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Fire/Explosion Hazard Scenario Identification Method Focusing on the Three Elements of Combustion (Simple Hazard Scenario Identification Method)

Japan Organization of Occupational Health and Safety

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1. Patterns of Causing Fire/Explosion (How Three Elements of Combustion Coexist)

To conduct risk assessments of chemical substances and to devise specific risk reduction measures, it is necessary to comprehensively identify the hazards and the hazard scenarios of how they cause a fire or explosion (hereafter referred to as "identifying the hazard scenarios"). The basis for identifying the hazard scenarios of causing a fire or explosion is to find the conditions under which the three elements of combustion[1] coexist. This means that a fire or explosion occurs when combustible or inflammable chemicals come into contact and mix with oxygen (air), forming an explosive atmosphere (an unsafe condition)[2], and at the same time, an ignition source occurs, so assuming work in an open area where oxygen (air) is always present, it is enough to focus on the two points of the formation of an explosive atmosphere and the occurrence of ignition sources. Based on whether risk reduction measures are taken against these two points (whether measures are taken to prevent the formation of an explosive atmosphere and the occurrence of ignition sources), hazard scenarios of causing a fire or explosion when combustible chemical substances are handled in an open area can be classified into four patterns (by how the three elements of combustion coexist) as shown in Table 1 below for identification.

Table 1 Identification Patterns for Hazard Scenarios of Causing Fire/Explosion during Work in an Open Area (by How the Three Elements of Combustion Coexist)[3]

I. Use of combustible chemicals		II. Formation of explosive atmosphere	
		(1) Measures are NOT taken to prevent formation of explosive atmosphere	(2) Measures are taken to prevent formation of explosive atmosphere
III. Occurrence of ignition source	(3) Measures are NOT taken to prevent occurrence of ignition sources	Pattern (a) Three elements of combustion may be coexisting Explosive atmosphere / Ignition source There is always a high risk of fire and explosion, so prompt measures are required.	Pattern (c) Three elements of combustion can coexist Explosive atmosphere / Ignition source An explosive atmosphere can be formed by a failure such as forgetting to close the container lid (trigger event B).
	(4) Measures are taken to prevent occurrence of ignition sources	Pattern (b) Three elements of combustion can coexist Explosive atmosphere / Ignition source Ignition sources can occur due to a failure such as poor ground connection caused by deterioration (trigger event A).	Pattern (d) Three elements of combustion can coexist Explosive atmosphere / Ignition source An explosive atmosphere can be formed and ignition sources can occur due to the simultaneous occurrence of trigger events A and B.

* In Table 1 above, events that can occur at any time are enclosed with a solid line ( ), and those that are triggered by a trigger event are enclosed with a dashed line ( ).

[1] Combustion is an oxidation reaction that involves the generation of heat and light, and it does not occur if even one of the three elements, "combustibles (combustible substances)," "oxygen supply sources (supporting materials)," and "ignition sources," is missing. The key to preventing combustion is to eliminate at least one of these three elements.

[2] During work that handles chemical substances but does not involve any reaction, such as coating, the chemical substances are always in contact with oxygen (air) (assuming that an explosive atmosphere is always formed during work in an open area if no preventive measures are taken).

[3] The "trigger events" mentioned in Table 1 are described in detail in Section 3.

Pattern (a): Measures are taken neither to prevent the formation of an explosive atmosphere nor to prevent the occurrence of ignition sources.

(1) An explosive atmosphere can always be present

(3) Ignition sources can occur at any time

e.g. When working with paint in a container without a lid (without taking measures to prevent the formation of an explosive atmosphere), there is always a risk of the formation of an explosive atmosphere. If this happens and an ignition source occurs due to electrostatic discharge, it could cause a fire or explosion.

Pattern (b): Measures are taken only to prevent the occurrence of ignition sources.

(1) An explosive atmosphere can always be present

(4) Ignition sources can occur due to the occurrence of a trigger event A

e.g. When working with paint in a container without a lid (without taking measures to prevent the formation of an explosive atmosphere), there is always a risk of the formation of an explosive atmosphere. If this happens and an ignition source occurs, for example, due to poor ground connection caused by deterioration (trigger event A), it could cause a fire or explosion.

Pattern (c): Measures are taken only to prevent the formation of an explosive atmosphere.

(2) An explosive atmosphere can be formed due to the occurrence of a trigger event B

(3) Ignition sources can occur at any time

e.g. Even when measures are taken to prevent the formation of an explosive atmosphere, an explosive atmosphere can be formed by forgetting to close the lid of the container (trigger event B), and if such an explosive atmosphere flows into another work site where measures are not taken to prevent occurrence of ignition sources (e.g., a place where fusion cutting is being performed), it could cause a fire or explosion.

Pattern (d): Measures are taken both to prevent the formation of an explosive atmosphere and to prevent the occurrence of ignition sources.

(2) An explosive atmosphere can be formed due to the occurrence of a trigger event B

(4) Ignition sources can occur due to the occurrence of a trigger event A

e.g. Even when measures are taken to prevent the formation of an explosive atmosphere, an explosive atmosphere can be formed by forgetting to close the lid of the container (trigger event B). If this happens and an ignition source occurs, for example, due to poor ground connection caused by deterioration (trigger event A), it could cause a fire or explosion.

The following is a summary of the hazard scenario identification method by checking in advance in which pattern the work subject to risk assessment is performed (hereafter referred to as "simple hazard scenario identification method")[4]. Figure 1 shows the outline of the simple hazard scenario identification method. Various hazard scenarios are identified by preparing three types of sheets in order.

(i) Prepare a "Working Condition Check Sheet" (Table 2).

Check in which pattern in Table 1 the work subject to risk assessment is performed (and if it is already in an unsafe condition) by checking the characteristics of the handled chemical substances, working conditions, measures already taken, and others.

(ii) Prepare a "Trigger Event Check Sheet" (Table 3).

Comprehensively identify trigger events that can cause an unsafe condition.

(iii) Prepare a "Hazard Scenario Identification Sheet" (Table 4).

Identify the hazard scenario of causing a fire, explosion, or effects on others (including industrial accidents) by checking whether an explosive atmosphere will be formed and whether ignition sources will occur due to the occurrence of an identified trigger event.

[4] The "simple hazard scenario identification method" summarizes the minimum points to be checked to identify the hazard scenario of causing a fire or explosion as easily as possible when conducting risk assessment and risk reduction of chemical substances. Note that this does not necessarily cover all risks (all fire and explosion hazard scenarios).

(i) Check the characteristics of chemical substances handled, working conditions, current measures, etc.

Prepare a "Working Condition Check Sheet"

I. Check whether combustible chemical substances are handled

II. Check whether measures are taken to prevent the formation of an explosive atmosphere (specific examples of measures to prevent the formation of an explosive atmosphere)

III. Check whether measures are taken to prevent the occurrence of ignition sources (specific examples of measures to prevent the occurrence of ignition sources)

IV. Check the identification pattern of the hazard scenario that the three elements of combustion coexist, causing a fire or explosion

(ii) Identify the trigger event of a fire or explosion

Prepare a "Trigger Event Check Sheet"

(iii) Identify the hazard scenario of causing a fire or explosion by checking the three elements of combustion

Prepare a "Hazard Scenario Identification Sheet"

Figure 1 How to Identify Hazard Scenarios of Causing Fire/Explosion Focusing on the Three Elements of Combustion

Table 2 Working Condition Check Sheet (Form)

[A] Work procedure/details		[B] Handled chemical substances and facilities, equipment, and others used for work				[C] Confirmation of pattern of the three elements of combustion that can cause fire or explosion			
		Handled chemical substances	Information on hazards of chemical substances concerned	Handling conditions (temperature, humidity, amount handled, storage conditions, etc.)	Facilities, equipment, and tools used for work	Q-1. Are the handled chemical substances combustible?	Q-2. Are measures taken to prevent the formation of an explosive atmosphere?	Q-3. Are measures taken to prevent the occurrence of ignition sources?	Pattern (a) - (d)
1									
2									
3									
-									

Table 3 Trigger Event Check Sheet (Form)

[A] Work procedure/details		[B] Handled chemical substances and facilities, equipment, and others used for work				[C] Confirmation of pattern of the three elements of combustion that can cause fire or explosion			[D] Trigger events related to facilities, equipment, and tools	[E] Trigger events related to work/operation (human errors)						
										Omission errors	Commission errors					
		Handled chemical substances	Information on hazards of chemical substances concerned	Handling conditions (temperature, humidity, amount handled, storage conditions, etc.)	Facilities, equipment, and tools used for work	Measures to prevent formation of explosive atmosphere	Measures to prevent occurrence of ignition sources	Pattern (a) - (d)	Facility, equipment, and tool failures (Failure mode)		Selection errors	Sequential errors	Time errors	Qualitative errors	Quantitative errors	Other errors
1																
2																
3																
-																

Table 4 Hazard Scenario Identification Sheet (Form)

[A] Work procedure/details		[C] Confirmation of pattern of the three elements of combustion that can cause fire or explosion			[D] [E] Trigger events	[F] Unsafe conditions		[G] Accidents and disasters	
		Measures to prevent formation of explosive atmosphere	Measures to prevent occurrence of ignition sources	Pattern (a) - (d)		Formation of explosive atmosphere	Occurrence of ignition source	Fire / explosion	Other effects
1									
2									
3									
-									

2. Checking Characteristics of Handled Chemical Substances, Working Conditions, Current Measures, etc. (Preparation of "Working Condition Check Sheet")

(1) Preparation of "Working Condition Check Sheet"

Prepare a "Working Condition Check Sheet" (Table 2) to check which hazard scenario identification pattern of causing a fire or explosion (how the three elements of combustion coexist) in Table 1 is applicable to each work subject to risk assessment. The method of filling in the form is described below.

[Column A]: Enter the work details/method described in the work procedure manual.

Enter work procedures and details referring to the latest version of the work procedure manual that reflects the details and methods of the work actually performed at the work site. At this time, clarifying the purpose (intent) of the work will enable a more detailed analysis.

* If there is no work procedure manual, check the work actually being performed and prepare such a manual, even a simple one, to clarify the work details.
* Even if there is a work procedure manual, check in advance that the contents of the manual match the actual work. If there is any difference, clarify which is wrong, correct the wrong one to make both match, and then proceed with the following analysis.
* If the results of the previous process performed in another place are expected to affect the process subject to risk assessment, or if the results of that process affect subsequent processes, it is advisable to include these processes in the same check sheet. If one process and another are analyzed separately because they are performed by different workers in different places, the hazard scenario that "another failure occurs while a process is performed under an unsafe condition caused by a failure in the previous process, causing a fire or explosion" will be overlooked.
* By using a detailed work procedure manual, you can devise and take more specific risk reduction measures.

[Column B]: Enter the handled chemical substances and facilities, equipment, and tools used in the work.

b-1) Enter the name of the handled chemical substances. If multiple chemical substances are handled, enter the name of each one[5].

* For chemical substances, you can enter their product names, but it is necessary to also enter chemical substance names so that their SDSs can be referred to.

b-2) Obtain information on hazards and applicable laws and regulations by checking GHS labels, SDSs, and the like. Enter the points that require special attention, such as physical property data (e.g., flash point and possibility of dust explosion of powdered material), if any.

* If there are no GHS labels or SDSs, order the latest one as soon as possible.

b-3) Enter the conditions of use (temperature, humidity, amount handled, storage conditions, etc.) of the handled chemical substances, and how to dispose of them[6].

* These will provide basic information for determining the possibility of formation of an explosive atmosphere.

b-4) List the facilities, equipment, and tools used in the work, and enter their names. Also check their purposes of use and appropriate use.

[Column C]: Enter the confirmed identification pattern of the hazard scenario of causing a fire or explosion.

Enter the answers to Q-1 through Q-3 below in their corresponding columns, and check which of the identification patterns of hazard scenarios of causing a fire or explosion in Table 1 applies.

[5] If multiple chemical substances are handled in a single process, it is advisable to subdivide the process and analyze each subdivided work.
[6] SDSs can contain notes on disposal, which you can refer to.

I. Check if the handled chemical substances are combustible.

Q-1. Are the handled chemical substances combustible?

Fires and explosions occur when combustible chemicals are handled. Check if the handled chemical substances are combustible by referring to the GHS labels or SDSs[7].

A-11 If combustible chemical substances are handled

- Enter the product name and chemical substance name, and then go to **Q-2** and **Q-3**.

A-12 If combustible chemical substances are NOT handled

- Enter "No."

II. Check whether measures are taken to prevent the formation of an explosive atmosphere.

Q-2. Are measures taken to prevent the formation of an explosive atmosphere?

In open work sites, oxygen is always present, and an explosive atmosphere is formed (the condition becomes unsafe) when combustible or inflammable chemicals come into contact and mix with oxygen[8]. Table 5 shows examples of measures to prevent the formation of an explosive atmosphere[9]. Check whether these measures are taken or not, and if they are taken, enter the details.

A-21 (1) If measures are NOT taken to prevent the formation of an explosive atmosphere

- Enter "No measures taken." An explosive atmosphere can always be present.

  * Enter the reason(s) why it has not been considered necessary to take measures, if any.

A-22 (2) If measures are taken to prevent the formation of an explosive atmosphere

- Enter the measures taken to prevent the formation of an explosive atmosphere, and also check their purposes. Even when measures are taken to prevent the formation of an explosive atmosphere, the measures can be invalidated and an explosive atmosphere can be formed by forgetting to close the lid of the container, failure of the local exhaust ventilation, forgetting to turn on the switch, or the like (trigger event B)[10].

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7 For chemical substances for which SDSs are not obliged to be prepared, you can determine if they are combustible or not based on your experience or knowledge.

8 This document covers the handling of chemical substances during work in open areas, such as coating. For the use of chemical substances in closed spaces, such as reactors in chemical plants, you can refer to "Hazardous Areas" defined in the following guidelines or the like:
- Technical Recommendations of the National Institute of Occupational Safety and Health, Recommended Practices for Explosion-Protected Electrical Installations in General Industries, TR-46 (2018) (the latest version at the time of writing this document)
- Guidelines on How to Precisely Define Hazardous Areas in Plants (Ministry of Economy, Trade and Industry, 2020)
- JIS C 60079-10:2008, Electrical apparatus for explosive gas atmospheres - Part 10: Classification of hazardous areas

9 Some of the measures listed in Table 5 are taken in combination with abnormality detection means (e.g., sensors) in order to detect the formation of an explosive atmosphere.

