Safe Control of Spontaneous Combustion Goaf Fires

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Outline

- Development of spontaneous combustion
- Preventive measures
- Ignition hazards and related safety regulations
- Fire fighting procedures
- Coal production in case of a goaf fire
- Goaf inertization
- Full space inertization
Main areas of spontaneous combustion

1. Face starting line
2. Face salvaging position
3. Residual pillars
4. Residual coal at faults
5. Rider seam in a vertical distance of < 10 m
Residual coal in longwall mining

Direction of conveyance
Förderrichtung

Unterkante
Panzar
Face conveyor – lower edge
Schleppkohle
Fault coal

Shield column – upper edge
Oberkante
Schild

b.V. – 7 m

No residual top coal left
Keine Topkohle stehen gelassen

Direction of conveyance
Förderrichtung

Unterkante Panzer
Face conveyor – lower edge

Shield column – upper edge
Oberkante Schild
Preventive measures – *basics*

- Required when mining or drifting in seams with coal prone to spon com – *especially bituminous/ coking coal*
- Aim: Minimizing stray ventilation currents with respect to residual coal
  - Sealing of seam cuts in roadways and of (rock burst prevention) testing and de-stressing drill holes during development
  - Sealing/ tightening of residual pillars, incl. treatment with reaction inhibiting agents
  - Sealing of the face starting line
  - Tight roadside packs and roadway seals
  - Measures for preservation of roadway cross section (e. g. dinting) – *to achieve low ventilation pressure drop*
  - Quick salvaging
Tight roadside pack
Tightening a shield column – *phenolic resin foam*
Tightening a face salvaging line – *building material*
Tightening a face salvaging line – foam cushions
Mine rescue work – *spon com fire in the goaf area*

- “Mine rescue work in the vicinity of a supposed fire zone – *e. g. for tightening air leaks or installing a goaf inertization* – is permitted as long as via sniffing pipes from the goaf area downwind the fire zone – *with respect to the supposed air leakage path* – no combustible gases are detected.”

- As a rule – *with a safety margin* – this means, if
  - \( \text{CH}_4 < 2.5 \text{ to } 3 \text{ vol.-%} \) or \( \text{O}_2 < 10 \text{ vol.-%} \) in sniffing pipes

- Only valid for fire gases containing \( \text{CH}_4 \) as main combustible component – *otherwise detailed calculation as to mixed burnable gases required!*
Sniffing pipe monitoring – *goaf stray ventilation*

- Sniffing pipes every 20-30 m and through seals
- Stray ventilation currents
- Gate road in course of withdrawal
- Permanent seal
- Starting line seal
Coward-diagram for CH$_4$ – mine rescue work

Red interrupted line = safety threshold for methane-concentration in stray ventilation air currents – sniffing pipe analyses from the goaf
Goaf inertization

- To reduce explosion hazards originating from the goaf area
- To support roadway-/ face-tightening and grout-injection measures serving for suffocating/ extinguishing the (smoldering) fire zone
- Air leakages/ stray vent currents in the goaf area are replaced by nitrogen via injection lances, drill holes and “lost tubes” – *as a rule about 20 to 50 m³/ min*
- Roadway and face ventilation remains unaffected and is continued as usual!
Goaf inertization

- Inert gas duct
- Gate road in course of withdrawal
- Permanent seal
- Starting line seal
- Lost injection tube
- Injection lances
- Injection drill hole
- Gob area
- Supposed concealed fire
Spon com fire fighting – *current procedures*

- Air leakage tightening measures
  - Shotcreting and re-backfilling of gate side pack and roadway shell
  - Re-tightening of face starting line, adjoining roadway seals and gate roads in course of withdrawal

- Injection of the fire zone within the goaf area with different types of sedimenting matter
  - Individual drill holes for mortar matter injection
  - “Building material wedges”

- Goaf inertization as supporting measure – *explosion prevention*

- Preceding full space inertization in case of explosion hazard, or following an explosion
Re-tightening the gate side pack – *schematic*

1. Begleitdamm
2. Trockenhinterfüllung
3. Spritzbeton
4. Nassverpressung

1. Gate side pack
2. Dry backfilling – filter ashes
3. Shotcreting
4. Mortar matter injection
Individual injection drillholes
Building material wedge

- Lost inertization pipeline
- Inertisierungsleitung
- Raubort
- Gateroad in course of withdrawal
- Vermuteter Brandherd
- Supposed fire zone
- Permanent seal
- Starting line seal
Hydraulic building material supply
Re-tightening the gate side pack – hard foam
Coal production in case of fire – preconditions

- Location of fire in goaf area known for certain
- Gate side pack(s) made of building material
  - Regularly spaced mortar sealing of residual open volume behind gate side pack(s)
- CH$_4$ < 1 resp. 1.5 vol.-% and O$_2$ > vol.-18 % in ventilated gate road cross-section
  - Air leakage/ stray vent stream from the goaf downwind the fire site – sniffing pipe monitoring – not combustible – with safety margin towards LEL
  - Graham’s ratio – not with inertization! – not rising and CO-production not rising
  - CO-production from fire < 20 l/min – exceptions are possible and subject to negotiations with mining authority
- Goaf inertization operational resp. running, if required for meeting the a. m. preconditions
- Equipment for sealing/ full space inertization ready for use at a moment’s notice
Full space inertization – *general*

