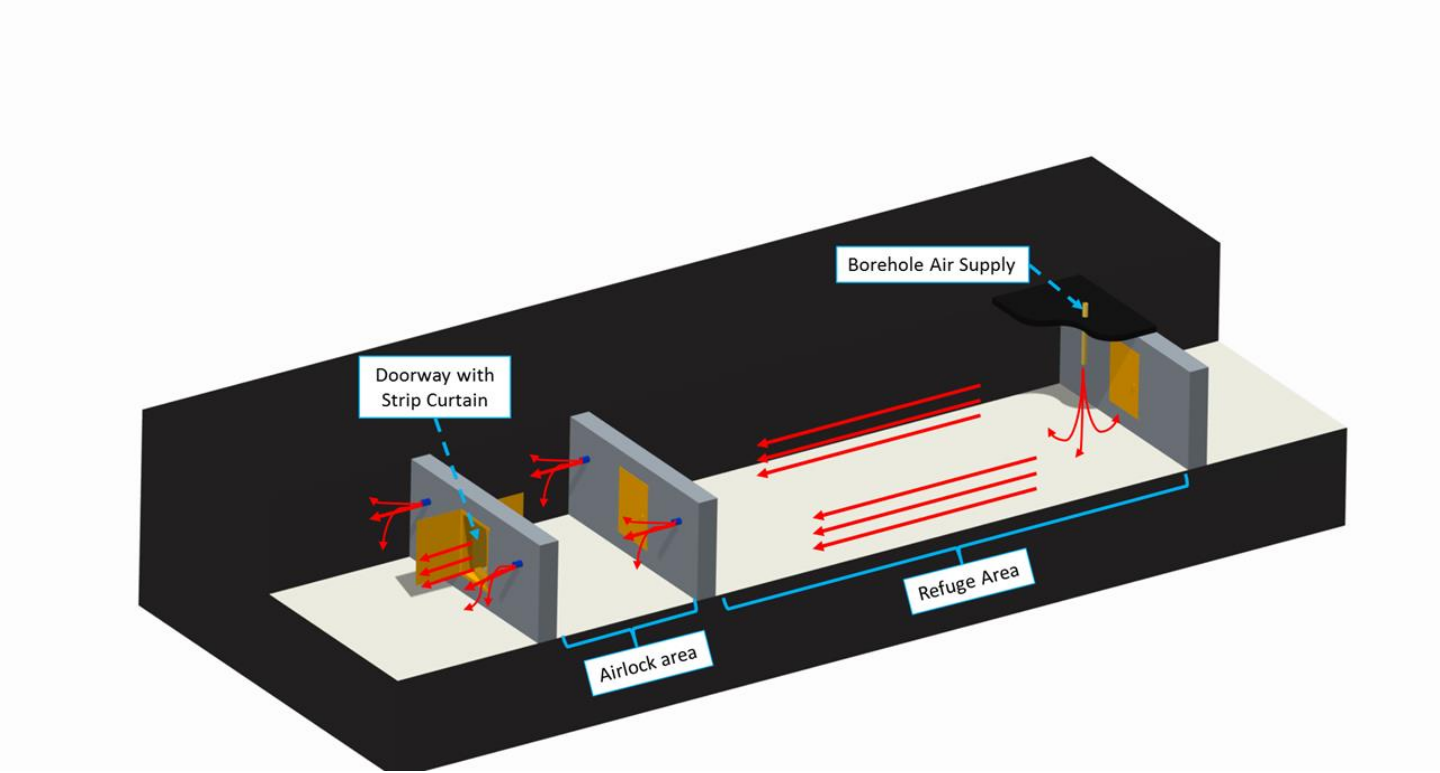
(without mine air flow)

Test	Outside BIP SF6 Concentration (ppb)	Inside BIP SF6 Concentration (ppb)	Contamination Factor
W/ Air Supply 5 Subjects	172.5	1.16	0.67%
W/O Air Supply 5 Subjects	146.6	1.48	1.01%
W/ Air Supply 15 Subjects	145.6	2.48	1.70%
W/O Air Supply 15 Subjects	200.1	2.85	1.42%

