"Prevention of Spontaneous Combustion with the Implementation of Pressure Balancing Techniques"

Felipe Calizaya
Mike G. Nelson
Chris Bateman
Ankit Jha

14 October 2015

Outline

- History of Sponcom in Underground Coal Mines
- Sponcom and Critical Areas
- Pressure Balancing Applications for this Study
- Mines Ventilation Surveys
- Numerical and Physical Modeling
- Implementation of Pressure Balancing
- Conclusion and Discussion

United States History of Coal

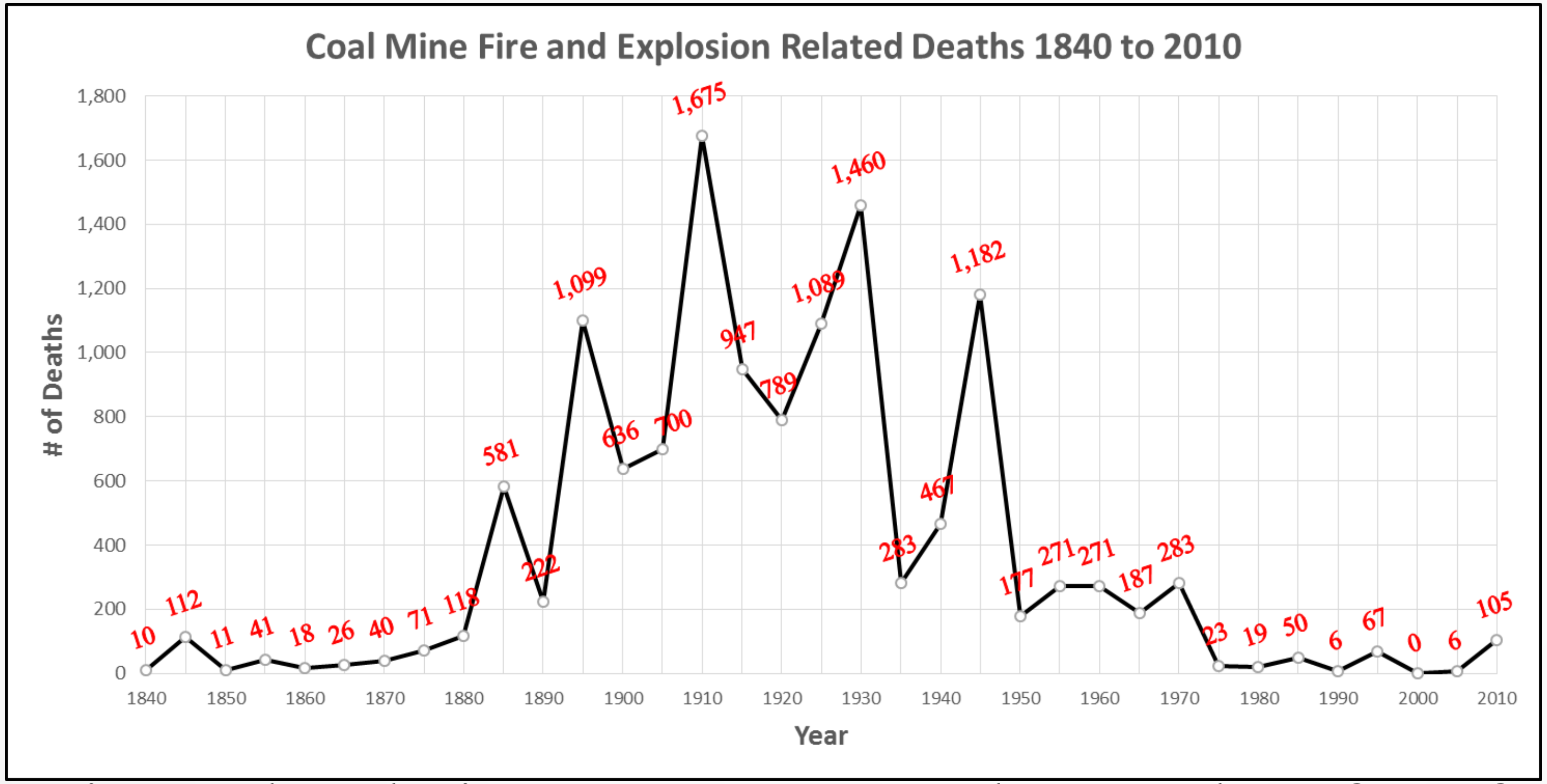
- Coal has been used to generate electricity in the United States ever since an "Edison" plant was built to serve New York City in 1882.

- Nearly 75 power plants from the 633 coal power plants that were operating in 2002 have shut down and are decreasing consistently.

Year	Electrical Generation from Coal (Thousand MWh)	Total Energy Generation (Thousand MWh)	Percent from Coal	Number of Coal Plants
2002	1,933,130	3,858,452	50.1%	633
2003	1,973,737	3,883,185	50.8%	629
2004	1,978,301	3,970,555	49.8%	625
2005	2,012,873	4,055,423	49.6%	619
2006	1,990,511	4,064,702	49.0%	616
2007	2,016,456	4,156,745	48.5%	606
2008	1,985,801	4,119,388	48.2%	598
2009	1,755,904	3,950,331	44.4%	593
2010	1,847,290	4,125,060	44.8%	580
2011	1,733,430	4,100,141	42.3%	589
2012	1,514,043	4,047,765	37.4%	557

Coal Fires and Explosions

- Since 1839 there have been at least a total of 13,042 deaths attributed to explosion and fires from U.S. coal mining (OMSHR).



- “Fires and explosions pose a constant threat to the safety of miners and to the productive capacity of mines. Mine fires and explosions traditionally have ranked among the most devastating industrial disasters.” (Grant 2011)

