

# Analysis of identification of unsafe behavior in mechanical operation of first line workers

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**Abstract.** The occurrence of mechanical accidents in petroleum enterprises is closely related to the operation of frontline workers. Based on the behavior observation method, the paper takes a petroleum enterprise as objective to identify the unsafe behavior of the operation workers and its contributing factors. The influences of the different factor on the mechanical operation are investigated by using the analytic hierarchy process. The results show that there are eight kinds of unsafe behaviors of the mechanical operation in the petroleum enterprise. The factors that induce the unsafe behaviors include safety knowledge, safety consciousness, emotion, physiological conditions, safety attitude, manager behavior, management system, production task and human environment. Among them, safety attitude, safety consciousness, manager behavior and production task are the most important factors. Therefore, the safety production capacity of the frontline workers in petroleum enterprises should be improved through safety education training, manager lead demonstration, enterprise safety culture construction.

## 1 Introduction

The characteristics of oil industries is flammable, explosive, toxic, harmful, high temperature, high pressure and continuous production, which leads to frequent production accidents<sup>[1]</sup>. Safety management has become the focus of sustainable development of petroleum enterprises.

Compared with other high-risk industries, there are many machineries and equipments, and the high level of automation in the petroleum industry. Once the operation fails, it will lead to shutdown, fire, explosion, environmental pollution, personal injury and other accidents. According to the accident statistics, it indicates that most of the mechanical accidents are directly related to the human operation<sup>[2]</sup>. The reliability of the human operation has become a decisional factor that affect the normal operation of the equipment and the prevention of accidents. In order to realize the safety production and reduce the accident, it is necessary to prevent and reduce the unsafe behavior of the workers in the operation of machinery and equipment. Therefore, taking a petroleum enterprise as the example, the paper identifies the unsafe behaviors in mechanical operation and its influencing factors by using the observation method. The influence degree of the influencing factors are analyzed by using Analytic hierarchy process method. The effective measures are taken to reduce the unsafe behaviors to improve the safe production capacity of petrochemical industry enterprise workers.

## 2 Identification of unsafe operation of machinery and equipment for petroleum workers

### 2.1 Identification methods and data sources

Because the operation behavior of mechanical equipment usually occurs on the job site, the behavior safety observation method is used to identify the unsafe behavior of employees and its contributing factors. Behavior safety observation method is that the observers directly observe the behaviors and reactions of the objects of study by using their senses and auxiliary tools in the field based on the research purpose<sup>[3]</sup>, the research outline or behavior safety observation table, in order to obtain data. The method is widely used in human unsafe behavior management in coal mines and other high-risk enterprises. It can effectively detect the hidden danger and danger in safety production staff.

The implementation of the behavior safety observation can be divided into three parts: analysis of tasks, implementation of safety behavior observation and recording of observation results. Among them, the implementation of behavior safety observation is the core, including the determination of observation objectives, the determination of the scope of behavior observation, field observation, and communication. In order to deeply analyze the causal factors of unsafe behavior in mechanical operation, the depth interviews with key personnel should be conducted during communication.

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## 2.2 Data sources

All work stations of oil production plant affiliated to PetroChina Co Ltd are taken as research object. The company is mainly engaged in oil and gas exploration and production, transportation and storage, the exploration and drilling, and planning research. The annual production capacity is more than 400 Million tons of crude oil, and the asset of oil and gas is of 200 Billion Yuan RMB. It has a strong representation in the scale of production and management.

In order to ensure the comprehension and extension of the investigation, five production areas, six auxiliary production units are selected in accordance with the production and management of oil production plant, including the oil production area, operation area, oil tubing maintenance station, operation team, engineering, Engineering Battalion and brigade electric pump center.

The whole data collection process took 45 days. Prior to the survey, the contents of the implementation and the interview of the behavior safety observation are determined by combining with the existing literature before survey, and then the preliminary research program is formed. The final draft of the interview outline is formed by consulting five experts in security management field. During survey, the unsafe behaviors in the operation field are observed, identified and recorded by the behavior observation method. According to the observation results, the stuffs observed with unsafe behavior are chosen to interview face-to-face. The interviews with the different levels, different emphases are conducted, which are recorded by the corresponding text and recording.

In order to ensure the authenticity of the collection data, the data alternate collection and analysis. Each data collection makes new adjustments according to the analysis of the existing data. During the analysis process, the data is also checked to continue to enrich the information and fill the void data. It is ensured that information is true and accurate to reflect the business conditions and realize that the data can reflect the research problem.

## 2.3 Identification results

### 2.3.1 Concrete manifestation of unsafe behavior in mechanical operation of first line workers

(1) The concrete manifestation of unsafe behavior.

