Pressure Palancmg Techniques For Pereventing Spontaneous Combustion in Coal Mines

Hava Basıncım Dengeleme Tekniklerinin Kömür Madenlerindeki Gizli Yangınların Önlenmesinde Kullanılması

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ABSTRACT

Air pressure balancing techniques can be used easily and efficiently for controlling and preventing spontaneous combustion of coal in gob areas. This paper provides descriptions of and examples for the application of the pressure chambers and pressure-adjusting fans, as well as discussing techniques of changing air-leakage paths.

ÖZET

Hava basıncını dengeleme teknikleri kömür madeni göçüklerindeki gizli yangınların kontrol ve önlenmesinde kolaylıkla ve başarılı olarak kullanılmaktadır. Bu yazıda, basınç odaları, basınç dengeleyici vantilatörler ve hava kaçak yollarının değiştirilmesi gibi teknikler incelenmekte ve bu tekniklerin kullanılışına ait örnekler verilmektedir.

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1. INTRODUCTION

Spontaneous combustion of coal has been one of the most serious problems
in coal mining. If not prevented or controlled at an early stage, a
spontaneous incident may endanger life by generating a mine fire or
explosion and may cause substantial loss in coal resources.

Early detection of spontaneous heating is very important in controlling
and minimizing fire and safety hazards, as well as costs associated with
these incidents. Coal mining companies operating in coal seams
susceptible to spontaneous combustion should develop methods for early
detection of spontaneous heating so that corrective measures may be
taken before it is too late.

Some coal seams are considered more susceptible to spontaneous
combustion than others. Studies indicate that rank of coal, friability
of coal and mining methods are important factors in this susceptibility
(Koenning, 1989 and Mitchell 1990). Lower-ranking coal tends to be more
susceptible than higher ranking coal to spontaneous combustion. In
general, lignite coals are the most susceptible with sub-bituminous and
bituminuous coal being progressively less prone to self-heating.
Friable coal, which breaks more finely and consequently exposes larger
surface areas to the mine atmosphere, promptes oxidation. Caving and
partial extraction methods leave loose and finely ground coal particles
in gob areas and this create potentially dangerous areas in which
spontaneous combustion may occur.

Coal susceptible to spontaneous combustion is easily oxidized. The heat
generated by this exothermic reaction causes temperature increases in
the coal and consequently a spontaneous incident can occur. This
incident will not occur if (i) all coal and timber are removed from the
area, (ii) heat generated by self-heating is removed from the area by
the incoming airflow, or (iii) the airflow into the area is not
sufficient to promote the oxidation process. In fact, statistical data
indicate that most spontaneous combustion occurs in gob areas where both
loose coal and an adequate air leakage into the area are present.

Several methods can be used to prevent or control spontaneous combustion
of coal. As suggested above, these methods are based on either removing
the fuel from the area or controlling ventilation into the area.
However, although removing the fuel — which consists of loose coal left
in the gob, or timber supports -- is a theoretically applicable measure,
its application is very limited and generally it is not practically
feasible. Therefore, controlling air flow into the area is the most
common measure taken. Two different air-flow control methods are used
to prevent or control spontaneous combustion of coal. The aim of both
methods is the reduction of air leakage into gob areas. The first deals
with the building of high-quality air seals in every roadway leading to
and from the area; the second reduces the air-pressure difference
between the inlet and the outlet of the leakage paths. The building of
high-quality seals is the traditional method; best results, however, can
be obtained when high-quality air seals are complemented with pressure
balancing techniques.

Many ventilation engineers have been doing research on minimizing the
air pressure differences along air leakage paths, since the leakage of

air is proportional to the pressure difference between the inlet and outlet ends of the paths. That is, the higher the pressure difference, the greater the quantity of air that leaks into fire areas. Pressure-balancing techniques can be used to reduce pressure differences and consequently to decrease airflow into these areas. Although there are many different techniques applied in quite different ventilation networks, the basic principles are relatively the same. Three of these techniques, including the building of pressure chambers, the installation of pressure-adjusting fans and the changing or adjusting of leakage paths, are described in this paper.

