This supplementary material records the principles, methods, concepts and the specific subcategories of coal mine gas explosion accident classification methods in the main text. The content is arranged as follows: The first section introduces the principles, methods, and concepts used to construct classification. The construction of classification relies on the constraints of principles, the guidance of methods, and the reuse of basic concepts; Section 2, 3 and 4 respectively introduce the subclasses of individual action causes, management system causes and other accident causes; Section 5 describes how to use the classification.

To ensure the validity of the classification, this study organises two researchers with more than 5 years of experience in the field of coal mine gas explosion accident analysis to participate in the construction of the classification. Two researchers belong to this research group, so they also have a deep understanding of the 24Model. The classification subcategories established are constructed through accident analysis and discussion. Because general causative factors can be used as the antecedents of failure of all the equipment and facilities, to maintain the simplicity of the classification, unless otherwise specified, general causative factors will not be mentioned in the following subclass construction.

1. Methods and basic concepts of classification construction

1.1. Classification subclass construction principles

The construction principles of classification subclasses should be determined before the subclass construction to constrain and guide the subclass construction process. Two construction principles were determined in this study, based on the accident investigation report and rules and regulations.

1.1.1. Based on accident investigation report

In China, the official accident investigation report is prepared by the official accident investigation agency on the basis of the accident investigation, and it is an important basis to grasp the accident situation, identify the cause of the accident, distinguish the responsibility of the accident, and formulate improvement measures (GB6442-86). The accident investigation report not only reflects the accident investigation mode, investigation results, as well as the data and information supporting the investigation results and safety recommendations, but also contains the country's basic attitude towards the accident, as well as the basic concepts and institutional arrangements for accident investigation. It is authoritative and scientific [1].

To ensure the objectivity and reliability of the accident information sources, the accident investigation reports published by the official departments were used as the sources of data in this study, similar to the previous studies, in which accident investigation reports were also the main source of data. Therefore, accident investigation report is an important basis for the construction of classification subclasses. While ensuring the scientific of the classification language and category, the classification should be highly compatible with the accident investigation report.

Accident cause classification methods such as energy models and human factor reliability analysis methods can classify the accident causes down to a very fine level of detail. If no stopping rules are set, then the causes can be segmented as events all the way down. However, these details are difficult to reflect in the accident investigation report. Therefore, in this study, the smallest cause details that can be shown in the accident investigation report were incorporated as the end point of category classification.

To ensure the validity of the classification method, we used the investigation reports of 198 major and extremely large gas explosion accidents that occurred in China from 2000 to 2009 as the main data source for the construction of the classification method and determined the indicators at all levels of the classification method through accident analysis.

1.1.2. Based on rules and regulations

Rules and regulations mainly refer to the Coal Mine Safety Regulations and other technical specifications of the coal mine industry (such as Coal Mine Outburst Prevention Rules, Coal mine Explosion Prevention Rules, etc.). These rules and regulations are rigid normative documents formed by the industry competent departments and experts in the field to summarise the experience of production and accidents, and they are an important technical support for China's regulation of coal safety production. Therefore, while the classification is scientific, it also needs to be highly compatible with the regulations to ensure the practicability of the classification.

1.2. Classification subclass construction method

The analysis of accidents and generalisation of the accident causes are the main methods used to determine the specific subclasses of the classification. Generalisation ability refers to the ability of a method to adapt to fresh samples; that is, the ability to obtain reasonable results by adding new datasets to the original dataset [2]. The generalisation ability of a classification is the key to guarantee the classification's coverage of causes. In this paper, the generalisation methods of accident causes are mainly divided into two types: consequence generalisation and characteristic generalisation.

1.2.1. Consequence generalisation

Consequence generalisation classifies many accident causes that lead to the same consequence according to different consequences. The inter-category logic obtained by this generalisation is that the subcategory causes the occurrence of the parent category causes. The specific process for determining the subclasses using the consequence class generalisation are shown in the following example.

Accident scenario 1: The use of a non-standard woven bag air duct for local ventilation in the process of wide excavation and coal mining, particularly in the case of no negative pressure ventilation system in the mine, results in gas accumulation that reaches explosion concentration.

Accident scenario 2: In the excavation head of 244 coal face in North No.2 mining area, where the accident occurred owing to the aging of the 5.5 kW local ventilator, the actual air suction volume was less than 140 m^3/min. In addition, the air duct hanging was not standard, and the joint had a large air leakage and many holes, resulting in an insufficient air volume at the working face.

Accident scenario 3: The ‘One Ventilation and Three Prevention’ management of the mine is chaotic. There is a series ventilation in the local ventilation; ventilation facilities are poor; air leakage is serious; airflow short circuit occurs; the working face has no wind; breeze operation takes place; and no gas inspection record, license plate, and statement are available.

Generalisation category: In the above accident scenarios, ‘local ventilation with a non-standard woven bag air duct’, ‘a non-standard hanging air duct’, and ‘poor ventilation facilities’ all lead to air leakage, short circuit, and blockage in the air duct; thus, ‘air duct failure’ is considered as a sub-category.

1.2.2. Characteristic generalisation

Characteristic generalisation classifies according to the characteristics of accident causes. These causes usually have a fixed fault mode (conditions) or behaviour mode (acts), but the main body of the fault or behaviour effect is different. The inter-category logic obtained by this generalisation method is that the parent class contains the subclass in the meaning, and the subclass cause is a further explanation of the parent class cause. See the following example for a detailed process for determining subclasses using feature class generalisation:

Accident scenario 1: The blaster fails to explode and sparks are generated to detonate the gas that has reached the explosive concentration (observe that there is no other electrical equipment near the explosion site).

Accident scenario 2: Natural ventilation of the mine, gas accumulation caused by circulating air in the three sections of oblique working face, and gas explosion caused by spark generated by the failure of the three sections of winch switch.

Accident scenario 3: The connection of the electric coal drill in use fails to explode, generating electric spark and causing gas explosion.

Generalisation category: In the above accident scenarios, the arc spark is caused by the explosion-proof performance failure of the electrical equipment, but the specific electrical equipment that generates the arc spark is different. Therefore, electrical equipment is collectively referred to as electrical equipment and its accessories, and 'failure of electrical equipment and its accessories' is used as a subcategory.

1.3. Basic concepts of classification subclass construction

In the process of generalising the classification subclasses according to the feature classes, it was found that the characteristics of some categories have commonality, and clarifying the commonality among these categories can make the construction of the classification more standardised and concise. Therefore, the representative characteristics were taken as the basic concepts for the construction of the classification subclasses; the statistics, specifications and interpretations were carried out, and these basic concepts can be directly applied to the subsequent subclass construction.

There are 4 basic concepts, which are equipment and facilities, failure mode, full life cycle of equipment and facilities, and general causative factors.

1.3.1. Equipment and facilities

Equipment and facilities in coal mines refer to utensils and structures that meet the purpose of coal mine production and safety [3, 4]. As an important material guarantee for coal mine production and safety, equipment and facilities cover every area of the coal mine [5]. Found in the sub-categories' generalisation processing, the mode of conditions and acts around the equipment and facilities are relatively fixed. Thus, most of the unsafe state related to the equipment and facilities is related to their functional failure, and most of the unsafe acts related to the equipment and facilities have obvious stage correlation with their life cycles.

