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Points to Be Checked When Performing Risk Assessment and Risk Reduction on Chemical Hazards to Prevent Explosions, Fires, and Other Accidents

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Japan Organization of Occupational Health and Safety
National Institute of Occupational Safety and Health, Japan

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[Background]

Pursuant to Article 28-2 of the Industrial Safety and Health Act, each business operator has an obligation to make efforts to perform risk assessment and risk reduction. In addition, the new rule went into effect in June 2016 that would make it mandatory to perform risk assessment and risk reduction on chemical substances that are recognized as having certain levels of physical and health hazard, due to which risk assessment and risk reduction might have already been performed at many work/operation sites. Meanwhile, there are also work/operation sites that have not been able to perform risk assessment and risk reduction because they do not know how to go about it, among other reasons.
The purpose of performing risk assessment and risk reduction on chemical hazards is to examine and implement measures for preventing accidents and disasters in advance, and to achieve this purpose, review and execution of the following action items are crucial.

1) List all potential chemical hazard that exist.
2) Identify every single process (scenario) through which a process accident could possibly occur.
3) Examine and implement measures that could effectively reduce the risks.
4) Accurately convey the results of the risk assessments and risk reduction to the workers, etc.

In order to effectively perform a risk assessment and risk reduction on chemical hazards to prevent explosions, fires, and other accidents, those performing the assessment and risk reduction must possess sufficient knowledge of chemical substances and the proper procedures through which to handle them. In addition, they must identify the hazard pertaining to the facilities and equipment on the work/operation site and also the work/operation processes through which the facilities and equipment are handled, and also each possible scenario that could lead to an explosion, fire, or other accidents.
However, when the results of risk assessments and risk reduction on chemical hazards that have been performed at work/operation sites are reviewed, accurate examination was not properly performed in 1) through 4) above in a large number of cases. In other words, although significant amounts of time and labor were spent to perform risk assessments and risk reduction, many of them failed to recognize all hazard or implement measures to properly reduce the risks that had been identified.

[Purpose of this Document]

The National Institute of Occupational Safety and Health, Japan (hereinafter referred to as the "JNIOSH") has created this document so that it can be used to verify and inspect whether basic points are properly reviewed while performing risk assessments and risk reduction on chemical hazards in order to prevent explosions, fires, and other accidents. By using this document, the responsible staff members working at work/operation sites (i.e., those in charge of performing risk assessments and risk reduction) can properly review the status and results of the risk assessments and risk reduction that are performed at their respective companies. In addition, occupational safety and health consultants and inspectors at the inspection offices can use this document to review the points that they should check when providing guidance at workplace.
It must be noted, however, that performing risk assessment and risk reduction in accordance with this document will not guarantee that all existing risks can be identified. Each person performing a risk assessment and risk reduction must keep in mind that it must constantly and carefully identify and investigate all potential risks on its own from a critical viewpoint to make sure there is no risk or issue left unchecked, with respect to the method through which each assessment is handled concerning each particular facility, equipment, etc.

[How to Use this Document]

As shown on P.4 and P.5, there are a total of 37 items to be checked. Those items are the focal points of the procedure of risk assessment and risk reduction as specified in the document titled 'JNIOSH-TD-No.5' published by the JNIOSH (see P.3), which is based on and conforms to the procedure indicated in the risk assessment guidelines issued by the Ministry of Health, Labour and Welfare ("MHLW") (see P.2). While each item must be answered with a 'yes' or 'no,' any items that cannot be answered with a definitive 'yes' (i.e., low confidence) and those that are answered with a 'no' must be reinvestigated and dealt with in a swift manner. As each point to be checked is explained (i.e., important points to keep in mind when providing answers) in P.6 and subsequent pages, use the information as reference.

I. Procedure for Performing Risk Assessment and Risk Reduction on Chemical Substances

(1) Procedure for Performing Risk Assessment and Risk Reduction on Chemical Substances as Specified in the Guidelines Issued by the Ministry of Health, Labour and Welfare

The following is an outline of the procedure for performing risk assessment and risk reduction on chemical substances as specified in the guidelines issued by the Ministry of Health, Labour and Welfare, as indicated in Figure 1 below.

Step 1: For each chemical substance involved, identify all work tasks/operations performed on or with the chemical substances that should be risk assessed. Then identify its physical and health hazard based on the GHS classification as stated in the SDS.

Step 2: Estimate risk for each work tasks/operations that involves manufacturing or handling of each applicable chemical substance using one of the methods as specified in A. through C. below or any combination of these methods.

A. A method that considers the level of risk (i.e., risk probability) of the applicable chemical substance causing danger and/or health impairment to the workers, and the magnitude (i.e., level of severity) of such danger and/or health impairment

B. A method that considers the degree of the workers' exposure to the applicable chemical substance (i.e., exposure concentration) and the level of health hazard of the applicable chemical substance

C. A method that is equivalent to either of the methods specified in A. and B. above

Step 3: Review the result of the risk assessment, and examine possible measures that can be implemented to prevent any physical and health hazard from occurring to the workers accordingly.

- If any measures are specified in the Industrial Safety and Health Act, it is necessary to implement those measures.
- It is necessary to review the risk reduction measures based on the priority specified below.
  (1) Inherent safety measures that involve switching to the use of chemical substances, etc. with lower physical and health hazard levels, and changing of operation conditions to chemical reaction processes, etc.
  (2) Engineering controls (i.e., adoption of explosion-protected structures of mechanical facilities and equipment, etc.)
  (3) Administrative controls (i.e., improvement of work/operation procedures, etc.)
  (4) Use of effective personal protective equipment

Step 4: Make efforts to implement the risk reduction measures that have been examined in a swift manner.

Especially concerning any risks that have been identified that could lead to death, residual disability, or serious disease, implement tentative measures immediately. After implementing risk reduction measures, reevaluate the risks.

Step 5: Convey the following information to the workers.

(1) Names of the applicable chemical substances
(2) Descriptions of the applicable work tasks/operations
(3) Results of the risk assessments and risk reductions performed (i.e., levels of physical hazards and health hazards identified, risk estimation)
(4) Descriptions of the risk reduction measures implemented

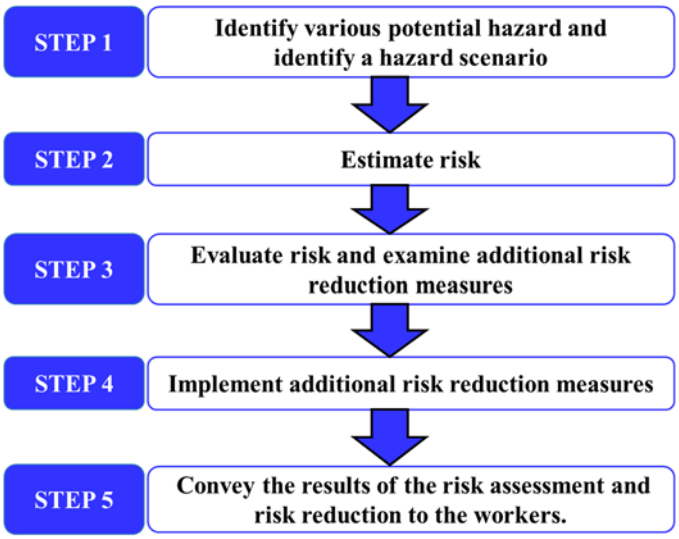

Figure 1: Risk assessment procedure on chemical substances (source: MHLW guidelines)

(2) Procedure for Performing Risk Assessment and Risk Reduction for the Prevention of Process Accidents (JNIOSH Method)

Figure 2 is an outline of the procedure for performing risk assessment and risk reduction proposed by JNIOSH (called JNIOSH Method) to prevent process accidents (i.e., explosion, fire, burst, leak, etc.).

