

Update on NIOSH BIP RA Contamination Ingress, Purging, and Relief Valve Research



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Breathing Air Supply and Refuge Alternative Workshop

NIOSH Mining Program



Outline

- **Why use built-in-place RA**
- **Why perform contamination ingress testing**
- **Summary of contamination ingress testing**
- **Why is purging important**
- **Purge testing**
- **Why relief valves/blast valves are important**
- **Relief valve/blast valve testing**

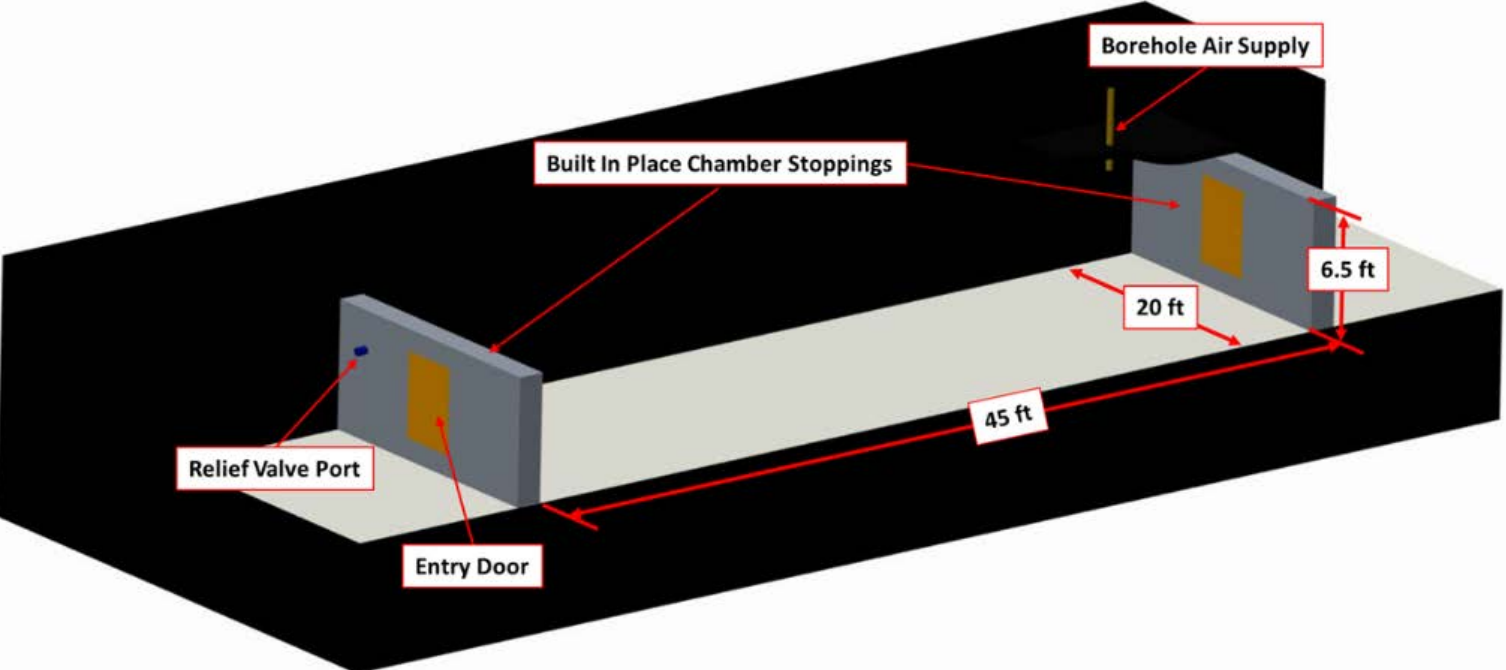
Advantages of BIP Refuge Alternatives

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

- Quicker and easier to prepare and operate
- Store more equipment
- Provide more space per occupant
- Increase likelihood communication system will survive
- Better chance of surviving a secondary explosion than a tent-type mobile RA
- Psychological advantages

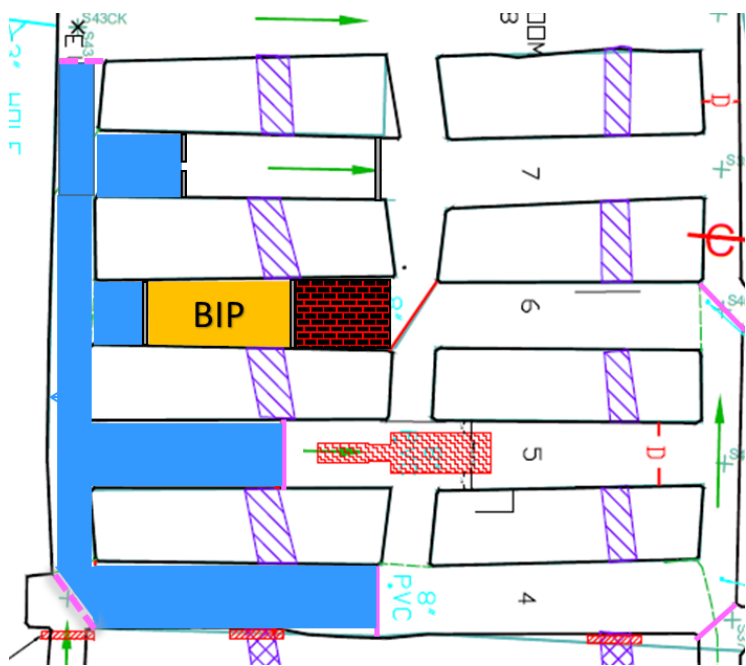


NIOSH Built-In-Place (BIP) Refuge Alternative (RA) Research Area



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.



CO Exposure

Concentration (ppm)	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.