Contamination Ingress Summary

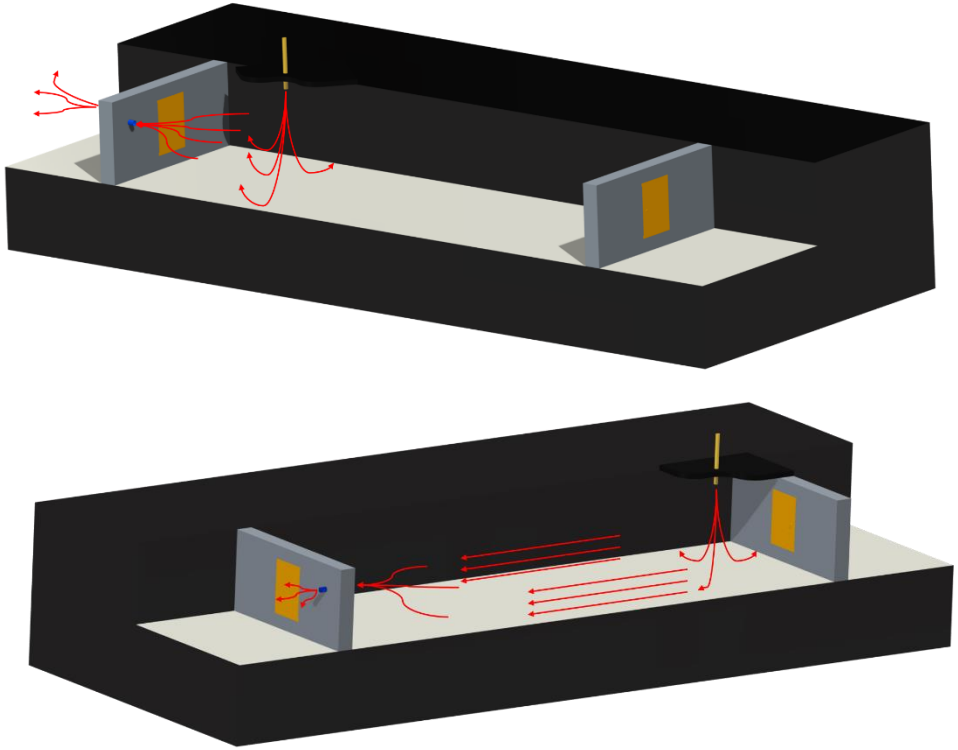
- 5 and 15 person tests resulted in contamination factors of 0.67% to 1.70% with and without air supply (no mine air flow)
  - Contamination factors less than 2% can result in hazardous atmosphere inside BIP RA
- Future contamination ingress tests
  - 30 person test with and without air supply (July 2016)
  - Contamination prevention strategies will be investigated (strip curtains, door bladder) (CY 2017)

Future Contamination Ingress Tests with Prevention Strategies



Purge Testing in BIP RA

- Once contaminant (CO) has entered an RA, purging is required to reduce the contaminant to safe levels
- NIOSH is performing BIP RA purging research to determine:
  - Time required to purge for various ventilation system layouts
  - If ventilation system layout creates “dead areas”



Air Supply System Connected to Borehole

BIP Purge Testing Overview

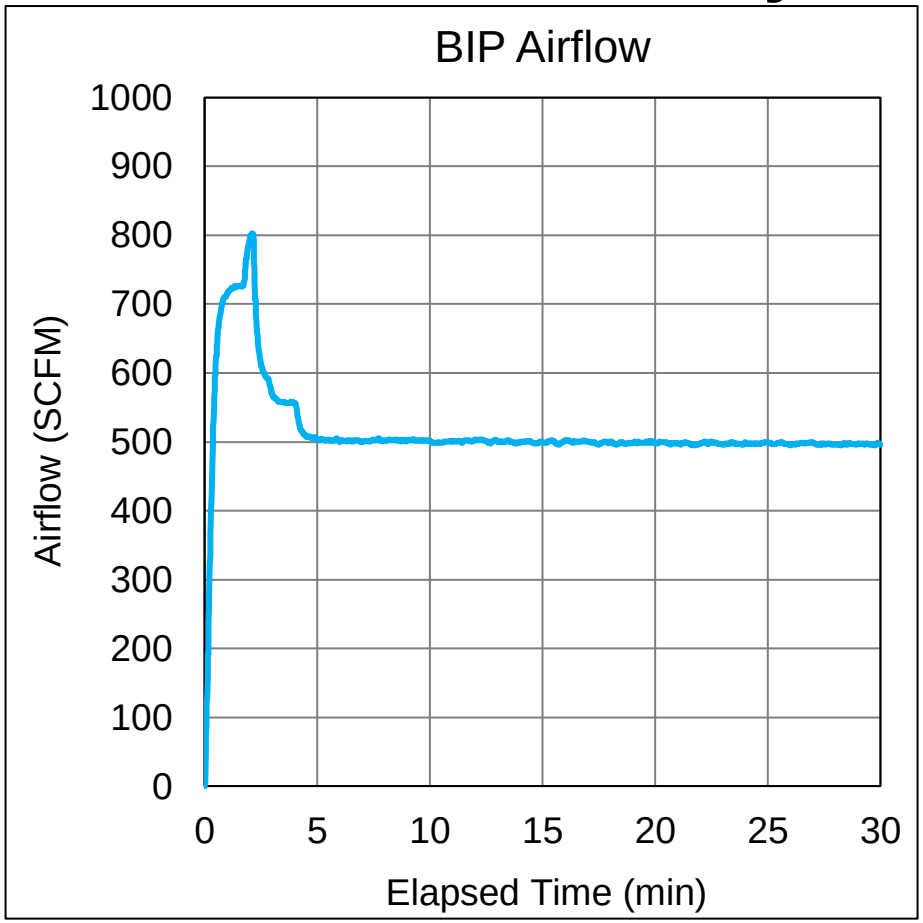
- Add SF_6 to sealed BIP area to a concentration of approximately 1000 ppm (maximum concentration for monitoring equipment, fans to disperse SF_6 evenly)
- Turn on air supply and measure concentrations in various positions within BIP
- Stop test when average concentration reaches approximately 25 ppm and record total time

