International Perspective on Outbursts

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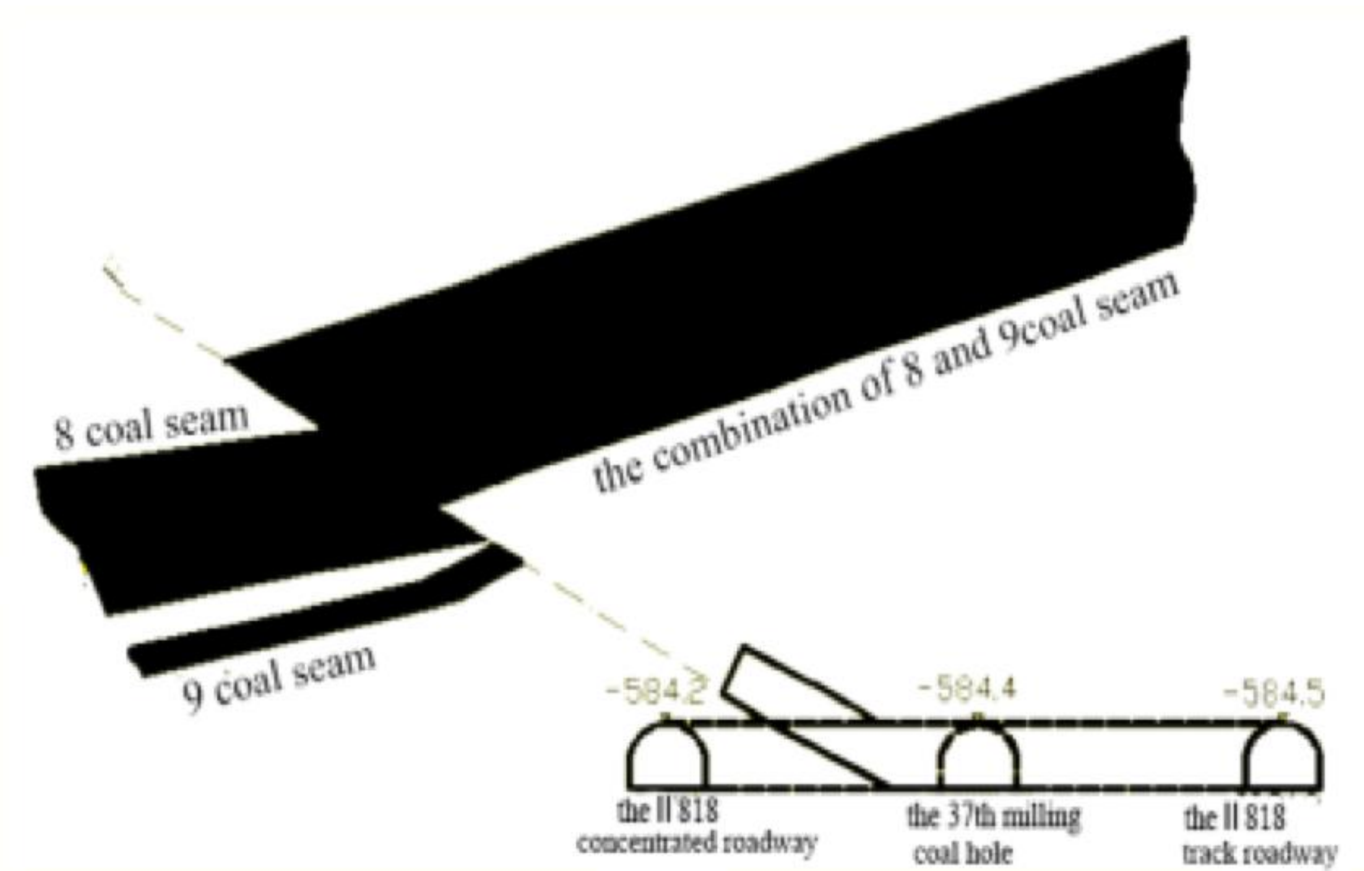
The Worst Outbursts

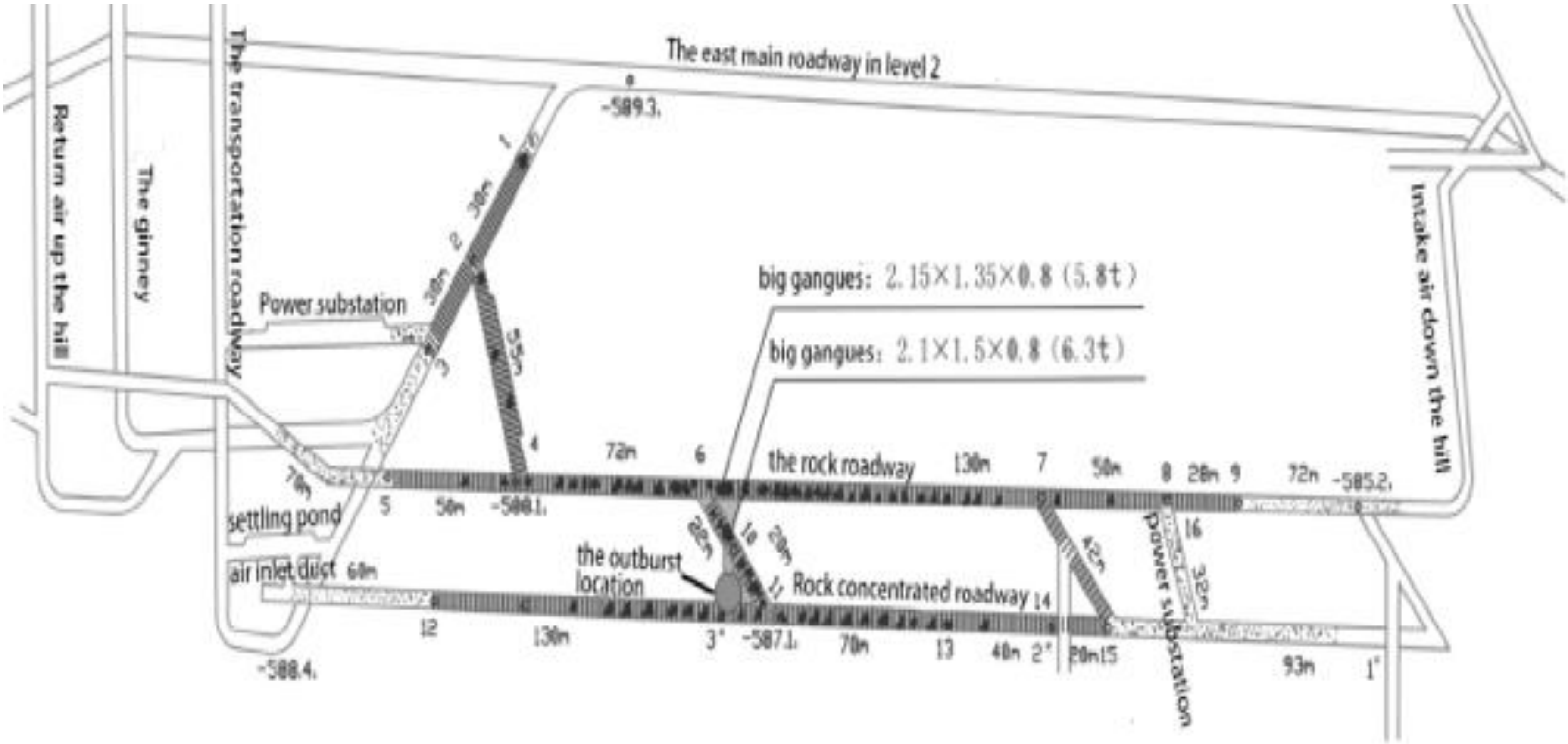
- Have always occurred when entering a gassy seam from a roadway in rock when there has also been a fault.