10 Even if there are existing risk reduction measures, the JNIOSH method identifies hazard scenarios assuming a case where these measures are invalidated. In contrast, for simplification purposes, the simple hazard scenario identification method checks whether there are measures to prevent the formation of an explosive atmosphere and the occurrence of ignition sources, and also identifies cases where each of the said measures is invalidated due to the occurrence of a trigger event.

III. Check whether measures are taken to prevent the occurrence of ignition sources.

Q-3. Are measures taken to prevent the occurrence of ignition sources?

Possible ignition sources of fire or explosion and examples of countermeasures are shown in Table 6. Table 7 shows the basics and examples of measures to prevent the occurrence of electrostatic sparks[11]. For the eight factors of (a) through (h) in Table 6, check whether measures are taken to prevent the occurrence of ignition sources, and if they are taken, enter the details.

A-31 (3) If measures are NOT taken to prevent the occurrence of ignition sources

- Enter "No measures taken." Ignition sources can occur at any time.

  * Enter the reason(s) why it has not been considered necessary to take measures, if any.

A-32 (4) If measures are taken to prevent the occurrence of ignition sources

- Enter the measures taken to prevent the occurrence of ignition sources, and also check their purposes. Even when measures are taken to prevent the occurrence of ignition sources, the measures can be invalidated and ignition sources can occur, for example, due to poor ground connection caused by deterioration (trigger event A)[10].

IV. Check the identification pattern of the hazard scenario that the three elements of combustion coexist, causing a fire or explosion.

Based on the answers to Q-1 through Q-3, check which of the identification patterns (a through d) of hazard scenarios of causing a fire or explosion in Table 1 applies, and enter it. The following apply depending on the pattern.

Pattern (a): Fire or explosion could occur at any time.

You should take some risk reduction measures before conducting risk assessment and risk reduction. After that, check Q-1 through Q-3 again.

Patterns (b) - (d): A trigger event can cause a fire or explosion.

Some risk reduction measures have already been taken, and provided these measures work, the three elements of combustion will not coexist, but the occurrence of a trigger event, such as an equipment failure and work error, can invalidate them, as a result of which the three elements of combustion coexist, causing a fire or explosion.

(2) Purposes of preparing a "Working Condition Check Sheet"

The purposes of preparing a "Working Condition Check Sheet" are as follows:

1) to confirm that the contents of the work procedure manual match the work actually being performed,
2) to check the characteristics of the handled chemical substances, handling conditions, equipment used, etc., and
3) to check how risk reduction measures are currently taken, and classify them into patterns to ascertain if an unsafe condition has arisen.

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[11] Measures to prevent the occurrence of electrostatic sparks are centered on those to prevent ignitable electrostatic discharge. In addition, Articles 286-2 and 287 of the Ordinance on Industrial Safety and Health also stipulate measures against static electricity.

Table 5 Examples of Measures to Prevent the Formation of an Explosive Atmosphere[12]

Measure	Examples
Suppress gas/vapor explosive atmospheres	- Remove unwanted combustible gas and liquid residues. - Prevent the leakage of combustible gas and liquid. - Control the release of combustible gas and vapor. - Ventilate to prevent the retention of combustible gas and vapor. Examples of ventilation equipment: Downward suction hood (e.g., ventilation workbenches), side suction hood, push-pull ventilators, enclosure hood (e.g., draft chamber) Examples of abnormality detection means: Concentration meter, gas detector * Should be appropriately installed in a place where the formation of an explosive atmosphere can be reliably detected. * The concentration should be controlled to be less than 1/4 of the lower explosive limit (LEL).
Suppress dust-explosive atmospheres	- Select an appropriate powder particle size. - Prevent powder from being more refined. - Prevent powder retention and accumulation (including accumulation in exhaust/ventilation equipment). - Limit the scale of handling. - Divide facilities into compartments. - Remove unnecessary protrusions from facilities. - Prevent leakage of combustible powder. - Prevent scattering and accumulation of combustible powder. Examples of ventilation equipment: Downward suction hood (e.g., ventilation workbenches), side suction hood, push-pull ventilators, enclosure hood (e.g., draft chamber)

[12] Prepared on the basis of the Technical Recommendations of the National Institute of Occupational Safety and Health, Recommendations for Requirements for Avoiding Electrostatic Hazards in Industry 2007 JNIOSH-TR-No.42 (2007).

Table 6 Possible Ignition Sources of Fire or Explosion and Examples of Countermeasures[13]

Classification		Possible ignition sources	Examples of measures
Electrical ignition sources	**(a) Electric sparks**	- Electric sparks emitted from relay contacts of heating devices, automatic temperature controllers, etc. - Arcs emitted when lighting equipment breaks - Arcs from electrical welding nozzles - Sparks from non-explosion protected equipment and leaking electrical equipment - Use of non-explosion-protected equipment (e.g., mobile phones, smartphones)	- Use explosion protected equipment.
	(b) Electrostatic sparks	● When an object is charged and the electric field strength formed by the charge exceeds a certain level, dielectric breakdown occurs, causing electrostatic sparks (discharge) ● Electrostatic sparks can occur in the following cases: - when there is metal near a charged metal object - when a charged worker touches metal such as a doorknob - when taking off work clothes - when a poorly grounded metal ladle touches the metal part of the manhole of the reaction tank during sampling of liquid samples - when there is metal near a poorly grounded metal part of a strainer with a built-in filter during the liquid transportation process - when there is metal near an insulated metal container being filled with charged liquid, powder, or the like	(Refer to Table 7 Basics of Measures to Prevent Occurrence of Electrostatic Sparks.)
High-temperature ignition sources	**(c) Hot surfaces**	- Exposed hot surfaces of electric heaters, heating conduits, hot metals, or the like - Fire sparks scattered during welding, gas cutting, or the like - The back side of a steel plate being welded or cut, etc.	- Maintain and inspect high-temperature equipment, monitor overload (using sensors). - Monitor the presence or absence of hot sections due to mechanical friction in equipment and devices. - Limit welding, gas-cutting, and other similar operations appropriately.
	(d) Thermal radiation	- Near burning material - Near an electric heater or boiler - Focused sunlight, etc.	- Remove hot objects from the surroundings. - Use heat shielding material.
Impact ignition sources	**(e) Impact/ friction**	- Collision/impact between metals (especially light metal alloys) - Friction due to foreign matter entering a moving part, etc. - Fluid friction	- Prohibit the use of light metal alloy products. - Remove combustibles and foreign matter from equipment and devices. - Take measures against fluid friction, such as operating the valve slowly and removing combustibles from the system (cleaning).
	(f) Adiabatic compression	- Adiabatic compression due to rapid inflow of high-pressure gas into a closed space such as a pipe, etc.[14]	- Operate the valve slowly. - Remove combustibles (cleaning).
Physicochemical ignition sources	**(g) Naked flame**	- Kitchen stove - Heating stove - Candle light - Match/lighter - Cigarette light - Oxyacetylene flame / blowtorch flame - Boiler - Fuel combustion flames in various furnaces - Small flames in analytical instruments, etc.	- Limit the use of fire according to the work environment. - Adequately control brought-in fire.
	(h) Spontaneous ignition	- Substances that ignite immediately upon contact with air or water - Ignition due to accumulation of chemical reaction heat inside combustible substances	- Prevent accumulation of heat by subdivision - Appropriately control temperature (using sensors). - Perform forced cooling.

13 Prepared on the basis of Analysis of Explosion Disasters (Kitagawa, Nikkan Kogyo Shimbun, 1980) (in Japanese).

14 Precautions for High Pressure Gas Accidents Caused by Adiabatic Compression of Oxygen and Frictional Heat (High Pressure Gas Safety Institute of Japan) https://www.khk.or.jp/Portals/0/resources/activities/incident_investigation/hpg_incident/pdf/dannetu.pdf (in Japanese, confirmed on May 22, 2021)

Table 7 Basics and Examples of Measures to Prevent Occurrence of Electrostatic Sparks[15]

Measure	Description and examples
Grounding all conductors	All conductors and conductive materials must be grounded because charged conductors can discharge sparks, causing a fire or explosion accident. Grounding is a measure to prevent electrification of a conductor by electrically connecting it to the ground. Bonding is to connect conductors electrically. This is used to ground a conductor that is not easy to ground directly by connecting it to another grounded conductor. Bonded conductors have the same potential. - Ground equipment, facilities, and other installed conductive structures (B-c). - Eliminate insulated metals: Ground metals on non-conductors (e.g., plastic pipes, container flanges, metal drums on insulated floorings) (B-c).
Grounding workers and preventing them from becoming charged	Since workers also cause electrostatic discharge, prevent workers from becoming charged (from accumulating of electric charge) by using antistatic work shoes and conductive flooring. - Ground the human body (C-c) by using antistatic work shoes and conductive flooring (B-c). - Wear antistatic work clothes (C-c)
Elimination of non-conductors[16]	The charge on a non-conductor is not easily dissipated even if it is grounded. The electric charge generated on a non-conductor accumulates and may cause a fire or explosion accident. You can reduce the static electricity-induced risk by improving electrical conductivity by using conductors instead of non-conductors and grounding them or adding an antistatic agent to non-conductors (e.g., insulating liquid). You can reduce the effect of charged non-conductors, and consequently reduce the static electricity-induced risk by covering non-conductors with grounded conductors or dividing non-conductors into compartments with the use of grounded conductors. A grounding wire spirally wound around an insulated hose is an example. - Use conductive containers, pipes, filters, and others (A-c), and ground them (B-c). - Use electrostatic shields (B-c). - Add an antistatic agent or conductive liquid to insulating liquid (B-c).
Suppressing charge generation	In general, the amount of electric charge generated depends on the contact area and the friction speed. You can suppress the generation of electric charge by reviewing the work process, such as slowing down the speed. - Limit the operation speed and flow rate of liquid/powder transportation (C-c). - Avoid turbulence and ejection of liquids that are easily charged (C-c).
Removing static electricity	This means to suppress electric charge using a static eliminator. The electric charge of the charged object is neutralized by the ions generated by the static eliminator. This is equivalent to increasing the conductivity of the medium around the charged object (to accelerate charge dissipation), and is effective for eliminating static electricity from non-conductors. However, the static eliminator should not be used alone as a risk reduction measure, but should always be used in combination with other measures (B-c).
Measurements related to static electricity[17]	Check the conductivity, charge electric potential, and leakage resistance, which are indicators of the above measures, through the following measurements. Even when an explosion-protected measuring instrument is used, it can be an ignition source, so never make measurements when combustible gas, solvent vapor, or dust is present in the work site (B-b). - Check whether all conductors are grounded using a tester. - Measure the electric potential of bags containing raw materials as well as workers with an electrostatic potentiometer. - Measure the leakage resistance of floorings, workbenches, carts, and others with an insulation resistance tester.

[15] Prepared on the basis of the Technical Recommendations of the National Institute of Occupational Safety and Health, Recommendations for Requirements for Avoiding Electrostatic Hazards in Industry 2007, JNIOSH-TR-No.42 (2007) (in Japanese). In Table 7, A) through D) correspond to the priority of risk reduction measures, and a) through d), to the classification of measures based on the concept of multiple protection measure.

[16] Regarding static electricity- and weather-induced changes in humidity, it is known that humidification decreases the surface resistance of non-conductors and accelerates charge dissipation. Therefore, with low humidity, the charge will not dissipate and non-conductors will be charged, increasing the possibility of generating electrostatic sparks. In other words, there is a risk that electrostatic sparks will be generated due to changes in humidity (in weather conditions). For work sites susceptible to changes in weather conditions, you should identify the hazard scenario assuming that no measures are taken to prevent the occurrence of ignition sources. On the other hand, even in workplaces where temperature and humidity are controlled, such as in sterile rooms, if a trigger event occurs, such as a worker forgetting to turn on the switch, it could cause a failure in humidity control (a lower humidity), and consequently the occurrence of electrostatic sparks, which you should consider when identifying the hazard scenario and devising risk reduction measures.

[17] Prepared on the basis of the Measures against Static Electricity Accidents (in Paint Manufacturing Industry), Second Edition (Japan Paint Manufacturers Association (November 2014) (in Japanese).

3. Identification of Trigger Events of Fire/Explosion (Preparation of "Trigger Event Check Sheet")

(1) What is a trigger event?

When conducting risk assessment and risk reduction of chemical substances, it is important to identify all the hazards hidden in the work and equipment used to handle chemical substances. The JNIOSH method comprehensively identifies the events that can actualize hidden hazards (trigger events) for each work described in the work procedure manual. The classification of trigger events is shown in Table 8. Trigger events are broadly classified into (i) facility, equipment, and tool failures, (ii) inappropriate work/operations, and (iii) external factors. These trigger events can trigger the formation of an explosive atmosphere or the occurrence of ignition sources.

Table 8 Classification of Trigger Events

Classification	Description and examples of how to identify the hazard scenario
(i) Facility, equipment, and tool failures	- Machines can break. E.g. What happens if the local exhaust ventilation does not work? What happens if the container lid is damaged?
(ii) Inappropriate works	- People (workers) can make errors. E.g. What happens if you forget to turn on the local exhaust ventilation? What happens if you press the wrong switch?
(iii) External factors	- The equipment can stop due to a power outage. In addition, large-scale disasters caused by natural disasters such as earthquakes, typhoons, and floods occur frequently. E.g. What happens if a large-scale power outage occurs? What happens if a flood occurs and the factory is inundated?

(2) Preparation of a "Trigger Event Check Sheet"

When conducting risk assessment and risk reduction of chemical substances, you should comprehensively identify trigger events and check if the formation of an explosive atmosphere or the occurrence of ignition sources is triggered by these events in order to identify various hazard scenarios that are hard to imagine (or recognize) only by checking work sites at normal times.

Identifying that the descriptions in the work procedure manual are followed, prepare a "Trigger Event Check Sheet" (Table 3) to comprehensively identify (i) facility, equipment, and tool failures and (ii) inappropriate works (human errors)[18]. The method of filling in the form is described below[19].

[Column A]: Transcribe the work details/method described in the work procedure manual.

Transcribe the matters entered in [Column A] of the "Working Condition Check Sheet."

[Column B]: Transcribe the handled chemical substances and facilities, equipment, and tools used in the work.

Transcribe the matters entered in [Column B] of the "Working Condition Check Sheet."

[Column C]: Transcribe the confirmed identification pattern of the hazard scenario of causing a fire or explosion.

Transcribe the matters entered in [Column C] of the "Working Condition Check Sheet."

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[18] In the simple hazard scenario identification method, fires and explosions caused by external factors such as large-scale power outages and natural disasters are omitted from consideration, but it is desirable to identify them as events that can actualize hazards depending on the characteristics of the region where the work site is located.

[19] Since this is intended to comprehensively identify possible trigger events in order to reduce unexpected accidents, you should try to fill in all the columns.

