# Analysing Risk Factor Identification for Deep Well Casting and the Current Situation of Safety Management in China

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**Abstract**

In recent years, several explosion accidents have occurred in the aluminium industry using Deep Well Casting also known as DC Casting pits. These accidents caused not only serious casualties but also near disasters. To effectively prevent and control explosion accidents in the Deep Well industry. This paper, firstly, starts from the mechanism and necessary conditions of deep-well casting explosions and provides a detailed analysis and introduction; secondly, summarizes the current main measures for explosion protection in Deep Well and describes the mandatory requirements imposed on deep-well casting enterprises by our safety authorities. Through these analyses, the aim is to provide scientific safety management guidance and accident prevention strategies for the Deep Well industry to reduce the occurrence of similar accidents and ensure personnel safety and production stability.

**Keywords:** Deep well, Risk factor identification, Safety management.

## 1. Introduction - Raising of the Problem

In recent years, production safety accidents in aluminium processing (Deep Well Casting or DC casting pits) enterprises have shown a tendency of frequent occurrence, bringing serious losses to the lives and properties of enterprises and employees, and attracting high attention from all sectors of society. The following are several typical accident cases:

On August 31, 2024, an aluminium liquid-water explosion accident occurred in the casting workshop of Shanxi Southeast Seiko Technology Co., Ltd. in Lüliang City, Shanxi Province, resulting in 3 deaths and 10 injuries. Before the accident, the cooling water pump relay had experienced multiple power outages and tripping, which was an obvious sign of equipment abnormality. However, the operators of the enterprise had a weak safety awareness and continued to organize production without thoroughly troubleshooting and completely repairing the fault. It was precisely this illegal operation that led to the cutoff of cooling water and eventually triggered the aluminium liquid-water explosion. The operators failed to fully recognize the serious consequences that equipment abnormalities might bring about and lacked sufficient attention to safety hazards. They took risks and continued working without solving the fundamental problems, which became the key human factor in the occurrence of this accident.

Similarly, on July 26, 2024, an aluminium liquid-water explosion accident also occurred in the deep well casting workshop of Henan Zhongrui Nonferrous Metal Materials Co., Ltd. in Shangqiu City, Henan Province, causing 5 deaths and 14 injuries. This accident also exposed the problem of illegal operations by operators. During the daily production process, the operators might not have carried out equipment inspection and maintenance in strict accordance with the safety operation procedures and turned a blind eye to the potential safety risks. When the aluminium liquid come into contact with water during the casting process, due to the lack of correct emergency treatment measures and sufficient safety awareness, a tragedy was finally caused.

In addition, there were several similar accidents in 2024. For example, on July 9, an aluminium liquid-water explosion accident occurred in the casting workshop of Fuan Aluminium Industry Co., Ltd. in Fuzhou City, Fujian Province, resulting in 2 deaths and 1 injury. On February 18, an aluminium liquid-water explosion accident occurred in the melting workshop of Asia-Pacific Light Alloy (Nantong) Technology Co., Ltd. in Nantong City, Jiangsu Province, causing 5 deaths and 13 injuries. Moreover, looking back at the past, similar metal smelting accidents were also common. See Table 1 for details.

**Table 1. List of liquid metal accidents.**

| Time | Accident Name | Casualties | Remarks |
|---|---|---|---|
| 2007 | "8·19" Aluminium Liquid Overflow and Explosion Accident of Shandong Weiqiao Pioneering Group | 20 deaths, 59 injuries (including 13 seriously injured) | |
| 2018 | "8.28" Larger Explosion Accident of Jiangyin Yize Aluminium | 5 deaths, 1 seriously injured | Deep well casting |
| 2022 | "4·3" Larger Explosion Accident of Guangdong Jingmei Special Profile in Qingcheng, Qingyuan | 5 deaths | Deep well casting |
| 2023 | "10·20" Larger Explosion Accident of Guangxi Xingyue Material Technology in Pingguo City, Baise | 6 deaths, 5 injuries | Deep well casting |
| 2024 | Aluminium Liquid-Water Explosion Accident of Asia-Pacific Technology in Haian City, Nantong, Jiangsu Province | 5 deaths, 13 injuries | Deep well casting |
| 2024 | Aluminium Liquid-Water Explosion Accident of Fuan Aluminium Industry in Fuzhou City, Fujian Province | 2 deaths, 1 injury | Deep well casting |
| 2024 | Aluminium Liquid-Water Explosion Accident of Henan Zhongrui Nonferrous Metal Materials in Yongcheng City, Henan Province | 5 deaths, 14 injuries | Deep well casting |
| 2024 | Aluminium Liquid-Water Explosion Accident of Shanxi Southeast Seiko Technology in Lüliang City, Shanxi Province | 3 deaths, 10 injuries | |

