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Risk assessment and drawing information system based change management

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Abstract−Most process changes and modifications, which are caused by the process failure, the process life cycle and the economic environment, have been generated at industrial facilities. However, management of change (MOC) is based on basic process safety, such as change judgment, risk check with accurate technical references and risk assessment, and is difficult to carry out because of the lack of experience, knowledge, and process safety specialists. In this study, the MOC system was developed based on process safety technology and the drawing information system (DIS) oriented method. This study recommends the MOC system to industrial facilities as the setup of the obvious standard for the decision-making process, the MOC procedure based risk assessment, and the judgment and risk estimation of the process modification. The HIT and CAT modules were developed using the risk assessment checklist, HAZOP risk ranking, scenarios for consequence analysis and reporting automation. These two modules provide a clear-cut view on the process risk. An effective risk-based MOC Review was performed by this new method. Additionally, this study suggests a new method for the MOC S/W system. This method was developed using a new technique which was based on the DIS system linking MOC system and the HIT and CAT Modules, including the process safety information. The goals of this method are to enhance the safety level and improve the performance efficiency.

Key words: Management of Change, Drawing Information System, Process Safety Management System, Risk Assessment, Process Hazard Index, Process Safety Information Management

INTRODUCTION

Numerous activities such as process change and new facility installation are executed in the chemical plant by the process technology, facility management and economical environment. These process changes and new facility installations are performed while based on the technology of securing fundamental process safety such as accurate technical review, risk identification and risk assessment. However, these are not easy tasks to accomplish due to lack of experience, knowledge and technical personnel [5,7].

The Flixborough accident case (a representative accident case of change), as the accident that has occurred while in the process of replacing the reactor of the caprolactam manufacturing process, is one that has initiated the process safety management (PSM) and management of change (MOC) [14]. The systemization and implementation of change management in the domestic equipment industry was initiated as the MOC is included as one of key factors in the PSM implemented in 1996 [10]. However, the change management as the job with the greatest correlations with several departments together with the complexity of the job is recognized as the most important and difficult job in the field.

This study intends not only to establish the change management system and procedure for the efficient implementation of change management, but also to suggest an efficient, reasonable and easy change management system through developing the key elements of change management. Also for the safety improvement of workplaces and practical change management, this performs a study on the integrated change management system based on the drawing information. The integrated MOC system is to present a web-based system that has organically combined four modules such as drawing management, change management, qualitative risk assessment and quantitative risk management.

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THEORY

1. MOC for the Process Industry

Process change begins with various inherent causes rather than being limited to the improvement of efficiency, operability and safety. Changes may occur from large-scaled facility expansion and new equipment installation up to a small change in chemical product, technology, equipment or procedure. Certain change shows a deviation from design, manufacture, installation and process operation. If it is not controlled appropriately by the technical criteria, even a simple change can result in a fatal disaster. Three types of change, which are technology, facility and organization, should be managed across all the plant parts according to the accurate criteria. Technical change includes facility change, use of new chemical material, and changes in the parameter or operation procedure. Facility change includes the temporary or permanent facility replacement with an alternative item that is not the same kind. Organizational change may include the range from replacement of new personnel to retirement. The most active perspective in managing changes is to separate the proposed repair/maintenance as an actual change. If judged as a change, it is essential to determine the need of change review. These activities are he important factors in the procedure of appropriate change management and are largely linked with other PSM elements of change management. Important common matters are followed as below [11].

· Organization Change
· Requirement of Procedure
· Process Safety Information
· Project Safety Review
· Work Permit
· Equipment Preventive Maintenance
· Process Risk Assessment
· Education and Training

Accordingly, clear guidelines shall be held for the changes and all the equipment changes except for the replacement with the same kind shall be made according to the specified change procedure. The proper definition of procedural change refers to requesting a change in the process safety information. It would be quite helpful in the analysis of change trend, by making sure that there is no misunderstanding for the changes necessary, to have a review procedure, and by building the change management database by listing the changes of each type for the efficient management of changes. The lists by the representative change specified in the AIChE CCPS Guideline are as follows [2].

· New Chemicals
· New Materials and Reagents
· Operation Procedure or Process Variables Modification
· Experimental (Operation)
· New Equipment and Instrument
· Explosion-proof Area Change
· Computer Software Change
· Alarm, Interlock or Relief Setting point Change
· By-pass of Alarm, Interlock, Relief
· Equipment By-Pass or Improvement
· Temporary Connection or Equipment
· Role Assignment

Of the guidelines for change management considering plant safety, the most reliable technical standards and related regulations in Korea and overseas are followed as below, suggesting the guideline for change management procedure and basic implementation items.