[Column D]: Enter the trigger events related to facilities, equipment, and tools.

d-1) Check the purposes of use of facilities, equipment, and tools.

d-2) Based on the idea that "machines can break (can fail to operate as expected)," identify facility, equipment, and tool failures as trigger events. For example, the following cases can be identified:

- The equipment breaks down and does not work.
- The equipment operates differently from the intended purpose due to some kind of failure (malfunction) (however, if the malfunction is caused by a worker's error, enter it in [Column E]).

* You should identify not only failures in the facilities and others described in [Column B] but also failures that can invalidate the facilities and others provided as the measures taken to prevent the formation of an explosive atmosphere or occurrence of ignition sources described in [Column C][20].

* At this point, all possible failures should be listed, since whether or not the identified failures in facilities, equipment, and tools can cause unsafe conditions (leading to the formation of an explosive atmosphere or the occurrence of ignition sources) or actually cause the formation of an explosive atmosphere or the occurrence of ignition sources is examined in the hazard scenario identification stage.

* It is also important to check according to the time axis of the work procedure on the basis of the *Genba* (actual place), *Genbutsu* (actual part), and *Genjitsu* (actual situation) principle[21]. Even if some measures have already been taken against near-misses, they should also be included in the analysis in order to recheck their effectiveness. Do not think you do not have to consider near-misses because they have already been addressed.

[Column E]: Enter the trigger events related to works (human errors).

e-1) Check the purpose and method of work or operation.

e-2) Based on the idea that "people can make errors," identify failures in work as trigger events[22], classifying them into the seven types of human errors[23] shown in Table 9.

* If there is any work to be carried out to prevent the formation of an explosive atmosphere or the occurrence of ignition sources, even if it is not specified in [Column A], "Work procedure/details," human errors that invalidate such work should also be identified[24].

* At this point, all human errors that could occur during the work should be listed, since whether or not the identified human errors can cause unsafe conditions (leading to the formation of an explosive atmosphere or the occurrence of ignition sources) or actually cause the formation of an explosive atmosphere or the occurrence of ignition sources is examined in the hazard scenario identification stage.

* Human errors are broadly classified into (A) "Careless mistakes" and (B) "Intentional violations"[25] by their background factors. All possible human errors should be identified as the trigger events that can actualize potential hazards. At this point, you do not have to classify human errors into (A) "Careless mistakes" and (B) "Intentional violations."[26]

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[20] Although failures in detectors (sensors) or alarms installed to detect abnormalities should also be identified as trigger events in principle, they are omitted here for simplification purposes. Since abnormality detection means are normally used in combination with risk reduction measures (contain and control, preventive safeguards, and detection means), failures in abnormality detection means can invalidate risk reduction measures. It is advisable to take into consideration failures in abnormality detection means when examining specific risk reduction measures.

[21] The idea of emphasizing the **three *Gen*s** (actualities) of *Genba* (actual place), *Genbutsu* (actual part), and *Genjitsu* (actual situation) and trying to solve the problem not at a desk but after observing the actual place and parts and recognizing the actual situation.

[22] Prepared based on the classification of human errors by Swain et al. in the Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, Final Report (A. D. Swain, H. E. Guttmann, 1983). In Table 9, human errors are broadly classified into omission errors and commission errors, and commission errors are further classified into six types.

[23] This method is basically the same as the guide word used in HAZOP for chemical plants.

[24] Work specified as risk reduction measures in the work procedure manual can be classified into errors (1) through (6). Further, even if not explicitly specified in the work procedure manual, failures experienced in daily work should also be classified as (7) "Other errors" as far as possible.

[25] Changing the work method on site in order to improve production efficiency should also be regarded as a rule violation.

[26] If you consider also the background factors at the hazard scenario identification stage, you should take into consideration combinations of more factors, which makes it difficult to systematically identify hazard scenarios. At this stage, human errors should be considered only by their consequences, and what results they can lead to should be identified as hazard scenarios. Background factors should be identified and classified when examining risk reduction measures against human errors.

Table 9 Classification of Human Errors

Classification		Description
(1) Omission errors		Fail to carry out the required work. E.g. Fail to activate the local exhaust ventilation.
Commission errors		Carry out the wrong work.
	(2) Selection errors	Select the wrong tool. Work on the wrong part. Issue the wrong instruction or information (setting error). E.g. Open Valve B by mistake. E.g. Set the wrong amount of raw material. Set the temperature too high.
	(3) Sequential errors	Work in the wrong order. E.g. Open Valve B before opening Valve A.
	(4) Time errors	Work at the wrong time (too early or too late). E.g. Be late to activate the local exhaust ventilation.
	(5) Qualitative errors	Non-standard work intensity (quality). E.g. Open/close a valve too fast/slow. E.g. Insufficient cleaning E.g. Failure to close the lid properly E.g. Insufficient stirring (not uniform after stirring for the set time)
	(6) Quantitative errors	Non-standard amount of work (filling rate, duration time, etc.). E.g. Wrong filling rate (resulting in too much/little filling amount) E.g. Wrong heating time (resulting in overheating/underheating)
	(7) Other errors	Errors other than the above. E.g. Drop tools, spill paint. E.g. Disconnect the ground wire (invalidating measures against ignition sources).

(3) Purposes of Preparing a "Trigger Event Check Sheet"

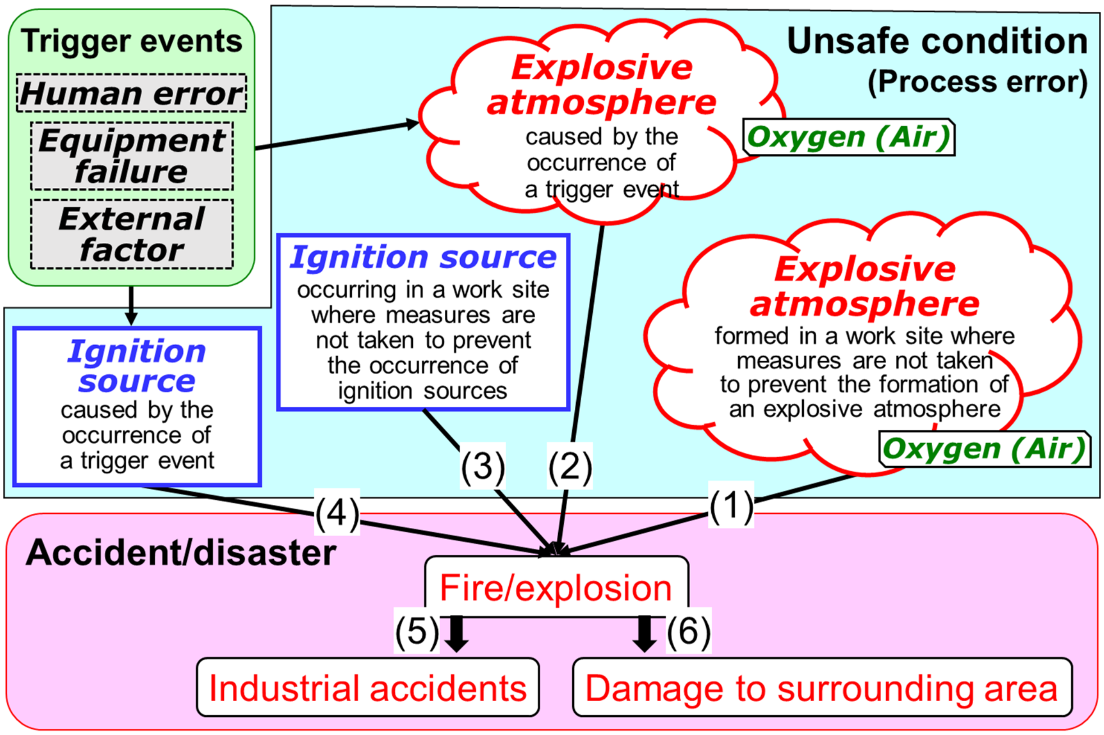
The purposes of preparing a "Trigger Event Check Sheet" are as follows:

1) to understand the work details (procedure), characteristics (risks) of the handled chemical substances, and how the chemical substances are handled, and to check the purposes of the facilities, equipment, and tools and how they are used,
2) to check in advance whether measures are taken to prevent the formation of an explosive atmosphere and the occurrence of ignition sources, to clarify the purposes of such measures, and also to be aware that such measures can be invalidated,
3) to comprehensively identify facility, equipment, and tool failures and inappropriate works (human errors) as events that can actualize the potential hazards of the handled chemical substances (trigger events),
4) to detect inappropriate alteration of the work procedure manual (e.g. shortcuts and unfounded changes) and unsafe behavior that deviates from the rules, and
5) to identify more specific hazard scenarios of causing a fire or explosion by examining the cases where an identified trigger event (e.g., the formation of an explosive atmosphere and the occurrence of ignition sources) occurs.

4. Identifying Hazard Scenarios of Causing Fire/Explosion by Checking the Three Elements of Combustion (Preparation of "Hazard Scenario Identification Sheet")

(1) Fire/Explosion Caused by Coexistence of the Three Elements of Combustion and Resulting Industrial Accidents and Spread of Damage to Surrounding Area

Figure 2 shows the flow of events from a trigger event to fire or explosion and the resulting industrial accident and the spread of damage to the surrounding area. There are cases where the condition is already unsafe due to insufficient measures ((1) and (3)) and cases where the condition becomes unsafe if a trigger event occurs ((2) and (4)). In either case, if both the formation of an explosive atmosphere and the occurrence of ignition sources occur, it could cause a fire or explosion[27]. Furthermore, a fire or explosion can cause industrial accidents (5) and damage to the area around the plant (e.g., spread of fire to neighboring houses) (6). Such a series of events that can lead to disasters should be identified as a hazard scenario.



(1) through (4) correspond to the numbers in parentheses in Table 1.
(5) If there is a worker near the place where fire or explosion occurs, it could cause an industrial accident.
(6) If the scale of the fire or explosion is large, it could cause damage to the area around the plant.

Figure 2 Flow of Events from Fire/Explosion to Industrial Accidents and Spread of Damage to Surrounding Area

(2) Preparation of "Hazard Scenario Identification Sheet"

In order to identify the hazard scenario of causing a fire or explosion, prepare a **"Hazard Scenario Identification Sheet"** (Table 4) by checking whether the occurrence of the trigger event identified in the "Trigger Event Check Sheet" can cause the formation of an explosive atmosphere and the occurrence of ignition sources, on the basis of the entry (which of patterns (a) through (d) applies) in the "Working Condition Check Sheet." The method of filling in the form is described below.

[27] According to the classification of accidents by the Ministry of Health, Labour and Welfare, ruptures caused by explosions are classified as "explosions."

[Column A]: Transcribe the work procedure/details.

Transcribe the work procedure/details described in [Column A] of the “Trigger Event Check Sheet.”

[Column C]: Transcribe the confirmed identification pattern of the hazard scenario of causing a fire or explosion.

Transcribe the matters described in [Column C] of the “Trigger Event Check Sheet.”

Select one from the trigger events listed in [Column D] and [Column E].

Select one from the trigger events listed in [Column D] and [Column E] of the “Trigger Event Check Sheet” and enter it.

[Column F]: Enter whether an explosive atmosphere can be formed and whether ignition sources can occur (possible unsafe conditions).

Based on the identification patterns (a) to (d) of the hazard scenario of causing a fire or explosion that is described in [Column C], check whether an explosive atmosphere can be formed and whether ignition sources can occur.

f-1) If pattern (a): Measures are taken neither to prevent the formation of an explosive atmosphere nor to prevent the occurrence of ignition sources.

Since **it is in an unsafe condition where fire or explosion can occur at any time**, the measures shown in Tables 5 to 7 should be taken before conducting a risk assessment.

f-2) If patterns (b) to (d):

Check **whether an explosive atmosphere can be formed and whether ignition sources can occur** when one of the trigger events listed in [Column D] or [Column E] occurs.

If pattern (b): Measures are taken only to prevent the occurrence of ignition sources.

Check whether the occurrence of ignition sources can be caused by any of the identified trigger events A under the unsafe condition that an explosive atmosphere can always be present.

If pattern (c): Measures are taken only to prevent the formation of an explosive atmosphere.

Check whether the formation of an explosive atmosphere can be caused by any of the identified trigger events B under the unsafe condition that ignition sources can occur at any time.

If pattern (d): Measures are taken both to prevent the formation of an explosive atmosphere and to prevent the occurrence of ignition sources.

Measures have been taken to prevent the formation of an explosive atmosphere and the occurrence of ignition sources, and the three elements of combustion cannot coexist and no fire or explosion will occur provided these measures work, but if a trigger event occurs, invalidating these measures, it could cause a fire or explosion[28]. The following two types of processes should be examined:

- Check whether the occurrence of ignition sources can be caused by any of the identified trigger events A under the condition that the formation of an explosive atmosphere has been caused by one of the identified trigger events B.
- Check whether the formation of an explosive atmosphere can be caused by any of the identified trigger events B under the condition that the occurrence of an ignition source has been caused by one of the identified trigger events A.

[28] Risk assessment and risk reduction are normally conducted without assuming the case where multiple trigger events occur at the same time, but in reality, there were some cases where multiple errors (failures) occurred at the same time, causing a fire or explosion. Pattern (d) covers cases where multiple trigger events occur.

For pattern (d), combinations of multiple identified trigger events should be examined, which means that you must examine a huge number of hazard scenarios. It is therefore advisable, for example, to identify the trigger event by combining the following α) and β), and then identify the hazard scenario of causing a fire or explosion.

α) Consider the occurrence of the trigger events related to facilities, equipment, and tools in [Column D] and the occurrence of those related to works in [Column E] separately. In other words, first take two of the multiple trigger events related to facilities, equipment, and tools in [Column D], and then identify the hazard scenario. Next, examine the multiple trigger events related to works in [Column E] in the same way.

β) Among the identified trigger events, first select the one that can cause the formation of an explosive atmosphere, and then the one that can cause the occurrence of ignition sources, or vice versa. In this case, confirming in advance whether the identified trigger event can cause the formation of an explosive atmosphere, the occurrence of ignition sources, or both at the same time will make the identification easier.

[Column G]: Enter accidents and disasters (fire/explosion, other effects).

