



TU Clausthal
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Safe Control of Spontaneous Combustion Goaf Fires

Walter Hermülheim, Institute of Mining

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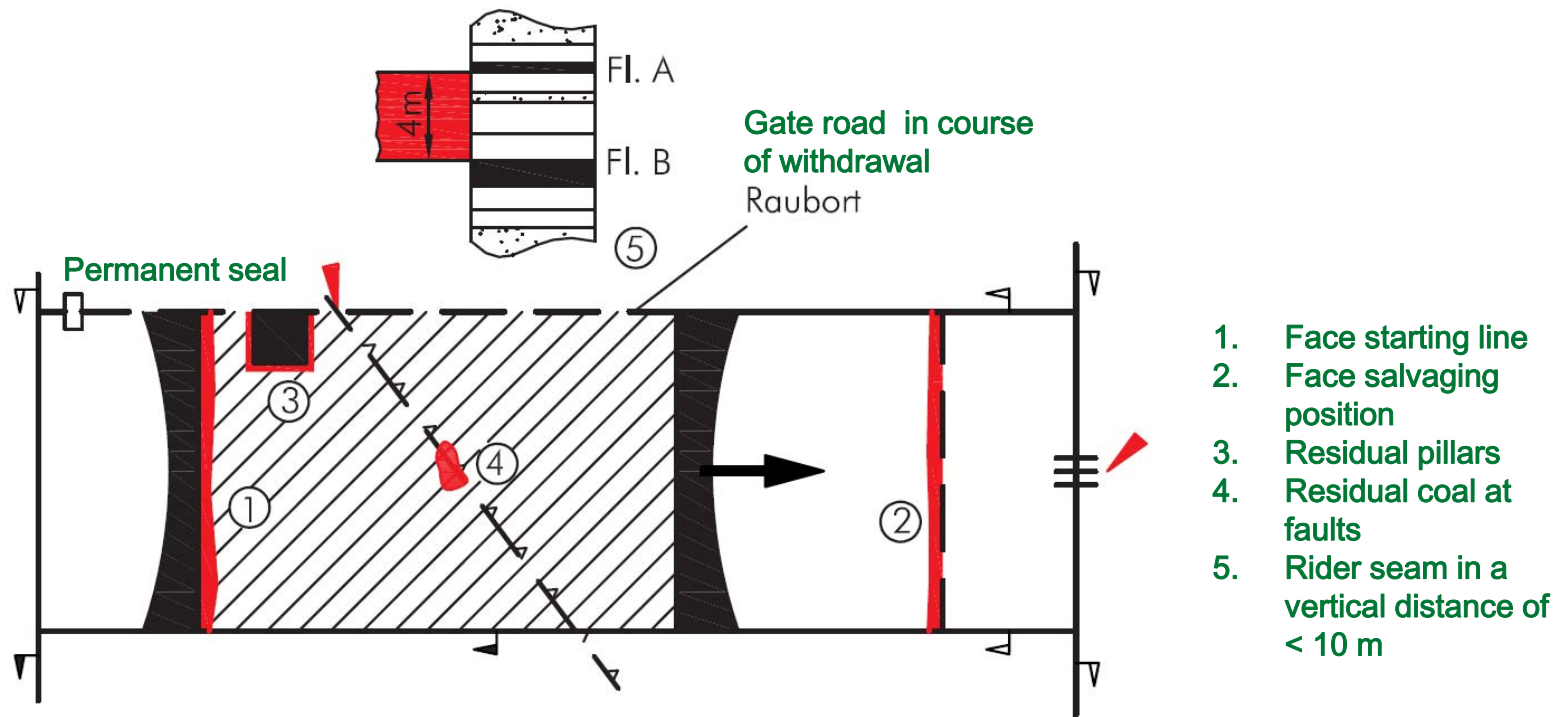