Sponcom and Critical Areas

Sponcom

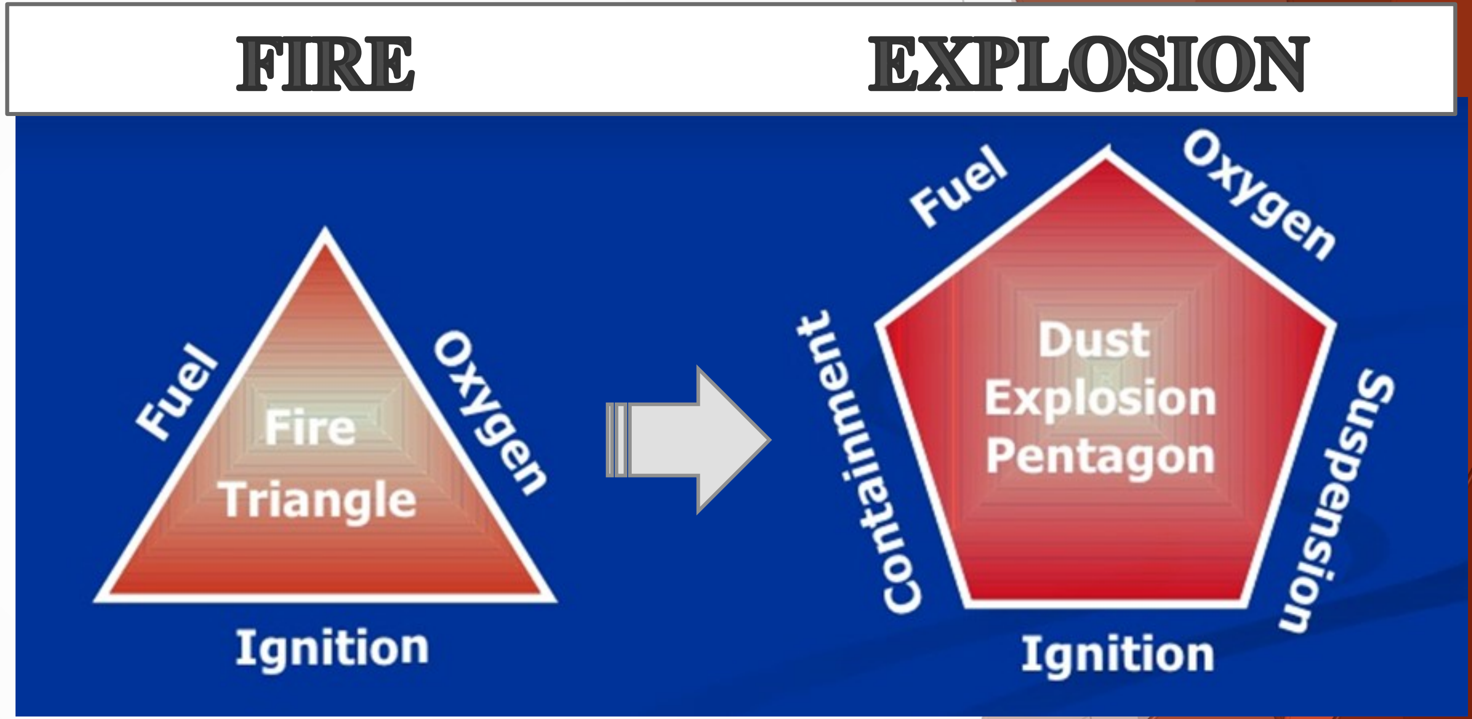
“Spontaneous combustion (Sponcom) is a process in which certain material can ignite as a result of internal heat which arise spontaneously.”

“In the process reactions generate heat faster than it can be removed from ventilation.”

Fires and Explosions

- Coal mining has all the variables for an explosive environment naturally occurring. To reduce the possibility of fires and explosions the variables that make up an explosive must be controlled.

- Ventilation is a primary tool used to prevent fires and explosion in a mining environment. Diluting contaminants that could be suspended is one method for preventing fires and explosions.

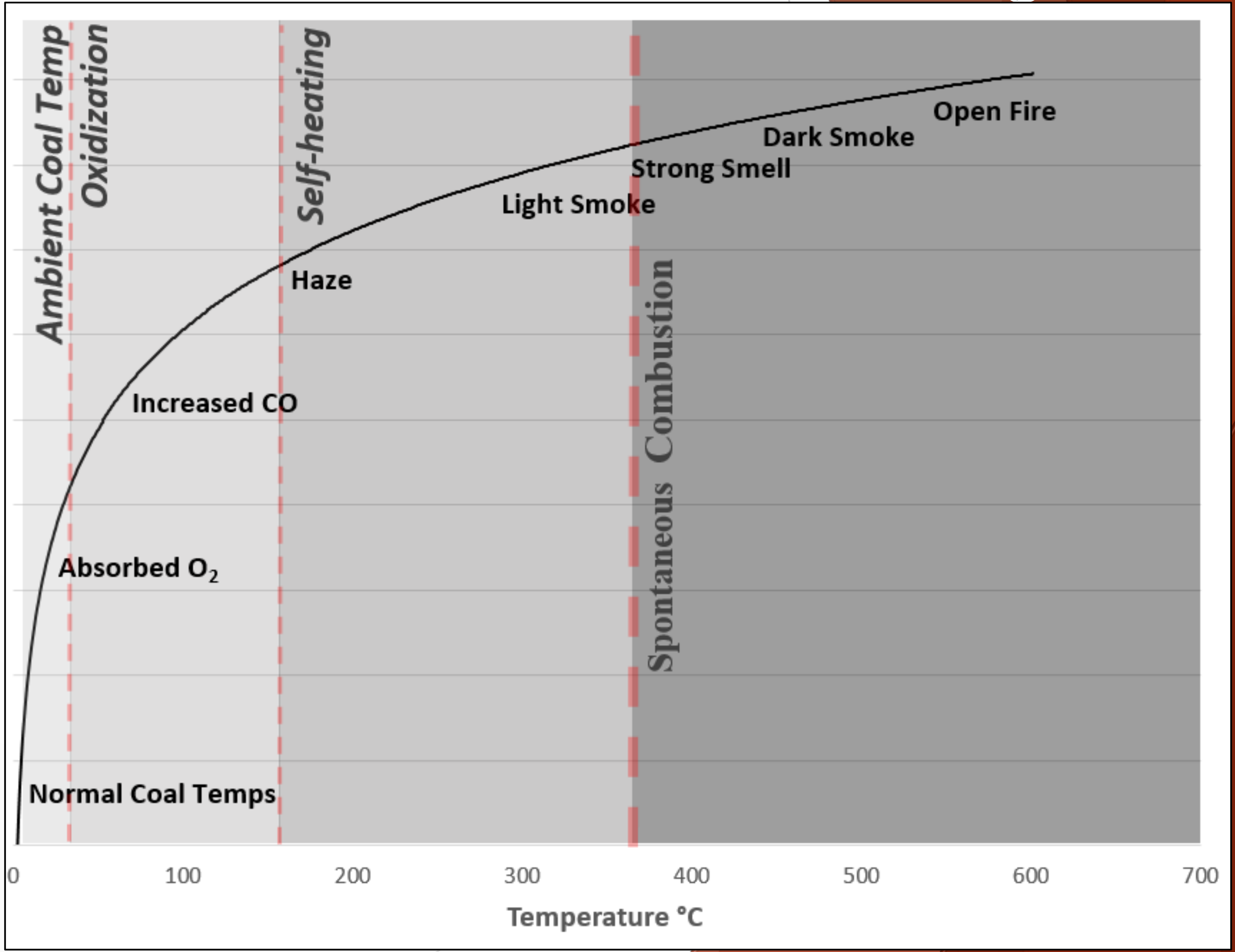


Spontaneous Combustion (SPONCOM)

- When a flow rate is insufficient at removing the heat of oxidation of coal it can create hot pockets within the gob.

- The temperatures will rise gradually to a point where heat is emitted from sources, to a point of fire, then into potential explosions.