- Full space inertization is generally applied, if in case of an imminent explosion risk an event must be fought from a safe distance.
- The affected mine workings are then completely locked against the remaining mine and, instead of ventilation air, injected with inert gas – *if applicable mixed with fresh air*.
- In the first approach with a maximum residual oxygen concentration not exceeding 10 vol.-% – *which is sufficiently low for extinguishing an open fire, or preventing a methane ignition*.
Full space inertization – *concealed fire*

- If prior to a deflagration/explosion signals of a fire were already present
  - Danger of secondary explosions, sometimes periodically!
- If after a deflagration/explosion the CO-signal doesn’t drop again to the original readout prior to the event
  - Danger of secondary explosions, sometimes periodically!
- If spon com fires are generally prone to explosions
  - In direct neighborhood of face line or gate roadway(s) – *indicated e. g. by a typical benzene/benzol-smell*
  - If in the gob area downwind the fire zone – *with respect to air leakage current* – combustible mixtures are detected in sniffing pipes – *safety margin 0.5 to 0.6 x LEL* – and a target inertization hasn’t been installed early enough to control gas composition in the gob area …
After a deflagration/ explosion – *risk assessment*

- Normal CO-concentration (as a rule 2 to 3 ppm)
- Not critical, if there were no signs of fire prior to event, and if ventilation is still OK
- Critical, potential ignition source – *smoldering fire*
- Critical, potential ignition source – *smoldering fire or open fire*
Full space inertization – concealed fire
Full space inertization – *open fire*

- If an open fire can’t be fought manually due to it’s size and/or radiant heat
- If dangers caused by a gas drainage pipeline within the range of the fire can’t be eliminated immediately
- If a gas fire at the coal face propagates into the gob area and can’t be reached by direct means of fire fighting – *hanging flames*
- If a fire occurs in a gassy roadway drivage, with simultaneous shut-off of the auxiliary ventilation
Full space inertization – *open fire*

- Inert gas duct
- Brattice 1
- Brattice 2
- Brattice 3
- Gateroad in course of withdrawal
- Permanent seal
- Starting line seal
- Gob area
- If applicable, 2. inert gas duct
- Open fire
Full space inertization – *emergency procedure (1)*

- Install brattices – *not necessarily explosion proof!* – with 2 seal pipes each for air-locking and future ventilating on fresh air side(s) of endangered area
- Site of brattices
  - A full (200 l/m²) water explosion barrier must be in place between the endangered area and each brattice site
  - A roadway length of approx. 1000 m must exist between this barrier and the brattice – *for allowing the pressure wave of to die down after the barrier having extinguished an explosion during preparation work*
Full space inertization – **emergency procedure (2)**

- Inject N\(_2\) through brattice(s)
  - As a rule, 100 to 200 m\(^3\) pure nitrogen/ min
  - Air leakage through brattice(s) must be smaller than nitrogen injection rate – *resulting in an inert gas-air stream with O\(_2\) < 10 vol.-%*
  - Flush endangered area – *open roadway cross-section* – 3 to 5 times with N\(_2\)-air-mixture
- Hereafter perform gas measurement on downwind side
  - *Explosion risk is averted, if O\(_2\) < 10 vol.-% in return air from inertized workings*
  - Then erect downwind brattices as close as possible to endangered area
Full space inertization – *emergency procedure (3)*

- After full space inertization is installed and working
  - Minimize nitrogen consumption, dependent on downwind gas monitoring results – *based on overall CO-make and on Coward diagram safety margin*
  - If applicable, constrict brattice sites, and fight residual glow in inertized mine workings under breathing protection
  - If applicable, with a goaf fire, install and start goaf inertization under breathing protection
  - With goaf inertization operative, re-open fire area – *ventilation trial* – and, with no sustainable CO-rise, stop full space inertization
  - If applicable, continue firefighting in the gob area with suitable direct means, under continued goaf inertization
Re-opening a fire area

- Only a ventilation trial gives reasonable guarantee whether a fire has been extinguished or at least been brought under temporary control by means of a goaf inertization
  - Re-establishment of ventilation in the affected area – *firstly on a trial basis* – with attention to particular safety rules
- This includes the possibility to quickly re-seal the area by closing the brattices again and to return to full space inertization, should the fire recover
  - Place a large cordon around the fire area during a ventilation trial
  - All opening/ closing and switching work to be completed by the mine rescue brigade with breathing protection and flameproof suits
Thank you – questions?
Attachments
References

Walter Hermülheim – biography

- 56 years old, married, 3 (grown-up) children
- Graduate of RWTH Aachen University – 1984 to 1986 research assistant – doctorate in strata mechanics
- Since 1987 in German coal mining – DMT Research & Testing Ltd. and RAG German Coal Co. – underground production engineer, certified fire protection and mine rescue expert, part-time lecturer at Georg Agricola University of Applied Sciences, head of Herne Mine Rescue Center, head of RAG’s mine safety and mine planning divisions
- Since 2009 head of occupational safety and health at RAG Holding Co. – retirement from RAG as longtime underground employee in 2012
- More than 40 publications on mining technology and mine safety issues, among them a mine rescue handbook, in 2007
- Lecturer for mine safety at Clausthal University of Technology
- Member of the German Mine Rescue Committee (DA GRW), and of the Standing Working Party for the Extractive Industries (SWP EI), of the EU-Advisory Committee on Safety and Health at the Workplace (ACSH W)
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