Outline

- 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



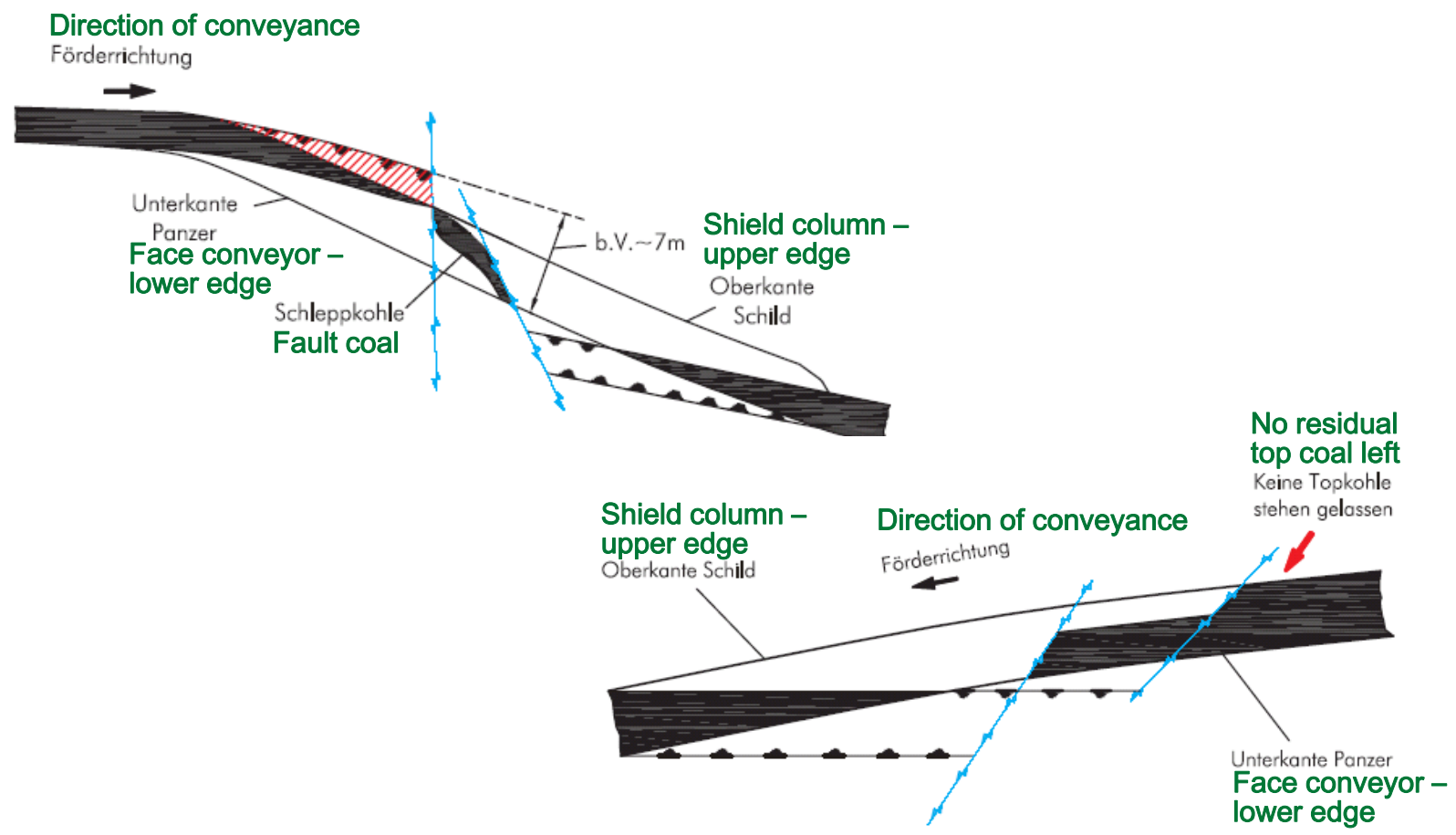
Main areas of spontaneous combustion



- | | |
|----------------|---|
| ① Anlaufkante | ④ Restkohle an Störungen |
| ② Raubstellung | ⑤ Hangendes Begleitflöz in weniger als 10 m Abstand |
| ③ Restpfeiler | |



Residual coal in longwall mining



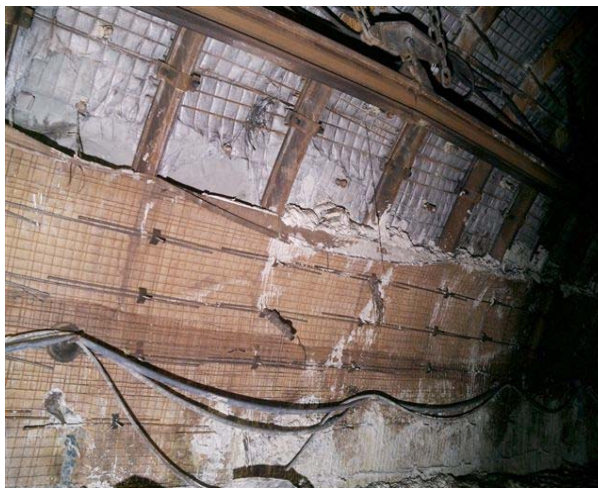


Preventive measures – *basics*

- Required when mining or drifting in seams with coal prone to spontaneous combustion – *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. dunting) – *to achieve low ventilation pressure drop*
 - Quick salvaging