These actual cases fully demonstrate a serious fact: the illegal operations and weak safety awareness of operators will bring great safety hazards to deep well casting production. Therefore, enterprises must strengthen the safety education and training for operators, effectively improve their safety awareness and operation skills, strictly implement safety regulations and systems, and eliminate illegal operations, to effectively prevent and reduce safety accidents caused by human factors.

## 2. Process Flow and Risk Factor Analysis of Deep Well Casting

### 2.1 Process Flow of Deep Well Casting

Deep well casting is a casting process commonly used for the forming of metal materials such as aluminium and aluminium alloys. Its basic principle is to use the effect of gravity to make the molten metal enter the crystallizer through the gate and gradually solidify and form under the action of water cooling.

In the preparation stage, it is necessary to melt the raw materials. Raw materials such as aluminium ingots are put into the furnace and heated to a molten state. At the same time, refining treatment is carried out to remove impurities and gases to ensure the quality of the metal liquid. Then, the refined metal liquid is transferred to the holding furnace to maintain its temperature and fluidity. After that, the metal liquid is slowly injected into the crystallizer installed in the deep well through the gate. There is cooling water circulating outside the crystallizer. The metal liquid contacts the water-cooled wall in the crystallizer, which rapidly cools and solidifies, and forms the outer layer of the ingot. As the metal liquid is continuously injected, the ingot gradually grows downward. During the casting process, it is necessary to precisely control parameters such as the injection speed of the metal liquid, the amount of cooling water, and the temperature to ensure the quality and dimensional accuracy of the cast ingot. When the ingot reaches the predetermined length, the injection of the metal liquid is stopped. After the ingot is completely cooled, it is taken out from the deep well for subsequent processing.

The whole deep well casting process has extremely high requirements for the control of process parameters. Any deviation in any link may affect the quality of the ingot and production safety.

### 2.2 Risk Factor Analysis of Deep Well Casting

The main equipment, facilities and personnel in deep well casting are usually concentrated. It mainly consists of equipment and facilities such as melting furnaces, holding furnaces (melting and holding integrated furnaces), casting units, bridge cranes, and sawing machines. In recent years, due to factors such as the low level of inherent safety of the deep well casting system and the production organization mode, multiple major production safety accidents have occurred continuously, making it a key area of national safety supervision.

At the same time, due to the limitation of the operation area in the production process, there are cross operations of forklifts, overhead cranes, vacuum ladle trucks, etc. During the casting process, if problems such as personnel absenteeism, aluminium running out, aluminium leakage, aluminium water overflow are not handled in a timely manner, new or wet residual aluminium boxes are used, and the moulds and tools in front of the chute are not fully preheated and dried before use, accidents are very likely to occur once they encounter water or moisture. When high-temperature molten metal contacts water, a large amount of steam will be generated instantaneously. The steam expands rapidly and will trigger an explosion in a limited space. For example, if the cooling system leaks, the site water accumulation is not cleaned up in a timely manner, or protective measures are not taken well when working in humid weather, the situation where the molten metal meets water may occur, and the explosive power will often cause great damage to personnel, factory building structures, etc.

In addition, during the deep well casting process, the temperature of the molten metal is usually very high. Once the operators accidentally come in contact with the molten metal in the process of lifting, pouring and other circulation processes, or the protection is improper when cleaning the chute, furnace mouth and other parts, they are very likely to be scalded by the high-temperature metal, causing serious surface injuries. Moreover, when pouring molten metal into the mould, if the pouring speed is not properly controlled, the ladle has defects, or there are problems in the mould cavity (such as blockage, poor exhaust, etc.), the molten metal may splash out, splash onto the surrounding personnel, causing burn and scald accidents, and may also damage the surrounding equipment and facilities.