· KOSHA Code P-26-2000 Management of Change Guideline [8]
· AIChE CCPS Guideline [2]
· EPA 40CFR68 Management of Change [15]
· OSHA 1910.119 Management of Change [13]
· ILO MOC Guideline [6]

2. Ordinary MOC Procedure

The most reliable elements in Korea and overseas from the guidelines about the change management procedure of equipment industry are shown as in the following. Change management is performed in most of the workplaces of the equipment industry according to the guidelines of these organizations.

· KOSHA Code P-26-2000 Management of Change Guideline
· AIChE CCPS Guideline
· EPA 40CFR68 Management of Change
· OSHA 1910.119 Management of Change
· ILO MOC Guideline
· RC (Responsible Care) MOC Guideline

The technical standard codes and regulations shown above suggest the matters to be executed when implementing the change management and the matters to be managed at the time of having change element are shown as in the following [12].

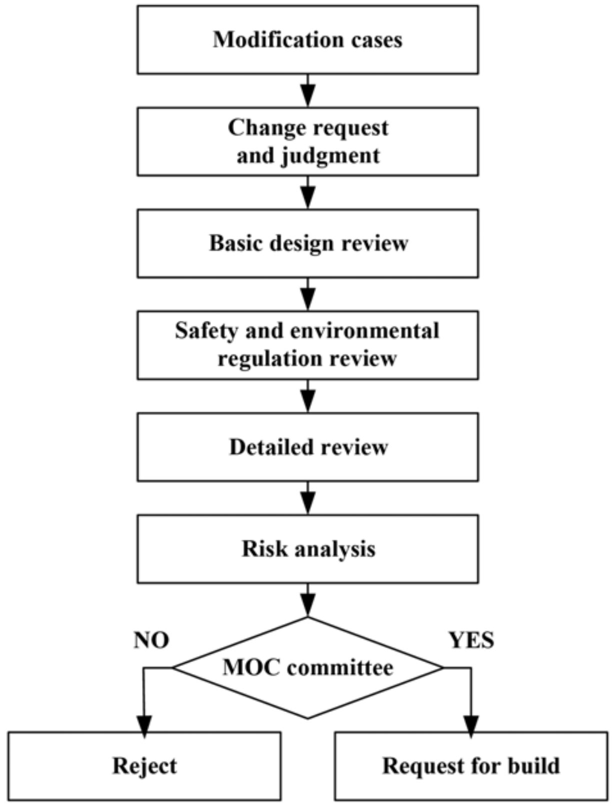

Fig. 1. General MOC procedure.

· Change Description
· Temporary Modification Management
· Change Approval
· Safety Review
· Education and Training
· Documentation

It is recommended by the leading organizations in the domestic/overseas safety field so that the change management activities can be performed around these elements. The change management procedure recommended by KOSHA, AIChE, EPA, OSHA, ILO and RC can be drawn as in the Fig. 1. The procedure from the change request that is the first phase of change up to the approval is explained. Most of workplaces in Korea also take it as the basics of change management by adopting this procedure. However for the details, it has the difficulty of developing them according to the characteristics of each workplace and especially, there exist a considerable part of this such as the implementation of risk assessment that is difficult to solve technically. The weaknesses in the existing procedure of change management can be summarized as follows.

· Lack of Change Classification Resources
· Non Practicable Risk Assessment Practice Guideline
· Insufficient Procedure for Risk Assessment Practice
· Delayed P&ID update

Accordingly, this study intends to present by studying the change management procedure that have improved on these weaknesses.

3. Process Safety Information

The process safety information, which covers the information such as process design, process operation information and chemical information, is the base data for the design and operation of equip-