For the function failure types, stages of equipment, and facility service cycle possible action type, the equipment and facilities provide a common statistical summary. For specific equipment, the facility of state and action can end through two forms of permutation and combination, and filtered according to the actual situation, elimination. This method can both simplify the tree classification and improve the exhaustive nature of the classification. Therefore, two concepts, failure mode and full life cycle of equipment and facilities, are specially proposed as elucidated in Sections 1.3.2 and 1.3.3, respectively.

1.3.2. Failure mode

Failure mode refers to the mode in which the equipment or facility loses its original design function or fails to meet the actual needs. Specific failure modes are determined by generalisation and induction from accident statistics and analysis, and several follow-up questions are used as classification basis, as shown in Table 1. Only when failure modes are combined with specific equipment and facilities can they have practical statistical significance. Table A.1 summarises 17 types of equipment and facilities for accident analysis and statistics. Notably, these 17 types of equipment and facilities are not independent and mutually exclusive.

They should be classified according to their consequences when used. The specific classification principles are described in detail in Supplementary material.

Table S1. Judgment logic of equipment and facility failure modes.

Failure mode of equipment and facilities	Judgment basis
No equipment and facilities	Is there any such equipment or facilities in the mine?
Use illegal equipment and facilities	Are substandard substitutes used in the mine?
The number of illegal equipment and facilities is insufficient	Does the quantity of the equipment and facilities meet the requirements?
Equipment and facilities cannot be used normally	Can the equipment and facility be used normally?

1.3.3. Full life cycle of equipment and facilities

Full life cycle of equipment and facilities is an extension and exploration of the concept of failure mode of equipment and facilities. The latter can be classified as the unsafe material state occurring in equipment and facilities, which can usually be observed, such as 'mine lamp failure', 'local fan shutdown', and 'poor sealing quality'. According to the 24Model, the further reason leading to the failure of equipment and facilities is the unsafe acts in the daily management and use of equipment and facilities, and the whole life cycle is the classification of these unsafe acts.

Article 440 of the Coal mine safety Code mentions that 'the design, installation, acceptance, operation, overhaul, testing and safety of heavier electrical equipment, power and communication systems on the surface and underground of coal mines may be carried out with reference to the regulations of the relevant departments.' Starting from the perspective of equipment and facilities, Wang [3] studied the distribution law of gas explosion and its causes on equipment and facilities and the unsafe acts of people acting on equipment and facilities. Taking a local fan as an example, the service cycle of local fan is divided into six stages: selection, commissioning, installation, maintenance, overhaul, and scrapping. The PDCA cycle control scheme of an unsafe action in a local fan stage is formulated. Zhiqiang [6] divided the whole life cycle of underground coal mine engineering into 10 main stages: design, budget, prevention, construction, management and control, operation, acceptance, evaluation, settlement, and analysis. He constructed the whole life cycle process system of underground coal mine engineering and conducted collaborative analysis and research based on it.

Herein, we refer to the above stage division of the whole life cycle of equipment and facilities, and expand and modify some stages according to the definition of equipment and facilities and the actual accident investigation report. Additionally, we define the whole life cycle to be composed of five stages: installation, use, maintenance, modification, and scrapping. The relationship of each stage of the whole life cycle is shown in Figure 1.

The purpose of dividing the full life cycle of equipment and facilities is to further classify the unsafe acts that occur at different stages. The setting of this group of categories refers to the classification method of category prompt words set in HRA method. Each stage can be used as prompt words for unsafe acts, such as installation stage, which can be associated with no installation, wrong installation position, poor installation quality, etc. Another example is the use stage, which can be associated with no use of equipment, improper use of equipment and unauthorized use (without approval), etc. In addition, there are some unsafe acts that may occur in multiple stages of the whole life cycle, such as disassembly of equipment, hitting/knocking, and other acts of deliberate destruction of equipment. For these acts, a separate 'other' category for statistics should be considered. The specific phases and unsafe acts are shown in Table A.2.

After obtaining the above table, the unsafe operation acts in the accident investigation report can be classified as well as used to speculate the possible unsafe acts in the coal mine

system and assist in risk assessment.

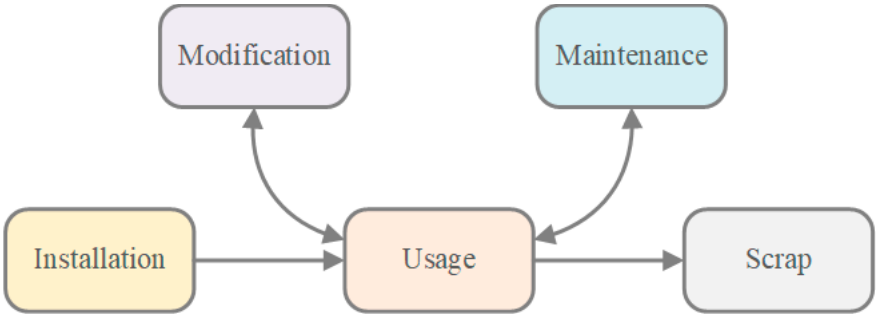


Figure. S1 Relationship between full life cycle of equipment and facility

1.3.4. General causative factors

Generalising according to consequences is the main method in the classification construction process. Thus, causality is the main logical relation that maintains the classification at the level of individual acts. However, this logic allows causes that may have multiple consequences to be repeated as subclasses of different categories. If the ventilator fails, then it will lead to circulating air as well as an insufficient air volume of the air source. Gas outbursts cause a large amount of gas emission, resulting in the destruction of electrical equipment installed on roadways via arc sparking.

In the accident analysis and accident cause statistics, it is found that the reasons leading to the failure of equipment and facilities have a certain commonality. To simplify the classification, they are classified as 'general causes'. General factors include: environmental factors, work disturbances, pre-accidents, equipment and facilities failure, and equipment and full life cycle of equipment and facilities.

(1) Environmental factors. Environmental factors refer to the factors related to the natural environment of the coal mine, which may lead to the unsafe acts of individuals. They mainly include the categories shown in Table A.3, which are for illustrative purposes only and are not considered as specific subcategories.

(2) Work disturbances. Work disturbance refers to some normal work contents in mine production, which may affect the surrounding environment, equipment and facilities. The common disturbances include blasting, drilling, and mining stress in the process of operation. Work disturbance can lead to a number of mission-related consequences, such as blasting through the goaf, drilling through the goaf, and roof caving induced by mining stress. These operations are usually not problematic in themselves, but can cause lack of coordination with other operational and environmental factors, ultimately leading to the emergence of accident causes.

(3) Pre-accidents. In the accident analysis, it was found that some gas explosion accidents had occurred in the mine before the occurrence of other types of accidents. These accidents may lead to a number of consequences, acting as a trigger for gas explosions. Therefore, in this paper, referring to the classification of coal mine accidents, this kind of accidents are classified and counted, and named as 'pre-accident'. According to the concept of pre-accident, coal spontaneous ignition is a common pre-accident in gas explosion, but this category is repeated with ignition source, so it is no longer set separately. The leading accidents of coal mine gas explosion accident include: gas combustion, flooding accident, regional collapsing, and coal and rock dynamic disaster (see Table A.4).