- Examples in China, Kazakhstan, France, Japan

Particular case 2002 Luling mine, Anhui, Province China



8730 tonne coal, 9.3×10^5 m^3 CH_4



The roadway was filled with the outburst coal
Powdered coal's thickness
the rock's distribution area

Luling Mine

- Drainage currently by drilling 6 m spaced cross measure holes through rock
- Drilling hazardous as fragments ejected from boreholes at high velocity
- Gas content 17 m^3/tonne
- Permeability approx 0.002 md
- Drainage time >6 years

D6 Seam in Karaganda Basin

- Mined in Lenina and Tentekskaya mines
- Seam 6 m thick
- Bottom 0.5 to 2 m consisting of coal sheared to a dust. Drag structures visible in seam.
- Coking coal with 25% ash
- Almost impossible to drill in seam
- Water flushing cannot be used as rods bind in hole. Air flush used successfully for cross measure drilling

D6 seam at test site

- Gas content 18.4 m^3/t
- Gas pressure 4.7 MPa
- Diffusion coefficient of upper (solid) part of seam $1.5 \times 10^{-12}\ m^2/s$
- Diffusion coefficient of lower (gouge) part of seam $10^{-10}\ m^2/s$
- 70% of lower seam sheared material < 1 mm diameter.

Lenina Outburst, March 1998

- The outburst occurred at the face of crosscut no.2 D6 seam, horizon -100. The crosscut was mined in the floor rocks (sandstone, siltstone and argillite). The distance between crosscut and seam at the moment of outburst was 5.5 m. The outburst occurred 4 hours after shot-firing, during loading out of rock mass.
- 1250 t stone, 2000 t of coal
- 1,300,000 m^3 CH_4
- Throw of waste 236 m

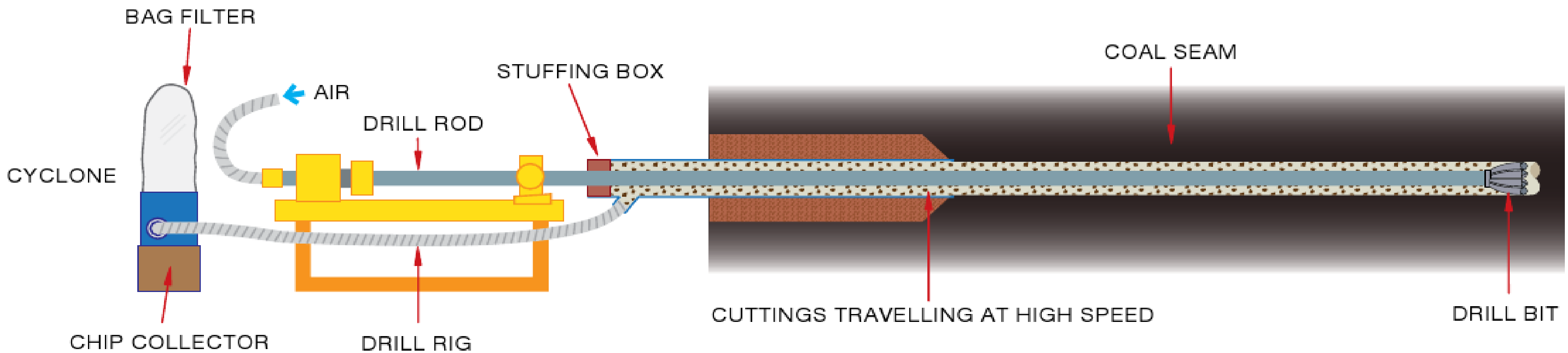
Lenina drilling outburst December 2008

- Roadway drivage without pre drainage impossible
- Drilling in seam impossible
- Therefore drill fan holes upward from roadway developed below the seam
- 5 holes every 4 m
- Left for months to drain
- Outburst on hole drilling into bottom of seam