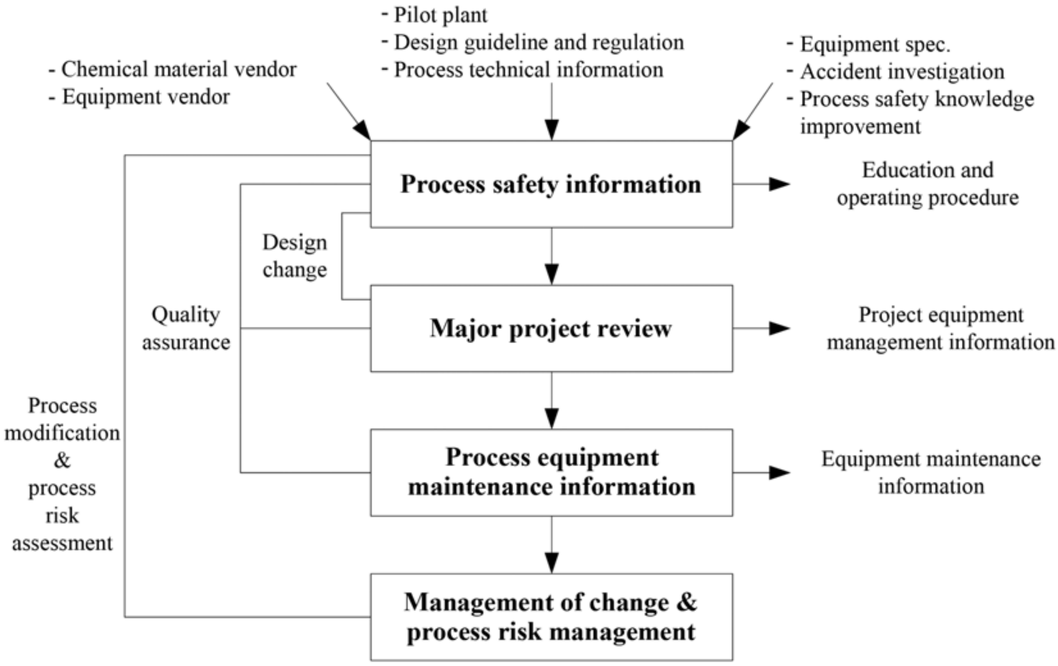

Fig. 2. Relation of process safety information.

ment industry facility. The process safety information shall be managed systematically and accurately so that the current situation can be assessed accurately when performing the process change, facility management and other maintenance jobs. The PSM for the project investigation, change management, process facility maintenance activity and process risk management that are the major activities of plant operation and design is closely related with the management of process safety information and can be drawn as in the Fig. 2 [3].

4. Quantitative Risk Assessment

The quantitative risk assessment can be said as the process of reviewing whether appropriate safety action devices and measures are prepared upon judging comprehensively about the diffusion process of risk elements and blocking ability of system level after investigating the risk elements within the facility that retains a certain amount or more of specific chemical material.

The quantitative risk assessment requires suggesting more systematic and objective methodology and standard from the perspective of business risk management. Here, the risk management, as one phase of the management decision-making process that sees the safety, health and environmental problems in a broader sense, shall be handled in the perspective of risk management rather than the restriction-oriented policy for the ultimate improvement of safety and health problems [9]. The identification phase of potential risk refers to the phase that checks the potential risk existing within a process through the data collection (such as material information, process information and operation information) needed in the risk assessment. In the analysis phase of accident result, the leakage model is the phase that calculates the leakage speed of material, total amount of release and leak duration when the external release of dangerous material has occurred from a tank or pipeline; and the dispersion model is the phase that calculates the degree of risk according to the damage distance by the dispersion form and factor of hazardous material. The frequency analysis is to analyze the occurrence frequency of accident scenario evaluated from the analysis of incident outcome. Finally, the impact model is to assess the toxic material impact of released hazardous material, radiation effect, and human/property damage by the explosion effect. In other words, the analysis of accident result is to assess the effect made on the human body or building by calculating the damage type and magnitude expected when discharging hazardous material to the outside of the process.

RISK BASED MOC SYSTEM

1. Risk Based MOC Procedure

The change management procedure proposed in this study ultimately targets improving the omission of risk assessment that is the common problem of change management procedure established by the existing workplace and process safety guidance/supervision and inappropriateness of change review. By conducting the risk assessment before the phase of change review, this study has prepared the procedural safety measure that can also review the contents of risk assessment. The first phase of change management procedure is to request the change, and the final phase is to perform the job by change approval. Based on the contents reviewed previously, the technical items to be solved by the change management procedure and to be suggested can be summarized as in the following.

· Change Judgment Criteria
· Change Risk Index and Criteria
· Checklist for Change Process
· HAZOP Risk Criteria
· Consequence Analysis
· Modification Review Practice

As for the above items as the key elements of suggested change management procedure, no reasonable measure has been suggested yet though they are the items to be performed at the time of change management and this study is to propose the procedural details. Looking at the change procedures organized around the flow of change management in phases, the following can be obtained.

First, through the procedure of judging the change at the occurrence of change item by relevant criteria, the change is judged arbitrarily so as to prevent classifying it as a maintenance or normal replacement job though it is subjected for change management.

Second, by determining the severity of risk assessment by the level of change risk, this study has suggested the phase of estimating the change risk. According to the estimated risk level, this determines whether to execute only the risk assessment of checklist technique or to perform the HAZOP and consequence analysis.

Third, by including the risk assessment result into the items of change review, this study has prepared a measure of improving the safety that performs the review of assessment result. This, as an important part that has not been solved in the existing change management procedure, is the key element of risk-based change management procedure that can be a turning point that considers safety from the change review of productivity and technical basis. The risk assessment flowchart based on the change management procedure that was presented above is shown on the Fig. 3, and the roles by the subject of executing the proposed change management procedure are as follows.

