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HAZOP_LOPA-based operation process risk analysis and management research

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Abstract: At present, HAZOP analysis and LOPA analysis are widely used to analyze and control the risk of process flow, but few people manage HAZOP and LOPA for risk during operation. Through the research of HAZOP and LOPA analysis methods, combined with long-term work experience in the field, the author proposes to combine HAZOP and LOPA analysis methods into operational process safety risk analysis, and use the same subject expert team to identify the risks in the operation process. Control and control results also help to re-revise the operating procedures, conduct risk management and control from the operational level, and improve the completeness of safety evaluation. This paper introduces the basic method of HAZOP_LOPA joint analysis operation process, clarifies the analysis points, and lists the commonly used 8 types of guidance words. Finally, the risk of maintenance and maintenance operation of quick-open blind filter is analyzed by examples. The results show that Based on HAZOP_LOPA, operational risk analysis can quantitatively evaluate the reliability of existing protection measures, eliminate or reduce safety risks, and achieve safety risk review of operational procedures. This method improves the reliability of operating procedures and enhances the safe operation level of employees. It is of great significance.

1. Introduction

HAZOP (Hazard and Operability Analysis) analysis was developed by the British Empire Chemical Industry Co., Ltd in the 1960s, and it is one of the most widely used risk analysis methods in the petrochemical industry[1].After long-term application in practice, it is found that there are some shortcomings in HAZOP: one is that it can only perform a qualitative analysis of the risk, and it is impossible to judge how much risk the parameter deviation will specifically generate, and whether its risk value is acceptable, etc ; During HAZOP analysis, it is easy to ignore certain triggering conditions and existing protection measures, which will affect the accuracy of accident risk analysis[2].The third is that HAZOP analysis rarely involves the analysis of specific operating steps in the operation process. Some statistics show that more than 85% of accidents are caused by unsafe behaviors of people, and a small part is caused by process or equipment defects[3, 4].The LOPA (Layers Of Protection Analysis) method is usually used to check the HAZOP analysis to obtain a high-risk scenario. Based on the probability of the failure of the protective layer, it is determined whether the existing protective measures can reach a level that makes the risk acceptable. Proposed measures[5].

Domestic scholars have actively explored and tried on the research and application of HAZOP and LOPA, such as Professor Fu Jianmin[6]The first application of HAZOP analysis to systematically review the safety of operating procedures and discuss key issues such as guide words and deviations in the analysis process, which is of great significance for optimizing operating procedures and improving the level of safe operations[1].It is proposed to integrate LOPA into the HAZOP analysis process and comprehensively use the advantages of the two methods to further improve the accident prevention ability of HAZOP and enrich the analysis results of HAZOP, which can provide managers with more comprehensive safety decision-making guidance.

Therefore, the author combined the current research problems, and no scholar has applied the HAZOP and LOPA analysis methods to analyze the operation process. Therefore, the author proposes a HAZOP_LOPA-based operation process risk analysis and management method. This method integrates and combines HAZOP and LOPA. The advantages of the two methods are comprehensively used, and the same subject matter expert team is used to complete the risk assessment.The quantitative risk analysis of high-risk operating process scenarios is carried out, and the targeted residual measures are adopted to make the final residual risk reach an acceptable level. Regulation deviations are eliminated in the design phase to improve the completeness of the safety evaluation.

2. HAZOP_LOPA technical principle of analysis operation process

From the perspective of the system, the connection point between the two analysis methods of HAZOP and LOPA is a high-risk event, that is, the use of HAZOP to analyze the security risks of the operation process, and the high-risk scenario will be used as the accident scenario of the LOPA analysis. Expert library to achieve seamless connection between the two analysis methods.