Exothermic Reaction of Self-heating Coal

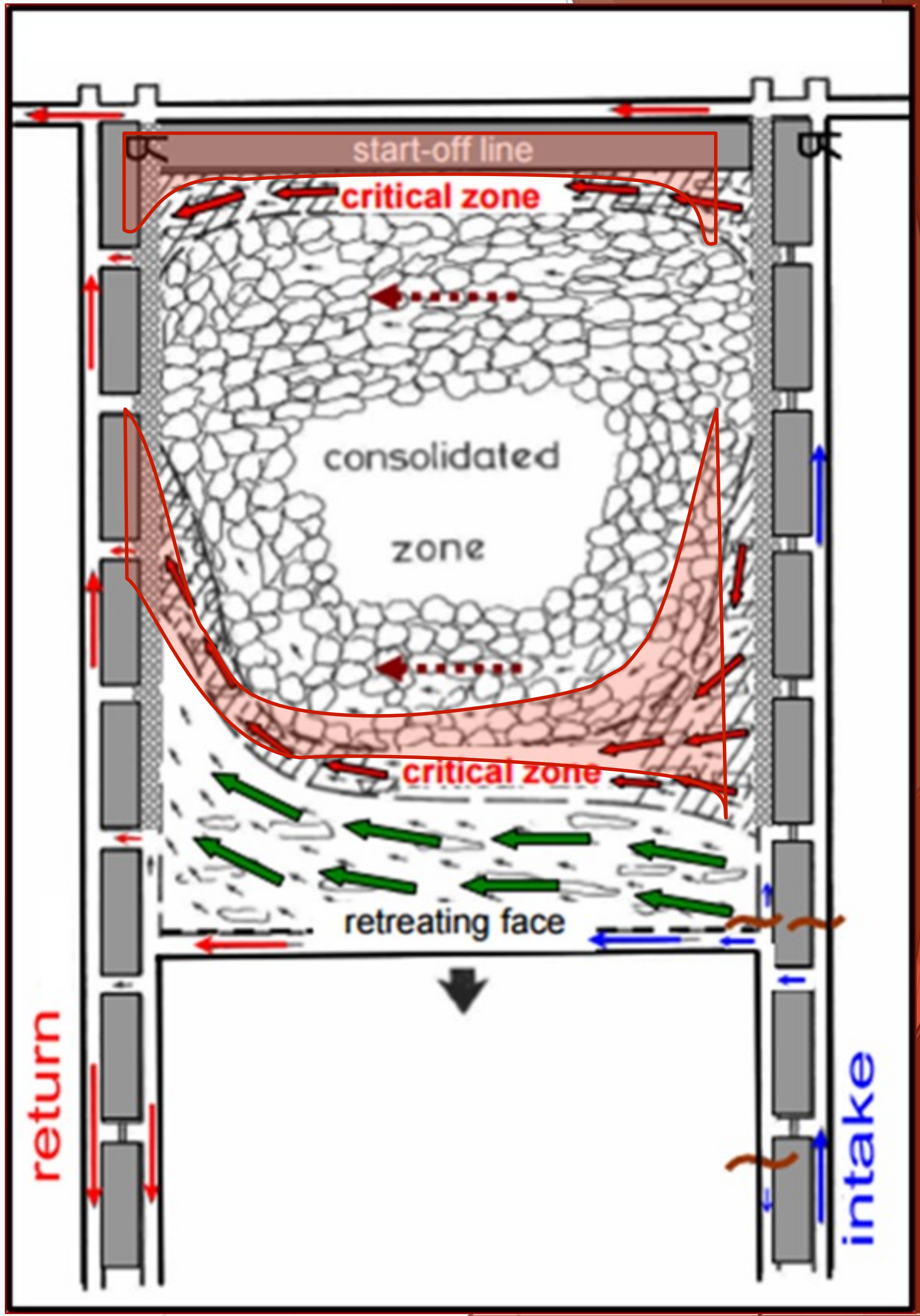


Critical Zones for Sponcom

- Most common areas for spontaneous combustion (Sponcom) are worked areas where broken coal can oxidize at a higher than normal rate. These areas are commonly found in stockpiles and gob areas of the mines.

- Broken coal has a higher risk for combustion. All of the variables for fires and combustion are present in the so called "critical zones".

- "These critical zones are where spontaneous heating and combustion are most likely to occur" (McPherson 1992).



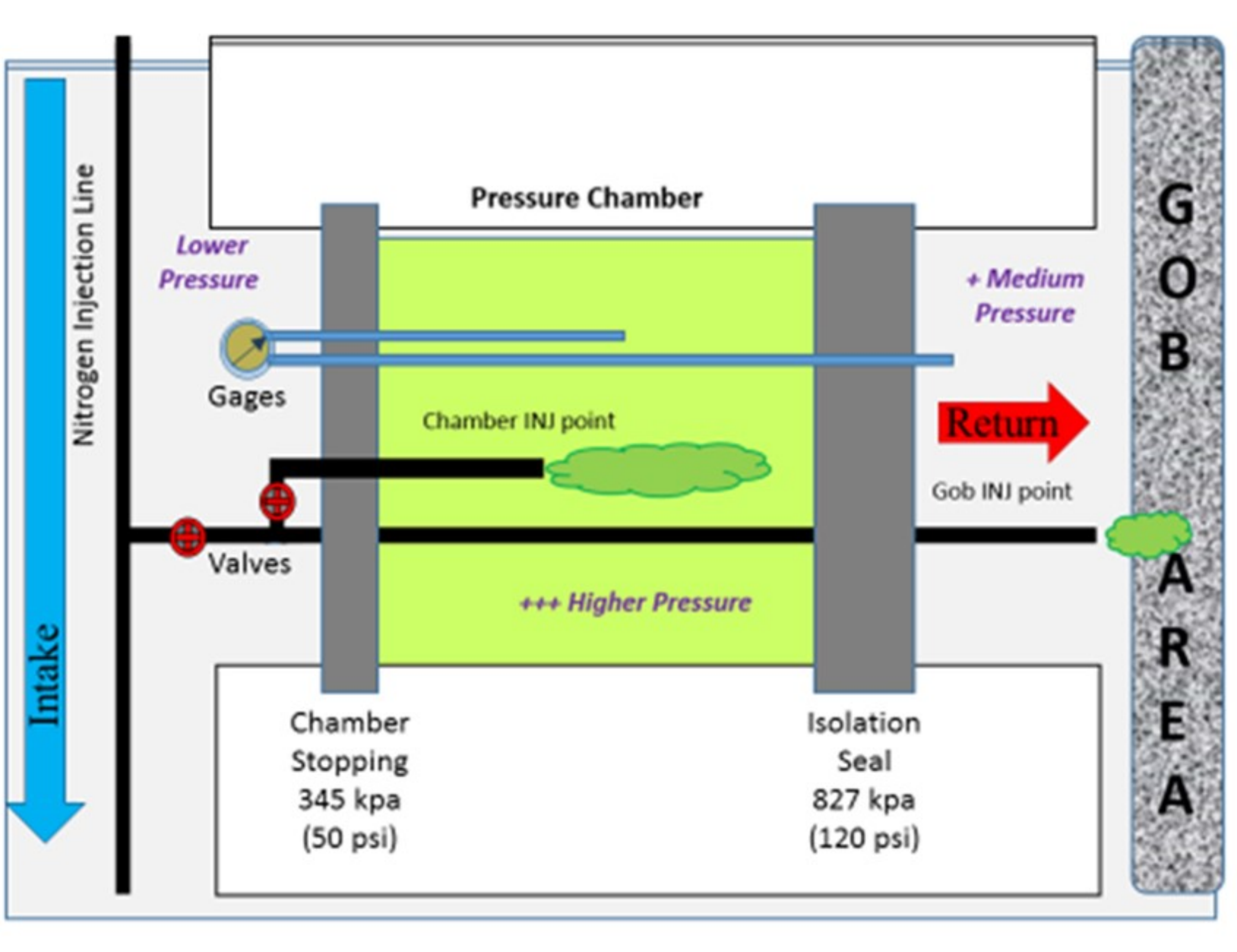
Pressure Balancing Applications

Pressure Balancing

"Pressure Balancing is the process of neutralizing pressure differentials in critical mined out areas. Pressure Balancing enables control of airflow into mined out areas to prevent spontaneous combustion"

Pressure Balancing

"Active Pressure Balancing Nitrogen Injected Pressure Chamber"



Passive Balancing

Includes the use of regulators and fan duties to decrease the pressure differentials across or around critical areas such as mine gobs.