(4) Failure of equipment and facilities. The foregoing has been described in section 1.3.2

(5) Full life cycle of equipment and facilities. The foregoing has been described in section 1.3.3.

2. Individual acts subclass construction

According to the expanded three elements of gas explosion, individual acts are divided

into four categories: gas explosion, improper emergency rescue, improper labour organisation, and secondary accidents. Among them, the gas explosion is used to explain 'why the gas explosion occurs', and the latter three are used to explain 'why the gas explosion causes a large number of casualties' and 'why the gas explosion causes other casualties outside the explosion area'.

2.1. Improper emergency rescue

Improper emergency rescue refers to the situation where the organisation of emergency rescue and emergency response is not timely, the measures are inappropriate, and the equipment and facilities are not supported after the gas explosion.

According to the accident analysis, it can be divided into 3 categories: failure to take effective measures to rescue, failure to report dangerous situations in time, and failure of emergency equipment and facilities (See Table B.1 for details).

2.2. Improper labour organisation

There are three sub-indicators of improper labour organisation: multi-head operation, over-limit entry personnel, and hazardous work performed without proper safeguards, as shown in Table B.2.

2.3. Secondary accident

Secondary accidents refer to other accidents or losses caused by ignition sources, harmful gases, shock waves, etc., generated after coal mine gas explosions. According to accident analysis, this category can be subdivided into four categories: secondary coal dust explosion, casualties in other areas, gas explosion in other areas, and other secondary accidents, see Table B.3 for details.

2.4. Gas explosion

The subclass construction of gas explosion refers to the three-element classification of gas explosion, which is divided into three categories: gas concentration reaching the explosion limit, ignition source, and encounter mode.

2.4.1. Gas concentration reaching the explosion limit

The gas concentration reaching the explosion limit is a necessary and sufficient condition for gas explosions to occur. There are three sub-categories, namely areas with increased gas contents, areas with an insufficient effective air volume, and areas with fresh wind flowing in.

(1) Areas with increased gas contents. Areas with increased gas contents are related to the source of the gas. Gas originates from the coal seams, whose occurrence depends on the geological structure and geological evolution [7]. A high gas content in some areas or the influence of geological and mining stress will lead to an increase in gas gushing, and in severe cases, gas distribution will suddenly change in a short period of time under the induction of gas geological disasters or other external forces. In addition to the gas occurring in the coal seam, some areas of the mine were also the source of the gas in the accident. Coal mining is a dynamic system. With the progress of production activities, windless or breezy abandoned areas such as goafs, old kilns, and blind alleys will be formed. These areas are usually sealed and are hotbeds for gas accumulation. Once the sealing fails, the accumulated gas will flow into the production area, causing the regional gas concentration to reach the explosion limit.

Therefore, according to the source of gas, three sub-categories for areas with increased gas contents were obtained: a large amount of gas escape, gas distribution mutation, and regional

gas release. The antecedents of the three categories of causes partially overlap, and the overlapping parts are described separately. For specific subcategories, see Table B.4.

(2) Areas with insufficient effective air volume. This category is related to the ventilation system. Mine ventilation is the main way to prevent gas accumulation in mines. Based on ventilation methods and ventilation networks, mines have formed a complex ventilation system. When the ventilation system cannot meet the ventilation requirements, the generated gas cannot be effectively discharged, which in turn leads to gas accumulation. Referring to the failure modes mentioned earlier, this situation is called ventilation system failure.

In addition to the failure of the ventilation system, there is a special situation that leads to insufficient effective air volume in the area, that is, the area itself is prone to gas accumulation. For example, the location or function of some areas in the mine is special, including the empty roof of the roadway, the corner of the working face, the coal hole, the coal bunker, etc. Another example is the behaviour of artificially constructing a confined space. The mine closes the mining area, goaf, abandoned roadway, etc., owing to special needs. The purpose of the above acts is to isolate the enclosed area from the normal ventilation system.

Therefore, there are two sub-categories for areas with insufficient effective air volume, namely ventilation system failure and areas prone to gas accumulation. The specific sub-indicators of ventilation system failure are summarised in Table B.5; areas prone to gas accumulation no longer have sub-indicators.

(3) Areas with fresh wind flowing in. The above categories explain the immediate cause of the gas concentration rising to the explosion limit (gas accumulation), but in the accident analysis, it is found that in addition to the gas accumulation, there are accident scenarios in which the gas concentration drops to the explosion limit. This type of accident is usually caused by the influx of fresh wind into the gas accumulation area. Gas accumulation is a prerequisite for such scenarios to occur, and the categories established above are also applicable here. Therefore, the category 'areas with fresh wind flows in' is added to the previous category of gas accumulation, see Table B.6.

2.4.2. Ignition source

At present, the academic community has basically reached a consensus on the ignition sources of the three-element classification of gas explosion, which are usually divided into five categories: arc sparks or electrical heat, blasting flames, frictional collision sparks, coal spontaneous combustion, other open flames and heat radiation (as shown in Table B.7).

(1) Arc sparks or electric heat. Electrical equipment and items that easily generate static electricity are the main sources of arc sparks or electrical heat. Due to the characteristics of electrical equipment, arc sparks or electric heat are inevitably generated during the working process, and some electrical faults and wrong use will increase the probability of electrical sparks and electric heat, such as failure of explosion-proof facilities, short circuit, etc. According to the source and characteristics of arc spark or electric heat, its sub-indicators can be divided into 3 categories: Failure of electrical equipment and its accessories, the electrical equipment is not firmly connected to the power source or falls off, and items that are prone to static electricity are carried into the well. The specific sub-indicators are shown in Table B.8.

(2) Blasting flames. Similar to electrical equipment, blasting flames are also unavoidable due to the properties of the explosives. The prevention and control of blasting flames can be divided into two aspects. On the one hand, the energy generated by blasting can be reduced from the source by using measures such as mining explosives and limiting the amount of charge. On the other hand, it can be suppressed by technical means to reduce the contact time of the fire source with the outside world or block its contact with the outside world. Consequently, six types of accident causes were obtained: failure of blasthole, continuous blasting work, failure of explosive devices, external charge blasting, one charging and multiple blasting, no cannon mud is used to seal the hole or the amount is not enough. See Table B.9 for the sub-indicators of the blasting flame.

(3) Coal spontaneous combustion. At present, the coal spontaneous combustion

mechanism includes many theories (pyrite theory, group action theory, electrochemical theory, Coal-oxygen composite theory, etc.), among which the coal-oxygen composite effect theory has been recognized by most scholars [8]. This theory holds that the physicochemical reaction process between coal and oxygen is the main cause of coal spontaneous combustion.

According to this theory, the prevention and control of spontaneous combustion in mines are mainly based on coal and oxygen. First, different coal seams have different risks of spontaneous combustion. The coal mine should regularly measure the spontaneous combustion period of mining coal seams to select fire-fighting measures. For the coal factor, the main method is to clean up the floating coal in the working area in time to prevent spontaneous combustion from the source. For the oxygen factor, technical measures are mainly used to block the contact between coal and oxygen to prevent coal spontaneous combustion or control the scope of the fire area. In addition, it is also necessary to monitor the indicators such as temperature and carbon monoxide in the mine area, and timely detect the signs of coal spontaneous combustion to prevent problems before they occur. Considering that mine fire prevention is a complex science, this article will not go into depth, and use fire-fighting facilities and measures to refer to specific measures such as grouting, flame retardants, and fire-fighting systems such as fire zone monitoring. Correspondingly, the sub-indicators of the coal spontaneous combustion coal are: areas with fresh wind flows in and the failure of fire-fighting facilities and measures; see Table B.10 for details.