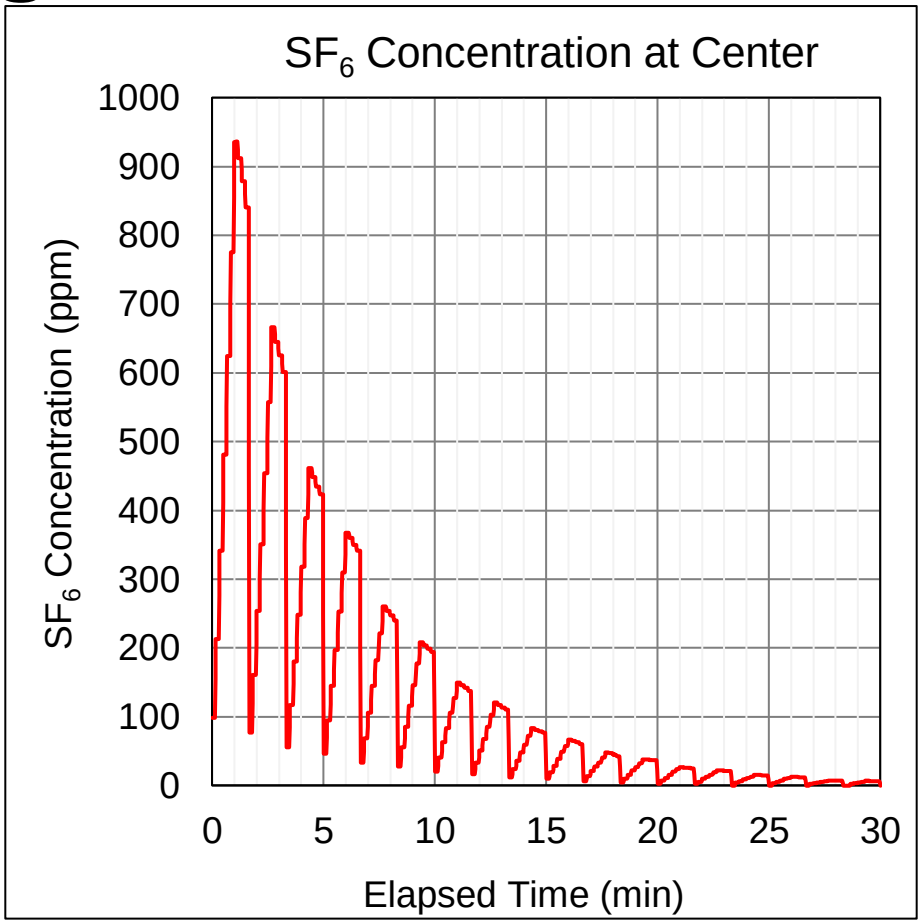
Purge Testing Setup

Sampling tubes in BIP RA

Real-time SF6 concentration monitor
(Maximum concentration – 1000 ppm)

