Study on Early Warning Method of Coal Mine Accident about Ventilation, Gas, Dust and Fire

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Abstract

The coal mine safety production is the difficulty and key study of coal producing countries, and the ventilation, gas, fire and dust accidents are the priority among priorities of safety production in coal mine. This paper established a set of coal mine accident early warning system which based on the coal mine accident early warning indicators such as gas concentration, coal dust concentration, the concentration of ethylene and the system risk assessment results. It determines the warning period according to different indicators, and then designs the early warning criteria by the index early warning method and factor warning method. At last it puts forward the warning process and warning levels and describes the release of early warning signals.

Keywords: early warning; index and factor method; coal mine safety

1. Introduction

Accident risk early warning methods include determination method of warning period, design method of early warning criteria and classification method of early warning level. The warning period is interval time of warning indicator and signal release; the design of early warning criteria is to determine the warning index limit, based on the security documents, procedures and standards, such as "coal mine safety regulations", and it also refers to the risk management of ALARP (As Low as Reasonably Practicable) principle; warning level is a description of the accident risk, namely to a description of the accident risk level.

Risk early-warning index system of ventilation, gas, fire and dust accidents includes four index which are gas concentration, coal dust concentration, the concentration of ethylene and the system risk assessment results[1].

2. Early Warning Cycle

Early warning must reflect the concept of time. Determination of the accident risk warning period varies because of early warning indicators. As for the negative index, gas concentration acquisition is mainly from the automatic monitoring system and manual work of three times one day inspection, here its warning period is 8 hours; the concentration of ethylene and dust, which detection also has an automatic monitoring system and manual detection by the workers, only consider daily inspection, so one day is their warning cycle. Also the risk evaluation system's is one day. So the gas concentration alarm cycle is 8 hours, the system safety evaluation, dust concentration, the concentration of ethylene warning period is one day.

3. Early Warning Criterion

Early warning criteria are the basis of warning signal distribution and the warning index. The boundaries of early warning indicators are based on the "coal

mine safety regulations" and "Administrative standard for personal exposure concentration of respirable coal dust in the air of workplace (AQ4202-2008)" and the standards principle of ALAPP.

3.1 *Design Method*

Results of risk evaluation system, gas, coal and dust concentration are quantitative indicators, so we will use the index early warning method. While, the concentration of ethylene is in line with the characteristics of factor early warning method.

3.2 *General Criterion*

The general design of early warning criteria accords to the principle of negative index priority, system risk assessment times. That is, if there is a negative factor in the warning, immediately issued a warning; if not, then examine the evaluation system of risk indicators, if it is in the warning limit, it can give the signal; if not, then forecast and analysis these items index, if the results are alarming, alarm is issued, if not, then no warning, and acquits index data of the next round. The detail of warning process is shown in Fig.1.

3.3 *Special Criteria*

Special criteria include the respective warning criteria for gas concentration, the coal dust concentration, the concentration of ethylene and risk evaluation result of the production system.

3.3.1 *Concentration of Gas*

According to "Coal mine safety regulations", gas concentration of the total return air lane or a wing in return airway should not exceed 0.75%, gas concentration of the return airway in mining area's should not exceed 1%, and special gas drainage roadway's should not be more than 2.5%. While in the stop wind zone, if the concentration is 1%-3% then do the first level emissions, if it is more than 3% then do the two level emissions [2].

According to the method of 5 times safety coefficient, the gas concentration prediction is 0.5%, 0.75, 1%, 1.5%, 3%. While the lower explosion limit of ideal condition is 5%, so if the gas concentration is 5%, the risk is very high. From the perspective of prevention, 4% is the first early warning grade; in accordance with the principle of maximum security, 3% is the second warning state; then the grade III warning state allows regional concentration to 3% in each airway; and grade IV early warning state is to allow the gas concentration in the wind. Details are as shown in Table 1.

Table 1: Early-warning limit of index.