As shown in the relationship diagram of HAZOP_LOPA joint analysis in Figure 1, the left part is the HAZOP analysis part, including traditional node division, deviation analysis, cause and effect analysis, and risk matrix; the right side is the conventional LOPA analysis, including scenario description, initial Condition / consequence event analysis, independent protection layer, scenario frequency, and risk assessment recommendations, etc.; the middle part is the connection point of HAZOP and LOPA analysis-a high-risk event HAZOP_LOPA joint analysis expert library. The cause of the deviation in HAZOP analysis can be the origin of LOPA The event determination and probability determination provide information and some basic data.The consequence and risk classification in the HAZOP analysis can provide corresponding information for the determination of the severity of the accident in the LOPA analysis. And verify the effectiveness and importance of security measures, determine the frequency of high-risk scenarios, and conduct risk assessments of the incident, which are rich and complementary to the results of HAZOP analysis [1].

This article will use the HAZOP_LOPA joint analysis method to perform risk analysis on the operation process. The biggest feature of this is to centralize resource allocation and simplify the analysis process. Specifically, the established HAZOP_LOPA joint analysis expert library can realize the risk identification and quantitative analysis of the operation process. And risk elimination; in the separate HAZOP and LOPA analysis process, the term "safety protection measures" is involved, so the HAZOP part of the HAZOP analysis is omitted in the "HAZOP_LOPA" joint analysis.

3. Analysis of key points

3.1 Establish an expert database

An experienced HAZOP / LOPA analysis expert plays an important role in the analysis research process [7]. Therefore, it is necessary to establish a comprehensive HAZOP_LOPA joint analysis expert database. Members of this expert database need to be familiar with both HAZOP analysis and LOPA analysis. Members include both experienced leaders who have worked in the field and skilled operators who have worked in the field for many years. During the HAZOP_LOPA joint analysis, the corresponding experts are selected from the library to form a group of 6 to 9 people, including the HAZOP_LOPA team leader (chairman), the operating procedure writer, field operators, equipment engineers, process engineers, safety engineers, etc.

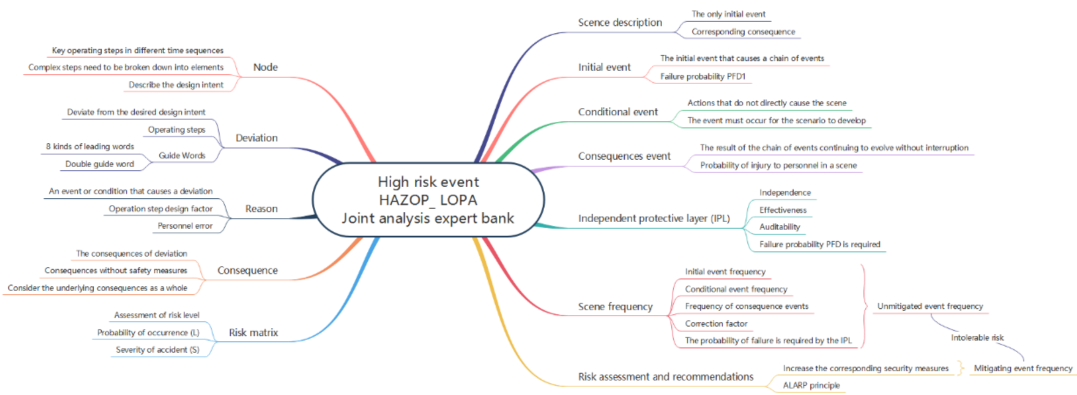

Figure1. Relationship diagram of HAZOP_LOPA joint analysis.

3.2Analysis Points and Leading Words

The HAZOP_LOPA joint analysis of the operating process is different from the previous analysis of the process flow. The main point of the analysis is to analyze a critical step that is extremely dangerous. What will happen if the step is skipped (or omitted)? What happens if the steps are performed incorrectly (without leaving out)? This is the main point of the analysis method. This involves the division of key nodes in the analysis process. In general, each step is an analysis node. Each step has only one performer, completes an action, and only acts on one goal. When encountering a more complex key step, it needs to be split into separate "actions".