Check the following based on whether an explosive atmosphere can be formed and whether ignition sources can occur that are described in [Column F].

g-1) If an explosive atmosphere is formed and ignition sources occur (the three elements of combustion coexist)

There is a risk of fire or explosion. Describe that process in as much detail as possible. Further, considering the number and placement of workers and work environment (e.g., implementation status of 5S activities, equipment layout, evacuation routes, factory location), examine other effects (e.g., industrial accidents and damage to the surrounding area) (Figure 2).

g-2) If no explosive atmospheres are formed or no ignition sources occur (the three elements of combustion do not coexist)

Since fires and explosions cannot occur, enter "No effect."[29]

* Here, the simple method for identifying hazard scenarios of causing a fire or explosion by checking whether the three elements of combustion coexist. On the other hand, fires and explosions can occur even when the three elements of combustion do not coexist, which needs to be considered separately.

(3) Purposes of preparing a "Hazard Scenario Identification Sheet"

The purposes of preparing a "Hazard Scenario Identification Sheet" are as follows:

1) to comprehensively identify the hazard scenarios of causing a fire or explosion triggered by the occurrence of a trigger event,
2) to clarify the purposes of devising and taking risk reduction measures, such as preventing the occurrence of ignition sources and the formation of an explosive atmosphere, by checking the occurrence of each of the three elements of combustion, and
3) to help perform the risk analysis of the identified hazard scenario and devise and take additional risk reduction measures by describing the hazard scenario in the "Risk Assessment Implementation Sheet" which is used for the JNIOSH method.

[29] As the "Trigger Event Check Sheet" comprehensively identifies possible errors as trigger events, there may be some events that will not cause fires or explosions, but even for such events, the results of checking the three elements of combustion should be recorded. These records will be useful when conducting risk assessment and risk reduction again in the future when the equipment or work is changed.

5. Example of Identification of Hazard Scenarios of Causing Fire/Explosion Focusing on the Three Elements of Combustion

(1) Description of work case

Here is an example of identifying a hazard scenario of causing fire or explosion focusing on the three elements of combustion. In this section, the following work case is examined referring to "Coating with Air Spray Gun Using Compressed Air" in "Human Resource Development Manual Using Practical Examination Tasks for Level 3 Technical Skill Test: Coating (Metal Coating Work),"[30] which is available on "Waza no Tobira (Door to Skills)," the portal site for the Ministry of Health, Labour and Welfare's Skill Test System, etc.

1) Work process overview

The work case roughly consists of the following five processes (29 steps: refer to Table 10 for details). The work is carried out at room temperature.

1. Degreasing: Remove oil and grease adhering to the object to be coated with lacquer thinner.
2. Primer coating: Apply a lacquer primer surfacer to the object to be coated so that the paint will adhere well.
3. Toning: Mix paints of different colors to prepare the paint of the prescribed color.
4. Trial coating: To check the color compatibility, dilute the toned paint with lacquer thinner and apply it to a sample for trial coating.
5. Top coating: Apply the toned paint to the primed object.

2) Handled chemical substances and facilities, equipment, and others used for work

The handled chemical substances and the facilities, equipment, and others used for the work are identified as follows.

- Handled chemical substances

White lacquer enamel, black lacquer enamel, lacquer thinner, and lacquer primer surfacer.

(See the next page (Reference Work Case) for the summaries of their SDSs (hazard information).)

- Facilities, equipment, and others used for work

Spray coating equipment (air compressor, spraying pressure regulator, air spray gun, antistatic hose, spraying workbench, spray booth [with local exhaust ventilation]), explosion protected equipment, conductive flooring, plastic container, (wooden) stirring rod, filter paper, (cotton) waste cloth, funnel, brush, trash can (for waste cloth, filter paper, stirring rod), and (metal) waste liquid container with lid

- Clothes and equipment for work

Antistatic work clothes, antistatic work shoes, safety glasses, work cap, work gloves, solvent-resistant gloves, and respirator

3) Safety measures already taken

The safety measures already taken are identified as follows.

- Measures to prevent formation of explosive atmosphere

Local exhaust ventilation attached to spray booth, lid of paint cup on spray gun, and disposal of waste liquid in (metal) waste liquid container with lid

[30] https://waza.mhlw.go.jp/shidousya/pdf/kinzokutosou.pdf (in Japanese, confirmed on May 22, 2021). Refer to the said manual for details on the original work. Here, the work case is based on the original work with additional assumptions about the facilities and equipment used for the work, safety measures taken, and safety work procedures.

(Reference Work Case) Summaries of SDSs of Handled Chemical Substances in Work Case
(Information on Hazards)

Lacquer thinner

- **GHS classification**
  Flammable liquids, Category 2, etc.
- **Composition and ingredient information**
  Toluene: 65–70%
  Ethyl acetate: 10–15%
  Butyl acetate: 10–15%, etc.
- **Physical and chemical properties**
  Boiling point: 64.1–125°C
  Flash point: 3.1°C
  Explosion range: 1.2–36.5%
  Autoignition temperature: 370°C
- **Applicable laws**
  Fire Service Act: Category IV hazardous material, class I petroleum (water-insoluble)
  Industrial Safety and Health Act: Hazardous substance for which name should be notified, Inflammable substance

White lacquer enamel

- **GHS classification**
  Flammable liquids, Category 2, etc.
- **Composition and ingredient information**
  Toluene: 30–35%
  Titanium dioxide: 10–15%, etc.
- **Physical and chemical properties**
  Boiling point: 77.2–144.4°C
  Flash point: 4.5°C
  Explosion range: 1.1–12%
  Autoignition temperature: 399°C
- **Applicable laws**
  Fire Service Act: Category IV hazardous material, class I petroleum (water-insoluble)
  Industrial Safety and Health Act: Hazardous substance for which name should be notified, Inflammable substance

Lacquer primer surfacer

- **GHS classification**
  Flammable liquids, Category 2, etc.
- **Composition and ingredient information**
  Toluene: 20–25%, etc.
- **Physical and chemical properties**
  Boiling point: 77.2–125°C
  Flash point: −0.5°C
  Explosion range: 1.2–15%
  Autoignition temperature: 370°C
- **Applicable laws**
  Fire Service Act: Category IV hazardous material, class I petroleum (water-insoluble)
  Industrial Safety and Health Act: Hazardous substance for which name should be notified, Inflammable substance

Black lacquer enamel

- **GHS classification**
  Flammable liquids, Category 2, etc.
- **Composition and ingredient information**
  Toluene: 25–30%
  Nitrocellulose[31]: 10–15%
  Ethyl acetate: 10–15%
  Methyl isobutyl ketone: 10–15%, etc.
- **Physical and chemical properties**
  Boiling point: 77.2–144.4°C
  Flash point: 5.5°C
  Explosion range: 1.1–12%
  Autoignition temperature: 367°C
- **Applicable laws**
  Fire Service Act: Category IV hazardous material, class I petroleum (water-insoluble)
  Industrial Safety and Health Act: Hazardous substance for which name should be notified, Inflammable substance

- Measures to prevent occurrence of ignition sources

(a)	Against electrical sparks:	Use explosion-protected equipment, and prohibit bringing-in non-explosion-protected equipment (e.g. smartphones).
(b)	Against electrostatic sparks:	Use conductive flooring, ground metal products, use antistatic hoses, and wear antistatic work clothes and work shoes.
(c)	Against hot surfaces:	No hot objects are used.
(d)	Against thermal radiation:	There are no hot objects nearby.
(e)	Against impact/friction:	No measures are taken.
(f)	Against adiabatic compression:	As compressed air is used, ignition due to adiabatic compression hardly occurs.
(g)	Against naked flame:	Control the use and bringing-in of fire.
(h)	Against spontaneous combustion:	Nothing generates heat.

[31] A chemical substance classified as explosive grade 1.1. Attention should be paid to accumulation of dry enamel and scattering of powder enamel.

(2) Description of analysis example

The following is an example that applies the simple hazard scenario identification method to the metal coating work described in (1).

1) Preparation of "Working Condition Check Sheet"

Table 10 shows an example of preparing a "Working Condition Check Sheet."

[Column A]: Enter the work details/method described in the work procedure manual.

The metal coating work consisting of five processes (29 steps) is entered in [Column A].

[Column B]: Enter the handled chemical substances and facilities, equipment, and tools used in the work.

The chemical substances to be handled in metal coating work, hazard information and handling conditions of these substances, and facilities, equipment, and others used for the work are checked and entered in [Column B].

[Column C]: Enter the confirmed identification pattern of the hazard scenario of causing a fire or explosion.

Questions Q1 to Q3 are answered for each process.

(Q1) All the handled chemical substances are combustible.

(Q2) Measures taken to prevent the formation of an explosive atmosphere (those entered in Table 5)

- Local exhaust ventilation attached to the spray booth
- Lid of the paint cup on the spray gun
- Disposal of waste liquid in the (metal) waste liquid container with a lid

(Q3) Measures taken to prevent the occurrence of ignition sources (those entered in Table 6)[32]

- **(a) Against electrical sparks**: Use explosion protected equipment, and prohibit bringing-in non-explosion-protected equipment (e.g. smartphones).
- **(b) Against electrostatic sparks**: Use conductive flooring, ground metal products, use antistatic hoses, and wear antistatic work clothes and work shoes.
- **(c) Against hot surfaces**: No hot objects are used.
- **(d) Against thermal radiation**: There are no hot objects nearby.
- **(e) Against impact/friction**: No measures are taken.
- **(f) Against adiabatic compression**: As compressed air is used, ignition due to adiabatic compression hardly occurs.
- **(g) Against naked flame**: Control the use and bringing-in of fire.
- **(h) Against spontaneous combustion**: Nothing generates heat.

From the above, the "degreasing process" and "toning process" are confirmed as pattern (b), and the others as pattern (d).

[32] In hazard scenario identification, the measures already taken to prevent the occurrence of ignition sources are classified into "Inherent safety measure (elimination/substitution)," "Engineering control," "Signage/warning and/or administrative control," "Personal protective equipment," and "Others (N/A, etc.)."

2) Preparation of "Trigger Event Check Sheet"

Table 11 shows an example of preparing a "Trigger Event Check Sheet." The entries in [Column A] to [Column C] are the same as those in the "Working Condition Check Sheet." For the 29 steps subdivided from the five processes, the facility, equipment, and tool failures in [Column D] and inappropriate works in [Column E] are identified as trigger events[33].

[Column D]: Enter the trigger events related to facilities, equipment, and tools.

In addition to the facility, equipment, and tool failures in [Column B], errors (failures) in the measures to prevent the formation of an explosive atmosphere and those to prevent the occurrence of ignition sources confirmed in [Column C] are identified.

[Column E]: Enter the trigger events related to works (human errors).

Based on the information on working conditions in [Column A] to [Column C], the six types of human errors from (1) omission errors to (6) quantitative errors in Table 9 are identified. For (7) other errors, human errors experienced in ordinary work and those that can be noticed by observing the work site are identified[34].

At this point, no distinction is made between "Careless mistakes" and "Intentional violations" (because both factors can work together).

3) Preparation of "Hazard Scenario Identification Sheet"

For the trigger events described in [Column D] and [Column E], hazard scenarios of causing fire or explosion and subsequent effects on others are identified on the basis of the information on the work details/conditions, chemical substances to be handled, and others. Tables 12 (a) and (b) show the Hazard Scenario Identification Sheets for Steps 1 and 2 of the degreasing process and Table 12 (c) shows that for Step 9 of the primer coating process[35]. Both processes are carried out in an open area where oxygen (air) is present.

<u>Degreasing Process (Steps 1 and 2) (Pattern (b)) (Tables 12 (a) and (b))</u>

Step 1: Using a waste cloth moistened with lacquer thinner, wipe the object to be coated so that no grease or oil stains remain, and then wipe it with a dry, clean waste cloth.

Step 2: Dispose of the used waste cloth in a trash can.

Although Steps 1 and 2 are classified as pattern (b) and measures are taken to prevent the occurrence of ignition sources, an explosive atmosphere can always be present. Whether ignition sources can occur when one of the trigger events listed in [Column D] or [Column E] occurs under this unsafe condition is checked. If an ignition source can occur, how it can cause a fire or explosion is entered in [Column F] (e.g., "Fire caused by ignition of vapor around thinner"), and effects on others are entered in [Column G] (e.g., "Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc."), to identify the hazard scenario.

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[33] To comprehensively identify safety-related trigger events, it is desirable to specify in advance the work and operations being implemented as risk reduction measures in the work procedure manual or others.

[34] Although "(a) Prohibit bringing-in non-explosion-proof equipment (e.g., smartphones)" and "(g) Control the use and bringing-in of fire" have been implemented, and trigger events that can invalidate these measures can be identified, they are omitted here.

[35] Due to space limitations, only Steps 1 and 2, which are classified as pattern (b), and Step 9, which is classified as pattern (d), are shown.

(Reference Work Case) Hazard Scenario Identification for Step 1

[Column F]		[Column G]	
Conditions for formation of explosive atmosphere	Conditions for occurrence of ignition sources	Fire/explosion	Other effects
An explosive atmosphere is considered to be present regardless of the occurrence of the identified trigger event.	Ignition sources can occur due to the occurrence of the following trigger events: - Explosion-protected lighting failure - Deterioration of antistatic work clothes - Dirty soles of antistatic shoes - Deterioration of ground wire of conductive flooring - Deterioration of ground wires of metal products - Bringing in non-explosion-protected lighting - Laying a stain-proof vinyl sheet on the floor - Wearing non-antistatic work clothes or work shoes	- Fire caused by ignition of vapor around thinner	- Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc.

* In Step 1, an explosive atmosphere has already been formed, and if an ignition source occurs due to the occurrence of a trigger event, it will cause a fire or explosion.
* The following trigger events can cause the formation of an explosive atmosphere, but cannot trigger the occurrence of ignition sources, and therefore cannot cause a fire or explosion:
- Damage to plastic container
- Damage to trash can
- Wiping the object to be coated with a waste cloth moistened with lacquer thinner after wiping it with a dry, clean cloth
- Wiping only a part of the object to be coated with lacquer thinner
- Too few times of wiping (Too many times of wiping is no problem.)
- Spilling the lacquer thinner

(Reference Work Case) Hazard Scenario Identification for Step 2

[Column F]		[Column G]	
Conditions for formation of explosive atmosphere	Conditions for occurrence of ignition sources	Fire/explosion	Other effects
An explosive atmosphere is considered to be present regardless of the occurrence of the identified trigger event.	Ignition sources can occur due to the occurrence of the following trigger events: - Explosion-protected lighting failure - Deterioration of antistatic work clothes - Dirty soles of antistatic shoes - Deterioration of ground wire of conductive flooring - Deterioration of ground wires of metal products - Bringing in non-explosion-protected lighting - Laying a stain-proof vinyl sheet on the floor - Wearing non-antistatic work clothes or work shoes	- Fire caused by ignition of vapor around thinner	- Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc.