STEP 1 Identify hazards pertaining to the chemical substances and processes being handled.

Use a questionnaire form to identify the hazards pertaining to the chemical substances and processes being handled at each chemical substance facility, and the process accidents that could arise from those hazards. Then, perform the risk assessment and risk reduction as specified in STEP 2 and STEP 3 focusing on the hazards and process accidents, etc. that have been identified. Even in cases where no hazard has been identified pertaining to the chemical substances and processes involved, there still remains a possibility for issues, etc. to arise concerning the work tasks/operations, facilities, equipment, etc. involved, for which it is necessary to perform the risk assessments and risk reduction specified in STEP 2 and STEP 3.

STEP 2 Perform risk assessments and risk reduction measures.

(1) Identify the events that would cause potential hazards pertaining to the applicable processes to happen (i.e., trigger events), and determine the scenarios through which the trigger events would cause process accidents while referencing the information found in STEP 1.
(2) Estimate the risk involved in each scenario (i.e., the level of risk) and determine whether the allowable risk level has been reached (i.e., risk evaluation). If there are risk reduction measures already implemented, estimate the risk for both the case where no risk reduction measures are implemented (1st) and the case where the risk reduction measures have been functioning (2nd) in order to verify the effectiveness of those measures.
(3) For each scenario where the risk level is high (i.e., the tolerable level is surpassed), examine (plan) additional risk reduction measures and estimate the risk level again (3rd). Determine the feasibility of implementing the additional risk reduction measures that have been proposed. If there is any information, etc. that should be communicated to the on-site workers in order to maintain the functions of the risk reduction measures implemented, it must be so stated on the plan execution sheet to raise caution. If there is any residual risk, also clarify how to address it. Repeat this process of risk reduction measure proposal until the risk level comes down to the tolerable range.

Repeat the process as described in (1) through (3) above to identify all various scenarios that could occur, estimate and evaluate the risks involved, and examine necessary risk reduction measures, etc.

STEP 3 Decide which risk reduction measures to implement.

Summarize the result of the examination performed on each scenario in the risk assessment and risk reduction sheet, and assign priorities to the risk reduction measures that should be implemented. Then decide which risk reduction measures to implement according to the prioritization while considering the technical and cost factors involved.

* In this document, the items for checking the status of risk assessments and risk reduction and reviewing their results are explained in accordance with the following procedure.

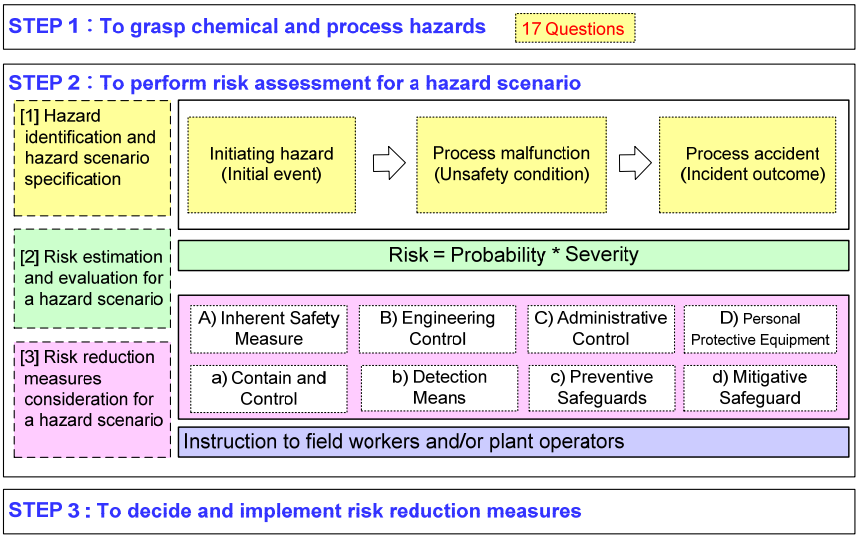

Figure 2: Procedure of performing risk assessment and risk reduction for the prevention of process accidents (JNIOSH Method)

II. Points to Be Checked When Performing Risk Assessment and Risk Reduction on Chemical hazards to Prevent Explosions, Fires, and Other Accidents

			Yes	No
1. Preparation				
(1) Staff members performing risk assessment and risk reduction (item 4 of the guidelines)				
	1	Is the safety (health) manager playing the leadership role in facilitating performing risk assessment and risk reduction (such responsibility is not delegated to the staff members in charge and those working on site)?		
(2) When risk assessment and risk reduction is performed (item 5 of the guidelines)				
	2	Are risk assessments and risk reduction performed at the times as specified in item 5 (2) of the guidelines (when the employer is obliged to make effort to conduct them) in addition to the times when it is obliged to perform risk assessment and risk reduction as specified in item 5 (1) of the guidelines?		
(3) Organization of information and documents that are necessary for performing risk assessment and risk reduction (item 7 of the guidelines)				
	3	Are GHS labels regularly checked? Have the latest versions of the SDSs been obtained?		
	4	In the process of information gathering, are the documents, etc. on the irregular (unsteady) work tasks/operations included as well as the documents, etc. on the regular work tasks/operations, depending on the applicable work task/operations, to reflect the actual status of the worksite?		
	5	Concerning the work/operation procedure manuals, schematic drawings, etc. that are referenced, does the staff working on site check and make sure that they correspond to the work task/operations that are actually performed and the facility and equipment that are used on site (Are their latest versions used)?		
2. Perform of risk assessment and risk reduction **2.1 Identification of trigger events and scenarios (items 6 and 8 of the guidelines)**				
(1) Entry of information on the purpose of work tasks/operations and the expected functions of the facilities and equipment (Table 1 on P.19)				
	6	Are the purpose of the work tasks/operations and the expected functions of the facilities and equipment, which are the objects of the risk assessment and risk reduction, clearly defined?		
(2) Identification of trigger events				
	7	Are the events that would cause potential hazards to happen (i.e., trigger events) identified in a comprehensive manner, based on the work/operation procedure manuals and the schematic drawings of the facilities, equipment, etc. that are the objects of risk assessment and risk reduction?		
	8	Are all work tasks/operations that are the objects of risk assessments reviewed one by one to identify each improper work/operation (i.e., erroneous operation, mistake due to misjudgment, missed work task, and other human errors) as a trigger event?		
	9	Are all facilities and all pieces of equipment that are the objects of risk assessment and risk reduction reviewed one by one to identify each issue or error (i.e., device malfunction, equipment failure, etc.) as a trigger event?		
	10	Are external factors (i.e., natural disasters, power outage, etc.) also identified as trigger events?		
(3) Identification of scenarios				
	11	Are scenarios examined based on the information stated in the GHS labels and SDSs?		
	12	Are the three elements of combustion considered when identifying the scenarios under which process accidents (i.e., explosion, fire, etc.) would occur?		
	13	Are the scenarios of process accidents (i.e., explosion, fire, etc.) occurring also considered that do not involve all three elements of combustion?		
	14	While identifying scenarios, does the examination process assume that there are no existing risk reduction measures implemented?		
	15	While identifying scenarios, is input from the on-site workers referenced as to the points they regularly feel unsafe or wary about, etc.?		
	16	Is information gathered on the company's own previous accident cases as well as those of other companies involving similar work tasks/operations and near-miss reports, etc. for reference purposes?		
	17	Are scenarios clearly stated in three separate categories, i.e., trigger events, process malfunctions/unsafety conditions, and process accidents (explosion, fire, etc.), in order to make it easier to examine risk reduction measures? (This is unique to JNIOSH Method.)		
2.2 Risk estimation and risk evaluation against scenarios **(1) Review of existing risk reduction measures**				
	18	Are the 'types' and 'purpose' of risk reduction measures clearly stated to facilitate understanding of the intentions behind their design (i.e., their expected functions and purpose)? (This is unique to JNIOSH Method.) * For more information on what 'types' and 'purpose' are, refer to the explanatory text.)		