To sum up, there are many safety risks on the site of deep well casting, mainly including aluminium liquid explosion, high-temperature scalding and other hazards.

## 3. Safety Precautions and Related Production Safety Management Policies for Deep Well Casting

### 3.1 Early Policies and Regulations

The construction of policies and regulations for the safety management of deep well casting in China was gradually promoted along with the development of industry. In the 1980s and 1990s, China's industry began to develop rapidly, the scale of the deep well casting industry gradually expanded, and safety problems became increasingly prominent. As a result, relevant policies and regulations emerged.

In the early 21st century, the "Work Safety Law" was officially implemented in 2002. As a comprehensive basic law in the field of work safety in China, this law has comprehensively regulated various aspects such as the work safety guarantee of production and operation units including deep well casting, the rights and obligations of employees, and the supervision and management of work safety. Its promulgation marked the initial formation of the policy and regulation system for the safety management of deep well casting in China, laying a solid legal foundation for the safe development of this industry.

### 3.2 Gradual Improvement of Policies

#### 3.2.1 Source Governance:

The "Industrial Structure Adjustment Guidance Catalogue" clearly defines the equipment to be eliminated and restricted. The "Criteria for Judging Major Accident Hazards in Industrial and Trade Enterprises" (Order No. 10 of the Ministry of Emergency Management in 2023) lists the situations that should be judged as major accident hazards, to control risks from the source.

#### 3.2.2 Standard Refinement

With the continuous development of the deep well casting process, the early broad standards have been difficult to meet the actual needs. Relevant departments have begun to formulate more detailed industry standards and conduct detailed specifications from aspects such as the safety performance of deep well casting equipment, process parameters, and operation procedures. For example, specific safety indicators of equipment such as melting furnaces and casting furnaces are clearly defined, so that enterprises have more accurate references in production. Among them, the "Seven Requirements for Aluminium" mainly puts forward requirements for the equipment and facilities and working environment of deep well casting, such as standardizing the setting of liquid level monitoring, cooling water system monitoring, and emergency discharge or emergency storage facilities, to reduce the probability of accidents by eliminating safety hazards and thus ensure the life safety of employees. Standards such as "Safety Requirements for Foundry Machinery" (GB 20905) put forward clear requirements for the safety performance of casting equipment.

In addition, relevant safety technical specifications such as the "Safety Specification for Aluminium Processing (Deep Well Casting)" in the AQ industry standard, the "Safety Technical Specification for Aluminium and Aluminium Alloy Deep Well Casting" (DB44/T 2480 - 2024) in Guangdong Province, and the "Safety Specification for Non-ferrous Metal Deep Well Casting Process" (DB32/T 3850 - 2020) in Jiangsu Province have all made detailed regulations on the basic safety requirements, plant layout, equipment and facilities, process safety, operation safety norms, and emergency response in the production process of aluminium processing (deep well casting), providing professional technical specifications and management requirements for the production safety of aluminium processing deep well casting enterprises. These laws, regulations

and standard specifications cooperate with each other to jointly build a policy system for the safety management of deep well casting.

### 3.2.3 Strengthened Supervision

To ensure the effective implementation of policies, the supervision intensity has been continuously strengthened. A stricter enterprise access system has been established, and it has been ensured that safety facilities must be designed, constructed, and put into production and use simultaneously with the main project, to ensure that the production safety conditions are implemented simultaneously with the main project. Newly established deep well casting enterprises are comprehensively reviewed, and strict checks are carried out from aspects such as site selection, equipment, and personnel. On the other hand, the frequency and depth of daily inspections have been increased, and advanced detection technologies and equipment have been used to detect and eliminate safety hazards in a timely manner.

For example, in 2010, the state issued the "Criteria for Judging the Work Safety Standardization of Electrolytic Aluminium (Including Casting and Carbon) Enterprises". Chinalco has established the CAHSE system and established the CARMS (Safety Risk Management Standard System) in 2025, cultivated a team of group-level assessors, and organized professional teams to conduct supervision and inspection of enterprises to strengthen supervision.

