Application of Three-phase Foam in Extinguishing Spontaneous Combustion of Coal

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Outline

- Background of Sponcom
- Components of Three-phase Foam(TPF)
- Characteristics of TPF
- Case Study of TPF
- Conclusions and Perspectives

Background

In the United States,

- 1978–1988: ~15% of underground coal mine (UGCM) fires were caused by the sponcom of coal
- 1990–1999: UGCM fires caused by sponcom account for >17%.
- 2000–2006: 10 UG sponcom of coal were reported.

Consequence of Sponcom

Sponcom may cause huge economic losses, temporary or permanent mine closures, significant environmental problems, even fatalities.

- Three of the reported mine fires resulted in subsequent methane explosions;

- In China, a coal mine explosion that happened in 2004 caused 166 fatalities. The most possible reason is the sponcom of coal.

Prevention of Sponcom

Table1. Comparison among Different Fire Fighting Agents

Agents	Components or Category	Main Pros	Main Cons	Cost ($/m^3)
Water	Tap Water	(1) Cool the temperature quickly; (2) Large amount of vapor produced can dilute the oxygen concentration in order to inert the fire zone; (3) Low cost	(1) Can only cover a small area because of its excessively good flowability; (2) Easily flow to the low area without reaching the higher fire zone; (3) May run out of the gob area and contaminate the working face and lower the coal quality.	Very low
Slurry	Fly Ash, Sand, Gypsum, Cement etc.	(1) Effectively cover the coal and isolate it from the oxygen; (2) Cool the temperature; (3) Simple technique; (4) Low cost	(1) Cannot uniformly cover the coal and can only cover a small area; (2) Flow to the low area without reaching the higher fire zone; (3) May run out of the gob area and contaminate the working face.	1.5-5
Inhibitor	Some surfactants such as $MgCl_2$, NaCl, $Ca(OH)_2$, Soluble Glass etc.	(1) Inert the surfactant structure of coal and prohibit the oxidation; (2) Cool down the coal and can keep the coal humid for a long time.	(1) Complex technique; (2) Difficult to uniformly sprinkle to the coal; (3) Corrode the equipment underground.	5-10

Prevention of Sponcom

Inert Gases	Nitrogen, CO_2 etc.	(1) Dilute the oxygen concentration; (2) Dilute the explosive gases in the gob area; (3) does not corrode the equipment and does not harm people's health;	(1) cannot stay in the gob area or fire zone for a long time due to the leakage; (2) The Nitrogen or CO_2 generator needs maintenance frequently. (3) Cannot cool down the fire zone and may take a long time to extinguish the fire.	Relatively low
Gels	Ammonium-salt Gel	(1) Can cover the coal and block the leakage; (2) High temperature resistance; (3) Effective for small and local fire zone.	(1) Poor flowability; (2) Doesn't work for large-area fire zone, (3) The gel will fracture in a certain time; (4) High cost	10-15
	Macromolecular Gel			20-25
Leakage-blocking Material	Luokexiu; Malisan; Urethane Foam	(1) Has excellent crush resistance and leakage blockage; (2) Isolate the coal from oxygen.	(1) Complex technique; (2) Liberate harmful gases during pyrolysis; (3) some are combustible in high temperature; (4) High cost	15-170
Regular Two-phase Foam	Nitrogen/CO_2-water Foam	(1) Can reach the high part of the fire zone; (2) Uniformly spread in the gob area; (3) Suitable for combustion in gob/mined-out area or deep part in a coal pile.	Foam is easy to rapture in order not to cover the coal for a long time.	Relatively low