Index	Area	IV	III	II	I
Gas concentration (%)	Gas drainage roadway	1.5	(1.5-3)	3	(3-4)
	return air	1	(1-3)	3	(3-4)
	Air intake	0.5	(0.5-3)	3	(3-4)
	Total return	0.75	(0.75-3)	3	(3-4)
Coal dust concentration(g/m^3)	Coal dust	0.006	(0.006-3)	(3-15) ∪ (20-00)	15-20
	Respirable coal dust	0.0035	(0.0035-3)	(3-15)∪ (20-200)	15-20
Ethylene concentration (%)	Every area of coal mine	-	-	-	>0
Risk assessment result	Ventilation system	low	middle	high	-

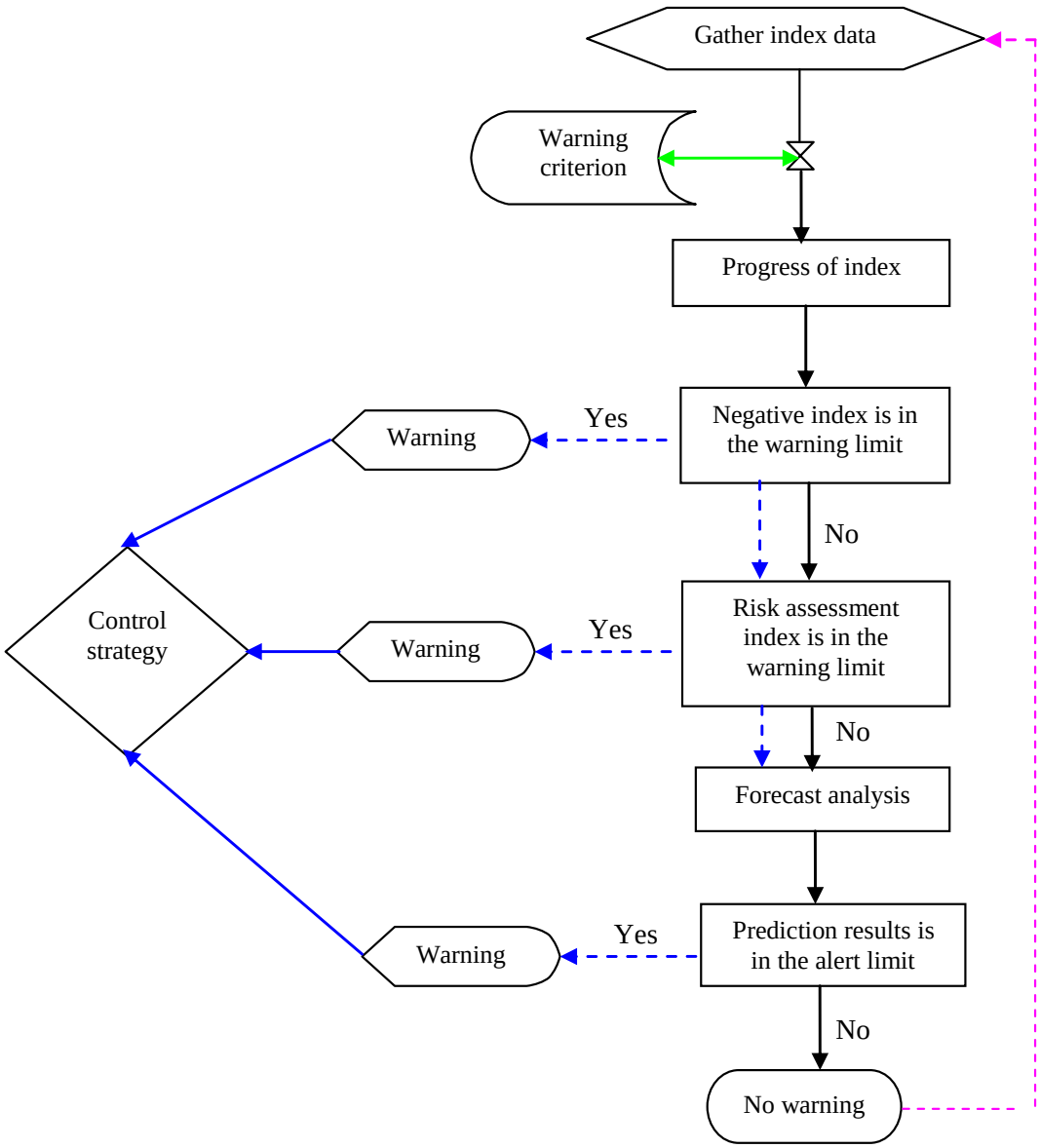

Fig. 1: Flow chat of risk early-warning index on ventilation, gas, dust and fire accidents.

3.3.2 *Coal Dust Concentration*

According to "Administrative standard for personal exposure concentration of respirable coal dust in the air of workplace"[3], if free silica content in all kinds of mine coal dust is less than 5%, then the respirable coal dust exposure concentration limits for 5mg/m^3. While the lower limit of the coal dust explosion are 30-50 g/m^3, the biggest limit is 1000-2000 g/m^3 and 300-400 g/m^3 is the most dangerous explosion concentration. Therefore, determine the four early warning grades as shown in Table 1.

In actual production, the coal dust explosion limit will become lower because of the gas. Therefore, when the gas concentration is lower than 4%, the coal dust explosion limit can be calculated using the following equation:

$\delta_m = k\delta$ (1)

e.g. δ_m-coal dust explosion limit with gas in the air，g/m^3；

k-lower limit of explosion of coal dust explosion，g/m^3；

δ-Coefficient，e.g. Table 2.

Table 2: Influence coefficient of gas concentration rate on dust lower explosion limits.

Gas concentration (%)	δ
0	1
0.5	0.75
0.75	0.6
1	0.5
1.5	0.35
2	0.25
3	0.1
4	0.05

In accordance with the maximum safe principle, establish the early warning index of coal dust concentration as shown in Table 1.

3.3.3 *Concentration of Ethylene*