Lenina Drilling OB Dec 2008

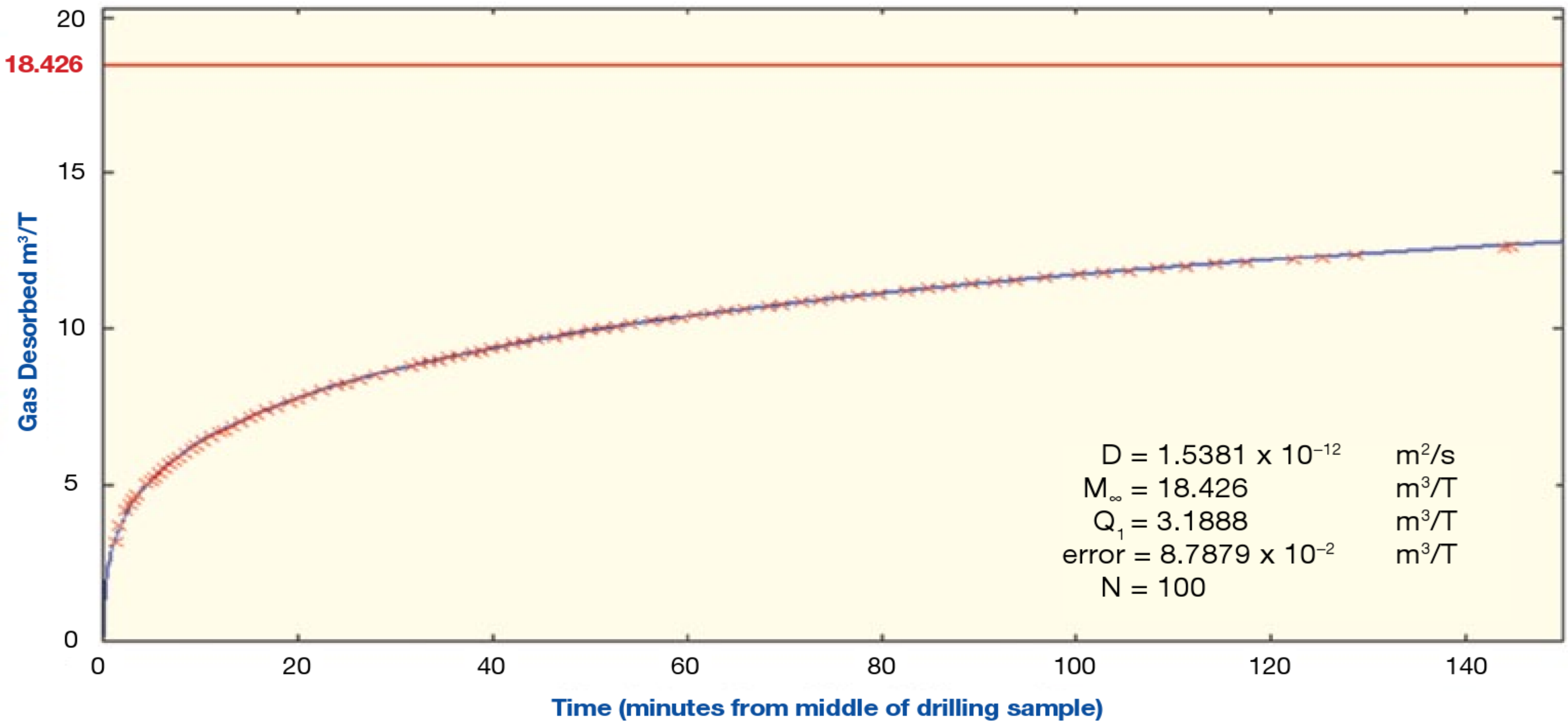
- Drill hit seam
- 8 m^3 fine coal ejected with rumble
- Vent tube ventilation reversed
- CH_4 exceeded 26%
- Dust so intense could not see watch with cap lamp
- Felt way up incline to fresh air
- Events such as this common and one led to 2 deaths 6 months later

Dry Drilling Sampling System



Dry drilling sampling system

Modelled Gas Desorption vs. Recorded Gas Desorption



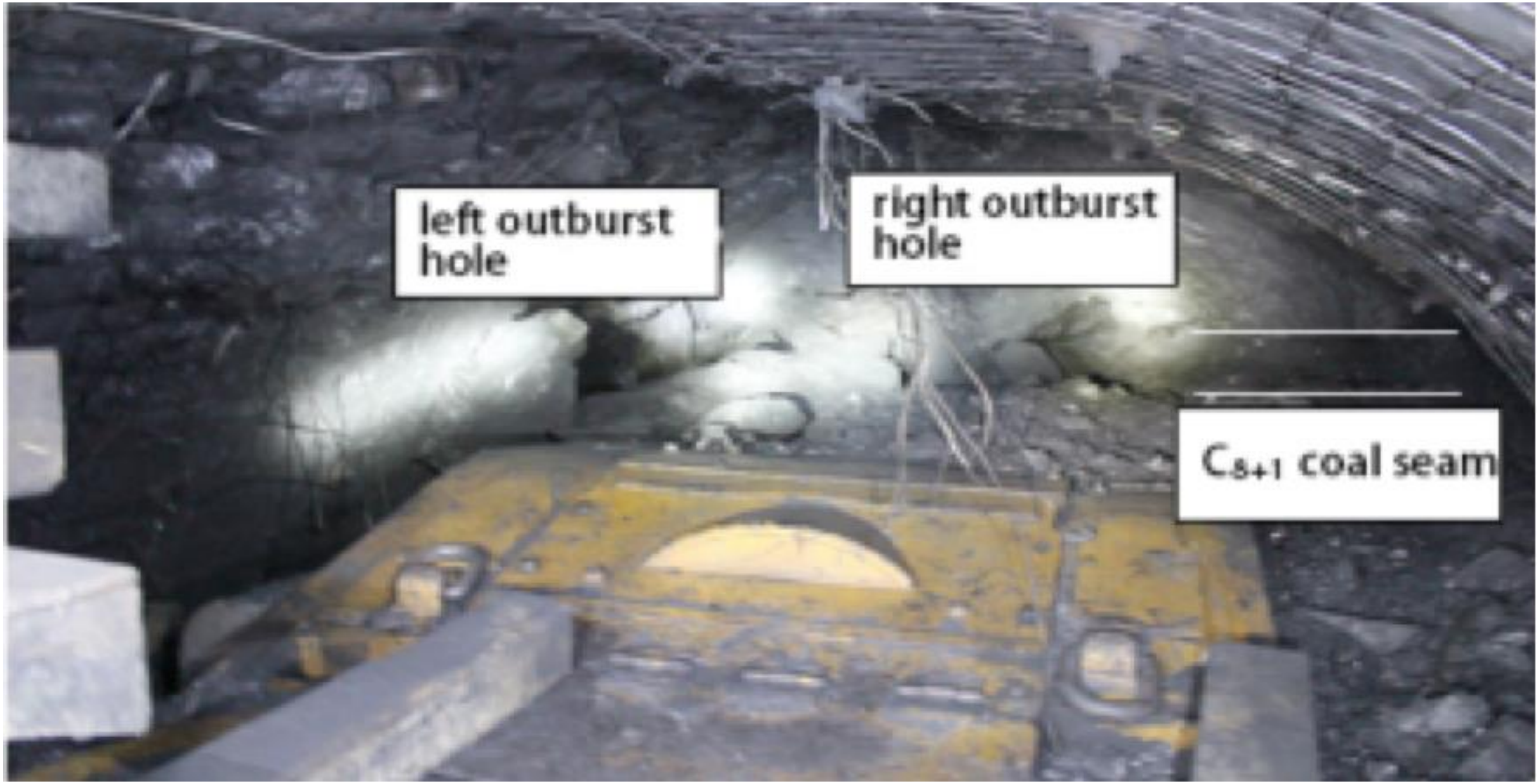
In seam mining can also have major outbursts

