IN SITU MEASUREMENT OF BREEDING-FIRE OF SULPHIDE ORE DUMPS①

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ABSTRACT By piling volumes of sulphide ore dumps in stope and testing their temperature, SO_2 and O_2 concentrations and the environmental conditions during breeding-fire, it was shown that the temperature in the ore dump is the most effective factor to pre-estimate breeding-fire. Since the oxygen concentration in the environment has little variation during breeding-fire, it can not be used as an obvious omen of fire pre-estimation. When the temperature in the melnikovite ore dump is greater than 70 ℃, there will be a large amount of SO_2 releasing, and the reaction velocity will become much greater. Therefore, SO_2 can not be taken as the key factor for fire pre-estimation too. To control the spontaneous combustion in time, some effective measures should be employed when the temperature in the ore dump is 5~ 10 ℃ higher than that of the environment.

Key words sulphide ore dumps breeding-fire behaviour in situ measurement

1 INTRODUCTION

It is well known that the spontaneous combustion is one of the most serious safety problems in the mining of sulphide orebody[1]. In fact, the spontaneous combustion of ore dump is caused not only by its high active potential to be oxidized, but also by a lot of factors, such as the volume of ore dump, fragmentation, storing time, piling shape, water content, heat transfer and diffusion, and relevant environmental conditions, etc[2]. Therefore, the research results on the self-heating behaviour and mechanism achieved by theoretical and experimental methods in laboratory are often not coincident with the practice. On the other hand, the conclusions drawn by investigating fire cases are still not satisfactory to know the whole process and features of breeding-fire, especially in the initial stage, since the fire in mine is often an accidental event and people can only see the phenomena of outbreaking fire, e. g. SO_2 gas releasing from the high temperature ore dump. To solve these problems, we designed a large scale field investigation by piling volumes of sulphide ore dumps in stope and drift from 1993.

2 EXPERIMENTAL

2.1 Experimental place and ore sample determination

The prerequisite to investigate the breeding-fire behaviour is that, the ore used for the experiments should have spontaneous combustion potential. Based on the examination of ore spontaneous combustion tendency for a sulphide iron mine and the investigation of several cases of outbreaking fire in the mine, the ore types with greater spontaneous combustion potential in the mine were determined to be melnikovite and pyrite of small crystal size. With the help of the mining technicians, ore blocks of these types were explored and the allowable places for experiments were selected. Results of mineragraphy analysis of the ore samples used are shown in Table 1. During a period of about 2 a, 10 ore dumps were piled and investigated.

2.2 Measuring method and devices

The measuring method and devices used in

① Supported by the Science Foundation of NECC for Returns Received Mar. 14, 1996; accepted Jun. 14, 1996

Table 1 Mineragraphy analysis results of the ore samples used in the research

No.	1	2	3	4
Ore types and content/ %	pyrite 75	melnikovite 70	melnikovite 48	melnikovite and copper pyrite 45
Structures	grain and breccia texture	colloid form and block	colloid form, grain and impregnation	grain, colloid form and impregnation
Crystal size / mm	0.03~ 0.88	0.02~ 0.32	0.32~ 0.48	0.08~ 0.38
Other minerals and content / %	ferruginous calcite 24, other 1	magnetite 7, pyrite 5, other 18	pyrite 12, ferrohydrite 7, other 33	pyrite 12, copper pyrite 2 other 41

the experiments are shown in Fig. 1. When piling the ore dump, several steel pipes which have a number of small holes drilled on the wall were set in it. To measure temperatures in the ore dump, the sensor of a thermel was put into the steel pipe and moved slowly from the top to the bottom. The thermal gradient in the ore dump was read out by the thermel monitor. When measuring O_2 and SO_2 concentrations, a rubber tube which connects with the gas sample collector was put into the steel pipe of which the inlet is sealed by a special rubber plug. First, the gas in the steel pipe was pumped out completely, so that the gas in the ore dump can flow through the small holes on wall of the steel pipe to occupy its place. Then, the gas was pumped out further from the steel pipe by the gas collector. At last, a colorimetric gas detector was used to test the SO_2 and O_2 concentrations. The environmental humidity was measured by a hygrometer.

