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Establishment of accident risk early-warning macroscopic model on ventilation, gas, dust and fire in coal mine

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Abstract

Based on the accident prevention of ventilation, dust, gas and fire in coal mines, and the risk early-warning theory of accidents, the risk early-warning principle is promoted. Then according to the principle and organization, combining the minds of safety scientific theory, cybernetics, information theory, decision theory and systems theory, using the computer technology, the macroscopic model of risk early-warning on ventilation, gas, dust and fire in coal mines is established. Then, it analyzed and introduced the process of detection, identification, early-warning analysis, early-warning signal distribution, and early-warning measures in the model. Finally, it developed a risk early-warning management information system on coal mine accidents by the model.

Keywords: coal mines; ventilation, gas, dust and fire accidents; risk; early-warning; model

1. Introduction

The accidents of ventilation, dust, gas and fire in coal mines are the most serious scourges. The prevention of these accidents, especially the gas accidents, has always been one of the main directions in the coal mine safety around the world. While it predicts the economic system, the risk early-warning theory is regarded as the theoretical foundation for resolving the safety problems in coal mines. Establishment of the macroscopic model of risk early-warning on it deepens the researches on safety early-warning mechanism and technology.

2. Theory of early-warning on ventilation, gas, dust and fire

The fundamental principles of early-warning on ventilation, gas, dust and fire in coal mines: according to the objective of accident early-warning, managers determine different monitoring targets and the standard of those targets to be used to control the early-warning management objects. Particularly, message channel is the feedback mechanism of this accident early-warning control system. The monitoring information got by pre-warning institutions or personnel, feedback the actual conditions of pre-warning targets ,then it supply a reference for pre-warning managers to carry out the pre-warning control policy. Based on the differences between feedback actual result information and pre-warning targets, early-warning managers correct the standard, improve measures and restart a new round of early-warning control process. With constant adjustment and control round by round, interiorly worked in the whole early-warning system shown as in the figure one, the pre-control in pre-warning discipline can be achieved, then actual condition will approach the planned early-warning objective, and the management objects can always be in a safety state. Follows in Fig 1.

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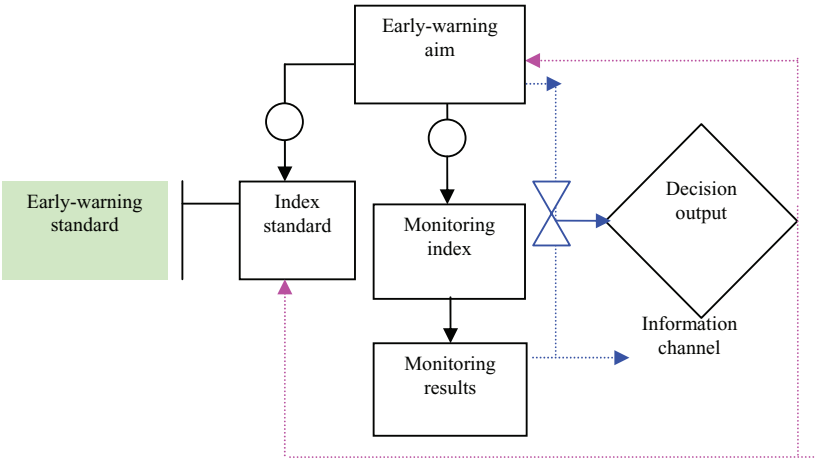


Fig. 1. Basic principles of early-warning management on accident.

3. Macroscopic model of risk early-warning on ventilation, gas, dust and fire

Theoretical principles of risk early-warning on accident is to be used as the theoretical direction of early-warning, while the organization of early-warning as the security of the implement of early-warning, principles of early-warning as the foundation of the establishment of risk early-warning model.

3.1. Establishment of early-warning model

Risk early-warning on ventilation, gas, dust and fire in coal mines, containing the knowledge of safety scientific theory, cybernetics, information theory, decision theory and system theory, is an extreme complicated work. Based on the theories and contents, the establishment of risk early-warning model on ventilation, dust, gas and fire in coal mines is shown in Fig 2.