* In Step 2, an explosive atmosphere has already been formed, and if an ignition source occurs due to the occurrence of a trigger event, it will cause a fire or explosion.
* The following trigger events can cause the formation of an explosive atmosphere, but cannot trigger the occurrence of ignition sources, and therefore cannot cause a fire or explosion:
- Damage to plastic container
- Damage to trash can with lid
- Leaving used waste cloth as it is
- Disposing of the plastic container in a container at hand other than a trash can with a lid
- Not disposing of used waste cloth immediately, but leaving it for a while
- Spilling the lacquer thinner

Primer Coating Process (Step 9) (Pattern (d)) (Table 12 (c))

(Step 9) Prime using the spray gun.

Step 9 is classified as pattern (d), for which some measures are taken to prevent the formation of an explosive atmosphere and the occurrence of ignition sources. The following is an example of a hazard scenario in which these measures are invalidated due to the occurrence of any of the trigger events in [Column D] and [Column E], causing a fire or explosion.

By considering a combination of a trigger event A, which can cause the formation of an explosive atmosphere, and a trigger event B, which can cause the occurrence of ignition sources, among the trigger events related to facilities, equipment, and tools listed in [Column D], a hazard scenario that can cause a fire or explosion and subsequent effects on others can be identified.

(Reference Work Case) Hazard Scenario Identification for Step 9
(Trigger Events A and B Related to Facilities, Equipment, and Tools)

[Column F]			[Column G]	
Conditions for formation of explosive atmosphere	×	Conditions for occurrence of ignition sources	Fire/explosion	Other effects
An explosive atmosphere can be formed due to the occurrence of the following trigger events A: - Local exhaust ventilation failure - Damage to lid of paint cup - Damage to waste liquid container with lid	×	Ignition sources can occur due to the occurrence of the following trigger events B: - Deterioration of antistatic hose - Explosion-protected lighting failure - Deterioration of antistatic work clothes - Dirty soles of antistatic shoes - Deterioration of ground wire of conductive flooring - Deterioration of ground wires of metal products	- Fire or explosion caused by ignition of vapor in the spray booth	- Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc.

* In the above table, "×" means to identify the hazard scenario by combining the left and right trigger events.
* The following trigger events cannot cause the formation of an explosive atmosphere, and are therefore omitted from the following analysis results:
- Clogging of or leakage from spray gun
- Air compressor failure
- Pressure regulator failure

By considering a combination of a trigger event C, which can cause the formation of an explosive atmosphere, and a trigger event D, which can cause the occurrence of ignition sources, among the trigger events related to works listed in [Column E], a hazard scenario that can cause a fire or explosion and subsequent effects on others can be identified.

(Reference Work Case) Hazard Scenario Identification for Step 9
(Trigger Events C and D Related to Work/Operations)

[Column F]			[Column G]	
Conditions for formation of explosive atmosphere	×	Conditions for occurrence of ignition sources	Fire/explosion	Other effects
An explosive atmosphere can be formed due to the occurrence of the following trigger events C: - Leaving the paint cup uncovered - Working in a place other than the spray booth - Spilling the lacquer primer surfacer - Dropping the spray gun	×	Ignition sources can occur due to the occurrence of the following trigger events D: - Dropping the spray gun - Bringing in non-explosion-protected lighting - Laying a stain-proof vinyl sheet on the floor - Wearing non-antistatic work clothes or work shoes	- Fire or explosion caused by ignition of vapor in the spray booth	- Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc.

* In the above table, "×" means to identify the hazard scenario by combining the left and right trigger events.
* The trigger event "Dropping the spray gun" can cause both the formation of an explosive atmosphere and the occurrence of ignition sources, leading to a fire or explosion.
* The following trigger events cannot cause the formation of an explosive atmosphere, and are therefore omitted from the following analysis results:
- Priming only a part of a steel plate
- Too thick/too thin coating film

Table 10 Working Condition Check Sheet (Example)

[A] Work procedure/details			[B] Chemical substances handled and facilities, equipment, and others used for work				[C] Confirmation of coexistence of three elements of combustion that could cause fire or explosion							
			Handled substances	Information on hazards of chemical substances concerned	Handling conditions (temperature, humidity, amount handled, storage conditions, etc.)	Facilities, equipment, and tools used for work	Q-1. Are the chemical substances handled combustible?	Q-2. Are measures taken to prevent the formation of an explosive atmosphere?	Q-3. Are measures taken to prevent the occurrence of ignition sources?					Pattern (a) - (d)
									Inherent safety measure (elimination/substitution)	Engineering control	Signage/warning and/or administrative control	Personal protective equipment	Others (N/A, etc.)	
1	Degreasing	Using a waste cloth moistened with lacquer thinner, wipe the object to be coated so that no grease or oil stains remain, and then wipe it with a dry, clean waste cloth.	Lacquer thinner (toluene, ethyl acetate, butyl acetate, etc.)	Flammable liquids, Category 2 (Flash point: 3.1°C) (Explosive range: 1.2 to 36.5%)	Room temperature, 500 mL Pour lacquer thinner into a plastic container, moisten a waste cloth with lacquer thinner from the container, and then use the cloth. Dispose of the waste cloth in a trash can.	- Plastic container - Waste cloth (cotton) - Trash can	Yes (Lacquer thinner)	No measures taken		(a) Use explosion-protectedl equipment (b) Use a conductive flooring (b) Ground metal products	(a) Prohibit bringing-in non-explosion-protected equipment (e.g., smartphones) (b) Ground metal products (b) Wear antistatic work clothes and antistatic shoes (g) Control the use and bringing-in of fire		(c) Avoid using hot objects (d) Remove hot objects from the surroundings (e) No measures taken (f) As compressed air is used, ignition due to adiabatic compression is unlikely to occur (h) There is nothing that generates heat	(b)
2		Dispose of the used waste cloth in a trash can.												
3	Primer coating	Activate the local exhaust ventilation for the spray coating equipment.	Lacquer primer surfacer (e.g., toluene)	Flammable liquids, Category 2 (Flash point: -0.5°C) (Explosive range: 1.2 to 15%)	Room temperature, 200 mL Use lacquer primer surfacer with a spray gun. Dispose of the waste cloth in a trash can. Dispose of the waste liquid in a waste liquid container with a lid.	- Spray coating equipment - Workbench - Plastic container - Trash can - (Metal) Waste liquid container with lid	Yes (Lacquer primer surfacer)	- Local exhaust ventilation attached to spray booth - Lid of paint cup on spray gun - Disposal of waste liquid in (metal) waste liquid container with lid		(a) Use explosion-protectedl equipment (b) Use a conductive flooring (b) Ground metal products (b) Use antistatic hoses	(a) Prohibit bringing-in non-explosion-protected equipment (e.g., smartphones) (b) Ground metal products (b) Wear antistatic work clothes and antistatic work shoes (g) Control the use and bringing-in of fire		(c) Avoid using hot objects (d) Remove hot objects from the surroundings (e) No measures taken (f) As compressed air is used, ignition due to adiabatic compression is unlikely to occur (h) There is nothing that generates heat	(d)
4		Pour lacquer primer surfacer into the cup on the spray gun.												
5		Dispose of the plastic container of the lacquer primer surfacer in a trash can.												
6		Adjust the air pressure to 0.2 to 0.3 MPa with the spray pressure regulator.												
7		Adjust the discharge rate of the lacquer primer surfacer emitted from the spray gun by spraying on a sample for trial coating.												
8		Pull the trigger of the spray gun one step to blow off the dust from the surface of the object to be coated.												
9		Prime using the spray gun.												
10		Dispose of the lacquer primer surfacer remaining in the cup in a waste liquid container with a lid.												
11		Allow to air-dry at room temperature.												
12	Toning	Pour white lacquer enamel into a plastic container.	Lacquer enamel (white) (toluene, titanium dioxide, etc.) Lacquer enamel (black) (toluene, cellulose nitrate, acetic ether, methyl isobutyl ketone, etc.)	Lacquer enamel (white) Flammable liquids, Category 2 (Flash point: 4.5°C) (Explosive range: 1.1 to 12%) Lacquer enamel (black) Flammable liquids, Category 2 (Flash point: 5.5°C) (Explosive range: 1.1 to 12%)	Room temperature, 200 mL (total) Use in a plastic container. Dispose of the used plastic container and stirring rod in a trash can.	- Plastic container - (Wooden) Stirring rod - Trash can	Yes (Lacquer enamel)	No measures taken		(a) Use explosion-protectedl equipment (b) Use a conductive flooring (b) Ground metal products	(a) Prohibit bringing-in non-explosion-protected equipment (e.g., smartphones) (b) Ground metal products (b) Wear antistatic work clothes and antistatic work shoes (g) Control the use and bringing-in of fire		(c) Avoid using hot objects (d) Remove hot objects from the surroundings (e) No measures taken (f) As compressed air is used, ignition due to adiabatic compression is unlikely to occur (h) There is nothing that generates heat	(b)
13		Add black lacquer enamel little by little to white lacquer enamel and stir with the stirring rod until uniform.												
14		Dispose of the used plastic container and stirring rod in a trash can.												
15	Trial coating	Place a small amount of the toned paint in a plastic container, and dilute it with lacquer thinner at a dilution ratio of 10:8.	Lacquer enamel (toned paint) Lacquer thinner	Lacquer enamel (white) Flammable liquids, Category 2 (Flash point: 4.5°C) (Explosive range: 1.1 to 12%) Lacquer enamel (black) Flammable liquids, Category 2 (Flash point: 5.5°C) (Explosive range: 1.1 to 12%) Lacquer thinner Flammable liquids, Category 2 (Flash point: 3.1°C) (Explosive range: 1.2 to 36.5%)	Room temperature, 700 mL (total) Dilute the toned paint with lacquer thinner in a plastic container. Use the toned paint with a spray gun. Dispose of the used plastic container, stirring rod, and filter paper in a trash can. Dispose of the remaining mixed paint in a waste liquid container with a lid.	- Spray coating equipment - Workbench - Plastic container - Stirring rod - Filter paper - Trash can - (Metal) Waste liquid container with lid	Yes (Lacquer enamel, lacquer thinner)	- Local exhaust ventilation attached to spray booth - Lid of paint cup on spray gun - Disposal of waste liquid in (metal) waste liquid container with lid		(a) Use explosion-protectedl equipment (b) Use a conductive flooring (b) Ground metal products (b) Use antistatic hoses	(a) Prohibit bringing-in non-explosion-protected equipment (e.g., smartphones) (b) Ground metal products (b) Wear antistatic work clothes and antistatic work shoes (g) Control the use and bringing-in of fire		(c) Avoid using hot objects (d) Remove hot objects from the surroundings (e) No measures taken (f) As compressed air is used, ignition due to adiabatic compression is unlikely to occur (h) There is nothing that generates heat	(d)
16		Activate the local exhaust system for the spray coating equipment.												
17		Pour the resulting paint into the cup on the spray gun while filtering it using filter paper.												
18		Dispose of the used plastic container, stirring rod, and filter paper in a trash can.												
19		Spray on a sample for trial coating using the spray gun.												
20		Dispose of the mixed paint remaining in the cup in a waste liquid container with a lid.												
21	Top coating	Activate the local exhaust system for the spray coating equipment.	Lacquer enamel (toned paint) Lacquer thinner	Lacquer enamel (white) Flammable liquids, Category 2 (Flash point: 4.5°C) (Explosive range: 1.1 to 12%) Lacquer enamel (black) Flammable liquids, Category 2 (Flash point: 5.5°C) (Explosive range: 1.1 to 12%) Lacquer thinner Flammable liquids, Category 2 (Flash point: 3.1°C) (Explosive range: 1.2 to 36.5%)	Room temperature, 200 mL Use the toned paint with a spray gun. Dispose of the used plastic container in a trash can. Dispose of the remaining mixed paint in a waste liquid container with a lid.	- Spray coating equipment - Workbench - Plastic container - Trash can - (Metal) Waste liquid container with lid	Yes (Lacquer enamel, lacquer thinner)	- Local exhaust ventilation attached to spray booth - Lid of paint cup on spray gun - Disposal of waste liquid in (metal) waste liquid container with lid		(a) Use explosion-protectedl equipment (b) Use a conductive flooring (b) Ground metal products (b) Use antistatic hoses	(a) Prohibit bringing-in non-explosion-protected equipment (e.g., smartphones) (b) Ground metal products (b) Wear antistatic work clothes and antistatic work shoes (g) Control the use and bringing-in of fire		(c) Avoid using hot objects (d) Remove hot objects from the surroundings (e) No measures taken (f) As compressed air is used, ignition due to adiabatic compression is unlikely to occur (h) There is nothing that generates heat	(d)
22		Pour the toned paint into the cup on the spray gun.												
23		Dispose of the used plastic container in a trash can.												
24		Adjust the air pressure to 0.2 to 0.3 MPa with the spray pressure regulator.												
25		Adjust the discharge rate of the paint emitted from the spray gun by performing trial spraying. Also, adjust the pattern adjustment knob appropriately.												
26		Pull the trigger of the spray gun one step to blow off the dust from the surface of the object to be coated.												
27		Apply a topcoat using the spray gun.												
28		Dispose of the mixed paint remaining in the cup in a waste liquid container with a lid.												
29		Allow to air-dry at room temperature.												