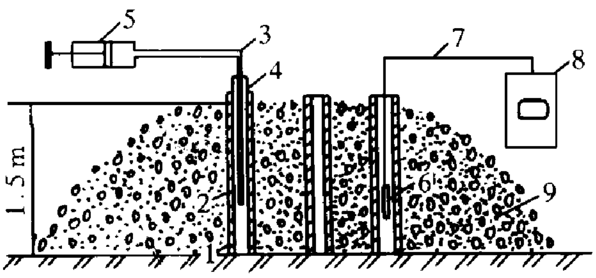

Fig. 1 Measuring method and devices for testing temperature and gases in the ore dump

1 —steel pipe; 2 —small hole drilled on the wall of steel pipe; 3 —rubber tube; 4 —rubber plug; 5 —gas sample collector; 6 —sensor of thermel; 7 —wire; 8 —thermel monitor

3 THE EXPERIMENTAL RESULTS AND ANALYSES

3.1 First-stage results and analyses

In the experiment, the blasted ore was piled in a half-pace shaped dump of 1.5 m high with total volume about 45 m^3. The ore block before blasted was exposed in atmosphere for about two years.

Mineral contents of the ore dump are melnikovite 60% and pyrite of middle and small crystal size 40%. Fragmental distribution of the ore dump is as follows:

> 300 mm,	30%
300~ 100 mm,	25%
100~ 50 mm,	25%
50~ 10 mm,	10%
≤10 mm,	10%

Environmental temperature in the experimental place is 22~ 23 ℃ and the relative humidity is above 90%. Bottom floor for storing the ore dump is a little damp. Air velocity is below 0.1 m/s. The ore dump was piled on May 28, 1993 and was almost dry then. Three steel pipes of 2.54 cm in diameter and 1.5 m in length were put into the ore dump vertically. The testing results of temperature, SO_2 and O_2 concentrations in the ore dump and the environmental conditions are shown in Table 2.

From Table 2, it can be seen that the average temperature in the ore dump rises to 27 ℃ after being stored for 16 d. The increment is only 2 ℃ and the rising rate is 0.143 ℃/d. After being stored for 28 and 43 d, the average temperatures in the ore dump rise to 32 and

Table 2 Results of first-stage piling test

Time /d	Temperature in the ore dump/ ℃			O_2 in the ore dump/ %			SO_2 in the ore dump/ %			Surface temperature on the ore dump / ℃	Environmental temperature / ℃
	Pipe 1	Pipe 2	Pipe 3	Pipe 1	Pipe 2	Pipe 3	Pipe 1	Pipe 2	Pipe 3		
2	25.0	25.5	24.5	18	18	18	0	0	0	23.0	23.0
16	27.0	27.3	28.0							23.5	22.5
21	31.1	31.1	29.5							23.5	23.5
24	32.0	31.1	30.0	18	18	18	0	0	0	23.0	23.0
27	32.0	32.1	30.5							24.5	23.0
28	32.2	32.5	31.0							26.0	24.0
43	68.0		48.0	17		17				28.0	24.0
44	87.3		49.0	17		17	0.04		0.01	40.0	24.0
45	97.0		53.0	18		15	0.04		0.012	42.0	24.0
46	107.0		77.0	18		16	0.07		0.07	48.0	24.0

68 ℃, and the rising rates are 0.23 and 1.69 ℃/d, respectively. Up to 44 d, the temperature and its rising rate are 87.25 ℃ and 18 ℃/d. After 45 d, they become 97 ℃ and 10 ℃/d. In the last period, temperature in the ore dump rises very quickly.

When temperature in the ore dump is less than 60 ℃, there is almost no SO_2 releasing since the testing results of SO_2 concentration by colorimetric gas detector are equal to zero. When the temperature is greater than 76 ℃, there is a large amount of SO_2 releasing, and with the temperature rising, the releasing rate increases sharply.