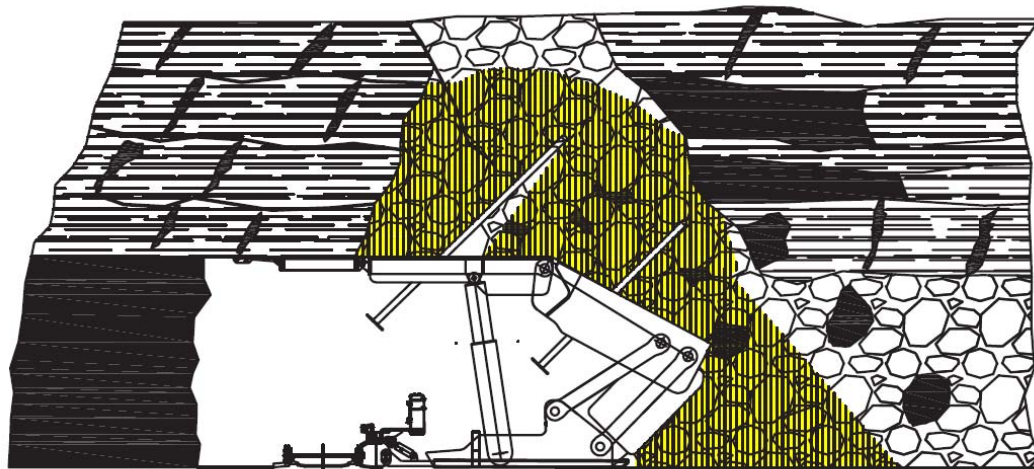


Tight roadside pack





Tightening a shield column – *phenolic resin foam*





Tightening a face salvaging line – *building material*





Tightening a face salvaging line – *foam cushions*



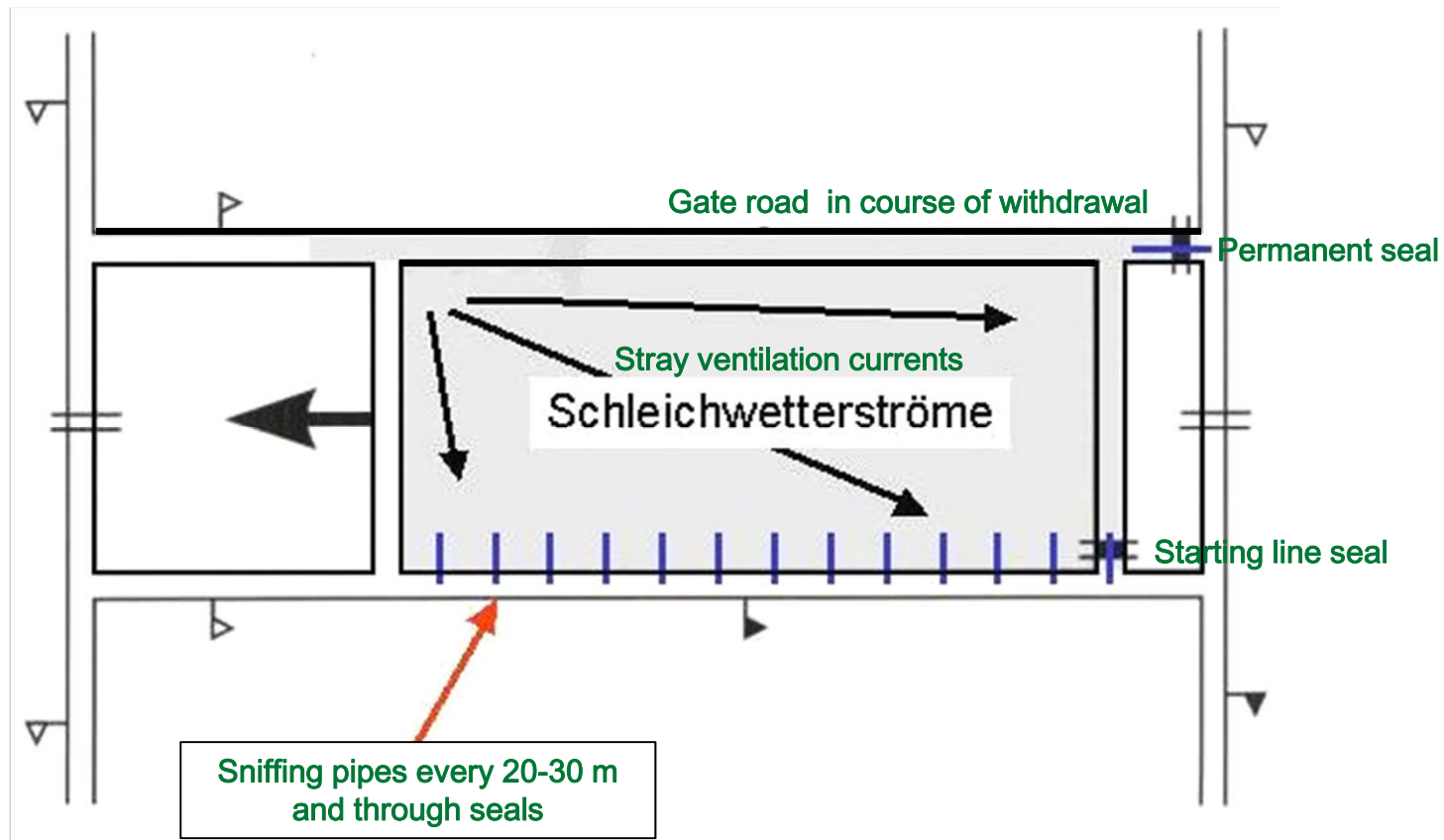


Mine rescue work – *spon com fire in the goaf area*

- “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
 - $\text{CH}_4 < 2,5$ to 3 vol.-% or $\text{O}_2 < 10$ vol.-% in sniffing pipes
- Only valid for fire gases containing CH_4 as main combustible component – *otherwise detailed calculation as to mixed burnable gases required!*