			Yes	No
(2) Risk estimation and risk evaluation (item 9 of the guidelines)				
	19	Are the standards and criteria set in advance, based on which to conduct risk estimation and risk evaluation?		
	20	Are risk estimation and risk evaluation conducted while always identifying the worst-case scenarios?		
	21	Is risk estimation conducted while taking the following points into consideration? ✔The level of severity of hazards that may arise can be reduced A) only by inherent safety measures. ✔If any B) engineering controls and C) administrative controls are implemented, those measures only contribute to reducing the frequency (i.e., possibility) of hazards occurring and do not reduce the level of their severity. ✔The reliability of the work tasks and operation performed by the workers and also the reliability of any engineering controls implemented such as interlocks must be considered. ✔When estimating the level of severity of hazards that could occur, the worst-case scenarios (i.e., all measures implemented would fail except for A) inherent safety measures) are assumed.		
	22	Is the result of risk reevaluation reviewed to check how effective the existing risk reduction measures are in reducing the risk levels?		
2.3 Examination of risk reduction measures against scenarios (planning of additional risk reduction measures) **(1) Examination of additional risk reduction measures and risk reevaluation (item 10 of the guidelines)**				
	23	Are risk reduction measures examined in the order of their priority? A) Inherent safety measures - B) Engineering controls - C) Administrative controls - D) Personal protective equipment		
	24	Are several risk reduction measures examined in accordance with the concept of the multiple protection measures as specified below, for the prevention of process accidents? (This is unique to JNIOSH Method.) The correct order is as follows: a) Contain and control - b) Detection means - c) Preventive safeguards - d) Mitigative safeguards		
	25	Are the SDSs of the chemical substances being handled reviewed with attention to the information provided on the measures to be implemented when fires, etc. occur?		
	26	Is the effectiveness of additional risk reduction measures checked during risk re-estimation and risk reevaluation, if any additional risk reduction measures have been implemented?		
(2) Examination of the feasibility of implementing additional risk reduction measures				
	27	Is the feasibility of implementing proposed risk reduction measures examined while taking into consideration the work/operation conditions of the existing risk reduction measures and the locations where the additional risk reduction measures are implemented?		
(3) Caution to be exercised by the workers, etc. in order to maintain the functions of risk reduction measures				
	28	Is information on the actions to be taken and the points to which attention must be paid stated in a detailed and specific manner, so that the workers can understand the intentions behind the design of the risk reduction measures and maintain their functions?		
	29	If any residual risks are present, are the methods of taking actions to deal with those risks on site examined, and clearly stated as items to be communicated to the workers?		
2.4 Repeat of the steps specified in 2.1 through 2.3 (comprehensive examination of various scenarios)				
	30	Are scenarios continuously examined while identifying various trigger events that can possibly occur?		
2.5 Decision on risk reduction measures (item 10 of the guidelines) **(1) Summarize multiple scenarios in one table (Table 2 on P.20)**				
	31	Are scenarios checked to make sure that estimated risks do not vary excessively between the scenarios and the scenarios and risk estimations are consistent throughout?		
(2) Decision on risk reduction measures to be implemented				
	32	Are risk reduction measures examined with attention to the cases where the same risk reduction measures have been proposed for multiple scenarios to determine whether those measures can be implemented all at once?		
3. Result of risk assessment and risk reduction				
	33	Are the results of risk assessment and risk reduction stated in a specific and easily understandable manner?		
	34	Is there any risk assessment result and risk reduction left abandoned before examination is completed on it?		
	35	Is the record of the scenarios identified also kept that would not lead to process accidents?		
	36	Are the name of the staff responsible for implementing risk reduction measures and the due dates by which to implement them clearly stated?		
4. Utilization of the result of risk assessment and risk reduction (item 11 of the guidelines)				
	37	Are the results of risk assessment and risk reduction performed shared with the concerned workers?		

III. Explanation of Points to Be Checked
(Important Points to Keep in Mind When Providing Answers)

1. Preparation

(1) Staff members performing risk assessment and risk reduction (item 4 of the guidelines)

1. Is the safety (health) manager playing the leadership role in facilitating performing risk assessment and risk reduction (such responsibility is not delegated to the staff members in charge and those working on site)?

* If the task of performing risk assessment and risk reduction is assigned to only a small number of staff members in charge, the chance of arriving at skewed evaluation results and failing to detect important hazards arises due to the bias or imbalance that exists in those staff members' knowledge, etc. Therefore, it is important to have the safety (health) managers play the leadership role with staff members from various positions forming teams around them, and create a climate where the managers and members can offer their opinions from their respective positions.

* While it may be sometimes difficult to have all experts, operators, maintenance staff members, etc. be present in one place, it must be recognized that the purpose of performing risk assessment and risk reduction is not to complete all tasks in a single session. Rather it is important continuously perform risk assessment and risk reduction even bit by bit. Therefore, formulate such a plan in advance by dividing up the areas, work tasks/operations, etc. to be assessed, and set up an environment where risk assessment and risk reduction can be performed continuously.

(2) When risk assessment and risk reduction is performed (item 5 of the guidelines)

2. Are risk assessment and risk reduction performed at the times as specified in item 5 (2) of the guidelines (when the employer is obliged to make effort to conduct them) in addition to the times when it is obliged to perform risk assessment and risk reduction as specified in item 5 (1) of the guidelines?