### 3.2.4 Improvement of Emergency Management

In view of the seriousness of deep well casting accidents, emergency management has become one of the key contents of policy improvement. Enterprises should formulate emergency plans for emergencies (such as water stoppage, power failure, furnace leakage, aluminium leakage, casting system failure, cooling water system failure, gas leakage, explosion, etc.) in the casting workshop, equip necessary emergency rescue equipment and materials, and organize regular drills. Government departments have also established emergency response mechanisms to improve the ability to respond to sudden accidents and minimize accident losses.

### 3.2.5 Strengthening Enterprise Safety Investment

According to the "Measures for the Withdrawal and Use of Enterprise Work Safety Expenses" (No. 136 of the Ministry of Finance in 2022), enterprises need to ensure capital investment in the safety management of deep well casting. On the one hand, it is necessary to conduct regular maintenance and renewal of casting equipment to ensure the safety performance of the equipment. On the other hand, it is necessary to equip complete and standard-compliant safety protection facilities. At the same time, capital should also be invested in the construction of emergency rescue facilities to deal with sudden safety accidents.

### 3.2.6 Personnel Training

Enterprises must conduct comprehensive safety training for employees. The main person in charge and safety management personnel of enterprises should participate in the initial safety education and training for no less than 48 class hours and should also participate in the continuing education and training for no less than 16 class hours every year, to possess the work safety knowledge and management ability suitable for the production and operation activities of the enterprise. The three-level education and training for personnel in positions such as melting and casting should not be less than 72 class hours, and the annual retraining should not be less than 20 class hours. The training content covers work safety laws, regulations and rules, casting process flow, identification of safety risks in each process link and specific preventive measures, wearing and use of personal protective equipment, operation procedures of casting equipment,

emergency response and rescue, etc. Enterprises should also regularly organize training and assessment to ensure that employees possess corresponding safety knowledge and skills.

#### 3.2.7 Hidden Danger Investigation

Enterprises should establish and improve the hidden danger investigation and treatment system and regularly conduct comprehensive investigations on the production process of deep well casting. Check the equipment and facilities to see if there are safety hazards, such as whether the operating state of the equipment is normal and whether the connection parts are loose. Investigate the working environment to see if there are factors that may cause accidents, such as water accumulation. For the safety hazards found out, timely rectification should be carried out, and the person responsible for rectification, rectification measures and rectification period should be clearly defined to ensure that the hidden dangers are eliminated in a timely manner.

## 4. Suggestions and Prospects

### 4.1 Strengthening Policy Publicity and Training

In order to effectively improve the safety awareness and policy implementation ability of enterprises and employees, it is necessary to adopt multi-dimensional policy publicity and personnel training measures.

Various channels can be used for wide dissemination. Through official websites, social media platforms, etc., the interpretation of deep well casting safety management policies and the analysis of typical cases can be regularly released, so that enterprises and employees can timely understand the policy dynamics and requirements. At the same time, policy publicity meetings can be organized to conduct on-site explanations in enterprises, explain the key and difficult points of policies in detail, and answer the questions of enterprises. In addition, promotional brochures, posters and other materials can be produced and distributed and posted in enterprises, industry associations and other places to create a strong policy publicity atmosphere. In terms of personnel training, enterprises should formulate systematic training plans. For newly recruited employees, induction safety training should be carried out to make them understand the safety risks and basic operation norms of the deep well casting industry. For in-service employees, professional skill improvement training should be regularly organized, and experts should be invited to give lectures to explain the latest safety technologies and processes. At the same time, emergency drill training should be strengthened, and accident scenarios such as fire and explosion should be simulated to make employees familiar with the emergency response process and improve their emergency response ability. Government departments can also organize unified training activities to conduct centralized training for enterprise leaders and safety management personnel to strengthen their safety management awareness and ability. Through these measures, the safety awareness and policy implementation ability of enterprises and employees can be comprehensively improved.