(4) Friction collision sparks. Compared with other causes, the causes of friction collision sparks are relatively simple. The ignition source is produced by the frictional collision of two objects, and it is only necessary to list the possible objects to make a pairing combination, and then get the specific cause of the accident. Notably, the accident analysis shows that the frictional collision spark can be divided into two accident scenarios: frictional collision between objects and that within objects. The former is the most common, and the main body of the latter is usually equipment and facilities with internal mechanical movements, such as local fans, scraper conveyors, etc. For this type of equipment, in addition to considering the question 'why does the frictional collision occur', it is also necessary to consider 'why the spark/thermal energy generated by the frictional collision comes into contact with the gas'. That is, it is necessary to consider whether there is an explosion-proof failure in the equipment and facilities that have internal friction and collision. The sub-indices of frictional collision sparks are shown in Table B.11.

(5) Other open flames and heat radiation. Other open flames and heat radiation refer to other ignition sources that cause gas explosions. According to the accident analysis, it mainly consists of illegal welding operations, smoking and some non-electrical equipment (such as diesel locomotives), as shown in Table B.12.

2.4.3. Encounter mode

After summarising the factors that cause the gas concentration to reach the explosion limit and the ignition source, we still need to consider: how did the two encountered? According to the accident analysis, the combination of the two must be based on certain scenarios. Therefore, the concept of 'encounter mode' is proposed, as the connection between the ignition and the gas, to supplement the background factors of the encounter between the two.

The subdivision of the coal mine area is complex. In addition to the normal production areas, there are still windless and abandoned blind alleys, sealed fire areas and goafs, and roadways that carry special functions such as pressure relief and gas drainage. To prevent the occurrence of gas explosion accidents or other accidents, these areas have stricter requirements for the entry and evacuation of personnel. To detect gas in a timely manner, gas inspections cooperate with most coal mine operations and cover most production areas. The electrical equipment in the coal mining face, the tunnel face and other areas will also use the blocking device to ensure that the arc spark and the gas do not encounter.

Therefore, when gas and ignition sources are encountered in accidents, particularly ignition sources caused by operators' activities, it is necessary to first consider why operators

appear in such areas and whether they violate the requirements of relevant regulations, and then consider the occurrence of ignition sources and gas.

This article uses 5 subcategories to distinguish between the above scenarios: the operator is working in the wrong place, areas are connected (the ventilation system is not adjusted in time), failure of the two locking devices, no gas found to reach the explosive limit, blindly sending electricity. See Table B.13 for details.

3. Safety management system subclass construction

A safety management system is a set of interrelated or interacting elements used by an organisation to establish its safety policy and safety objectives and the processes by which these objectives are achieved [9]. The 24Model divides the safety management system into three parts: safety policy, safety management organisational structure and safety management system. The organisation guides individual behaviour through various procedure in the safety management system, and in turn, the dynamic operation of the safety management system is the emergence of individual behaviour.

Owing to the limitation of the accident information itself, it is difficult to trace the specific actors of some acts, such as 'insufficient safety investment' and 'refusal to implement supervision instructions'. Combined with the 24Model's definition of the relationship between organisational behaviour and individual behaviour, organisational behaviour is added on the basis of the original classification of the safety management system. Organisational behaviour specifically refers to the behaviour or state of the organisation that is issued by the organisation, but is essentially the emergence of individual behaviours, from the perspective of outside the organisation. The relationship between individual behaviour, organisational behaviour, and management system is: the management system is developed by the organisation, it is the product of the organisation's behaviour, and it is used to guide the behaviour of individuals; organisational behaviour is the emergence of individual behaviour; organisational behaviour and individual behaviour can reflect the operation of the management system. To sum up, the classification indicators at the level of the organisational management system are determined as the unsafe behaviour of the organisation and the failure of the safety management system. To sum up, the sub-indicators of the organisational management system are: organisational unsafe behaviour and safety management system deficiencies.

3.1. Organisational unsafe behaviour

According to the statistical analysis of accidents, there are three types of organisational unsafe behaviour, namely avoid, resist, or ignore departmental supervision; organisations without production qualifications; and insufficient security investment (See Table C.1 for details).

3.2. Safety management system deficiencies

In the accident investigation report, the deficiencies of the safety management system are mainly manifested in two aspects: the safety management organisation structure and the safety management system. To simplify the classification structure, expand the application scope of equipment and facility failure modes, and apply them in the construction of subclasses of the safety management system. The subcategories of safety management system deficiencies are shown in Table C.2.

Like the failure modes of equipment and facilities, after the general failure mode is defined, it needs to be combined with the specific subject to get a meaningful category. Therefore, it is necessary to classify the safety management system. The organisation's safety management system needs to cover relevant laws, regulations, etc. Among them, the 'Coal Mine Safety Regulations' is undoubtedly the most important technical regulation for coal mine safety, and has the highest priority of industry regulations and standards. Therefore, this paper classifies

coal mine safety management systems based on accident statistics and with reference to the Regulations, as shown in Table C.3.

The above classification is mainly based on the work content guided by the procedure. However, in the accident analysis, it is found that there is some common 'sub-procedure' in the management system that guides different work contents. They ensure that the above system operates effectively. But in some accident investigation reports, the failure of these procedures is also mentioned separately. This paper refers to these procedures as 'generic sub-system', and they are summarised in Table C.4.

4. Other category construction

Incident investigation reports can provide a wealth of information on unsafe acts, unsafe conditions, and safety management system deficiencies. However, for capability and cultural factors, the available information is relatively limited, so no subcategories are set.

All the sub-categories of the classification have been constructed, and the classification includes a total of 3 categories and 138 sub-categories. Each subclass corresponds to a table, and the relationships between the subclasses and their corresponding tables are summarised in Figure 2.

