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Analysis Methods for Human Factors in Chemical Plant Accidents

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It is important to analyze the cause of an accident so as to prevent further incidents of a similar kind.
Variation Tree Analysis (VTA) and Why-Why analysis are accident investigation methods to analyze an accident due to human factors in Mitsubishi Chemical Corporation.
VTA is the method to employ time series analysis of the circumstances at the time of an accident, with particular emphasis on the actions and judgments of human. Why-Why analysis is the method to identify the underlying causes of accidents and develop countermeasures by continually questioning the causes of accidents. So, the causes of an accident are identified through VTA, after that, the causes of the accident are analyzed through Why-Why analysis.
These methods are used easily because they do not need special skill and knowledge. On the other hand, according to the internal investigation, these methods have some problems that they take much time to analyze an accident, it is difficult to identify the root cause of an accident and these analyses sometimes lead to take misguided measures. Because process of Why-Why analysis tend to depend on personal skills, it is difficult to obtain logical results through Why-Why analysis.
To solve these problems, we improve VTA and Why-Why analysis by the following viewpoints.
1) Narrowing analysis targets
The comprehensive analysis across the all scenario would take much time and manpower. To select the upstream deviation node as the starting point of Why-Why analysis is one of the effective approaches.
2) Standardizing analysis procedures
The standardized templates will be applied to the analysis procedure to reduce the variation in the analysis results by providing the templates.
3) Outlining policy for preventive measures against accidents
Accident prevention countermeasures are recognized as three steps as follows,
a) Improvement of the design of manufacturing process and maintenance management
b) Improvement of the management of the SOP and the skill of the operating staff
c) Improvement of reliability of the individual work execution by operating staff
On assumption the human errors is inevitable, countermeasure of accident is preferentially carried out first to (a), followed by (b) and (c). The analysis of human factors could be analyzed more effectively by these improved methods. Moreover, more effective risk assessment will be possible by using these improved methods and their output.
Improved methods for Human Factors analysis are introduced.

1. Introduction

Recently, the number of accidents in the industry is increasing in Japan. One of the causes is human factor. It is important to analyze root causes of accidents when they occurred. Variation Tree Analysis (VTA) and Why-Why analysis are often used to analyze an accident due to human factors. These methods are often used but there are some problems that it takes much time to analyze an accident, it is difficult to identify the root cause

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of an accident and these analyses sometimes lead to take misguided measures. These methods need to be improved.

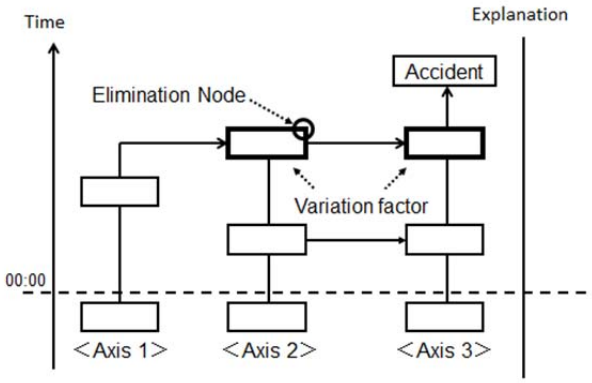

Figure 1: VTA

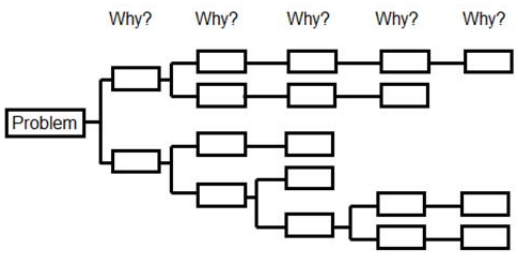

Figure2 Why-Why analysis

2. Variation Tree Analysis(VTA) and Why-Why analysis

2.1 VTA

VTA is the method to employ time series analysis of the circumstances at the time of an accident, with particular emphasis on the actions and judgments of human. The progress of the accident along the time series is illustrated in a VTA. A situation, work, judgement or behaviour that diverges from the usual condition in the VTA is picked up as a variation factor. After that, how the variation factors caused the accident is analysed. Figure 1 shows a basic concept of VTA. This Figure consists of preconditions, explanations, time axis and diagram which illustrate the sequence of the accident and the relationship between direct and indirect contributing factors. In a VTA chart, the time goes from the bottom to the top. The event at the top of VTA is expressed as an accident. By using this method, the key point that leads to the accident can be identified. This method is effective for the analysis of any accident. After the key-points of an accidents are identified through VTA, after that, the causes of the accident are analyzed through Why-Why analysis.