25 ppm



10,000 ppm



Contamination Ingress Testing Results

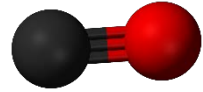
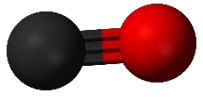
(without mine ventilation)

Test	Outside BIP SF ₆ Concentration (ppb)	Inside BIP SF ₆ Concentration (ppb)	Contamination Factor
W/ Borehole Air Supply 5 Subjects	139	~3	~2%
W/O Borehole Air Supply 5 Subjects	152	~3	~2%
W/ Borehole Air Supply 15 Subjects	150	~3	~2%
W/O Borehole Air Supply 15 Subjects	205	~3	~2%
W/ Borehole Air Supply 30 Subjects	238	~5	~2%
W/O Borehole Air Supply 30 Subjects	122	~4	~3%

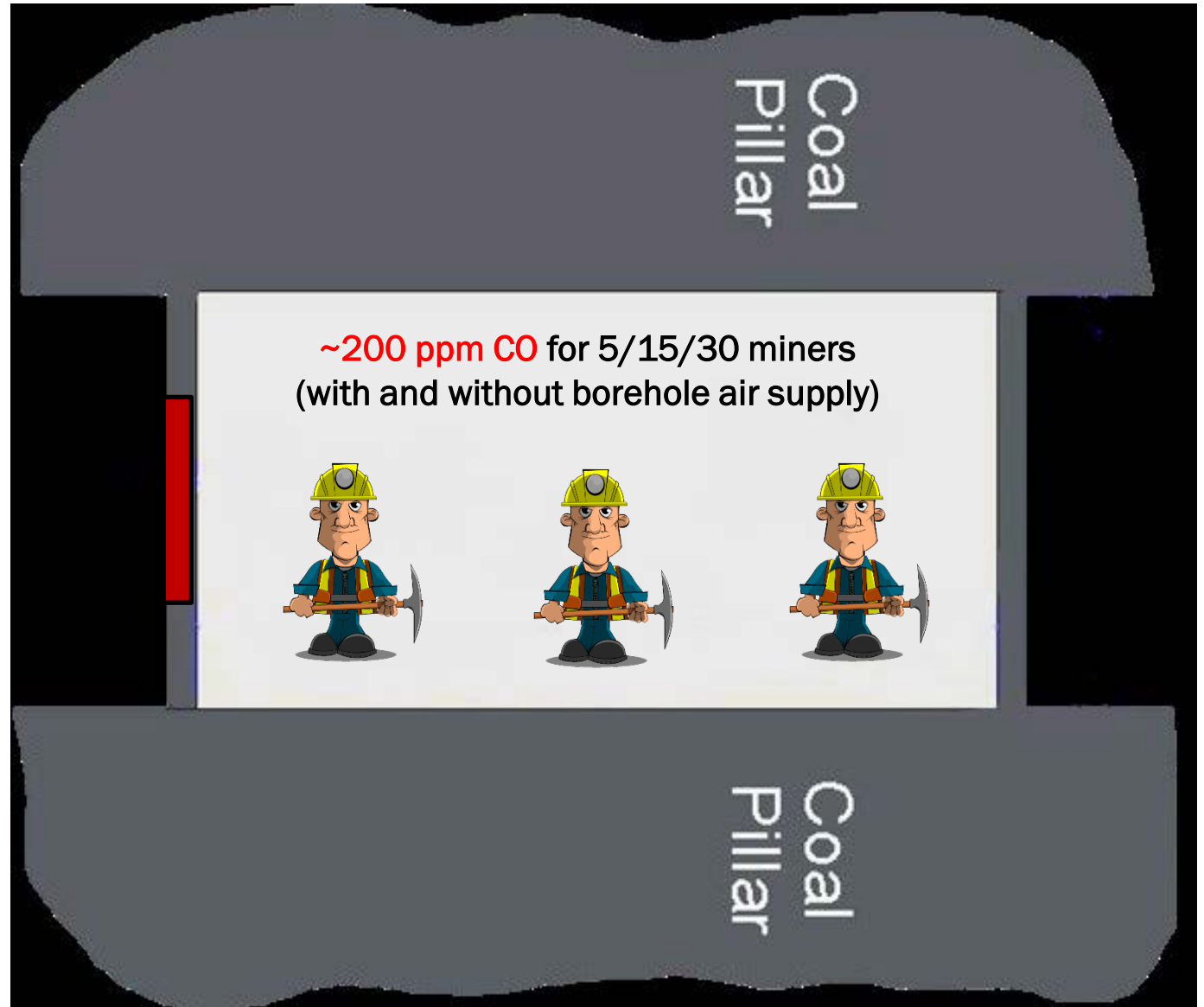
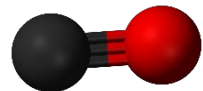
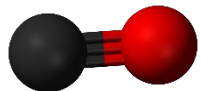
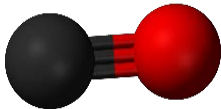
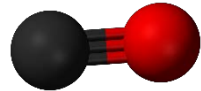
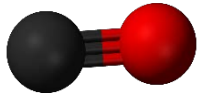
Note: Gas Chromatograph limit of detection - 1 ppb, limit of quantification - 3 ppb

Contamination Ingress Testing Results

(without mine ventilation)

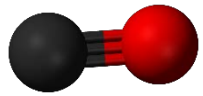
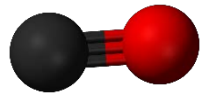