On the basis of the existing research results, and combining with the field observation results, the unsafe behavior of mechanical operation of the front-line workers in the oil production plant is determined. There are eight main forms of mechanical operation unsafe behavior:

- ① Operation under the condition of no danger elimination, lack of protective measures;
- ② The operation under unsafe speed;
- ③ Operating unsafe equipment;

- ④ Unsafe operation of equipment;
  - ⑤ In unsafe position;
  - ⑥ Using unsafe operation posture;
  - ⑦ Working on dangerous equipment in operation;
  - ⑧ Not operate according to the rules of procedure.
- (2) Frequency of unsafe behavior

According to statistics, the unsafe behavior is mainly due to no operating according to the rules of procedure, and followed by unsafe operation of equipment, In unsafe position, operation under the condition of no danger elimination, lack of protective measures, operating unsafe equipment, using unsafe operation posture, and operation under unsafe speed. As shown in Fig. 1.

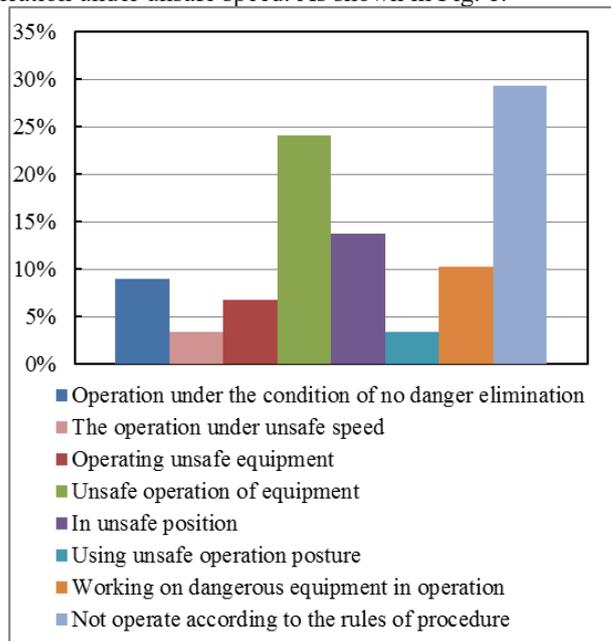


Fig. 1. Frequency of unsafe behavior

### 2.3.2 Contributing factors of unsafe behavior due to mechanical operation of first line workers

According to the results of behavior observation, and through interviews with key personnel, it is determined that the factors causing unsafe behavior of workers' mechanical operation mainly include two factors, the worker's own factor and the external factor.

- (1) Worker own factors
- ① Knowledge and skills

The survey indicates that most of worker having unsafe behavior have the following features: the low level of culture, lack of oil production safety knowledge, poor skill, misunderstand relevant provisions, weak judgment ability to danger. When the environmental conditions change or new methods and new processes are in use, the occurrence of unsafe behavior is due to the misunderstood and unaccepted by these workers.

- ② Safety attitude

Some employees do not pay attention to safety in mind, and even think that some security systems, regulations, measures will have an impact on their work.

They know the existing danger, but they do not take safety measures due to feeling trouble.

③Emotional factors

The emotion also has a great influence on employees' behaviour<sup>[4]</sup>. Because of family, work pressure, interpersonal relations and other reasons, some of employee have a lot of emotional problems. The fact results in job irritability, mental concentration and other phenomena, and result problems in the work.

④Physiological factors

Because of the physiological factors, some workers cannot discover some accident sign in production process and production environment. especially for some employees with physical discomfort, they cannot recognize and adapt to the environment, and cannot discover the omens of risk factors and the environment and equipment accidents, which results in unsafe behavior.

⑤Safety consciousness

The Interviews found that some of workers have weak safety awareness, and safety concept is transferred from the passive stage to the active stage. They blindly believe that the existing measures and technology have been more perfect and slightly unsafe behavior cannot cause the accident, even if the accident could not happen in their own on the body. Some others think that those enterprises safety regulations and safety measures are used to lead management and remediation of employees, which lead them relax their vigilance in the work process, and the violations seriously.

(2)External factors

①Management rules and regulations

The survey indicates that the enterprise has many rules and regulations related to safety operation, but the implement shows poor execution in staffs. According to interviews with workers, it is found that there are too many rules, and the rules are often changed, and it results that some rules is not fully understood and replaced. on the other hand, the lack of effective training and explanation to the issued rulers lead to the fact that the specific requirements in rulers cannot be fully understood. The deviations in the implementation process happen and affect the policy making effect.