Preliminary Purge Test Results





Purge Testing Summary

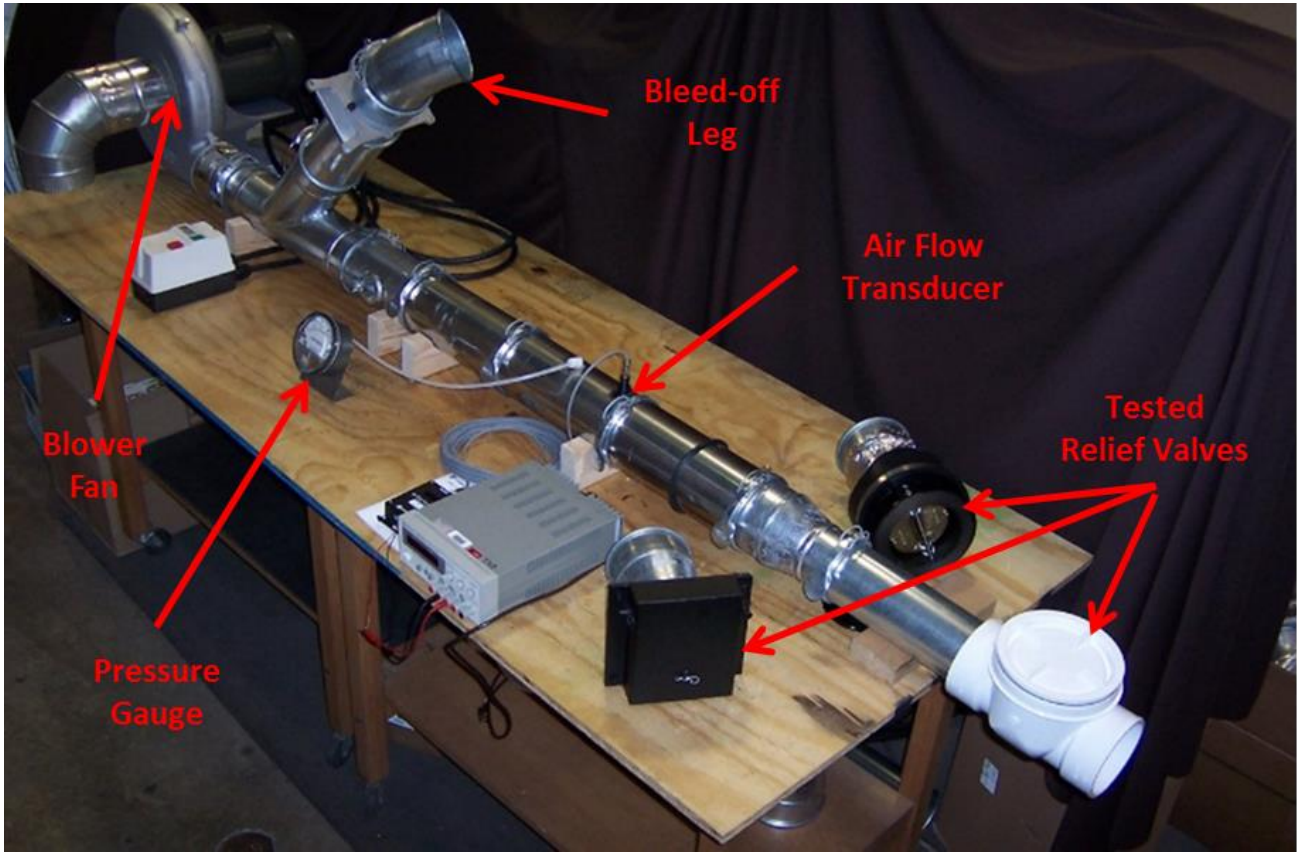
- Purging is critical to making the BIP air breathable
- Different configurations will be tested to reduce the "dead" zones and decrease time to purge to 25 ppm
- Input from stakeholders will aid in determining configurations to be tested

Pressure Relief Valves

Pressure Relief Valves

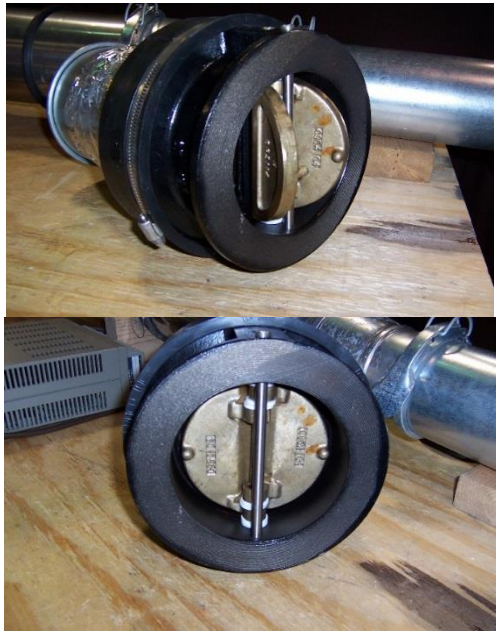
- Pressure relief valves are an important feature of RAs to prevent methane migration from the strata, post-disaster contamination ingress, and excessive pressure buildup.
- Over-pressure causes stress/discomfort to the occupants and possibly the inability to open the entry door or close it.