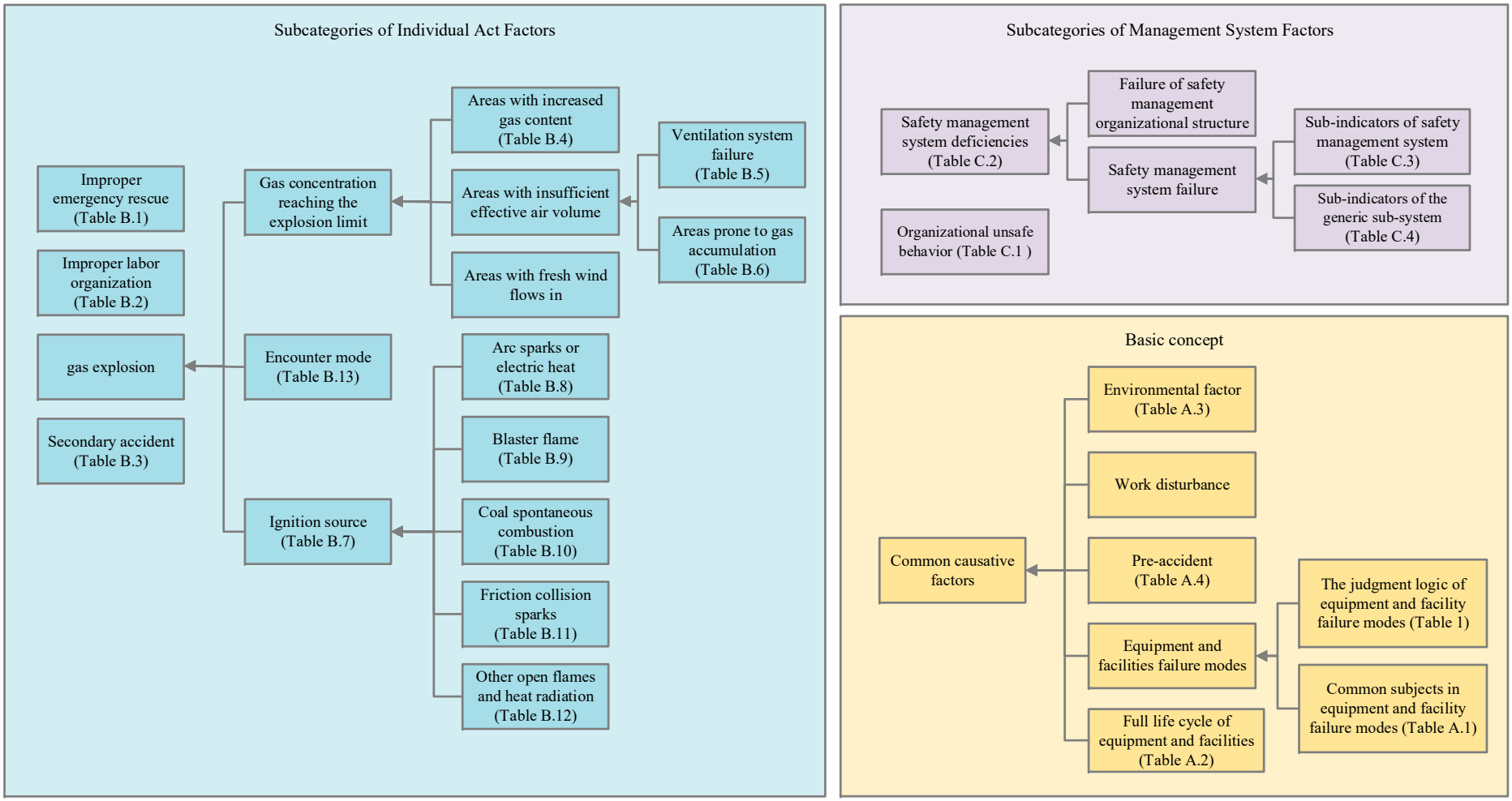


Figure. S2 Summary of sub-categories for the classification of coal mine gas explosion accident causes

5. Classification usage principles

According the related studies, there are two ways of using the accident causation model: accident cause analysis and accident cause classification [10-12]. The analyst can not only analyse the causes of the accident using this model, but can also classify the causes of the accident. The classification is built on the accident causation model and is used in the same way as the accident causation model. To ensure that the classification can give full play to the dual functions of guiding accident cause analysis and accident cause classification, and improve the consistency of accident analysis results, two classification usage principles are proposed:

(1) Classification according to the consequences. Some categories are not independent and mutually exclusive. For example, 'ventilators' belong to the category of 'ventilators' in equipment and facilities, and also belong to the category of 'electrical equipment and its accessories'.

In addition, there are some accident causes that may lead to multiple consequences, such as 'failure of ventilation facilities' may lead to 'failure of ventilation path', or 'explosion damages mine facilities'. For the above two types of reasons, it is necessary to determine their categories according to their consequences and the context in the accident investigation report. If the current information does not support the judgment, it will be counted separately. For example:

'The power outage caused the coal mine ventilation to be interrupted, and the gas gushed out of the goaf, causing the gas to accumulate in the 2110 mining face and reach an explosive concentration. After the generator was powered on, the operator violated the regulations and blasted, the blaster lost its explosion-proof performance, and sparks were generated to detonate the gas'.

'Do not use clay to fill the holes as required, do not implement the system of one blasting three times inspection, and do not use special blasters'

Both texts contain the accident causes about the blaster. However, the consequence of the former is arc sparks, and the consequence of the latter is that operators use informal blaster for blasting operations, namely external charge blasting. Therefore, the former is classified as 'failure of electrical equipment and its accessories', and the latter is classified as 'external charge blasting'.

Notably, accident causes with multiple consequences can cause cross-repetition of the sub-categories of different categories. Therefore, the classification needs to show the individual accident causes as well as focus on the causal logic of the accident causes. The final accident cause classification result is a chain of events, not individual categories. For example, the gas accumulation caused by the circulating air of the local ventilator, the final result of applying the classification method is: 'Local ventilator failure - circulating air - ventilation system failure - areas with insufficient effective air volume - gas concentration reaching the explosion limit'.

(2) Specifics take precedence over generals. The classification may establish multiple levels of detail to describe the same cause according to the details of the accident information, such as failure of equipment and facilities, failure of explosive devices, and failure of ventilators. These factors different levels of detail but have duplicate meanings. Thus, it is preferred to classify them as more specific reasons.

Appendix A: Basic Concepts

Table A1 Common subjects in equipment and facility failure modes

Number	Subject	Description
1	Ventilator	Refers to the equipment that provides the air source for the mine, including the main ventilator, auxiliary ventilator and local ventilator
2	Air ducts	A pipe that directs air flow in a certain direction, usually used on a working face where a local fan is used, including hard air ducts (e.g., iron air ducts) and flexible air ducts
3	Roadway	Various pathways drilled between the surface and the ore body assume the functions of transportation, ventilation, pedestrians and so on
4	Power supply	The power supply in this paper refers specifically to downhole power supply equipment, such as generators, supply loops, and backup power supplies
5	Electrical equipment and accessories	The general term of electrical and mechanical equipment that can produce electric arc spark or electric heat not only includes equipment with independent functions such as coal electric drill, submersible water pump and lighting device, but also includes accessories of electrical equipment such as comprehensive protection device, cable and junction box
6	Blasthole	A blasthole is a hole drilled in a blasted body such as rock or ore
7	explosive Devices	The explosive devices in this article refer specifically to explosive items in coal mines, such as explosives, detonators, detonating cords, etc.
8	Water control facilities	Refers to the equipment and facilities that undertake the function of preventing and controlling water, such as submersible pumps, water tanks, drainage pipes, etc.
9	Non-electrical equipment and facilities	The general term for equipment and facilities corresponding to electrical equipment and its accessories, characterized by the fact that other ignition sources other than arc sparks and electric heat can be generated due to the failure of its explosion-proof performance, such as diesel locomotives, lifting devices, etc.
10	Coal pillar	Unmined coal bodies reserved for the safety of surface construction and mine production within coal mining areas
11	Support equipment	Refers to the equipment used for roadway support, including wood support, single hydraulic prop, fully mechanized mining hydraulic support, bolt, anchor net, etc.

