Blasting in Underground Coal Mines

ACARP Project

C20033

Blasting in Coal Mines

- Modern mechanised coal mines use machines and longwall mining methods to cut solid coal and convey the broken coal out of underground workings.
- Continuous mining equipment has escalated coal production and introduced more effective and efficient coal handling facilities.
- Traditional drilling and blasting methods are no longer employed as the primary means of breaking coal in Australia, when mining has reached the coal seam.

Why Blast Coal

- Outburst prone coal.
- Locations where it is difficult or not feasible to install CM, SCs and belt.
- Initial development at seam in Shaft Sinking

Other Blasting Applications

- Overcasts
- Belt overpasses
- Weight Towers
- Intrusions.
- Shaft sinking
- Drifting

Applicable Hazards

- **Coal mines can have hazardous atmospheres and environments underground which need to be understood, monitored and managed to prevent ignition, combustion or explosion.**
  - Methane
    - **Flammable gases are easy ignited and may explode**
  - **Liberated Coal Dust**
    - **Dust cloud can be formed during blasting process**

Unacceptable Outcomes from Explosives Use

- Ignition of Methane by the Explosive
- Ignition of Coal Dust by the explosive
- Burning explosives in the shot that then ignite Methane that is liberated by or during the shot.

Ignition Mechanisms

- Explosives produce a short duration, high heat intensity flame
- Explosives generate a shock wave that will compress the atmosphere in its propagation.
- Explosives may have incomplete combustion and leave burning fragments.
- Explosives may deflagrate.

Characteristics of a suitable Explosive for delay firing.

- Ultra Safe
  - Unstemmed charge will not ignite
    - preformed Methane/ air mix (9%CH_4)
    - Preformed Coal Dust cloud
  - Detonating charge will not cause adjacent explosive to deflagrate
  - Stemmed charge
    - preformed Methane/ air mix (9%CH_4)

Characteristics of a suitable Explosive for Single or Simultaneous Blasting.

- Stemmed charge will not ignite
  - preformed Methane/ air mix (9%CH_4)
  - Preformed Coal Dust Layer
- Full charge weight stemmed charge.
  - preformed Methane/ air mix (9%CH_4)
- This explosive will also be suitable for delay firing in stone.

Conditions prior to blasting

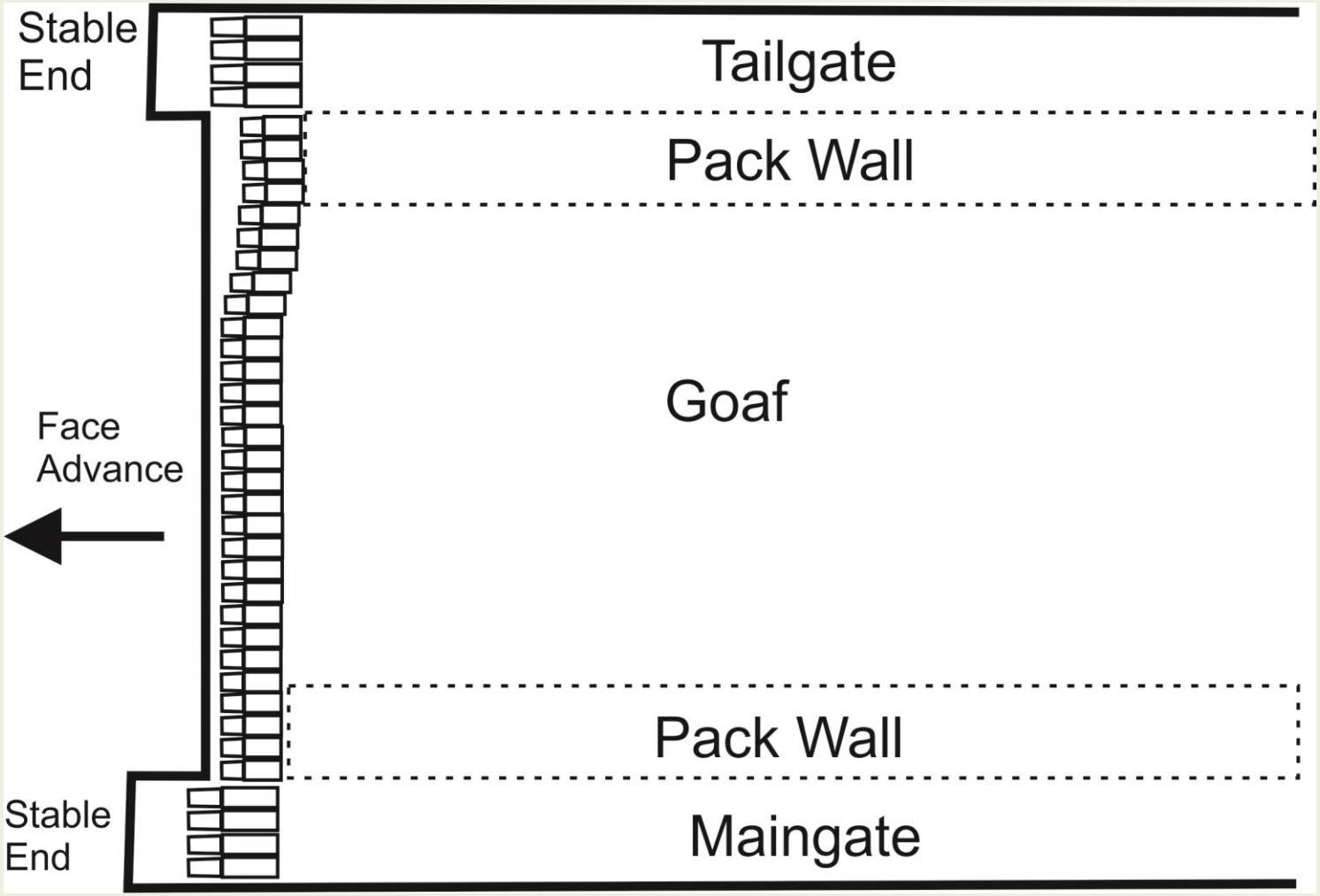
- ✓ **Only use permitted explosive, detonators and Equipment**

- Place to be free of gas i.e less than 1.25% methane
  - Before charging
  - Before firing
- Place to be stone dusted.
- Power switched off before wiring up.
- Pattern designed to minimise risk of blown out shots
- Place to be ventilated
- Exclusion Zones
- Safe re-entry procedures

