RANK-MATRIX Method for Safety Evaluation of Complex Systems

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Contents

Foreword

Safety is the most important consideration of all for human beings. The method of safety evaluation is still insufficient. Many kinds of effort to ensure the safety of manufacturing systems are required in the manufacturing industry. For this reason, an international standardization related to safety is presently being implemented.

Meanwhile, for complex system, appropriate method have not been published yet. We find out that this RANK-MATRIX method is applied for complex systems such as safety evaluation for traffic systems, medical management, security alart systems and etc.

Therefore, this RANK-MATRIX method is proposed as the Technology Trend Assessment (TTA) of the safety evaluation method for complex systems.

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Ackowlegement

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Chapter 1 Basic Concept of RANK-MATRIX Method

1. Introduction

According to our investigation of some 300 companies in Japan, it is important to evaluate the comprehensive safety of the system, as well as the individual safety of equipment, machine, etc., since most accidents in systems occurred when failure of the system and error by personnel occurred at the same time. We therefore developed the RANK-MATRIX method for the comprehensive safety evaluation of complex systems based on the current safety management technology of Japanese companies. From April 1994 through March 1997, this RANK-MATRIX method was improved and sufficiently adjusted through trial applications for actual systems in Japan for the purpose of applying it for international safety evaluation.

The RANK-MATRIX method can be applied to various complex systems like an integrated manufacturing system. The example that the RANK-MATRIX method was applied to an integrated manufacturing system is explained.

The RANK-MATRIX method aimes at safety management to evaluate the possibilities of injuries to personnel while working on or adjacent to complex systems, as well as the possibility of injury to other person(s).

The intention of application of RANK-MATRIX method is to provide a comprehensive safety evaluation for the design, construction (fabrication, assembly and installation), operation and maintenance of complex systems.

2. RANK-MATRIX Method for safety evaluation of complex systems

In order to facilitate a comprehensive safety evaluation of a system, evaluation items such as automation level, stress level, level of risk index, diagnosis level, interlock rate, fail-safe rate, backup level of power, warning level, etc., which are generally utilized in Japan, should be organized in a matrix table and evaluated in accordance with purpose and safety measures.

As a result of the 12-year period of our investigation of safety evaluation methods, it is recommended that the RANK-MATRIX method as shown in Table - 1 be used.

2.1 Safety Design and Measures

Safety design and measures are set for the 10 items defined in Table - 2. These are the most important items in evaluating the safety of a system. If any special safety-related item corresponding to the characteristic of the system needs to be considered, it will be added to the matrix table.

2.2 Evaluation Categories

The safety evaluation of integrated manufacturing systems is divided into four categories as follows, since evaluation purposes vary with safety design and measures to ensure the health, safety and environment against hazards for each category.

(S) Design stage:
This is to ensure reliability, operability and safety of the system/facility incorporated in the design and construction (fabrication and installation) stages.

(W)Normal operation (Working):
This is to ensure safety and health of personnel concerned in normal.

(M)Maintenance work:
This is to ensure safe maintenance work.

(O)Other (Third party):
This is to ensure the health, safety and environment (HES) of other persons such as visitors or those persons in the neighborhood around a factory /plant.

2.3 Safety Rank of Evaluation Items in the Rank -Matrix table

The safety of each item is classified in accordance with safety rank as expressed by the following six ranks, instead of by numerical values:
General standard level or general average level
0 : Safe level achievable with economical effort
+1 : Normally achievable safe level

The larger the negative value, the safer.
- 2 : Ideal level without any consequences potential factors
-1 : Ideal level with consequences potential factors below rank 2

The larger the positive value, the less safe.
+2:Insufficiently safe level which requires improvement
+3: Dangerous level which requires improvement

2.4 Ranks of Consequences Potential Factors

Consequences potential factors are classified into ranks corresponding to the extent of consequences potentials as shown in Table - 3. These are not problems in themselves and in fact are necessary to realize safety functions. If control is not exercised, these consequences higher potential factors can expose persons to considerable danger.

The basis of Table - 3 is as follows;

A person may perform dangerous acts alone, but without dangerous special tools. The danger posed may not be so great and this case is classified as rank 1.
Where no danger exists, the rank given is 0.

Since consequences potential factors of rank 2 cause problems in many complex systems, rank 2 is further broken down into three sub-levels.
A consequences potential factor of rank 4 refers to the potential to cause fatal injuries to numerous people and result in large-scale damage, such as in the case of an atomic bomb attack.

Although the term “rank” is used, it should be noted that this consequences potential factor rank is fundamentally different from the safety ranks of the matrix table.

Table 1 - RANK-MATRIX for Safety Evaluation of complex systems

Category Measures	Design stage **(S)**	Normal operation (Working) **(W)**	Maintenance work **(M)**	Other (Third party) **(O)**
(A)	**AS** Automation level	**AW** Amenity level	**AM** Maintenance frequency degree	**AO** Safe guarding rate
(B)	**BS** Stress level	**BW** Working safety management level	**BM** Maintenance educational level	**BO** Pollution control level
(C)	**CS** Level of risk index	**CW** Stopping rate	**CM** Risk index of maintenance	**CO** Protection level
(D)	**DS** Diagnosis level	**DW** Warning level	**DM** **[DW]**	**DO** **[DW]**
(E)	**ES** Interlock rate	**EW** Rate of interlock manual cancellation	**EM** Interlocking level for maintenance	**EO** **[ES]**
(F)	**FS** **[FW]**	**FW** Fail-safe protection rate	**FM** **[FW]**	**FO** **[FW]**
(G)	**GS** **[GW]**	**GW** Level of fault tolerance	**GM** Self-repairing level	**GO** **[GW]**
(H)	**HS** **[HW]**	**HW** Alarm and stop level	**HM** Modulability rate	**HO** **[HW]**
(I)	**IS** Backup level of power	**IW** Backup level of power	**IM** **[IW]**	**IO** **[IW]**
(J)	**JS** Disaster-proof level	**JW** Escape system level	**JM** **[JW]**	**JO** Disaster measures level

Items marked [XY] are interchangeable with the item of [XY],since these almost coincide with the purpose and content of [XY].

Table 2 - Safety Design and Measures for complex systems

	Safety design and measures	Purpose
Safety design	Working environment and space (Ergonomic considerations) (A)	Reduction of human intervention and to create comfortable and safe working environment and space with ergonomic considerations
	Safety management system (B)	Ensuring safety and health of personnel by management system
	Reliability design (C)	Adoption of highly reliable safety devices
	Monitoring/diagnosis (D)	Monitoring and diagnosing abnormalities during operation for early repair
Measures for consequences reduction	Interlock (E)	Reduction of hazards and interference between personnel and machines
	Fail-safe (F)	Reduction of occurrence of abnormalities and ensure safe stoppage
	Fault tolerance (G)	Reduction of dysfunction as a whole system with backup functional measures
Measures for emergency/ accident/ disaster	Emergency (H)	Limiting trouble caused by emergency
	Power failure (Accident) (I)	Limiting accidents resulting in injury or death by power failure
	Disaster (J)	Protection and measures against disaster limiting

Table 3 - Ranks of Consequences Potential Factor

Rank of consequences potential / Source		0	1	2			3	4
				2^{--}	2^{-}	2		
Thermal energy (degree C)		Lower than 40	40 to 60	60 to 80	80 to 100	100 to 200	200 to 700	Over 700
Weight		Lower than 20kg	20 to 50kg	50 to 70kg	70 to 300kg	300kg to 1 ton	1 to1000 ton	Over 1000 ton
Kinetic energy (velocity)		Under 4km/hr	4 to 5 km/hr	5 to 10 km/hr	10 to 40km/hr	40 to 80 km/hr	80 to 200 km/hr	Over 200km/hr
Sharp-shaped objects				Angular products		Edged tools		
Combustibles, explosives			3 lighters	18 liters of Kerosene	Gas station		Tanker	Oil field
Poison		Water	Alcohol	Ar	CO_2		Cyanogen	Poison gas
Ray / radiation			X-ray room		Acceler-ator		Nuclear reactor	Atomic bomb
Laser				Less than 80mW	Process machine			
Voltage		Lower than 40V	40 to 80V	80 to 250V	250 to 400V	400 to 1KV	1 to 10KV	Higher than 10KV
Reference	Extent of influence (area)	Unmanned	Work-station	Shop			Plant	Regional
	Extent of influence for human	No human	One human	A few			Several thousand	Several million
	Fuel stock	No stock	1 bottle of Gasoline 18 liters of Kerosene	Gas station			Tanker	Oil field
	Operator's level	Expert	Unskilled operator with manual	Unskilled operator without manual			Feeble-mindedness	Malicious crimes

[Note] Majority of complex systems are within rank 2 of consequences potential factors. Consequences potential factors of ranks 3 or 4 are included in large-scale process plants (e.g. chemical ,energy and steel plants, etc.)

References

(1) Y. Mineo, Y. Suzuki : Journal of IEICE J-77A (12), pp 1725~1732 " Application of Safety Index for FA System" (Dec. 1994)
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(2) Yoshihisa Suzuki : Proc. ICS' 89. S 89-5 " Tree Analysis for Safety" (Aug. 1989)

(3) Y. Suzuki, Y. Mineo, K. Iwatani, T. Niinomi, H. Sekiguchi :IC on PSA pp 774~779 "Safety Assessment by Matrix of Safety Rank" (Nov. 1995)
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Chapter 2 Application for Integrated Manufacturing Systems

Background of chapter 2

From April 1989 through March 1994, the Agency of Industrial Science and Technology of the Japanese MITI entrusted to the International Robotics and Factory Automation Center, or IROFA (New name: Manufacturing Science and Technology Center, or MSTC), the “research and investigation on standardization on the safety and reliability of integrated manufacturing systems”.

In November 1997, the committee of IROFA (new MSTC) created application requirements for the RANK-MATRIX method for safety evaluation of integrated manufacturing systems as a product of the research and investigation, since no adequate standard related to safety evaluation method was available in the world.

International standard ISO11161, “Industrial automation systems - Safety of integrated manufacturing systems - Basic requirements”, specifies the safety requirements for integrated manufacturing systems that incorporate two or more industrial machines interconnected with and operated by (a) control device(s) capable of being reprogrammed for the manufacturing of discrete parts or assemblies. However, it dose not cover the safety evaluation method of integrated manufacturing systems.

ANNEX B of these requirements is for information only.

The RANK-MATRIX method is aimed at safety management to evaluate the possibilities of injuries to personnel while working on or adjacent to an integrated manufacturing systems, as well as the possibility of injury to other person(s).

The safety evaluation varies in accordance with the types of workstations, machines, and control devices incorporated in the integrated manufacturing system and the application of such a system as to how it is designed, installed, operated, maintained and repaired.

The intention of these requirements is to provide a comprehensive safety evaluation by applying the RANK-MATRIX method for the design, construction (fabrication, assembly and installation), operation and maintenance of integrated manufacturing systems.

For specific requirements, or a safety related projects, these requirements should be used as a mandatory requirement or criteria, giving appropriate considerations to the relevant project or requirements under some form of contract. When invoked, the recommendation in these requirements by using the form “should” can change to a requirement expressed by the form ”shall”. Additionally, in such case, the concerned parties or persons should document modified portions by means of an arrangement in line with appropriate documentation procedures.

These requirements have been prepared in recognition of the particular consequences potential factors that exist in integrated manufacturing systems, being harmonized with ISO11161 and other relevant standards concerning safety. It describes consequences potential factors associated with these systems and evaluates the safety rank of these systems by applying the RANK-MATRIX method.

1 Scope

These requirements specify the general application of the RANK-MATRIX method for the safety evaluation of integrated manufacturing systems in order to ensure the health, safety and environment (HSE) for personnel and others, including third parties, visitors, etc.

2 Normative references

The following standards are the normative references of these requirements. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on these requirements are encouraged to investigate the possibility of applying the latest editions of the standards indicated below.

ISO 11161:1994 Industrial automation systems - Safety of integrated manufacturing systems - Basic requirements

ISO 6385:1981 Ergonomic principles in the design of work systems

ISO 102118:1981 Manipulating industrial robots - Safety

IEC 1508: (Draft) Industrial-process measurement and control - Functional safety

3 Definitions

For the purpose of these requirements, the following definitions apply.

3.1 Ergonomic consideration:

Adequate consideration to safety and comfort of working environment and space, such as lighting, noise/vibration, air conditioning (temperature, humidity), amenities, safeguarding, etc.

3.2 Consequences potential factors:

Factors of possible injury or damage to health, where no control is exercised.