· Change Originator
- MOC Coordinator
· Risk Assessment TFT (Task Force Team)
- Team Leader and writer
- Operating Engineer and Operator
- Technical Engineer
- Safety and Environmental Engineer
- Electricity and Instrument Engineer

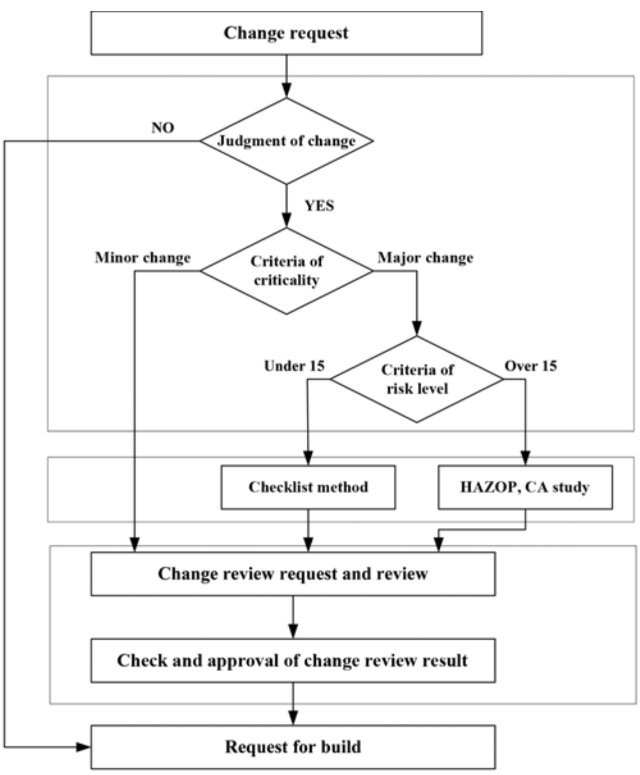

Fig. 3. MOC Procedure based on risk assessment.

- Maintenance Engineer
- Other Specialist
· MOC Committee
- Head: Plant Manager or Senior Team Leader
- Member: Senior Engineer

2. The Criteria Elements for Modification

As one of major phases in change management, this is the first decision-making phase of change management procedure. The change judgment criteria are the determination tool of classifying execution of change management by suggesting the clear criteria of judging a change.

KOSHA (Korea Occupational Safety & Health Agency), which is the organization for guiding/supervising the safety management of chemical factory and equipment industry, has established the "KOSHA Code P-26-2000 Change Management Guide." This suggests the guideline of change management. Currently, each workplace determines a change by internal judgment. This guide primarily deals with the judgment of approval/permission.

According to the change management criteria of PSM system implemented by the KOSHA, each worksite shall submit the PSM report for the following three items [10].

· Reactor (Include Accessory) Replacement or Addition
· Flare Stack Install or Modification
· Utility's Total Rated Capacity over 300 KW

Accordingly, this study classifies three items above as important change. Together with this, this study has analyzed the domestic/overseas criteria in order to study the reasonable and efficient change judgment criteria. Table 1 has classified the items not needing to have approval and other items needing to have approval.

To fulfill the legal criteria and technical guidelines in Korea, the change judgment criteria proposed in this study have clearly classified the items and have drawn a checklist type of judgment table as the outcome for each application. As a result, the important judgment elements as shown on the Table 2 could be drawn and they play the role of key judgment basis that determines the major change, minor change and maintenance.

The change judgment criteria checklist consists of 29 judgment criteria items in 3 phase structure. The first phase of checklist consists of 24 items from #1 to #24, which are the items for judging major changes.

3. Risk Matrix for Modification

To determine the type and scope of risk assessment to be performed for the requested change, this study has conducted a research

Table 1. Change without authorization

Elements
1. Equipment or Piping repair in conformity with the repair procedure
2. Equipment or Piping Replacement (Same Spec)
3. Heat exchanger, Piping etc. Cleaning
4. Insulator Replacement
5. Packaging
6. Painting
7. Instrument Repair
8. Operating Information Alarm Change
9. Modification in conformity with Inherent MOC experience or Standard Operating Practice