* The information provided in 5 (2) C) of the guidelines is unique to the guidelines for performing risk assessment and risk reduction on chemical substances. Therefore, if any of the action items specified by the information are not executed, be sure to address them.

(3) Organization of information and documents that are necessary for performing risk assessment and risk reduction (item 7 of the guidelines)

3. Are GHS labels regularly checked? Have the latest versions of the SDSs been obtained?

* Concerning all chemical substances that are known to possess a certain level of physical hazard and health hazard to humans, the parties handling them have the obligation to put labels on the containers, etc. of the chemical substances and also issue SDSs to indicate such information on the substances when assigning or providing it.

4. In the process of information gathering, are the documents, etc. on the irregular (unsteady) work tasks included as well as the documents, etc. on the regular work tasks/operations, depending on the applicable work tasks/operations, to reflect the actual status of the work/operation site?

* Explosions, fires, and other accidents also occur from non-manufacturing tasks, such as materials switching, facility and equipment maintenance and inspection, cleaning, etc. Therefore, it is necessary to perform risk assessment and risk reduction on such work tasks/operations as well.

* While it is ideal to arrange all necessary information and documents before performing risk assessment and risk reduction, it is also possible to prepare them as much as possible in advance and then gather and introduce the rest of information, documents, etc. while performing the risk assessment and risk reduction.

* While it is ideal to have all documents prepared and stored as official ones, documents that could not be prepared as such may be created on site in the form of notes, drawings, etc. to supplement for any insufficient documentation. In this case, it is important to organize the notes, drawings, etc. as official documents and share them with all concerned staff members later.

5. Concerning the work/operation procedure manuals, schematic drawings, etc. that are referenced, does the staff working on site check and make sure that they correspond to the work tasks/operations that are actually performed and the facility and equipment that are used on site (Are their latest versions used)?

* Referencing old work/operation procedure manuals, schematic drawings, etc. when performing risk assessment and risk reduction is not a proper way to examine risk reduction measures to implement on the existing facilities, equipment, and work tasks/operations. Those documents must be always kept up-to-date.

2. Perform of risk assessment and risk reduction

2.1 Identification of trigger events and scenarios (items 6 and 8 of the guidelines)

(1) Entry of information on the purpose of work tasks/operations and the expected functions of the facilities and equipment **(Table 1 on P.19)**

6. Are the purpose of the work tasks/operations and the expected functions of the facilities and equipment, which are the objects of the risk assessment and risk reduction, clearly defined?

* All hazardous situations and conditions can be identified as deviations (errors) from the correct work task/operation performance or from the desirable state of the facilities and equipment. Therefore, it is necessary to clearly state the purpose of performing the work tasks/operations and also the expected functions of the facilities and equipment, etc.

(2) Identification of trigger events

Typical issues that arise when identifying hazards (i.e., trigger events)
- Typically attention is only paid to the characteristics of chemical substances, reactions they cause, etc. while the possibility of facility and equipment failures and mistakes made by the workers while performing work tasks/operations causing (i.e., events triggering) an explosion or fire is overlooked.
- External factors such as natural disasters including earthquakes and typhoons, and power outage can become trigger events as well.

7. Are the events that would cause potential hazards to happen (i.e., trigger events) identified in a comprehensive manner, based on the work/operation procedure manuals and the schematic drawings of the facilities, equipment, etc. that are the objects of risk assessment and risk reduction?

* The purpose of performing risk assessment and risk reduction is to comprehensively identify the events that could cause potential hazards to happen (i.e., trigger events) and examine the likelihood of accidents occurring. Therefore, it is necessary to identify all inappropriate work tasks/operations, and facility and equipment issues that exist or potentially arise, including all events imaginable that have not been experienced before, while managing to avoid any forgotten or missed items that should be examined (see check points 8 through 10 for more specific information).

* Not all trigger events that have been identified will necessarily lead to process accidents. Even so, it is important to understand why occurrence of certain trigger events will not cause explosions, fires, and other accidents.

* It is not necessary to identify all trigger events and examine all risk reduction measures that can be thought of, all at once. It is rather important to narrow down the objects of risk assessment and risk reduction and continuously perform them in several times.

  → Generally there is a tendency to only pick and choose the work tasks/operations, facilities, and equipment that might lead to process accidents. So first, identify trigger events by referencing the similar malfunctions and erroneous operations and other issues experienced in the past. Then, to identify more potential trigger events, think of error events that could possibly arise concerning each work task/operation, facility, and equipment.

8. Are all work tasks/operations that are the objects of risk assessment and risk reduction reviewed one by one to identify each improper work/operation (i.e., erroneous operation, mistake due to misjudgment, missed work task, and other human errors) as a trigger event?

* If any detailed work/operation instruction manual, etc. are referenced, the number of issues that get identified will be enormous. In such case, first clarify the purpose of each work task/operation (i.e., intent or significance of each work task/operation, etc.); then put the works tasks/operations into groups; and identify issues or errors that would prevent the grouped work tasks/operations from achieving their purpose. As for any grouped work tasks/operations for which the order of work task/operation, etc. must be paid attention to, they should be divided up and examined again.

9. Are all facilities and all pieces of equipment that are the objects of risk assessment and risk reduction reviewed one by one to identify each issue or error (i.e., device malfunction, equipment failure, etc.) as a trigger event?

* An issue with or failure of any facility and equipment could possibly cause its content to leak and eventually lead to an explosion or fire. In addition, if any worker is stationed near where such leak occurs, it could lead to the worker suffering health impairment (i.e., poisoning or another type of work-related accident).

10. Are external factors (i.e., natural disasters, power outage, etc.) also identified as trigger events?

* It is noteworthy that many external factors could lead to (i) issues with or errors of work tasks/operations, or (ii) issues with or failures of facilities and equipment, which could lead to results similar to those reached after examining the external factors. As for power outages, they could be caused by various external factors. Therefore, it is necessary to consider about backup power supply to be used in case of emergency stop, the work task/operation stopping procedure, etc. thoroughly.

(3) Identification of scenarios

Typical issues that arise when examining scenarios

- Even if there are risk reduction measures already implemented, there is a possibility that they may not function properly when an abnormality occurs. Therefore, it is necessary to always identify that the worst-case scenario will play out.
- By reviewing the GHS classification and SDSs, one can obtain information on the level of physical hazard of each chemical substance and what points to pay attention to when handling the chemical substances. However, it is difficult to identify a scenario with respect to each process through which multiple chemical substances show reactions (including not only the materials from which the products are manufactured but also the materials from which various pieces of equipment, etc. have been built).
- It is pointed out in the risk assessment guidelines, etc. that uncontrolled reactions of chemical substances could cause process accidents. However, as the ability to acquire data on any such uncontrolled reactions is dependent on the technological capability of the work/operation site, the aforementioned data still lack consistency.
- When identifying scenarios, it is recommendable to gather information on the past cases of process accidents and near-miss incidents that involve similar work tasks/operations and chemical substances, for reference purposes.