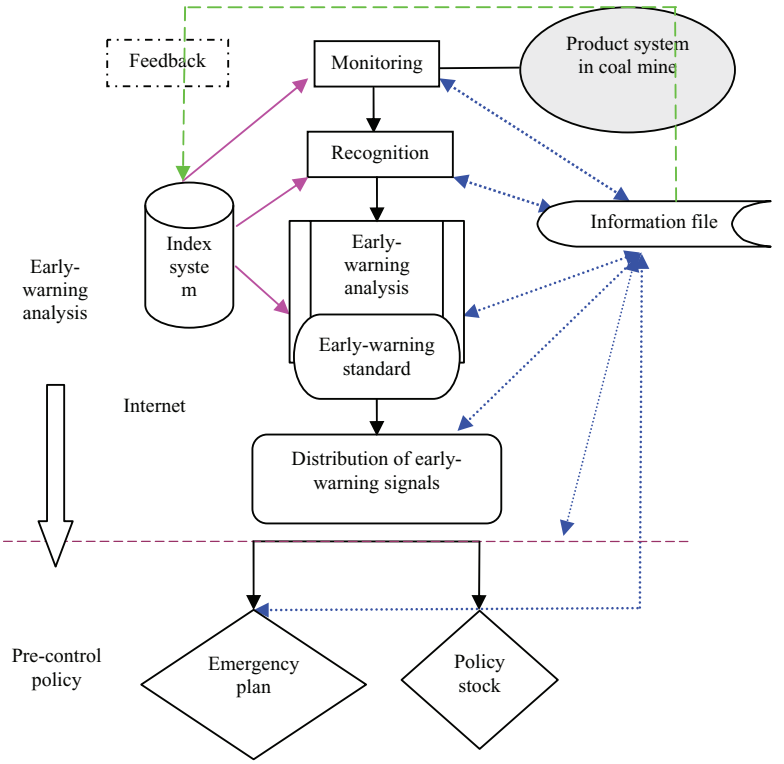


Fig. 2. Risk early-warning micro-model of ventilation, gas, dust and fire accidents in coal mines.

As illustrated in Fig 2, the whole process of risk early-warning can be considered as a closed loop running process. Even if an excellent state is maintained by the product system on ventilation, dust, gas and fire in coal mines, the early-warning objective exactly is to send the product system into a safe state. The idea of decision theory are to be involved, and the decision lag must be considered from the distribution of early-warning signals to the startup of pre-control strategy, or the due effects of pre-control strategy can not be reached, even to fail. Information is the foundation of risk early-warning on ventilation, dust, gas and fire in coal mines, running through the whole process of early-warning behavior, from the original monitoring information to the evaluation, early-warning and strategy information, the contents and transitive quality of information must be guaranteed as much as possible, in addition, the intervening of computer make information a common resource and greatly increase the early-warning efficiency. The final goal of risk early-warning on ventilation, dust, gas and fire in to control. Pre-control is the center in this control, yet the risk early-warning process on accident is a process of real-time and feedback control. The actual risk early-warning on ventilation, dust, gas and fire in coal mines is the content of safety science, while the establishment of early-warning index system, evaluation method and choice on early-warning method, decision on early-warning standard, dividing on early-warning grade and stipulation on early-warning signals are all the content of safety scientific theory.

3.2. Analysis on early-warning model

The risk early-warning object is the key system on ventilation, dust, gas and fire. The following are the main parts of the model.

(1) Monitoring

Monitoring is to detect and mainly collect information on ventilation, dust, gas and fire. The so-called information is a congregation of information concerned with ventilation, dust, gas and fire and had an effect on it. It is the resource to be depended by risk early-warning management activities on ventilation, dust, gas and fire. The information, including the information reflecting the inside of product system, contains people's insecure behavior, insecure state of thing, insecure environmental condition and management flaw and so on, from various aspects.

The information acquisition on ventilation, dust, gas and fire has two methods, artificial and automatic. Artificial collection on risk information is the common and main way in current coal company. Its primary channels are daily safety examined by safety supervisory personnel, managers and company part-time safety inspectors, and major safety examines organized by government or higher authority. In actual practice, applicable safety check list should be designed and adopted, making the collection process standard and ordered, in order to receive general and accurate safety information on ventilation, dust, gas and fire. The information reporting form written by managers and safety inspectors, and information got by other channels on ventilation, dust, gas and fire have been collected, classified and arranged by department on ventilation, dust, gas and fire or early-warning department. Then according to the criticality of the information, the department take preliminary measures, input the information into computer, transmit it to server, then store and manager it uniformly. The list of gas information is shown in Table 1.