10,000 ppm CO

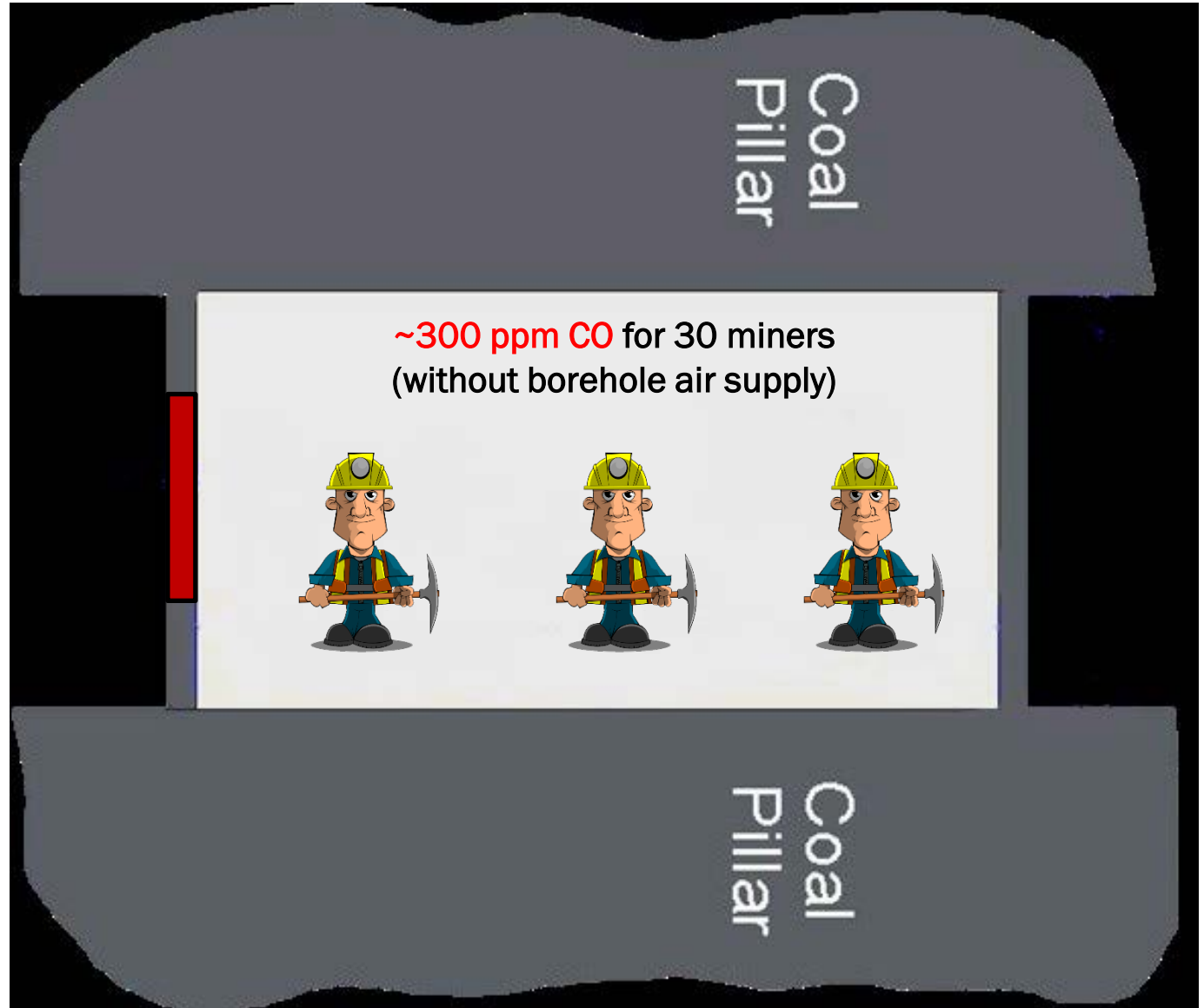
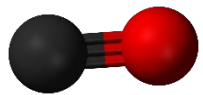
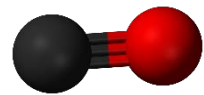
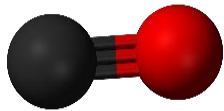
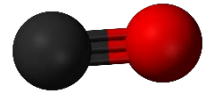
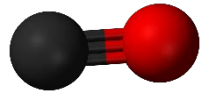


Contamination Ingress Testing Results

(without mine ventilation)



10,000 ppm CO



Summary

- 5, 15, 30 person tests: ~2% contamination factor ~200 ppm CO inside RA
- 30 person: ~3% contamination factor ~300 ppm CO inside RA
- Contamination due to ingress can result in a hazardous atmosphere inside BIP RA until purged

Ongoing Research

- ❖ Contamination prevention strategies will be investigated (strip curtains, door bladder, airlock if necessary)
- ❖ Further testing with real-time SF₆ monitors will be used with higher concentrations pending approval

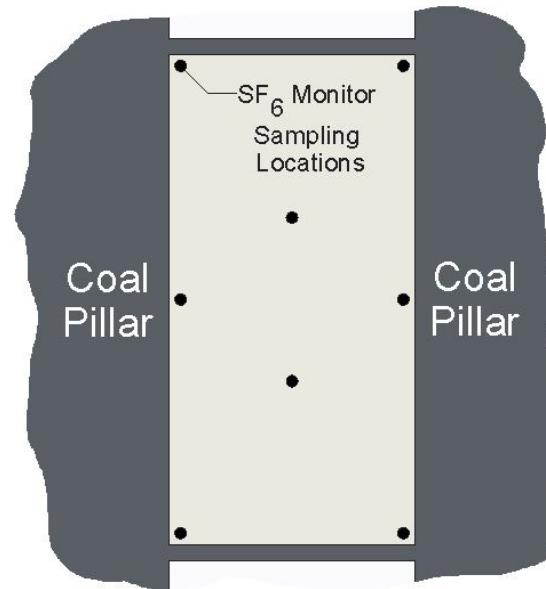
Purge Testing in BIP RA

- 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”



Test setup simulates purging of CO contaminated air using SF₆ monitors at several locations inside the BIP RA

Injection of SF₆



Real-time monitoring of SF₆ concentration

Purge Testing Setup



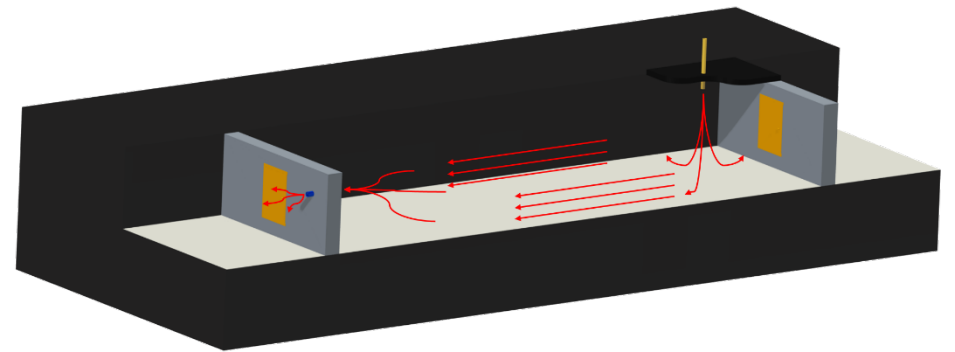
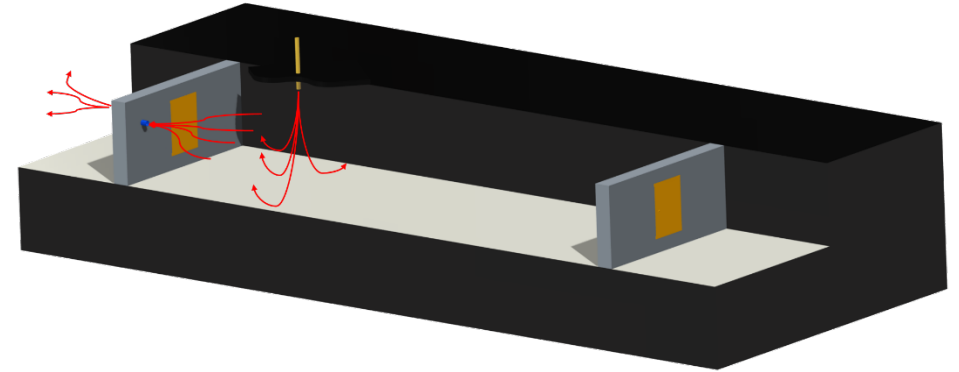
Sampling tubes in BIP RA