Active Balancing

Includes an external pressure source, stoppings, pressure chambers, gages, and an atmospheric monitoring system. The process can be manual or automatic.

Process for Evaluating Pressure Balancing Techniques

- <u>Mine Visits (3 mines, A, B and C)</u>

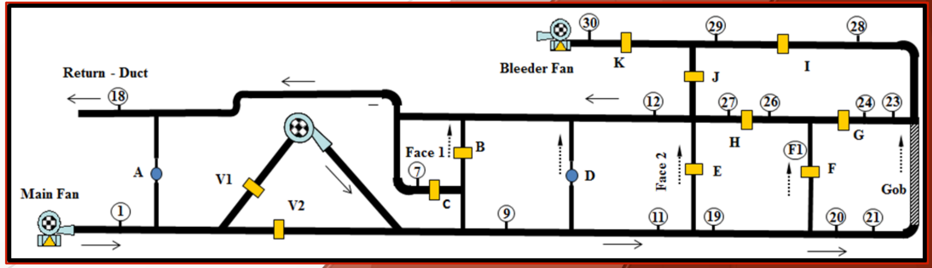
  Pressure/quantity surveys as well as regulator and seal inspections were conducted for two underground coal mines.

- <u>Ventilation Software</u>

  The surveyed data from mine visits were used to build numerical models in VentSim to study different pressure balancing techniques.

- <u>University Lab Model</u>

  The surveyed and simulated data were used to calibrate a physical lab model where pressure balancing techniques can be applied.