11. Are scenarios examined based on the information stated in the GHS labels and SDSs?

* If any GHS pictogram s are indicated, they must be always checked. The SDSs also include information on the level of physical hazard of each chemical substance involved. When they are examined along with the conditions for performing the work tasks/operations, handling the facilities and equipment, and chemical substances, etc., the scenarios that could lead to explosions and fires can be identified.

* Of the nine pictogram labels that exist, the following five are related to explosion and fire hazards.

Pictogram	Representative hazard or chemical hazard	Pictogram	Representative hazard or chemical hazard
[Flame] 	Extremely flammable gas and aerosol Extremely flammable liquid and vapor Flammable solid Heating may cause a fire May ignite spontaneously if exposed to air In contact with water releases flammable gases	**[Flame over circle]** 	May cause or intensify fire May cause fire or explosion May intensify fire
[Exploding bomb] 	Explosive: mass explosion hazard Explosive: fire, blast, or projection hazard Heating may cause an explosion	**[Gas cylinder]** 	Contains gas under pressure: may explode if heated Contains refrigerated gas: may cause cryogenic burns or injury
[Corrosion] 	May be corrosive to metals		

* GHS labels contain various types of information such as ‘signal words’ and ‘hazard statement’ that notify the level of physical and health hazard of each chemical substance involved, and ‘precautionary statement’ specifying the points to pay attention to concerning safety measures, emergency responses, and storage and management, and so they can be referenced when examining scenarios.

* As SDSs contain the following types of information, they can be referenced when examining the trigger events, scenarios, and risk reduction measures.

1. Product and company identification	9. Physical and chemical properties (flash point, vapor pressure, etc.)
2. Hazards identification (GHS classification)	10. Stability and reactivity
3. Composition/information on ingredients (CAS numbers, chemical names, content, etc.)	11. Toxicological information (LD50 value, IARC classification, etc.)
4. First-aid measures	12. Ecological information
5. Fire-fighting measures	13. Disposal considerations
6. Accidental release measures	14. Transport information
7. Handling and storage	15. Regulatory information (the Industrial Safety and Health Act, the Act on Confirmation, etc. of Release Amounts of Specific Chemical Substances in the Environment and Promotion of Improvements to the Management Thereof, the Fire Service Act, etc.)
8. Exposure controls/personal protection (tolerable exposure threshold, protective gear, etc.)	16. Other information

12. Are the three elements of combustion considered when identifying the scenarios under which process accidents (i.e., explosion, fire, etc.) would occur?

* When identifying the scenarios that could lead to process accidents, it is helpful to consider whether the three elements of combustion are present in each case.

13. Are the scenarios of process accidents (i.e., explosion, fire, etc.) occurring also considered that do not involve all three elements of combustion?

* Process accidents could still occur even if not all three elements of combustions are present. As some examples of such case are provided below, reference them when identifying the scenarios.

- The explosives, self-reactive substances, and organic peroxides so specified in the GHS classification could possibly cause an explosion in the absence of air (i.e., oxygen) if they are exposed to heat, spark, flame, impact, friction, shock, or other form of energy.
- Some of the substance which, in contact with water, emit flammable gases so specified in the GHS classification could vigorously react when exposed to water or moisture in the air and cause an explosion.
- Oxidizers could naturally combust or cause an explosion or fire especially when they are mixed with flammable substances.
- Certain combinations of substances other than oxidizers and flammable substances could also cause an explosion or fire.
- Polymerizable substances could start an exothermic polymerization reaction that may get out of control and cause an explosion or fire, if polymerization inhibitors are removed from them or if their concentration is not sufficiently high.
- The gas under pressure so specified in the GHS classification could explode if heated up. Also there are certain gases such as acetylene and ethylene oxide that could cause explosive decomposition without being heated up.
- If the balance between heat generation, heat dissipation, and heat removal is lost during a reactive process, the reaction could get out of control and possibly cause an explosion or fire.
- If two or more substances are mixed, they could cause an explosion or fire, or form an explosive substance, etc.
- Methods of performing detailed examination include literature research, discussion with employees, consultation with experts, and tests to evaluate their levels of physical hazard.

(Note) The examples provided above are just sample cases and not comprehensive. Therefore, paying attention to these examples will not be sufficient. Therefore, examine the scenarios that could lead to process accidents while taking into consideration the characteristics of the chemical substances being handled at each work/operation site, the chemical reactions those substances could possibly cause, the work tasks/operations that are actually performed on site, and the handling conditions, etc. of the chemical substances.

14. While identifying scenarios, does the examination process assume that there are no existing risk reduction measures implemented?

* If it is assumed that there are existing risk reduction measures implemented during the identification of scenarios, it may occasionally prevent all scenarios that could lead to process accidents from being identified. If scenarios are examined in such manner, the scenarios through which process accidents are caused due to certain risk reduction measures not functioning as they are supposed to might be ignored. Therefore, attention must be paid to avoid such situation.

15. While identifying scenarios, is input from the on-site workers referenced as to the points they regularly feel unsafe or wary about, etc.?

* The purpose of identifying scenarios is to help the workers, etc. become more aware that there are trigger events that could lead to process accidents. Therefore, it is necessary to review the opinions of not only the staff members performing risk assessment and risk reduction but also those of the on-site workers as to what they regularly feel unsafe or wary about, etc., and examine scenarios in a comprehensive manner.

16. Is information gathered on the company's own previous accident cases as well as those of other companies involving similar work tasks/operations and near-miss incident reports, etc. for reference purposes?

* While it might be unlikely that the same exact accidents, and near-miss incidents that previously occurred would occur, similar physical hazards could happen in cases involving same substances. In addition, erroneously performed work tasks/operations (i.e., human errors) and issues with or failure of certain facilities and equipment that previously caused accidents or near-miss incidents could possibly cause accidents or near-miss incidents while performing different work tasks/operations. Therefore, it is necessary to gather information on the company's own accident cases that previously occurred but also other companies' accident cases that occurred while performing similar work tasks/operations, by using accident case database services that are available to the general public, and reference the information when identifying scenarios. In addition, if measures are implemented after experiencing accidents, and near-miss incidents, they can be also referenced for this purpose.

17. Are scenarios clearly stated in three separate categories, i.e., trigger events, process malfunctions/unsafety conditions, and process accidents (explosion, fire, etc.), in order to make it easier to examine risk reduction measures? (This is unique to JNIOSH Method.)

* If each scenario is clearly stated in the three separate categories of 'trigger events (i.e., causal events),' 'process malfunctions/unsafety conditions (i.e., intermediate events linking between trigger event occurrence and process accident occurrence),' and 'process accidents (i.e., the accidents that would finally occur and their effects),' examination of risk reduction measures as shown below becomes possible.
  - Measures against trigger events - Measures against the causes of process malfunctions/unsafety conditions
  - Measures against process malfunctions/unsafety conditions - Measures that detect process malfunctions/unsafety conditions as they occur and prevent process accidents
  - Measures against process accidents - Measures to reduce the damage by process accidents when they occur

* When identifying scenarios, be sure to describe the event progression from the time a trigger event occurs and how that will lead to a process accident in details as much as possible, so that when the scenarios are reviewed later, they can be easily understood. It is acceptable to do this using bullet points and listing events in a chronological order for easy comprehension.