3.3 Integrated manufacturing system:

Group of two or more industrial machines working together in a coordinated manner normally interconnected with and operated by a supervisory controller or controllers capable of being reprogrammed for the processing and inspection of discrete parts or assemblies, with the exception of the continuous process plant related to steel, chemicals, etc.

3.4 Interlock:

Function which prevents the operation of system elements under specified conditions, such as abnormality, danger, etc.

3.5 Person:

Any individual person who is not associated with the system.

3.6 Personnel:

Persons specifically employed and trained in the use and care of a machine or manufacturing system.

3.7 Safety rank:

Safety level of matrix item expressed with numerical value by the quantification method of the third type.

3.8 RANK-MATRIX method:

Safety evaluation method which expresses the safety rank by using a matrix of evaluation categories and design/measures.

3.9 Tree analysis for safety (TAS):

Analysis for safety which constitutes causes of failure, accidents in the tree structure and easily calculates the safety level by using a risk index.

3.10 Workstation:

Working unit with each local control device such that an integrated manufacturing system is divided into an appropriate size in order to facilitate safety evaluation.

4 Safety evaluation

4.1 General

The comprehensive safety evaluation of integrated manufacturing systems should require both the safety evaluation of a whole system and of individual workstations, machines and control devices.

The safety of a whole system should be evaluated by this RANK-MATRIX method, together with the safety management standard(s), including safety check lists, of the factory/plant concerning health, safety and environment (HSE) management systems, safety education for personnel and disaster countermeasure systems that take into consideration local conditions, purpose, performance and operation methods.

The safety of individual workstations, machines, control devices and safety equipment of a system should be evaluated by the relevant individual standards, together with these requirements in consideration of the purpose and operation methods. In cases where individual standards have not yet been established or where individual standards cannot be applied, an alternative appropriate evaluation method should be prepared based on these requirements.

4.2 Safety evaluation process

The safety evaluation of a whole system should proceed in accordance with Table 1 - Safety evaluation process of integrated manufacturing systems.

The evaluation of the safety design and measures should be executed taking the following into consideration:

[A] The safety design of a new or revamped integrated manufacturing system is evaluated as follows:

[1] safety design review in the design, fabrication and assembly/installation phase

[2] validation on the test operation phase based on the results of the safety design review

[B] Safety measures for a new or revamped integrated manufacturing system are evaluated for each workstation/facility/ machine and control device as follows:

[1] shop test/inspection phase before shipping or acceptance test at the place of receipt

[2] validation on the test operation phase

[C] General safety during normal operation (after new installation and test operation, maintenance or improvement of an integrated manufacturing system) is evaluated periodically based on purpose and the content of maintenance or improvement.

Table 1 - Safety evaluation process of integrated manufacturing systems

[1] Planning, design, fabrication and assembly/ installation phase	Planning phase	Preparing and applying own safety management standards concerning health, safety and environment (HSE), safety education and disaster countermeasure system for the evaluation of the safety strategy of the integrated manufacturing system
	Design phase	Preparing and applying design standards concerning the reliability and safety of components, inavoidable risks, workstations layout and safeguarding, etc., for the safety design review of the integrated manufacturing system
	Fabrication phase	Conducting separately or individually shop test/inspection by a supplier or acceptance test/inspection by a purchaser concerning function/performance tests of components of the integrated manufacturing system
	Assembly and installation phase	Conducting mechanical and electrical examinations of the whole integrated manufacturing system as "safety examination at the system completion "
[2] Test operation phase		Conducting validation tests under unloaded and loaded conditions of the integrated manufacturing system as the final safety examination prior to its use in normal operation
[3] Operation phase	Normal operation mode	Re-evaluating safety and to provide safety education for personnel through daily inspections and monitoring of the integrated manufacturing system operation
	Occurrence of abnormality or emergency mode	Recording troubles / accidents / disasters and to re-evaluate the safety through recovery/repair work of the system, determination of causes, relief work of victims and prevention of secondary disaster. Studying measures against re-occurrence of same troubles /accidents/disasters through fault-tree analysis (FTA)
	Maintenance mode	Evaluating safety through the maintenance work with shutdown of mechanical and electrical systems, removal of obstacle or dangerous materials, and safety measures for maintenance work

[Notes] 1) Safety measures, especially these related to the interactions between individual workstations or machines, should be coordinated during the fabrication phase of [1]. This applies also where a system consists of a combination of workstations and/or single units from different suppliers.

2) The validation tests include correction of any faults or failures found during the test operation of the systems.

5 RANK-MATRIX method for safety evaluation

5.1 General

The safety evaluation by the RANK-MATRIX method classifies each safety rank of the safety design and measures for each evaluation category in the matrix, shown in Table 2 - RANK-MATRIX for safety evaluation of integrated manufacturing systems, in order to facilitate relative comparisons for the safety of systems.

Table 2 - RANK-MATRIX for safety evaluation of integrated manufacturing systems

Evaluation category / Safety design and measures		Manufacturing system/facility (S)	Normal operation (Working) (W)	Maintenance work (M)	Other (Third party) (O)
Safety design	Working environment and space (Ergonomic considerations) (A)	AS Automation level	AW Amenity level	AM Maintenance frequency degree	AO Safe guarding rate
	Safety management (B)	BS Stress level	BW Working safety management level	BM Maintenance educational level	BO Pollution control level
	Reliability design (C)	CS Level of risk index	CW Stopping rate	CM Risk index of maintenance	CO Protection level
	Monitoring/diagnosis (D)	DS Diagnosis level	DWn Warning level	DM [DW]	DO [DW]
Measures for consequences reduction	Interlock (E)	ES Interlock rate	EW Rate of interlock manual cancellation	EM Interlocking level for maintenance	EO [ES]
	Fail-safe (F)	FS [FW]	FW Fail-safe protection rate	FM [FW]	FO [FW]
	Fault tolerance (G)	GS [GW]	GW Level of fault tolerance	GM Self-repairing level	GO [GW]
Measures for emergency /accident /disaster limiting	Emergency (H)	HS [HW]	HW Alarm and stop level	HM Modulability rate	HO [HW]
	Power failure (Accident) (I)	IS Backup level of power	IW Backup level for personnel	IM [IW]	IO [IW]
	Disaster (J)	JS Disaster-proof level	JW Escape system level	JM [JW]	JO Disaster measure level

[Note] Item marked [XY] are interchangeable with the item of [XY], since these almost coincide with the purpose and content of [XY].

5.2 Safety design and measures

Safety design and measures are specified in Table 3 - Safety design and measures for integrated manufacturing systems.

Table 3 - Safety design and measures for integrated manufacturing systems

Safety design and measures		Purpose
Safety design	Working environment and space (Ergonomic considerations) (A)	Reduction of human intervention and to create comfortable and safe working environment and space with ergonomic considerations
	Safety management system (B)	Ensuring safety and health of personnel by management system
	Reliability design (C)	Adoption of highly reliable safety devices
	Monitoring/diagnosis (D)	Monitoring and diagnosing abnormalities during operation for early repair
Measures for consequences reduction	Interlock (E)	Reduction of hazards and interference between personnel and machines
	Fail-safe (F)	Reduction of occurrence of abnormalities and ensure safe stoppage
	Fault tolerance (G)	Reduction of dysfunction as a whole system with backup functional measures
Measures for emergency /accident /disaster limiting	Emergency (H)	Limiting trouble caused by emergency
	Power failure (Accident) (I)	Limiting accidents resulting in injury or death by power failure
	Disaster (J)	Protection and measures against disaster

5.3 Evaluation categories

The safety evaluation of integrated manufacturing systems is divided into four categories as follows, since evaluation purposes vary with safety design and measures to ensure the health, safety and environment against hazards for each category.

[S] Manufacturing system/facility:
This is to ensure reliability, operability and safety of the system/facility incorporated in the design and construction (fabrication and installation) stages.

[W] Normal operation (Working):
This is to ensure safety and health of personnel concerned in normal operation as required to be implemented by the user (e.g. “kaizen”).

[M] Maintenance work:
This is to ensure safe maintenance work.

[O] Other (Third party):
This is to ensure the health, safety and environment (HSE) of other persons such as visitors or those persons in the neighborhood around a factory/plant.

5.4 Classification of safety rank

Each evaluation item in Table -2 is classified in accordance with the following six ranks:

- General standard level or general average level
  [0] : Safe level achievable with economical effort
  [+1] : Normally achievable safe level
- The larger the negative value, the safer
  [-2] : Ideal level without any consequences potential factors
  [-1] : Ideal level with consequences potential factors below rank 2
- The larger the positive value, the less safe
  [+2] : Insufficiently safe level that requires improvement
  [+3] : Dangerous level that requires improvement

The consequences potential factors used herein are specified in Table 4 - Ranks of consequences potential factors.

Table 4 - Ranks of consequences potential factor

Rank of consequences potential / Source of hazards		0	1	2			3	4
				2^{--}	2^{-}	2		
Thermal energy (temperature degrees C)		Lower than 40	40 to 60	60 to 80	80 to 100	100 to 200	200 to 700	Over 700
Weight		Lower than 20kg	20 to 50kg	50 to 70kg	70 to 300kg	300kg to 1 ton	1 to 1000 ton	Over 1000 ton
Kinetic energy (velocity)		Under 4km/hr	4 to 5 km/hr	5 to 10 km/hr	10 to 40km/hr	40 to 80 km/hr	80 to 200 km/hr	Over 200km/hr
Sharp-shaped objects				Angular products		Edged tools		
Combustibles, explosives			3 lighters	18 liters of Kerosene	Gas station		Tanker	Oil field
Poison		Water	Alcohol	Ar	CO_2		Cyanogen	Poison gas
Ray / radiation			X-ray room		Acceler-ator		Nuclear reactor	Atomic bomb
Laser				Less than 80mW	Process machine			
Voltage		Lower than 40V	40 to 80V	80 to 250V	250 to 400V	400 to 1KV	1 to 10KV	Higher than 10KV
Refere nce	Extent of influence (area)	Unmanned	Work-station	Shop			Plant	Regional
	Extent of influence for human	No human	One human	A few			Several thousand	Several million
	Fuel stock	No stock	1 bottle of Gasoline 18 liters of Kerosene	Gas station			Tanker	Oil field
	Operator's level	Expert	Unskilled operator with manual	Unskilled operator without manual			Feeble-mindedness	Malicious crimes

[Note Majority of complex systems are within rank 2 of consequences potential factors. Consequences potential factors of ranks 3 or 4 are included in large-scale process plants (e.g. chemical, energy and steel plants, etc.)

6 Evaluation procedure by RANK-MATRIX method

6.1 Evaluation for a manufacturing system/facility

6.1.1 Safety rank of AS

"AS" shows the safety rank of ergonomic considerations for a manufacturing system /facility itself, expressed by the automation level combined with the automation rate related to man-machine interface and the degree of consideration for safety.

AS: Automation level

-2 : Automation rate of 100%, or no consequences potential factor of rank 2 or higher
-1 : Automation rate of 90% or more, with adequate consideration for safety
0 : Automation rate of 80% or more, with adequate consideration for safety
+1 : Automation rate of less than 80%, with adequate consideration for safety
+2 : Automation rate of less than 80%, with some consideration for safety
+3 : Automation rate of less than 80%, with inadequate consideration for safety

$$\text{Automation rate} = \frac{\text{Number of automated workstations with consequences potential factor of rank 2 or higher}}{\text{Total number of workstations with consequences potential factor of rank 2 or higher}}$$

"Consideration for safety" means safety and protection devices for the consequences potential factors of rank 2 or higher and protecting personnel from the system.

6.1.2 Safety rank of BS

"BS" shows the safety rank of safety management for a manufacturing system/facility itself, expressed by the stress level combined with operability and comfort for personnel as shown in Table 5 - BS: Stress level.

BS: Stress level (Refer to Table 5)

Table 5 - BS: Stress level

Comfort for personnel \ Operability of system/facility		A	B	C	D
A	Feeling comfortable	- 2	- 1	0	+1
B	Not feeling odd or irritated	- 1	0	+1	+2
C	Feeling somewhat difficult, odd or irritated	0	+1	+2	+3
D	Feeling difficult, odd or irritated	+1	+2	+3	+3

- Operability of system/facility itself

  A : Satisfy all of the tests shown below

  B : Satisfy 5 or more of the tests shown below, including Irregular test I

  C : Satisfy 3 or more of the tests shown below

  D : Satisfy 2 or fewer of the tests shown below

- Operability tests requiring evaluation at the system level

  (1) Irregular test I : Examine safety under irregular operations

  (2) Irregular test II: Examine safety under supposed failure based on FTA evaluation and simulation

  (3) Noise immunity test: Examine safety under electromagnetic noise over the specified level

  (4) Noise electric intensity test: Examine electric wave noise within the specified values

  (5) Safety verification test for moving elements: Examine interlock functions before person touches a dangerous moving element

  (6) Power safety test: Examine insulation resistance, insulation resisting pressure and leakage currents within the specified values

  (7) Installation environment and power source test: Examine installation environment and power source conditions within the specified

6.1.3 Safety rank of CS (Risk based)

"CS" shows the safety rank of reliability design for a manufacturing system/facility, expressed by the level of risk index meaning a higher degree of safety by employing more reliable safety devices.