Pressure Relief Valve Test Stand (PRVTS)

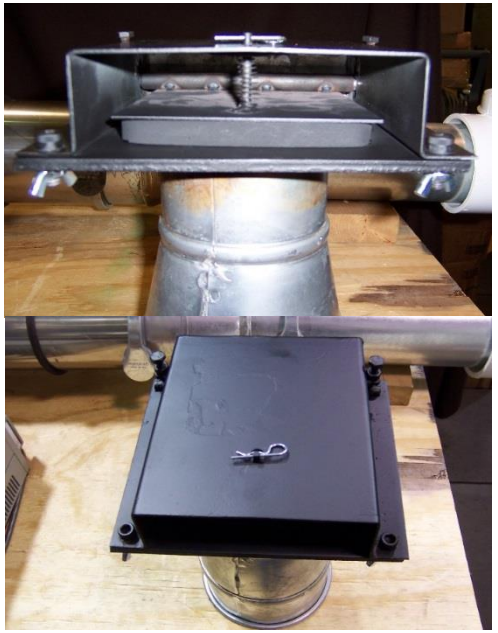


Tested Relief Valves (backflow preventers)

PVC Check Valve
(modified)



Brass/Cast-Iron
Butterfly Check Valve



RA Manufacturer
Relief Valve

Pressure Relief Valve Test Procedure

- Mount/adapt relief valve to ductwork
- Power up blower fan
- Record readings indicated on pressure gauge and digital velocity probe
- Make any modifications to valve to meet CFR standard (0.18 psi or 5 in-H_2O relief pressure)
- Retest valve in new configuration

Test Results

Pressure and Velocity Data for the modified PVC PRV

Angle	Weight added to flapper (lb)	Velocity (ft/s)	Volume Flow Rate (CFM)	Steady State Pressure	
				(psi)	(in-H20)
0°	0.00	74.7	610.9	0.04	1.2
	0.95	67.1	548.7	0.08	2.2
	1.92	65.0	532.1	0.10	2.8
45°	0.00	74.6	610.2	0.04	1.2
	0.95	69.5	568.8	0.09	2.4
	1.92	64.9	530.6	0.11	3.0
90°	0.00	73.5	601.2	0.04	1.2
	0.95	72.5	593.0	0.07	1.8
	1.92	70.7	578.4	0.08	2.2

MSHA relief valve pressure specifications (30 CFR):
0.18 psi (5 in-H_2O) or as specified by manufacturer.

Test Results

Pressure and Velocity Data for the Brass/Cast-Iron Butterfly PRV

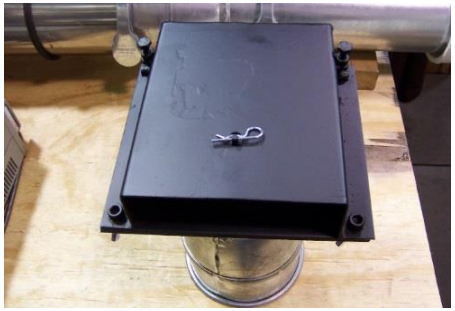
Angle	Configuration	Velocity (ft/s)	Volume Flow Rate (CFM)	Steady State Pressure	
				(psi)	(in-H_2O)
45°	No springs	49.5	405.3	0.18	5.0
90°	No springs	46.3	378.5	0.19	5.2

MSHA relief valve pressure specifications (30 CFR):
0.18 psi (5 in-H_2O) or as specified by manufacturer.