2.2 Risk estimation and risk evaluation against scenarios

(1) Review of existing risk reduction measures

18. Are the 'types' and 'purpose' of risk reduction measures clearly stated to facilitate understanding of the intentions behind their design (i.e., their expected functions and purpose)? (This is unique to JNIOSH Method.)

* If the purpose of each risk reduction measure is clearly stated, it will lead to a better recognition and understanding of the importance of implementing risk reduction measures and maintaining their functions not only among the staff members performing risk assessments and risk reductions but also the on-site workers.

* The **types** of risk reduction measures mean any of the following measures that apply as specified in the MHLW guidelines.

  A) Inherent safety measure, B) Engineering controls, C) Administrative controls, D) Personal protective equipment

* The **purpose** of risk reduction measures means any of the following measures that apply based on the concept of multiple protection measures.

  a) Contain and control, b) Detection means, c) Preventive safeguards, d) Mitigative safeguards

(2) Risk estimation and risk evaluation (item 9 of the guidelines)

Typical issues that arise when estimating risks

- There is a tendency to estimate risks low from the start, so that implementation of any inherent safety measure and engineering control can be avoided. It must be also noted that even if engineering controls and administrative controls are implemented and protective gear is worn, the level of physical hazard will not change, and so its level of severity cannot be lowered. In some cases, risks are re-estimated assuming that those measures are implemented, while not properly understanding the aforementioned point, and concluding that the risk level will come down. In such case, even if the hazards are correctly identified and hazard scenarios are properly identified, it does not necessarily result in a correct examination of risk reduction measures.

19. Are the standards and criteria set in advance, based on which to conduct risk estimation and risk evaluation?

* If the standards and criteria based on which to conduct risk estimation and risk evaluation are different between various scenarios, it is impossible to correctly set the priority for examining risk reduction measures. Therefore, it is necessary to define the standards and criteria for conducting risk estimation and risk evaluation in advance based on the consent of all concerned staff members, etc. and evaluate risks accordingly.

  Important The standards and criteria for conducting risk estimation as shown in Table 11 of the technical document (JNIOSH-TD-No.5), in which the JNIOSH procedures are explained, are provided as examples. Therefore, each company must define its evaluation standards and criteria in advance while taking into consideration the scale of each work task/operation site, the characteristics of the manufacturing processes and the products it manufactures, etc., which may be divided into and examined in three or more stages.

* The originally intended purpose of performing risk assessment and risk reduction is served by first examining and implementing risk reduction measures on the items with high risk levels (i.e., scenarios for which the level of physical hazard is relatively high) and then gradually moving to lower risk items in sequence after checking the risk level of each item as to how high or low it may be, instead of seeing how large or small the number (i.e., I, II, or III) assigned to the risk level of each evaluation item. This, however, does not mean that it is unnecessary to implement any measure on low-risk-level items.

20. Are risk estimation and risk evaluation conducted while always assuming the worst-case scenarios?

* For risk evaluation (1st), it assumes that there are no existing risk reduction measures or the functions of the risk reduction measures implemented have been nullified. Therefore, it is necessary not to under-evaluate the risks involved, thinking that the existing risk reduction measures would sufficiently cover those risks.

* Even if risk reduction measures are specified in schematic drawings and documents, there is a possibility that their functions are nullified on the actual site. Therefore, it is necessary to check and see whether or not the measures are functioning.

* Review the result of risk estimation and check whether or not the tolerable risk level has been reached (e.g., eliminate all scenarios under which risk level III would be reached).

21. Is risk estimation conducted while taking the following points into consideration?
- The level of severity of hazards that may arise can be reduced A) only by inherent safety measures.
- If any B) engineering controls and C) administrative controls are implemented, those measures only contribute to reducing the frequency (i.e., possibility) of hazards occurring and do not reduce the level of their severity.
- The reliability of the work tasks/operations performed by the workers and also the reliability of any engineering controls implemented such as interlocks must be considered.
- When estimating the level of severity of hazards that could occur, the worst-case scenarios (i.e., all measures implemented would fail except for A) inherent safety measures) are assumed.

* When estimating the level of severity, be sure to identify the worst-case scenarios (including cases where all risk reduction measures fail to function except for the inherent safety measures).

* It is important to clearly specify the grounds and the thought process based upon which risks are estimated. It is necessary to leave notes in the remarks section, etc. so that when the documents are reviewed again later, the rationale behind the risk estimation can be easily understood.

22. Is the result of risk reevaluation reviewed to check how effective the existing risk reduction measures are in reducing the risk levels?

* Conduct risk estimation and risk evaluation on each case where the risk reduction measures properly function as they are supposed to, and verify how effective they are (risk evaluation (2nd)).

* It is possible in some cases that even if risk reduction measures are implemented, it is unable to reduce the level of severity of the hazard involved and/or the frequency of the hazard occurrence. In such cases, it is occasionally determined that the risk level has not come down (risk level III → III, etc.). However, if risk reduction measures that cause any positive effects are implemented, maintaining their functions reduces the relative risk level. So clearly stating this sort of information in the remarks section, etc. on the sheet will help indicate the significance of implementing those risk reduction measures. Meanwhile, it is also important to recognize that the risk level still remains high in such case.

* If the risk level of any evaluated item exceeds the tolerable threshold, it is necessary to consider implementing additional or alternative risk reduction measures.

2.3 Examination of risk reduction measures against scenarios (planning of additional risk reduction measures)

(1) Examination of additional risk reduction measures and risk reevaluation (item 10 of the guidelines)

Typical issues that arise when examining risk reduction measures

- If there is a plan to consider implementing administrative controls such as creation of manuals and enforcement of the procedural rules, etc. to reduce risks, one must recognize that successful implementation of those measures will heavily depend on the capability of the on-site workers, and that possible human errors such as erroneous judgments made and incorrect work tasks/operation performed by the workers should be considered but are often overlooked.
- When considering risk reduction measures for preventing fires and explosions, such process must be also approached based on the concept of multiple protection measures, which consists of contain and control, preventive safeguards, and mitigative safeguards. However, risk reduction measures are occasionally considered without clearly distinguishing between these different purposes of measures.

23. Are risk reduction measures examined in the order of their priority?
A) Inherent safety measures - B) Engineering controls - C) Administrative controls - D) Personal protective equipment

* It is important to implement the types of measures that properly function despite any incorrect judgments made by the workers or erroneous actions taken by them. First examine the inherent safety measures such as changing materials to make products from and modifying work task/operation conditions, abolishing or modifying any hazardous work tasks/operations, replacing hazardous materials and work methods with safer ones, etc. If, however, the circumstances prevent one from examining any inherent safety measures, then examine the feasibility of implementing engineering controls such as implementation of guards, interlocks, safety equipment, etc. If, however, even engineering controls cannot be implemented, then move onto examining the feasibility of implementing administrative controls, such as creation of manuals, specification of off-limits areas, provision of worker education and training, etc. and use of protective gear by individual workers as a last resort. The order in which the different types of measures are considered as explained above should be the order of priority to be followed.