②Manager behavior

Managers' exemplary role plays an extremely important role in the behavior of employees, and is the criterion and reference of workers. If the managers themselves attach great importance to safety in production, strictly follow the norms in the job, and in the safety supervision in accordance with the requirements of strict management, the staff will pay attention to their behavior in the work.

But the survey found that some managers do not pay enough attention to the safety, and lack the safety awareness and habit. They do not care about security, and operate in accordance to work experience and habits. They do not know their security responsibilities, and assume that security should only belong to department of safety and safety supervision personnel matters. They have passive attitudes to the safety requirements and

cannot strictly control the unsafe behavior of employees. These factors affect the correct execution of employee behavior.

(3) Production tasks and benefit factors

The extensive and long duration of management results in the dispersed operation and the lack of operators. The enterprise's own production task is also heavier, and the fact lead to the managers ignore the safety to complete the production tasks. On the other hand, in order to complete the production tasks, the employees work continuously in a state of tension. Especially, when high yield wells are found, the employees may violate the operation rules in order to catch the progress schedule and improve the volume of products, which produce some hidden dangers for the enterprise production safety accidents.

(4)Influence of environmental factors

Behavior is the result of interaction between human and environment, and changes with the change of human and environment. Therefore, the production environment has a direct impact on the emergence of unsafe behavior. The observation indicates that the enterprise has the clean and orderly working environment, advanced production equipment and other advanced hardware conditions. The environmental factor which affects the behavior of employees is the human environment, i.e. the relationship and the behavior among the workers. The disharmony behaviors between workmates are the main causes of unsafe behaviors.

### 3 Impact of unsafe behavior of mechanical behaviors

#### 3.1 Research method

Analytic hierarchy process (AHP) was used to analyze the influence of above internal and external factors on unsafe behavior of mechanical operation of first line workers. AHP is a system analysis method proposed by Professor T.L.Saaty. Compared to other methods, it can measure qualitative factors to compare different factors and determine the influence degree of the different factors, which can ensure the accuracy of analysis results<sup>[4]</sup>.

#### 3.2 Establishment of a hierarchical structure model

An analytic hierarchy process model is generally divided into target layer, standard layer and decision layer. Combined with the previous analysis of constraint factors, a hierarchical model is established to consider the social responsibility information disclosure, as shown in Table 1.

#### 3.3 Construction of judgment matrix and consistency test

The comparison is conducted by using the matrix scaling method (see Table 2) for comparison. The relative importance of factors and their scores are determined by using expert scoring method. All judgment matrixes in various levels are given. The weight vectors are calculated and the consistency is tested.

**Table 1** The hierarchical model of information disclosure

Target layer	Standard layer	Decision layer
Unsafe behavior of mechanical behaviors	External factor G <sub>1</sub>	Production tasks and benefit factors G <sub>11</sub>
		Manager's behavior G <sub>12</sub>
		Humanistic environment factors G <sub>13</sub>
		Management rules and regulations G <sub>14</sub>
	Internal factor G <sub>2</sub>	Knowledge and skills G <sub>21</sub>
		Safety attitude G <sub>22</sub>
		Emotional factors G <sub>23</sub>
		Physiological factors G <sub>24</sub>
		safety consciousness G <sub>25</sub>

**Table 2** Scale rules of judgment matrix

Scaling a <sub>ij</sub>	Mean
1	Factors c <sub>i</sub> and c <sub>j</sub> have same effect
3	Effect of factors c <sub>i</sub> is slightly greater than that of c <sub>j</sub>
5	Effect of factors c <sub>i</sub> is greater than that of c <sub>j</sub>
7	Effect of factors c <sub>i</sub> is strongly greater than that of c <sub>j</sub>
9	Effect of factors c <sub>i</sub> is extremely greater than that of c <sub>j</sub>
2、4、6、8	Take the intermediate value between two adjacent numbers as c <sub>i</sub> and c <sub>j</sub> is near.
Reciprocal	When Effect of factors c <sub>j</sub> is slightly greater than that of c <sub>i</sub> , the reciprocal values are taken

The consistency test of the judgment matrix is as follows:

(1) The judgment matrix of the influence degree of internal factors and external factors on social responsibility information disclosure is as follows.

G	G <sub>1</sub>	G <sub>2</sub>
G <sub>1</sub>	1	1/3
G <sub>2</sub>	3	1

The judgment matrix  $A = \begin{bmatrix} 1 & 1/3 \\ 3 & 1 \end{bmatrix}$ , the

eigenvalue value is calculate by using MATLAB:  $W_a = \{0.25, 0.75\}$ ,  $\lambda_{max} = \sum_{i=1}^n \frac{(AW)_i}{nW} = 2$ , the judgment matrix is completely consistent. The weight in the matrix  $W_a$  is the weight value of the internal and external factors.