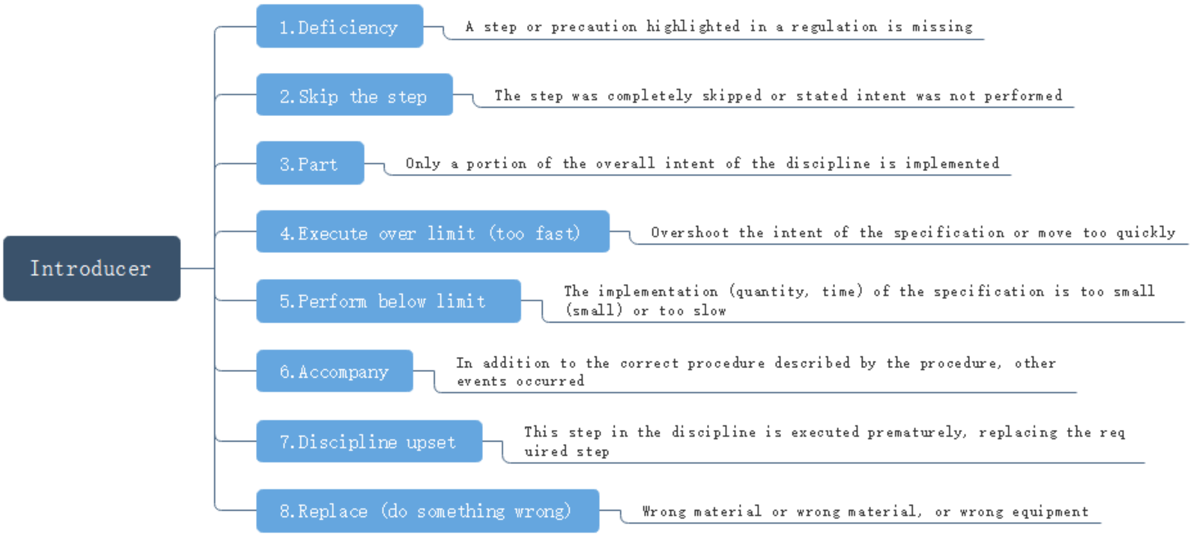

Figure 2. 8 types of leading words for analysis of the operating process.

The determination of keywords is also determined based on the above-mentioned analysis points of the analysis of the operating process by the HAZOP_LOPA joint. The leading words are generally verbs used to describe the operating steps, and the analysis concludes 8 types of leading words, as shown in Figure 2.

3.3 Event probability calculation

Identifying independent protection layers and evaluating the probability of failure at the time of each independent protection layer calculation, calculating the probability of occurrence of an event, and determining whether the risk tolerance standard is met are the core content of the HAZOP_LOPA joint analysis [8]。

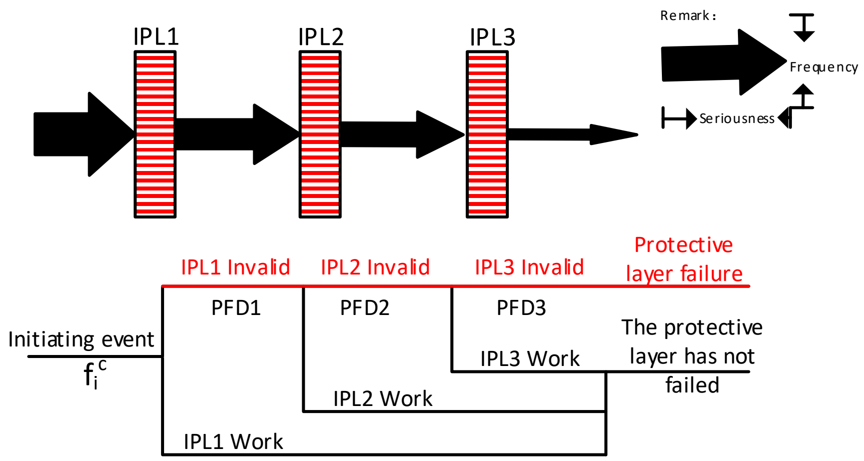

Figure 3. Relationship between initial events, independent protection layers, and frequency of consequences.