Three-phase Foam

- **Three phases**

（1）Gas: N_2

（2）Liquid: Water

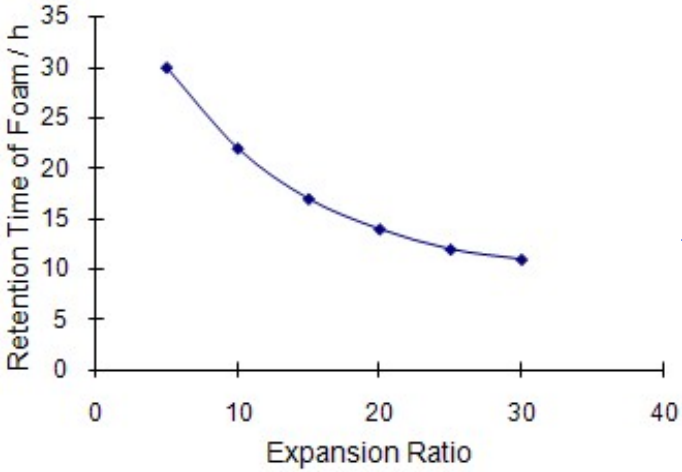
（3）Solid: Fly ash or Earth

Principles of TPF in Fire Fighting

Each phase has its own purpose:

- Water: Cool down the fire and lower the temperature
- Nitrogen: Inert gas $\longrightarrow$ Dilute the concentration of oxygen
- Fly ash/earth: Cover the coal to isolate the air
- Capture the Free Radicals