Bailongshan mine, 2013

- Roadway development in seam with roadheader
- Mined into undetected reverse fault
- Gas content 16.4 m^3/t
- Sorption pressure 1.57 MPa
- 868 tonnes of coal
- 84130m^3 CH_4

Piled coal outbye

Face



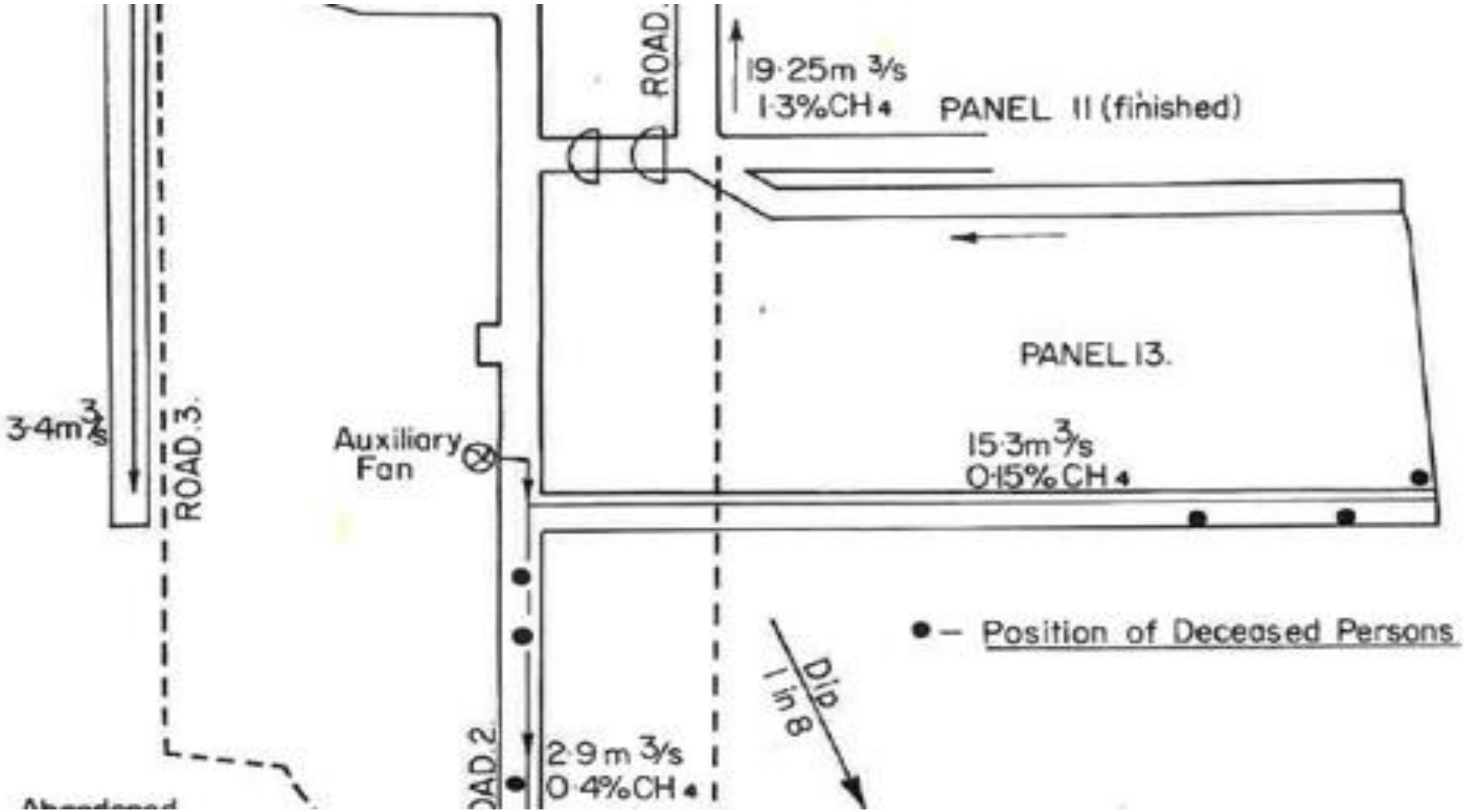
Hole on left hand side of face

Hole on right side of face

Cynheidre, Wales

- Anthracite mine
- 600 m + deep
- Gas content > 8.5 m^3/t from face without Q1
- Solid outbursts producing fine material
- Gouge material outbursts on faults
- Solid outbursts accompanied by sound like two stroke engine being revved up, called ‘pouncing’