The relationship between the initial event, the independent protection layer and the frequency of the consequences is shown in Figure 3.According to the frequency of the initial event and the failure probability of the independent protection layer, the probability of the occurrence of the initial event consequences can be calculated, as shown in the following formula (1).

$$f_i^C = f_i^I \times \prod_{j=1}^{J} PFD_{ij} = f_i^I \times PFD_{i1} \times PFD_{i2} \times \cdots \times PFD_{ij} \tag{1}$$

f_i^C-The frequency of consequences C of the initial event i;
f_i^I-The frequency of the initial event i;
IPL-independent protective layer;
PFD-failure probability when required;
PFD_{ij}-The PFD of the IPL of the jth organizational consequence C in the initial event i.

When there is a conditional event and a consequence event from the initial event to the consequence, the frequency of the conditional event should be considered P^t And consequence frequency P^h As shown in the following formula (2).

$$f_i^C = f_i^I \times \prod_{j=1}^{J} PFD_{ij} \times P^t \times P^h \tag{2}$$

According to the calculated frequency of consequences, compare with the risk tolerance standard. If the standard is exceeded, corresponding security measures need to be added.

4. Application examples

In order to facilitate understanding, a long-distance pipeline named "Quick Open Blind Plate Filter Maintenance and Maintenance Operating Procedures" was selected, and the HAZOP_LOPA combined analysis method was used to analyze and explain the operation process. The fast open blind plate filter diagram is shown in Figure 4. The operating procedures for the maintenance and maintenance of the blind panel filter are as follows:

Step 1: Make sure that the inlet and outlet valves are closed and the blowdown valve is closed to ensure the safety of equipment and people.

Step 2: Confirm that the values of the pressure gauge and differential pressure gauge on the quick opening blind plate filter are correct.

Step 3: Check that the drain valve, ball valve and manual mechanism at the bottom of the quick-opening blind plate filter are intact.

Step 4: Open the bottom drain valve to release the pressure on the filter and reduce the pressure to zero;

Step 5: Open the vent valve on the top of the filter to drain the internal liquid;

Step 6: Open the filter blind plate and remove the filter element;

Step 7: Check and clean the filter. If the filter element is deformed or the filter screen is damaged, the filter element of the same specification must be replaced;

Step 8: Install the filter element and fix it;

Step 9: Perform maintenance on the quick opening blind plate and close the blind plate;

Step 10: Slowly open the upstream valve and the exhaust valve, fill the filter with oil and exhaust, and check the tightness of the blind plate;

Step 11: Put the filter on standby.

Table 1. HAZOP analysis risk matrix

	as a result of					Likelihood (/ year)				
						1	2	3	4	5
	personnel casualties	property loss	surroundings influences	service Break	reputation influences	Not happening in the industry $10^{-4}\sim10^{-5}$	Happened in the industry $10^{-3}\sim10^{-4}$	Happened in the country $10^{-2}\sim10^{-3}$	Happened in the company $10^{-1}\sim10^{-2}$	Has happened inside the station $1\sim10^{-1}$
	No casualties or minor injuries	No damage or economic loss below 100,000 yuan	No impact or slight impact	Less than 3 hours	No impact or slight impact	low	low	low	low	medium
2	Seriously injured	Economic losses 10-100 million yuan	Minor impact	Less than 12 days	Minor impact	low	low	low	medium	high
3	1-2 deaths	Direct economic loss of 1 million to 3 million yuan	Local influence	Less than 3 weeks	Serious impact	low	low	medium	medium	high
4	3-9 deaths	Direct economic loss of 3-10 million yuan	Tremendous influence	Less than 1 week	National influence	low	medium	medium	high	high
5	More than 10 people died	Direct economic loss of more than 10 million yuan	Great influence	More than 1 week	International influence	medium	medium	high	high	high