ee-phase Foam



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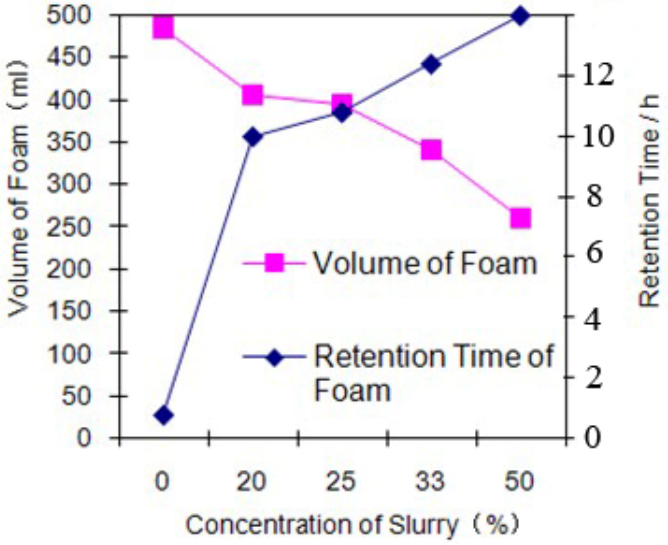
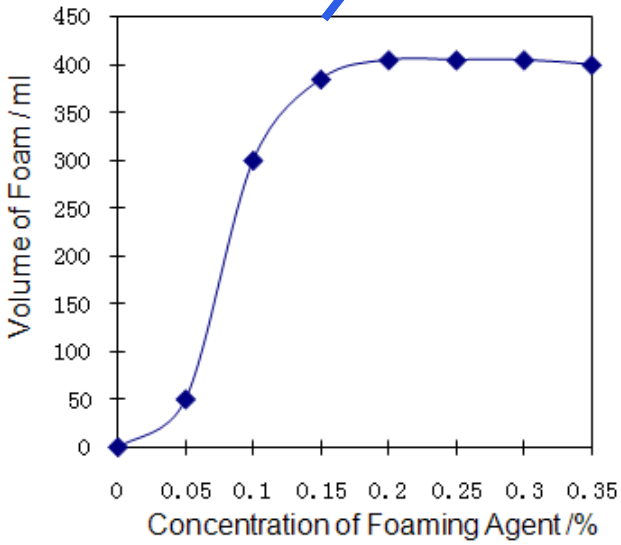
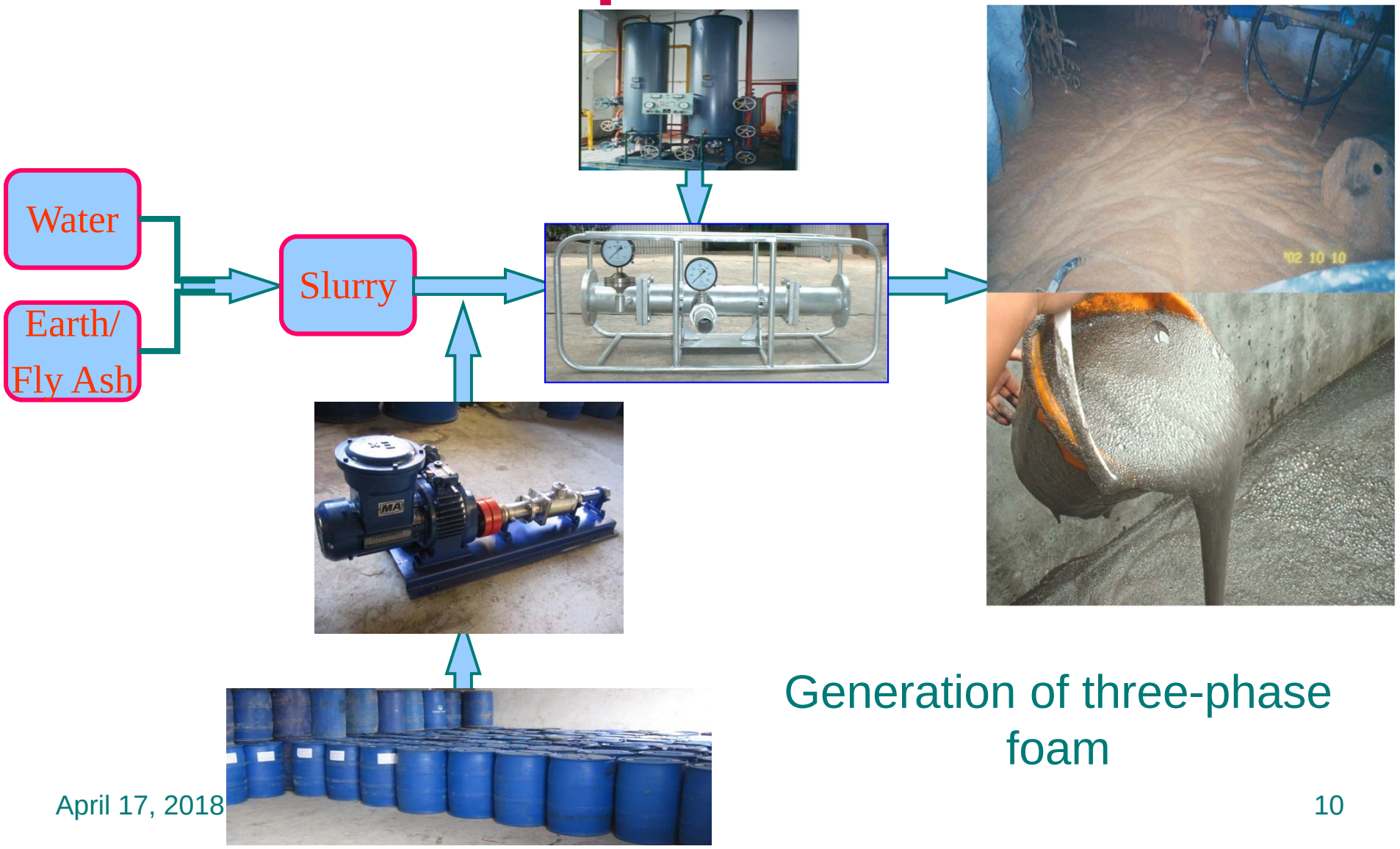
- Expansion Ratio of Foam to Water: 30
- Mass Ratio of Fly ash to Water: 4:1
- Concentration of Foaming Agent: 0.2%
- Retention Time of Foam: ~10h
- Cost: 0.4¢ /ft^3 (0.2$/m^3)