Table 2. Decision making checklist of change management

No.	Classification elements	Y/N
1	Do new chemicals add up in process by the modification?	
2	Do construction materials change by the modification?	
3	Does the modification lead process to pollution, impurity increasing and another problem?	
4	Does process need to tie-in with another process?	
5	Does the modification lead process to use abnormal chemicals as a raw material?	
6	Does the modification lead process to abnormal operating condition as out of ordinary safe operating range?	
7	Does the operating safety margin decrease?	
8	Do the procedures and sequencing such as batch and continuous operation, shutdown, maintenance and emergency operation practice require changing?	
9	Is there new type process upset?	
10	Are upsets happening more often after modification?	
11	Does the equipment maintenance procedure require being changed?	
12	Are operators', who keep the process operating condition and response process upsets, operating ability getting worse by the modification?	
13	Take process equipment to pieces or change a use, material, structure of main equipment?	
14	Do the protection systems such as alarm, interlock, trip, etc. require being changed?	
15	Do the emergency relief systems and sizing standards require being revised?	
16	Does the modification make new ignition sources, flammable material release and increasing fire accident likelihood?	
17	Does the modification make process accident severity become worse?	
18	Do fire fighting systems require adjustment or rearrangement?	
19	Is there new facility by modification?	
20	Is there new standard operating practice?	
21	Are there new process hazards?	
22	Does the modification make the process more dangerous?	
23	Is the process interconnection and interaction with other processes affected by the modification?	
24	Is the accident response system affected by the modification?	
25	Is the process changing temporary piping, joint and using hose under ordinary operating condition?	
26	Does it review reactivity of process chemicals and changing building materials?	
27	Does it review the equipment operability of alternative one to keep ordinary operating condition?	
28	Is it simple replacement and repair?	
29	Is it simple replacement as same spec?	

on the judgment criteria of change risk and has reviewed two techniques easy to apply the change management from the techniques of risk indices proposed so far.

· DOW Fire and Explosion Index [1]

· Process Risk Index (KOSHA Guideline) [8]

The Fire and Explosion Index Method from two risk index methods above is well organized with respect to the fire and explosion characteristics of chemical materials. It can be a powerful tool to de-

Table 3. Changing risk matrix

Elements \ Risk indices		1	2	3	4	Risk Index
Material	Increase (kg)	Under 1,000	1,000-45,000	45,001-90,000	Over 90,000	
	Flash point (°C)	Over 37.8	37.8-22.8	22.7∼−17.8	Under −17.8	
	TLV-TWA (ppm)	Over 500	500-201	200-5	Under 5	
	Heat of reaction (kcal/mole)	No reaction	0-50	51-100	Over 100	
Parameters	Operating temperature (°C)	No Change	$0 \le T \le 100$	$-45<T<0$ $100<T<340$	$T \le -45$, $T \ge 340$	
	Operating pressure (kg/cm^2)	$P<1.05$	$1.05 \le P<10.5$	$10.5 \le P<42.2$	$P \ge 42.2$	
Total risk undices						

※ TLV-TWA: Threshold Limited Value - Time Weighted Average

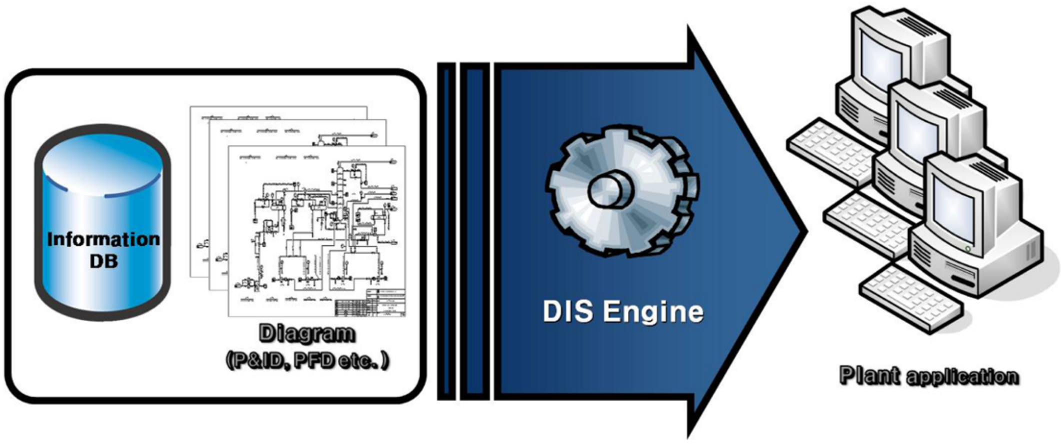

Fig. 4. Concept of DIS.

scribe a complex system if some improvements are made. The process risk index suggested by the Korea Occupational Safety Agency as the weighted technique that has reflected the characteristics of process operation and raw material as the guideline of operating PSM is also appropriate to explain the risk priority of change. It also has the advantage of easy application. Accordingly, this study has prepared the judgment criteria of change risk according to the process risk index method suggested by the Korea Occupational Safety Agency. As for the judgment criteria of suggested change risk shown on the Table 3, the judgment basis and risk estimation method are suggested for change materials and process operation conditions.

DIS BASED MOC SYSTEM

1. DIS (Drawing Information System)

The process drawing that is P&ID, as the key element of including the basic items of equipment industry process information, includes the following information.