Table 1. Gas information check list

No.	Name of test point	Parameter	Value	Unit	Date	Time	Probe
1	4-3thirteen layer orbit upward	gas concentration	0.04	%	2010-8-2	18：15	1
2	4-3 thirteen layer orbit downward charging place	gas concentration	0.06	%	2010-8-2	18：15	2
3	-550 3-1eleven layer	temperature	24	℃	2010-8-2	18：15	3
4	609Xiping lane twist drill coal mining place	gas concentration	0	%	2010-8-2	18：15	4

Automatic information acquisition on ventilation, dust, gas and fire has two modes, self-service instrument and computer monitoring system. In the first mode, self-service instrument is to be used by personnel to collect concerned parameters in the course of production, such as harmful gas concentration, temperature, humidity, pressure and so on. Then the risk information reflected by these parameters is analyzed and processed by information acquisition personnel, transmitted by manpower or computer network, shown as in the figure one. As can be seen, this method, actually, is a semiautomatic information acquisition and transmission mode. In the second one, computer monitoring system is to be used to collect risk information. It use the transducer placed in production field to make real time acquisition of numerical value of concerned parameters in the course of production, and communication system, that is, linked sensor and computer communication and optical cable, etc, to transmit these parameter value to monitoring computer. The concerned information is transmitted by computer network. The automatic information acquisition and transmission is completely resolved by this system, but it will be difficult to depend on it entirely in risk information acquisition. Based on the foregoing analysis, the firm should adopt

the conjoint mode.

(2) Identifying

Identifying is to filter the monitored information on ventilation, dust, gas and fire and distinguish the parameter of early-warning index.

(3) Early-warning analysis

Early-warning analysis is that, according to the actual value of early-warning index, compared with the standard, than based on the comparative results, signals about the fatalness of accident send out in advance. Therefore, to do early-warning work, firstly, early-warning index system and standard should be established, scientific and reasonable method should be used to deal with the risk information, and then getting the early-warning grade.

(4) Distribution of early-warning signals

The distribution is accomplished mainly by computer, particularly by the optical and audio prompt in computer system. While another common way is distributed by phone, correlative managers of early-warning department transmit signals to administrators and field personnel by phone. Before the distribution, the standard on risk early-warning signals must be constituted yet.

(5) Pre-control policy

Pre-control policy includes security policy and emergency rescue counter plan. Feasible and effectual security policy about early-warning information on all kinds of accidents in the product process should be proposed in time and the implementation effects of security policy should be guaranteed by the scientific and efficient safety management work.

Security policy has three levers, safety technical measures, operating instructions and safety standard and regulations. The first level is the measures pointed to a certain potential hazard, and the technical scheme to be direct implemented in the process of controlling accidental risk. The second level is the operation technical scheme pointed to a certain individual item, to be used to remove and control all kinds of accidental risk in this item. The third level is universal and imperative, standardizing and guiding the establishment of the first and second level. The security policy in this technical system mainly is the first level, while the second and the third as its organic part, can make different levels of security policy timely and precisely under the support of auxiliary application software.

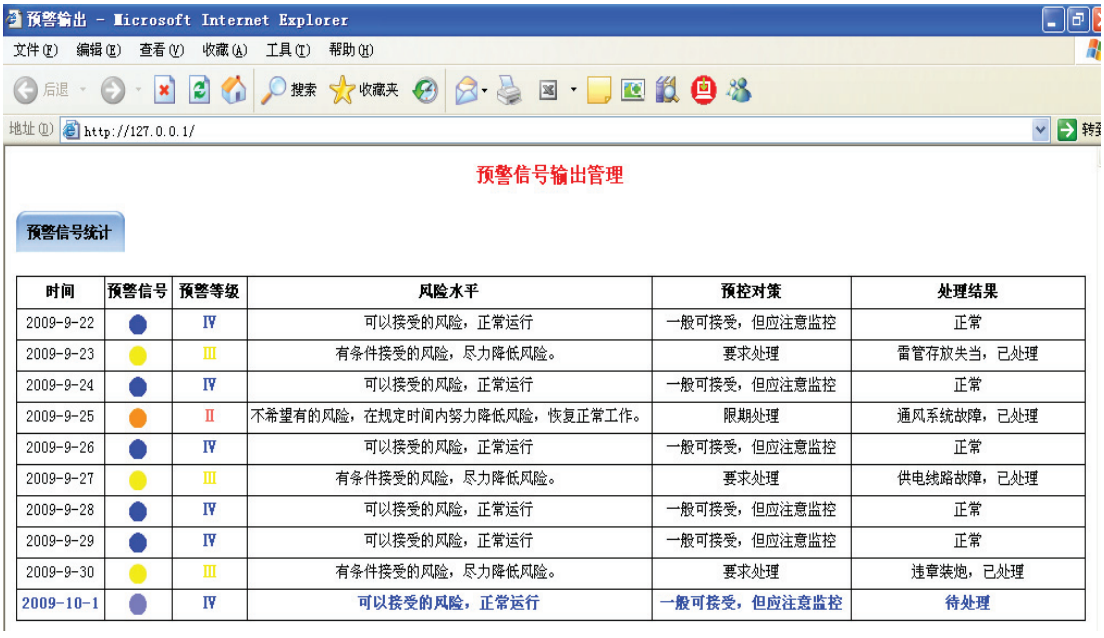
Emergency rescue counter plan, also known as major accident emergency rescue counter plan or emergency plan is a predefined accident emergency countermeasure. It is generated from the prediction of possible major accident, according to the practical situation, in order to enhance the handling ability on major accident. In other words, after understanding an accident is likely to happen and estimating its consequences, emergency processing methods and measures can be assured, including inside and outside. An integrated emergency plan consists of two components, inside and outside. They should be separated but coordinate, that is they must involve the same estimated emergency. The inside plan is prepared by coal industry, while the outside by the local government. The establishment of emergency rescue counter plan needs the cooperation of all departments of early-warning management system in coal mines. If the security policy is disabled, the emergency rescue system must be started right now, in order to retrieve the accident loss.