2.2 Why-Why Analysis

Why-Why analysis is the method to identify the root causes of accidents and develop countermeasures by continually questioning the causes of accidents logically. The procedure of Why-Why analysis is as follows,

1) Starting with a problem, asking why it occurred.
2) Then, turning the answer to the first question into a second why question.
3) After that, next answer becomes the third why question and so on.
4) Asking more or less whys until identifying the root cause for the appropriate countermeasures.

Figure 3 shows the relationship between VTA and Why-Why Analysis. The starting point of Why-Why analysis is the variation factor which is identified through VTA.

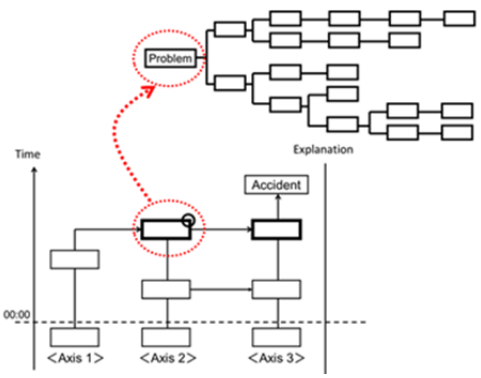

Figure 3: VTA and Why-Why Analysis

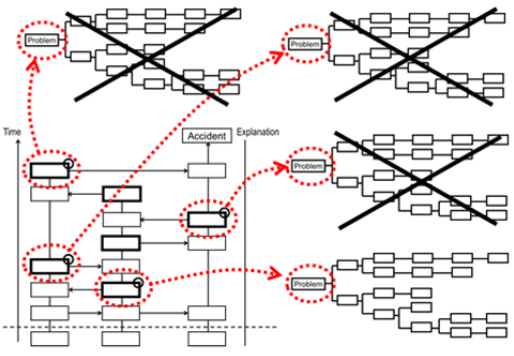

Figure 4: Problem of VTA and its countermeasure

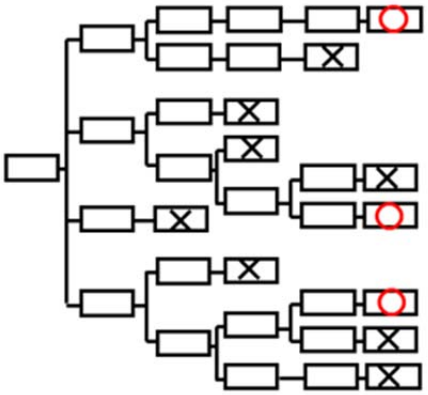

Figure 5: Example of extracting possibility of root cause widely

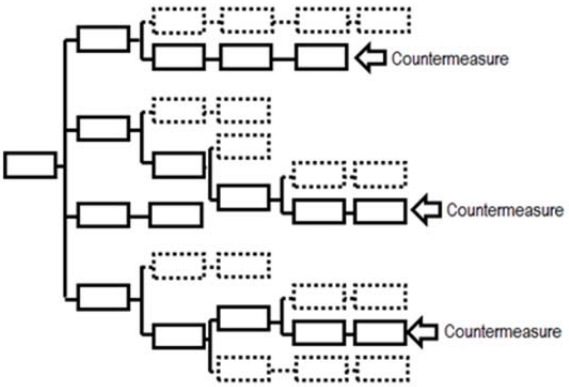

Figure 6: identifying root cause from a beginning of analysis

3. Problems of VTA and Why-Why analysis and their countermeasures

As a result of the investigation of the performance of VTA and Why-Why analysis in Mitsubishi Chemical Corporation, it was recognized there are some problems. The problems of VTA and Why-Why analysis to identify their countermeasures are as follows.