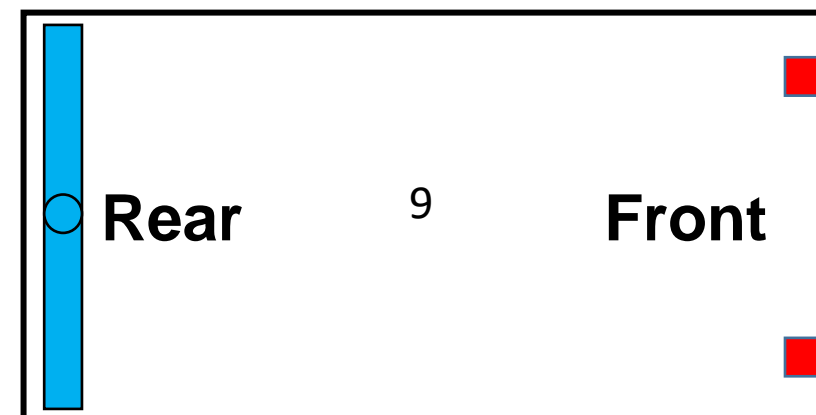
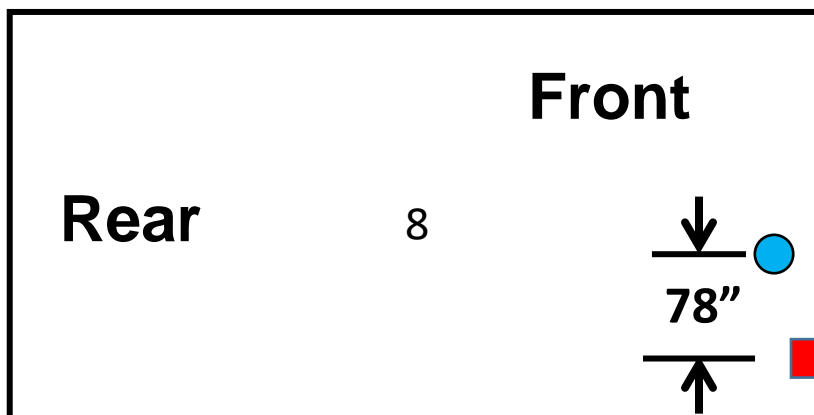
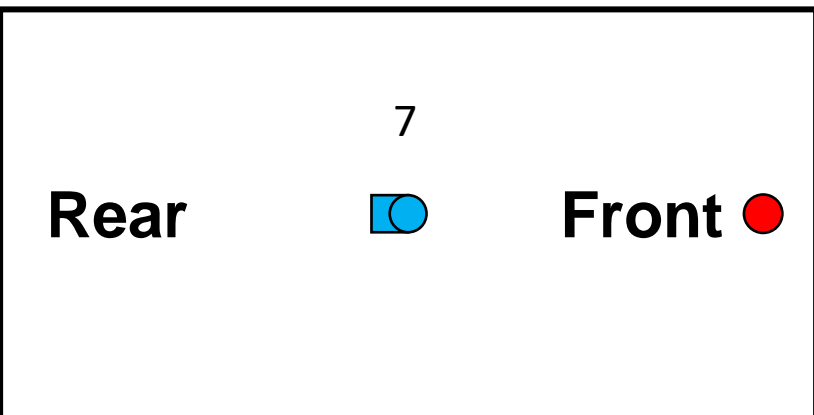
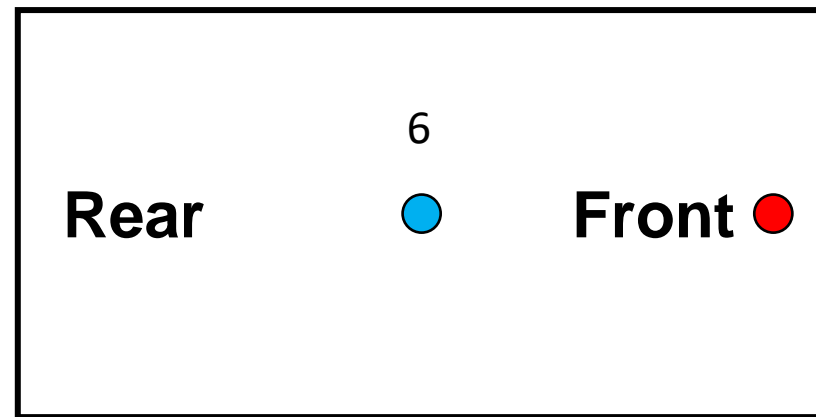
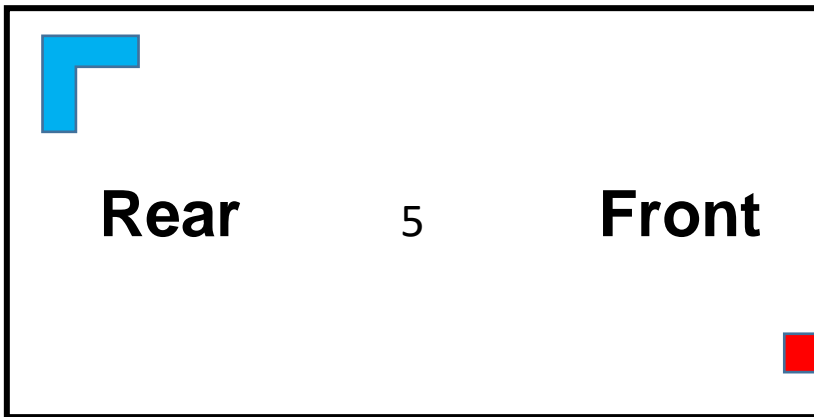
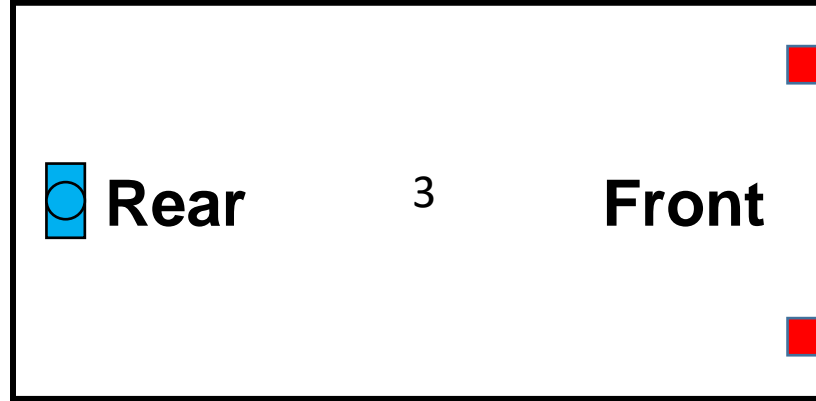
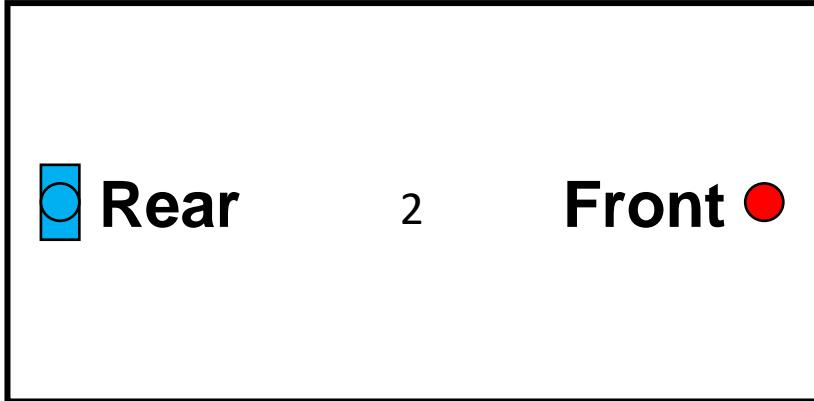
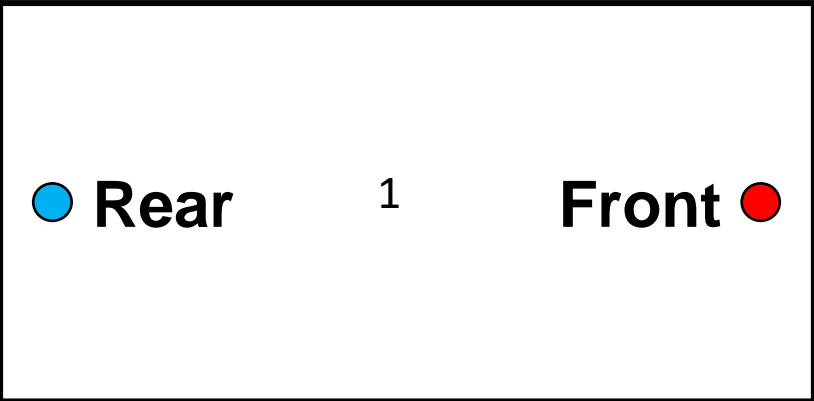
Real-time SF₆ concentration monitor
(Maximum concentration–1000 ppm)

