Study on fire area unsealing method in high gas outburst mine

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Abstract. The unsealing fire zone is very particular of the in the high-gas outburst mine. By analyzing the limitation of the ventilation unsealing method and the reduced ventilation unsealing method during unsealing fire area in the high-gas outburst mine, it is proposed to use the gas drainage system to unseal. It also is proposed to strengthen gas index analysis in the closed deep fire zone in order to improve the verdict accuracy of fire extinguish judgment. And it can speed up the safety process of high concentration gas in the unsealed area. By adjustment the ventilation system, mine rescue team in the process of unsealing the fire area is always in the fresh air space, which avoid the vicious incidents of gas explosion during the wind tunnel closed wall unsealing in order to protect the personal safety of the team members.

1. Introduction
Mine fire disasters are among the five major disasters in China's coal mining industry. In recent years, with the widespread adoption of fully mechanized top-coal caving mining technology and non-coal pillar mining technology, spontaneous combustion of coal in the goaf occurs frequently due to the large amount of lost coal, the wide range and interconnection of the goaf, the air leakage with oxygen supply in the goaf are serious, despite improved mining efficiency. According to incomplete statistics, a total of 201 fire accidents have broken out in state-owned key coal mines in China, including 182 spontaneous combustion of coal seams, accounting for 90.5% of the total number of mine fire disasters; 64 mining areas were closed due to spontaneous combustion of coal seams, and 32.25 million tons of coal was frozen. When the fire zone is closed, various fire-fighting measures will be taken in the enclosed fire area and the enclosed fire area will be reopened in order to reduce the economic loss of various equipment and coal resources frozen in the enclosed area, remove the hidden safety dangers completely and meanwhile prevent the disaster from further expansion.

2. Risk analysis of unsealing of fire area
“The Coal Mine Safety Regulations” shall meet the following requirements for opening a closed fire area: (1) The air temperature in the fire zone drops below 30℃, or the same temperature as the daily air before the fire occurs in this zone; (2) In the air in the fire zone, the oxygen concentration drops below 5%; (3) The air in the fire zone should not contain carbon monoxide, or the carbon monoxide concentration gradually decreases during the closed period and stabilizes below 0.001%; (4) The water temperature in the fire zone should be lower than 25 ℃, or the same as the daily water outlet temperature before the fire occurs in this zone; (5) The above four indicators shall remain stable for at least one month. The above data requirements are very demanding, due to the complexity and variability of the environmental impact within the fire zone, the difference between the sampling point and the ignition zone state, there is great uncertainty in the unsealing process of the fire zone, resulting
in re-ignition and re-closure of the fire zone, and even gas explosions, CO poisoning and other casualties. Therefore, before the fire zone is unsealed, comprehensive analysis and judgment should be made on the combustion status of the fire source in the closed area and the possibility of reburning after the fire area is re-opened to fully analyze the development trend of the fire and predict the consequences of the unsealing and ensure the safe re-opening of the fire zone.

3. The particularity of fire area unsealing in high gas outburst mine

Due to the large amount of gas emission from the high gas outburst mine and the easy accumulation of gas, the risk of gas explosion during the closure of the fire zone is much greater than that of the low gas mine. Therefore, when choosing the construction location of the sealed wall in the fire area, the sealing range of the fire area will be expanded, which also occurs uncertain factors to the later fire zone governance, fire judgment and fire zone unsealing.

Due to the long sealing time, wide range and unclear location of the fire zone, it is difficult to achieve the expected effect by conventional means such as water injection, grouting and gel injection. During the closure of the fire area, the sealing wall is mainly adopted to reinforce and stop the leakage of air, stop gas drainage, nitrogen injection, pressure equalization and other technical measures to reduce air leakage in the enclosed area, inerting the enclosed area to achieve the effect of suffocation fire in the area. During the implementation of the above technical measures, due to the lack of fresh air flow and the constant gas analysis in the enclosed area, a large amount of high concentration gas has accumulated in the enclosed space, even reaching over 90%. The accumulation of large amount of high concentration gas in the closed fire area also increases the difficulty of safety unsealing in the later fire area.