12	Ventilation facilities	The general term for all kinds of facilities that control the flow of mine air, including wind bridges, seal walls, dampers, air windows, etc.
13	Gas drainage facility	Refers to the gas drainage facilities used in gas prevention and control, such as gas drainage pumping stations, gas drainage pipelines, etc.
14	Dustproof facilities	Refer to equipment and facilities that undertake dust-proofing functions, such as wet sprayers, dust-proof water supply pipes, dust-proof covers, etc.
15	Two-locking devices	Refers to the wind-electric locking device and the gas-electric locking device
16	Gas monitoring equipment	Refers to a series of equipment and facilities for gas monitoring, including gas monitoring station, working face gas probe, portable gas alarm, alarm miner's lamp, etc.
17	Emergency equipment and facilities	Refers to the equipment and facilities that undertake post-disaster emergency rescue functions, including emergency hedging systems, self-rescuers, safety exits, personnel positioning systems, personnel positioning identification cards, etc.

Table A2 Mapping table of specific phases of the full life cycle and unsafe acts

Full life cycle	Keywords	Examples of specific unsafe acts
Installation	Not installed	No methane alarms are installed on the working face
	Poor installation quality	Poor quality of seal wall
	Wrong installation location	Improper installation location of local ventilator
Usage	Not used	Coal electric drill does not use comprehensive protection device
	Improper use	The busbar hangs on the metal anchor net during blasting
	Unauthorised use	Turn off the ventilator without authorization
Modification	Modification without authorization	Workers alter the structure of miner's lamp without authorization
Maintenance	No scheduled maintenance	Failure to maintain the safety monitoring system as required

	Not repaired in time	Damaged sensor was not repaired in time
	Improper maintenance	Use pliers to short the junction box terminals to test the bell and no ringing
Scrap	Not scrapping the equipment in time	Aging equipment is not eliminated in time
	Incomplete removal of the device	Incomplete withdrawal of rails in goaf
	Illegal removal of equipment	Unauthorized removal of the gas sensor on the working face
	Dismantling the device	Dismantling miner's lamp
Others	Bumping and hitting the device	Banging and hitting miner's lamp
	Other unsafe acts	……

Table A3 Sub-indicators of environmental factors

Number	Indicators	Description
1	Pressure	Refers to pressure-related factors such as natural wind pressure, fire wind pressure, gas pressure, surrounding rock pressure, etc.
2	Temperature	Refers to factors related to ambient temperature
3	Humidity	Refers to factors related to ambient humidity
4	Geological structure	Refers to factors related to geological structures that may affect gas occurrence and coal mining methods. Such as faults, fold structures, hydrogeological conditions, roof rock quality [13], etc.
5	In-situ stress	In-situ stress refers to the original rock stress in the crust without being disturbed by mining engineering [14]

Table A4 Subclass of pre-accident

Number	Indicators	Description
1	Gas burning	The mechanism is similar to that of gas explosion, which is a relatively slow oxidation reaction. Once the gas burns, the flame will spread rapidly along the accumulated gas, causing gas explosion
2	Permeability accident	It refers to the event in which surface water and ground water flow into the mine area uncontrollably through various channels such as fissures, faults, and subsidence areas. It usually acts as a factor leading to gas accumulation in gas explosion accidents.
2.1	Areas are connected (the ventilation system is not adjusted in time)	Area connection is the main channel for surface water and groundwater to flow into the mine area
2.2	Work disturbance	Various operations may induce permeability accident
2.3	Environmental factor	It refers to the existence of geological structures related to the occurrence of water sources around the mine.
2.4	Failure of water control facilities and measures	Including the failure of water prevention facilities and the ineffective implementation of measures related to water prevention, such as failure to take effective drainage measures, failure to predict and prevent hydrogeological conditions such as old kiln water, surface water, and groundwater sources around the mine
2.5	Failure of coal pillar	Coal pillars can act as isolation zones, mining or breaking coal pillars may lead to permeability accident
3	collapse	Including events such as roof falling, bottom bulging, side wall collapse, etc.
3.1	Empty roof	Refers to the suspended roof space in the coal mine
3.1.1	No measures were taken to deal with the empty roof	Including support, roof control and other safety measures to deal with the empty roof
3.2	Areas are connected (the ventilation system is not adjusted in time)	Area connection may cause the roof to exceed the limit span or generate other disturbances, which may induce collapse
3.3	Work disturbance	Various operations may induce collapse
3.4	Environmental factor	Geologically related environmental factors such as geological structure and roof hardness may induce collapse
3.5	Failure of coal pillar	Coal pillars can act as load-bearing walls and mining or breaking coal pillars can lead to collapse

3.6	Failure of support equipment	The support equipment is the main equipment for preventing the collapse. The main body of the specific failure mode has been described in detail in the previous section
4	Coal-rock dynamic disaster	Common dynamic disasters, including coal and gas outbursts, rock bursts, etc.
4.1	Areas are connected (the ventilation system is not adjusted in time)	Area connection, such as uncovering coal seams, uncovering faults, etc., may induce coal-rock dynamic disasters.
4.2	Work disturbance	Various operations may induce coal-rock dynamic disaster
4.3	Environmental factor	Environmental factors related to geology, such as geological structure, coal and gas occurrence, are one of the main factors leading to coal-rock dynamic disasters.
4.4	Failure of gas drainage facilities and measures	It has been described in detail above (Table A.1)
4.5	Failure of gas geological prediction facilities and measures	Refers to the prediction and exploration of the geological conditions around the mine, occurrence of gas and distribution of old empty areas

Appendix B: Individual Action Factors

Table B1 Sub-indicators of improper emergency rescue

Number	Indicators	Description
1	Failure to take effective measures to rescue	Including but not limited to: Rescue not organised, no continuous observation of the dangers in the disaster area, failure to restore air supply to other areas in time, failure to organise the evacuation of personnel from other areas in time, Managers flee, etc.
2	Failure to report dangerous situations in time	
3	Failure of emergency equipment and facilities	It has been described in detail above (Table A.1)

Table B2 Sub-indicators of improper labour organisation

Number	Indicators	Description
1	Multi-head operation	Refers to arranging more than a specified number of working faces to engage in production operations
2	Over-limit entry personnel	The actual number of people entering the coal mine exceeds the specified number
3	Hazardous work performed without proper safeguards	For example, no cordon off for blasting operations, failure to evacuate irrelevant workers to a safe distance, parallel work while performing hazardous work, etc.