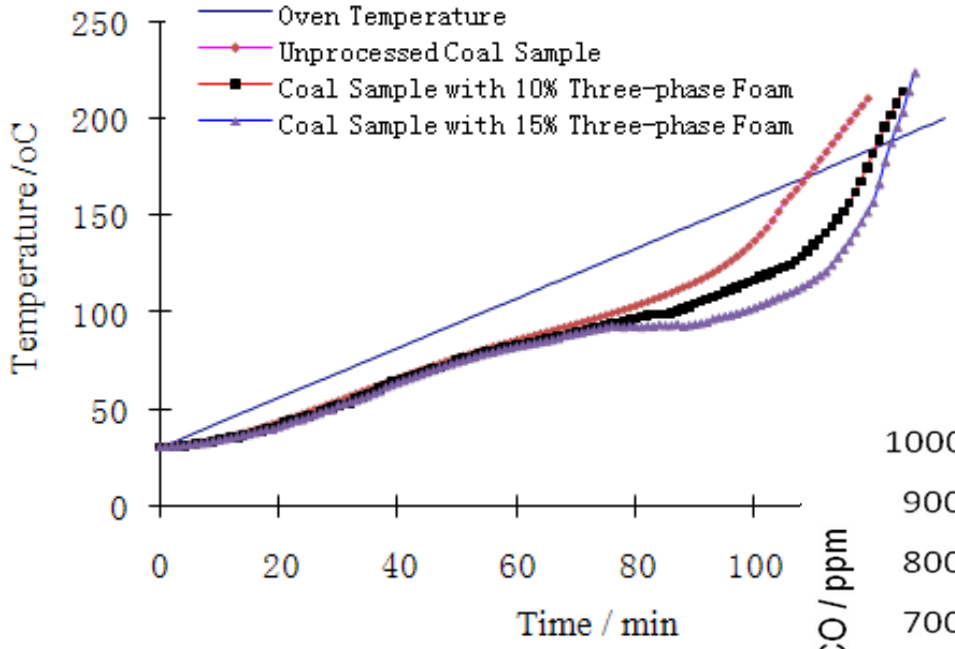


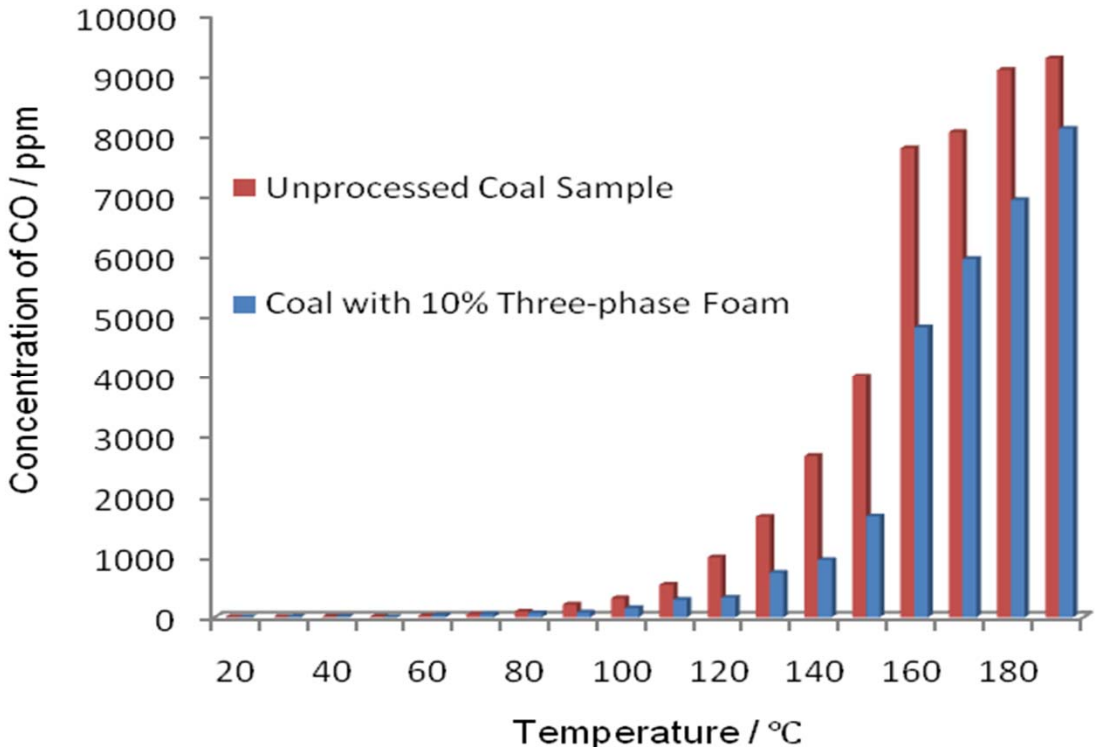
Three-phase Foam



Generation of three-phase foam