An interesting phenomenon is that O_2 concentration in the ore dump is almost unvaried and keeps in 15% ~ 18% even though temperature in the ore dump rises continuously. The reason is that the diffusion ability of air in the ore dump increases with increasing temperature since the thermal potential between inside and outside of the ore dump increases.

When temperature in the ore dump rises to 90 ℃, the environmental temperature still keeps normal in 23~ 24 ℃.

Because there was no effective method of extinguishing a fire when dump temperature rose to 80~ 90 ℃, we decided to deal with the smoking ore dump by sprinkling water. The temperature and SO_2 concentration were tested at the same time and the results are shown in Table 3.

Table 3 Test results of sprinkling water to the firing ore dump

Time /d	Temperature in the ore dump/ ℃		SO_2 in the ore dump / %		Water spraying quantity		
	Pipe 1	Pipe 3	Pipe 1	Pipe 3	Flowrate / L·min^{-1}	Time / min	Volume / L
1	77~ 95	52~ 60	0.07	0.07	30	30	900
2	50~ 74	40~ 64	0.047	0.003	30	30	900
4	50~ 58	40~ 51			30	20	600
6	45~ 48						

From Table 3, it can be seen that in this special case, sprinkling water has an obvious effect on suppressing the temperature rising potential in the ore dump. At the same time, the releasing rate of SO_2 from the ore dump is also decreased to some extent.

This experiment shows that water can be used to extinguish the spontaneous combustion of small sulphide ore dump with temperature less than 60 ℃. When the volume of ore dump is very large and its temperature is up to the point of SO_2 releasing, heat energy in the ore dump is so high that the sprinkled water will evaporate quickly and the ore will still keep in the high speed reaction status. At the same time, the water vapor can react with the released SO_2 into sulphuric acid fog and furthermore pollute the environment. Since another fire accident of ore spontaneous combustion occurred near the experimental place at that time, further water spraying experiment was compelled to break.

3.2 Second-stage results and analyses

In order to investigate the breeding-fire behaviour of pyrite ore with middle and small crystal size, we planned to do the second-stage experiment. Since there was no allowable stope for storing ore dumps at that time, the experimental ore dumps were piled in some waste roadways. In the second-stage experiment, three ore dumps were piled and the conditions are described in Table 4. The testing method is the same as above and the measuring results are shown in Table 5.

From Table 5, it can be seen that temperature in the ore dumps is a little higher than that of the environment (0.5~ 1.5 ℃), since volume of the ore dumps is very small and the self-heating quantity is dissipated fully into the environment at ambient temperature. These results also prove that the self-heating quantity of the ore dumps at normal temperature is very small and spontaneous combustion will never occur when the self-heating quantity is diffused fully at the beginning. Therefore, in order to prevent the breeding-fire, it is significant to avoid the heat accumulation at the initial time of storing ore dump.

4 CONCLUSIONS

(1) Temperature in the ore dump can represent the oxidizing velocity in the whole period from self-heating to combustion. To pre-estimate breeding-fire, the most effective factor is to detect temperature in the ore dump continuously. When temperature in the ore dump is kept in constant, even though it is 1~ 2 ℃ higher thanthat of the environment, the ore dump cannot break out fire. If temperature in

Table 4 Description of ore dumps in the second-stage experiments

No. of ore dump	I	II	III
Position	dead-end place	dead-end place	waste roadway
Ore type and content	middle crystal pyrite 80%, small crystal pyrite 20%	middle to small crystal pyrite 80%, big crystal pyrite 20%	middle to small crystal pyrite 80%, big crystal pyrite 20%
Shape, volume and mass	cone-shaped, 1.5 m^3, 6.2 t	half-pace shaped, 2.1 m^3, 8.82 t	cone-shaped, 2.2 m^3, 9.24 t
Environmental conditions	damp floor, 19~ 20 ℃, humidity> 90%	damp floor, 19~ 20 ℃, humidity> 90%	floor with water, 19~ 20 ℃, humidity> 90%
Air velocity	≈0	≈0	0.05 m/s