(2) According to the relationship between the external factors, the judgment matrix is as follows:

G <sub>1</sub>	G <sub>11</sub>	G <sub>12</sub>	G <sub>13</sub>	G <sub>14</sub>
G <sub>11</sub>	1	1	5	7
G <sub>12</sub>	1	1	5	7
G <sub>13</sub>	1/5	1/5	1	3
G <sub>14</sub>	1/7	1/7	1/3	1

The eigenvalues of the matrix are  $W = \{W_1, W_2, W_3, W_4\} = \{0.41, 0.41, 0.13, 0.05\}$ , and  $\lambda_{max} = 4.129$ ,  $CI = \frac{(\lambda_{max} - n)}{n - 1} = \frac{4.129 - 4}{3} = 0.043$ ,  $RI = 0.90$ ,

$CR = \frac{CI}{RI} = \frac{0.043}{0.9} = 0.048 < 0.1$ . The consistency can be accepted.

(3) According to the relationship between the internal factors, the judgment matrix is as follows:

G <sub>2</sub>	G <sub>21</sub>	B <sub>22</sub>	G <sub>23</sub>	G <sub>24</sub>	G <sub>25</sub>
G <sub>21</sub>	1	1/5	1	5	1/5
G <sub>22</sub>	5	1	4	7	1
G <sub>23</sub>	1	1/4	1	3	1/3
G <sub>24</sub>	1/5	1/7	1/3	1	1/7
G <sub>25</sub>	5	1	3	7	1

The eigenvalues of the matrix are  $W = \{0.152, 0.369, 0.094, 0.037, 0.348\}$ , the maximum eigenvalue  $\lambda_{max} = 5.351$ , and the consistency index is  $CR = \frac{0.088}{1.12} = 0.078 < 0.1$ . the consistency is acceptable.

All single sorted  $CR < 0.1$ , therefore, the consistency of each judgment matrix is acceptable.

### 3.4 Level total ordering and consistency test

According to the above analysis results, the factors causing the unsafe behavior of the first line workers are sorted out as shown in Table 3.

**Table 3** total factor ranking of the unsafe behavior of mechanical behavior

Target layer	Standard layer	Decision layer	Total weight	Weight sorting	
Unsafe mechanical behavior	G <sub>1</sub>	0.25	G <sub>11</sub> 0.41	0.1025	3
		G <sub>12</sub> 0.41	0.1025	3	
		G <sub>13</sub> 0.13	0.0325	6	
		G <sub>14</sub> 0.05	0.0125	8	
	G <sub>2</sub>	0.75	G <sub>21</sub> 0.152	0.114	4
		G <sub>22</sub> 0.369	0.2768	1	
		G <sub>23</sub> 0.094	0.0705	5	
		G <sub>24</sub> 0.037	0.0277	7	
		G <sub>25</sub> 0.348	0.261	2	

### 3.5 result analysis

According to the above results, the factors that cause the unsafe behavior of the front-line employees in oil enterprises are safety attitude, safety awareness, manager behavior and production. The main reason is the safety attitude, which is the evaluation of safety and tendency of behavior that people make in their own morality and values. The safe attitude has directly, instructive and dynamic effect on the behavior of people. Safety awareness is the safety concept set up in people's minds. The weak safety

awareness will produce an incorrect cognition and lead to unsafe behavior. The behaviors of managers and production tasks have an indirect effect on the behavior of staff by a mean of model effect and external pressure. , if the managers obey safety regulations and the production task is light, the behavior of employees will be relatively safe.

The above analysis indicates that in order to control the unsafe behavior of mechanical operation, the following aspects should be done: (1)strengthening the safety education and training, (2)managers play a leading role model, (3)reasonable arrangement of work tasks and establishment of the concept of effective security, and (4)promote the construction of enterprise safety culture.

## 4 Conclusions

(1) The eight unsafe behavior is observed on site as follows: not operate according to the rules of procedure, unsafe operation of equipment, in unsafe position, working on dangerous equipment in operation, operation under the condition of no danger elimination, lack of protective measures, operating unsafe equipment, using unsafe operation posture, and operation under unsafe speed.

(2) Self factors induce the unsafe mechanical operation behaviors of the front-line workers has its internal factors and external factors. The internal factors include safety knowledge, safety awareness, emotion, physiological and safety attitude. The external factors include management behavior, management system, production task and humanistic environment.

(3) The influence degree is analyzed by using AHP. The result indicated that the main influence factors are safety attitude, safety awareness, management behavior and production tasks. Other factors are safety knowledge and skills, humanistic environment, emotion, and management rules and regulations.

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