Table 11 Trigger Event Check Sheet (Example)

[A] Work procedure/details			[B] Chemical substances handled and facilities, equipment, and others used for work				[C] Confirmation of coexistence of three elements of combustion that could cause fire or explosion				[D] Trigger events related to facilities, equipment, and tools	[E] Trigger events related to work/operation (human errors)						
			Handled substances	Information on hazards of chemical substances concerned	Handling conditions (temperature, humidity, amount handled, storage conditions, etc.)	Facilities, equipment, and tools used for work	Measures to prevent formation of explosive atmosphere	Measures to prevent occurrence of ignition sources		Pattern (a) - (d)	Facility, equipment, and tool failures	Omission errors	Commission errors					
								Engineering control	Signage/warning and/or administrative control				Selection errors	Sequential errors	Time errors	Qualitative errors	Quantitative errors	Other errors
1	Degreasing	Using a waste cloth moistened with lacquer thinner, wipe the object to be coated so that no grease or oil stains remain, and then wipe it with a dry, clean waste cloth.	Lacquer thinner (toluene, ethyl acetate, butyl acetate, etc.)	Flammable liquids, Category 2 (Flash point: 3.1°C) (Explosive range: 1.2 to 36.5%)	Room temperature, 500 mL Pour lacquer thinner into a plastic container, moisten a waste cloth with lacquer thinner from the container, and then use the cloth. Dispose of the waste cloth in a trash can.	- Plastic container - Waste cloth (cotton) - Trash can	No measures taken	(a) Use explosion-protected equipment (b) Use a conductive flooring (b) Ground metal products	(a) Prohibit bringing-in non-explosion-protected equipment (e.g., smartphones) (b) Ground metal products (b) Wear antistatic work clothes and antistatic work shoes (g) Control the use and bringing-in of fire	(b)	- Damage to plastic container - Damage to trash can - Explosion-protected lighting failure - Deterioration of antistatic work clothes - Dirty soles of antistatic work shoes - Deterioration of ground wire of conductive flooring - Deterioration of ground wires of metal products			- After wiping the object to be coated with a dry, clean cloth, wipe it with a waste cloth moistened with lacquer thinner		- Wipe only a part of the object to be coated with lacquer thinner	- Too few times/too many times of wiping	- Spill lacquer thinner - Bring in non-explosion-protected lighting - Lay a stain-proof vinyl sheet on the floor - Wear non-antistatic work clothes or work shoes
2		Dispose of the used waste cloth in a trash can.										- Leave the used waste cloth as it is	- Dispose of the plastic container in a container at hand other than a trash can		- Do not dispose of the used waste cloth immediately, but leave it for a while			Same as above
3	Primer coating	Activate the local exhaust ventilation for the spray coating equipment.	Lacquer primer surfacer (e.g., toluene)	Flammable liquids, Category 2 (Flash point: -0.5°C) (Explosive range: 1.2 to 15%)	Room temperature, 200 mL Use lacquer primer surfacer with a spray gun. Dispose of the waste cloth in a trash can. Dispose of the waste liquid in a waste liquid container with a lid.	- Spray coating equipment - Workbench - Plastic container - Trash can - (Metal) Waste liquid container with lid	- Local exhaust ventilation attached to spray booth - Lid of paint cup on spray gun - Disposal of waste liquid in (metal) waste liquid container with lid	(a) Use explosion-protected equipment (b) Use a conductive flooring (b) Ground metal products (b) Use antistatic hoses	(a) Prohibit bringing-in non-explosion-protected equipment (e.g., smartphones) (b) Ground metal products (b) Wear antistatic work clothes and antistatic work shoes (g) Control the use and bringing-in of fire	(d)	- Local exhaust ventilation failure - Clogging of or leakage from spray gun - Air compressor failure - Pressure regulator failure - Deterioration of antistatic hose - Damage to lid of paint cup - Explosion-protected lighting failure - Deterioration of antistatic work clothes - Dirty soles of antistatic work shoes - Deterioration of ground wire of conductive flooring - Deterioration of ground wires of metal products - Damage to waste liquid container with lid	- Forget to start the local exhaust ventilation		- Activate the local exhaust ventilation after a trial blow	- Too early/too late activation of the local exhaust ventilation			
4		Pour lacquer primer surfacer into the cup on the spray gun.										- Leave the paint cup uncovered	- Work in a place other than the spray booth	- Handle the lacquer primer surfacer before activating the local exhaust ventilation			- Let the lacquer primer surfacer overflow from the paint cup	- Spill the lacquer primer surfacer - Bring in non-explosion-protected lighting - Lay a stain-proof vinyl sheet on the floor - Wear non-antistatic work clothes or work shoes
5		Dispose of the plastic container of the lacquer primer surfacer in a trash can.										- Leave the used plastic container as it is	- Dispose of the plastic container in a container at hand other than a trash can		- Do not dispose of the used plastic container immediately, but leave it for a while			Same as above
6		Adjust the air pressure to 0.2 to 0.3 MPa with the spray pressure regulator.										- Forget to adjust the air pressure - Leave the paint cup uncovered	- Work in a place other than the spray booth			- Too high/too low air pressure		- Spill the lacquer primer surfacer - Drop the spray gun - Bring in non-explosion-protected lighting - Lay a stain-proof vinyl sheet on the floor - Wear non-antistatic work clothes or work shoes
7		Adjust the discharge rate of the lacquer primer surfacer emitted from the spray gun by spraying on a sample for trial coating.										- Forget to perform trial spraying - Leave the paint cup uncovered	Same as above			- Too high/too low discharge rate		Same as above
8		Pull the trigger of the spray gun one step to blow off the dust from the surface of the object to be coated.										- Forget to blow off the dust - Leave the paint cup uncovered	Same as above			- Pull the trigger all the way		Same as above
9		Prime using the spray gun.										- Leave the paint cup uncovered	Same as above			- Prime only a part of the object to be coated	- Too thick/too thin coating film	Same as above
10		Dispose of the lacquer primer surfacer remaining in the cup in a waste liquid container with a lid.										- Leave the waste liquid container uncovered	- Dispose of lacquer primer surfacer in a plastic container at hand					Same as above
11		Allow to air-dry at room temperature.											- Dry in a place other than the spray booth			- Take out of the spray booth before drying completely	- Too long/too short drying time	
12	Toning	Pour white lacquer enamel into a plastic container.	Lacquer enamel (white) (toluene, titanium dioxide, etc.) Lacquer enamel (black) (toluene, cellulose nitrate, acetic ether, methyl isobutyl ketone, etc.)	Lacquer enamel (white) Flammable liquids, Category 2 (Flash point: 4.5°C) (Explosive range: 1.1 to 12%) Lacquer enamel (black) Flammable liquids, Category 2 (Flash point: 5.5°C) (Explosive range: 1.1 to 12%)	Room temperature, 200 mL (total) Use in a plastic container. Dispose of the used plastic container and stirring rod in a trash can.	- Plastic container - (Wooden) Stirring rod - Trash can	No measures taken	(a) Use explosion-protected equipment (b) Use a conductive flooring (b) Ground metal products	(a) Prohibit bringing-in non-explosion-protected equipment (e.g., smartphones) (b) Ground metal products (b) Wear antistatic work clothes and antistatic work shoes (g) Control the use and bringing-in of fire	(b)	- Damage to plastic container - Damage to trash can - Explosion-protected lighting failure - Deterioration of antistatic work clothes - Dirty soles of antistatic work shoes - Deterioration of ground wire of conductive flooring - Deterioration of ground wires of metal products		- Pour black lacquer enamel by mistake				- Let the white lacquer enamel overflow from the plastic container	- Spill the lacquer enamel - Bring in non-explosion-protected lighting - Lay a stain-proof vinyl sheet on the floor - Wear non-antistatic work clothes or work shoes
13		Add black lacquer enamel little by little to white lacquer enamel and stir with the stirring rod until uniform.											- Mistake white lacquer enamel for black lacquer enamel - Use a metal rod at hand as the stirring rod	- Pour black lacquer enamel after stirring		- Do not stir until uniform	- Let the black lacquer enamel overflow from the plastic container	Same as above
14		Dispose of the used plastic container and stirring rod in a trash can.										- Leave the used plastic container and stirring rod as they are	- Dispose of the used plastic container and stirring rod in a container at hand other than a trash can		- Do not dispose of the used plastic container or stirring rod immediately, but leave them for a while			Same as above

Table 11 Trigger Event Check Sheet (Example) (Continued)

No.	Stage	[A] Work procedure/details	[B] Chemical substances handled and facilities, equipment, and others used for work				[C] Confirmation of coexistence of three elements of combustion that could cause fire or explosion				[D] Trigger events related to facilities, equipment, and tools
			Handled substances	Information on hazards of chemical substances concerned	Handling conditions (temperature, humidity, amount handled, storage conditions, etc.)	Facilities, equipment, and tools used for work	Measures to prevent formation of explosive atmosphere	Measures to prevent occurrence of ignition sources		Pattern (a) - (d)	Facility, equipment, and tool failures
								Engineering control	Signage/warning and/or administrative control		
15	Trial coating	**Place a small amount of the toned paint in a plastic container, and dilute it with lacquer thinner at a dilution ratio of 10:8.**	Lacquer enamel (toned paint) Lacquer thinner	Lacquer enamel (white) Flammable liquids, Category 2 (Flash point: 4.5°C) (Explosive range: 1.1 to 12%) Lacquer enamel (black) Flammable liquids, Category 2 (Flash point: 5.5°C) (Explosive range: 1.1 to 12%) Lacquer thinner Flammable liquids, Category 2 (Flash point: 3.1°C) (Explosive range: 1.2 to 36.5%)	Room temperature, 700 mL (total) Dilute the toned paint with lacquer thinner in a plastic container. Use the toned paint with a spray gun. Dispose of the used plastic container, stirring rod, and filter paper in a trash can. Dispose of the remaining mixed paint in a waste liquid container with a lid.	- Spray coating equipment - Workbench - Plastic container - Stirring rod - Filter paper - Trash can - (Metal) Waste liquid container with lid	- Local exhaust ventilation attached to spray booth - Lid of paint cup on spray gun - Disposal of waste liquid in (metal) waste liquid container with lid	(a) Use explosion-protected equipment (b) Use a conductive flooring (b) Ground metal products (b) Use antistatic hoses	(a) Prohibit bringing-in **non-explosion-protected equipment** (e.g., smartphones) (b) Ground metal products (b) Wear antistatic work clothes and antistatic work shoes (g) Control the use and bringing-in of fire	(d)	- Local exhaust ventilation failure - Clogging of or leakage from spray gun - Air compressor failure - Pressure regulator failure - Deterioration of antistatic hose - Damage to plastic container - Damage to trash can - Damage to waste liquid container with lid '- Rip filter paper - Damage to lid of paint cup - Explosion-protected lighting failure - Deterioration of antistatic work clothes - Dirty soles of antistatic work shoes - Deterioration of ground wire of conductive flooring - Deterioration of ground wires of metal products
16		**Activate the local exhaust ventilation for the spray coating equipment.**									
17		**Pour the resulting paint into the cup on the spray gun while filtering it using filter paper.**									
18		**Dispose of the used plastic container, stirring rod, and filter paper in a trash can.**									
19		**Spray on a sample for trial coating using the spray gun.**									
20		**Dispose of the mixed paint remaining in the cup in a waste liquid container with a lid.**									
21	Top coating	**Activate the local exhaust ventilation for the spray coating equipment.**	Lacquer enamel (toned paint) Lacquer thinner	Lacquer enamel (white) Flammable liquids, Category 2 (Flash point: 4.5°C) (Explosive range: 1.1 to 12%) Lacquer enamel (black) Flammable liquids, Category 2 (Flash point: 5.5°C) (Explosive range: 1.1 to 12%) Lacquer thinner Flammable liquids, Category 2 (Flash point: 3.1°C) (Explosive range: 1.2 to 36.5%)	Room temperature, 200 mL Use the toned paint with a spray gun. Dispose of the used plastic container in a trash can. Dispose of the remaining mixed paint in a waste liquid container with a lid.	- Spray coating equipment - Workbench - Plastic container - Trash can - (Metal) Waste liquid container with lid	- Local exhaust ventilation attached to spray booth - Lid of paint cup on spray gun - Disposal of waste liquid in (metal) waste liquid container with lid	(a) Use explosion-protected equipment (b) Use a conductive flooring (b) Ground metal products (b) Use antistatic hoses	(a) Prohibit bringing-in non-explosion-protected equipment (e.g., smartphones) (b) Ground metal products (b) Wear antistatic work clothes and antistatic work shoes (g) Control the use and bringing-in of fire	(d)	- Local exhaust ventilation failure - Clogging of or leakage from spray gun - Air compressor failure - Pressure regulator failure - Deterioration of antistatic hose - Damage to trash can - Damage to waste liquid container with lid - Damage to lid of paint cup - Explosion-protected lighting failure - Deterioration of antistatic work clothes - Dirty soles of antistatic work shoes - Deterioration of ground wire of conductive flooring - Deterioration of ground wires of metal products
22		**Pour the toned paint into the cup on the spray gun.**									
23		**Dispose of the used plastic container in a trash can.**									
24		**Adjust the air pressure to 0.2 to 0.3 MPa with the spray pressure regulator.**									
25		**Adjust the discharge rate of the paint emitted from the spray gun by performing trial coating. Also, adjust the pattern adjustment knob appropriately.**									
26		**Pull the trigger of the spray gun one step to blow off the dust from the surface of the object to be coated.**									
27		**Apply a topcoat using the spray gun.**									
28		**Dispose of the mixed paint remaining in the cup in a waste liquid container with a lid.**									
29		**Allow to air-dry at room temperature.**									

No.	[E] Trigger events related to work/operation (human errors)						
	Omission errors	Commission errors					
		Selection errors	Sequential errors	Time errors	Qualitative errors	Quantitative errors	Other errors
15		- Work in a place other than the spray booth - Use a metal rod at hand as the stirring rod	- Add the toned paint to subdivided lacquer thinner		- Do not stir until uniform	- Let the toned paint overflow from the plastic container - Let the lacquer thinner overflow from the plastic container - Mistake the ratio of lacquer thinner to the paint	- Spill the mixed paint - Spill the lacquer thinner - Bring in non-explosion-protected lighting - Lay a stain-proof vinyl sheet on the floor - Wear non-antistatic work clothes or work shoes
16	- Forget to start the local exhaust ventilation		- Activate the local exhaust ventilation during or after trial coating	- Too early/too late activation of the local exhaust ventilation			Same as above
17	- Pour the paint into the cup without filtering it - Leave the paint cup uncovered	- Use filter paper of a wrong size at hand - Work in a place other than the spray booth			- Pour the resulting paint too fast/too slow into the cup	- Let the resulting paint overflow from the cup	- Spill the mixed paint - Spill the lacquer thinner - Drop the spray gun - Bring in non-explosion-protected lighting - Lay a stain-proof vinyl sheet on the floor - Wear non-antistatic work clothes or work shoes
18	- Leave the used plastic container, stirring rod, and filter paper as they are	- Dispose of the used plastic container, stirring rod, and filter paper in a container at hand other than a trash can		- Do not dispose of the used plastic container, stirring rod, or filter paper immediately, but leave them for a while			Same as above
19	- Leave the paint cup uncovered	- Work in a place other than the spray booth			- Coat only a part of the object to be coated - Too high/too low paint discharge rate	- Too thick/too thin coating film	Same as above
20	- Leave the waste liquid container uncovered	- Dispose of the mixed paint in a plastic container at hand					
21	- Forget to start the local exhaust ventilation		- Activate the local exhaust ventilation during or after trial coating	- Too early/too late activation of the local exhaust ventilation			
22	- Leave the paint cup uncovered	- Work in a place other than the spray booth	- Handle the paint before activating the local exhaust ventilation			- Let the paint overflow from the cup	- Spill the paint - Bring in non-explosion-protected lighting - Lay a stain-proof vinyl sheet on the floor - Wear non-antistatic work clothes or work shoes
23	- Leave the used plastic container as it is	- Dispose of the plastic container in a container at hand other than a trash can		- Do not dispose of the used plastic container immediately, but leave it for a while			Same as above
24	- Forget to adjust the air pressure - Leave the paint cup uncovered	- Work in a place other than the spray booth			- Too high/too low air pressure		- Spill the paint - Drop the spray gun - Bring in non-explosion-protected lighting - Lay a stain-proof vinyl sheet on the floor - Wear non-antistatic work clothes or work shoes
25	- Forget to perform trial spraying - Leave the paint cup uncovered	Same as above			- Too high/too low discharge rate		Same as above
26	- Forget to blow off the dust - Leave the paint cup uncovered	Same as above			- Pull the trigger all the way		Same as above
27	- Leave the paint cup uncovered	Same as above			- Prime only a part of the object to be coated	- Too thick/too thin coating film	Same as above
28	- Leave the waste liquid container uncovered	- Dispose of the mixed paint in a plastic container at hand					Same as above
29		- Dry in a place other than the spray booth			- Take out of the spray booth before drying completely	- Too long/too short drying time	