Cynheidre, 6 April 1971

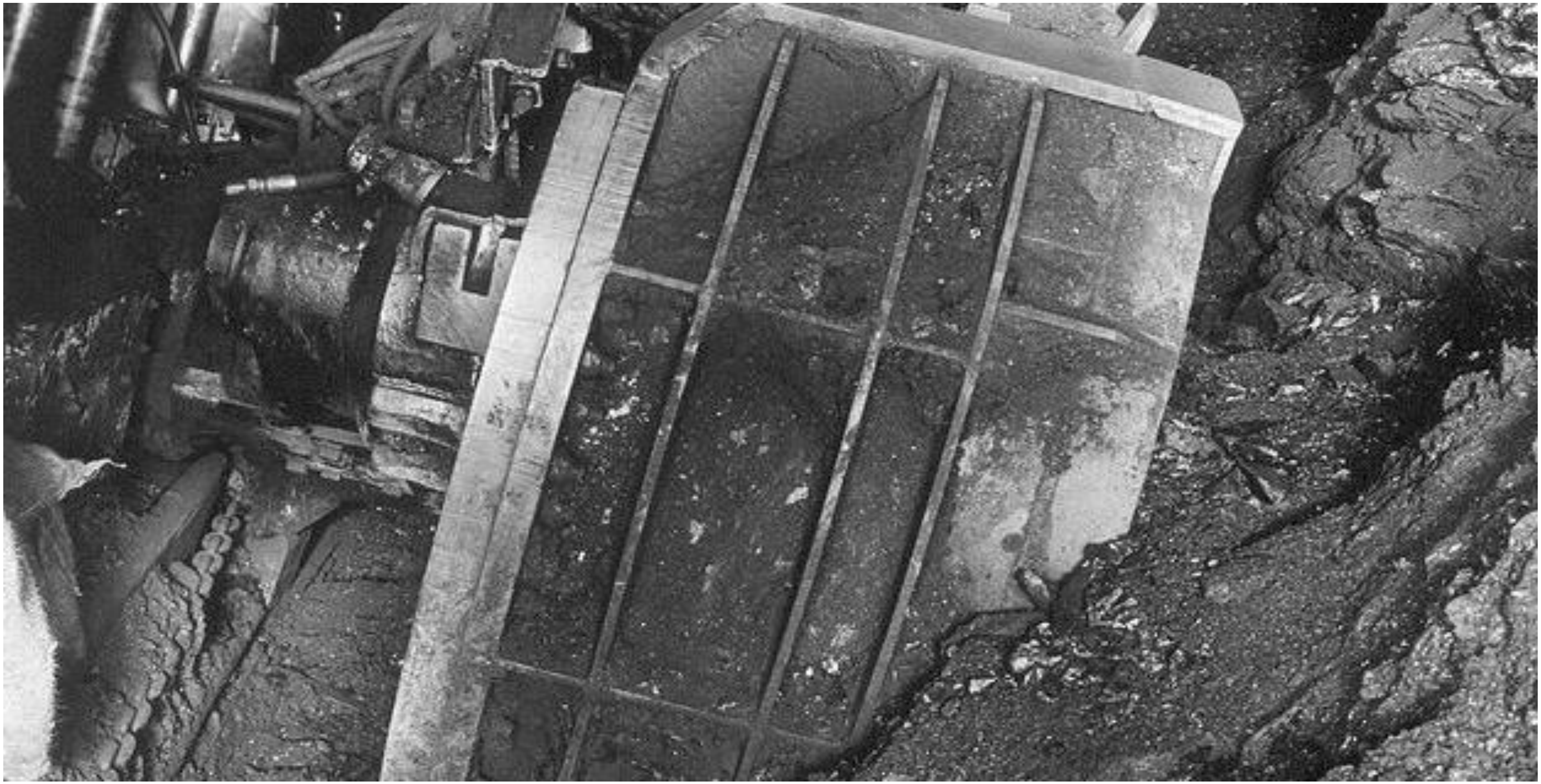


6 April Outburst

- Coal continuously broke away from roadway walls so that steel sets could not be sensibly placed
- Solid coal outburst?
- No warning with raised gas make or “pouncing” noise
- Outburst 20 hours after shotfiring

Fine outburst material

Fine material to shearer from earlier outburst on longwall face



Outbursts behind the face

- Pervomayskaya Mine, Kuzbass, Russia, 2005
- Roadheader and gathering arm loader developing heading
- Outburst occurred 15 m behind the face trapping two crew
- Origin of outburst – sheared material associated with fault in ribside

Common Features of Outbursts

- Large amount of fine material present in quantity in the outburst mass
- Minimal warning
- Gas make frequently out of proportion with broken material mass or volume – typically 100 m^3/tonne – but gas volume usually measured over period after event

Chinese approach to men and mine surviving an outburst

- Fit outburst containment doors so that the whole mine ventilation is not overcome – this means keeping surviving workforce inside doors
- Supply lots of compressed air breathing stations – sit down and breathe from rubber tube
- Good methanometer based trips for power

Russian Outburst Regulations

Basin by basin quantification

Uses:

Initially by critical depth determined by experience

Later by other parameters such as

Initial gas content daf basis

Volatile matter on daf basis

Metamorphic Coal Index

Critical depth

Coal basin, region	Critical depth, m
Prokop'evsko-Kiselevskiy	150
Uskatskiy and Tom'-Usinskiy	200
Kemerovskiy	210
Bunguro-Chumyshskiy	220
Belovskiy, Baidaevskiy, Osinnikovskiy, Kondomskiy and Tersinskiy	300
Leninskiy	340
Anzherskiy	500
Aralichevskiy	190
Pechorskiy	400
Partizanskoe deposit and deposits of Sakhalin island	250

Critical depth for Rostov Basin (Donbass) is based on **metamorphic coal index *M***

- Coal index M is determined as follows:
- If V^{daf} = 9-29 % the equation

  $M = V^{daf} – 0.16y$ is used (2.1)
- If V^{daf} more 29 % the equation

  $M=(4.V^{daf}-91)/(y+29)+2.4$ is used, (2.2)
- where y — coal plastimetry layer thickness in mm (for coals non-clinkering prone, y = 0).

Rostov (Donbass) Basin Outburst Thresholds for *M*>29

M=26.3-27.7	GCdaf>8 m3/t	>400 m deep
M=24.5-26.2	GCdaf>9 m3/t	>380 m deep
M=23.7-27.6	GCdaf>9 m3/t	>380 m deep
M=17.6-23.6	GCdaf>11 m3/t	> 320 m deep
M=13.5-17.5	GCdaf>12 m3/t	> 270 m deep
M=9.0-13.6	GCdaf>13 m3/t	> 230 m deep

For low volatile coals

If Vdaf<9	GCdaf>15 m3/t	> 150 m deep

Very high rank coals considered to be less prone to outbursts

- If electrical resistivity below threshold in Anthracite then it is not considered to be outburst prone. (Coal approaches graphite?)

logarithm of electrical resistivity of anthracite

$$\lg \rho < 3.2$$

- If the metamorphic coal index $M > 27.7$

It is not considered to be outburst prone

Basin by basin case by case determinations

- Kuznetskiy basin outburst forecast during coal seam entry from stone is based on the index $\mathbf{П_в}$
- $$\mathbf{П_в = P_{gmax} - 14}\boldsymbol{fmin}^2$$
- If $П_в > 0$ it is considered to be outburst prone
- Where P_{gmax} is the maximum seam pressure in kgf/cm^2
- *fmin* the minimum value of hardness/toughness (by drop hammer) coefficient of coal layers, determined by exploration borehole.

Area by area regulations

- In deposits of Pechorskiy basin, Primorie and Sakhalin island (which are less well developed)

- coal seams in the mining area are considered to be outburst prone for seam entry if the gas pressure in boreholes more than 10 kgf/cm^2. (1 MPa)

Rostov region

- forecast in mining area for seam entry is based on
- desorption rate (g) litres/minute/metre for hole

  > 2 litres/min/m
- iodine index (ΔI), >3.5 mg/g
- and hardness coefficient of coal (f). < 0.6

- The control boreholes are drilled from not less than 3 metre distance in the seam to measure the desorption rate and sampling for coal properties.