3.1 Problem of VTA and its countermeasure

A node for elimination in VTA is a factor that was a direct or indirect cause of the accident. Ishida and Kanda (1999) describe that it is desirable that there should be not only one but many such nodes. Therefore, it is necessary to analyze a lot of Why-Why analysis. As a result, it is necessary to take many countermeasures corresponding to problems. The comprehensive analysis across the all scenario would take much time and manpower. As a result, notable problems become inarticulate essentially adversely because it is necessary to take a lot of worthless measures. It is necessary to clarify an important factor.

To solve this problem, selecting the first deviation node as the starting point of Why-Why analysis is the one effective approach (Figure 4). The deviation is a situation, work, judgement or behaviour that diverges from the range assumed as normal condition during operation. Because the subsequent deviation node is considered to be the further deviation from an abnormality state, it is not recognized as deviation node.

3.2 Problem of Why-Why Analysis and its countermeasure

The procedure of Why-Why analysis has two steps which extract the potential causes widely (Figure 5) and identify the actual causes (Figure 6). A relationship of the trade-off between manpower and prospect of finding root causes depends on the procedure.

The procedure of Why-Why analysis which extracts the potential causes widely and then determines whether the cause is appropriate is a step which gives a new awareness. This procedure is very effective for awareness of new root cause, but it needs a lot of manpower because it extracts many worthless causes.

On the other hand, the procedure of Why-Why analysis which identifies actual causes and connects deviation node and its cause is a step which enumerats definite factors. Only by this procedure, validity of enumerated root causes cannot be confirmed. In other words, this procedure is not an analysis process but an expression process.

A template has been developed to reduce the personal skill difference of the analysis and manpower. A cyclopedic analysis following the abnormal condition iteratively is carried out by referring the tree form templates. Figure 7 shows image of the template. There are seven kinds of templates at the present time. They are (1) Abnormal phenomenon, (2) Operator action failure, (3) Decision mistake, (4) Slip, (5) Lapse, (6) Violation, (7) communication error.

Figure 8 shows how to use the template.

(1) Firstly, selecting template corresponding to the deviation node of the starting point of Why-Why analysis
(2) Next, selecting a node which is an actual cause to develop next node (next Why) and excluding other nodes which are not.
(3) After that, selecting template corresponding to the node and repeating similar process.

The standardized templates can be applied to the analysis procedure to reduce the variation of personal skill in the analysis results by providing the template.

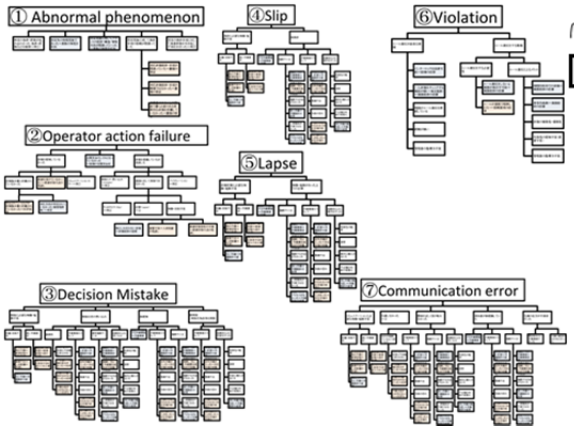

Figure 7: Why-Why Analysis Template

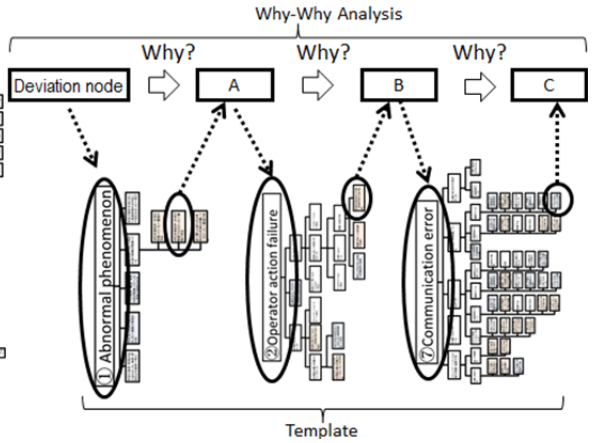

Figure 8: How to use the template

4. Outlining policy for preventive measures against accidents

As a result of having investigated the accident reports and interviewed with staffs in Mitsubishi Chemical Corporation, accident factor was categorized 5 types and its countermeasure was categorized 3 types.
Accident factors are as follows,