Table B.3 Sub-indicators of secondary accidents

Number	Indicators	Description
1	Secondary coal dust explosion	Refers to coal dust explosion caused by gas explosion
1.1	Coal dust accumulation	Coal dust reaches explosive concentration
1.1.1	Improper ventilation distribution	Improper ventilation distribution will lead to excessive wind speed on the working face, blowing up the accumulated coal dust

1.1.2	Failure of dustproof facilities and measures	Including the failure of dust prevention facilities and the ineffective implementation of dust prevention-related measures, such as the failure to implement water spraying to reduce dust
2	Casualties in other areas	
2.1	Independent ventilation system	Independent ventilation system will cause the harmful gas to spread to other areas after the accident, resulting in the expansion of losses. For example, multi-face tandem ventilation and relying on the leakage ventilation of adjacent coal mines.
2.2	Explosion damages mine facilities	Refers to mine facilities damaged by shock waves generated by gas explosions, such as seal wall broken, damper broken, etc., which in turn leads to casualties in other areas
2.2.1	Failure of ventilation facilities	Mainly refers to the ventilation facilities do not meet the disaster resistance strength
3	Gas in other areas involved in the explosion	Refers to gas explosion in other areas after gas explosion
4	Secondary other accident	Refers to non-coal dust explosions, fires and other accidents caused by gas explosions

Table B4 Sub-indicators of areas with increased gas content

Number	Indicators	Description
1	Large amount of gas escape	Refers to the situation in which gas slowly gushes out from areas prone to gas accumulation, such as geological structures and confined spaces
1.1	Failure of gas extraction facilities and measures	Including the failure of gas extraction facilities and the ineffective implementation of measures related to gas extraction, such as failure to implement gas pre-drainage, etc.
1.2	Failure of gas geological prediction facilities and measures	It has been described in detail above (Table A.1)
2	Gas distribution mutation	Refers to the situation in which the gas distribution in the region changes in a short period of time under the induction of gas geological disasters or other external forces

2.1	Failure of gas emission measures	Here it refers specifically to 'one-time emission of gas'
3	Area Gas Release	Refers to gas escaping from confined spaces to other production areas
4	Common causes	Refers to the common cause of large amount of gas escape or gas distribution mutation
4.1	Environmental factor	Mainly refers to environmental factors related to gas pressure and gas occurrence
4.2	Work disturbance	Mainly refers to the factors such as blasting, drilling and mining stress
4.3	Pre-accident	Some other accidents, such as coal and rock dynamic disasters, collapses, and permeability accident will lead to large amount of gas escape or gas distribution mutation
4.4	Failure of ventilation facilities	Poor quality of ventilation facilities such as seal wall can lead to large amount of gas escape or gas distribution mutation
4.5	Areas are connected (the ventilation system is not adjusted in time)	The connection of areas such as surrounding rock and roadway cracks will lead to large amount of gas escape or gas distribution mutation

Table B5 Sub-indicators of ventilation system failure

Number	Indicators	Description
1	Circulating air	Refers to the return air flow of the local ventilator re-merges into its intake air flow. When there is circulating air, the dirty air cannot be effectively discharged, which may easily lead to gas accumulation
1.1	Failure of ventilator	
1.1.1	Ventilator life cycle	Mainly refers to the wrong installation position of the local ventilator, such as installed on the return air side, installed on the roadway, too close to the roadway entrance, etc.
1.1.2	Suction air volume of the local ventilator is greater than the air supply volume	

2	Failure of ventilation path	Refers to the situation that the ventilation path cannot complete the air supply function due to air leakage, blockage, short circuit, etc.
2.1	Areas are connected (the ventilation system is not adjusted in time)	It has been described in detail above (Table B.4)
2.2	Failure of air duct	Refers to the non-standard hanging of the air duct, damage, the use of plastic woven bags instead of the air duct, etc.
2.3	Failure of roadway	Refers to the situation that the roadway is blocked or the section is reduced due to collapse
3	Insufficient ventilation of the air source	Insufficient air volume provided by main and local ventilators
3.1	Failure of ventilator	The main reason for the insufficient ventilation of the air source is that the ventilator stops running or its performance is insufficient.
4	Unstable ventilation system	Some factors will not immediately lead to gas accumulation, but will greatly affect the stability of the ventilation system
4.1	Areas are connected (the ventilation system is not adjusted in time)	It has been described in detail above (Table B.4)
4.2	Improper development layout	Unreasonable development layout refers to the unreasonable layout of coal mining face, driving face and other roadways
4.3	Production beyond limits	Production beyond limits or illegal mining will increase the air demand in the mine, resulting in unstable ventilation system
4.4	Local ventilator multi-head air supply	Refers to a local ventilator supplying air to multiple working faces
4.5	Local ventilator relay ventilation	Refers to multiple local ventilators connected in series for ventilation
4.6	High cost of ventilation management	Refers to the excessive and miscellaneous settings of roadways and ventilation facilities, resulting in high ventilation management costs and difficulty in maintaining ventilation systems
4.7	Independent ventilation system	Refers to multi-face tandem ventilation and relying on the leakage ventilation of adjacent coal mines

4.8	Improper ventilation distribution	Refers to the situation that the air distribution in the mine area does not meet the requirements of the regulations, or the wind measurement has not been carried out, and the wind measurement record is false, etc.

Table B6 Sub-indicators of areas with fresh wind flows in

Number	Indicators	Description
1	Areas with fresh wind flows in	Refers to the scenario in which the gas concentration reaches the explosion limit due to the influx of fresh wind in the high-concentration gas area
1.1	Failure of ventilation path	The failure of ventilation path here mainly refers to air leakage, which is the main reason for the influx of fresh air into the high-concentration gas area.

Table B7 Sub-indicators of ignition source

Number	Indicators	Description
1	Arc sparks or electric heat	Refers to arc sparks and electric heat generated by electrical equipment
2	Blaster flame	Refers to blasting flames produced by explosives, excluding arc sparks produced by electrical explosion networks
3	Friction collision sparks	Refers to the sparks produced by the friction and collision of objects
4	Coal spontaneous combustion	Refers to the flame or heat radiation produced by coal spontaneous ignition, re-ignition in the fire area, smoldering in the fire area, etc.
5	Other open flames and heat radiation	Other ignition sources or heat radiation, such as smoking downhole, welding operations, etc.

Table B8 Sub-indicators of arc sparks or electric heat

Number	Indicators	Description
1	Failure of electrical equipment and its accessories	The failure modes mainly include explosion-proof performance failure, short circuit, leakage and overload. The main body of failure mode has been described in detail above (Table A.1)
1.1	Electrical equipment life cycle	It mainly exists in the use and maintenance stage of the whole life cycle, such as frequent switching of power supply, circuit detection by short-circuit, live maintenance, etc.
2	The electrical equipment is not firmly connected to the power source or falls off	This scenario can cause the contacts between the electrical equipment and the power source to be smaller than the discharge gap, resulting in arcing sparks
3	Carry items that are prone to static electricity into the coal mine	Such as wearing non-anti-static work clothes, carrying non-explosion-proof mobile phones and other utensils into the coal mine

Table B9 Sub-indicators of blaster flame

Number	Indicators	Description
1	Failure of blasthole	Means that the blasthole is not drilled or the blasthole parameters do not meet the specification requirements
2	Continuous blasting work	Refers to the act of continuing to carry out blasting without discharging and inspecting gas after blasting
3	Failure of explosive devices	The categories of explosive devices have been described in detail above. The failure of explosives includes the use of non-mining explosives, expired explosives, excessive charge, etc.
4	External charge blasting	Refers to the use of no blaster or the use of informal equipment as a source of ignition for detonating explosives.
5	One charging and multiple blasting	It refers to the blasting of explosives in two or more times during full-section blasting. The gas or coal dust produced by the previous blasting can easily be ignited by the flame produced by the subsequent blasting. In addition, other blastholes may be affected when detonating in different stages, affecting the blasting effect, which is very dangerous.