CS: Level of risk index

- 2 : Level of risk index as -2
- 1 : Level of risk index as -1
  0 : Level of risk index as 0
+1 : Level of risk index as +1
+2 : Level of risk index as +2
+3 : Level of risk index as +3

The level of risk index for the integrated manufacturing system is calculated as follows.

Step 1. The risk index of each workstation for every consequences potential factor is calculated by Fault Tree Analysis (FTA) for normal operations of ANNEX A, which links with a check list for every consequences potential factor of each workstation.

$$\text{Risk index} = \frac{\text{Absolute value of the index part of failure rate product (X)}}{\text{Degree of multiple installations of safety devices (M)}}$$

In case of logic symbol AND: $\frac{X}{M} = \frac{\sum Xi}{\sum Mi}$

In case of logic symbol OR: $\frac{X}{M} = \min.\left\{\frac{Xi}{Mi}\right.$

(Meaning of min.: choose i making the minimum Xi - 3 x Mi)

Step 2. Translate the risk index calculated in Step 1 into the level of risk index of each workstation for every consequences potential factor in accordance with Tables 6. (A), 6. (b) and 6. (c).

Step 3. Choose the maximum level of risk index of each workstation for every consequences potential factor in Step 2.

Step 4. Determine the maximum level of risk index among workstations in Step 3 as the level of risk index of the integrated manufacturing system concerned.

Table 6. (a) - Level of risk index (In case of consequences potential factor of rank 2)

Level of risk index	-2	-1	0	+1	+2	+3
Safety possibility index	20/0 or more	15/0 or more	10/0 or more	7/0 or more	4/0 or more	3/0 or less
	NPR[*1] 32/4 35/5	24/3 27/4 30/5	16/2 19/3 22/4	10/1 13/2 16/3 HEA[*2] FAS[*3]	4/0 7/1 10/2	3/0 6/1 9/2 Fuse

Here, NPR[*1] : Nuclear power reactor HEA[*2] : Household electric appliances FAS[*3] : Integrated manufacturing systems (Factory automation systems)

Table 6. (b) - Level of risk index (In case of consequences potential factor of rank 2 ⁻)

Level of risk index	-2	-1	0	+1	+2
Safety possibility index	15/0 or more	10/0 or more	7/0 or more	4/0 or more	3/0 or less

Table6. (c) - Level of risk index (In case of consequences potential factor of rank 2 ⁻⁻)

Level of risk index	-2	-1	0	+1
Safety possibility index	10/0 or more	7/0 or more	4/0 or more	3/0 or less

6.1.4 Safety rank of DS

"DS" shows the safety rank of monitoring and diagnosis for a manufacturing system/ facility, expressed by the diagnosis level based on the detection rate as follows. The high detection rate improves the system operation rate and reduces dangerous repair work, thereby serving to promote safety.

DS: Diagnosis level

- 2: Possible to predict failure with a detection rate of 100% and records of failure
- 1: Detection rate of 100% with indication of instructions for failure repair
0: Detection rate of 80% with indication of failure and contents
+1: Detection rate of 60% or more
+2: Detection rate of less than 60%
+3: No diagnosis device

$$\text{Detection rate} = \frac{\text{Number of workstations with diagnosis device}}{\text{Total number of workstations}}$$

6.1.5 Safety rank of ES

"ES" shows the safety rank of interlocking system for a manufacturing system/facility, expressed by the interlock rate as follows. The interlocking system is designed to reduce consequences potential factors and to prevent mutual interference between personnel and machines.

ES: Interlock rate

- 2 : Interlock rate of 100%
- 1 : Interlock rate of 80% or more
0 : Interlock rate of 60% or more
+1 : Interlock rate of 40% or more
+2 : Interlock rate of less than 40%

$$\text{Interlock rate} = \frac{\text{Number of interlocking workstations with consequences potential factor rank 1 or higher}}{\text{Total number of workstations with consequences potential factor rank 1 or higher}}$$

[Notes] 1) The interlock rate is the degree of maintaining the current condition or safe operation so as to prevent accidents at time of incorrect operation and failure.

2) In cases where a workstation has many consequences potential factors, an interlocking system shall be installed.

6.1.6 Safety rank of FS

"FS" representing the safety rank of fail-safe function for a manufacturing system/facility may be replaced by the fail-safe protection rate of "FW" of normal operation.

6.1.7 Safety rank of GS

"GS" representing the safety rank of the fault tolerance for a manufacturing system/facility may be replaced by the level of fault tolerance of "GW" of normal operation.

6.1.8 Safety rank of HS

"HS" representing the safety rank of measures in case of emergency for a manufacturing system/ facility may be replaced by the alarm and stop level of "HW" of normal operation.

6.1.9 Safety rank of IS

"IS" shows the safety rank of power supply for a manufacturing system/facility itself, expressed by the backup level of power as follows, since power supply is required to prevent power failure from threatening the safety of the system itself.

IS: Backup level of power

-2 : No usage of electric power supply from outside of the system, except for the control system and safety functions
-1 : Full electric power supply backed-up by an emergency power source in order to maintain system operation without failure
0 : System designed for prevention of troubles such as damage to machines, leading to injury or death by power failure
+1 : Electric power for safety functions backup by other independent electric power source, etc. (No failure of control device-related safety functions)
+2 : Safety functions for a short period of time or during partial power failure
+3 : No consideration made for power failure

6.1.10 Safety rank of JS

"JS" shows the safety rank of disaster-proof for a manufacturing system/facility, expressed by the disaster-proof level as follows.

JS: Disaster-proof level

-2 : Not damaged by earthquake (7 or less on the Japanese scale of 7), fires (all surrounding directions), storms and floods (typhoons)
-1 : Not damaged by earthquakes (5 or less on the Japanese scale of 7) and fires (one direction)
0 : Temporary shutdown and possible early recovery
+1 : Automatic shutdown at time of disaster
+2 : No secondary disaster (radioactivity, poison gas, explosion, etc.)
+3 : Only conventional measures in event of emergency without special measures

6.2 Evaluation for normal operation (Working)

6.2.1 Safety rank of AW

“AW” shows the safety rank of the working environment and space for normal operation, expressed by the amenity level, since a comfortable working environment and space will reduce the incidence of incorrect work by personnel.

AW: Amenity level

-2 : Comfortable working environment and space for all manned workstations during full working time
-1 : Comfortable working environment and space for 80 percent of manned workstations during full working time
0 : Comfortable working environment and space for 50 percent of manned workstations during full working time
+1 : Somewhat inadequate working environment and space for manned workstations, but with consideration given to sufficient time for rest and some improvement in comfort
+2 : Inadequate working environment and space for manned workstations, as well as the requirement for improvement in working space
+3 : Insufficient working environment and space for health and safety of personnel

- Regarding the evaluation of "comfortable environment," the following conditions are considered level "-2."

  (1) Lighting: luminous intensity of 300 lux or more (600 lux or more for precision work)

  (2) Noise: 80 dB (A) or less

  (3) Temperature: 17-28 degrees Celsius

  (4) Humidity: 40-70%

  (5) Odor and dust: not causing discomfort

- For "comfortable working space", comprehensive evaluation is made of the layout of a manufacturing system/facility, including the following items, and with color tones creating a sense of security and spaciousness.

  (1) Prevention of stumbling and slipping over wiring and plumbing

  (2) Elimination of obstacles in passages

  (3) Emergency exits

  (4) Temporary storage places for intermediate inventory, and storage places for tools

6.2.2 Safety rank of BW

"BW" is the safety rank of safety management for normal operation, expressed by the working safety management level combined with the educational level of personnel and the degree of the working safety management system, since it is essential for personnel to be able to conduct normal operations with ease and comfort in order to ensure safety.

BW: Working safety management level

- 2 : Educational level as A and working safety management system as U
- 1 : Educational level as A and working safety management system as V
0 : Educational level as more than B and working safety management system as W
+1 : Educational level as more than C and working safety management system as X
+2 : Educational level as more than D and working safety management system as Y
+3 : Educational level as more than D and working safety management system as Z

- The educational level of personnel for normal operations is classified into the following four levels:

  A: Sufficient for normal operations by qualified personnel

  B: Adequate education and training level for normal operations

  C: Only basic education and training level for normal operations

  D: No basic education and training level for normal operations

- The working safety management system is evaluated for the management organization and normal operation manuals, data, etc., in accordance with its own safety management standards specified by a factory or a plant, as follows.

  U: All staff concerned participate in working safety management organization, and manuals and data necessary for judgment are established.

  V: Working safety management organization, and manuals and data necessary for judgment are established, but safety management activities are conducted mainly by staff responsible for safety management.

  W: Working safety management organization is established, but manuals and data necessary for judgment are insufficient, and safety management activities are left only to staff responsible for safety management.

  X: Only staff responsible for working safety management is assigned and manuals and data required for judgment are insufficient.

  Y: Only staff responsible for working safety management without means to collect data necessary for judgment is established.

  Z: No safety management system (no safety management activities)

6.2.3 Safety rank of CW

"CW" shows the safety rank of reliability design for normal operation, expressed by the stopping rate as follows, since frequent stops in a system increase the number of personnel errors as a result of the intervention of personnel for operation, checking and repair.

CW: Stoppping rate

- 2 : Stopping rate of once in 10 years (almost non-stop)
- 1 : Stopping rate of once a year (requiring periodical inspection once a year)
0 : Sopping rate of once a month (once a month stoppage considered allowable)
+1 : Stopping rate of once a day (once a day stoppage considered as allowable limit)

+2 : Stopping rate of once an hour (difficult situation)
+3 : Stopping rate of once in 10 minutes (operation should be prohibited.)

6.2.4 Safety rank of DW

"DW" shows the level of completeness of monitoring and diagnosis for normal operation, expressed by the warning level as follows, since detection and warning of abnormal conditions contributes to the prevention of troubles, accidents, etc.

DW: Warning level

- 2 : Detection rate of abnormal situation as 100 percent
- 1 : Detection rate of abnormal situation as 80 percent or more
0 : Detection rate of abnormal situation as 60 percent or more
+1 : Detection rate of abnormal situation as 40 percent or more
+2 : Detection rate of abnormal situation as 20 percent or more
+3 : Detection rate of abnormal situation as less than 20 percent

$$\text{Detection rate of abnormal situation} = \frac{\text{Number of workstations so designed as to detect and warn of abnormal situation}}{\text{Total number of workstations}}$$

6.2.5 Safety rank of EW

"EW" shows the safety rank of interlock for normal operation, expressed by the rate of interlock manual cancellation, since a manual cancellation of interlocking functions is required to solve troubles and recover system operation.

EW: Rate of interlock manual cancellation

- 2 : Rate of interlock manual cancellation as 0%
- 1 : Rate of interlock manual cancellation as less than 20%
0 : Rate of interlock manual cancellation as less than 30%
+1 : Rate of interlock manual cancellation as less than 50%
+2 : Rate of interlock manual cancellation as less than 80%
+3 : Rate of interlock manual cancellation as 80% or more

[Note] The rate of interlock manual cancellation is the percentage of workstations with interlock functions, which can be canceled manually. In cases where a workstation has several interlocks, if personnel can cancel one interlock manually, the workstation is considered subject to interlock manual cancellation.

$$\text{Rate of interlock manual cancellation} = \frac{\text{Number of workstations with interlock manual cancellation function}}{\text{Number of workstations with interlocking function}}$$

6.2.6 Safety rank of FW

"FW" shows the safety rank of fail-safe protection for normal operation, expressed by the fail-safe protection rate as follows, since this reduces hazards by abnormal situation or accidents in a workstation and safely stops the system operation.

FW: Fail-safe protection rate

- 2 : Fail-safe protection rate as 100%
- 1 : Fail-safe protection rate as 80% or more
0 : Fail-safe protection rate as 60% or more
+1 : Fail-safe protection rate as 40% or more

+3 : Fail-safe protection rate as less than 40%

$$\text{Fail-safe protection rate} = \frac{\text{Number of workstations with fail-safe protection}}{\text{Number of workstations with consequences potential factor rank 2 or higher}}$$

[Note] Merely calling the attention of personnel through a warning or a display panel is not recognized as fail-safe protection for a system.