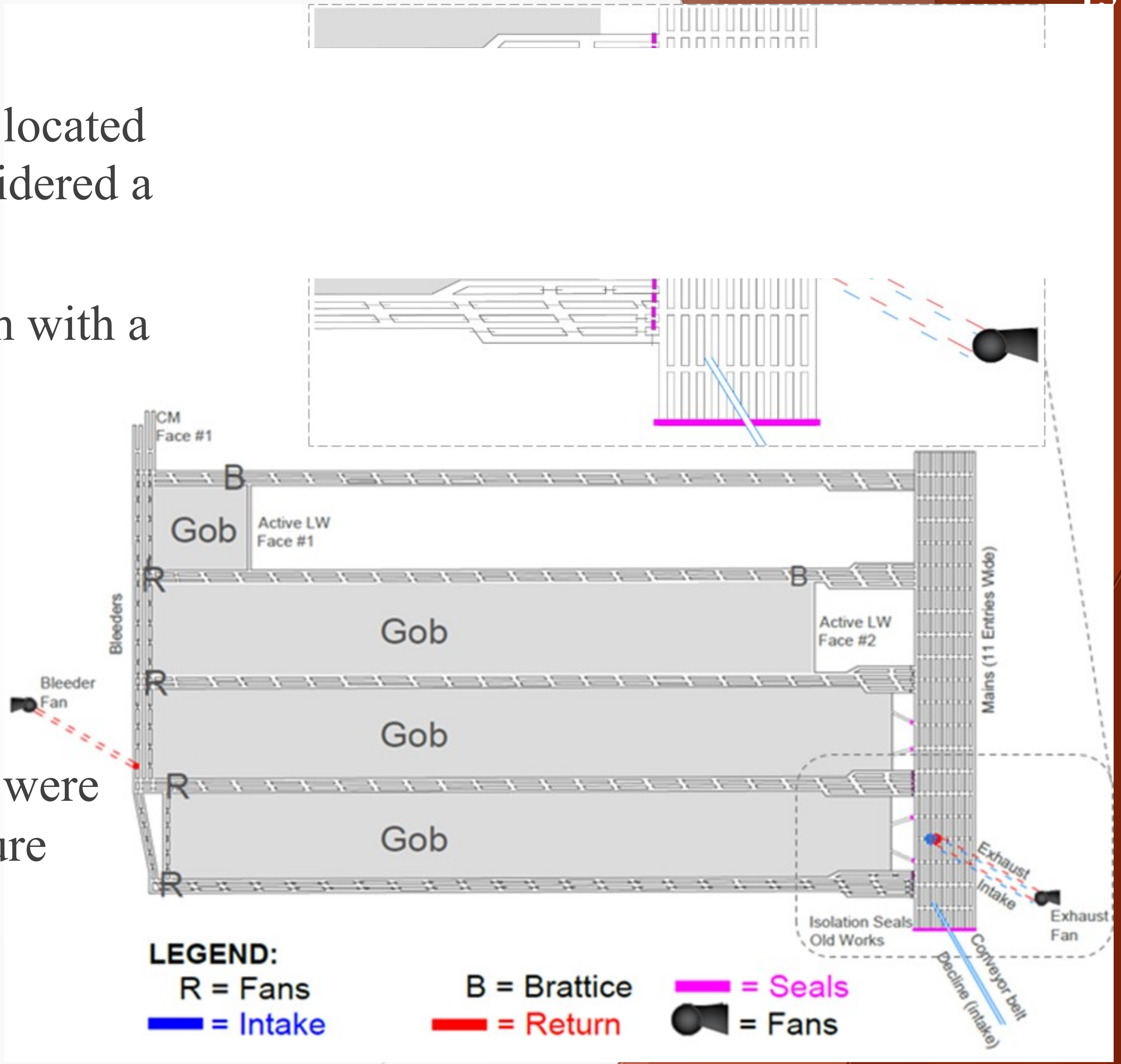
Mine “B” Ventilation Survey

Mine “B” Layout

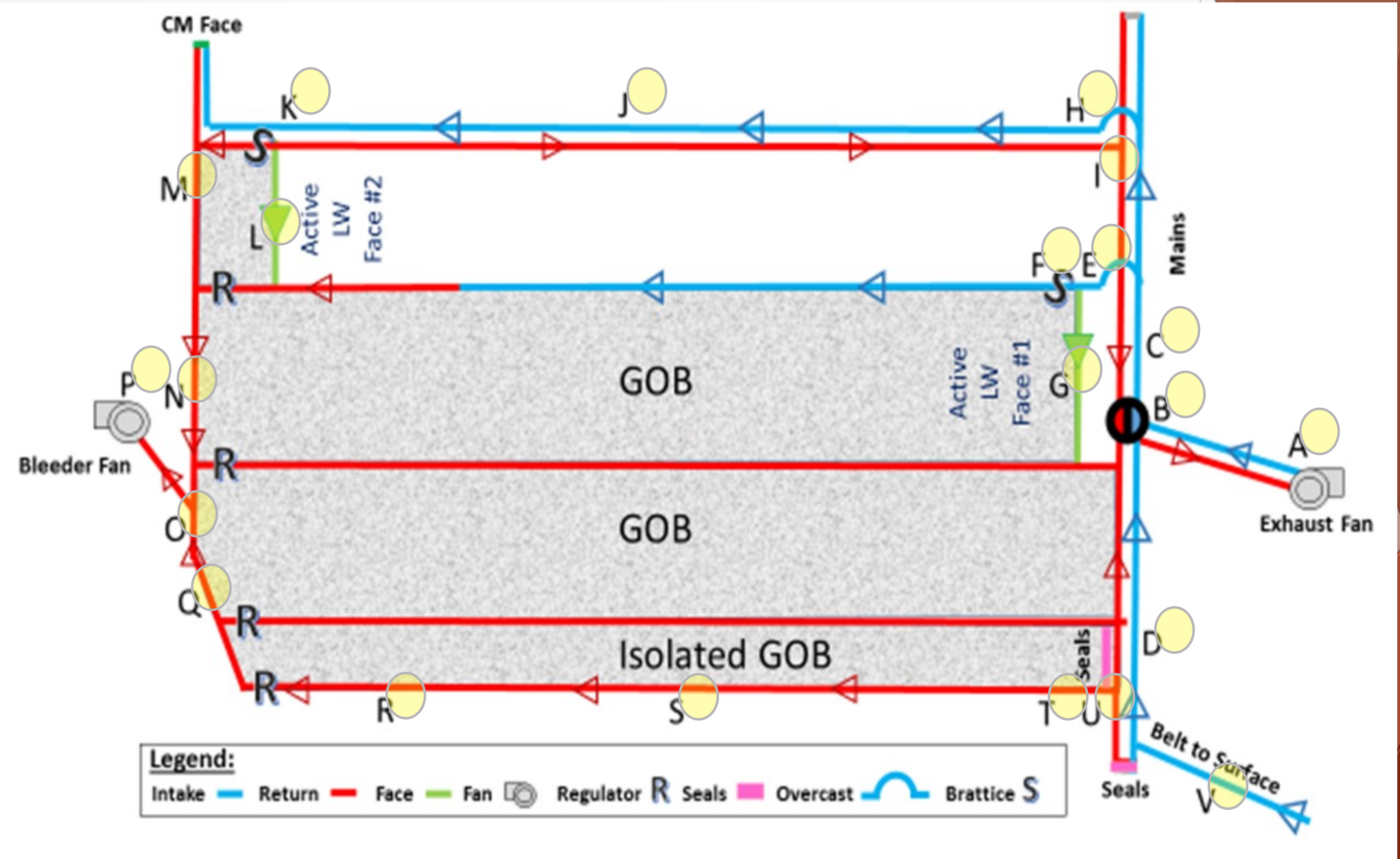
- Mine “B” is an underground coal mine located on the east coast. This mine is not considered a gassy mine.
- This mine uses a “Flow-though” system with a main exhaust and bleeder fan.

Main Fan	Q = 323 m^3/s
	P = 2.54 kPa
Bleeder Fan	Q = 139 m^3/s
	P = 5.28 kPa

- Flow rates, pressures, and dimensions were measured at multiple locations for future modeling and calculations.



Mine "B" Line Diagram



Mine "B" Data

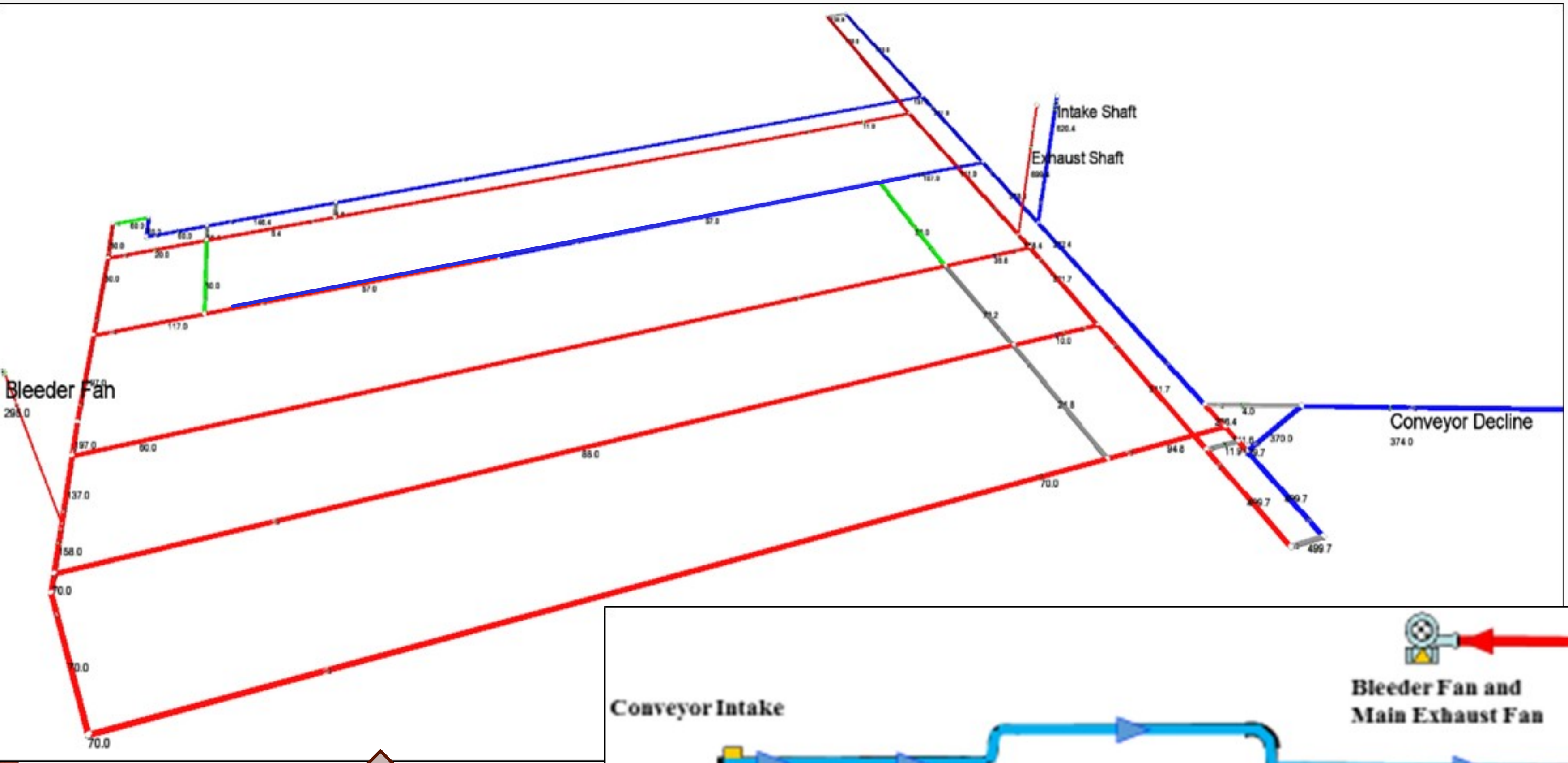
- Total relative pressure and pressure differentials in the bleeders and gob areas were low and nearly balanced.
- The pressures all measured within the range of 50 to 175 Pa (0.20 to 0.75 in wg) in the bleeders and gob.
- Pressure differentials and quantities were taken at the active faces and were found to be:

LW Face	$Q = 28\ m^3/s$
	$\Delta P = 0.75$ Pa
CM Face	$Q = 14\ m^3/s$
	$\Delta P = 0.65$ Pa

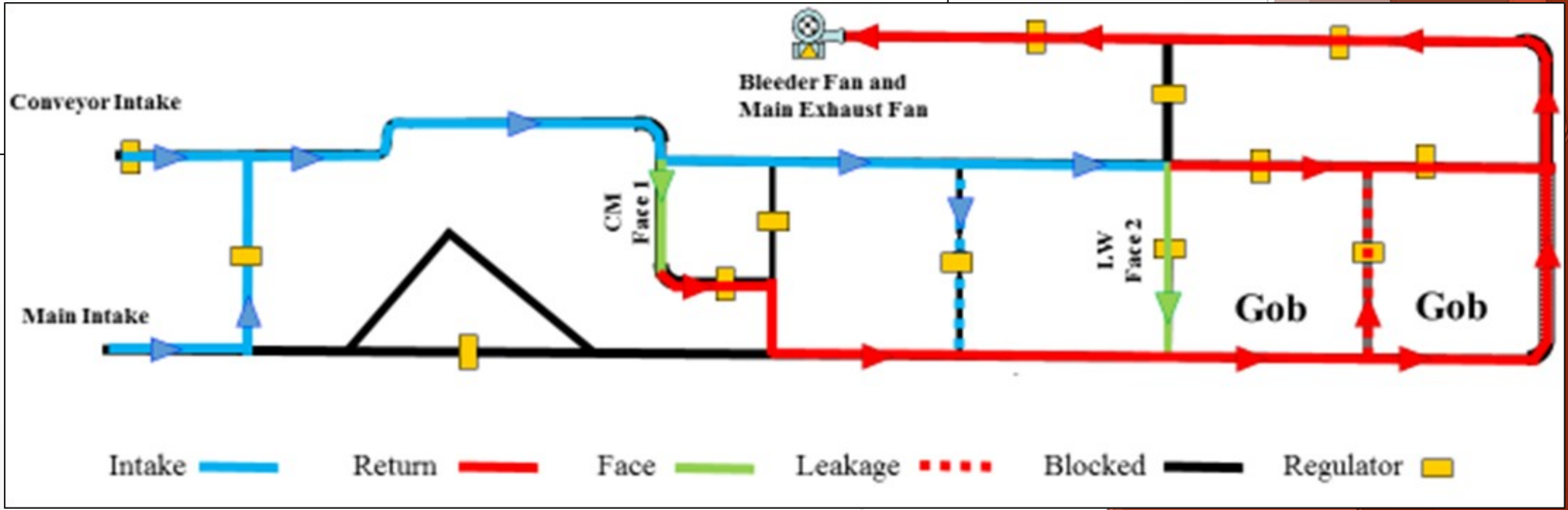
Mine "B" Bleeder System with "Flow-through" Bleeder Fan			
Station	Type of Airway	Flowrates $Q\ (m^3/s)$	Pressures (kPa)
A	Main Fan inlet	323	2.54
B	Pressure differential (airlock)		2.05
C	Intake	162	
D	Intake	161	
E	Intake	50	
F	Intake	24	
G	LW Face 1 (active)	23	
H	Intake-Return	71	
I	ΔP across intake to belt		0.40
J	ΔP across intake to belt		0.19
K	Intake-Return	67	
L	LW Face 2 (active)	28	
M	Bleeders regulator differential	25	0.39
N	Bleeders regulator differential		0.40
O	Bleeders regulator differential	64	
P	Bleeder Fan Outlet	139	5.28
Q	Bleeders	75	
R	Return to Gob		0.17
S	Return to Gob		0.16
T	Return to Gob		0.31
U	Return	32	
V	Conveyor Belt	177	

Numerical and Physical Modeling

Mine "B" Bleeder Flow-through System



Ventsim Model



Physical Lab Model

Similarities

- Lab models were scaled down by a factor of nearly 1:1,600 in terms of airflow.
- Pressures were near the same values for field and modeling data
- The target ratio values of face demands out of total supplied for both mines was achieved mine.

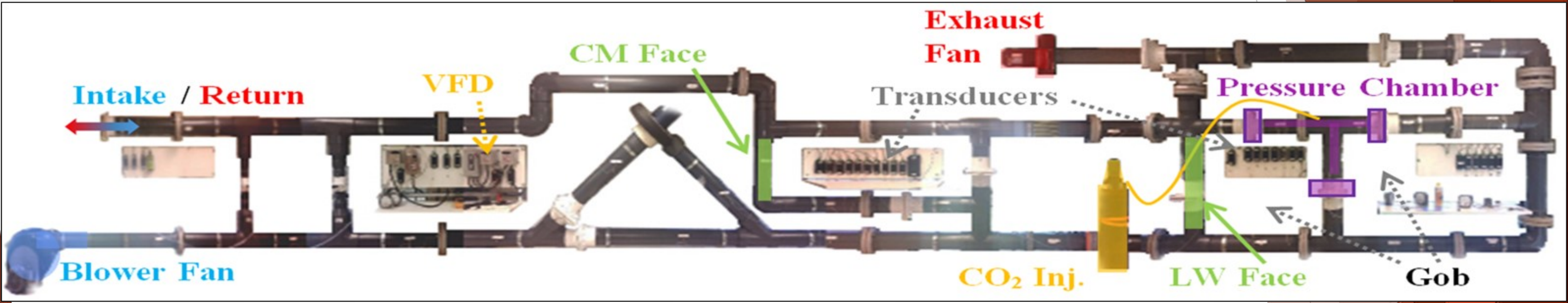
Mine "B" Lab Results Airflow

Location	Field Data (m^3/s)	Ventsim Data (m^3/s)	Lab Model Data (m^3/s)
Active LW Face #2	28	28	0.20
CM Face	14	14	0.10
Total Intake	458	460	0.28
Total Exhaust	4,623	463	0.28

Mine "B" Lab Results Pressure

Location	Field Data (Pa)	Ventsim Data (Pa)	Lab Model Data (Pa)
Active LW Face #2	747	802	852
CM Face	747	797	844
ΔP Across Gob	722	772	757
Base of Intake Shaft	2,052	2,017	2,027