4. **Application example: integrated early-warning management information system**

According to the risk early-warning theory and mode on ventilation, gas, dust and fire in coal mines above, adopting object oriented method, and then the integrated early-warning management information system can be developed. Its interface is shown in the figure three. The database of this system is Microsoft SQL Sever 2000, and standard measures and methods are adopted to optimize the database as many as possible. Its operating system is Chinese version of WINDOWS XP, browser is Internet Explorer 6.0, development tool is Microsoft FrontPage 2000, client operating system is WINDOWS 2000 or XP, browser is the upper version of Internet Explorer 5.0, and the operating environment of sever end is WINDOWS XP or 2000, SQL Server 2000. This system adopts B/S structure, ASP and Web service technology.

Besides some achievement, such as management of base information, figure analysis, system establishment and so on, early-warning management information system emphatically has resolved the issue of information sharing between systems. Take the case of information sharing between methane monitoring system and early-warning management system, as the first system has the information of gaseous consistency and the second is responsible for early-warning of gaseous consistency, they need to exchange. On the basis of remaining the unchanging application of original system, methane monitoring system redevelops a set of Web Service registered on UDDI in mineral bureau. It provides the part of methane information in the monitoring database for the outside, then early-warning management system get the needed information on gaseous consistency by calling the Web Service. The main interface of the system is shown in Figure 3 and the interface of early-warning signals output management of the system is shown in Fig 4.

Fig. 3. Main interface.



时间	预警信号	预警等级	风险水平	预控对策	处理结果
2009-9-22	●	Ⅳ	可以接受的风险，正常运行	一般可接受，但应注意监控	正常
2009-9-23	●	Ⅲ	有条件接受的风险，尽力降低风险。	要求处理	雷管存放失当，已处理
2009-9-24	●	Ⅳ	可以接受的风险，正常运行	一般可接受，但应注意监控	正常
2009-9-25	●	Ⅱ	不希望有的风险，在规定时间内努力降低风险，恢复正常工作。	限期处理	通风系统故障，已处理
2009-9-26	●	Ⅳ	可以接受的风险，正常运行	一般可接受，但应注意监控	正常
2009-9-27	●	Ⅲ	有条件接受的风险，尽力降低风险。	要求处理	供电线路故障，已处理
2009-9-28	●	Ⅳ	可以接受的风险，正常运行	一般可接受，但应注意监控	正常
2009-9-29	●	Ⅳ	可以接受的风险，正常运行	一般可接受，但应注意监控	正常
2009-9-30	●	Ⅲ	有条件接受的风险，尽力降低风险。	要求处理	违章装炮，已处理
2009-10-1	●	Ⅳ	可以接受的风险，正常运行	一般可接受，但应注意监控	待处理

Fig. 4. Interface of early-warning signal output management.

5. Conclusions

The establishment of accident risk early-warning macroscopic model on ventilation, dust, gas and fire in coal mines provides the rationale for the realization of safety early-warning in production of coal mine, with significant realistic and social meaning. However, this model is just in the macroscopic level, more microcosmic quantized study should be used in the specific implementation procedure and the actual production state in coal mines should be used as original information to make a perfect model. For to collect monitoring data of risk early-warning management information system is mainly by human, the strength of automation has much room for improvement. Pre-control policy is mainly based on the policy of static security and emergency rescue counter plan, and its dynamics and flexibility should be studied deeply.

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