Test Results

Pressure and Velocity Data for the RA Manufacturer Relief Valve

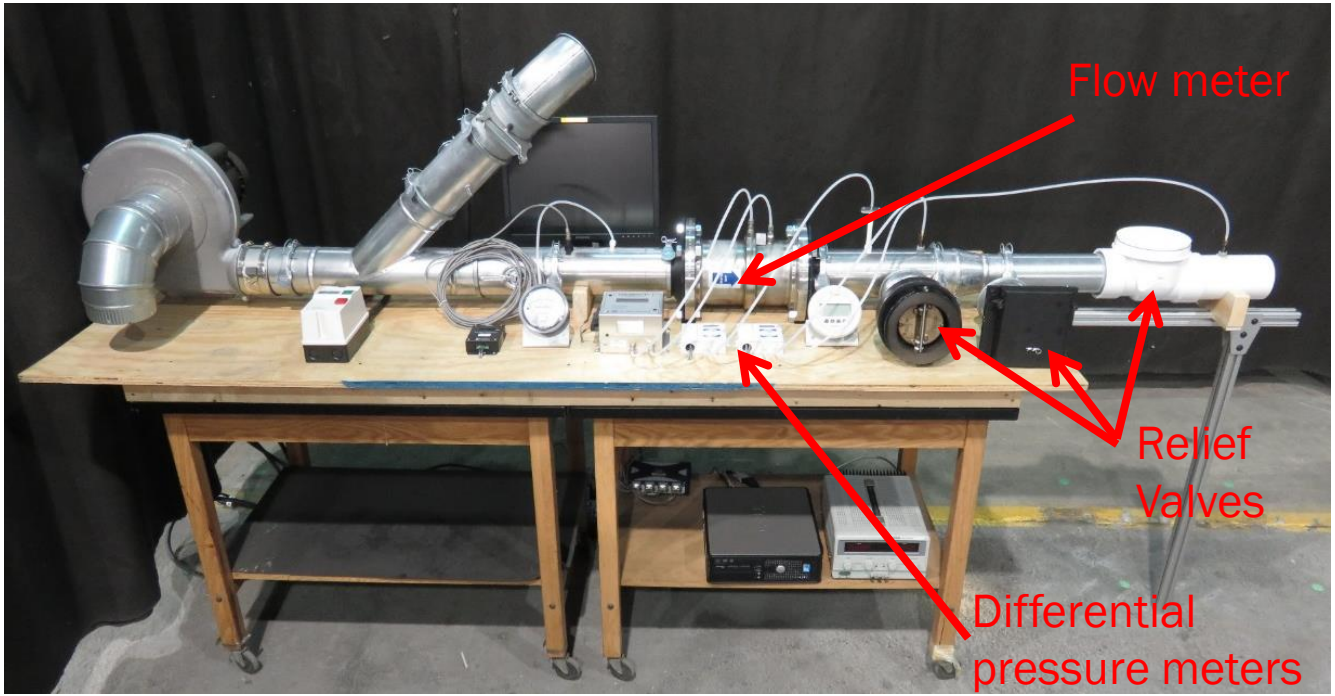
Angle	Configuration	Velocity (ft/s)	Volume Flow Rate (CFM)	Steady State Pressure	
				(psi)	(in-H_2O)
0°	Original	0.0	0.0	0.23	6.5
	Removed preload washers	0.0	0.0	0.23	6.5
	Replaced factory spring with 1 lb/in spring + washer	37.1	303.3	0.21	5.8



MSHA relief valve pressure specifications (30 CFR):
0.18 psi (5 in-H_2O) or as specified by manufacturer.

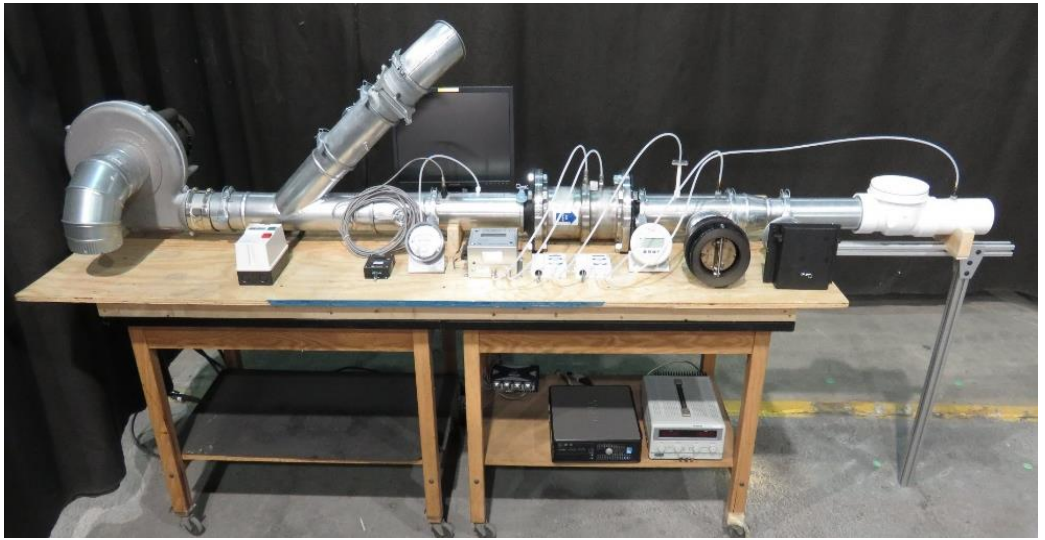
Updated Relief Valve Test Stand with Relief Valves

NIOSH is performing additional research to test and fully develop relief valves to ensure performance and structural integrity.



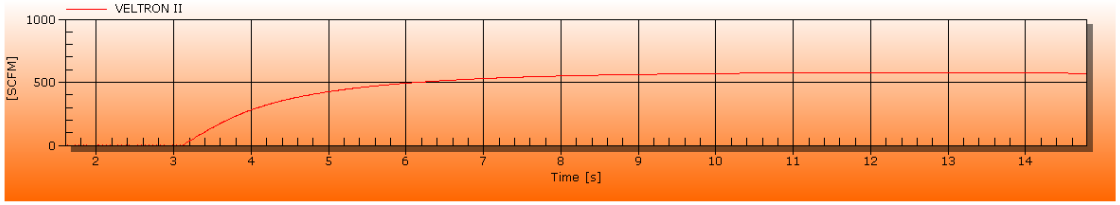
Updated Pressure Relief Valve Test Stand (PRVTS)