Table 12 (a) Hazard Scenario Identification Sheet (Degreasing Process: Step 1)

[A] Work procedure/details		[C] Confirmation of coexistence of three elements of combustion that could cause fire or explosion				[D] [E] Trigger events	[F] Unsafe conditions		[G] Accidents and disasters	
		Measures to prevent formation of explosive atmosphere	Measures to prevent occurrence of ignition sources: Engineering control	Measures to prevent occurrence of ignition sources: Signage/warning and/or administrative control	Pattern (a) - (d)		Formation of explosive atmosphere	Occurrence of ignition source	Fire/explosion	Effects on others
1	Using a waste cloth moistened with lacquer thinner, wipe the object to be coated so that no grease or oil stains remain, and then wipe it with a dry, clean waste cloth.	No measures taken	(a) Use explosion-protected electrical equipment (b) Use a conductive flooring (b) Ground metal products	(a) Prohibit bringing-in non-explosion-protected equipment (e.g., smartphones) (b) Ground metal products (b) Wear antistatic work clothes and antistatic shoes (g) Control the use and bringing-in of fire	(b)	- Damage to plastic container	Working in an open area can cause an explosive atmosphere to be formed around thinner.	N/A	No effect	No effect
						- Damage to trash can	Same as above	N/A	No effect	No effect
						- Explosion-protected lighting failure	Same as above	Poor lighting insulation can cause electric sparks.	Fire caused by ignition of vapor around thinner	Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc.
						- Deterioration of antistatic work clothes	Same as above	Workers can become charged, causing electrostatic sparks.	Same as above	Same as above
						- Dirty soles of antistatic work shoes	Same as above	Same as above	Same as above	Same as above
						- Deterioration of ground wire of conductive floor	Same as above	Same as above	Same as above	Same as above
						- Deterioration of ground wires of metal products	Same as above	Coming close to a conductive object can cause electrostatic sparks.	Same as above	Same as above
						- After wiping the object to be coated with a dry, clean cloth, wipe it with a waste cloth moistened with lacquer thinner	Working in an open area can cause an explosive atmosphere to be formed around thinner.	N/A	No effect	No effect
						- Wipe only a part of the object to be coated with lacquer thinner	Same as above	N/A	No effect	No effect
						- Too few times/too many times of wiping	Same as above	N/A	No effect	No effect
						- Spill the lacquer thinner	Same as above	N/A	No effect	No effect
						- Bring in non-explosion-protected lighting	Same as above	Bringing in non-explosion-protected lighting can cause electric sparks from the power source of the lighting.	Fire caused by ignition of vapor around thinner	Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc.
						- Lay a stain-proof vinyl sheet on the floor	Same as above	Workers can become charged, causing electrostatic sparks.	Same as above	Same as above
						- Wear non-antistatic work clothes or work shoes	Same as above	Same as above	Same as above	Same as above

Table 12 (b) Hazard Scenario Identification Sheet (Degreasing Process: Step 2)

[A] Work procedure/details		[C] Confirmation of coexistence of three elements of combustion that could cause fire or explosion				[D] [E] Trigger events	[F] Unsafe conditions		[G] Accidents and disasters	
		Measures to prevent formation of explosive atmosphere	Measures to prevent occurrence of ignition sources: Engineering control	Measures to prevent occurrence of ignition sources: Signage/warning and/or administrative control	Pattern (a) - (d)		Formation of explosive atmosphere	Occurrence of ignition source	Fire/explosion	Effects on others
2	Dispose of the used waste cloth in a trash can.	No measures taken	(a) Use explosion-protected electrical equipment (b) Use a conductive flooring (b) Ground metal products	(a) Prohibit bringing-in non-explosion-protected equipment (e.g., smartphones) (b) Ground metal products (b) Wear antistatic work clothes and antistatic shoes (g) Control the use and bringing-in of fire	(b)	- Damage to plastic container	Working in an open area can cause an explosive atmosphere to be formed around thinner.	N/A	No effect	No effect
						- Damage to trash can with lid	Same as above	N/A	No effect	No effect
						- Explosion-protected lighting failure	Same as above	Poor lighting insulation can cause electric sparks.	Fire caused by ignition of vapor around thinner	Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc.
						- Deterioration of antistatic work clothes	Same as above	Workers can become charged, causing electrostatic sparks.	Same as above	Same as above
						- Dirty soles of antistatic work shoes	Same as above	Same as above	Same as above	Same as above
						- Deterioration of ground wire of conductive floor	Same as above	Same as above	Same as above	Same as above
						- Deterioration of ground wires of metal products	Same as above	Coming close to a conductive object can cause electrostatic sparks.	Same as above	Same as above
						- Leave the used waste cloth as it is	Working in an open area can cause an explosive atmosphere to be formed around thinner.	N/A	No effect	No effect
						- Dispose of the plastic container in a container at hand other than a trash can with a lid	Same as above	N/A	No effect	No effect
						- Do not dispose of the used waste cloth immediately, but leave it for a while	Same as above	N/A	No effect	No effect
						- Spill the lacquer thinner	Same as above	N/A	No effect	No effect
						- Bring in non-explosion-protected lighting	Same as above	Bringing in non-explosion-protected lighting can cause electric sparks from the power source of the lighting.	Fire caused by ignition of vapor around thinner	Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc.
						- Lay a stain-proof vinyl sheet on the floor	Same as above	Workers can become charged, causing electrostatic sparks.	Same as above	Same as above
						- Wear non-antistatic work clothes or work shoes	Same as above	Same as above	Same as above	Same as above

Table 12 (c) Hazard Scenario Identification Sheet (Primer Coating Process: Step 9)

[A] Work procedure/details		[C] Confirmation of coexistence of three elements of combustion that could cause fire or explosion: Measures to prevent formation of explosive atmosphere	Measures to prevent occurrence of ignition: Engineering control	Measures to prevent occurrence of ignition: Signage/warning and/or administrative control	Pattern (a) - (d)	[D] [E] Trigger events	[F] Unsafe conditions: Formation of explosive atmosphere	[F] Unsafe conditions: Occurrence of ignition source	[G] Accidents and disasters: Fire/explosion	[G] Accidents and disasters: Effects on others
9	**Prime using the spray gun.**	- Local exhaust system attached to spray booth - Lid of paint cup on spray gun - Disposal of waste liquid in (metal) waste liquid container with lid	(a) Use explosion-protected lighting (b) Use a conductive flooring (b) Ground metal products (b) Use antistatic hoses	(a) Prohibit bringing-in non-explosion-protected equipment (e.g., smartphones) (b) Ground metal products (b) Wear antistatic work clothes and antistatic shoes (g) Control the use and bringing-in of fire	**(d)**	- Local exhaust ventilation failure	An explosive atmosphere can be formed in the spray booth during coating.	The spray gun can become charged due to deterioration of the antistatic hose, causing electrostatic sparks. An explosion-protected lighting failure can result in electric sparks due to poor lighting insulation. Deterioration of antistatic work clothes can cause workers to become charged, causing electrostatic sparks. Deterioration of antistatic work shoes can cause workers to become charged, causing electrostatic sparks. Deterioration of the ground wire of the conductive flooring can cause workers to become charged, causing electrostatic sparks. Deterioration of ground wires of metal products can cause workers to become charged, causing electrostatic sparks.	Fire or explosion caused by ignition of vapor in the spray booth	Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc.
						- Clogging of or leakage from spray gun	N/A	(Omitted)	No effect	No effect
						- Air compressor failure	N/A	(Omitted)	No effect	No effect
						- Pressure regulator failure	N/A	(Omitted)	No effect	No effect
						- Deterioration of antistatic hose	An explosive atmosphere can be formed in the spray booth during coating due to a local exhaust ventilation failure. If the lid of the paint cup is damaged, causing the added paint to evaporate and exceed the capacity of the local exhaust system, an explosive atmosphere can be formed in the spray booth during coating. If the waste liquid container with a lid is damaged, causing the added paint to evaporate and exceed the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating.	The spray gun can become charged, causing electrostatic sparks.	Fire or explosion caused by ignition of vapor in the spray booth	Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc.
						- Damage to lid of paint cup	If the added paint evaporates and exceeds the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating.	The spray gun can become charged due to deterioration of the antistatic hose, causing electrostatic sparks. An explosion-protected lighting failure can result in electric sparks due to poor lighting insulation. Deterioration of antistatic work clothes can cause workers to become charged, causing electrostatic sparks. Deterioration of antistatic work shoes can cause workers to become charged, causing electrostatic sparks. Deterioration of the ground wire of the conductive flooring can cause workers to become charged, causing electrostatic sparks. Deterioration of ground wires of metal products can cause workers to become charged, causing electrostatic sparks.	Same as above	Same as above
						- Explosion-protected lighting failure	An explosive atmosphere can be formed in the spray booth during coating due to a local exhaust ventilation failure. If the lid of the paint cup is damaged, causing the added paint to evaporate and exceed the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating. If the waste liquid container with a lid is damaged, causing the added paint to evaporate and exceed the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating.	Poor lighting insulation can cause electric sparks.	Same as above	Same as above
						- Deterioration of antistatic work clothes	An explosive atmosphere can be formed in the spray booth during coating due to a local exhaust ventilation failure. If the lid of the paint cup is damaged, causing the added paint to evaporate and exceed the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating. If the waste liquid container with a lid is damaged, causing the added paint to evaporate and exceed the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating.	Workers can become charged, causing electrostatic sparks.	Same as above	Same as above
						- Dirty soles of antistatic work shoes	An explosive atmosphere can be formed in the spray booth during coating due to a local exhaust ventilation failure. If the lid of the paint cup is damaged, causing the added paint to evaporate and exceed the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating. If the waste liquid container with a lid is damaged, causing the added paint to evaporate and exceed the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating.	Workers can become charged, causing electrostatic sparks.	Same as above	Same as above
						- Deterioration of ground wire of conductive flooring	An explosive atmosphere can be formed in the spray booth during coating due to a local exhaust ventilation failure. If the lid of the paint cup is damaged, causing the added paint to evaporate and exceed the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating. If the waste liquid container with a lid is damaged, causing the added paint to evaporate and exceed the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating.	Workers can become charged, causing electrostatic sparks.	Same as above	Same as above
						- Deterioration of ground wires of metal products	An explosive atmosphere can be formed in the spray booth during coating due to a local exhaust ventilation failure. If the lid of the paint cup is damaged, causing the added paint to evaporate and exceed the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating. If the waste liquid container with a lid is damaged, causing the added paint to evaporate and exceed the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating.	Metal products can become charged, causing electrostatic sparks.	Same as above	Same as above
						- Damage to waste liquid container with lid	If the added paint evaporates and exceeds the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating.	The spray gun can become charged due to deterioration of the antistatic hose, causing electrostatic sparks. An explosion-protected lighting failure can result in electric sparks due to poor lighting insulation. Deterioration of antistatic work clothes can cause workers to become charged, causing electrostatic sparks. Deterioration of antistatic work shoes can cause workers to become charged, causing electrostatic sparks. Deterioration of the ground wire of the conductive flooring can cause workers to become charged, causing electrostatic sparks. Deterioration of ground wires of metal products can cause workers to become charged, causing electrostatic sparks.	Same as above	Same as above

Table 12 (c) Hazard Scenario Identification Sheet (Primer Coating Process: Step 9) (Continued)

[A] Work procedure/details		[C] Confirmation of coexistence of three elements of combustion that could cause fire or explosion: Measures to prevent formation of explosive atmosphere	Measures to prevent occurrence of ignition: Engineering control	Measures to prevent occurrence of ignition: Signage/warning and/or administrative control	Pattern (a) - (d)	[D] [E] Trigger events	[F] Unsafe conditions: Formation of explosive atmosphere	[F] Unsafe conditions: Occurrence of ignition source	[G] Accidents and disasters: Fire/explosion	[G] Accidents and disasters: Effects on others
9	**Prime using the spray gun.**	- Local exhaust system attached to spray booth - Lid of paint cup on spray gun - Disposal of waste liquid in (metal) waste liquid container with lid	(a) Use explosion-protected lighting (b) Use a conductive flooring (b) Ground metal products (b) Use antistatic hoses	(a) Prohibit bringing-in non-explosion-protected equipment (e.g., smartphones) (b) Ground metal products (b) Wear antistatic work clothes and antistatic shoes (g) Control the use and bringing-in of fire	(d)	- Leave the paint cup uncovered	If the added paint evaporates and exceeds the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating.	Sparks can occur due to the impact of dropping the spray gun. Bringing in non-explosion-protected lighting can cause electric sparks from the power source of the lighting. Laying a stain-proof vinyl sheet on the floor can cause workers to become charged, causing electrostatic sparks. Wearing non-antistatic work clothes or work shoes can cause workers to become charged, causing electrostatic sparks.	Fire or explosion caused by ignition of vapor in the spray booth	Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc.
						- Work in a place other than the spray booth	Working in an open area can cause an explosive atmosphere to be formed in the work area.	Sparks can occur due to the impact of dropping the spray gun. Bringing in non-explosion-protected lighting can cause electric sparks from the power source of the lighting. Laying a stain-proof vinyl sheet on the floor can cause workers to become charged, causing electrostatic sparks. Wearing non-antistatic work clothes or work shoes can cause workers to become charged, causing electrostatic sparks.	Same as above	Same as above
						- Prime only a part of the steel plate	N/A	(Omitted)	No effect	No effect
						- Too thick/too thin coating film	N/A	(Omitted)	No effect	No effect
						- Spill the lacquer primer surfacer	If the added paint evaporates and exceeds the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating.	Sparks can occur due to the impact of dropping the spray gun. Bringing in non-explosion-protected lighting can cause electric sparks from the power source of the lighting. Laying a stain-proof vinyl sheet on the floor can cause workers to become charged, causing electrostatic sparks. Wearing non-antistatic work clothes or work shoes can cause workers to become charged, causing electrostatic sparks.	Fire or explosion caused by ignition of vapor in the spray booth	Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc.
						- Drop the spray gun	If the added paint spilled from the paint cup evaporates and exceeds the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating.	Sparks can occur due to the impact of dropping the spray gun. Bringing in non-explosion-protected lighting can cause electric sparks from the power source of the lighting. Laying a stain-proof vinyl sheet on the floor can cause workers to become charged, causing electrostatic sparks. Wearing non-antistatic work clothes or work shoes can cause workers to become charged, causing electrostatic sparks.	Same as above	Same as above
						- Bring in non-explosion-protected lighting	If the paint cup is left uncovered, causing the added paint to evaporate and exceed the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating. Working in an open area other than the spray booth can cause an explosive atmosphere to be formed in the work area. If the lacquer primer surfacer is spilled and the added paint evaporates and exceeds the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating. If the spray gun is dropped and the added paint spilled from the paint cup evaporates and exceeds the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during	Electric sparks can be generated from the lighting power supply.	Fire or explosion caused by ignition of vapor in the spray booth	Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc.
						- Lay a stain-proof vinyl sheet on the floor	If the paint cup is left uncovered, causing the added paint to evaporate and exceed the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating. Working in an open area other than the spray booth can cause an explosive atmosphere to be formed in the work area. If the lacquer primer surfacer is spilled and the added paint evaporates and exceeds the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating. If the spray gun is dropped and the added paint spilled from the paint cup evaporates and exceeds the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during	Workers can become charged, causing electrostatic sparks.	Same as above	Same as above
						- Wear non-antistatic work clothes or work shoes	If the paint cup is left uncovered, causing the added paint to evaporate and exceed the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating. Working in an open area other than the spray booth can cause an explosive atmosphere to be formed in the work area. If the lacquer primer surfacer is spilled and the added paint evaporates and exceeds the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating. If the spray gun is dropped and the added paint spilled from the paint cup evaporates and exceeds the capacity of the local exhaust ventilation, an explosive atmosphere can be formed in the spray booth during coating.	Same as above	Same as above	Same as above