Bench Test of TPF





Fire Fighting Test

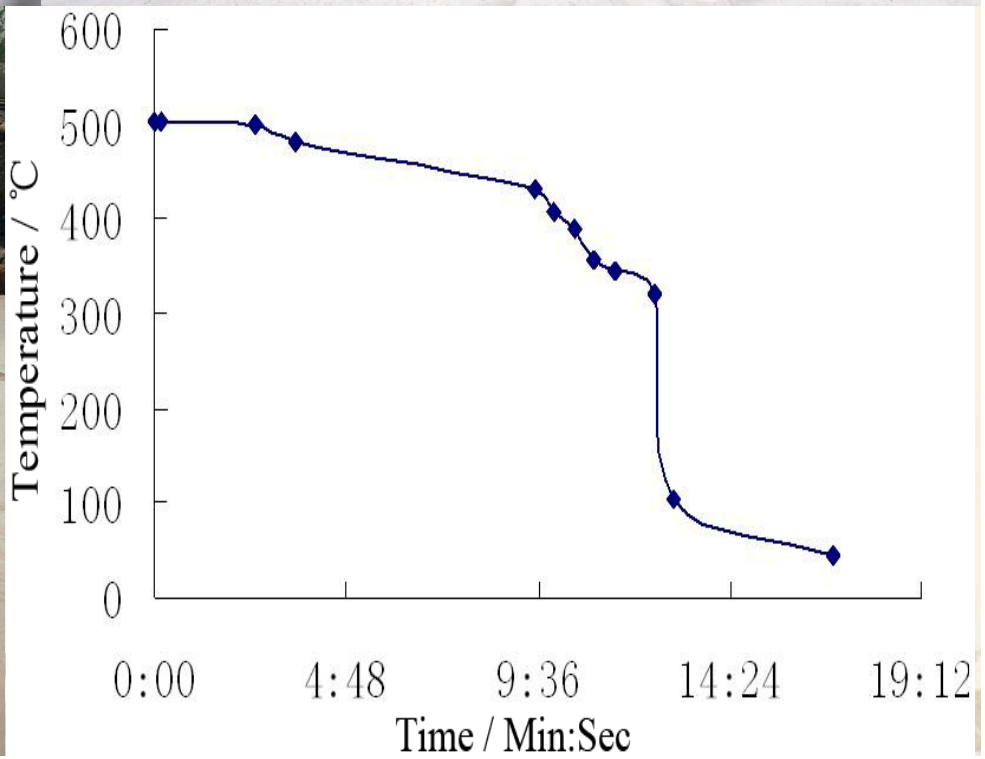
Comparison between water and three-phase foam