a) Plant & management design: Deficiency of plant design and maintenance
b) Operational design: Deficiency of the work procedure design
c) Understanding work: Deficiency of conveying the work contents
d) Collaborative work: Human error in the collaborative work
e) Personal work: Human error in the personal work

Accident prevention countermeasures are as follows,

A) Improvement of the design of manufacturing process and maintenance management
B) Improvement of the management of the SOP and the skill of the operating staff
C) Improvement of reliability of the individual work execution by operating staff

The result of the investigation shows that the following facts were revealed.
Improvement of the design of manufacturing process and maintenance management were taken against accident which occurred due to deficiency of plant design and maintenance.
On the other hand, the causes of failure of the protecting responses are those of the personal work and failure of collaborative work. The countermeasures for such causes are spreading of information and re-education in most cases.
Recently, operating staff's opportunity to experience plant troubles and unsteady operations of a plant is decreasing because steady operation and high reliability in a plant are required in the society. It is necessary to take countermeasure by assuming that human error is inevitable. Therefore, to reduce occurrence of accident, it is necessary to change the management style from depending on human factor to depending on inherently safer design or functional safety. As it was already explained, countermeasure against accident consists of 3 walls which are (A) improvement of the design of manufacturing process and maintenance management, (B) improvement of the management of the SOP and the skill of the operating staff and (C) improvement of reliability of the individual work execution by operating staff. If countermeasure (A) could be realized, it is not related to human factor. It cannot be expected that countermeasure (C) has high reliability because this countermeasure includes human factor. Therefore, countermeasure of accident is preferentially carried out first to (A), followed by (B) and (C). It may be said that the management policy is not appropriate if countermeasure (C) with low reliability was only taken even if it is possible to take countermeasure (A) and (B).

5. Application example

Application example of VTA guideline and Why-Why analysis template are as follows.

5.1 Example flow

This example shows that the residual oil polluted the reactor while the line was being washed by the steam.

(1) The slight blockage of the pipe was confirmed while the line was being washed by the steam. The pressure of the steam was lowered by the valve which opened by half.
(2) To remove the blockage, steam wash was added from the different line. This valve was fully opened.
(3) The steam which had been flowing in the pipe flowed backward.
(4) The residual oil in the steam pipe polluted the reactor.