· Process Flow
· Process Operating Condition and Design Condition
· Piping and Equipment
· Safety Device and Instrument
· Equipment and Piping Material
· Line Size and Flow Direction
· Equipment Size and Type
· Connection Marking to up and down stream
· Drawing Revision and Establishment History

Since the items above are basic and essential, they are chosen and added selectively. The drawing management in the workplaces of equipment industry is generally conducted in the hard copy type of Master P&ID form. The most important part of this management system is to update and retrieve relevant data. The change job of process is performed relatively often in accordance with the safety and operation issue and market change. Therefore, it is necessary to perform the update of process information as soon as possible in order to prevent a safety accident and operation error from the outdated process information. Therefore, this study has proposed the DIS with a real-time update function. The DIS is designed so that all the drawings existing in the form of CAD file can be easily viewed on the web-based environment without the need for CAD S/W. In other words, the engine of this system converts the key data of holding major process information such as P&ID and PFD existing in the form of CAD file into images for easy viewing through DIS while facilitating the update in a way of uploading updated CAD files onto DIS.

The CAD files are structured in a way that they are converted into the web images to allow multiple users viewing the drawings simultaneously through the DIS via the DIS engine as in the process of Fig. 4. Also, since P&ID is the data of holding detailed process information, its reading can be done freely as needed by process workers. However, the update like revision can be performed only by the staffs of holding relevant authority. Recently, studies have been conducted by government organizations about how to build an integrated risk management system based on the GIS engine. However, these attempts have been focused on the management rather than safety improvement of workplaces. Hence, this study intends to propose an integrated structure based on the DIS of different purpose though the DB integration method is the same. P&ID that makes the basis of DIS holds all the information of process design, operation information and process equipment information. Such information is basically constructed in the bi-directional method that the information is exchanged in both directions in accordance with the potential risk analysis module, accident damage prediction module and change management system as shown on the Fig. 6. Together with these, this study proposes the UI (user interface)

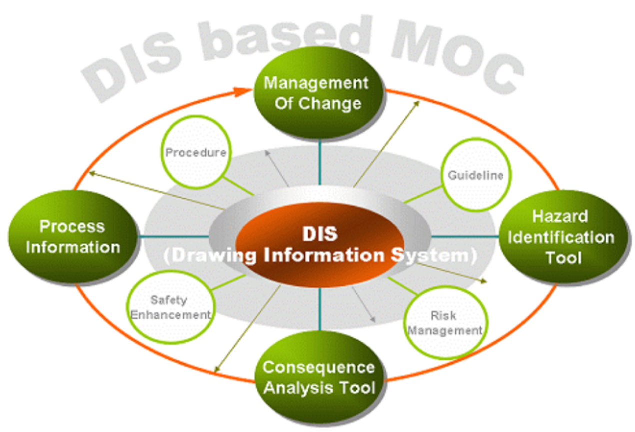

Fig. 5. Structure of MOC system based on DIS.

method that allows the DIS accessing the remaining three systems independently.

2. Risk-based MOC System

In this study, the MOC system was created based on process safety technology and the DIS oriented method. This system enhanced the safety by finding and complementing weaknesses in the facilities MOC. This system was also designed to enhance the facilities safety by performing a risk-based MOC and to improve the MOC by providing a useful tool as DIS-based MOC system. Fig. 5 shows the MOC system concept and related structure of each tool.

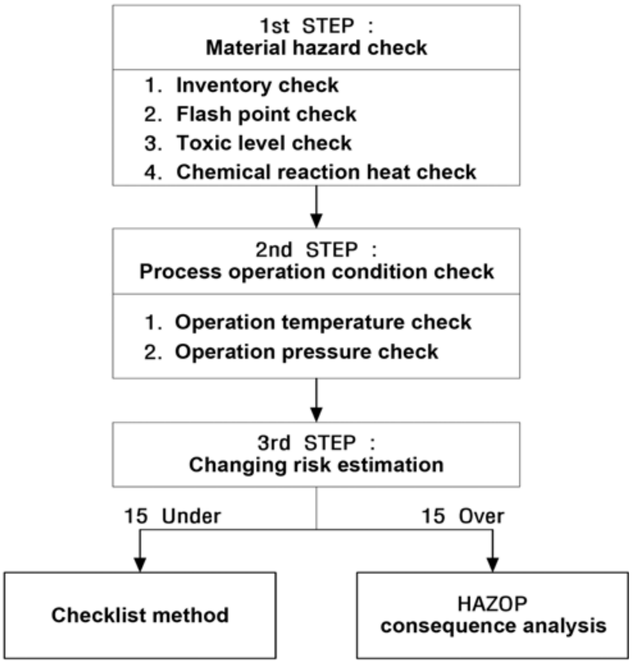

Fig. 6. Changing risk estimation flow.