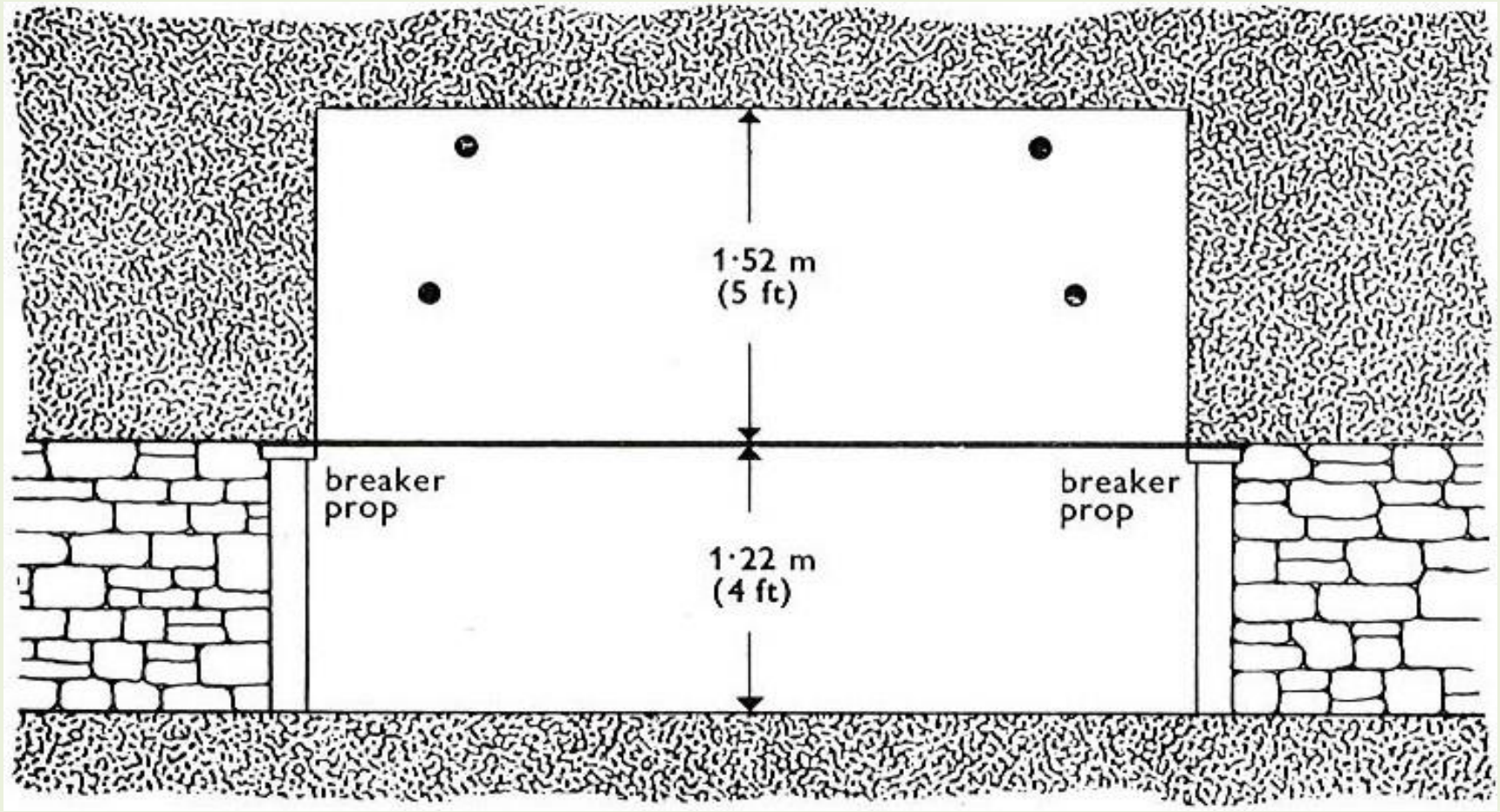
UK Mining Practices

- The Buxton tests were developed for UK Mining Practices
  - Advancing Longwall panels.
  - Gate road rippings
  - Stable advances
  - Gateroad Pack Walls

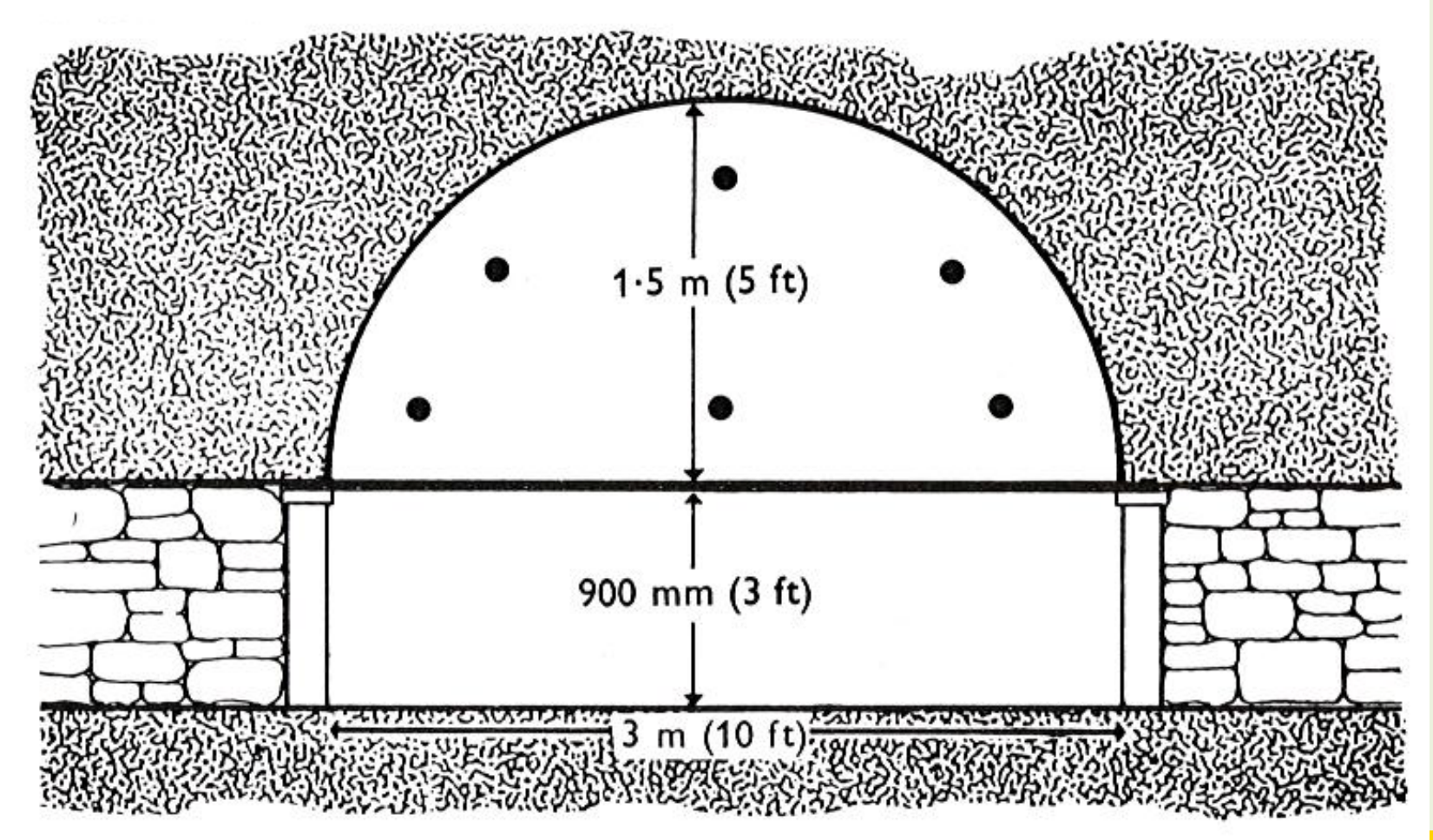
Advancing longwall



Ripping



Ripping



Additional Stone

- Where the ripping was unable to provide sufficient stone for the pack walls, stone was removed from the roof.
- Cavities were generated in the roof.