24. Are several risk reduction measures examined in accordance with the concept of the multiple protection measures as specified below, for the prevention of process accidents? (This is unique to JNIOSH Method.) The correct order is as follows:
a) Contain and control - b) Detection means - c) Preventive safeguards - d) Mitigative safeguards

* While it is ideal to implement all risk reduction measures as specified in a), c), and d) in a well-balanced manner, it is not necessary to implement all of the three types of measures if the targeted risk level is met.

* As for the risk reduction measures that function based on detected temperature and pressure data, etc., a method of detecting process abnormality occurrence (i.e., sensor, etc.) as specified in b) must be also examined together. For this particular process, it is important to choose effective detection points (positions) and adopt a redundancy of detection means, etc.

* Even if all imaginable risk reduction measures are implemented, the risk level cannot be reduced in certain cases. However, as long as measures are continuously implemented based on the concept of multiple protection measures, the risk will become relatively low.

* Except in cases where the cost of risk reduction measure implementation far exceeds the benefit in preventing work-related process accidents achieved due to the risk reduction, there is a significant imbalance between the aforementioned cost and benefit, and requiring implementation of those measures is deemed significantly unreasonable, it is necessary to implement risk reduction measures to which high priority is assigned as much as possible (paragraph 10 (2) of the guidelines, ALARP).

* As for the concept of multiple protection measures, what is important is to integrate the protection measures in a well-balanced manner and improve the reliability of the functions of the measures as specified in a), c), and d), instead of creating a large number of their designs.

25. Are the SDSs of the chemical substances being handled reviewed with attention to the information on the physical and chemical properties, etc.?

* SDSs include information on first-aid measures, fire-fighting measures, accidental release measures, physical and chemical properties, regulatory information, etc., which can be referenced when examining risk reduction measures.

26. Is the effectiveness of additional risk reduction measures checked during risk re-estimation and risk reevaluation, if any additional risk reduction measures have been implemented?

* Risks should be reevaluated in order to determine how effective additionally implemented risk reduction measures might be (3rd). If it is found that the additional measures have not been able to reduce the risk level, it is necessary to examine the feasibility of adding other risk reduction measures.

(2) Examination of the feasibility of implementing additional risk reduction measures

27. Is the feasibility of implementing proposed risk reduction measures examined while taking into consideration the work task/operation conditions of the existing risk reduction measures and the locations where the additional risk reduction measures are implemented?

* It is necessary to check the feasibility of implementing proposed risk reduction measures by examining how well they could function when combined with the existing risk reduction measures and by considering where the additional risk reduction measures should be implemented, etc.

(3) Caution to be exercised by the workers, etc. in order to maintain the functions of risk reduction measures

28. Is information on the actions to be taken and the points to which attention must be paid stated in a detailed and specific manner, so that the workers can understand the intentions behind the design of the risk reduction measures and maintain their functions?

* The following are examples of work tasks/operations that are needed to maintain the proper functions of risk reduction measures.
  - Method of understanding why the inherent safety measures are adopted and maintaining their proper functions, etc.
  - Inspection of interlock start alarm operation, regular check on fire walls and blast walls, etc.
  - Instructions on how to deal with the consequences of not following the precautions stated in the manuals or not complying with the manuals, etc.
  - Instructions on how to conduct a pre-work check, etc. in order to make sure that the workers wear the protective gear at all times

* If there is a plan to make any change that could alter the design intent of any risk reduction measure, it is necessary to perform a risk assessment and risk reduction once again (i.e., revision management). Especially concerning inherent safety measures, their functions and why they are effective are not clearly stated in many cases. Therefore, if any facility, equipment, work tasks/operations procedure, etc. are changed unknowingly, their functions might be lost, which could lead to process accidents, so one must be careful to make changes in such manner.

* If the frequency with which operation verification, daily check, and other similar work tasks/operations should be performed is clarified (i.e., once a day, once a month, etc.), it will help create an on-site environment where the workers are able to function in a highly effective manner.

* All information that should be communicated to the on-site workers must be also stated in the work/operation procedure manuals, etc. so that the workers are able to take actions in a reliable manner, based on the information in their daily production activities.

* Even in cases where it is determined that no additional risk reduction measure is required, the reason why the currently implemented measures are sufficient should be stated and communicated to all concerned staff members, etc.

29. If any residual risks are present, are the methods of taking actions to deal with those risks on site examined, and clearly stated as items to be communicated to the workers?

* If there are any residual risks, it is important to have the workers recognize the possibility that process accidents could occur, plan a course of action to be taken on site, and communicate the plan to the workers in advance.

* If there is any other information that should be communicated to the on-site workers in particular concerning the result of risk assessment and risk reduction performed, it should be also stated. Then the on-site workers will be able to understand it through personnel education, training, etc.

* (In the examples where the JNIOSH procedures are applied) explanations are provided with the goal of eliminating all level III scenarios. However, it does not mean that it is unnecessary to take any action for the level II and level I scenarios. Indeed, it is desirable to examine and implement appropriate risk reduction measures for these scenarios as well, based on the priority (i.e., from level II to level I).

2.4 Repeat of the steps specified in 2.1 through 2.3 (comprehensive examination of various scenarios)

30. Are scenarios continuously examined while identifying various trigger events that can possibly occur?

* When performing risk assessment and risk reduction, it is necessary to identify all imaginable trigger events to the extent possible and examine scenarios accordingly. However, it may be difficult to perform risk assessment and risk reduction on identified items all at once. In such cases, it is important to take the approach of gradual risk reduction, by focusing on specific items each time, and continuously perform risk assessment and risk reduction (through the PDCA cycle) to eventually reduce the risks as much as possible.

2.5 Decision on risk reduction measures (item 10 of the guidelines)

(1) Summarize multiple scenarios in one table **(Table 2 on P.20)**.

31. Are scenarios checked to make sure that estimated risks do not vary excessively between the scenarios and the scenarios and risk estimations are consistent throughout?

* Once a risk assessment and risk reduction is successfully concluded on multiple scenarios, summarizing the result in a single table will enable examination of all risk reduction measures in a well-balanced manner.

* Extract the content of all risk assessment sheets, etc. in which the result of examination of various scenarios is stated, and summarize the key points in a single table. Then examine the measures identified in the descending order of risk levels (i.e., III → II → I) one by one.

* Risk estimation results could vary depending on the staff member performing the task. Therefore, check each risk estimation again by scenario to review the process through which the risks were estimated, and unify the risk evaluation standards and criteria. For example, such standards and criteria can be set by first deciding which events might have the highest occurrence rates and then discussing and verifying all other events one by one in comparison to the highest occurrence events.