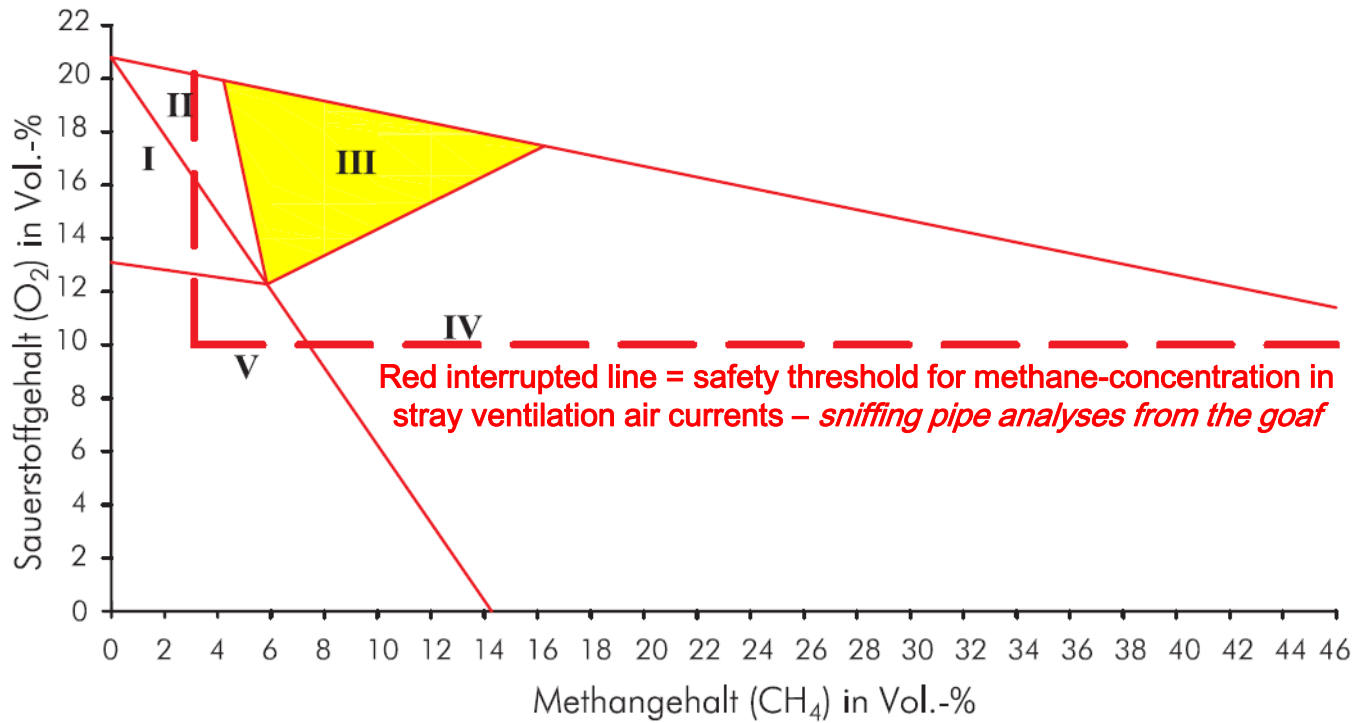


Sniffing pipe monitoring – *goaf stray ventilation*





Coward-diagram for CH₄ – *mine rescue work*



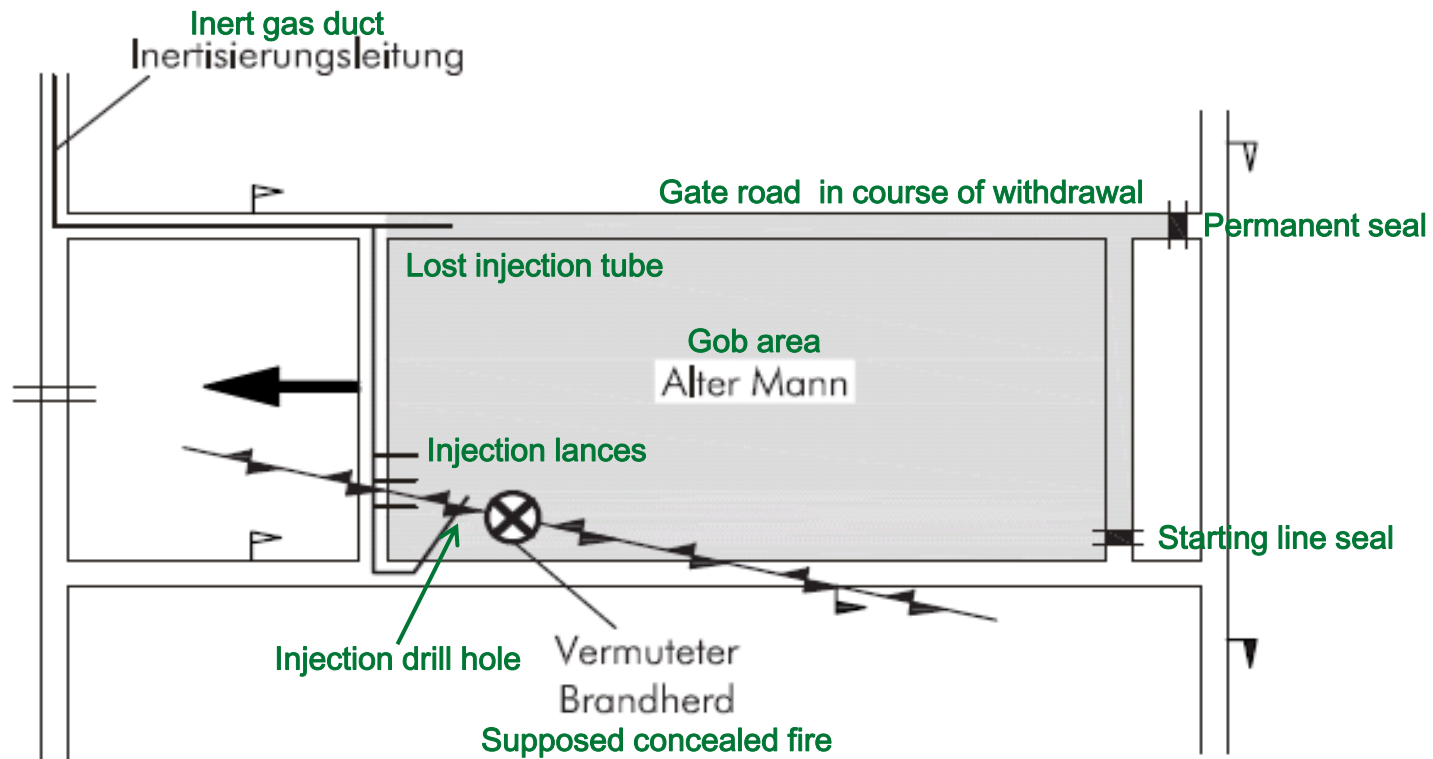


Goaf inertization

- 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