Variety of Conditions

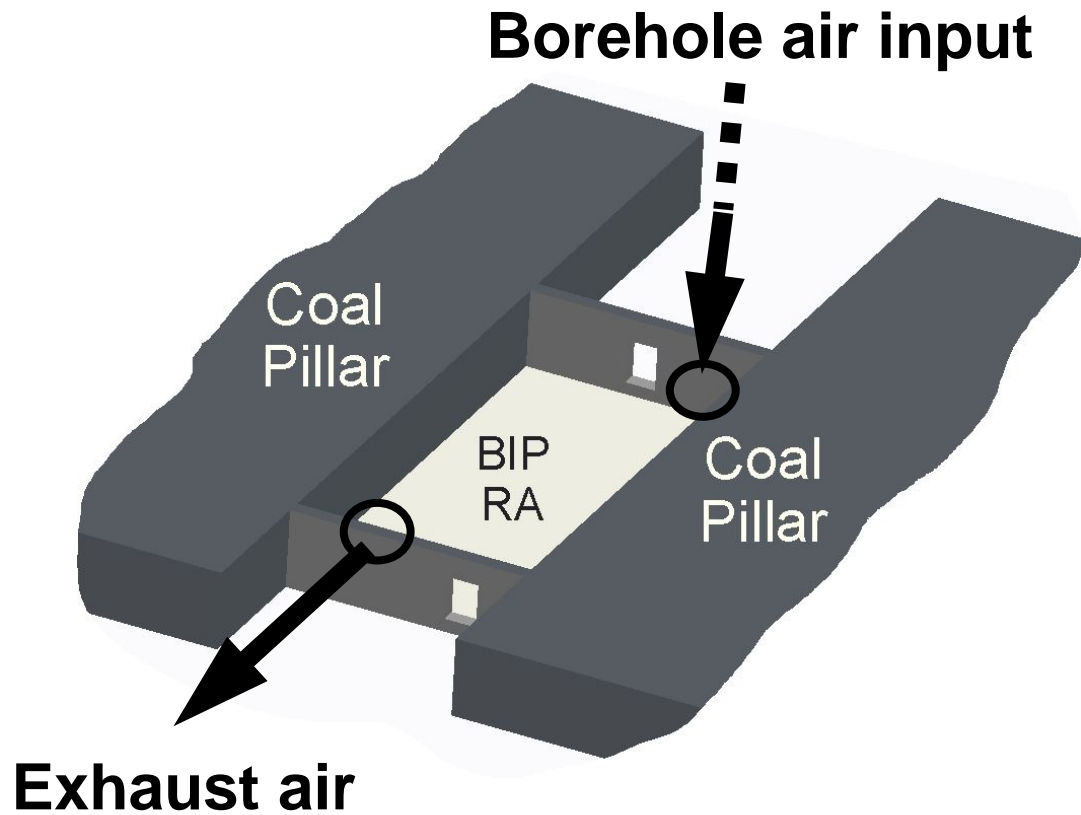
- Variety of ventilation designs
 - 60-person rectangular BIP
 - Mandated square footage (15 sq ft per miner, 900 sq ft min, 2018 rule)
 - Minimum mandated flow rate (12.5 CFM per miner, 750 CFM min)
 - 1000 CFM



BIP RA Purging Layouts (blue-inlet, red-exhaust)