Three-phase Foam


Thirty minutes

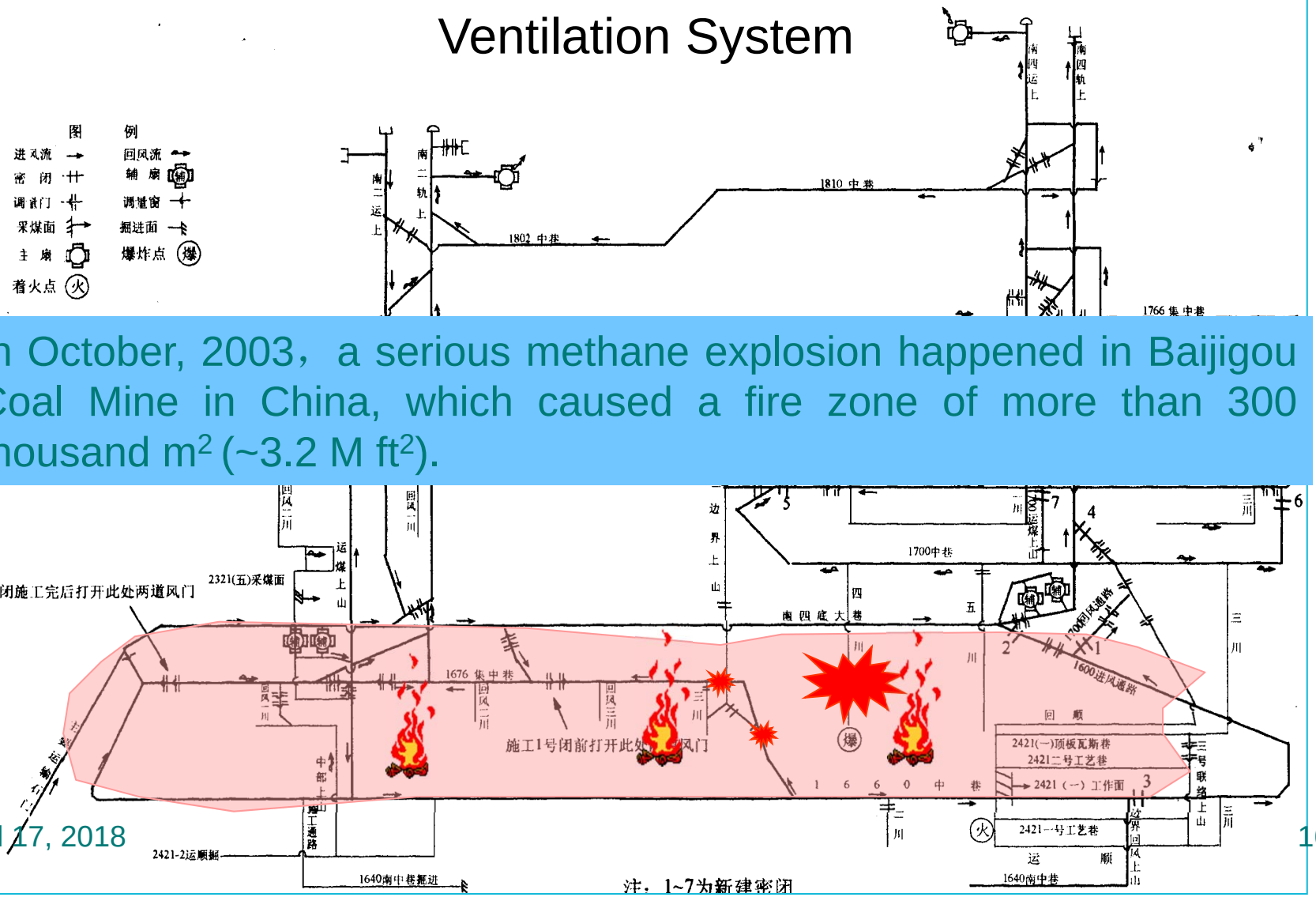

Two minutes


Thirty minutes


600
500
400
300
200
100
0
Temperature / °C
0:00
4:48
9:36
14:24
19:12
Time / Min:Sec