2. PRESSURE CHAMBERS

Pressure chambers are used to reduce the air pressure difference between the two sides of a fire area. The chambers are formed between the original stopping and the auxiliary stopping on one or both sides of the fire area. For example, in Figure 1, the original stoppings SI and S2 and the auxiliary stoppings Tl and T2 form the chambers CI and C2, respectively.
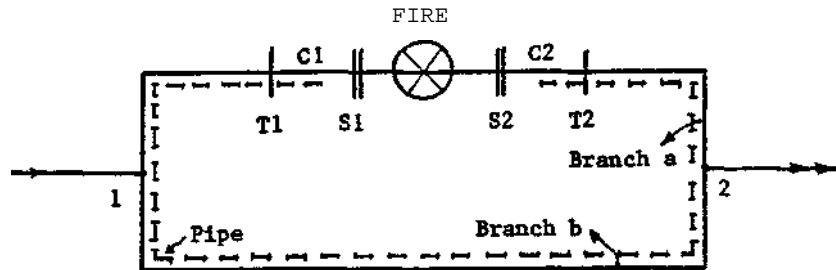

Figure 1. Pressure Chambers

In order to reduce pressure differences between both sides of the fire area, an additional airway is created by an iron pipe connecting the two air chambers. If the pressure difference between the nodes 1 and 2 is H_{12}, the air quantity flowing through branch b is Q_j, and the air quantity flowing into the fire area is Q_a before the pipe is connected, then:

$$H_{12} = R_b Q_b^2$$

$$H_k \approx H_{12} \quad \text{and} \quad H_k = R_f Q_a^n$$

where R_b is the resistance of branch b, and H_j and R_f are the pressure difference and the resistance between the two chambers, respectively. The exponent n may have a value between 1 and 2 depending upon the state of air flow in the leakage area. After installation of the pipe, the leakage through Branch a plus the flow in the pipe is greater than Q_a because the total resistance of the branch is less than it was before the pipes were installed. However, most of Q_a now flows through the connecting pipe since the resistance of the connecting pipe is less than the resistance of the stoppings. Therefore, the leakage into the fire area is less than it was previously.

Assume that the air quantity flowing into the fire area is Q_f, and that

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Qf is much less than Q_a. Then:

$$H'_k = R_f \, Q_f^n \ll H_k$$

$$Q_a = Q_f + Q_p$$

where H'^ is the pressure difference after the pipe is installed and Q_p is the air quantity flowing through the pipe.

There are different ways of using pressure chambers to adjust air pressure (Vutukuri and Lama, 1986). A single pressure chamber is shown in Figure 2. In Figure 2 (a), the pressure chamber is set up on the intake side of the fire area and connected to the return side of the network by a pipe. Because the two ends of the pipe connect the intake and return sides by adjusting the pressure difference between these sides, most of the air flowing through branch a must flow through the pipe. This in turn reduces the air quantity feeding the fire area.

The quantity of air flowing through the connecting pipe depends on the diameter and length of the pipe and on the location of exit 2. When the diameter of the pipe is chosen, the closer point 2 is to the upcast shaft the higher the pressure difference between both ends of the pipe. As a result of this greater difference in pressure, more air flows through the pipe which in turn reduces air flow into the fire area. The arrangement in Figure 2 (b) uses the same principle.
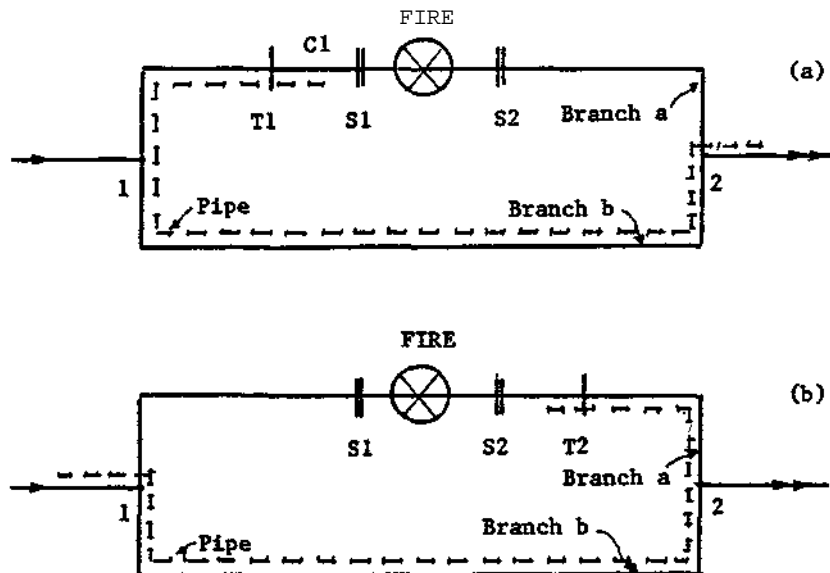