6.2.7 Safety rank of GW

"GW" shows the safety rank of fault tolerance for normal operation, expressed by the level of fault tolerance that is a combination of the buffer level and the rate of multiple function with backup, since sufficient buffer (stock) functions and multiple functions contribute to ensuring the safety of personnel and prevent a whole system stoppage by failure of a workstation.

GW: Level of fault tolerance

-2 : Buffer level of A in 30% or more of workstations, or the rate of multiple function with backup of 80% or more
-1 : Buffer level of B in 30% or more of workstations, or the rate of multiple function with backup of 50% or more
0 : Buffer level of C in 30% or more of workstations, or the rate of multiple function with backup of 30% or more
+1: Buffer level of D in 30% or more of workstations, or the rate of multiple function with backup of 10% or more
+2: Buffer level of E in 30% or more of workstations, or the rate of multiple function with backup of less than 10%
+3: Buffer level of E in 70% or more of workstations, and no multiple function with backup

[Note] Buffer level means allowance of time or quantity to stock products (goods in process) to be delivered to a following workstation:

A: one month or more

B: one day or more

C: one hour or more

D: one minute or more

E: less than one minute or automatic delivery to a following station

$$\text{Rate of multiple function with backup} = \frac{\text{Number of workstations with multiple function backup}}{\text{Number of workstations with consequences potential factor rank 2 or higher}}$$

6.2.8 Safety rank of HW

"HW" shows the safety rank of emergency measures for normal operation, expressed by the alarm and stop level, since all workstations or a system can stop immediately and safely when an emergency is notified through an alarm.

HW: Alarm and stop level

- 2 : Notify an emergency through an alarm and stop all workstations or a system immediately and safely

- 1 : Notify an emergency through an alarm and stop a workstation concerned, and other workstations are stopped after completion of work
0 : Notify an emergency through an alarm and stop system after completion of sequential operations
+1 : Notify an emergency through an alarm and system is stopped manually
+2 : Emergency stop function (manual) is available, but no device to notify an emergency is available.
+3 : No device to notify an emergency and no emergency stop functions are available.

6.2.9 Safety rank of IW

"IW" shows the safety rank of power failure measures for normal operation, expressed by the backup level for personnel, since this is necessary to ensure the safety of personnel during a power failure.

IW: Backup level for personnel

-2 : No usage of electric power supply from outside of the system, except for the control system and safety functions
-1 : Full electric power supply backup with an emergency power source are available in order to maintain system operation without failure
0 : Backup power sources for a certain period to maintain safe operation are available.
+1 : Backup power sources for control devices are available in order to confirm the system safety and re-running of a system.
+2 : Working records remain and the system can easily be put into operation again after electricity is recovered.
+3 : No consideration for power failure

6.2.10 Safety rank of JW

"JW" shows the safety rank of measures in the event of disaster in normal operation, expressed by the escape system level, since escape systems are required to ensure that personnel can escape safely.

JW: Escape system level

- 2 : Escape system level as -2
- 1 : Escape system level as -1
0 : Escape system level as 0
+1 : Escape system level as +1
+2 : Escape system level as +2
+3 : Escape system level as +3

[Notes] 1) Grade is raised by one level if training for emergency escape is carried out passages.frequently.

2) Special equipment is provided when access of personnel is restricted;
for example, a clean room, a shield room for radioactivity and working space exclusively used for automatic machines.

3) Escape equipment is provided where it helps personnel to more easily escape; for example, emergency exits and emergency lights, in addition to escape

Table 7 - Escape system level

	No special equipment	Special equipment available
Escape equipment fully installed	- 2	0
Escape by worker alone possible	- 1	+1
Notification possible	0	+2
Two (2) escape passages	+ 1	+3
One (1) escape passage	+ 2	+3

6.3 Evaluation for maintenance work

6.3.1 Safety rank of AM

"AM" shows the safety rank of working environment and space for maintenance work, expressed by the maintenance frequency degree as follows, since the shorter working time for repair and preventive maintenance and the longer interval between repair/maintenance works reduce opportunities for personnel to come into contact with machines /system.

AM: Maintenance frequency degree

- 2 : Repair /preventive maintenance not required
- 1 : Repair /preventive maintenance occupying one hour or less once in 5 years
0 : Repair / preventive maintenance occupying one hour or less once a year
+1 : Repair / preventive maintenance occupying one day or less once in 6 months
+2 : Repair / preventive maintenance occupying one day or less once a month
+3 : Repair / preventive maintenance occupying more than one day once a month

6.3.2 Safety rank of BM

"BM" shows the safety rank of safety management for maintenance work, expressed by the maintenance educational level combined with the educational level and the availability of manuals, since education (including training) and manuals contribute to reducing incorrect maintenance.

BM: Maintenance educational level

- 2 : Educational level as A, and the availability of manuals as W
- 1 : Educational level as A, and the availability of manuals as X
0 : Educational level as B, and the availability of manuals as X
+1 : Educational level as C, and the availability of manuals as Y
+2 : Educational level as C, and the availability of manuals as Z
+3 : Educational level as D, and the availability of manuals as Z

- Educational level

  A : Education requiring acquisition of qualifications by authority

  B : Education and training for safe maintenance work by internal authority without qualifications

  C : Education and training for safe maintenance work with manual alone

  D : No special education or training, with only on-the-job training

- Availability of manuals

W : Maintenance work is instructed directly by a system without the use of manuals

X : Availability of manuals enabling personnel to become familiar with maintenance work within one week

Y : Availability of manuals enabling personnel to become familiar with maintenance work in more than a week

Z : Manuals for maintenance work are not prepared.

[Note] Manuals must be supplemented with warnings and alarms.

6.3.3 Safety rank of CM

"CM" shows the safety rank of reliability design for maintenance work, expressed by the risk index in maintenance as follows, since high reliability of safety devices for maintenance work contributes to ensuring safety of personnel.

CM: Risk index of maintenance

- 2 : Level of risk index of maintenance as -2
- 1 : Level of risk index of maintenance as -
0 : Level of risk index of maintenance as 0
+1 : Level of risk index of maintenance as +1
+2 : Level of risk index of maintenance as +2
+3 : Level of risk index of maintenance as +3

$$\text{Risk index of maintenance} = \frac{\text{Absolute value of index part of failure rate product}}{\text{Degree of multiple safety functions/devices for maintenance}}$$

[Note] For the calculation of risk index of maintenance, the fault tree for maintenance, instead of the fault tree for normal operation, is used in Step 1 of the calculation of the risk index of manufacturing system/facility [CS]. The procedures applicable for other steps are the same.

6.3.4 Safety rank of DM

"DM" representing the safety rank of monitoring and diagnosis for maintenance work may be replaced by the warning level "DW" of normal operation.

6.3.5 Safety rank of EM

"EM" shows the safety rank of interlocking for maintenance work, expressed by the interlocking level of maintenance as follows, since it is important in terms of safety to interlock all the devices with a consequences potential factor rank 1 or higher.

EM: Interlocking level of maintenance

- 2 : Interlocking device cuts-off power to all machines with consequences potential factor rank 1 or higher, except for safety devices.
- 1 : Interlocking device cuts-off power to all machines and safety devices with consequences potential factor rank 1 or higher.
0 : Interlocking device cuts-off power to machines with consequences potential factor rank 1 or higher requiring maintenance, with exception of safety devices.
+1 : Interlocking device cuts-off power to all machines and safety devices with consequences potential factor rank 1 or higher requiring maintenance.

+2 : Interlocking device does not cut-off power, but an instant leakage current interception device for weak current is installed.
+3 : No interlocking device for maintenance work

6.3.6 Safety rank of FM

"FM" representing the safety rank of fail-safe for maintenance work may be replaced by the fail-safe protection rate "FW" of normal operation.

6.3.7 Safety rank of GM

"GM" shows the safety level of fault tolerance for maintenance work, expressed by the self-repairing level as follows, since self-repairing functions reduce intervention of personnel.

GM: Self-repairing level

- 2 : Self-repairing function without any intervention of personnel
- 1 : Failed parts are replaced by remote instruction of personnel with confirmation of safe normal operation.
0 : Failed parts are replaced by remote instruction of personnel with temporary stoppage
+1 : Failure/trouble of workstations is displayed automatically, and all repairs are performed manually within one hour.
+2 : Failure/trouble of workstations is displayed automatically, and all repairs are performed manually in over one hour.
+3 : Failure/trouble of workstations is identified by personnel, and all repairs are performed manually.

6.3.8 Safety rank of HM

"HM" shows the safety rank of emergency measures for maintenance work, expressed by the Modulability rate as follows, since modularization of devices and parts enables easy repair and change in the event of emergency.

HM: Modulability rate

- 2 : Modulability rate as 90% or more
- 1 : Modulability rate as 70% or more
0 : Modulability rate as 50% or more
+1 : Modulability rate as 30% or more
+2 : Modulability rate as 10% or more
+3 : Modulability rate as less than 10%

$$\text{Modulability rate} = \frac{\text{Number of replaceable devices/parts as a unit of a workstation/system}}{\text{Total number of devices/parts of a workstation/system}}$$

6.3.9 Safety rank of IM

"IM" representing the safety rank of power failure measures for maintenance may be replaced by the backup level "IW" of normal operation.

6.3.10 Safety rank of JM

"JM" representing the safety rank of appropriateness of measures against disasters for maintenance may be replaced by the escape system level "JW" of normal operation.

6.4 Evaluation for other (Third party)

6.4.1 Safety rank of AO

"AO" shows the safety rank of the working environment and space for others, expressed by the safeguarding rate as follows, since it is safer to guard the workstation from other persons (third parties).

AO: Safe guarding rate

- 2 : Safe guarding rate as 100%
- 1 : Safe guarding rate as 90% or more
0 : Safe guarding rate as 80% or more
+1 : Safe guarding rate as 70% or more
+2 : Safe guarding rate as 60% or more
+3 : Safeguarding rate as less than 60%

$$\text{Safe guarding rate} = \frac{\text{Number of workstations with consequences potential factor rank 2 or higher with guarding to prevent visitors/other person from entrance into a system or touching products}}{\text{Total number of workstations with consequences potential factor rank 2 or higher}}$$

6.4.2 Safety rank of BO

"BO" shows the safety rank of safety management for others, expressed by the pollution control level as the environmental management to prevent pollution around the factory /plant.

Pollution items to be controlled are noise and vibration, electromagnetic waves and radioactive materials, air pollution (offensive odor, poison gas, acid rain, etc.) and water (acid, oily-wastage, hot water, etc.)

BO: Pollution control level

- 2 : No pollution around factory/plant and no dangerous equipment, such as high frequency machine, gas treatment or chemical equipment, is installed in an integrated manufacturing system.
- 1 : Completely controlled pollution around factory/plant (no pollution)
0 : Control pollution within comfortable living level around factory /plant, and noise from high frequency equipment is insulated.
+1 : Control pollution within allowable level for ordinary living around a factory /plant, and noise from high frequency equipment is insulated.
+2 : Control pollution within the environment local assessment with third party around the factory /plant.
+3 : No control for pollution

[Note] It is necessary to consider regulations separately, regarding workplace, for potential problems from chemicals and vibrations.

6.4.3 Safety rank of CO

“CO” shows the safety rank of reliability design for others, expressed by the protection level such that malfunctions of an integrated manufacturing system are confirmed not to harm other persons (i.e. third party, visitors, etc.).

CO: Protection level

-2 : No workstations subject to protection/safeguarding
-1 : Separated from person by thick concrete wall
0 : Separated from person by steel or stainless steel
+1 : Separated from person by wood or glass
+2 : Only passage for person displayed
+3 : Free access of person to stations concerned

[Note] A workstation with a consequences potential factor rank 2 or higher is subject to protection.

6.4.4 Safety rank of DO

“DO” representing the safety level of supervision and diagnosis for others may be replaced by the warning level “DW” of normal operation.

6.4.5 Safety rank of EO

“EO” representing the safety rank of interlocking for others may be replaced by the interlock rate “ES” of the manufacturing system.

6.4.6 Safety rank of FO

“FO” representing the safety rank of fail-safe for others may be replaced by the fail-safe protection rate “FW” of normal operation.

6.4.7 Safety rank of GO

“GO” representing the safety rank of fault tolerance for others may be replaced by the buffer level “GW” of normal operation.

6.4.8 Safety rank of HO

“HO” representing the safety rank of emergency measures for others may be replaced by the alarm level “HW” of normal operation.

6.4.9 Safety rank of IO

“IO” representing the safety rank of power failure measures for others may be replaced by the backup level “IW” of normal operation.