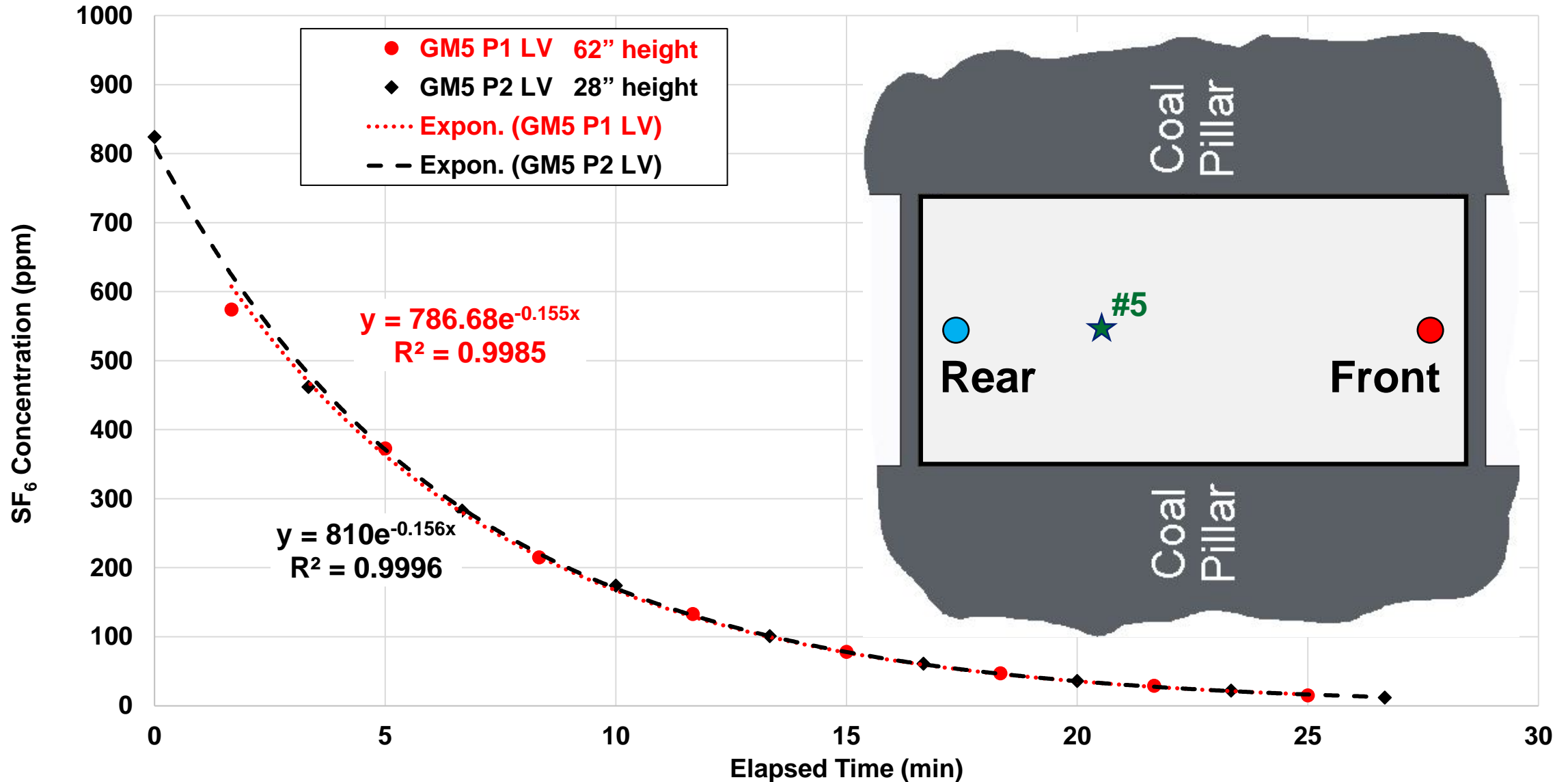


Tests will be conducted to evaluate purging performance for borehole-ventilated BIP RAs for various piping system layouts



Example of Purging Test Results for 1st Configuration

SF₆ Concentration at Sample Location #5



Summary

- 16 sample locations within RA are being used for each test
- Multiple ventilation layouts for 60-person RA have been started

Ongoing Research

- ❖ Two airflows: 750, 1000 cfm will be evaluated
- ❖ Multiple layouts to be tested to represent good and bad installations