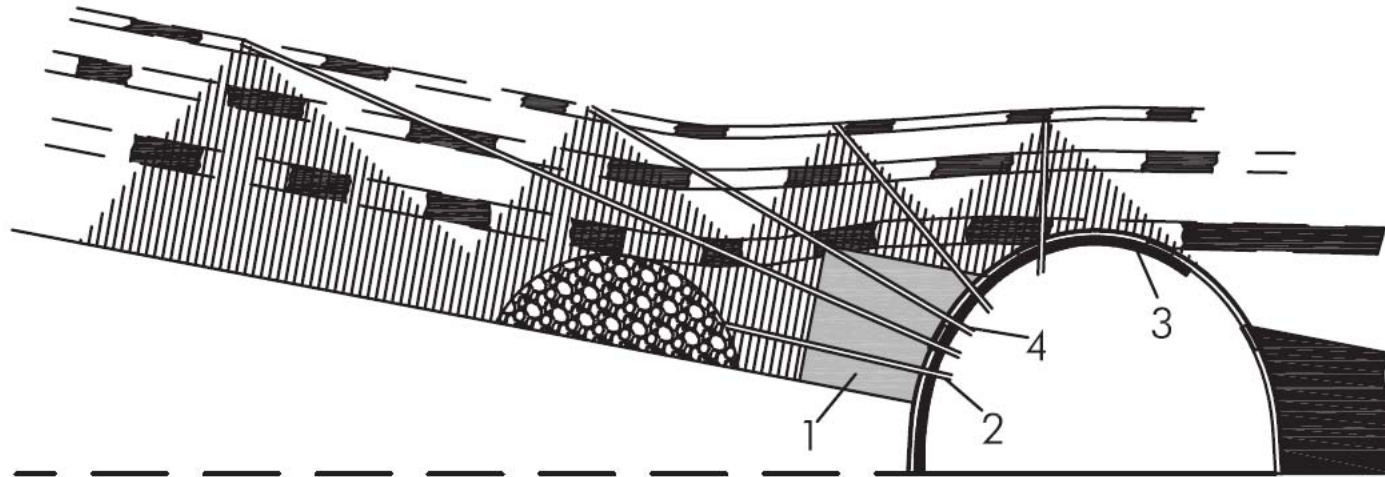


Spon com fire fighting – *current procedures*

- 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



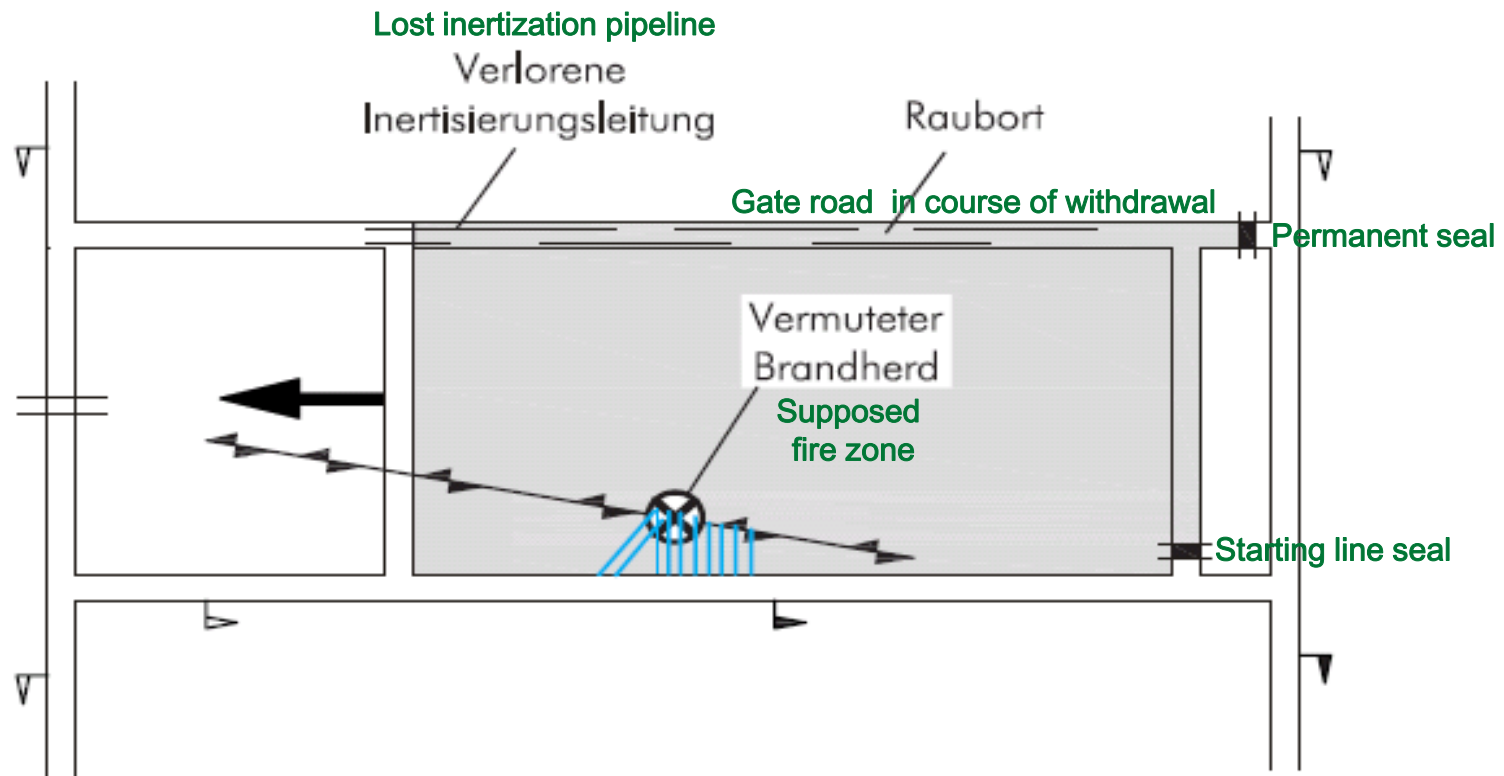
Re-tightening the gate side pack – *schematic*