Case Study

Ventilation System



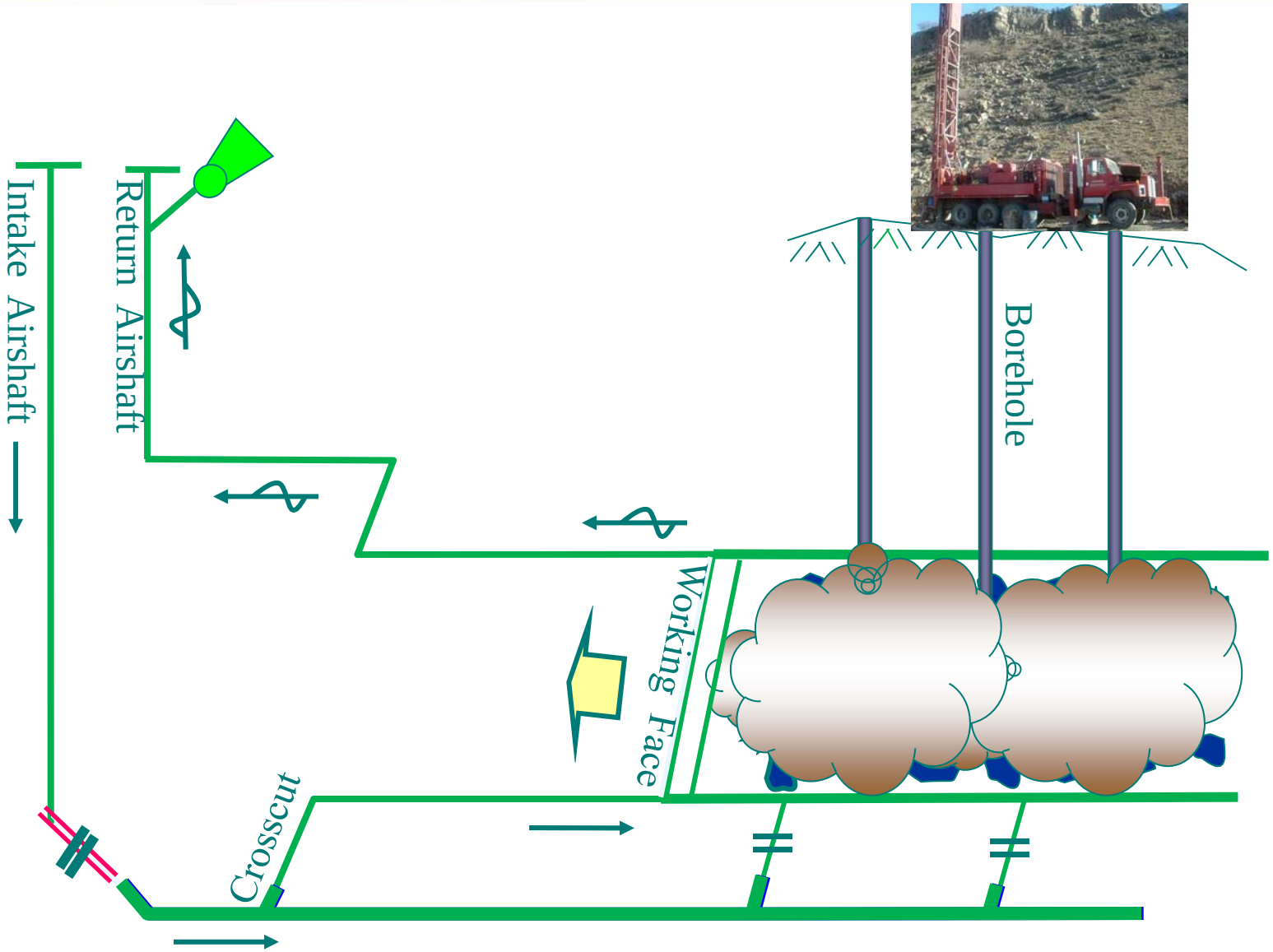
In October, 2003，a serious methane explosion happened in Baijigou Coal Mine in China, which caused a fire zone of more than 300 thousand m^2 (~3.2 M ft^2).