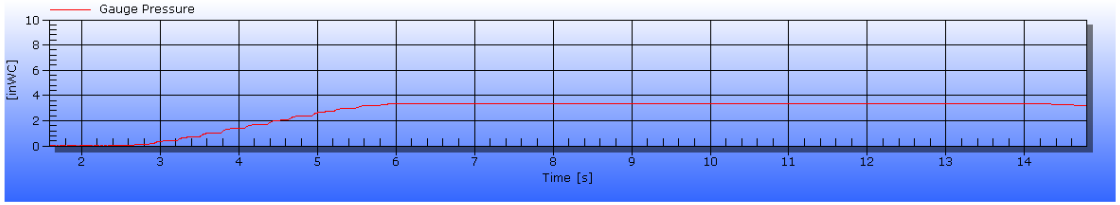
- The updated test stand allows the following parameters to be measured/recorded:
  - "Cracking pressure"
  - Pressure/flow characteristics for each relief valve tested (SCFM, pressure differential across valve)

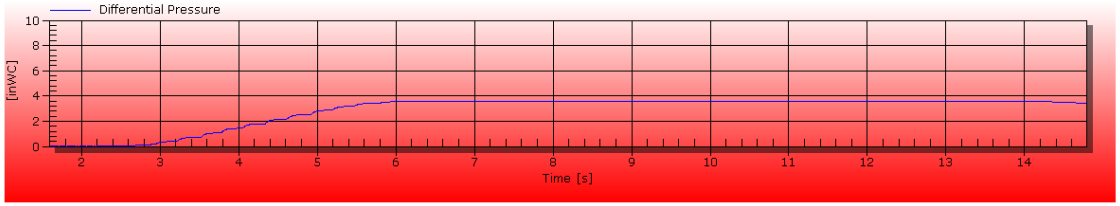


RA Relief Valve Tests
Example of Test Results w/ Updated PRVTS

578.60 SCFM	3.373 inWC	3.606 inWC
VELTRON II	Gauge Pressure	Differential Pressure







Relief Valve Testing Summary

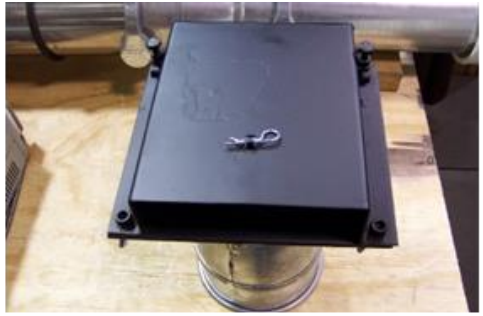
- Tested relief valve alternatives can meet the CFR standard (0.18 psi/5” H_2O relief pressure) with modifications
- Redesign/analysis/testing will include the ability of relief valves to withstand 15 psi blast pressure using FE analysis and testing and to meet relief pressure specification (CY 2017)

Check Valves to be Tested and Modified

PVC Check Valve
(modified)

Butterfly Check Valve

Steel Check Valve



RA Manufacturer Relief Valve

PVC Check Valve in
NIOSH BIP

Summary and Conclusions

- Built-in-place refuge alternatives offer advantages over portable RAs (increased space, unlimited air flow, additional supplies stored inside)
- Contamination ingress is a critical parameter to be minimized
- Purging is important to make the BIP air breathable
- Relief valve alternatives exist

Questions?

Tim Lutz, PE

tlutz@cdc.gov

412-386-4904

www.cdc.gov/niosh/mining

PITTSBURGH MINING RESEARCH DIVISION

Contract Update: Design and Construction Considerations for a Protected Compressed Air Line to a Refuge Alternative

Tim Lutz, PE

Refuge Alternative Webinar
June 23, 2016
Pittsburgh PA

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NIOSH

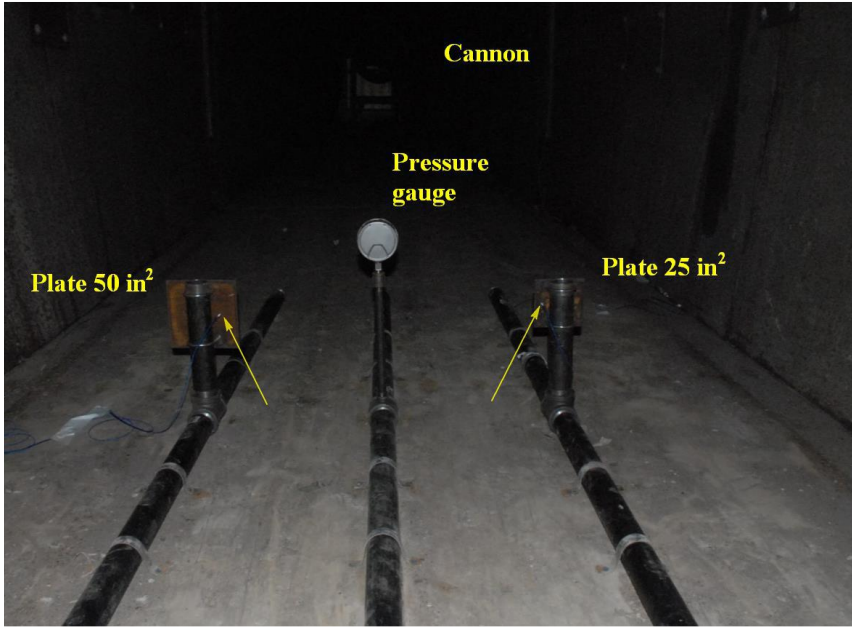
University of Kentucky Research Contract