- | | | | |
|---|----------------|---|--------------------------------|
| 1 | Begleitdamm | 2 | Trockenhinterfüllung |
| 3 | Spritzbeton | 4 | Nassverpressung |
| 1 | Gate side pack | 2 | Dry backfilling – filter ashes |
| 3 | Shotcreting | 4 | Mortar matter injection |

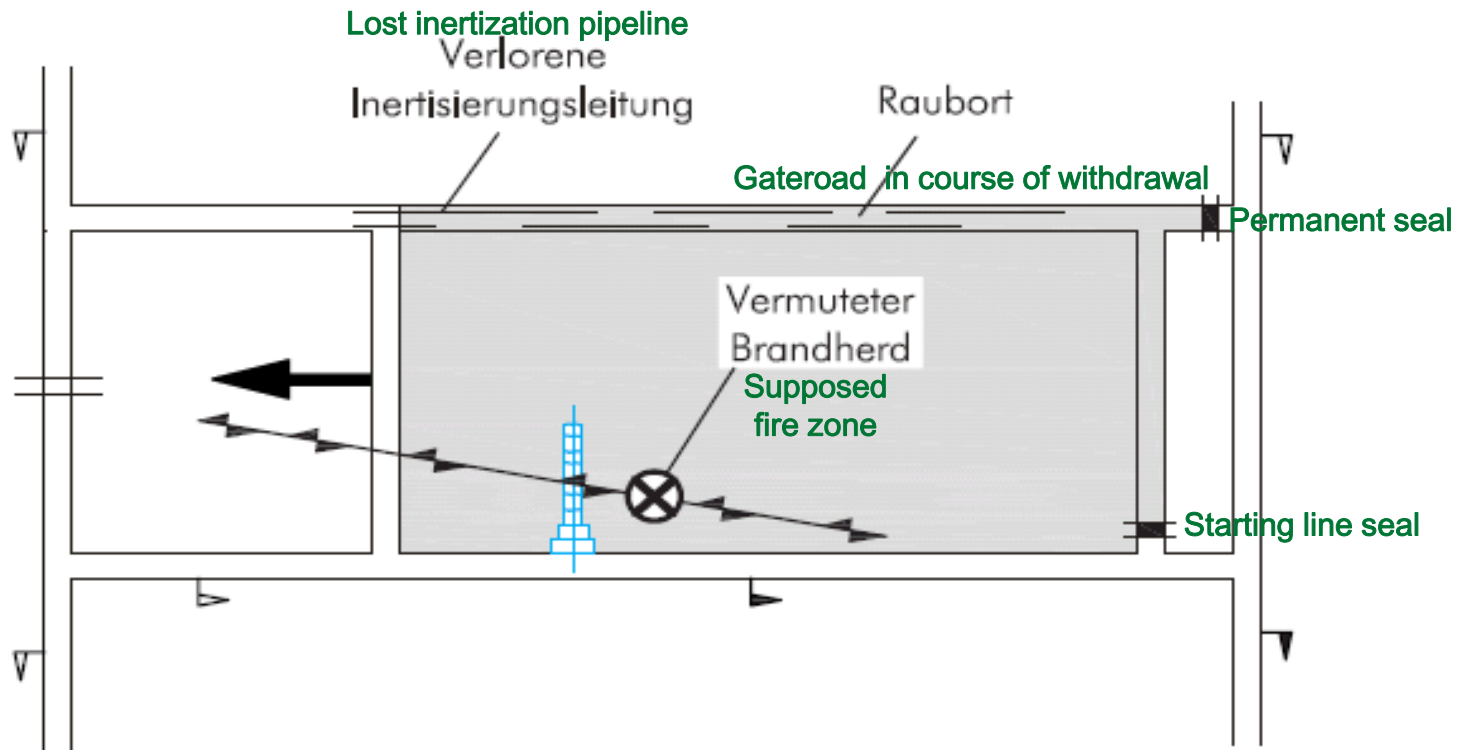


Individual injection drillholes





Building material wedge





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)
- $\text{CH}_4 < 1$ resp. 1.5 vol.-% and $\text{O}_2 > \text{vol.}-18 \%$ 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*