U of U Ventilation Lab Models

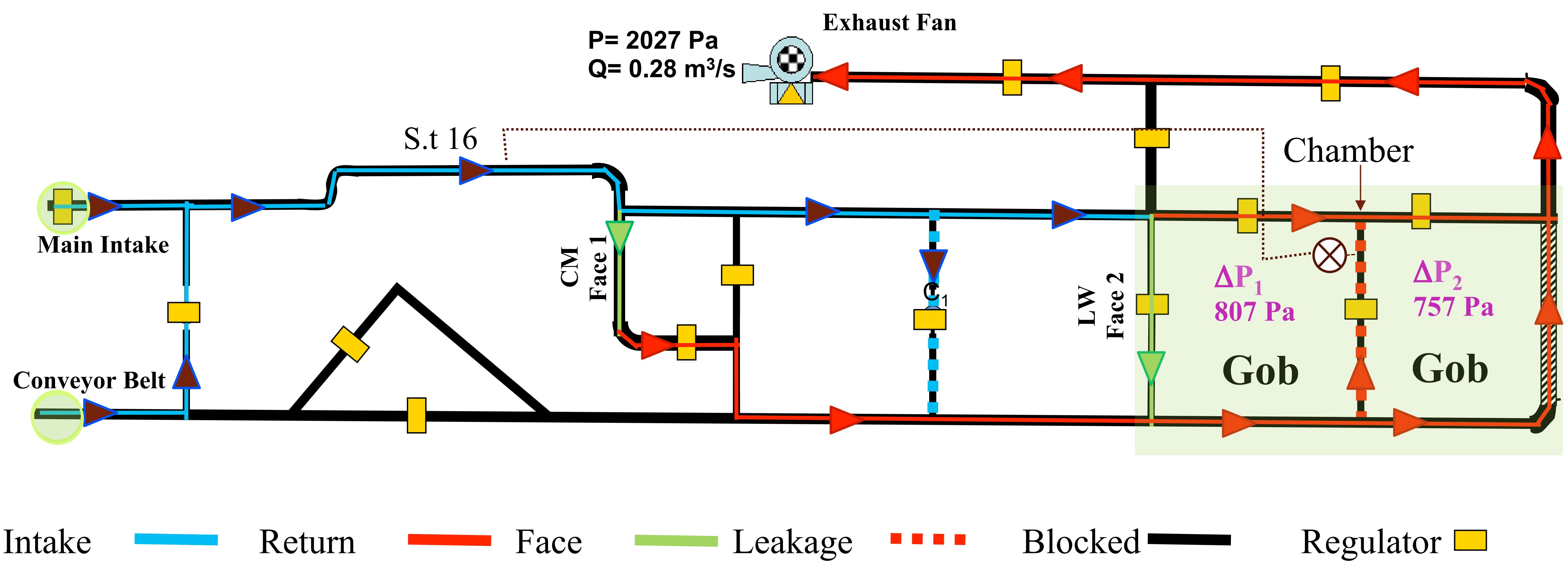


U of U Ventilation Lab Models

Lab Model Versatile system for mimicking multiple ventilation layouts.

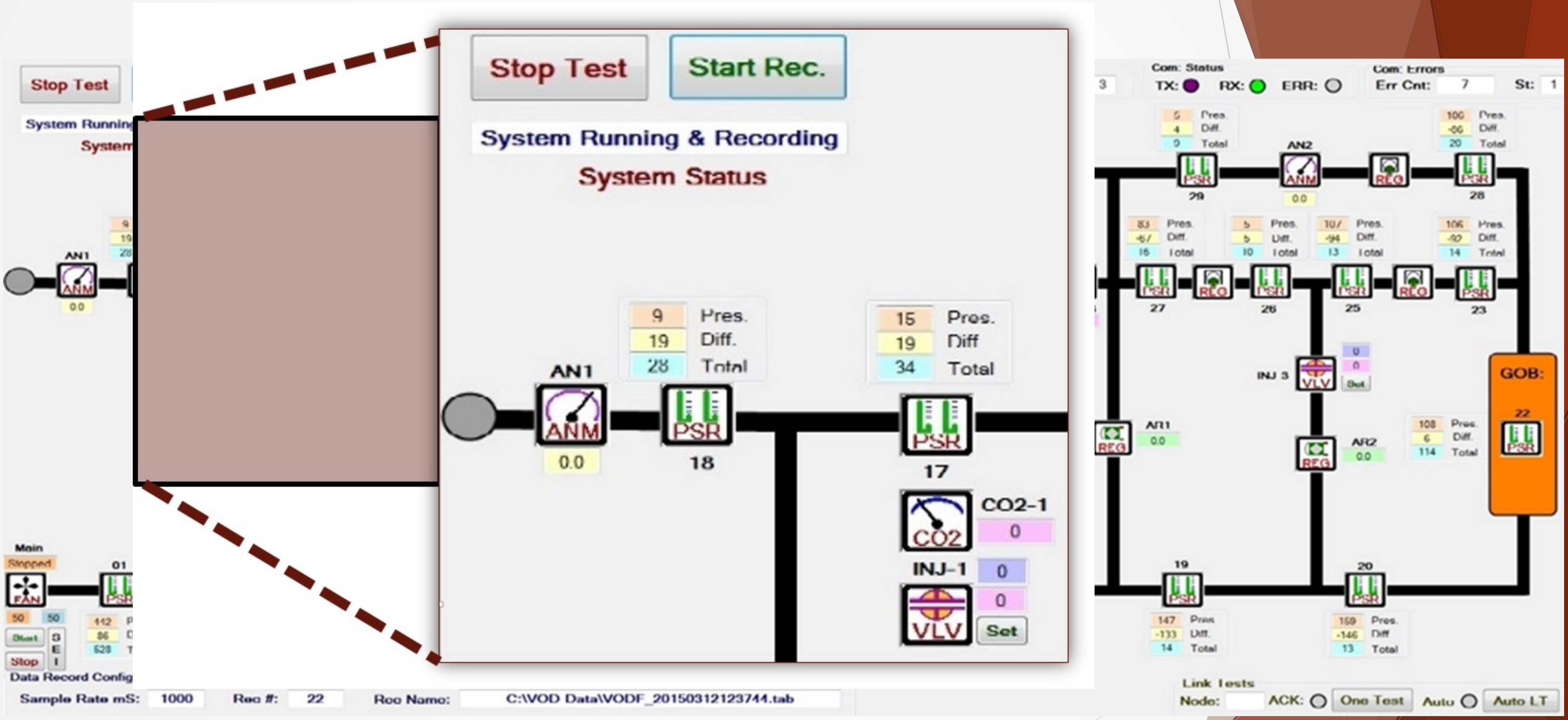
- 6” PVC Piping
- Three Adjustable Fans
- 14 Adjustable Regulator Locations
- Atmospheric Monitoring System
  - Environmental (Barometric, CO_2, Humidity, Contamination, Temperature)
  - Pressure Differentials
  - Quantity
  - CO2 injection and sampling

Model Representation



Flow-Through Exhaust System (Mine B)