Current outburst forecast

- visual examination of working face,
- coal plies determination,
- thickness measurements,
- strength measurements using strength meter П-1 for each ply.

Current outburst forecast

- If the outburst prone ply (plies) is found then the outburst forecast, based on control shot-holes, is made.
- The drilling rate should be 1m in 2 min. In 2 min after drilling the gas desorption rate is measured.
- If $g_{\text{н.max}} \geq 4$ l/min, the area is outburst prone, if $g_{\text{н.max}} < 4$ l/min – not.

Current outburst forecast

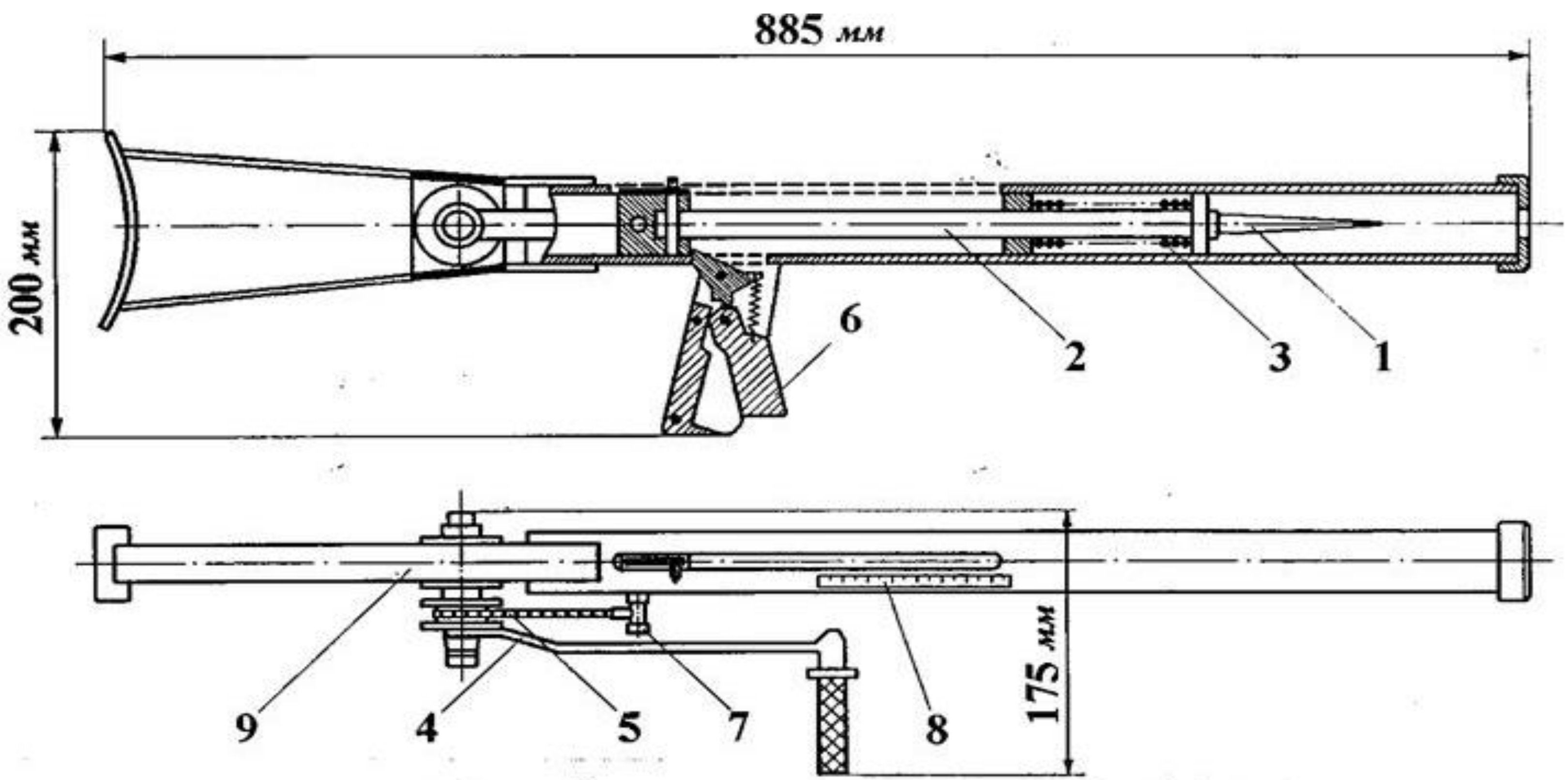
- The current forecast can be done using the automatic equipment (AKM complex).
- The following parameters are used in monitoring:
- $C_ф$ — methane concentration in monitoring area, %;
- C_{max} — maximum methane concentration after blasting, %;
- $t_р$ — reaction time of the seam for blasting in the working face, min;
- n — the amount of 15 min time intervals in time $t_р$;
- $C_1, C_2, ..., C_n$ — methane concentration at the end of each time interval, %;
- $Q_1, Q_2, ..., Q_n$ — Airflow rates at each time interval, m^3/min;
- $S_{пр}$ — surface area of coal in working face, m^2;
- $l_п$ — length of face advance in one blasting cycle, m;
- γ — coal density, t/m^3;
- $f_в$ — coal strength coefficient of outburst prone ply.

Coal Strength

- Coal strength parameter q
- q is related to underground strength test probe by
  $q = 100 — l$
- where l — depth of cone punching-in coal, mm.
- Coal strength is determined as average from 5 measurements.
- If $q \leq 75$, then the ply is outburst prone.

In situ coal cone punching toughness test tool П-1

In situ coal cone punching toughness test tool П-1



Общий вид прочностномера П-1:
1 – наконечник; 2 – шток; 3 – пружина; 4 – рукоятка; 5 – цепь; 6 – курок; 7 – палец; 8 – линейка.