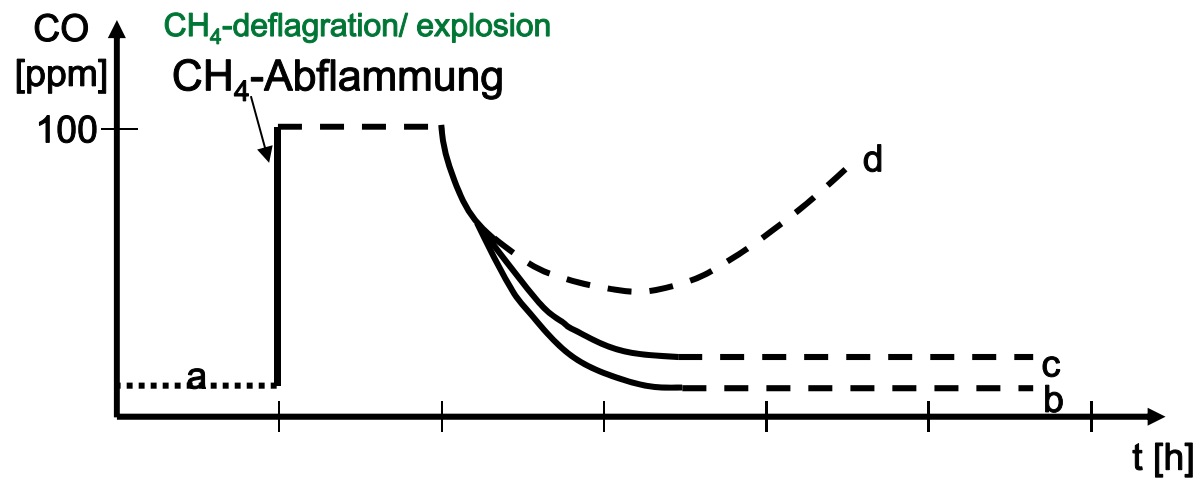


Full space inertization – *concealed fire*

- 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*

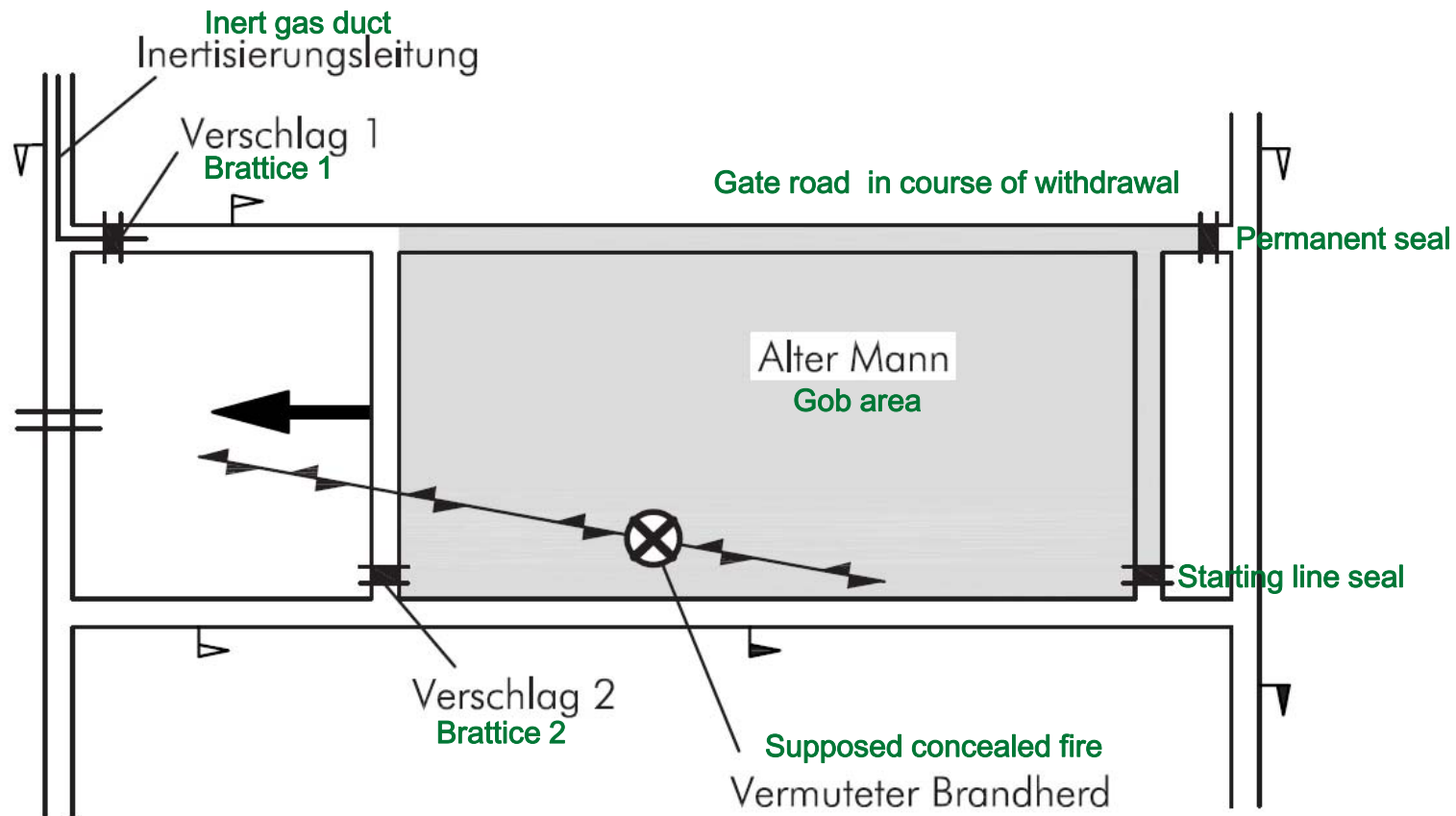


- a) Grundbelastung (i. d. R. 2 bis 3 ppm)
- b) Unkritisch, wenn zuvor kein Brandanzeichen vorhanden war und Bewetterung noch i. O. ist
- c) Kritisch, potentielle Zündquelle - *Glimmbrand*
- d) Kritisch, potentielle Zündquelle - *Glimmbrand oder offener Brand*