6.4.10 Safety rank of JO

“JO” shows the safety rank of measures against disaster for others, expressed by the disaster measure level to prevent pollution of consequences potential factors of rank 2 or higher.

JO: Disaster measure level

- 2 : No consequences potential factor of rank 2 or higher

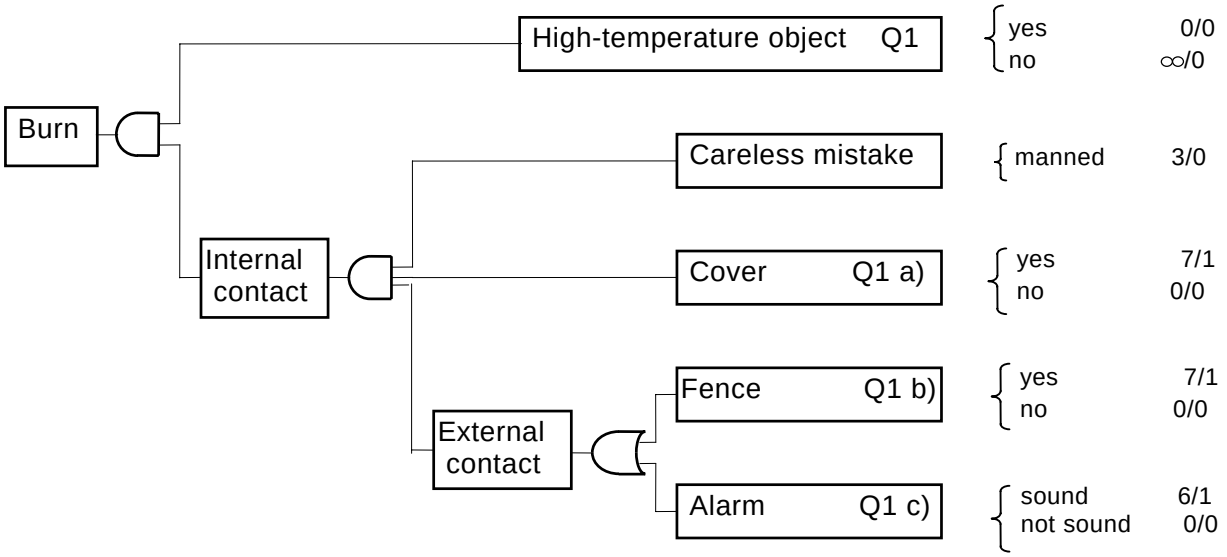
- 1 : Pollution of consequences potential factors of rank 2 or higher are measured completely against huge disaster
0 : Pollution of consequences potential factors of rank 2 or higher is measured completely against disaster
+1 : Pollution of consequences potential factors of rank 2 is measured against disaster within the legal permissible limit
+2 : Pollution of consequences potential factors of rank 2 are for the most part measured against disaster within the legal permissible limit
+3 : Consequences potential factors are not measured against disaster

ANNEX A

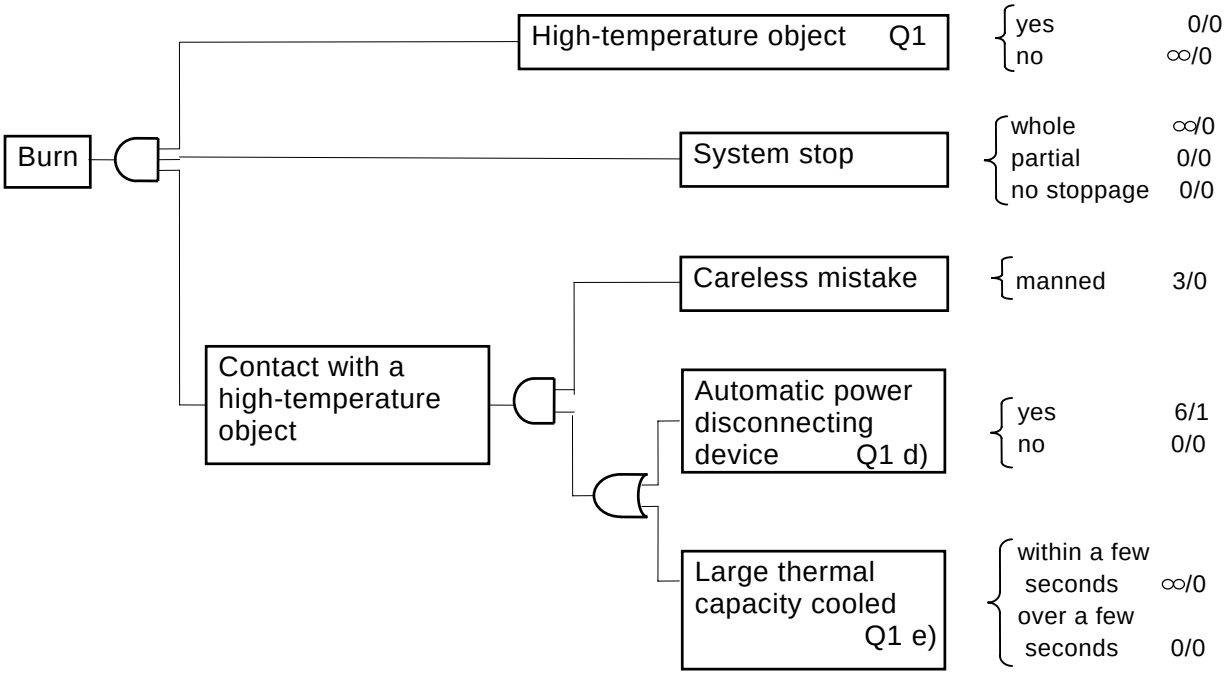
FTA for calculation of risk index and check list

List of figures

a) Operation



b) Maintenance

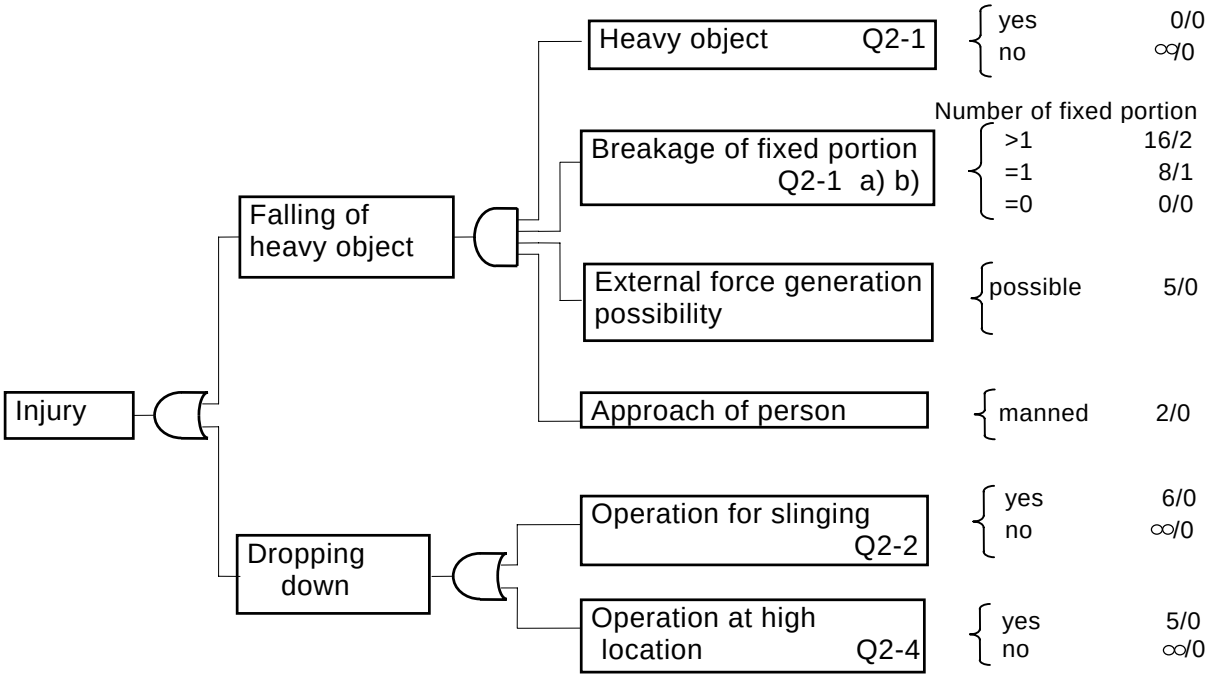


c) Check list for high-temperature object

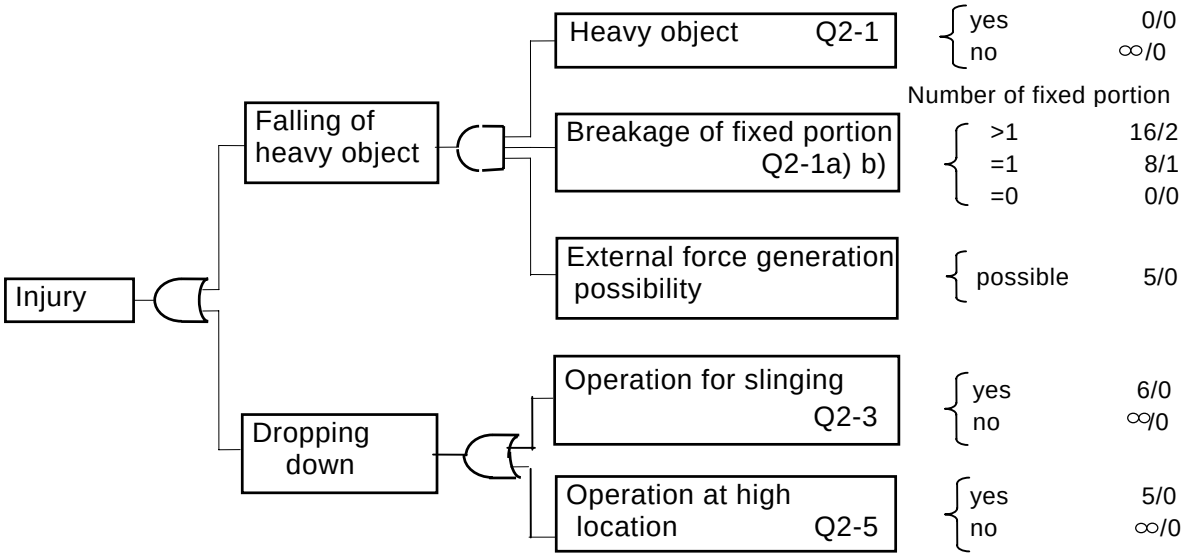
Q1: Does a high-temperature object (60 degrees C or more) exist in the system?	
If yes to Q1	a) Is there a cover on the high-temperature object ?
	b) Is there a fence protecting against a high-temperature object ?
	c) Does an alarm sound on approach to a high-temperature object ?
	d) Is there an automatic power disconnecting device ?
	e) Is a high-temperature object cooled down to 60 degrees C or less within a few seconds after cutting off power ?