(2) Decision on risk reduction measures to be implemented

Typical issues that arise when implementing risk reduction measures

- Even after risk assessment and risk reduction are performed, and additional risk reduction measures are examined, those measures are not implemented in a number of instances. While the Industrial Safety and Health Act stipulates that the employers have the obligation to make effort to implement risk reduction measures, the work/operation site conditions will not be improved, and no safety management activities will be conducted without the implementation of risk reduction measures.
- If administrative controls such as creation of manuals and enforcement of compliance with certain rules, etc. are implemented as risk reduction measures, the actual work tasks/operations must be finally delegated to the on-site workers. Therefore, unless the information is shared with the workers as to the purpose of requested work tasks/operations and those work tasks/operations to be specifically performed, the workers sometimes perform the risk-reducing work tasks/operations as they are requested to do, without realizing what the significance of those work tasks/operations are.

32. Are risk reduction measures examined with attention to the cases where the same risk reduction measures have been proposed for multiple scenarios to determine whether those measures can be implemented all at once?

* If the same risk reduction measures are proposed for several scenarios, they can be implemented together at once.

* While this is not provided in the format specified in Table 2 (P.20), it is desirable to create a section on the format for indicating that measures have been finally implemented, the dates on which they were implemented, etc.

* If more than one scenario has been examined, the existing risk reduction measures and simultaneously proposed risk reduction measures must be checked to make sure that they do not interfere with each other and mutually nullify their intended effects.

3. Result of performing risk assessment and risk reduction

33. Are the results of risk assessment and risk reduction stated in a specific and easily understandable manner?

* The result of each risk assessment and risk reduction performed must be recorded in a specific and easily understandable manner to the extent possible, so that the information can be later reviewed and also referenced for training the on-site workers, etc. A sample table format that may be used for such purpose is provided in Table 2 (P.20).

* In the 'day' and 'sign' sections, state the date on which each risk assessment and risk reduction were performed and the name of the staff member in charge (responsible person). If any change is made to the result of a risk assessment and risk reduction for revision or other purposes, create an additional section and clearly state in it the fact that the change was made as a result of reexamination.

34. Is there any risk assessment result and risk reduction left abandoned before examination is completed on it?

* If no risk reduction measure is implemented based on the result of a risk assessment and risk reduction, the time spent on performing the risk assessment and risk reduction goes to waste. If it becomes necessary to implement additional measures, they should be implemented as swiftly and reliably as possible, by integrating them into the health and safety plan, etc.

35. Is the record of the scenarios planned also kept that would not lead to process accidents?

* Not all identified trigger events would necessarily lead to process accidents. Even concerning cases that would not lead to process accidents, it is important to understand, for example, why an erroneous work task/operation, etc. would not cause an explosion, fire, or other accident. For instance, even if a certain piece of equipment failures, it might not lead to a process malfunction/unsafety condition or a process accident as long as the rest of the equipment maintains its normal functions.

36. Are the name of the staff responsible for implementing risk reduction measures and the due dates by which to implement them clearly stated?

* When additional risk reduction measures are proposed, it is necessary to implement them as swiftly as possible. However, in cases where it is difficult to implement them right away, it is necessary to appoint a staff member, etc. responsible for their implementation and the due dates by which to implement them, and execute such plan in a systematic manner.

4. Utilization of the result of risk assessment and risk reduction (item 11 of the guidelines)

37. Are the results of risk assessment and risk reduction performed shared with the concerned workers?

* It is the obligation of each employer to share the result of the risk assessment and risk reduction performed with the workers. Therefore, it is important to communicate such information to all concerned workers without fail and have them understand what the shared information means, in order to make sure that the risk reduction measures will be effective.

* If there are any residual risks, it is necessary to share information on the measures for addressing such risks with all concerned staff members, etc. so that those involved in the on-site work tasks/operation will be able to continuously manage them.

Table 1: RA implementation sheet (Format)

<table>
<tr><td colspan="2">Day</td><td colspan="2">, ,</td><td>Sign</td><td colspan="4"></td></tr>
<tr><td colspan="8">STEP-1: To confirm chemical and process hazards</td></tr>
<tr><td colspan="2">Responses to questionnaires</td><td colspan="6"></td></tr>
<tr><td colspan="8">STEP-2: To perform risk assessment for an initiating hazard</td></tr>
<tr><td colspan="2">[1] Purpose of objective work task/operation & equipment and facility</td><td colspan="6"></td></tr>
<tr><td rowspan="3">[1] Hazard scenario</td><td>Initiating hazard (Initial event)</td><td colspan="6"></td></tr>
<tr><td>Process malfunction (Unsafety condition)</td><td colspan="6"></td></tr>
<tr><td>Process accident (Incident outcome)</td><td colspan="6"></td></tr>
<tr><td colspan="2">[2] Existing risk reduction measures</td><td colspan="6"></td></tr>
<tr><td colspan="2" rowspan="2">[2] 1st step risk estimation and evaluation; Under assumption of no existing risk reduction measures</td><td>Severity</td><td>Probability</td><td colspan="4">Risk Level</td></tr>
<tr><td>Minor, Medium, Major</td><td>Unlikely, Possible, Likely</td><td colspan="4">I, II, III</td></tr>
<tr><td colspan="2" rowspan="2">[2] 2nd step risk estimation and evaluation; Confirmation of effectiveness of existing risk reduction measures</td><td>Severity</td><td>Probability</td><td colspan="4">Risk Level</td></tr>
<tr><td>Minor, Medium, Major</td><td>Unlikely, Possible, Likely</td><td colspan="4">I, II, III</td></tr>
<tr><td colspan="2" rowspan="4">[3] 3rd step risk estimation and evaluation; Confirmation of effectiveness of additional risk reduction measures</td><td colspan="3"></td><td>S</td><td>P</td><td>RL</td></tr>
<tr><td colspan="3"></td><td></td><td></td><td></td></tr>
<tr><td colspan="3"></td><td></td><td></td><td></td></tr>
<tr><td colspan="3"></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">[3] Availability of additional risk reduction measure</td><td colspan="6"></td></tr>
<tr><td colspan="2">[3] Message or instruction to on-site workers</td><td colspan="6"></td></tr>
<tr><td colspan="2">[3] Residual risk</td><td colspan="6"></td></tr>
<tr><td colspan="2">Remark</td><td colspan="6">---</td></tr>
</table>

Table 2: RA result sheet (Format)

Responses to questionnaires	[1] Purpose of objective work task/operation & equipment and facility	Day and Sign		Day and Sign	

No.	[1] Hazard scenario			[2] Existing risk reduction measures	[2] 1st step risk estimation and evaluation; under assumption of no existing risk reduction measures			[2] 2nd step risk estimation and evaluation; Confirmation of effectiveness of existing risk reduction measures			[3] Additional risk reduction measures	[3] 3rd step risk estimation and evaluation; Confirmation of effectiveness of additional risk reduction measures			[3] Availability of additional risk reduction measure	[3] Message or instruction to on-site workers	[3] Residual risk
	Initiating hazard (Initial event)	Process malfunction (Unsafety condition)	Process accident (Incident outcome)		Severity	Probability	Risk Level	Severity	Probability	Risk Level		Severity	Probability	Risk Level			

Record of STEP 2 (Scenario 2)