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



Full space inertization – *concealed fire*



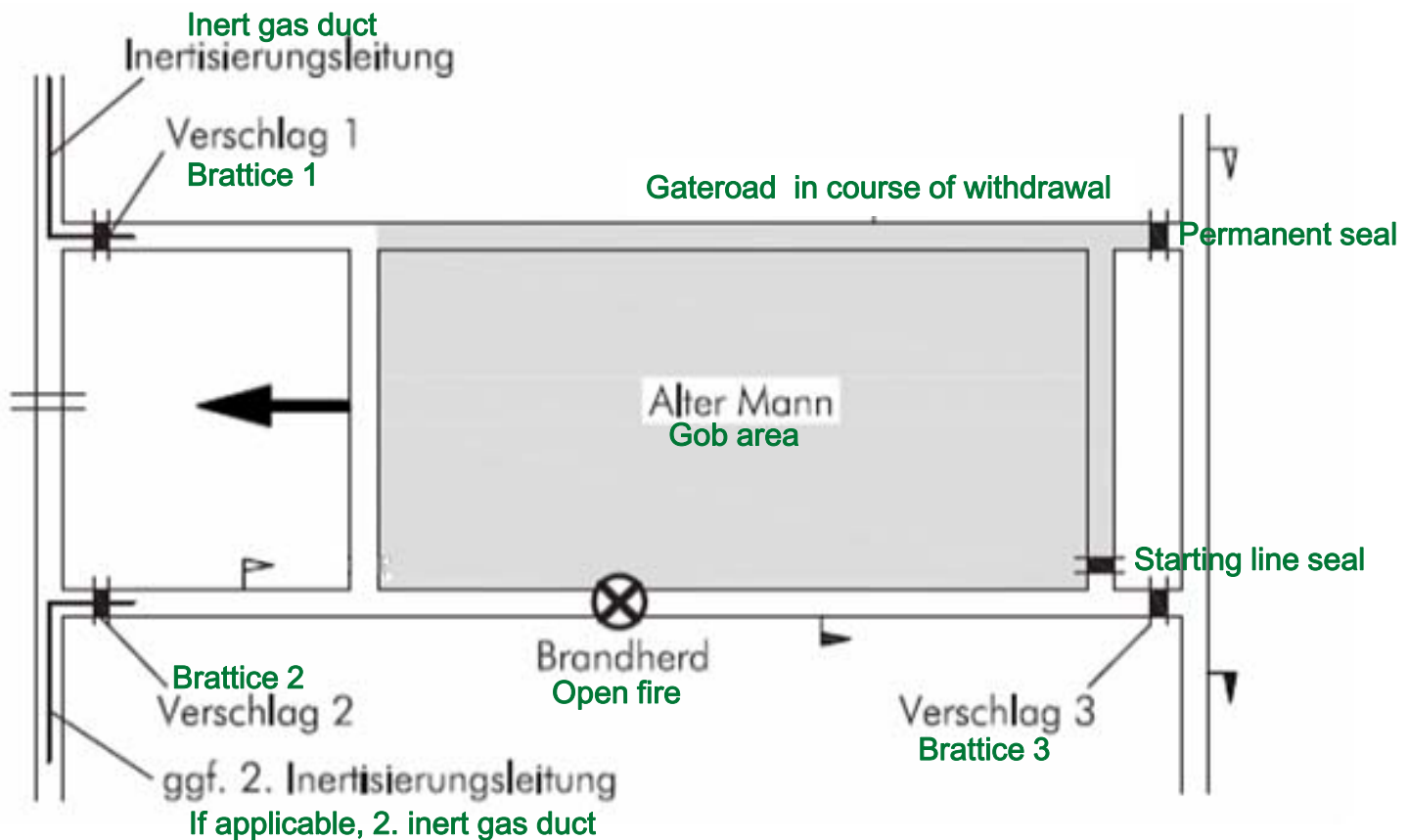


Full space inertization – *open fire*

- If an open fire can't be fought manually due to its 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*





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 N₂ through brattice(s)
 - As a rule, 100 to 200 m³ pure nitrogen/ min
 - Air leakage through brattice(s) must be smaller than nitrogen injection rate – *resulting in an inert gas-air stream with O₂ < 10 vol.-%*
 - Flush endangered area – *open roadway cross-section* – 3 to 5 times with N₂-air-mixture
- Hereafter perform gas measurement on downwind side
 - *Explosion risk is averted, if O₂ < 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

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- Hermülheim, W. et al: Handbuch für das Grubenrettungswesen im Steinkohlenbergbau (*Colliery Mine Rescue Handbook*). Essen, VGE-Verlag, 2007.
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- Hermülheim, W./ Betka, A.: Cutting down Production Loss after Mine Fires and Explosions. Glückauf Mining Reporter I/ Apr. 2010, P. 31/34.
- Plan für das Grubenrettungswesen (*Colliery Mine Rescue Directives*). Edited by the RAG Mine Rescue Center, Herne, Edition: Sept. 2012.



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)
- E-mail: walter.hermuelheim@tu-clausthal.de