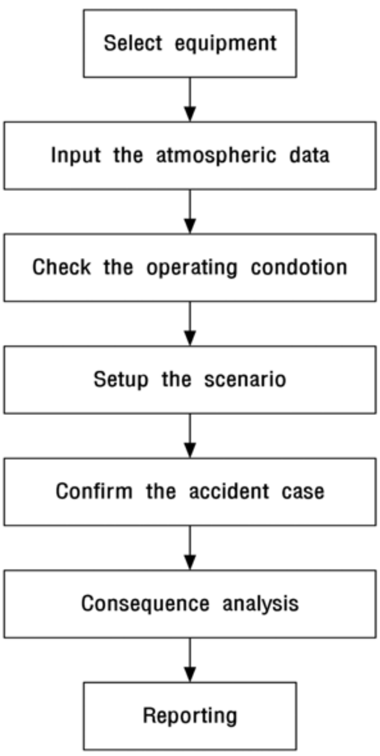

Fig. 7. Logic of consequence analysis tool.

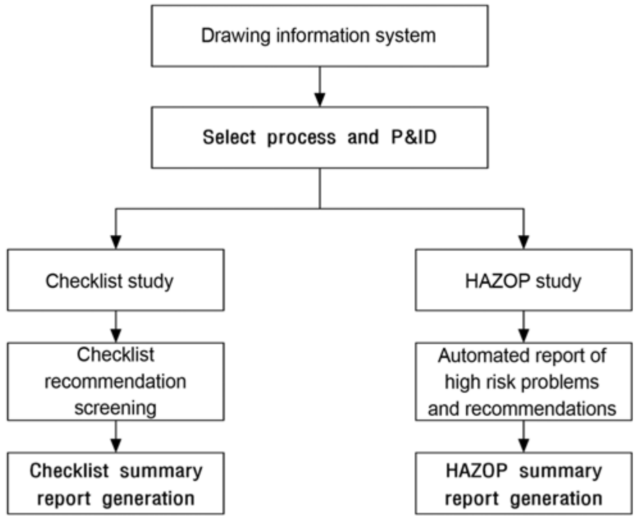

Fig. 8. Logic of potential hazard analysis tool.

This study recommended the MOC system to industrial facilities as the setup of the model standard for the decision-making process, the MOC procedure based risk assessment, and the judgment and risk estimation of the process modification. These analyses procedures are presented.

HIT (Hazard Identification Tool) and CAT (Consequence Analysis Tool) modules were developed using the risk assessment checklist, the HAZOP risk ranking, the scenarios for consequence analysis and reporting automation. Figs. 7 and 8 show the CAT procedure and the HIT system flow.

These modules make the process risk easier to understand. An effective risk-based MOC review was conducted by this new method. A new method for the MOC S/W system was also investigated vigorously in this study.

This method was developed using a new technique which was based on the DIS linking MOC system and the HIT and CAT Modules, including the process safety information. The goals of this work were to enhance the safety level and improve the performance efficiency.

CASE STUDY

The piping alteration case corresponded to the change in CS (carbon steel) quality of the material using SUS 304 (304 stainless steels) to elevate the authoritativeness of the piping that supplies styrene. According to the ANSI 1006 code, a weak special quality heat and corrosion were exhibited for the CS. The ANSI type 304 stainless steel with SUS 304 quality exhibited strong special quality heat and corrosion properties, and therefore, was better than CS for piping that handles the chemicals.

1. Step 1. Change Judgment and Importance Screening

Judgment of change study can be estimated by Table 2. This case is checked against #2 and #25 elements. The change is evaluated