The experimental findings show that when the coal temperature is up to 80-120℃, it will resolve alkenes gas product such as ethylene and propylene, and so on. And the quantity of gas and coal temperature has an exponential relationship. As long as ethylene in the air, it illustrates the existing in the coal spontaneous combustion. The factors early warning method is used in the design of ethylene concentration criterion.

3.3.4 *System Risk Assessment*

The results of risk assessment reflects the overall safety of ventilation system, because it is a comprehensive evaluation, and the evaluation of the content is very complex, which cannot accurately identify the risk, therefore, establish its risk grade as shown in Table 1.

3.4 *General Criterion*

The above indexes are statistic and lack of time in advance. According to the early warning indexes, we can establish dynamic indexes by regression analysis to predict the risk of an accident, take the risk assessment for an example.

We collect the risk assessment result which is “high” of a mine about the last one year and conduct the regression analysis by Excel, and the result is shown in table 3 to table 5.

Table 3: Regression statistics results.

Multiple R	0.85
R Square	0.72
Adjusted R Square	0.70
Standard error	2.25
Observations	12

Table 4: Variance analysis results.

Items	Regression analysis	Residuals	Total
df	1	10	11
SS	133.1748	50.8252	184
MS	133.1748	5.0825	
F	26.2		
Significance F	0.0005		

Table 5: Hypothesis testing analysis.

Items	Intercept	X Variable
Coefficients	8.2424	-0.5629
Standard error	1.7364	0.2359
t Stat	4.7467	-2.386
P-value	0.0008	0.0382
Lower 95%	4.3734	-1.0886
Upper 95%	12.1114	-0.0372
lower limit 95.0%	4.3734	-1.0886
Upper limit 95.0%	12.1114	-0.0372

From table 3 to table 5, we know that the correlation coefficient Multiple R is 0.87, so the regression forecast equations is:

$$y=8.2424-0.5629x \qquad (2)$$

Also, the prediction of concentration of gas, dust and ethylene can also use this method. If the prediction of warning index is in the warning limit, issue an early warning signal; if not, then no warning.