Figure 2.   Single Pressure Chamber

Example 1

An application of the pressure chamber technique in the No.1 Coal Mine of DaTong Bureau in ShanXi province, P.R.C., is illustrated in Figure 3. In this mine, the first level was extracted many years ago and a spontaneous combustion occurred (Fan, 1988). The carbon monoxide and

other harmful combustion gases subsequently spread to the second level. In order to extract the second level safely, a single pressure chamber was used in order to adjust the pressure difference at the first level. This consisted of Chamber 4, auxiliary stopping T and a pipe of 0.5m. diameter extending from Chamber 4 to the surface. As a result of reduced air flow, the fire in the waste area was extinguished six months later.
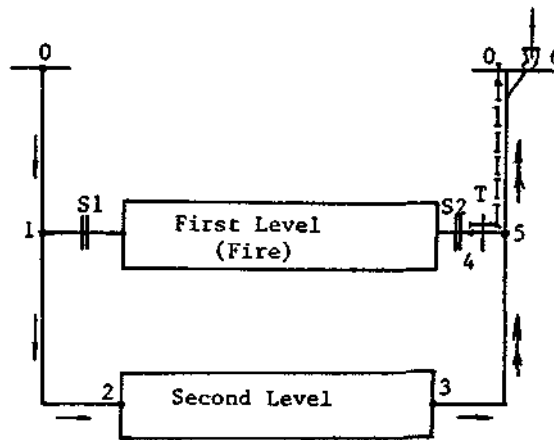

Figure 3. Number 1 Coal Mine

The reduction of airflow into the fire area may be explained by the following pressure-balance equations.

Let the air quantity flowing into the fire area be equal to zero. Then:

$$HOI \quad {}^{X\ H}0\,4 \quad = \quad *0U \quad Q04^{2}$$

$$\^4 \quad = \quad Rp \quad = \quad {}^{H}01 \quad I \quad \%\,4$$

where R_ is the resistance of the pipe, $HQ^{\wedge}$ is head loss in the downcast shaft, and $QQ^{\wedge}$ is the estimated leakage into the fire area. If needed, a valve may be installed in the pipe, allowing airflow to be regulated by adjusting the resistance of the pipe.

3. ADJUSTING FANS

The purpose of using adjusting fans is also the adjustment of pressure differences between the inlet and outlet of air leakage paths. Several different combinations of booster and/or auxiliary fans can be used for the same purpose.

In Figure 1, a booster or auxiliary fan could be installed in Branch b as an alternative to the pressure chamber and pipe arrangement shown. In this case, the operating point of the fan should be selected carefully so that the pressure difference between nodes 1 and 2 would be equal to zero.

A combination of one auxiliary fan and one pressure chamber used in order to prevent air leakage through the fire area is shown in Figure 4.

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On the 'intake side of stopping SI, an auxiliary stopping T is built in order to form a pressure chamber, A fan and a duct are used to exhaust the air leakage flowing into the chamber and to deliver the leakage into airway b. If all of the leakage flowing into the chamber is exhausted by the local fan, the leakage flowing into the fire area will be zero. In order to adjust the air quantity, valves VI and V2 can be used.
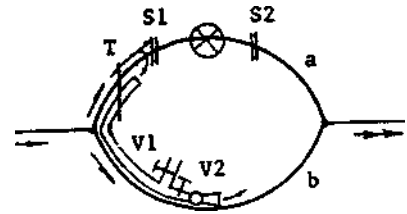
Figure 4. Fan and Pressure Chamber

Different combinations of this pressure-adjusting technique are shown in Figures 5 (a), (b) and (c). A rather different pressure-adjustment method is illustrated in Figure 5 (c). In this case a spontaneous combustion occurs in the gob area, spreading harmful gases toward the working face. In order to continue to extract the coal in the panel, an auxiliary fan at the intake gate and an air regulator at the return gate have been installed. The pressure increase between the fan and the air regulator keeps the gob area under high pressure and thus prevents harmful gases from reaching the working face.
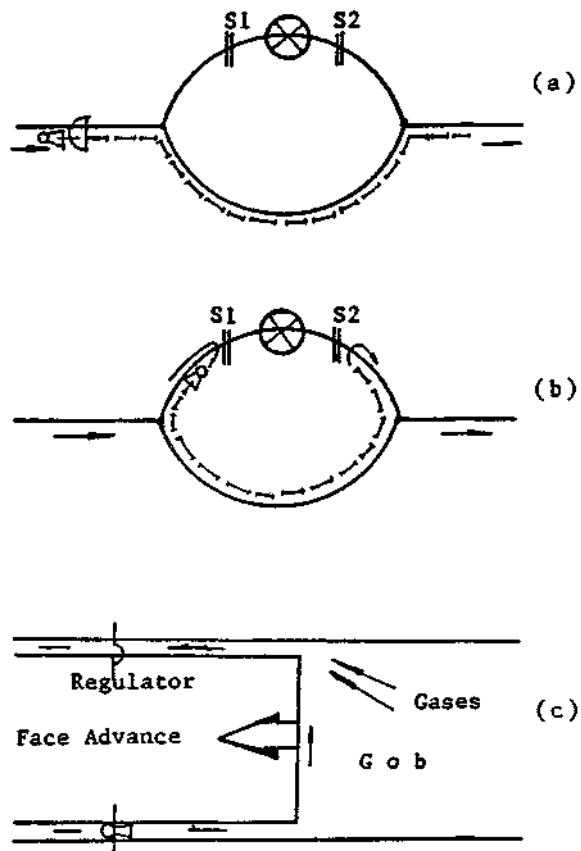
Figure 5. Fan and Pressure-Chamber Combinations