Fig.1 FTA for high-temperature object and Check list

a) Operation



b) Maintenance

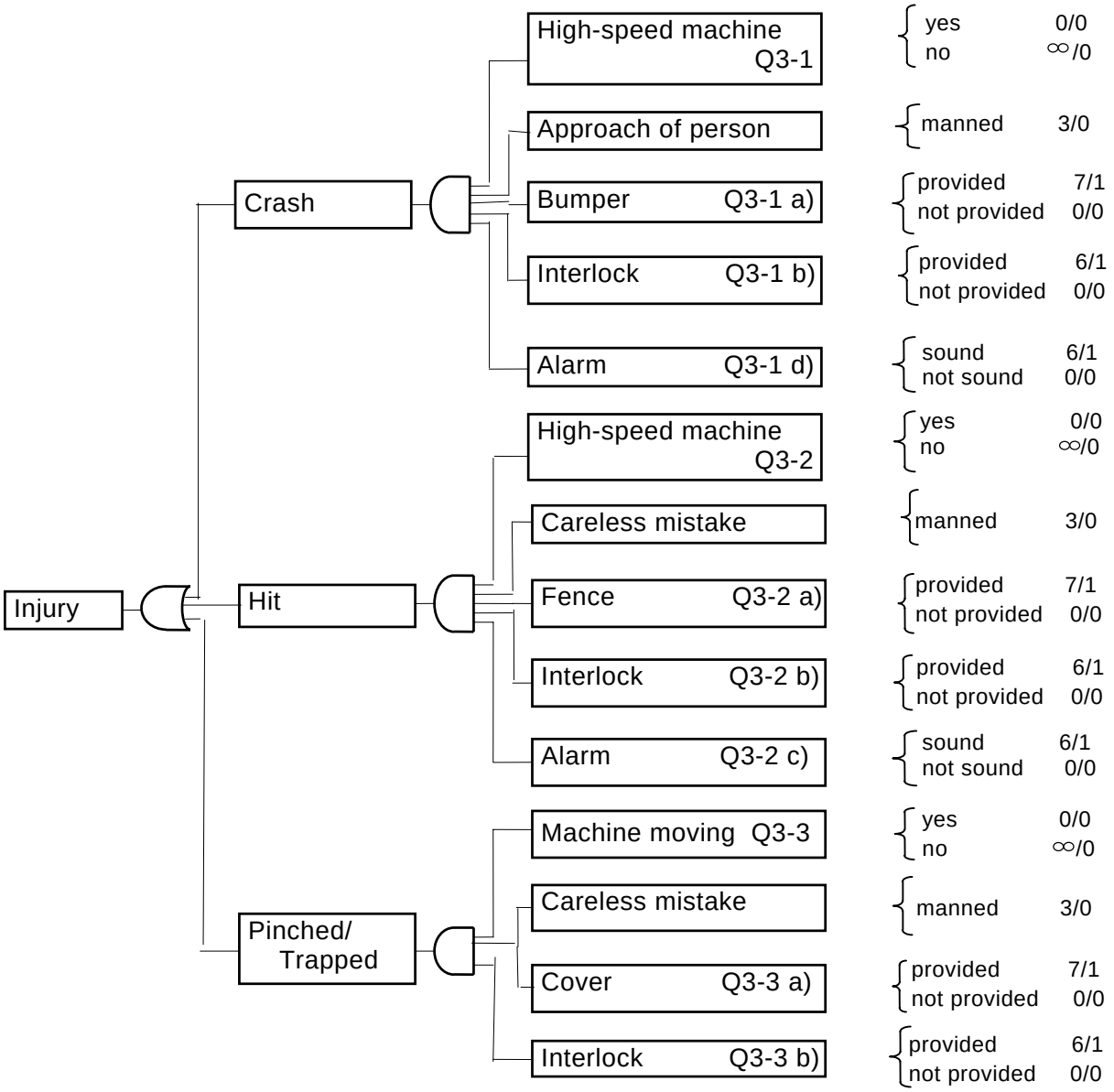


c) Check list for heavy object

Q2-1): Does a heavy object (50kg or more), which could become detached, exist in the system ?	
If yes to Q2-1	a) Is the heavy object fixed with bolts or others to endure a seismic intensity of 5 ?
	b) How many fixing points does it have ?
Q2-2) : Is slinging work required ?	
Q2-3): Is slinging work required also during maintenance ?	
Q2-4): Is there work at a high location?	
Q2-5): Is there a work at a high location also during maintenance ?	

Fig. 2 FTA for heavy object and Check list

a) Operation

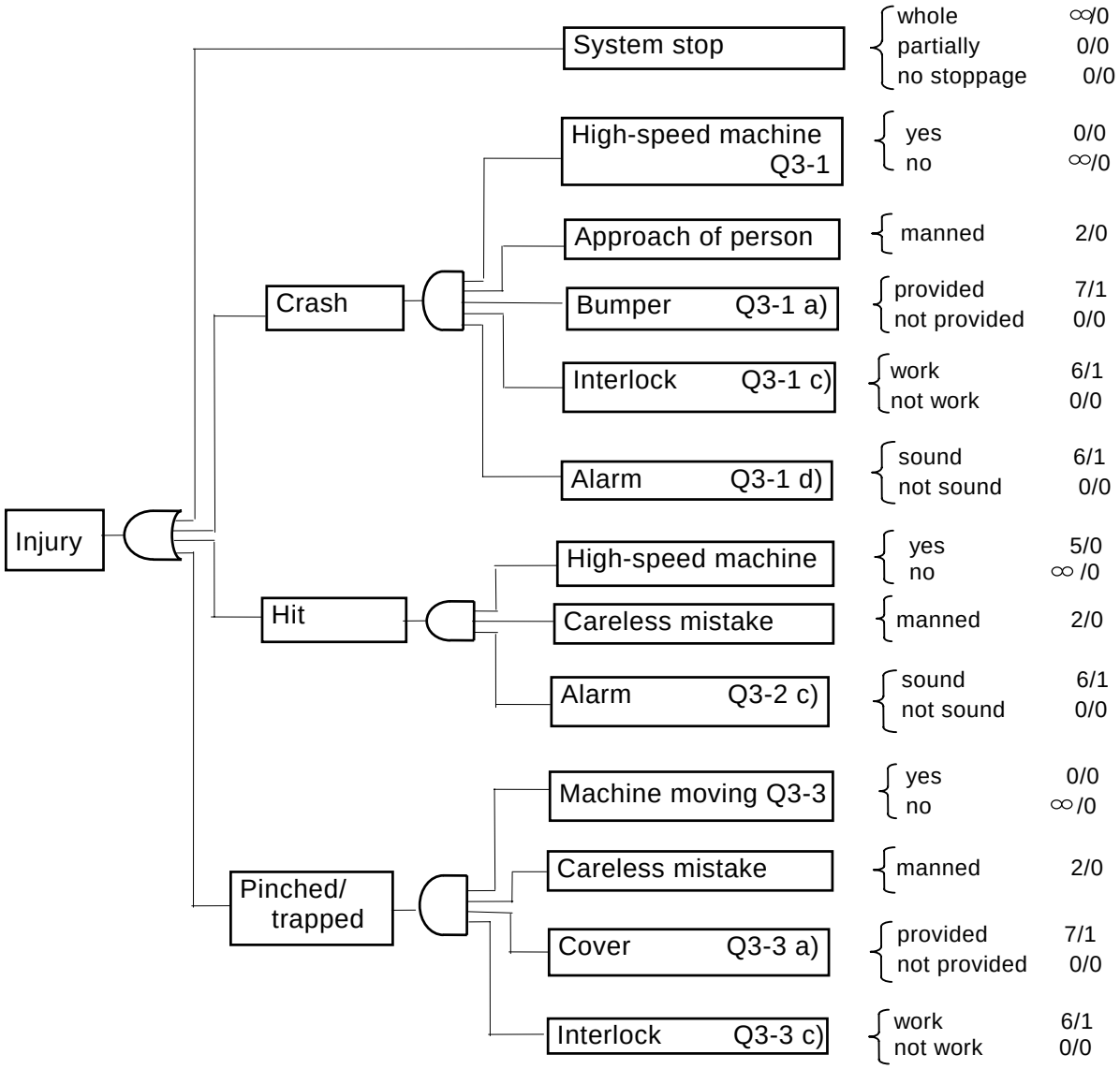


c) Check list for high-speed machine

Q3-1: Is a machine moving at high speed (5km/h or more) in the system ?	
If yes to Q3-1	a) Is a bumper provided for a machine with high-speed motion?
	b) Is an interlock provided for stopping the high-speed machine in case of contact?
	c) Does the interlock work during maintenance?
	d) Does an alarm sound?
Q3-2): Is a machine (component) moving at high speed (5km of more) in the system ?	
If yes to Q3-2	a) Is a fence provided to keep persons out of the operation area?
	b) Is an interlock provided to stop the machine when a person enters the operation area?
	c) Does an alarm sound when a person enters the operation area?
Q3-3): Does a machine capable of pinching or trapping a person exist in the system ?	
If yes to Q3-3	a) Is a cover provided to prevent pinching or trapping a person?
	b) Is an interlock provided to stop the machine when pinching or trapping occurs?
	c) Does the interlock also work during maintenance?

Fig. 3 a FTA for high-speed machine and Check list

b) Maintenance

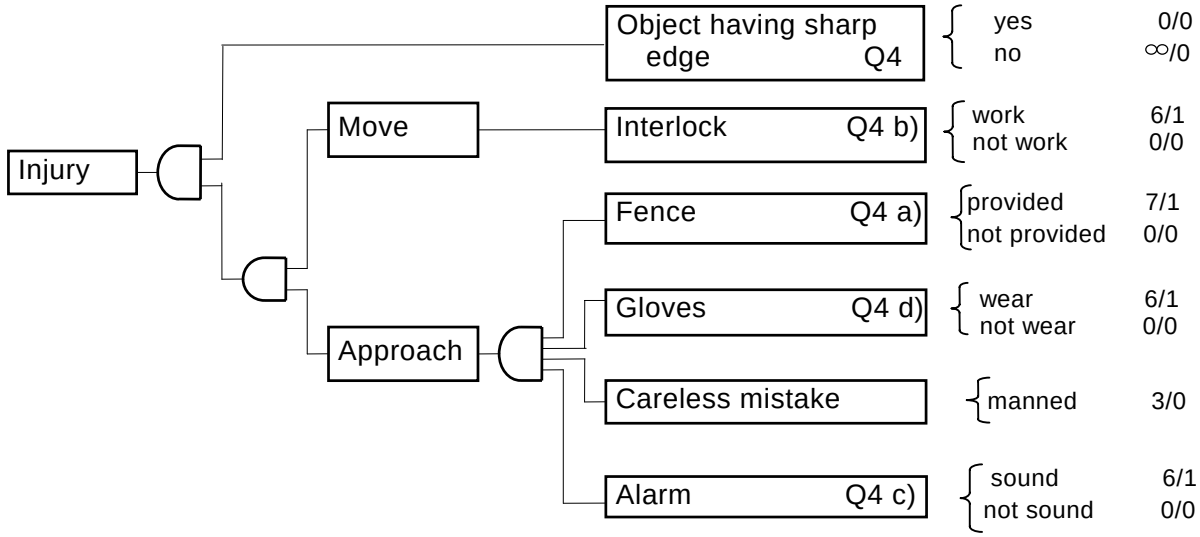


c:) Check list for high-speed machine

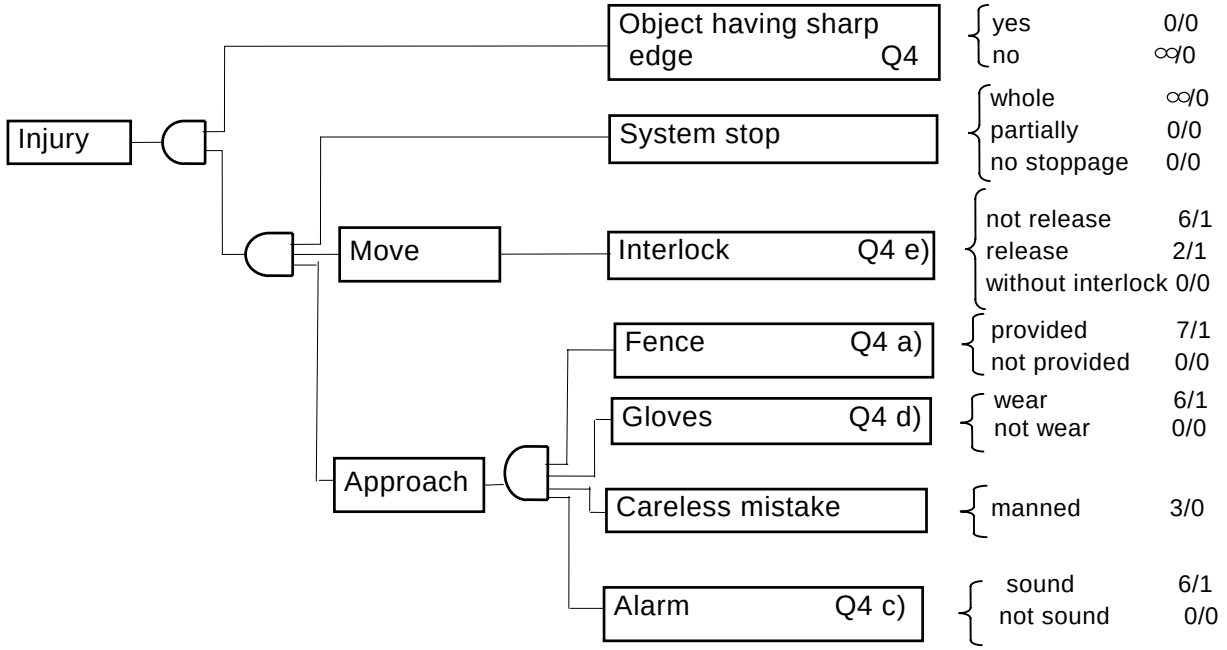
Q3-1): Is a machine moving at high speed (5km/h or more) in the system?	
If yes to Q3-1	a) Is a bumper provided for a machine with high-speed motion?
	b) Is an interlock provided for stopping the high-speed machine in case of contact?
	c) Does the interlock work during maintenance?
	d) Does an alarm sound?
Q3-2): Is a machine (component) moving at high speed (5km of more) in the system?	
If yes to Q3-2	a) Is a fence provided to keep persons out of the operation area?
	b) Is an interlock provided to stop the machine when a person enters the operation area?
	c) Does an alarm make sound when a person enters the operation area?
Q3-3): Does a machine capable of pinching or trapping a person exist in the system?	
If yes to Q3-3	a) Is a cover provided to prevent pinching or trapping a person?
	b) Is an interlock provided to stop the machine when pinching or trapping occurs?
	c) Does an interlock also work during maintenance?