4. Early Warning Signal

Warning signal distribution is the implementation of warning indicators, only the timely and effective warning signals can provide basis for decision making.

4.1 *Determination of Early Warning Signal*

According to warning signals of seven kinds meteorological disasters in China, it can concludes that the classification are all related with time, which defined the longest in 24 hours disasters and will bring minimal disasters; the shortest in 1 hours and will bring enormous disasters. The coal mine accident risk warning level can be divided into 4 grades, respectively with blue, yellow, orange and red in turn which said the accident risk upgrade. This is as shown in table 6.

4.2 *Release of Early Warning Signal*

Early warning signals issued mainly through two ways which are computer and telephone. For the negative index, the staff should be immediately report through the alarm telephone, and warning department immediately issued an early warning signal by telephone and computer network, start the Countermeasures of library. While, the risk assessment indicators need to be issued by the computer network.

Table 6: Corresponding table of early-warning grade and signal.

Grade	Signal	Risk level description	Control strategy
I	Red	Risk is not acceptable, and work after risk reduction to recover.	Immediate treatment
II	Orange	Don't wanted risks, in a specified time to reduce the risk, to resume normal work.	Deadline processing
III	Yellow	Risk acceptance in conditions, to reduce the risk.	Request processing
IV	Blue	Risk can be accepted, the normal operation.	General acceptance, but attention should be paid to monitoring

5. Conclusions

This paper established a set of coal mine accident risk early warning system, which can be used in safety production of coal mine. But the deficiency is that the warning period is too long and it failed to achieve totally real-time early warning. The issuance of early warning countermeasures need more study in the future.

6. References

[1] Lin Xiaofei, Gao Hua, Zhang Peng, “Study on the risk early-warning index about ventilation, gas, fire and dust accidents in coal mines”, Safety in Coal Mines, 42Pp166–169, 2011.

[2] State Administration of Work Safety, “Coal mine safety regulations”, China Coal Industry Publishing House, Pp12-19, 2011.

[3] State Administration of Work Safety, “Administrative standard for personal exposure concentration of respirable coal dust in the air of workplace”, AQ4202, 2008.

[4] Lin Xiaofei, Chen Guang, Du Xiaoyan, “Establishment of accident risk early-warning macroscopic model on ventilation, gas, dust and fire in coal mine”, Procedia Engineering, 45Pp53-58, 2012.

[5] Cao Qinggui, Liu Yejiao, Lin Xiaofei, et al., “Application of coal mine dynamic safety management and occupational health and safety management system”, Journal of Coal science & engineering (China), 13Pp319-322, 2007.

[6] Ioannis M. Dokas, John Feehan, Syed Imran, “EWaSAP: An early warning sign identification approach based on a systemic hazard analysis”, Safety Science, 58Pp11-26, 2013.
[7] Hopkins, A, “Thinking about process safety indicators”, Safety Science, 47Pp460-465, 2009.
[8] Körvers, P.M.W., Sonnemans, P.J.M., “Accidents: a discrepancy between indicators and facts”, Safety Science, 46Pp:1067-1077, 2008.
[9] Woods, D.D., “Escaping failures of foresight”, Safety Science, 47Pp498-501, 2009.
[10] Christopher B. Mayhorn, Anne Collins McLaughlin, “Warning the world of extreme events: A global perspective on risk communication for natural and technological disaster”, Safety Science, 61Pp43-50, 2014.
[11] Cao Qinggui, Li Kai, Liu Yejiao, et al., “Risk management and workers’ safety behavior control in coal mine”, Safety Science, 50Pp909-913, 2012.
[12] Hiltunen, E., “The future sign and its three dimensions”, Futures, 40Pp247-260, 2008.