At present, the method of unsealing the fire zone is mainly divided into the ventilation unsealing method and the lock wind unsealing method. The ventilation unsealing method are only applicable to the small area of the fire area. There is no large collapse of the roof near the fire area. The concentration of flammable gas in the fire area is lower than the explosion limit. For the gas outburst mine, a large amount of high concentration gas accumulates in the closed fire area. During the unsealing process, the gas emission time is long, and it is easy to cause the gas concentration to exceed the limit. In addition, in the process of discharging the gas, it is necessary to return the wind, power off, evacuate, and set the warning, so that the normal production of the adjacent working face is affected. The lock air unsealing method is mainly used in the case of large fire area and it is difficult to confirm whether the fire source is completely extinguished. However, in the process of unsealing, it is necessary to establish multiple temporary sealing. The ambulance members have greater labor intensity and must take the machine to work further, which increased the difficulty of the unsealing work. In addition, when the initial firewall is opened, fresh air enters the original enclosed space, and explosive gases are easily formed, and harmful gases emerging from the enclosed area may also threaten workers.

Whether using the ventilation unsealing method or the lock wind unsealing method, before the fire zone is unsealed, the decision-makers can only sample the sampling holes through the closed wall to analyze and judge the development of the fire in the enclosed area. Due to the wide coverage of the fire area, the sampling point is far away from the ignition point, and the gas flow in the enclosed area is poor. The gas sample taken may not be the true reaction of the fire point. Due to the complexity and variability of the environmental impacts in the fire zone, only the sampling hole from the fire source point is sampled and analyzed to judge the combustion status of the fire source point. There is a great uncertainty in the process of unsealing the fire zone, which is easy to cause errors. The judgment caused the fire zone to re-ignite and re-close. In addition, once the original closed wall and the explosion-proof wall are removed, once the re-ignition occurs, it is difficult to re-close the fire area in a short time, which may easily cause the fire to expand and even the gas explosion accident. Therefore, before the removal of the original closed wall and the explosion-proof wall, it is necessary to sample and analyze the gas index in the deep part of the enclosed area, so as to more accurately analyze the extinguishing of the fire source and the possibility of re-ignition after unsealing.
4. Pipe flow unsealing method
On the basis of a series of fire-fighting measures in the enclosed area and sampling and analysis through the sampling hole, in order to ensure the safe unsealing of the fire area, reduce the risk of re-closing the fire area due to misjudgment and re-ignition of the fire area, under the premise of without removing the closed wall and the explosion-proof wall, the reserved gas is used to sample and analyze the deep gas in the enclosed area, and the closed area is micro-unsealing, which is the pipe flow unsealing method.

The essence of the pipe flow unsealing method is to connect the existing gas drainage system of the high gas outburst mine with the pipelines for the closed area, such as sampling holes and measure holes in the process of constructing the closed wall, and install them in the drainage pipe. CO, CH₄, O₂, temperature and other sensors and reserve sampling holes, in order to carry out real-time online monitoring of various index parameters in the pumping pipeline, through the change trend of various technical indicators such as CO, CH₄, O₂, temperature, etc. The source is extinguished and the possibility of re-ignition of the fire zone after unsealing is judged. After the pipe flow is unsealed for a period of time, if there is an air leakage phenomenon in the closed wall, the valve of the reserved pipe on the other side of the closed wall can be opened as a fresh air flow passage to form a small U-shaped air supply system to realize the pipe flow micro-unsealing to the closed area. In the process of unwinding the pipe flow, if the CO, C₂H₄, C₂H₂, temperature and other indicators in the pumping pipeline are abnormal, the re-ignition signs in the closed area can be immediately unsealed, and the fire zone can be re-closed to ensure the safety of the fire zone reliable.