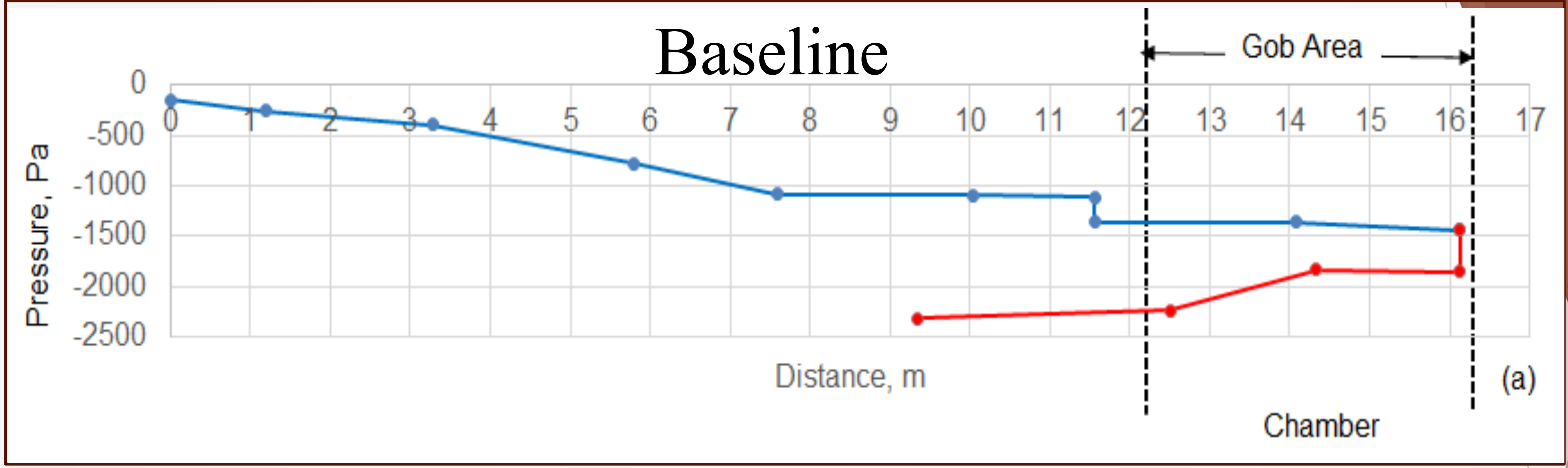
Monitoring System

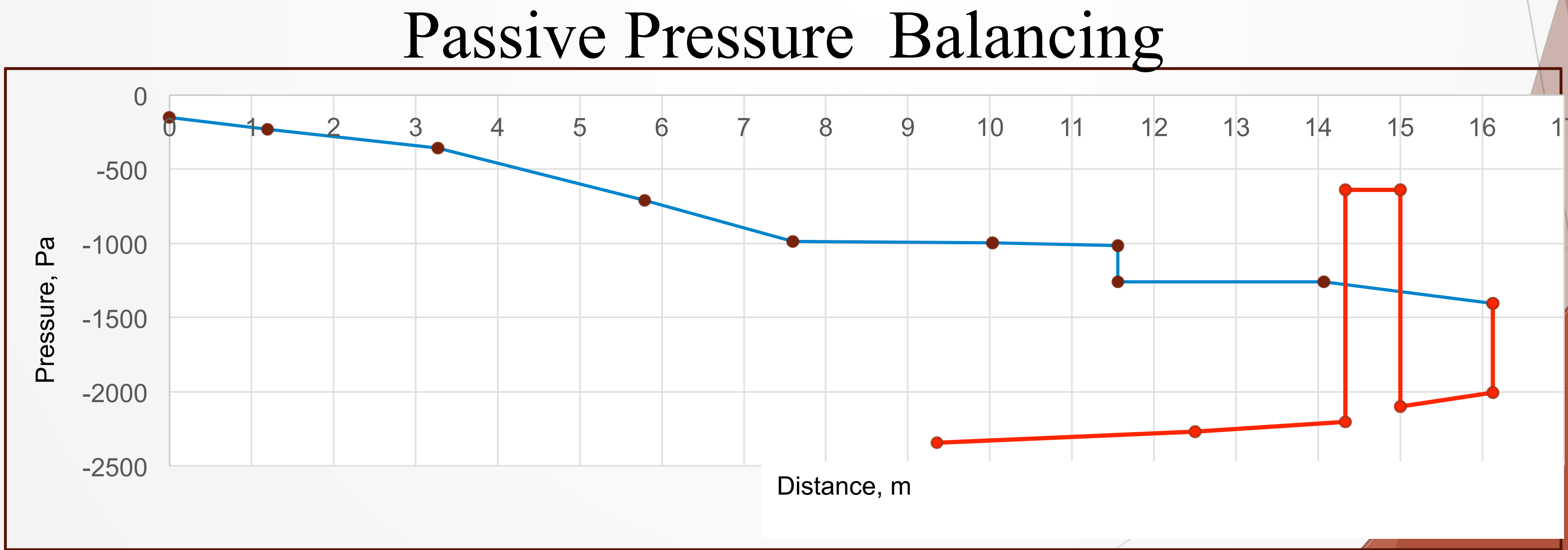


Continuous monitoring system

- Consists of set of pressure transducers, hot wire anemometer, atmospheric sensor
- Vital ventilation parameters are monitored and relayed to a host computer every second
- Data can be recorded and imported to an excel sheet
- Sub-routine program can be used to achieve automatic pressure balancing

Pressure Balancing Test – Pressure Profiles





Conclusion

- PB is not used in US but it is effectively used in other countries to control Sponcom.
- Two types of PB “Active” and “Passive” techniques.
- Physical and numerical models were used to neutralize differential pressures across the gob.
- Active PB is a more versatile method to control Sponcom.
- Passive PB is a simple and cost effective method.

Acknowledgement

This study was sponsored by the Alpha Foundation for the Improvement of Mine Safety and Health, Inc. (**ALPHA FOUNDATION**).

The views, herein are solely opinions and recommendations expressed those of the authors and do not imply any endorsement by the ALPHA FOUNDATION, its Directors and staff.

References

1. Grant, C. C., 2011, “Fires and Explosions in Mines”, International Labor Organization. http://ilo.org/iloenc/part-xi/mining-and-quarrying/item/607-fires-and-explosions-in-mines Accessed June 2015
2. McPherson, M. J., 1993. “Subsurface Fires and Explosions”, http://mvsengineering.com/files/Subsurface-Book/MVS-SVE_Chapter21.pdf Accessed May 2015
3. MSHA, 2002, “Bleeder and Gob Ventilations Systems - Ventilations Specialist Training Course”, U.S. Department of Labor Mines Safety and Health Administration.
4. MSHA, 2013, “Winter Alert 2013 - Preventing Fires and Explosions”, United States Department of Labor Mine Safety and Health Administration, http://msha.gov/winteralert2013/winteralert- 2013.asp. Accessed June 2015
5. Office of Mine Safety and Health Research (OMSHR), 2015, “Coal Mining Disasters: 1839 to Present”, http://cdc.gov/niosh/mining/statistics/content/coaldisasters.html Accessed June 2015
6. Smith, A. C., Diamond W.P., 1994. “Bleederless Ventilations Systems as a Spontaneous Combustion Control Measure in U.S. Coal Mines”.