6	No cannon mud is used to seal the hole or the amount is not enough	Cannon mud refers to the cannon mud and water cannon mud used to plug the blasthole

Table B10 Sub-indicators of coal spontaneous combustion

Number	Indicators	Description
1	Areas with fresh wind flows in	The influx of fresh wind will provide sufficient oxygen conditions for the coal to spontaneously ignite
2	Failure of fire-fighting facilities and measures	Including the identification of coal seam spontaneous combustion tendency, specific measures such as grouting and flame retardants, and fire prevention and fire extinguishing systems such as fire monitoring and monitoring

Table B11 Sub-indicators of friction collision sparks

Number	Indicators	Description
1	Frictional collision between objects	Refers to the frictional collision between objects, such as the winch wire rope friction against the rock wall, the collision between the gangue, etc.
2	Frictional collisions inside objects	Refers to the friction and collision of internal components of equipment and facilities, such as fan blade friction shell of fan, gear friction of scraper conveyor, etc.
3	Common causes	Refers to the common cause of friction and collision
3.1	Work disturbance	All kinds of work can cause friction and collision sparks
3.2	Pre-accident	Some pre-accidents will be accompanied by dynamic phenomena, which will impact the surrounding environment, equipment and facilities, resulting in friction and collision sparks.
3.3	Failure of non-electrical equipment and facilities	Including deformation of equipment, internal components or shells of facilities, failure of explosion-proof performance, etc. The main body of failure mode is mainly equipment and facilities that do work through mechanical motion

Table B12 Sub-indicators of other open flames and heat radiation

Number	Indicators	Description
1	Failure of non-electrical equipment and facilities	The failure modes under this category are mainly explosion-proof performance failures. The main body of the failure mode is non-electrical equipment and facilities, such as diesel locomotives, tricycles and other transportation and lifting equipment
2	Illegal welding operations	Refers to illegal welding or cutting operations
3	smoking	

Table B13 Sub-indicators of the encounter mode

Number	Indicators	Description
1	Blindly sending electricity	Refers to the transmission of electricity to the area without detecting the gas concentration in the power outage area
2	Areas are connected (the ventilation system is not adjusted in time)	It has been described in detail above (Table B.4)
3	Failure of the two locking devices	The body of this failure mode has been described in detail above (Table A.1)
4	Operator is working in the wrong place	Refers to the operator working in the area that is expressly prohibited in the regulations or the area where there are obvious danger signs
4.1	Illegal command	Refers to the acts of managers who violate safety policies, laws, regulations, procedures, and systems to direct front-line employees. Illegal command is an unsafe action issued by management personnel, including but not limited to: failure to take improper steps to protect workers in a hazardous situation
4.2	Adventure operation	Refers to the situation in which the operator still carries out the operation even when the danger is found. The specific situations mainly include: Continue to operate or refuse to obey the evacuation instructions issued by management personnel after finding that the gas concentration exceeds the limit or other obvious danger signs

5	No gas reaches the explosive limit	
5.1	Gas inspection not strictly enforced	Refers to unsafe acts related to gas inspection, which cause operators to fail to detect gas concentration exceeding the limit in time. Specifically: not checking gas, not checking gas carefully, etc.
5.3	Unidentified gas level	
5.4	Failure of gas monitoring equipment	The body of this failure mode has been described in detail above (Table A.1)

Appendix C: Management System Factors

Table C1 Sub-indicators of organisational unsafe behaviour

Number	Indicators	Description
1	Avoid, resist or ignore departmental supervision	Refers to the organisational behaviour of mines evading, resisting, ignoring supervision orders issued by superior departments, and organising production in violation of regulations
2	Organisations without production qualifications	Refers to coal mining enterprises or mines that do not have production qualifications, including missing or expired licenses such as 'Mining License', 'Coal Production License', 'Safety Production License', and the mine is ordered to stop production or rectify, etc.
3	Insufficient security investment	Refers to the lack of economic investment in ensuring the personal safety of employees in the mine

Table C2 Sub-indicators of safety management system deficiencies

Number	Indicators	Description
1	Failure of safety management organisational structure	Refers to the safety management organisational structure cannot properly play the function of safety management
1.1	Improper organisational structure	For example, there is no special safety management organisation or the management relationship between departments is chaotic, etc.
1.2	Insufficient number of relevant personnel or no full-time personnel	For example, the number of safety inspector or gas inspector is insufficient
2	Failure of safety management system	It means that the safety management system cannot play the role of guiding and regulating the behaviour of employees normally
2.1	System not established	The accident organisation has not formulated relevant systems

2.2	System formulation, approval process is not strict	System or procedure formulation process is not strictly approved
2.3	Incomplete system content	The content of the system is lacking
2.4	Inadequate implementation of the system	The system is not effectively implemented

Table C3 Sub-indicators of safety management system

Number	Indicators	Description
1	Mining management system	Management system related to coal mining, excavation, retraction, roadway support, etc.
2	Blasting management system	Management systems related to the storage, transportation and usage of blasting materials, including 'One blasting three times inspection' and 'three-people-interlocking'
3	One ventilation and three prevention management system	Including ventilation and gas management system, fire-fighting management system and dust management system
3.1	Ventilation and Gas Management System	Management systems related to ventilation and gas, including regulations on air demand in various areas of the mine, daily gas inspection and records
3.2	Fire-fighting management system	Management systems related to fire prevention, fire zone management and welding operations
3.3	Dust management system	Management system related to dust control
4	Water infiltration management system	Management system related to water control
5	Electromechanical equipment management system	Management system related to the life cycle of electromechanical equipment

6	Coal-rock dynamic disaster prevention and management system	Management system related to coal, rock, gas, carbon dioxide outburst prevention, and rock burst prevention
7	Monitoring and Communication Management System	Management system related to mine monitoring and communication equipment and facilities, including daily maintenance of methane sensors and other sensors
8	Hierarchical supervision system	Refers to the supervision and management between the internal levels of the organisation, including the relevant management systems for branch companies and contract units, such as the review of contract unit qualifications, the supervision of branch companies, and the safety management of third-party operators
9	Risk control and hazard screening system	Management systems related to risk management and control and hazard source investigation, including: proactively conducting hazard source investigation and rectification, proactively conducting risk assessment, management and control, and accepting orders from the regulatory authorities for suspension of production and rectification, etc.
10	Employee qualification assessment and training system	Management systems related to qualification review and training of coal mine employees
11	Coal mine entry inspection and personnel record system	Management systems related to personnel entering and leaving the coal mine, including: checking whether the personnel conform to the regulations for entering the coal mine, and counting and recording the number of personnel entering the coal mine
12	Regular safety meeting and special safety meeting system	Relevant management system for holding regular safety meetings on a regular basis and special safety meetings for special events
13	Emergency rescue management system	Refers to the management system related to emergency rescue work, including emergency plans, daily maintenance of emergency equipment and facilities, agreement and management of mine rescue teams, emergency training, etc.

Table C4 Sub-indicators of the generic sub-system

Number	Indicators	Description
1	Shift system	Refers to the system related to shift handover, including pre-job handover, pre-shift meeting
2	Safety production responsibility system	Refers to the clear division of safety responsibilities in each system
3	Labour discipline management system	Mainly refers to the management system related to job attendance
4	System implementation document record	The system should form documents such as text and drawings to ensure its effectiveness. The text includes policy documents, system documents, gas reports, operating procedures, etc.; the drawings include ventilation system drawings, mining engineering drawings, power supply system drawings, etc.

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