Table 5 Results of second-stage piling test

Time /d	Temperature in the ore dumps/ ℃			O_2 in the ore dumps/ %			SO_2 in the ore dumps/ %			Environmental dry bulb temp. / ℃			Environmental wet bulb temp. / ℃		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
3	20	20.5	20.5	–	–	–	–	–	–	19	20	20	18.5	19.5	19.5
5	21	21.5	21.5	13	12	13	–	–	–	19	19.5	19.5	18.5	19	19
8	21.5	21.5	21.6	–	–	–	–	–	–	20	20.5	20.5	19	19.5	19.5
10	21.3	21.3	21.3	–	–	–	0	0	0	20.2	20.3	20.3	19	19	19
12	20.5	20.7	20.7	13	12	13	–	–	–	20.2	20.5	20.7	19.5	20	20
14	20.8	20.8	20.7	13	13	12	–	–	–	19.5	20.5	20.7	19.8	20	20
17	20.2	20.5	20.5	16	16	15	0	0	0	19.5	19.5	20.2	18.5	19.8	20
22	20.4	20.9	20.3	15.5	12.5	12	–	–	–	19.8	20.5	19.8	19.5	20	19.8
24	20.7	20.7	20.5	17	16.5	16	–	–	–	20.3	20.5	20.1	20.1	20.4	19.8
50	21	21	21	–	–	–	–	–	–	21	20.5	21	20	20.5	20.5
71	24.2	–	–	16.5	–	–	–	–	–	23	–	–	23	–	–
80	22	21.5	22	20	20	19	0	0	0	22	21.5	22	21.5	21	21.5

the ore dump rises continuously, even though it is very slow at first, some effective measures should be applied on time to prevent its breeding-fire.

(2) Since the oxygen concentration in the ore dump and the environment has little variation during the whole period of breeding-fire, it can not be used as an obvious omen for breeding-fire pre-estimation.

(3) When the fire is near outbreak or the temperature in the ore dump reaches a very high point, there will be SO_2 gas releasing. Therefore, measuring the concentration of SO_2 cannot pre-estimate the breeding-fire of an ore dump.

(4) For melnikovite ore, there will be a large amount of SO_2 releasing when temperature in the ore dump is greater than 70 ℃. For pyrite ore, the critical temperature of releasing SO_2 gas is about 110 ℃. In practice, the ignition point of ore should be defined as its smoking point rather than the cross-point tested in laboratory since the latter is much greater than the former.

(5) In order to control the spontaneous combustion of ore dump in time, some effective measures, e. g. drawing or spreading ore dump, sprinkling water, etc., should be taken immediately when temperature in the ore dump is 5~ 10 ℃ higher than that of the environment with a rising potential. Otherwise, when temperature in the ore dump becomes very high, a large amount of heat energy will be stored in it and the oxidizing speed of the ore dump will be accelerated. At this time, it is very difficult and dangeous to deal with and a fire disaster will be unavoided.

(6) For an ore dump with small volume of several hundred tons, sprinkling water and spreading method can be employed to deal with the self-heating. While sealing, filling and other safe measures should be used for a large volume of ore dump on spontaneous combustion, because there is not enough water to absorb the total heat energy of the ore dump in this case.

(7) All the experiments show that for a sulphide ore dump without breeding-fire, temperature in the ore dump can keep 0. 5~ 2 ℃ higher than that of the environment when there is no ventilation. This phenomenon indicates that there is always a little heat releasing from the ore dump, and hence to control the breeding-fire ventilation is required for the ore dump to dissipate heat to keep up to normal temperature. At ambient temperature, an ore dump of any sulphide ore of block structure with volume of less than 10 m^3 will not result in spontaneous combustion.

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(Edited by Li Jun)