In addition, due to the large enclosed area of the fire area and the long sealing time, a large amount of high-concentration gas accumulates in the enclosed area. It is easy to exceed the gas concentration limit by adopting the measure of full wind pressure emission, and the gas emission time is longer. In addition, in the process of gas emission, it is necessary to return the air, cut off the power, evacuate the crowd and set alert, which affect the normal production of adjacent working face. In the process of unwinding the pipe flow, the gas drainage system is mainly used for gas emission. Since the drainage pipe is not affected by the gas emission concentration, the size of the roadway and the discharge path, the gas emission in the closed area can be ensured and the gas emission time can be greatly shortened.

5. Ventilation system adjustment and unsealing method
The ultimate goal of unsealing the mine fire zone is to remove the closed wall of the closed fire zone and achieve normal ventilation of the working face to restore the safe production of the coal mine. In the process of removing the closed wall of the return airway, due to the large amount of toxic and harmful gases such as CO and CH₄ in the enclosed area and the spontaneous combustion of coal, a large amount of heat is generated, which is likely to cause gas explosion accidents caused by gas overruns. In addition, the bad construction environment seriously affects the rescuers. Personal safety and work efficiency. In order to ensure the safe opening of the fire zone and avoid the occurrence of a gas accident, the ventilation system is used to adjust the unsealing method so that the rescuers are always in the fresh air flow during the unsealing process.

Before the removal of the closed wall, the local ventilation system is adjusted for the area that needs to be unsealed to ensure that the closed air wall of the return airway is in the fresh air flow and leaks inward, and the small section opening of the return airway sealing wall is started, and the monitoring of gas drainage intensity on the closed side of the former air inlet roadway and the indicator gas and temperature in the drainage pipeline should be strengthened. Stop the gas drainage system in the air inlet roadway after the small section of the closed wall is safely unsealed, and restore the ventilation system in the unsealed area to the original state. CO, CH₄, O₂ and temperature sensors are installed at the opening of the closed wall of the return air lane, and the small section of the closed wall of the inlet air lane is unsealed. In the process of unsealing the two sections of the closed wall, if there is no jump growth in the CO concentration and temperature index in the return airflow, it will gradually increase to a certain extent and then show a steady downward trend, indicating that the fire does not appear deterioration due to the inflow of fresh airflow, and the fire zone should be unsealed.
Otherwise the fire zone should be closed. After the small sections of the two lanes are safely unsealed, the full-section unsealing of the two lanes of the closed wall should be carried out to finally realize the safe unsealing of the working face.

Before the small section of the closed wall of the return airway is unsealed, although the ventilation system is adjusted to the working surface for exchanging the inlet and return air paths, the wind flow is small (the ventilation volume is the drainage volume of the original gas drainage system in the air inlet roadway) on the working face, which has little impact on the possibility of reignition in the fire area, and it is also a further verification of whether the fire source in the enclosed area is completely extinguished.

6. Conclusion
Due to the complexity and variability of environmental impacts within the closed fire zone, there is great uncertainty in the process of unsealing the fire zone. The opening of the mine fire zone itself is a dangerous and complicated task, but it is extremely so for high gas outburst mines. This paper analyzes the limitations of unsealing of the high-gas outburst mine fire area and the limitations of the ventilation unsealing method and the lock-wind unsealing method in the unsealing process of the high-gas outburst mine fire area, and proposes to use the gas drainage system for the pipe flow micro-unsealing, strengthen the analysis of the deep gas index in the closed fire zone, improve the accuracy of the judgment of the extinguishing degree of the fire source in the enclosed area, and ensure the safe and rapid discharge of high-concentration gas in the enclosed area; and adjust the unsealing method by adopting the ventilation system. The ambulance team is always in the fresh air flow during the unsealing process of the fire zone, which can avoid the gas explosion accident caused by the gas overrun in the airtight sealing wall of the return airway, and at the same time can guarantee the personal safety of the rescue team. By adopting the combination of the pipe flow unsealing method and the ventilation system adjustment and unsealing method, it is possible to improve the safety guarantee coefficient for the closed fire zone of the unsealed high gas outburst mine.

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