Locations where Gas may Accumulate

- Ripping cavities
- Stable ends
- Goaf
- Longwall face
- Additionally,
- Barometric pressure drop = goaf expansion

The “Buxton Tests”

TYPE OF TEST[1]	Charge Masses and Test Requirements (Ignitions/Shots) for each Group				
	Group P1	Group P3	Group P4	Group P5	Group P4/P5
BLOWN OUT SHOT TEST Inverse initiation No stemming 9% methane/air	142 g ≤ 13/26 (emulsions ≤ 6/26)	400 g ≤ 13/26	400 g ≤13/26	-	*
CUT OFF SHOT TEST Inverse initiation No stemming 9% methane/air	-	-	-	570 g 0/20	570 g 0/20
STEMMED SHOT TEST Direct initiation 1 clay stemming plug 9% methane/air	800 g 0/5 (emulsions 0/10)	1020 g 0/5	-	1020 g 0/5	1020 g 0/5
COAL DUST TEST (STEMMED) Direct initiation 1 clay stemming plug Coal dust deposit on platform	800 g 0/5[1]	-	-	-	-
COAL DUST TEST Inverse initiation No stemming Pre-formed coal dust cloud	-	570 g 0/5	-	570 g 0/5	570 g 0/5
BREAK TEST Inverse initiation No stemming 3.6% propane/air+nitrogen	-	-	227 g ≤ 13/26	-	227 g ≤ 13/26
DEFLAGRATION TEST 3.2 mm diameter pressure release 100 mm coal dust barrier between charges	-	-	-	2 x 57 g ≤ 13/26 #	2 x 57 g ≤ 13/26 #

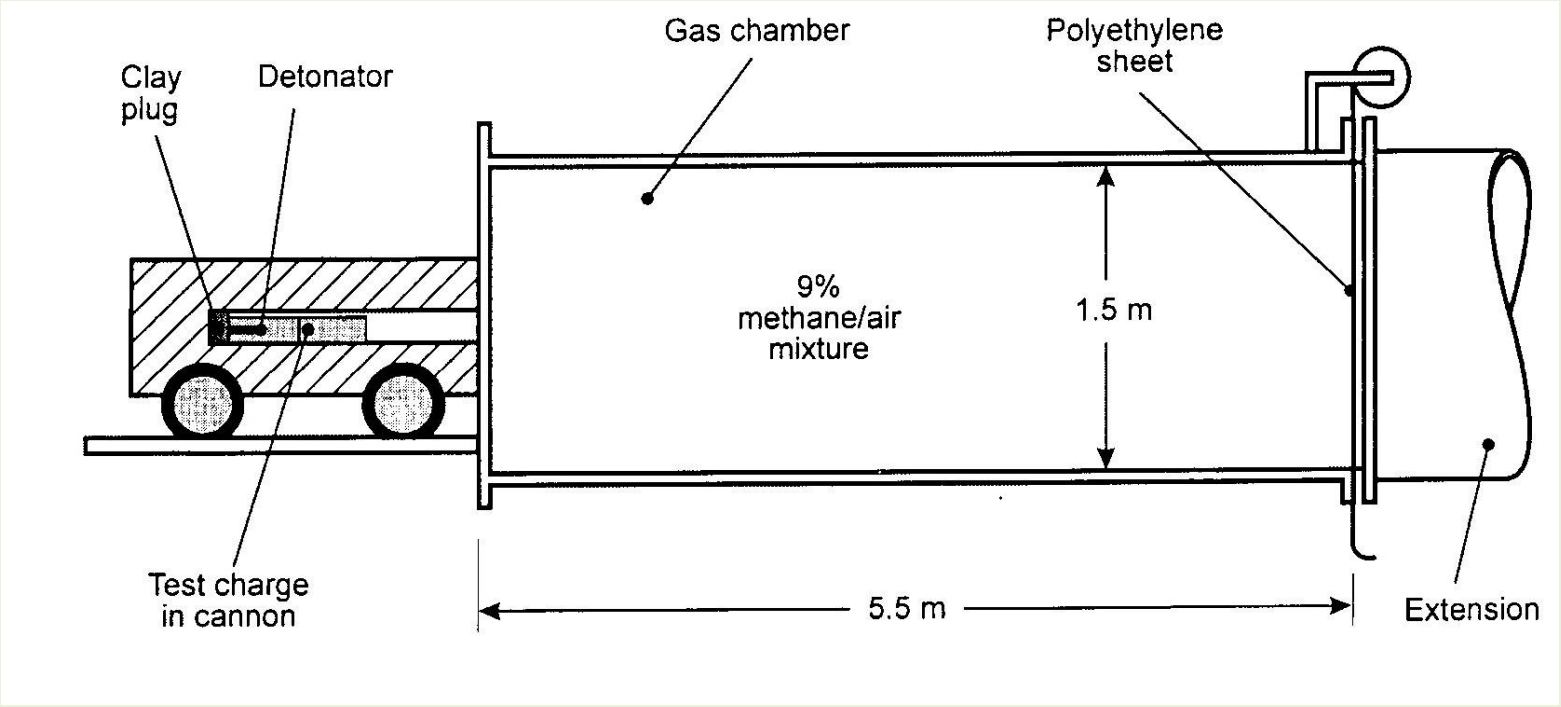
\- Test not applicable to this group of explosives

* For type P4/P5 explosives the P4 blown out shot test is omitted because the P5 cut off shot test is more stringent.

\# Deflagrations/shots

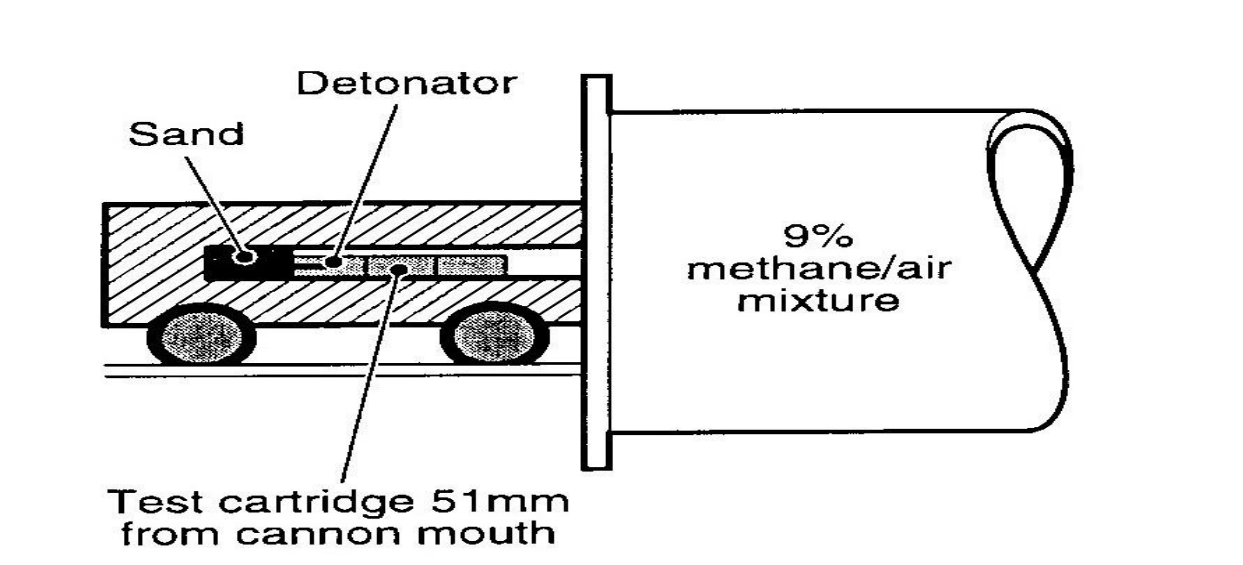
Description of Tests

- Blown Out Shot Test (BOST)
  - Tests for safety if stemming is missing or dislodged when firing a single or simultaneous shot.