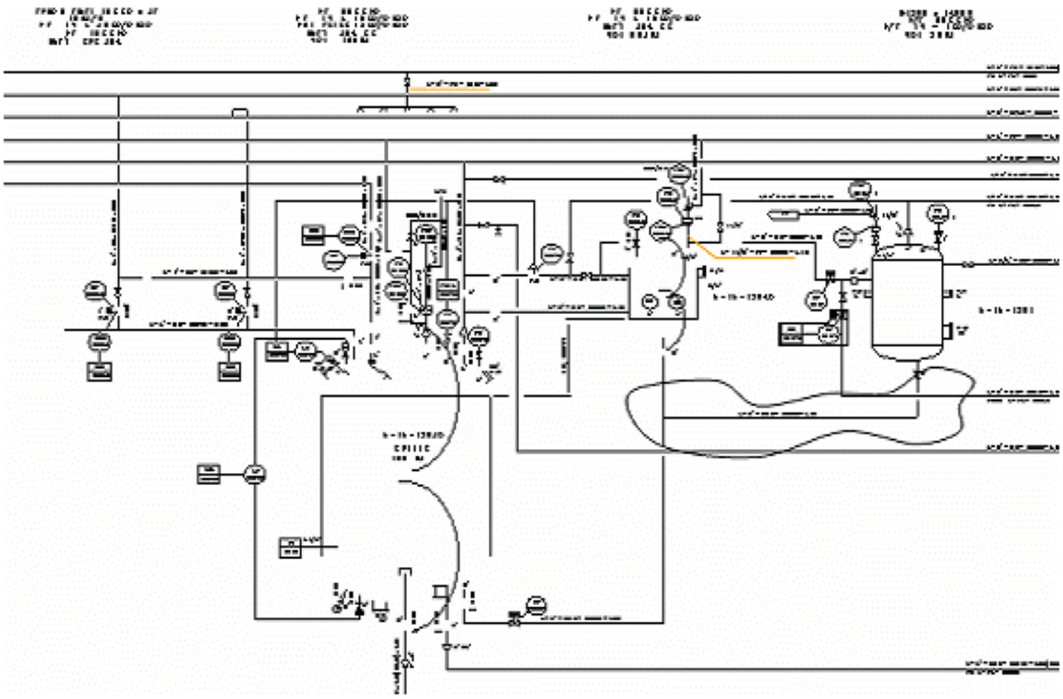

Fig. 9. P&ID of pipe change section.

as major change case by risk-based MOC procedure.

2. Step 2. Change Risk Assessment

Risk-based MOC system provided in Table 3 of change risk matrix to calculate risk levels. Results, that calculate the above material special quality and process driving conditions inflecting alteration danger index checklist, display nine prognostications. To achieve danger estimation which could take place after modification, a checklist technique was applied according to the procedure. Detailed process condition is as below.

· Material: Styrene (CAS No. 96-09-3)
· Flow in the process: No change
· Flash point: 165 °F (74 °C)
· Reaction condition change: No change
· Operating temperature change: No change
· Operating pressure: 5 kg/cm^2

3. Step 3. Checklist Study

Execute checklist estimation. As a result, two problems that correspond to piping hitch upside pollution and branch that stand-by drew to improvement advice examination item. The checklist study is needed working days and five task team members. Checklist methodology is complied with Hazard Evaluation Procedure of AIChE CCPS.

4. Step 4. Change Request and Item Setting

Execute field investigation and consult with person in charge to achieve appropriateness examination of items and change review that is achieved on amendment. The review activities are required at MOC committee which should approve ranks on modification government officials. MOC committee is run by brainstorming way.

5. Effect Analysis of Risk Assessment and DIS Based MOC System

First, this research had a fixed pattern and enabled the fast deduction of the result.

Second, all sorts of items about the alteration material and the process driving conditions were incorporated. Therefore, reliable alteration danger is evaluated through computation, and the checklist that estimation items are run against is confirmed with a great deal

Table 4. Analysis of risk assessment and DIS based MOC system efficiency (Pipe material changing)

Elements	Ordinary MOC	New MOC
Change judgment clarity and time	8 hr/The results depend on case by case situations	4 hr/Expect uncertainty reduced by more improved criteria
Change risk estimation clarity and time	Not available	2 hr/Change risk level evaluation as reasonable and practicable as possible
Risk assessment Clarity and time	1 week/Checklist elements are not clear Hazard identification is unseasonable	2 days/Proposed procedure and checklist can make reasonable risk evaluation
Change review efficiency	This method has some limitations such as committee organization, time, and effort etc	Web based system improves accessibility for MOC committee operation. It can lead to précised change review activities

of user-friendliness.

Third, an inspection was conducted on alteration administration progress situation, and relevant business personnel in charge was evaluated to achieve relevant business without dropping essential particulars.

The benefit elements of risk assessment and DIS based MOC system are resented a variety of views as Table 4.

CONCLUSIONS

The functional advantages of the risk and DIS-based MOC were studied for the risk-based MOC procedure and the effective MOC was determined.

First, this study recommended the MOC system to industrial facilities as the setup of the obvious standard for the decision-making process MOC procedure-based risk assessment and the judgment and risk estimation of the change.

Second, the HIT and CAT modules were developed using the risk assessment checklist, the HAZOP risk ranking, the scenarios for consequence analysis and reporting automation. These modules were excellent for the process risk. This new method was incorporated in an effective risk-based MOC review.

Third, this study suggested a new method for the MOC S/W system. This method was developed using a new technique, which was based on the DIS system linking MOC system and the HIT module and CAT Modules, including the process safety information. The goals were to enhance the safety level and improve the performance efficiency.

Finally, the two case studies of the major change proved that the PSM that was performed using DIS was very efficient, and the safety of plants was improved because the risk assessment, which is the most difficult part of work in most chemical plants, was easily performed using MOC. Additionally, the risk-based MOC system and the technical judgment of the change increased the accuracy of the MOC process.

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