Smoke run out of the shaft

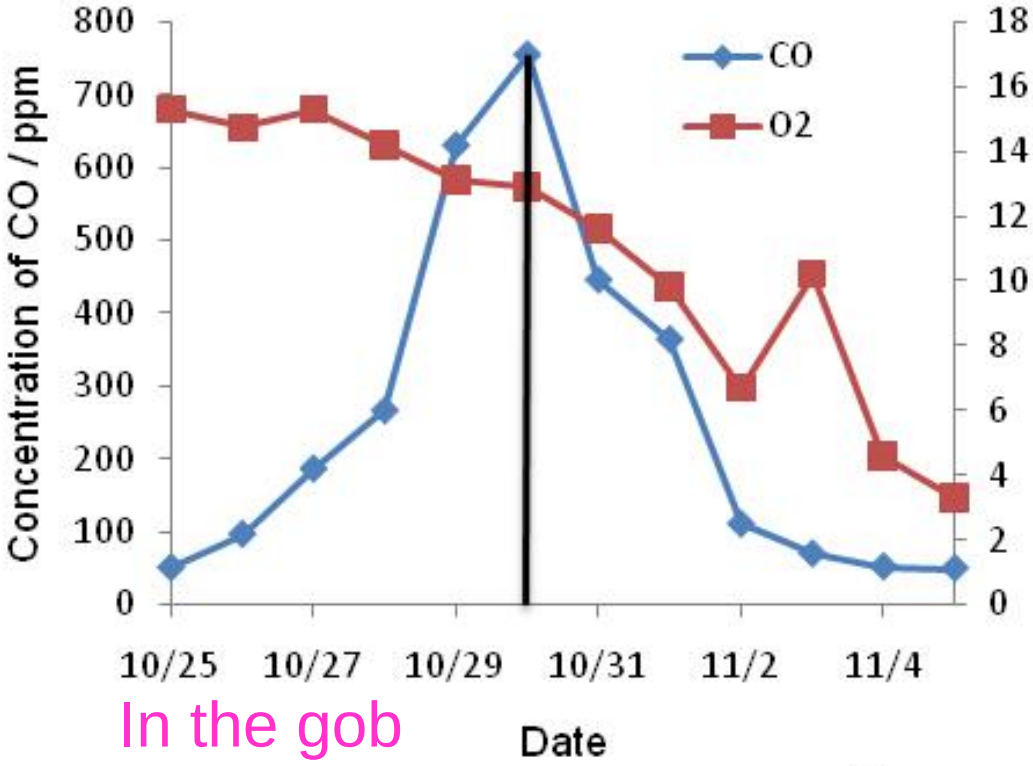
The destruction of a seal

A destroyed air door near a shaft

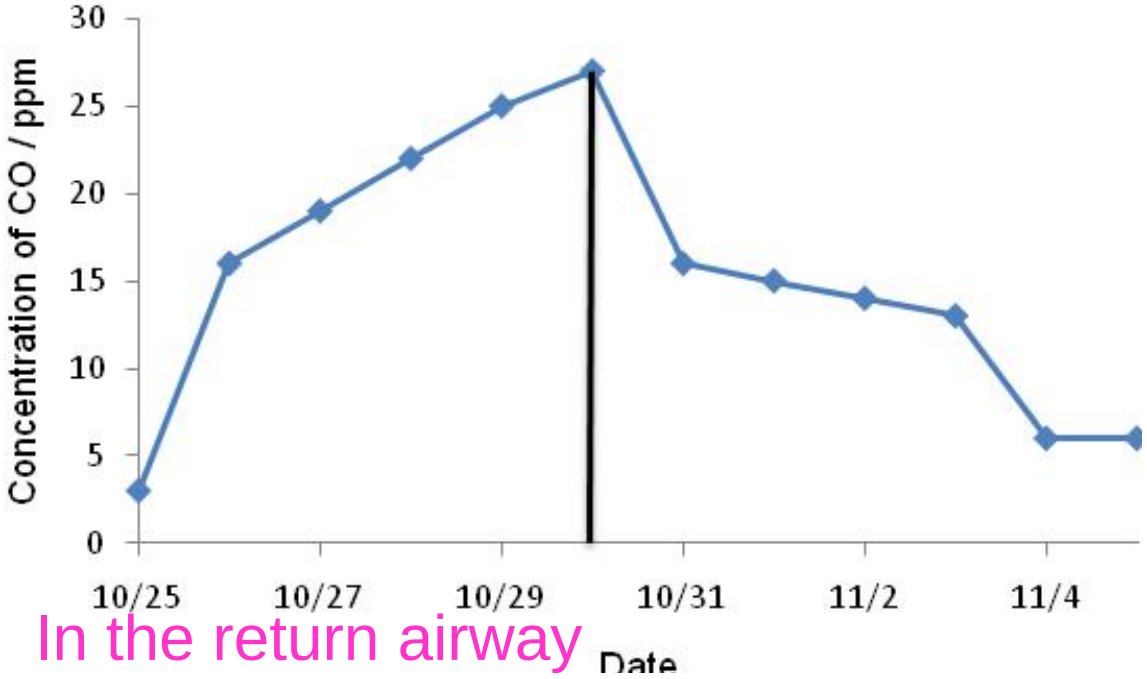
The destruction of ventilation equipment room


Intake Airshaft
Return Airshaft
Borehole
Working Face
Crosscut

e Foam



In the gob



In the return airway

Conclusions and Perspectives

- TPF works very well in controlling the spontaneous combustion of coal
- TFP is not quite effective for the prevention of air leakage into the gob after the rupture of the foam.
- The combination of TPF and Gel may be a good solution


Thank You!