Description of Tests

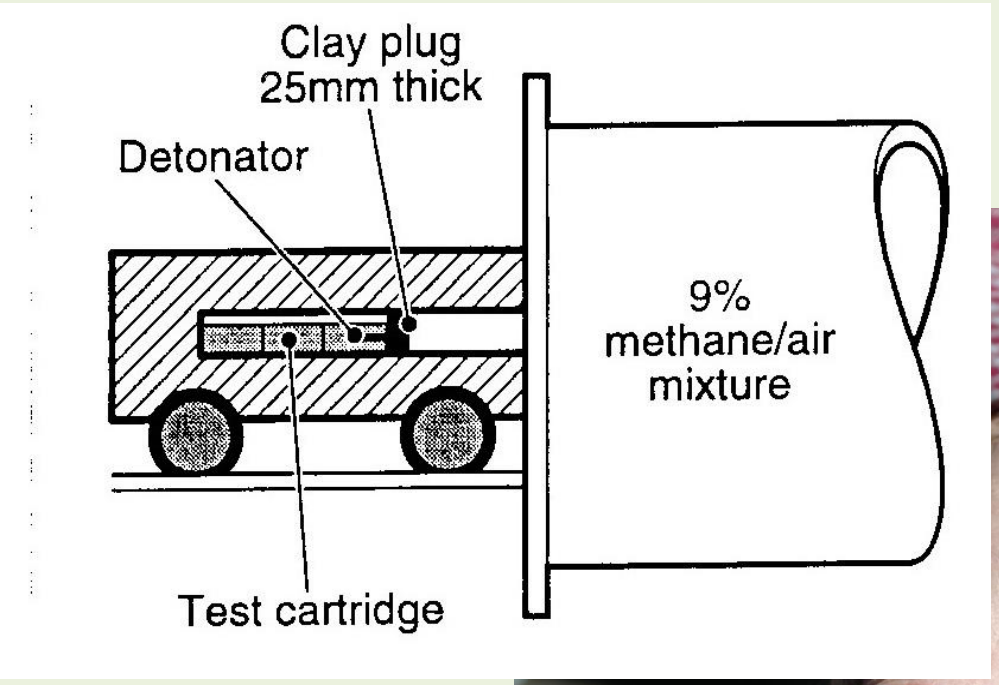
- Cut Off Shot Test
  - Tests for hole / stemming disturbed during delay firing.
    - Similar to “Blown Out Shot Test” pass 0/20

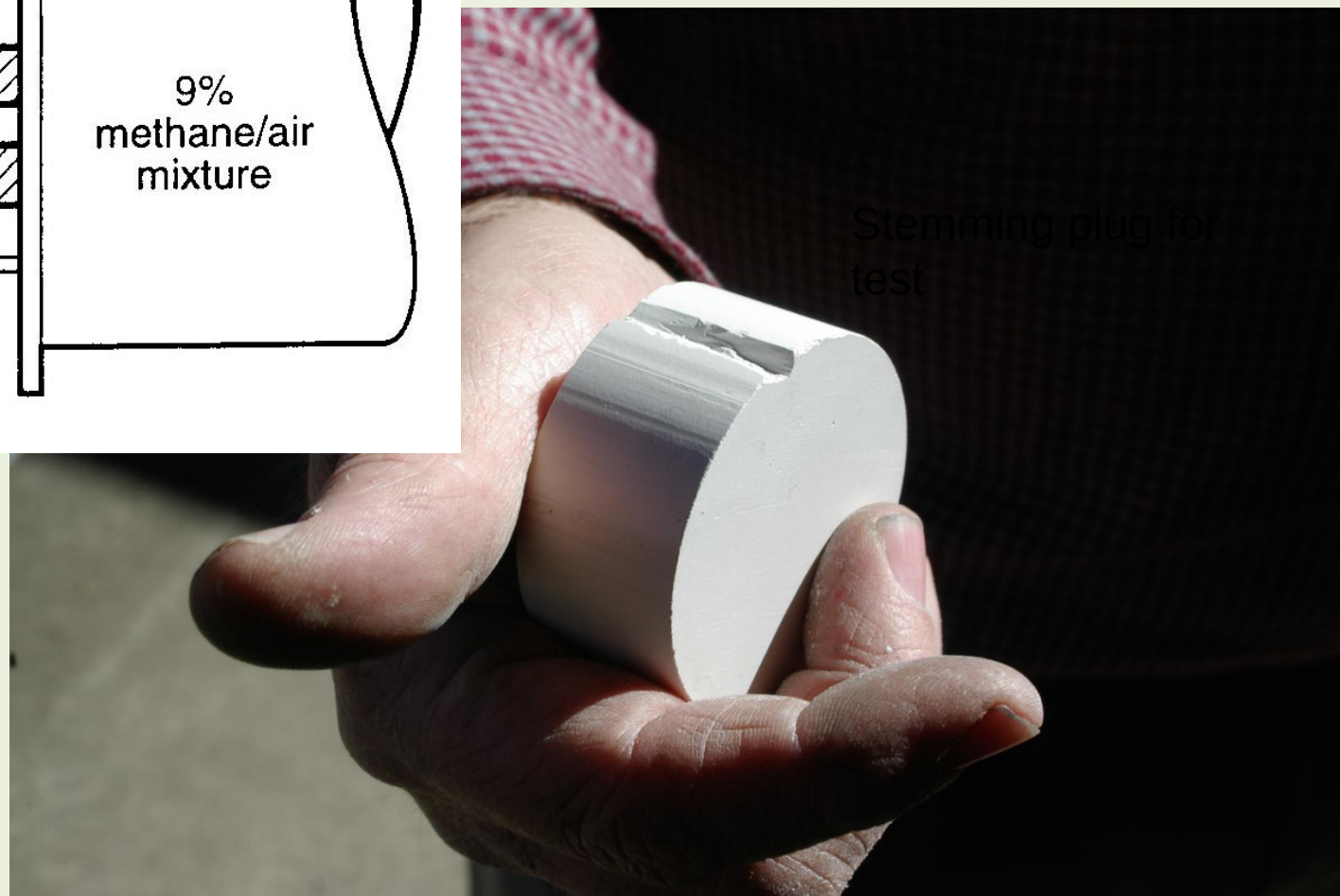


Description of Tests

- Stemmed Shot Test - Gas.
  - If the shots ignited when unstemmed this test ascertains that the explosive cannot ignite when stemmed.
  - i.e in normal use in coal (single or simultaneous).
  - NG explosive 0/5
  - Emulsions 0/10 to build up the statistical database (no science involved)