Fig.3 b FTA for high-speed machine and Check list

a) Operation



b) Maintenance



c)Check list for sharp object

Q4: Does equipment or material having sharp edge exist in the system?	
If yes to Q4	a) Is a fence or cover provided ?
	b) Does an interlock work when a person crosses the fence or cover ?
	c) Does an alarm sound when a person crosses the fence or cover ?
	d) Do personnel wear gloves.?
	e) Can an interlock be released during maintenance ?

Fig. 4 FTA for sharp object and Check list

a) Operation

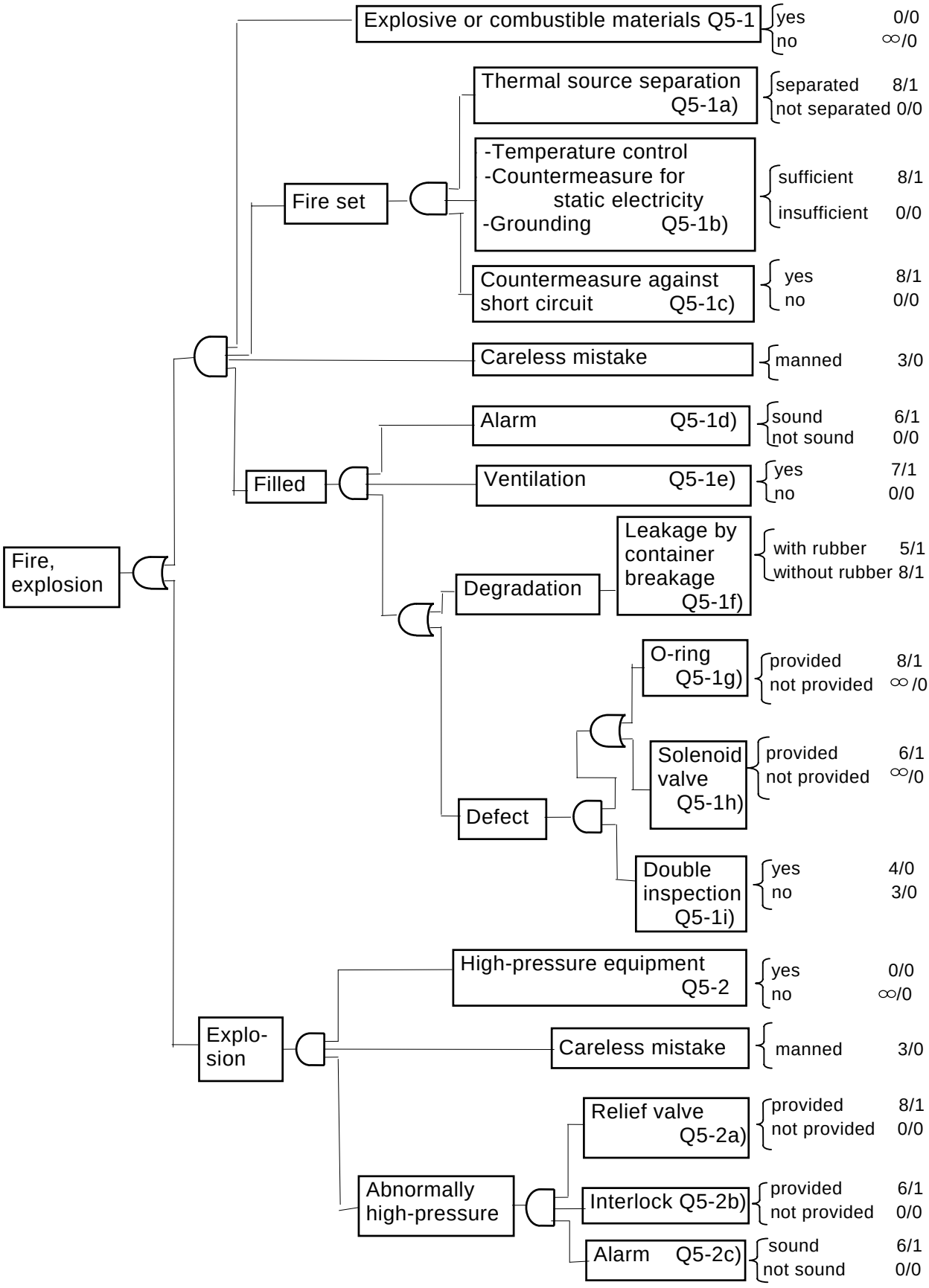


Fig. 5a FTA for explosive or combustible materials and Check list

b) Maintenance

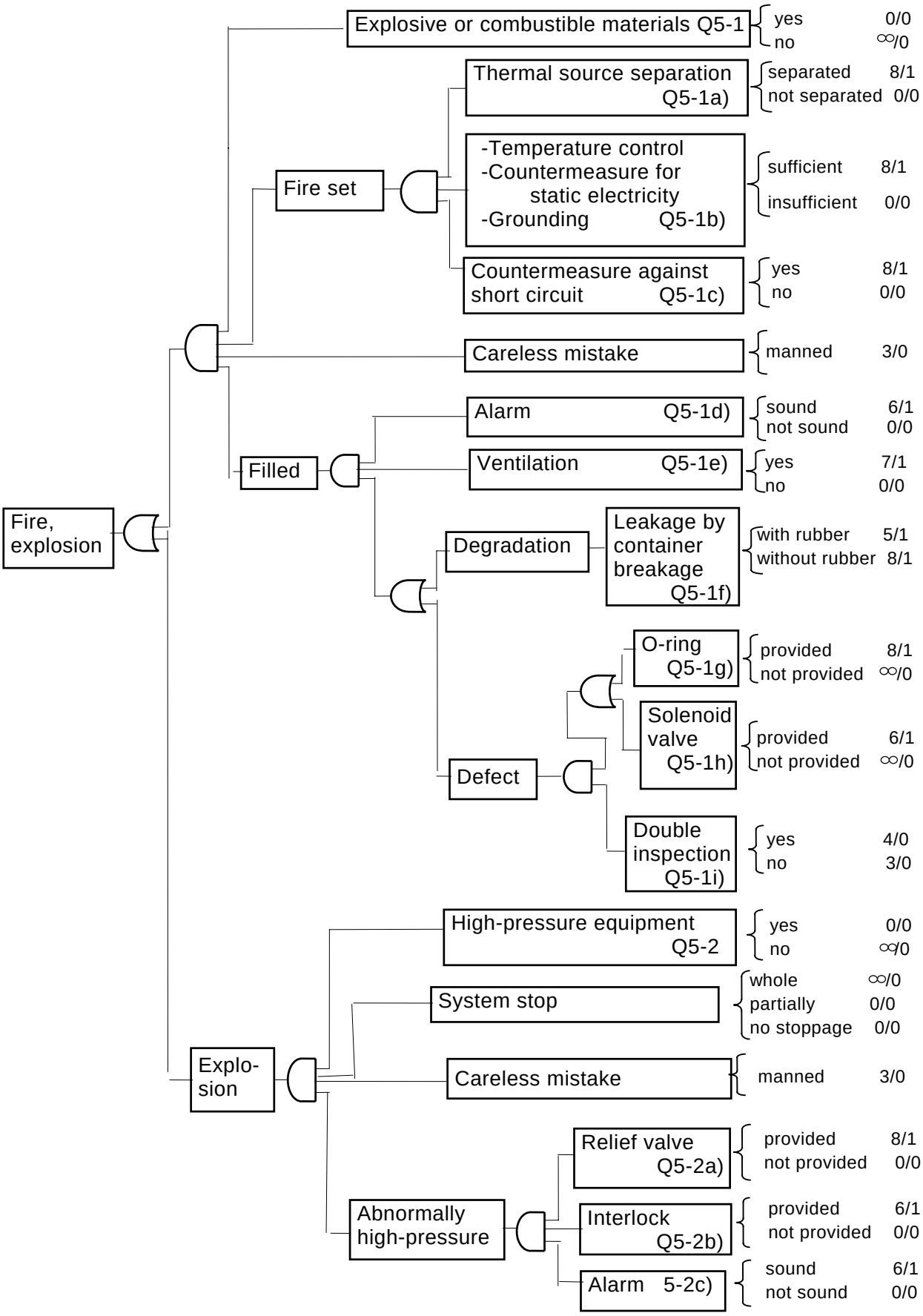


Fig. 5 b FTA for explosive or combustible materials and Check list

c) Check list for explosive or combustible materials

Q5-1: Do explosive or combustible materials exsit in the system?	
If yes to Q5-1	a) Is an appropriate distance secured between flammable combustible-materials and thermal source ?
	b) Are grounding devices, countermeasures for static electricity and temperature control secured ?
	c) Are countermeasures against short-circuits secured ?
	d) Does an alarm sound when explosive or combustible materials are released?
	e) Is there a ventilation or exhaust hole ?
	f) Is rubber used for equipment?
	g) Is an O-ring provided?
	h) Is a solenoid valve provided?
	i) Is the double check for the leak test executed ?
Q5-2: Is there high-pressure equipment in the system?	
If yes to Q5-2	a) Is the high-pressure equipment provided with a relief valve ?
	b) Is an interlock provided to be actuated at abnormally high pressure ?
	c) Does an alarm sound in abnormally high pressure ?