### 4.2 Strengthening the Intensity of Supervision and Law Enforcement

#### 4.2.1 Innovative Supervision Technology

Introduce advanced technologies such as the Internet of Things, big data, and artificial intelligence to conduct real-time monitoring of deep well casting enterprises. By installing sensors in key equipment and working environments, collect information such as equipment operating parameters and environmental data, to achieve precise early warning and rapid disposal of safety hazards.

#### 4.2.2 Implementation of Differentiated Supervision

Implement differentiated supervision according to factors such as the safety management level and risk level of enterprises. For enterprises with better safety management and lower risk, appropriately reduce the inspection frequency; for enterprises with weak safety management and higher risk, increase the inspection frequency and intensity and implement key supervision.

#### 4.2.3 Strengthening the Training of Law Enforcement Personnel

Regularly organize law enforcement personnel to participate in professional training to improve their professional level and comprehensive quality. The training content includes laws and regulations, safety technical standards, law enforcement procedures and other aspects to ensure that law enforcement personnel can accurately grasp the policy requirements and strictly standardize law enforcement.

#### 4.2.4 Strengthening Social Supervision

Establish and improve the reporting and reward system, encourage the public to report the safety violations of deep well casting enterprises. For those whose reports are verified, give certain rewards to the informants to form a good atmosphere of the whole society participating in supervision together.

### 4.3 Promoting Technological Innovation and Application

Promoting the safety technological innovation in the deep well casting industry and encouraging enterprises to adopt advanced safety technologies and equipment are the key measures to enhance the overall safety level of the industry.

In terms of monitoring and early warning technologies, enterprises can introduce advanced sensors and monitoring systems to conduct real-time monitoring on key parameters in the casting process, such as temperature, pressure, and liquid level. Through big data analysis and artificial intelligence algorithms, abnormal situations can be detected in a timely manner, and warnings can be issued, providing decision-making basis for operators and avoiding the occurrence of accidents. For example, by using infrared thermal imaging technology to monitor the temperature of furnaces and ingots, potential thermal faults can be detected in time, and measures can be taken in advance for handling.

The application of automation and intelligent technologies is also an important direction. The adoption of automated casting equipment and production lines can reduce manual operations and lower the safety risks caused by human factors. For instance, realizing the automatic pouring of molten metal and the automatic removal of ingots can prevent operators from directly contacting high-temperature molten metal and dangerous equipment. Meanwhile, intelligent control systems can automatically adjust process parameters according to the production situation, improving the stability and safety of production.

In addition, the research, development, and application of new materials and protection technologies cannot be ignored. The research and development of new casting materials that are resistant to high temperature and corrosion can extend the service life of equipment and improve its safety. The adoption of advanced protection materials and technologies, such as thermal insulation coatings and protective barriers, can effectively reduce the harm caused by high temperature, radiation, etc. to operators.

By promoting technological innovation and application, the deep well casting industry can achieve inherent safety, improve production efficiency and quality, and promote the sustainable development of the industry.

### 4.4 Establishing a Long-Term Mechanism

To establish a long-term mechanism for deep well casting safety management, it is necessary to start from multiple aspects such as systems, technologies, and cultures to ensure the long-term safe and stable development of the industry.

At the institutional level, it is required to continuously improve the regulatory and standard systems, update relevant policies in a timely manner according to the development of the industry, further clarify the responsibilities of all parties, and establish strict access and exit mechanisms. Meanwhile, strengthen the construction of supervision systems, build a joint supervision network involving multiple departments, and achieve normalized and precise supervision to ensure that the development of the industry is always on a standardized and orderly track.

At the technological level, it is necessary to unremittingly promote the innovation of safety technologies, encourage enterprises to increase their investment in research and development, actively promote and apply advanced monitoring and early warning, automation, and protection technologies, and continuously enhance the inherent safety level of the industry, thus building a solid safety defence line at the technological level.

At the cultural level, strengthening the construction of safety culture is of vital importance. Through diversified means such as publicity, education, and training, the safety awareness and sense of responsibility of enterprises and employees can be enhanced. In addition, an accident case database and an experience sharing platform should be established to facilitate exchanges and learning among enterprises, jointly improve the safety management level, make the safety concept deeply rooted in people's hearts, and become the internal driving force for the development of the industry.

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