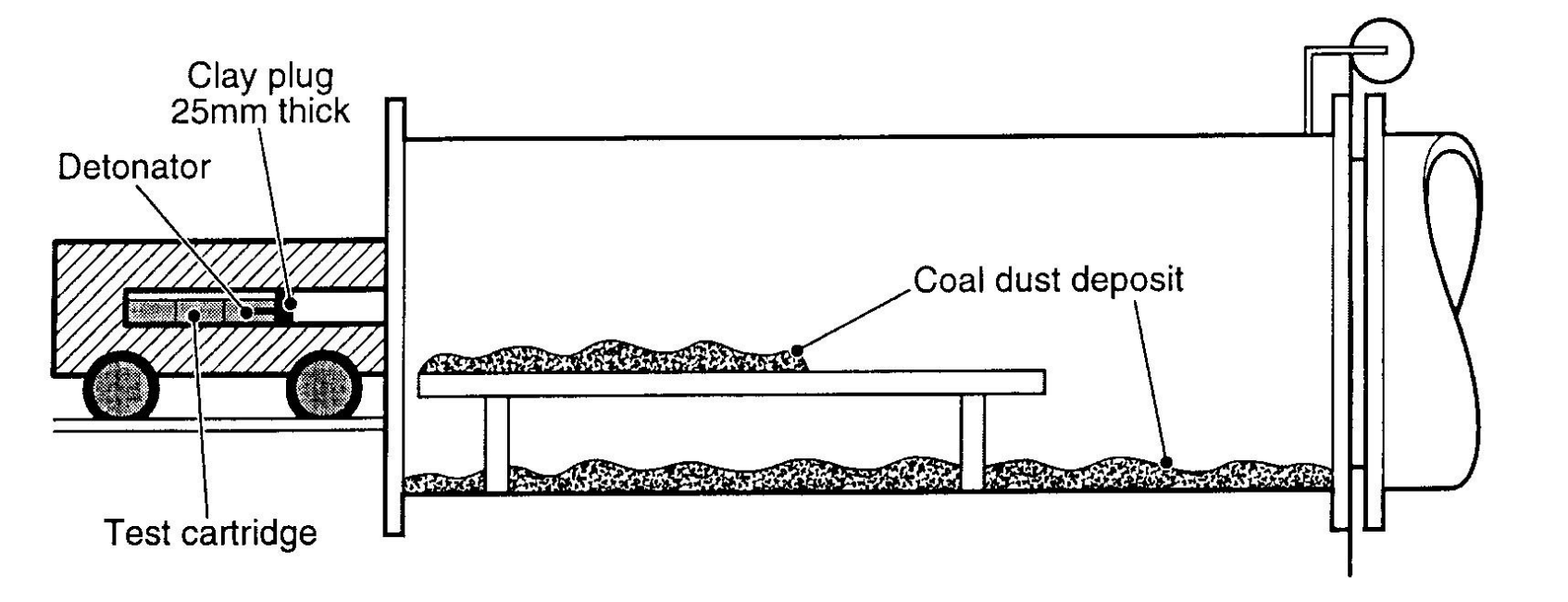
Stemmed Gas Test





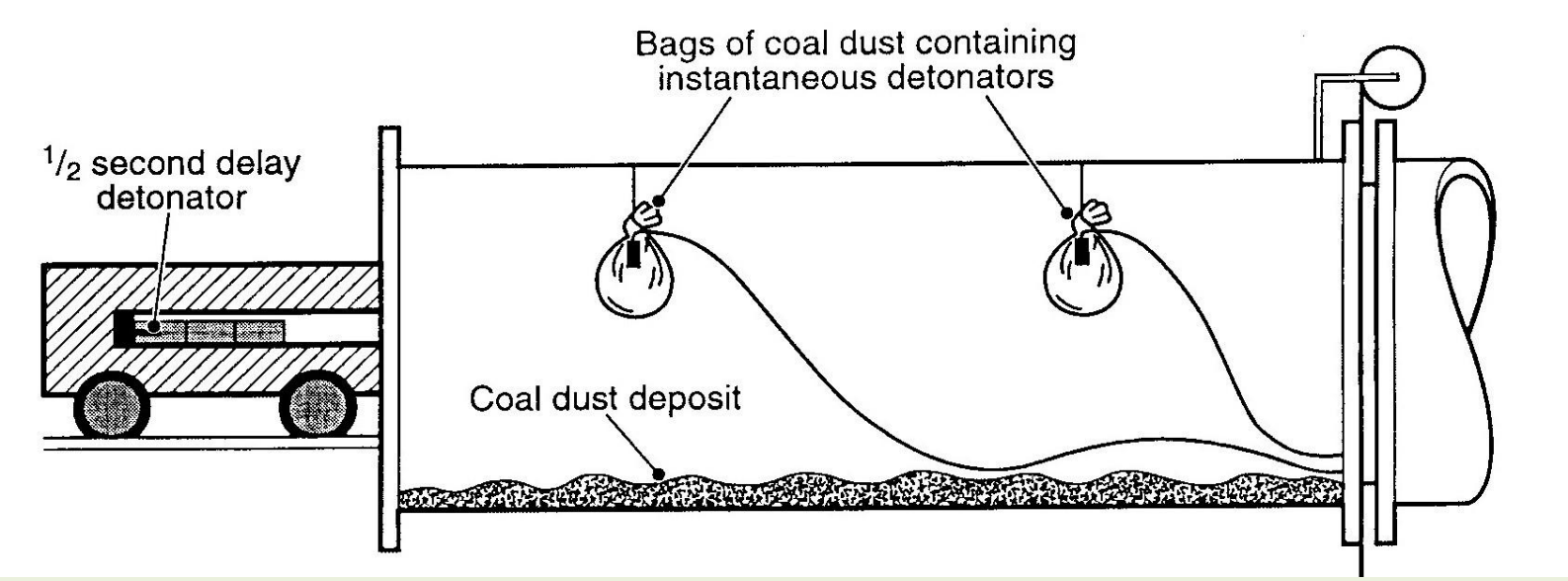
Description of Tests

- Coal Dust Stemmed
  - Only P1 explosives
  - P1 single shot or simultaneous firing

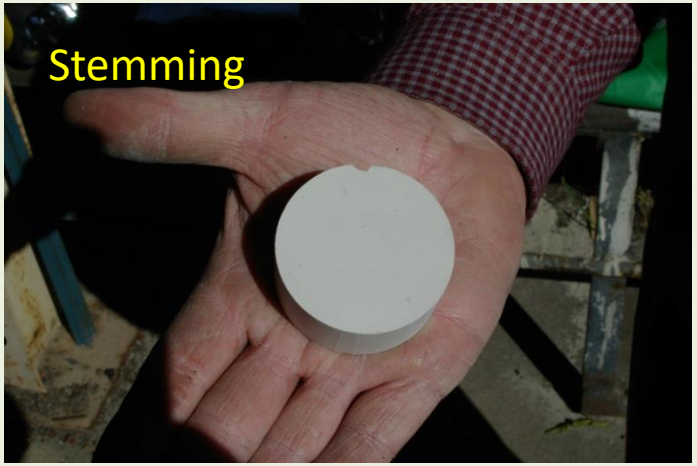


Description of Tests

- Coal Dust unstemmed
  - P3 & P5 P4/5
  - Test simulates cut off shot detonating into coal dust cloud



Type 1 Gallery



ACARP: the Movie

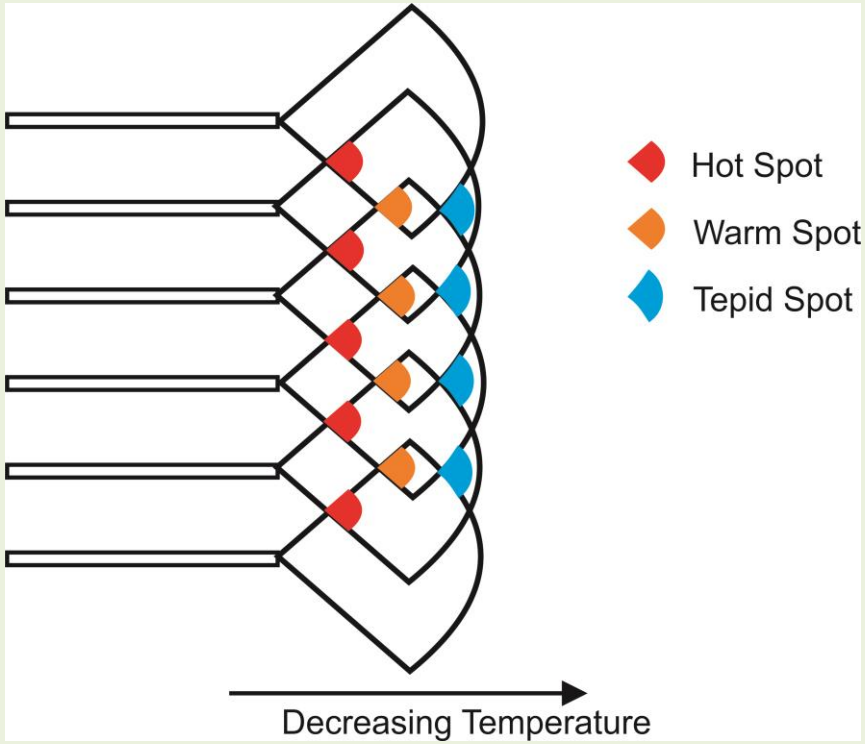
Selected Test Video

Test
8 P1 Unstemmed set 51mm
14 P1 Unstemmed TM2
17 P5 set 51mm
26 P1 unstemmed set 51mm
38 Non permitted explosive
46 P5 explosive
49 P1 unstemmed set 51mm
79 P1 unstemmed set 200mm