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

The proposed research includes:

- Air line anchoring system designs and air line fitting survivability
- Impact testing of different air line materials and thicknesses
- Air line impact protection scenarios
- Effects of corrosion on air lines

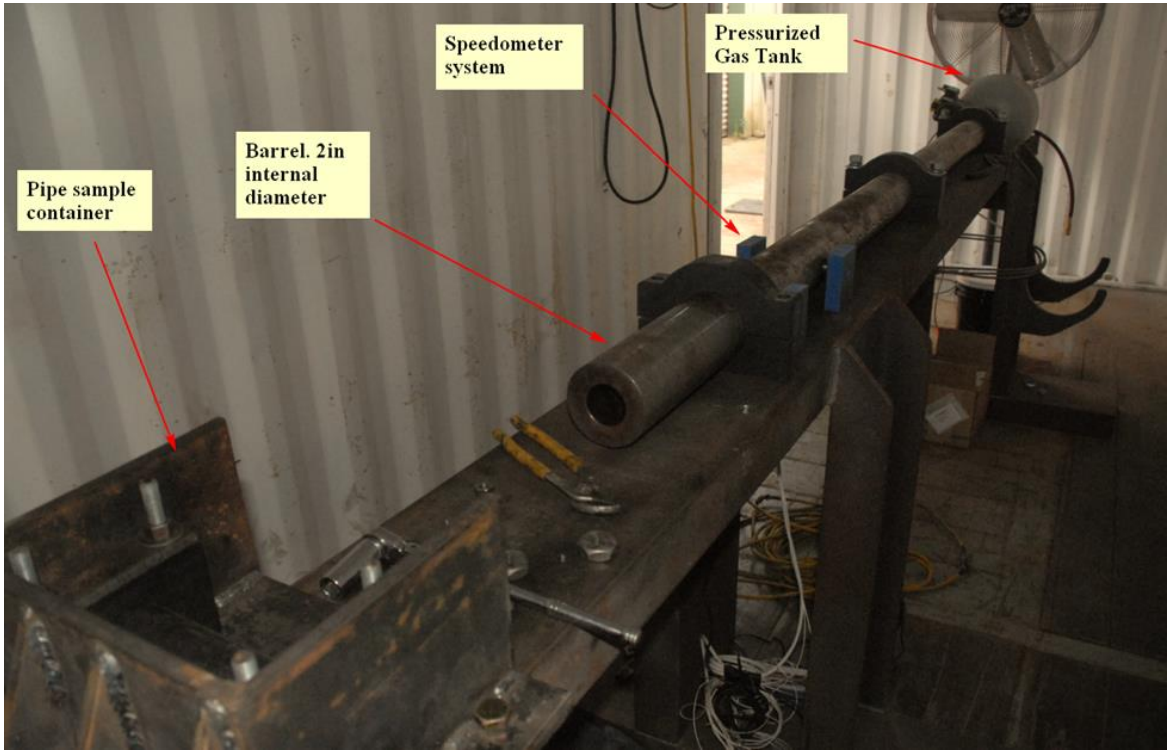
Pipe Samples for Shock Tube Testing



Photos courtesy of University of Kentucky

Shock Tube Explosion with Pipe Samples

Pipe Impact Tests



Modified Hopkinson-Bar device for high strain-rate experiments

Photos courtesy of University of Kentucky

Pipe Impact Video

Video courtesy of University of Kentucky

Pipe Impact Samples

Different pressures and different wall thickness pipe

Photos courtesy of University of Kentucky

Pipe Impact Samples

Different protection scenarios
using clay, gravel, clay with gravel

Photos courtesy of University of Kentucky

Research Contract Summary

- Shock tube tests on air line anchoring, pipe fittings and gauges completed
- Pipe impact tests of different materials, thicknesses, and protection scenarios completed
- Corrosion testing in progress
- Results to be available upon contract completion (August 2016)

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