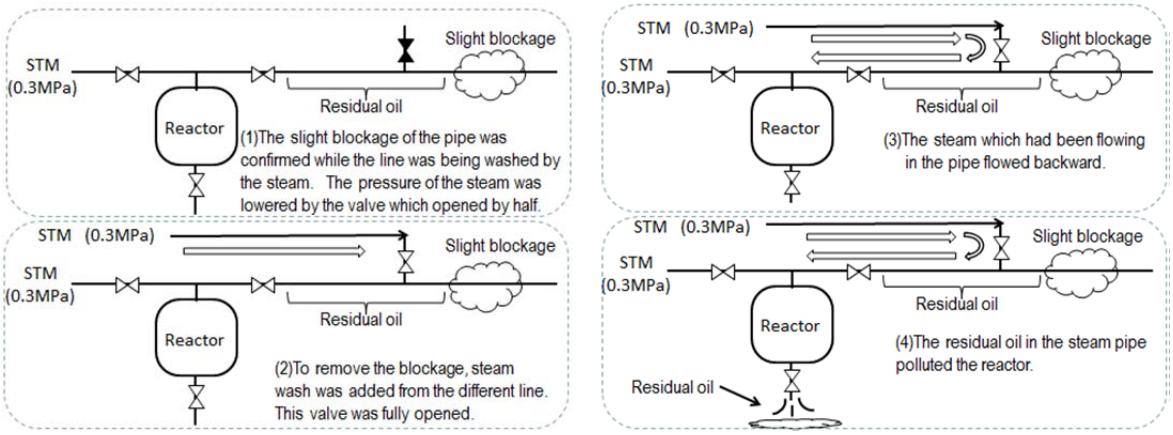

Figure 9: Example flow

5.2 VTA

The outline of example model is expressed as VTA format. Two axes are expressed as operators and one axis is expressed as the model flow. The node for elimination in this VTA is "Indicating to connect the different steam pipe to the pipe being washed and to wash by steam." This node for elimination is used as starting node of Why-Why analysis.

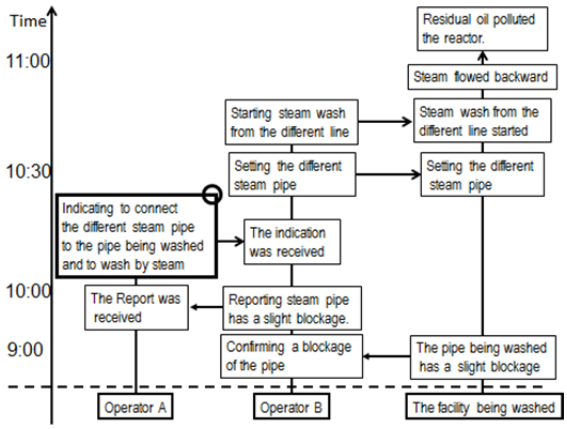

Figure 10: Example VTA

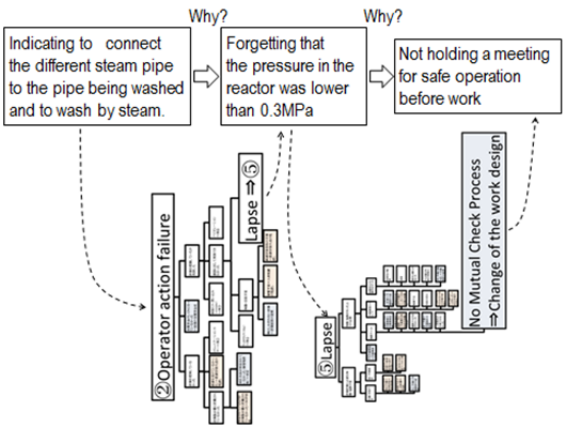

Figure 11: Example Why-Why Analysis

5.3 Why-Why Analysis

The procedure of Why-Why Analysis by using template is as follows,

(1) First of all, checking seven templates corresponds to "Indicating to connect the different steam pipe to the pipe being washed and to wash by steam". In this case, "Action failure" is selected.
(2) Next, investigating which lower event in the template of "Action failure" corresponds to "Next Why?" In this case, Operator A forgot that the line was being washed by the steam of which pressure was lowered by the valve which opened by half. Therefore, lapse is selected as “Next Why”. So, the sentence of "Forgetting that the pressure in the reactor was lower than 0.3MPa" is written in the "Next Why" column.

(3) Then, checking seven templates corresponds to "Forgetting that the pressure in the reactor was lower than 0.3MPa". In this case, “Lapse” is selected. Next, investigating lower event in the template of “Lapse” which corresponds to “ Next Why?”. No Mutual Check Process is selected as final "Why". And then, it comes to the recommendation of “Change of the work design to remind the point (pressure)” and the countermeasure “Before work, holding a meeting in which various information such as methods of work and risks associated with work is shared among workers” is proposed.

6. Conclusion

VTA and Why-Why analysis was improved to implement effective cause analysis. As a result of having investigated the incident reports and interviewed with staffs in Mitsubishi Chemical Corporation, incident factor was categorized 5 types and its countermeasure was categorized 3 types. Countermeasure of accident is preferentially carried out first to improvement of the design of manufacturing process and maintenance management, followed by improvement of the management of the SOP and the skill of the operating staff and improvement of reliability of the individual work execution by operating staffs.

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