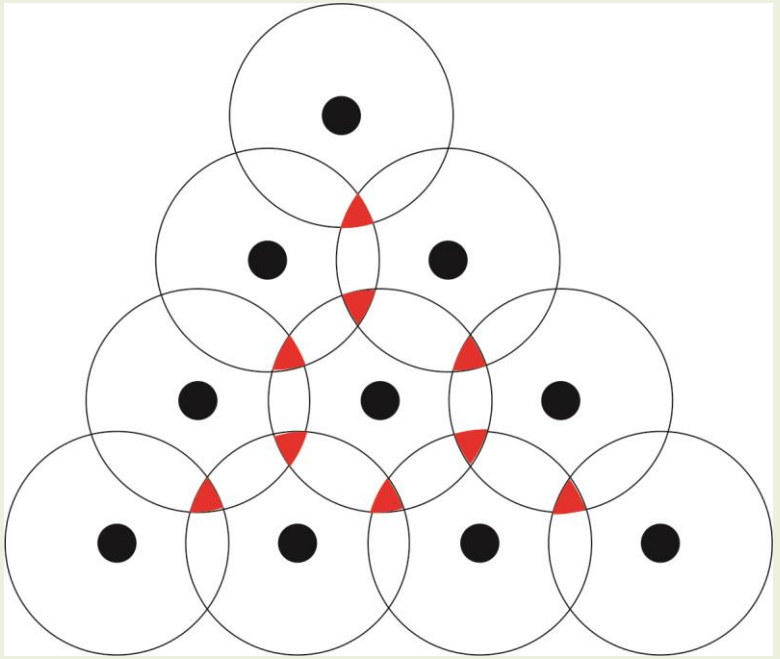
Ignition Mechanism

- Ignition occurs when the shock waves focus on a point
- Gallery is Cylindrical – focus is most intense
- Rows of simultaneous shots can reinforce (focus) shock wave, however intensity is far less than that of gallery

Reinforcement zones



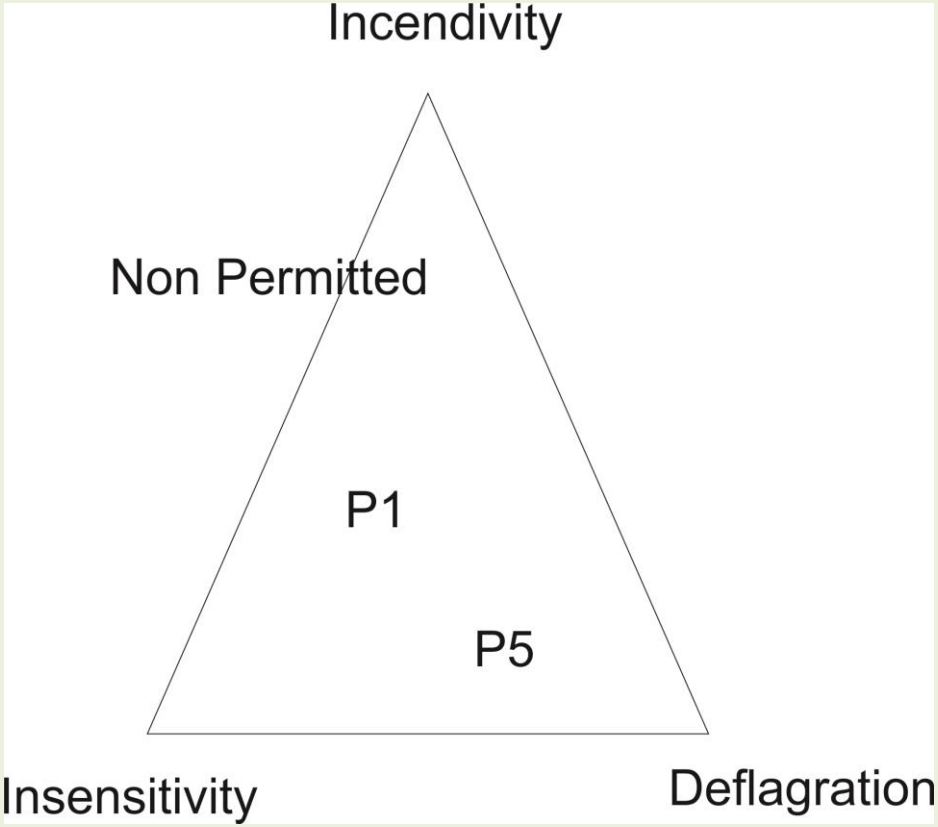
Single row



Multiple cannons

after Cybulski

Relationship Explosive properties



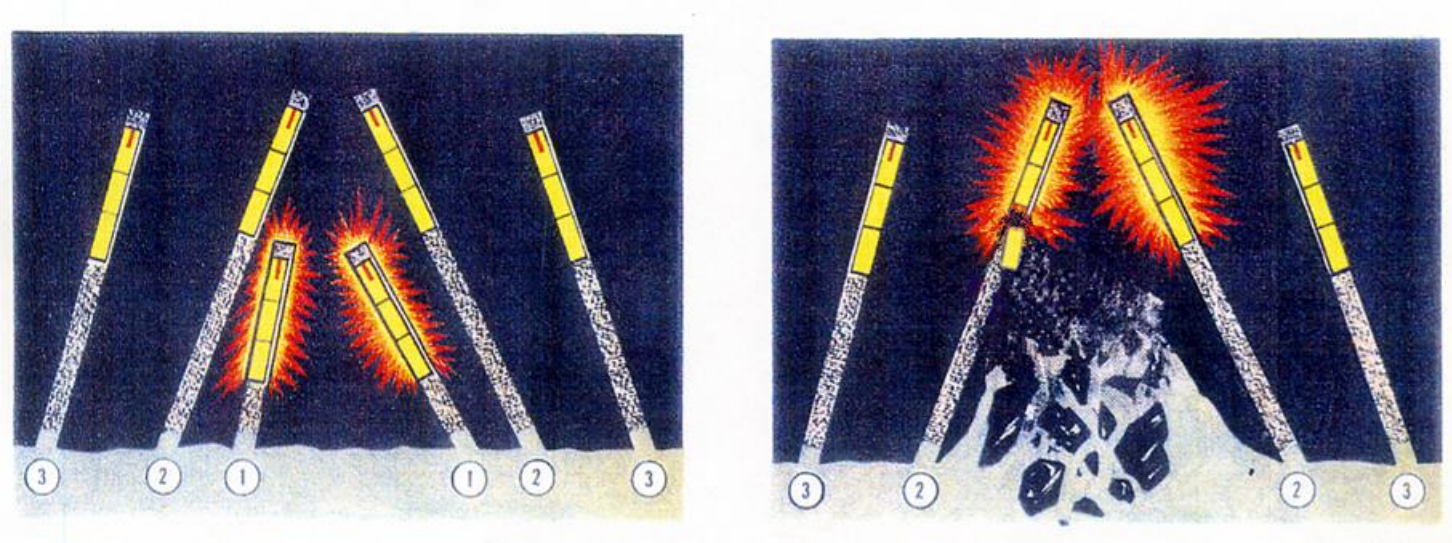
Ignition Results

- No ignitions at CH4 levels below 8%
- No tests conducted above 9.5%
- No Ignitions with more than 400mm unstemmed bore.
- No ignitions with direct initiation i.e. Detonator facing into the solid