Example 2

A fire was detected at the intake airway of a section in Chai Li Coal
Mine, Shandong province, P.R.C. The source of the fire was located 70m
from the working face, where CO content was found to measure as high as
60 to 100 ppm. In order to be able to continue production at the section
and to put out the fire quickly, an air door in the intake airway of the
working face and two fans outside of the door were installed, as well as
a duct for delivering fresh air to the end of the face, used in order to
block the flow of oxygen to the fire. At the same t'ime, an air regulator
was installed in the return airway of the*face as shown in Figure 6. As
a result of these measures, it was possible to extinguish the fire
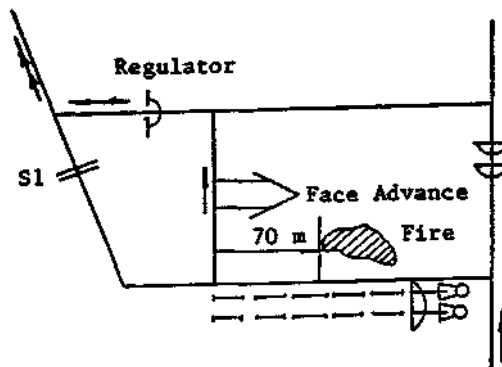quickly (Fan, 1988).

Figure 6. Chai Li Coal Mine

4. CHANGING LEAKAGE PATHS

This method changes the locations of ventilation devices so that the
pressure distribution and leakage paths will be correspondingly changed.
This usually necessitates installation or removal of air locks or
permanent stoppings, alterations capable of reducing pressure
differences between the inlet anti outlet sides of a fire area.

The return airway is cut off and then reconnected to the intake airway.
In this way, the pressure difference between the intake and return
airway is minimized and air leakage paths are changed. Assume that the
gob area of a longwall panel is sealed off by stopping SI and S2 as
shown in Figure 7. If no additional measures are taken, there will exist
a pressure difference between stoppings SI and S2, resulting a rather
large leakage into the gob area. This may create a potentially dangerous
area for spontaneous combustion. In order to reduce the pressure
difference between stoppings SI and S2, the following measures may be
taken: (i) build an air lock or stopping at B; and (ii) remove the air
lock set in position A. After these two measures are taken, stoppings SI
and S2 will both be connected to the intake airway, which will
substantially reduce the pressure difference between the two outby sides
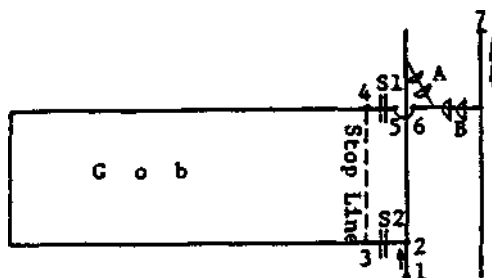of stoppings SI and S2.

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ligure 7. Changing Leakage Paths

5. CONCLUSION

rhe air-pressure adjusting techniques discussed can be used for controlling spontaneous combustion not only in a localized area but also in large waste areas. They are easy to implement, feasible and efficient.

In applying these methods, the ventilation engineer may have- several choices which will bring about the same results. Canonical pressure diagrams of a ventilation network can be used in order to identify high head-loss areas and consequently the applicability and expected efficiency of various pressure-adjusting techniques.

In order to increase the stability of airflow, it is highly advisable to use these measures in addition to high-quality air seals. Irrespective of the control method selected, careful engineering analysis and constant monitoring of the effectiveness of the pressure balancing techniques should be performed.

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