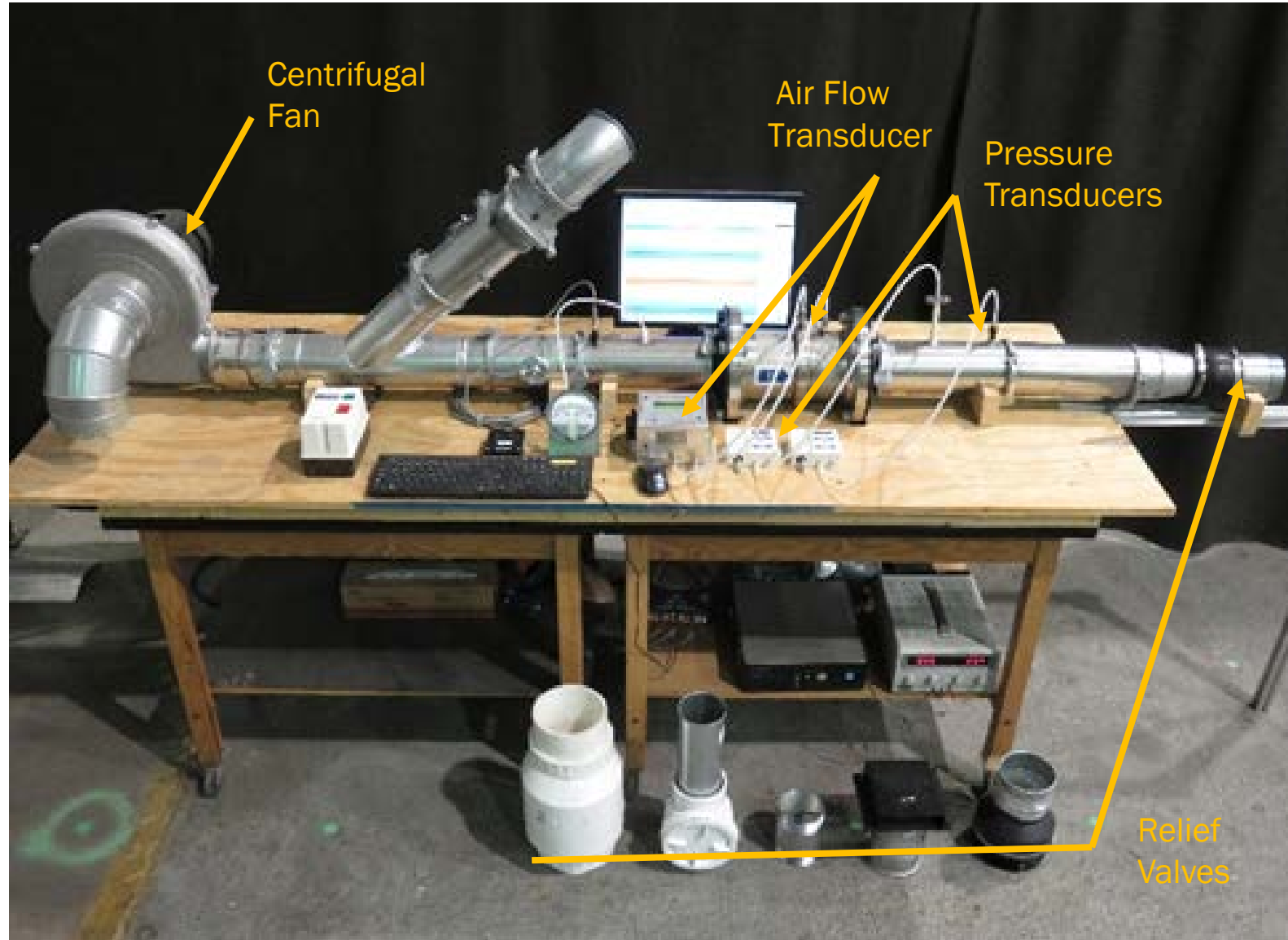
Relief Valve/Blast Valve Research



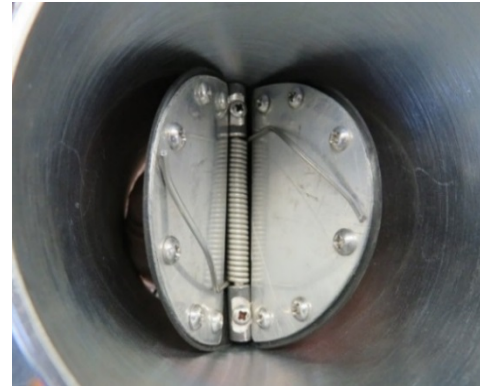
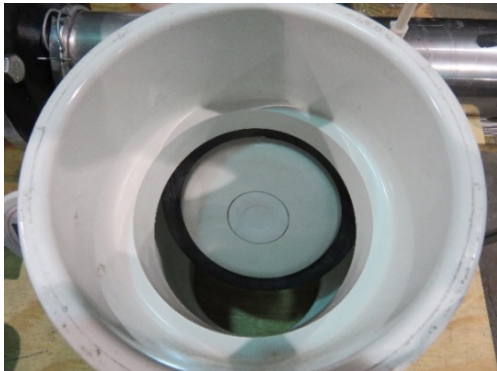
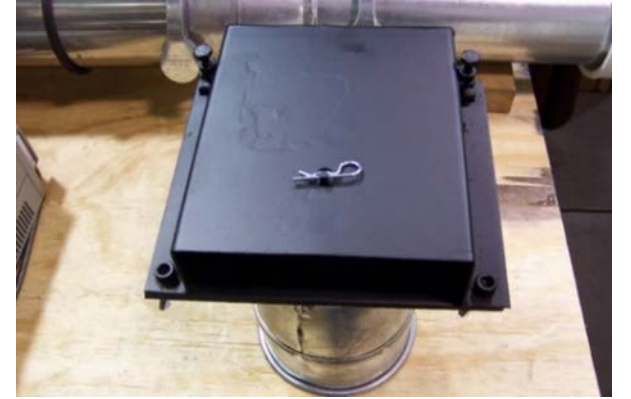
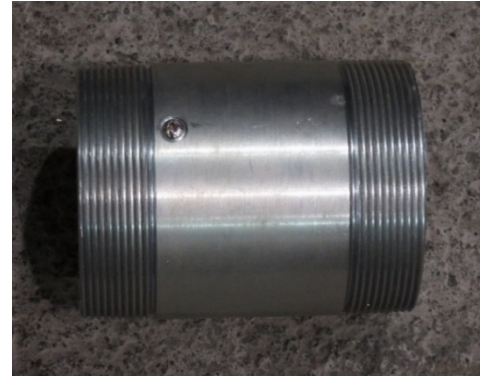
Relief Valve Research Outline

- **Relief Valve Test Stand**
- **Relief Valves/Blast Valves Tested**
- **Results**
- **Summary**

Pressure Relief Valve Test Stand Setup



Relief Valves Tested



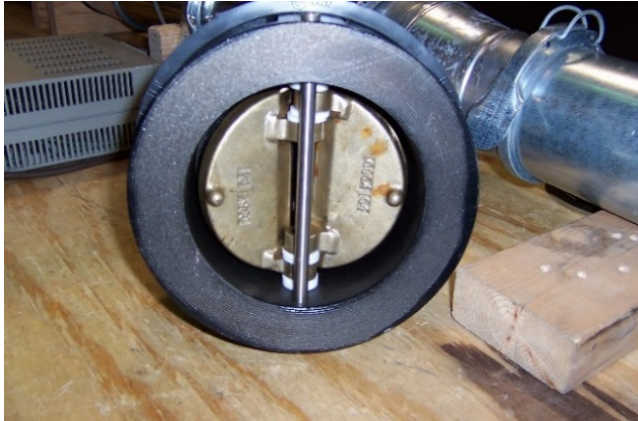
PVC Check Valve 6"

PVC Check Valve 4"
(modified)

Steel Check Valve 4"

RA Manufacturer
Relief Valve 4"

Relief Valves/Blast Valve Tested



Brass/Cast-Iron Butterfly
Check Valve 4.5"

Brass RA Manufacturer
Relief Valve 2"

Blast Valve 4"

Blast Valve 9"
(not tested)