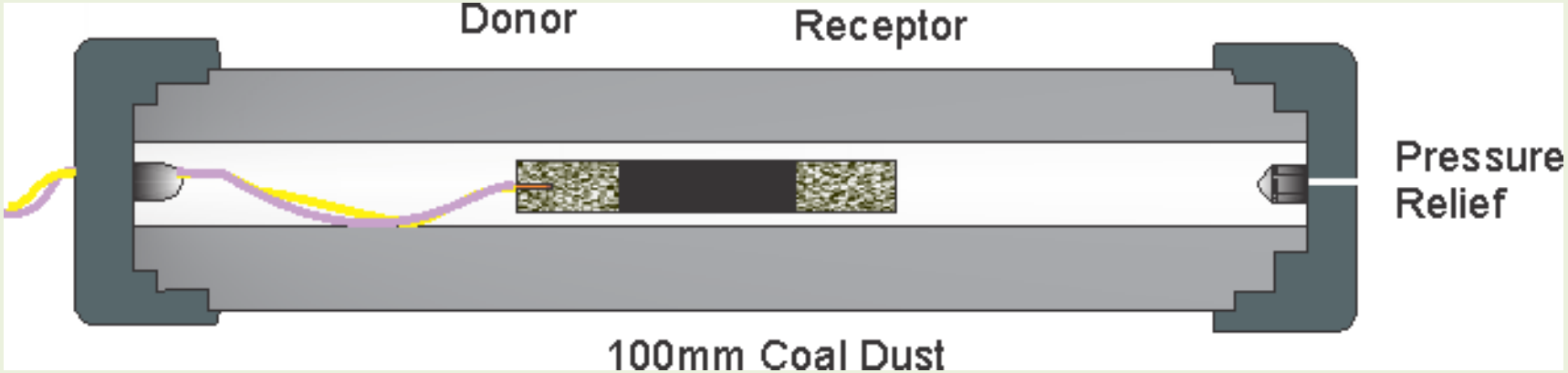
Deflagration tests

- Based on Nitroglycerin powder explosives
- Emulsions less prone to deflagration
  - Higher fluid content
  - More prone to sympathetic detonation
  - More prone to be desensitised.

Deflagration Condition

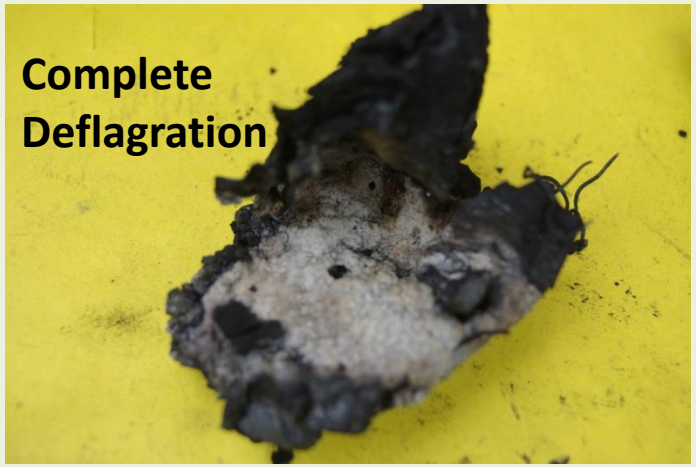


Deflagration Test



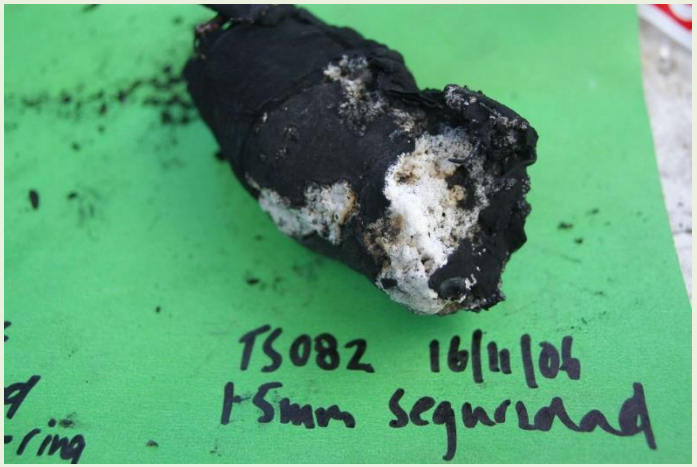
Deflagration Cannon

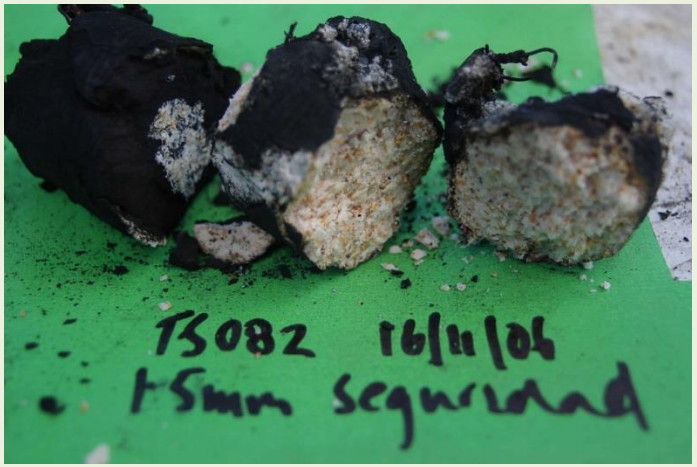
Deflagration Results



Deflagration Results

- These two photographs show a non deflagration
- There is evidence of some deflagration occuring on the surface.
- The added salts etc have done their job in extinguishing the process
- The bulk of the explosive is intact





Implications

- Tests can be simplified (Draft Testing Memorandum written)
- Capability to test P5 style explosive in Australia for the first time.
- Possibility to develop P5 style explosive in Australia.
- New Deflagration test required for emulsions or demonstration that it is not warranted

Summary

- Hazards associated with Shotfiring in modern coal mines
  - Ignition of Methane
    - By compression of pre formed gas mixture
    - By flame /hot gases from explosives not possible (salts effective)
    - By deflagrating explosives potentially
  - Ignition of Coal Dust
    - By flame /hot gases from explosives not possible
    - By deflagrating explosives not possible

Summary

Ignition of Methane (very low risk) -Why

- Place free from gas prior to firing
- Mechanism is pressure driven (shock wave)
  - Flame duration 1millisecond
  - Measurement shows temperature drops below ignition temp when flame disappears
  - Temperature reduced by salts in explosive
- By deflagrating explosives
  - P5 explosives are designed to have a high resistance to deflagration
  - Deflagration is time & temperature dependent
    - » Both time and temperature are confinement dependent
  - Properly designed, loaded and fired round poses very little risk