Drop hammer toughness test to provide measurement *f*

- Involves dropping known weight over known distance onto coal lumps and determining the change in particle size for various numbers of hammer drops
- Method also extensively used in China
- **Sigra has built this tool for comparison purposes**

Summary of Russian Approach

- Examine whole seam ply by ply to determine total outburst proneness
- Use pressure measurement
- Use toughness measurements
- Use initial desorption rate from hole

  (we think this unusual)

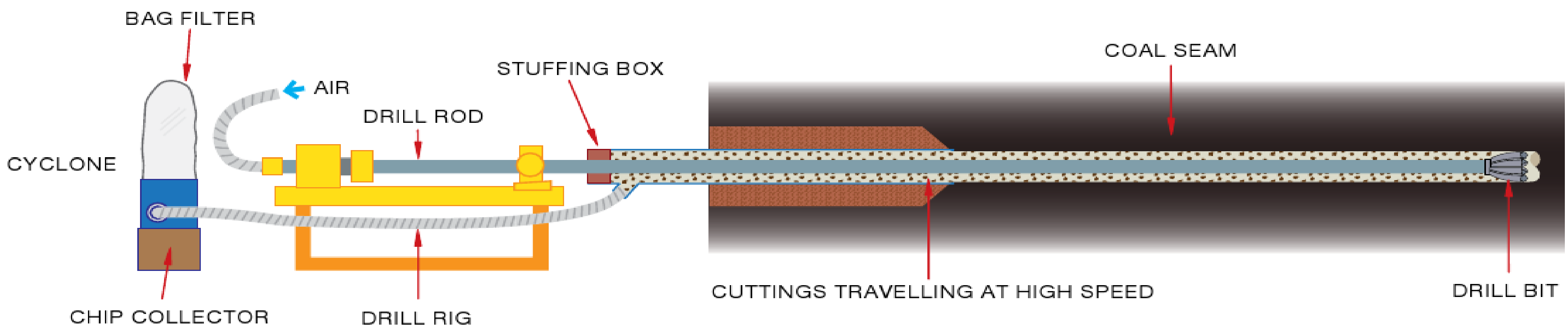
Chinese Approach

- Look at area regionally
- Measure gas pressure from rock into coal

(critical pressure 0.74 MPa) never from coal to coal as inadequate sealing

- Carry out survey of structural disturbance
- Measure coal toughness (drop hammer test)
- Measure indexes related to diffusion and gas content delta P etc
- Gas content – but often impossible to determine as coal disintegrates as at Luling mine.

Dry Drilling Sampling System enables the measurement of multiple parameters – could also be wet drilling