Due to space limitations, the higher risk steps 1 and 4 in the operating procedures were selected for analysis according to the HAZOP_LOPA joint analysis method. The detailed analysis process is shown in Tables 2 and 3, and it can be seen that the HAZOP analysis gives steps 1 and Step 4 Reasons for the deviation, possible consequences and its risk level[9]. It can be seen from Table 2 that "the implementation of step 1 does not reach the limit" will lead to high risks. Therefore, "inlet and outlet valves, blowdown valves are not closed effectively, and there is leakage" are selected as the accident scenarios for the analysis of LOPA. But how specific the risk of this high-risk event is, whether it is acceptable, and whether the remaining risk can be reduced to an acceptable level after taking measures, these need to be obtained through LOPA analysis. The event frequency is 5×10^{-4}, which exceeds the acceptable risk value of 1×10^{-4}. Therefore, two separate protective layers, "truncating valve chain reaction" and "guardian ballot system", were adopted to reduce the event frequency to $2.5 \times 10^{-6,}$ which is lower than the risk tolerance value, and the remaining risk level changes from high risk to low risk. At the same time, the result also shows that no additional security measures are needed.

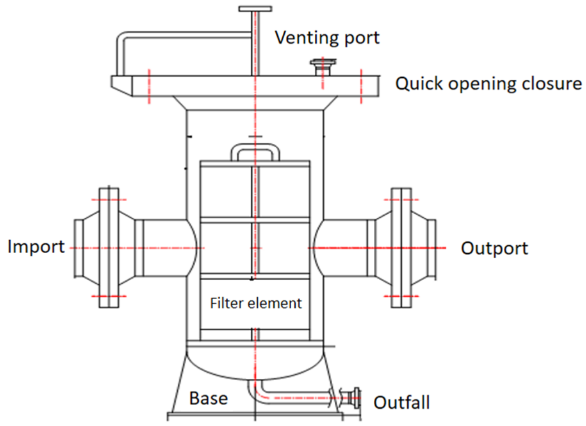

Figure 4. Schematic diagram of quick opening blind plate filter

Table 2. HAZOP analysis results of pressure vessel parts (partial)

Analysis node	Leading word	deviation	the reason	as a result of	Risk matrix		
					S	L	R
step 1	no	Step 1 is not performed	1. The inlet and outlet valves and blowdown valves are not closed	1. Oil leakage and waste of resources	3	5	high
	Inadequate execution	Step 1 does not reach the limit	2.The inlet and outlet valves and blowdown valves are not closed effectively and there is a leak	2.Oil leakage caused fire and explosion	3	3	medium
Step 4	Inadequate execution	Step 4 does not reach the limit	1.Bottom blowdown valve does not open effectively	1.The filter is not fully depressurized, and the pressure release during operation causes the blind plate to hurt	2	4	medium
	Premature execution	Step 4 is executed too early	2.Filter pressure has not dropped to 0	2.The filter is under pressure, and the pressure release during operation causes the blind plate to hurt people.	2	4	medium

5. Conclusion

(1) Using the HAZOP_LOPA joint analysis method for the operation process, not only can identify and analyze the consequences when there is a deviation in the operation process, but also analyze and

calculate whether the event risk under the current protection measures is within the allowable range, and then make targeted protection Measures.

(2) Integrate and joint HAZOP and LOPA to analyze the operation process, so that the comprehensive analysis results are more complete.The analysis results are used to guide the re-revision of the operating procedures and improve the completeness of the safety evaluation from the operating procedure level.

(3) HAZOP_LOPA-based operational process risk analysis and management research is one of the best security risk review methods at present.This method is of great significance for improving the reliability of operational processes and enhancing the level of employees' safe operations.

Table 3. LOPA analysis results based on HAZOP analysis

Accident scenario description	as a result of		Acceptable risk		Originating event	Conditional event	Consequences	Unmitigated event	Independent protective layer	Mitigate event			Suggested measures
	description	severity	Unacceptable value	Allowable value	description And frequency	description And frequency	description And frequency	frequency	Description and pfd	frequency	Frequency level	Residual risk level	
Inlet and outlet valves, blowdown valves are not closed	Cause oil leakage, resulting in fire and explosion accidents	3	1×10-4	1×10-5	Inlet and outlet valves are not closed effectively, 0.1	1. Oil leakage probability, 0.1 2.Ignition probability of combustible substances, 0.1	1. Fire and explosion probability 0.5 2. Casualty probability 1	5×10-4	1. Cut-off valve chain reaction, 0.05 2. Guardian "voting system" 0.1	2.5×10-6	1	low	no

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