Summary

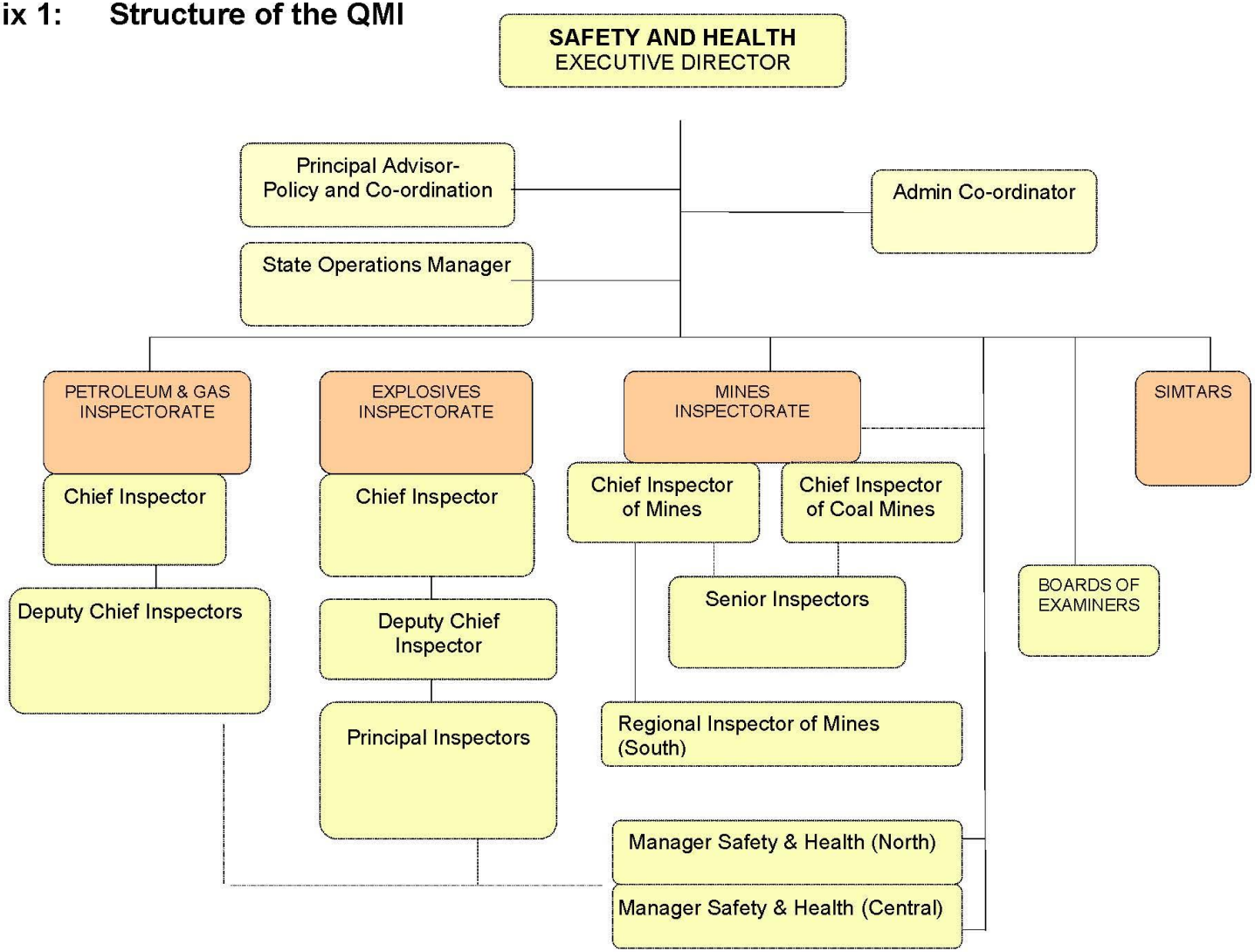
- Ignition of Methane
  - No formation of flammable gas mixture is possible if face is free of gas before firing
    - Emission from coal not fast enough to provide required gas volume (even with delay firing)
    - Shot pressurises coal and gas adsorbs onto coal (Langmuir)
    - Blast fumes will partially inert atmosphere ($16m^3$/ 20kg)
  - Possible when delay blasting
    - blasting intersects pressurised borehole containing methane
    - Small outbursts may provide sufficient gas to mix turbulently with the air in face.

Summary-Ignition of Coal Dust not possible.

- Why
  - By flame /hot gases from explosives
    - Flame duration 1millisecond
    - Measurement shows temperature drops below ignition temp when flame disappears
    - Temperature reduced by salts in explosive
    - Coal dust is harder to ignite than methane/air mix
  - By deflagrating explosives
    - P5 explosives are designed to have a high resistance to deflagration
    - Deflagration is time & temperature dependent
      - » Both time and temperature are confinement dependent
    - Properly designed, loaded and fired round poses very little risk

Queensland

Appendix 1: Structure of the QMI



Queensland Experience

- Grunching has been conducted in methane rich coal.
- Decisions based on lack of availability of P5,
  - Followed practice in NSW under 1912 CMRA.
  - if no P5 is available utilizing P1 was permitted
- Explosive authorised based on expiry date (use by date)
  - Explosive cannot be used once it looses its authorisation

Explosives beyond the authorised shelf life (Qld)

- Still authorised for possession, transport, storage and disposal if:
  - their composition, quality or character hasn't changed
  - not more than 12 months beyond the authorised shelf life
  - In good condition and order
  - If the explosives are outside specification, the manufacturer or supplier must certify that the product is fit for the required activity
  - In their original or approved packaging
  - You're not using them and you'll dispose of them as soon as possible within the 12 months after expiry
  - They're for 1 or more of these activities only:
    - possession,
    - transport,
    - storage,
    - disposal.

Applying to temporarily authorise explosives (Qld)

- explosives that don't meet the above criteria and are for disposal,
  - apply to the Chief Inspector of Explosives to temporarily authorise them for possession, transport, storage or disposal.
- If the explosives may still be suitable for use
  - (i.e. beyond shelf life but still meet the manufacturer's specifications for use).
  - test results required to confirm that the explosives are still fit for purpose according to the manufacturer's specifications.

Permitted explosives (Qld)

Permitted Classification	Explosive Name
N/A	Carrick R Detonators
N/A	Carrick Short Delay Detonators No. 8
N/A	Daveydet "P"
N/A	Detonators Electric Carrick II
P5	Dynagex C
P5	Explosivo de Seguridad No 20SR
P1	Polar Ajax
P1	Powergel Permitted 2000
P1	Powergel Permitted 3000
P1	Senatel Permitted 1000
P5	Wincoal A

Explosives in Coal

CARBOROUGH DOWNS COAL MINE **MORANBAH, CENTRAL QUEENSLAND**

Scope of Works (Redpath Mining)

- Carborough Downs Coal Mine is situated in the Bowen Basin, 15 kilometres east of Moranbah and about 170 kilometres south-east of Mackay in Queensland.
- The project required the excavation and support of three drifts to enable commencement of longwall mining operations.
- Drill & blast methods were used in a coal mining environment,
- utilising both standard explosives and permitted explosives. The drifts were generally 250m long at 1 in 7 grade commencing from the base of a box cut 70m deep
- x 30m wide x 70m long.
- All equipment and procedures utilised were compliant to Queensland Coal Mining Regulations.

Grunching

- Grunching has been conducted at:
- Central,
- Southern
- Grasstree

Other than Qld

- Where:-
  - Metropolitan
  - Old Bulli
  - Tahmoor
  - Solid Energy (Spring Creek) NZ

Conclusions

- The use of Permitted explosives is necessary
- Single and simultaneous in coal is standard usage
- Full face firing of simultaneous shots increases the risk of
  - blown out shots
  - Ignition hot spots
- Delay firing with P1 is done and has been without incident

Conclusions

- Risk of a gas mixture forming during outburst is increased.
  - Large outburst too much gas –exclusion of O_2 by displacement
  - Small cone – potential to provide just enough gas
- Probability
  - If outburst occurs before last hole fires
  - If mixing gets 8+% -10% CH_4
  - If stemming is removed or hole opened up

Conclusions

- Consequences
  - Damage to face machinery
  - Small coal dust explosion triggered by ignition of gas
  - Mine fire
    - coal set on fire
    - Gas set on fire
  - Damage to VCD's
  - Injury to personnel if too close

Recommendations

- Increase size of exclusion zone
- Maintain ventilation throughout shotfiring process
- Ensure all personnel are out of direct line of fire.
- Minimise number of personnel in section when firing (withdraw non essential to mains)
- Develop new explosive

Ongoing Research

- Develop new Emulsion for Delay Firing
- Develop new deflagration test or demonstrate it is no longer needed for emulsions
- Rationalise tests for Australian Conditions.

Thank you

- Questions