Dry drilling sampling system

Overall Summary

Need for outburst threshold which takes into account

Gas content and gas pressure

Diffusive behaviour

Coal toughness

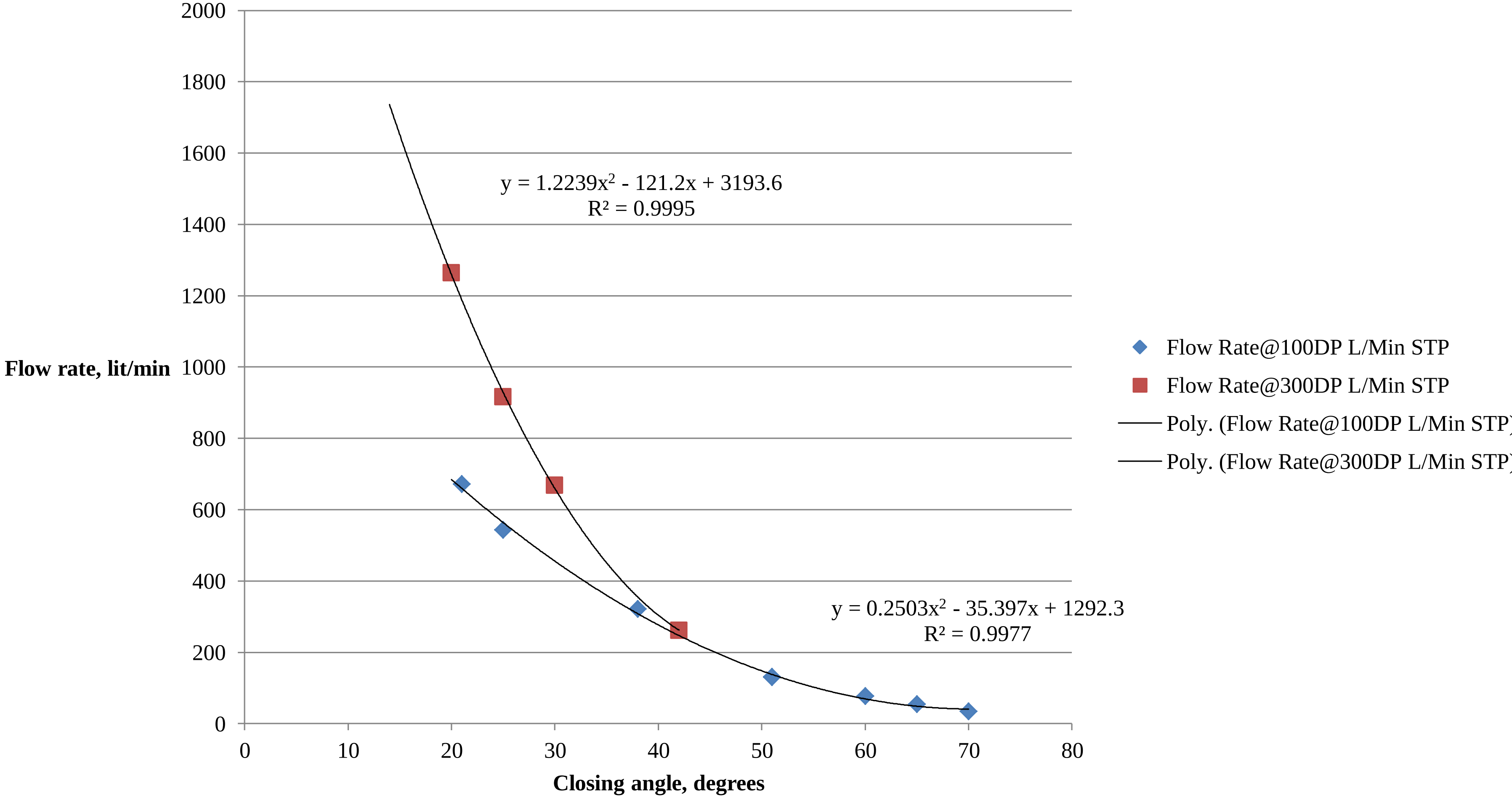
Structural state of coal seam

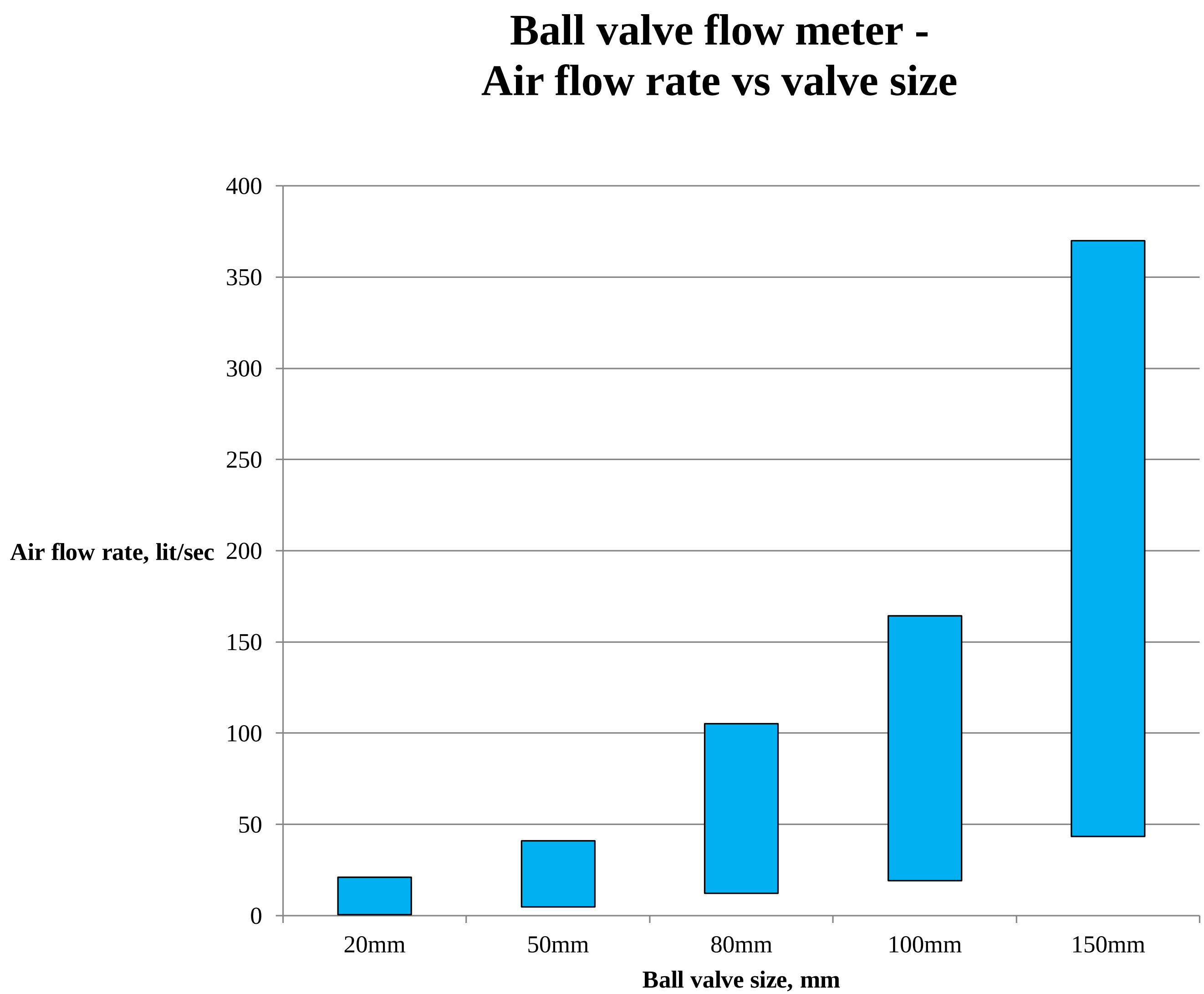
Is adequately simple to use

Flow Measurement

- Flow rate is critical in establishing the material balance
- Is gas flow measurement done easily now or is it still a pain of fiddling with orifice plates and dP measurements?
- Sigra alternative – use ball valve as meter with fixed dP

20mm Ball Valve Flow Meter Measurements - Air flow rate vs Closing angle




Ball valve flow meter -
Air flow rate vs valve size
Air flow rate, lit/sec
400
350
300
250
200
150
100
50
0
20mm
50mm
80mm
100mm
150mm
Ball valve size, mm

Questions and Discussion

John Hanes, Outburst Seminar Committee – Re the stuffing box for dry cuttings, is there a depth of hole limit for its use?

Ian Gray – It is not for very long holes. With long holes there are two fundamental problems. How long does it take to get the cutting out of the hole and what is the desorption rate of the cutting along the length of the hole? Currently, we put core into canisters and seal it a certain amount of time after the core is cut. We then measure the gas desorbed and plot it against square root of time, then happily draw a straight line against part of the arc to estimate gas lost between the time of cutting to the time the core is sealed in the canister. However, the piece of coal is not a perfect cylinder and its real behaviour has deviated from that of cylindrical diffusion. If the sample has fine particles, particularly outburst prone sheared coal, the time to get the sample out of the hole is critical. An outburst involves breakage of particles and fine coal particles are released into dust. They are either dust size already or they become dust size in the outburst and there is gas lost from the fine particles. With the fine particles, the time for desorption is much shorter than with large particles. Much attention should also be paid to what is happening during core retrieval. I suggest that many operations are running well over the time limits for core retrieval for valid estimation of lost gas from square root of time.

At Sigra, we have a system of gas content without coring primarily for the coal seam methane business. It was trialled for Anglo. As the drilling from surface is an overbalanced situation, we sealed the hole around its collar. Gas is not lost from the seam and we capture all gas that is released from the cuttings as they pass up the borehole.

I suggest you check the Sigra website for much more detail on this.

http://sigra.com.au/services/reservoir-characterisation/gas-content/gas-content-without-coring/

In answer to John's question, if you can get the cuttings out of the hole, sealed into a canister and desorbing within 3 minutes of being cut, the system will work accurately. With a stuffing box this can be done with ease. At Lina mine, we did capture cuttings without a stuffing box, without a cyclone and without being properly set up, and with Maarten Velzeboer we had the cuttings in the canister in 2 minutes. The holes were up to 80 m in that case and we could have got to 100 m as the air flush was high velocity.

John Hanes – I was impressed by your development of the stuffing box many years ago and was disappointed the coal industry did not take it up at the time. Montan Consulting used reverse circulation of air to capture dry cuttings quickly from shallow test holes at Leichhardt Colliery for rapid desorption testing and obtained gas contents similar to the slow desorption method. This was in the 1970's. And now, nearly 40 years later, Australian coal mines are still are not using any rapid desorption techniques to test face gas contents. The industry is still relying on desorption of cores taken from long holes and (blindly?) accepting the inaccuracies of lost gas estimation during the long time to recover core. I commend your work Ian and hope we will eventually see the industry have a closer look at the efficiency of its gas content testing.