Relief Valve vs. Blast Valve

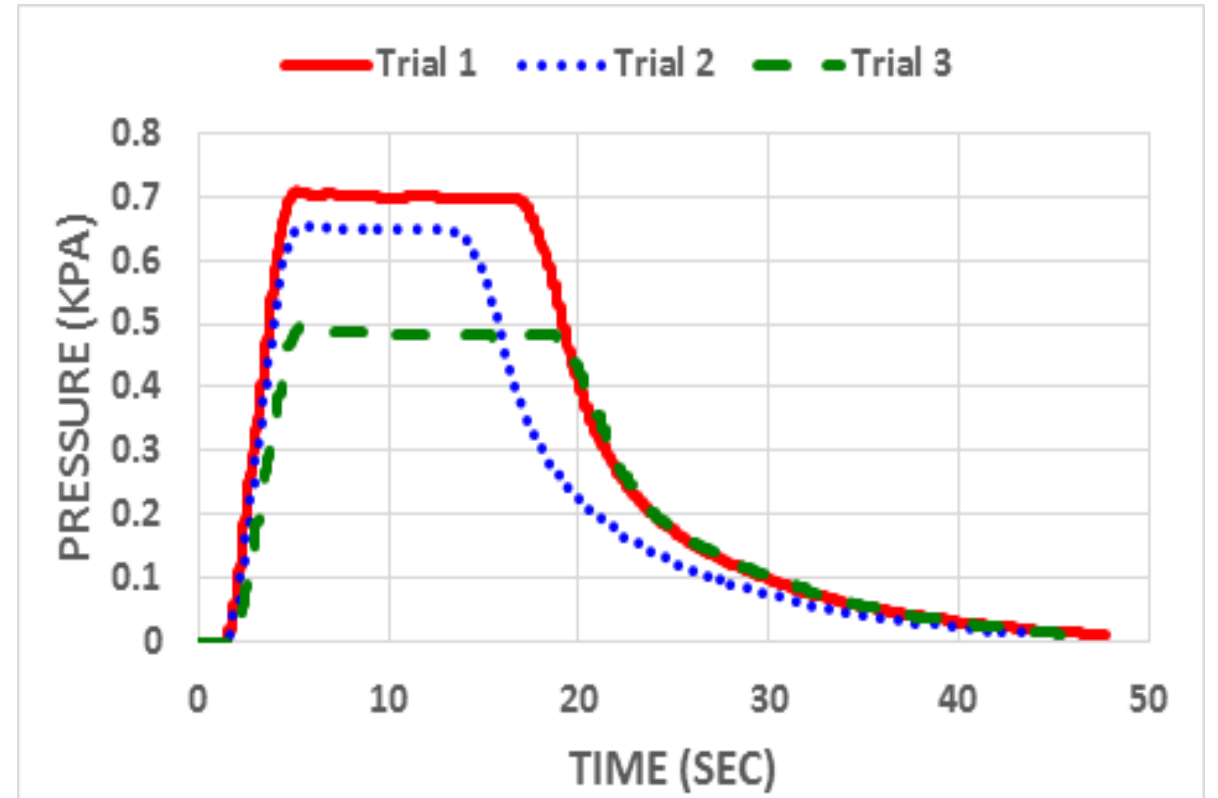
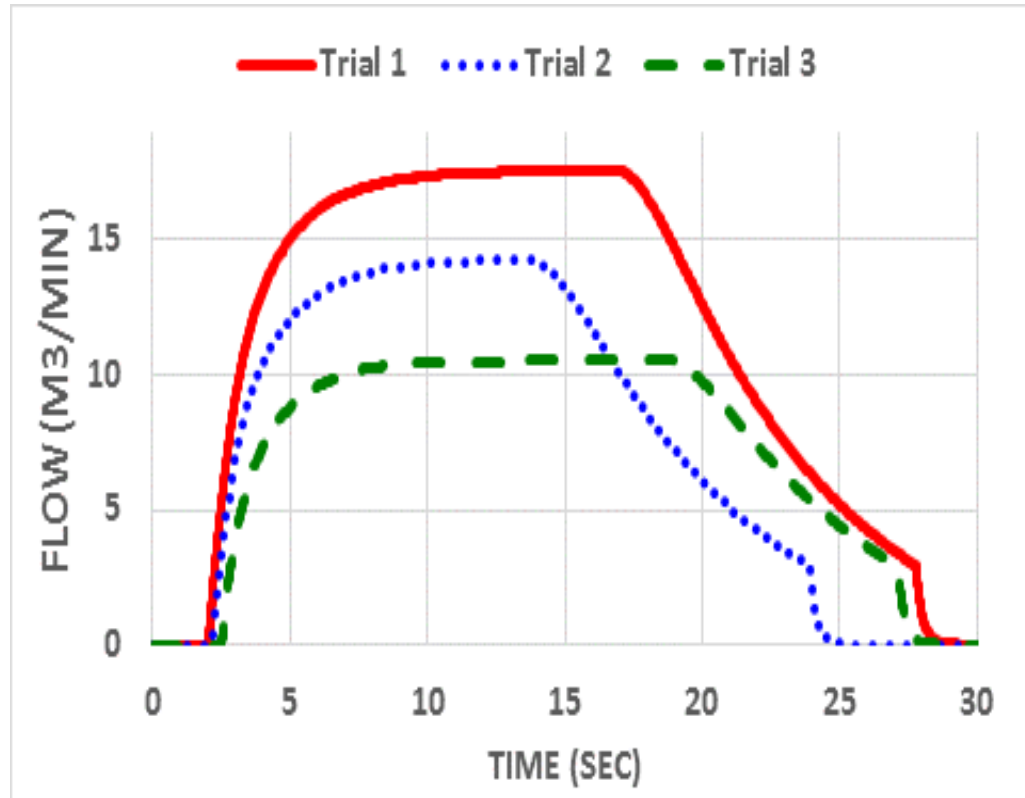
Relief Valve (check valve)

- Flow in one direction only
- Relief pressure is critical
- No blast testing done

Blast Valve

- Most allow flow in 2 directions under normal conditions
- May close when flow rate reaches a threshold
- Blast tested

Graphical Results of Airflow and Static Pressure



Trial 1: Airflow for 50 person RA
Trial 2: Airflow for 40 person RA
Trial 3: Airflow for 30 person RA

Airflow and Static Pressure Test Results

PRV/ Blast	Configuration (Pressure Relief Valve/Blast Valve)	Trial 1		Trial 2		Trial 3	
		Q (SCFM)	P (psi)	Q (SCFM)	P (psi)	Q (SCFM)	P (psi)
A	<i>PVC (6 in)</i>	628	0.10	510	0.09	379	0.07
B.1	<i>PVC (4 in) (no weights)</i>	683	0.07	505	0.05	378	0.03
B.2	<i>PVC (4 in) (one weight, 0.95 lb)</i>	642	0.09	506	0.05	376	0.05
B.3	<i>PVC (4 in) (two weights, 1.9 lb)</i>	605	0.11	497	0.10	383	0.08
C.1	<i>Steel check valve (4 in) (original spring)</i>	0.0	0.25	--	--	--	--
C.2	<i>Steel check valve (4 in) (modified spring)</i>	558	0.15	555	0.15	369	0.13
D	<i>Purpose-built RA relief valve (4 in) (modified spring)</i>	361	0.22	--	--	--	--
E.1	<i>Brass/cast iron butterfly (4.5 in) (no spring) 45 degree</i>	444	0.18	--	--	--	--
E.2	<i>Brass/cast iron butterfly (4.5 in) (no spring) 90 degree</i>	414	0.20	--	--	--	--
F	Brass RA manufacturer relief valve (2 in)	142	0.18	--	--	--	--
G	Blast Valve (4 in)(max flow prior to closing)	150	0.07	--	--	--	--

Summary

- Relief valve concepts can meet the CFR relief pressure specification and flow requirements as purchased or with modifications
- Additional testing is needed to include blast pressures of 15 psi
- Blast valves in combination with relief valves may be the best solution to protect the RA occupants and relief valve in a blast event

Thank you! Questions?

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NIOSH Mining Program – www.cdc.gov/niosh/mining