6. Diversion of Hazard Scenario Information Obtained by Simple Hazard Scenario Identification Method to JNIOSH Method

The information contained in the three types of sheets prepared by the simple hazard scenario identification method can help prepare the Risk Assessment Implementation Sheet to be used in the JNIOSH method. Table 13 shows the correspondence between the entries in the Risk Assessment Implementation Sheet to be used in the JNIOSH method and the hazard scenario information obtained by the simple hazard scenario identification method. In Step 2 (1) "Identification of trigger event and hazard scenario" of the JNIOSH method, entries shall be classified into "Trigger events (Initial events)," "Unsafe conditions (Intermediate events)," and "Process accidents/disasters (Consequential events)," which you can transcribe from [Column D] or [Column E], [Column F], and [Column G], respectively. In Step 2 (2), you can enter the measures to prevent the formation of an explosive atmosphere and those to prevent the occurrence of ignition sources that are confirmed in [Column C] in the "Confirmation of existing risk reduction measures" column. You can also enter the matters listed in [Column A] and [Column B] in the "Understanding hazards related to handled chemical substances and processes" column in Step 1, and in the "Results of understanding hazards related to handled chemical substances and processes" column in Step 2. Based on the above entries, you can perform the risk analysis and risk evaluation of the hazard scenario, and devise risk reduction measures and examine how to implement them. Tables 14 (a) and (b) show (a part of) the hazard scenario identification results diverted from Tables 10 through 12 to the Risk Assessment Implementation Sheet to be used in the JNIOSH method. The risk analysis and risk evaluation results of the hazard scenario and examination results of additional risk reduction measures are included[36].

Table 13 Correspondence between Entries in Risk Assessment Implementation Sheet Used in JNIOSH Method and Information Obtained by Simple Hazard Scenario Identification Method

(JNIOSH method) Entries in Risk Assessment Implementation Sheet		**(Simple hazard scenario identification method) Information obtained by preparing three types of sheets**
Step 1: Understanding hazards related to handled chemical substances and processes		
Response to questionnaires (Results of understanding hazards related to chemical substances handled and processes)		[Column B] Handled chemical substances and facilities, equipment, and others used for work/operation - Handled chemical substances - Information on hazards of chemical substances concerned - Handling conditions
Step 2: Implementation of risk assessment and risk reduction		
Purpose of objective work/operation & equipment and facilities		[Column A] Work/operation procedure/details (purpose of work/operation) [Column B] Facilities, equipment, and tools used for work/operation
(1) Hazard identification	Initiating hazard (Trigger event)	[Column D] Trigger events related to facilities, equipment, and tools [Column E] Trigger events related to work/operation
	Process malfunction (Unsafe Conditions)	[Column F] Unsafe conditions - Formation of explosive atmosphere - Occurrence of ignition source
	Process accidents (Fire/explosion, Other effects)	[Column G] Accidents and disasters - Fire/explosion - Other effects
(2) Existing risk reduction measures		[Column C] Confirmation of pattern of causing fire or explosion - Measures to prevent formation of explosive atmosphere - Measures to prevent occurrence of ignition sources

[36] Risk analysis and risk evaluation in Table 14
Part 1: Assuming that there are no existing (functioning) risk reduction measures, both Steps 2 and 9 are classified as pattern (a), which always has a risk of fire or explosion; therefore the hazard scenario occurrence frequency is evaluated as "Likely" (risk level III).
Part 2: Based on the implementation status of existing risk reduction measures, Step 2 is classified as pattern (b), and the hazard scenario occurrence frequency is evaluated as "Possible" (risk level III), whereas Step 9 is classified as pattern (d), and the hazard scenario occurrence frequency is evaluated as "Unlikely" (risk level II).
Part 3: Since the current risk level is III or II, considering the additional risk reduction measures, the hazard scenario occurrence frequency is evaluated as "Unlikely" (risk level II). Here, the risk level of Step 9 remains at II, which seems at a glance that the risk level does not change, but this is because it is evaluated by the criteria for risk analysis and risk level determination (risk matrix), and does not mean that the additionally proposed risk reduction measures are ineffective (the occurrence frequency is slightly lower, but is evaluated as "Unlikely" in light of the criteria). To reduce the risk level to I, it is necessary to reduce the severity by devising and taking inherent safety measures (elimination/substitution), but if this is not possible, you should always be aware of the possibility of fire or explosion as a residual risk, and record the importance of working while maintaining the measures to prevent the formation of an explosive atmosphere and those to prevent the occurrence of ignition sources.

Table 14 (a) Diversion to Risk Assessment Implementation Sheet Used in JNIOSH Method (Step 2)

Risk Assessment Implementation Sheet

Date of implementation	XX XX, XXXX
Implemented by (Prepared by)	XXXXX

Step 1: Understanding hazards related to handled chemical substances and processes

Response to questionnaires (Results of understanding hazards related to chemical substances handled and processes)	[Handled chemical substances] Lacquer thinner - Pour lacquer thinner into a plastic container, moisten a waste cloth with lacquer thinner from the container, and then use the cloth - Room temperature, 500 mL - Flammable liquids, Category 2 (Flash point: 3.1°C) (Explosion range: 1.2–36.5%) [Answers to Q1 through Q17] 1. Subject to risk assessment, 2. GHS, 3. Combustibility, inflammability	Items for which "Yes" is circled in the questionnaire

Step 2: Implementation of risk assessment and risk reduction

<table>
<tr><td colspan="2">Purpose of objective work/operation & equipment and facilities</td><td colspan="3">[Work/operation] Step 2: Dispose of used waste cloth in trash can
[Facilities, equipment, and tools] Plastic container, waste cloth, and trash can
[Purpose] To organize the work environment</td><td colspan="3"></td></tr>
<tr><td rowspan="3">(1) Hazard identification</td><td>Initiating hazard (Trigger event)</td><td colspan="3">[Trigger event] Explosion-protected lighting failure</td><td colspan="3"></td></tr>
<tr><td>Process malfunction (Unsafe Conditions)</td><td colspan="3">[Formation of explosive atmosphere] Working in an open area can cause an explosive atmosphere to be formed around thinner.
[Occurrence of ignition sources] Poor lighting insulation can cause electric sparks.</td><td colspan="3"></td></tr>
<tr><td>Process accidents (Fire/explosion, Other effects)</td><td colspan="3">[Fire/explosion] Fire caused by ignition of vapor around thinner
[Other effects] Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc.</td><td colspan="3"></td></tr>
<tr><td colspan="2">(2) Existing risk reduction measures</td><td colspan="3">Pattern (b)
(a) Use explosion-protected equipment (B-c)
(a) Prohibit bringing-in non-explosion-protected equipment (e.g. smartphones) (C-c)
(b) Use conductive flooring (B-c)
(b) Ground metal products (B-c) (C-c)
(b) Wear antistatic work clothes and antistatic shoes (C-c)
(g) Control the use and bringing-in of fire (C-c)</td><td colspan="3" rowspan="5">● Types of risk reduction measures conducted (implemented)
A) Inherent safety measure (elimination/ substitution)
B) Engineering controls
C) Administrative control, (Signage/warning)
D) Personal protective equipment

● Purposes of risk reduction measures
a) Contain and control
b) Detection means
c) Preventive safeguards
d) Mitigative safeguards</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 (Frequency)</td><td>Risk level</td></tr>
<tr><td>Major</td><td>Likely</td><td>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 (Frequency)</td><td>Risk level</td></tr>
<tr><td>Major</td><td>Possible</td><td>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/F</td><td>R</td></tr>
<tr><td colspan="3">a) Install gas concentration meter and local exhaust ventilation (B-a, b)</td><td>Major</td><td>Unlikely</td><td>II</td></tr>
<tr><td colspan="3">b)</td><td></td><td></td><td></td></tr>
<tr><td colspan="3">c)</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">(3) Availability of additional risk reduction measure</td><td colspan="6">a) Available</td></tr>
<tr><td colspan="2">(3) Message or instruction to field workers and plant operator</td><td colspan="6">a) Periodic operation check of gas concentration meter, operation check of local exhaust ventilation
(Others) Make sure to implement measures to prevent static electricity.</td></tr>
<tr><td colspan="2">(3) Residual risk</td><td colspan="6">Check for residual risk: Yes
How to deal with residual risk: An explosive atmosphere can always be present, so be careful of ventilation.</td></tr>
<tr><td colspan="2">Remark</td><td colspan="6"></td></tr>
</table>

Table 14 (b) Diversion to Risk Assessment Implementation Sheet Used in JNIOSH Method (Step 9)

Risk Assessment Implementation Sheet

Date of implementation	XX XX, XXXX
Implemented by (Prepared by)	XXXXX

Step 1: Understanding hazards related to handled chemical substances and processes

Response to questionnaires (Results of understanding hazards related to chemical substances handled and processes)	[Handled chemical substances] Lacquer primer surfacer - Pour lacquer primer surfacer into the cup on the spray gun, - Room temperature, 200 mL - Flammable liquids, Category 2 (Flash point: 0°C) (Explosion range: 1–15%) [Answers to Q1 through Q17] 1. Subject to risk assessment, 2. GHS, 3. Combustibility, inflammability, 13. High pressure	Items for which "Yes" is circled in the questionnaire

Step 2: Implementation of risk assessment and risk reduction

Purpose of objective work/operation & equipment and facilities		[Work/operation] Step 9: Prime using the spray gun. [Facilities, equipment, and tools] Spray coating equipment, workbench, plastic container, trash can, and (metal) waste liquid container with lid [Purpose] To improve adhesion of paint		
(1) Hazard identification	Initiating hazard (Trigger event)	[Trigger event] The Local exhaust ventilation, and then the explosion-protected lighting fail.		
	Process malfunction (Unsafe Conditions)	[Formation of explosive atmosphere] An explosive atmosphere can be formed in the spray booth during coating. [Occurrence of ignition sources] An explosion-protected lighting failure can result in electric sparks due to poor lighting insulation.		
	Process accidents (Fire/explosion, Other effects)	[Fire/explosion] Fire or explosion caused by ignition of vapor in the spray booth [Other effects] Burns caused by fire, spread of fire to surrounding combustibles, spread of fire to work clothes, etc.		
(2) Existing risk reduction measures		Pattern (d) - Local exhaust ventilation attached to the spray booth (B-a) - Lid of the paint cup on the spray gun (B-a) - Disposal of waste liquid in the (metal) waste liquid container with a lid (C-a) (a) Use explosion-protected lighting (B-c) (a) Prohibit bringing-in non-explosion-protected equipment (e.g. smartphones) (C-c) (b) Use conductive flooring (B-c) (b) Ground metal products (B-c) (C-c) (b) Use antistatic hoses (B-c) (b) Wear antistatic work clothes and antistatic shoes (C-c) (g) Control the use and bringing-in of fire (C-c)		● **Types of risk reduction measures conducted (implemented)** A) Inherent safety measure (elimination/ substitution) B) Engineering controls C) Administrative control, (Signage/warning) D) Personal protective equipment ● **Purposes of risk reduction measures** a) Contain and control b) Detection means c) Preventive safeguards d) Mitigative safeguards

	Severity	Probability (Frequency)	Risk level
(2) 1st step risk estimation and evaluation; Under assumption of no existing risk reduction measures	Major	Likely	III
(2) 2nd step risk estimation and evaluation; Confirmation of effectiveness of existing risk reduction measures	Major	Unlikely	II

		S	P/F	R
(3) 3rd step risk estimation and evaluation; Confirmation of effectiveness of additional risk reduction measures	a) Oblige to measure the front wind speed of the local exhaust ventilation before starting work and not to start work if there is no wind. (C-a)	Major	Unlikely	II
	b) Oblige to conduct inspection and maintenance of explosion-protected equipment about once every two years to maintain explosion-protected performance. (C-c)	Major	Unlikely	II

(3) Availability of additional risk reduction measure	a) b) Available
(3) Message or instruction to field workers and plant operator	a) Periodic operation check of gas concentration meter, operation check of local exhaust ventilation (Others) Make sure to implement measures to prevent static electricity
(3) Residual risk	Check for residual risk: Yes How to deal with residual risk: Give education once a year to notify that risk reduction measures are implemented as measures to prevent the formation of an explosive atmosphere and the occurrence of ignition sources, and subsequent fires and explosions. In addition, patrol the work site to check the implementation status and check the inspection records once a month.
Remark	