Fig. 5c FTA for explosive or combustible materials and Check list

a)Operation

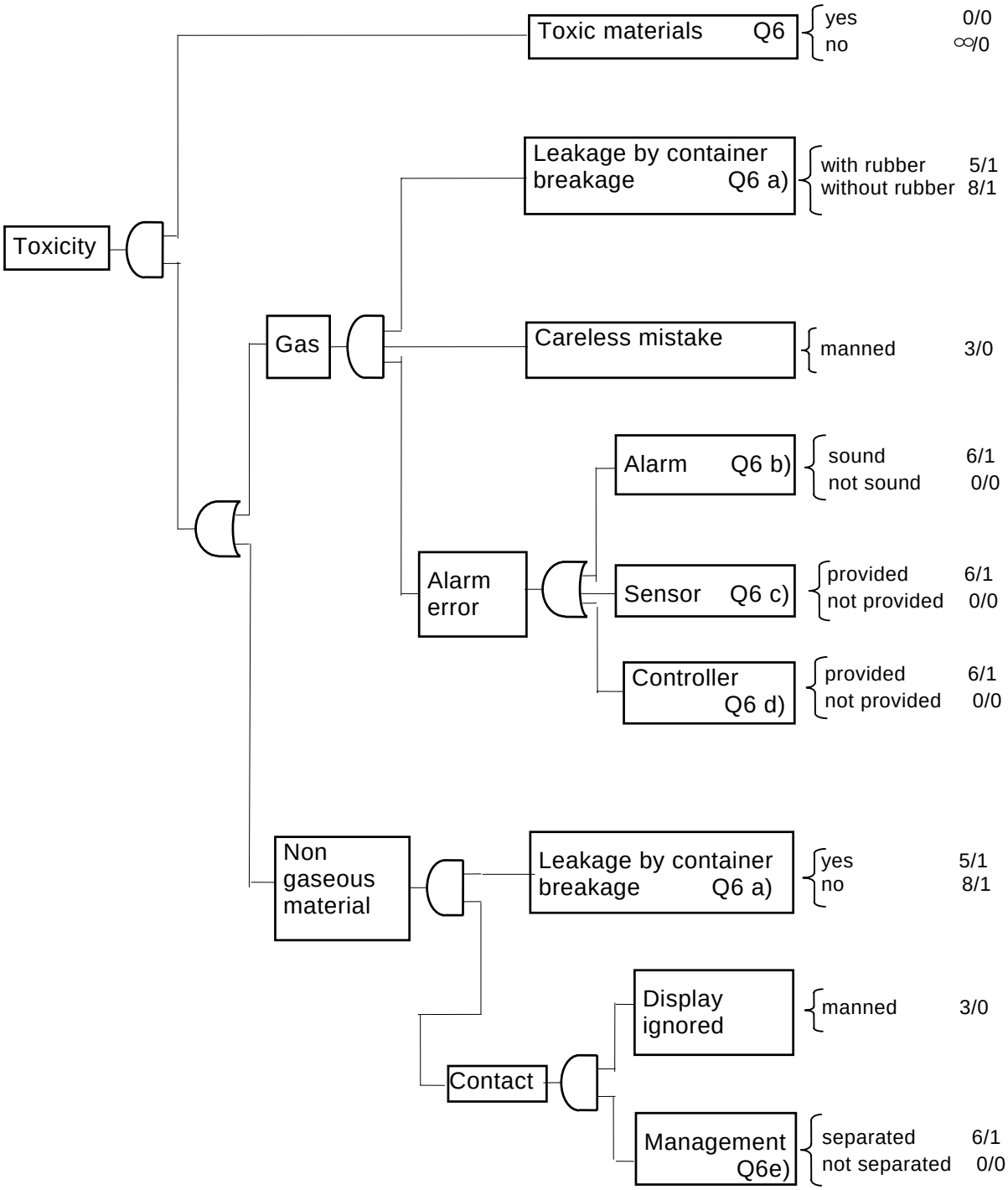
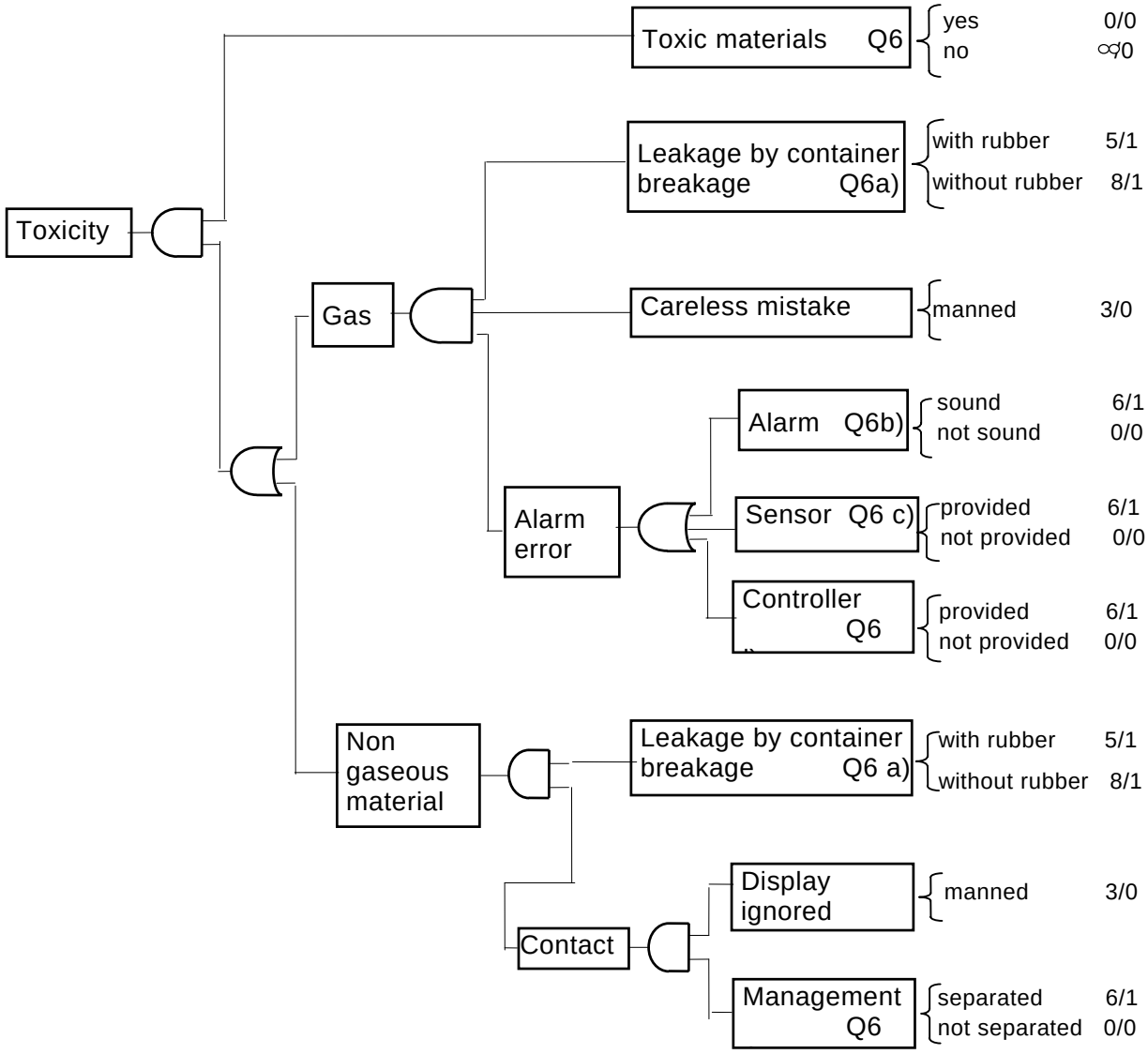


Fig. 6a FTA for toxic materials and Check list

b) Maintenance

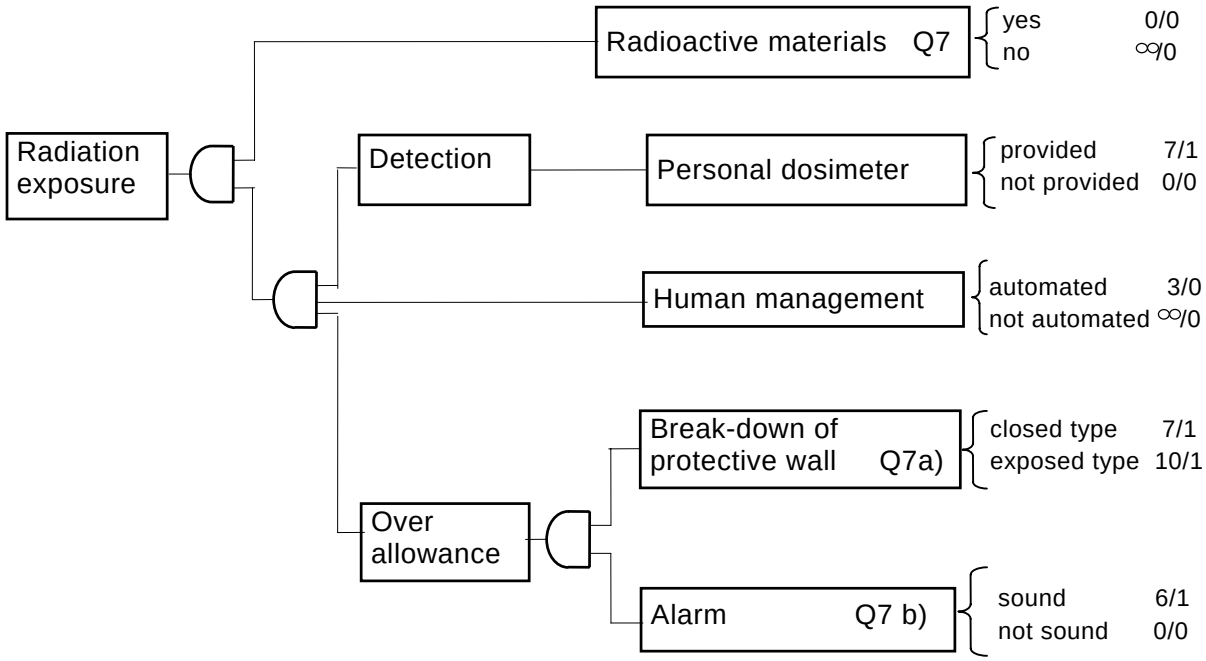


c) Check list for toxic materials

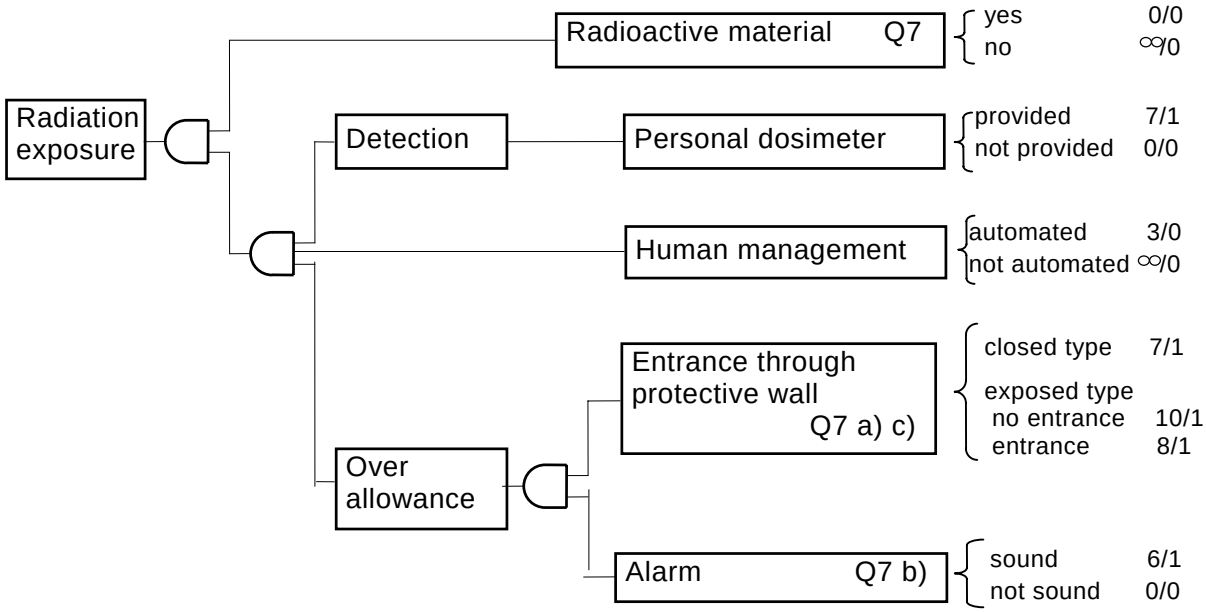
Q6: Are toxic materials present in the system ?	
If yes to Q6	a) Is rubber used for equipment?
	b) Does an alarm sound in case of container leakage ?
	c) Is a gas detection sensor provided ?
	d) Is equipment for gas control provided ?
	e) Are managers and operators for handling toxic materials assigned separately ?

Fig. 6b FTA for toxic materials and Check list

a) Operation



b) Maintenance

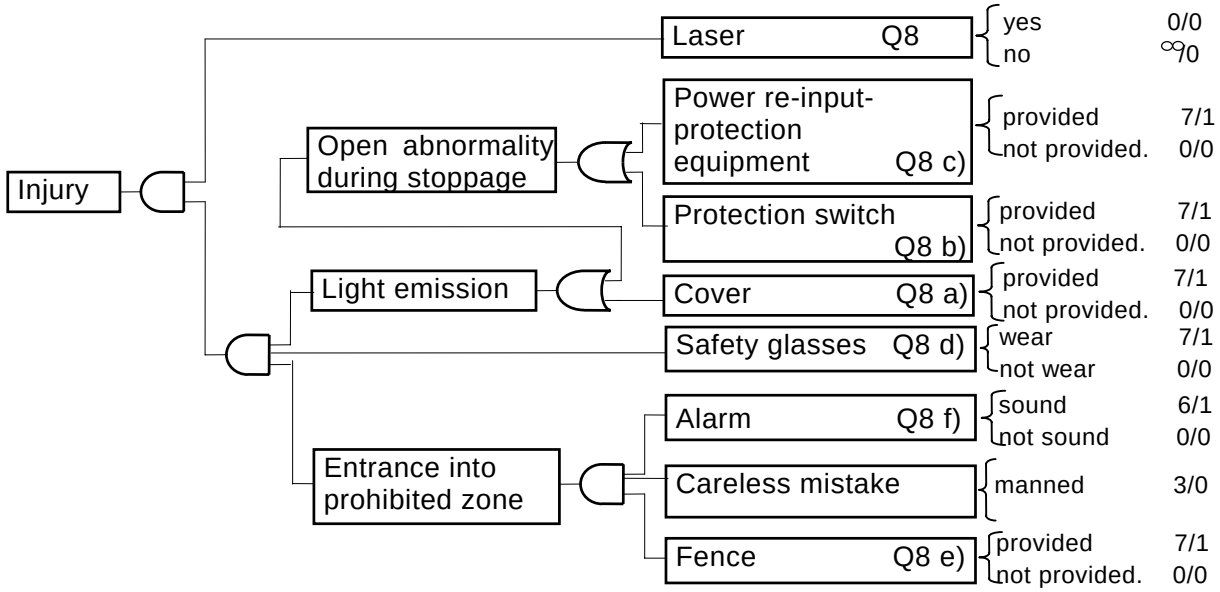


c) Check list for radioactive materials

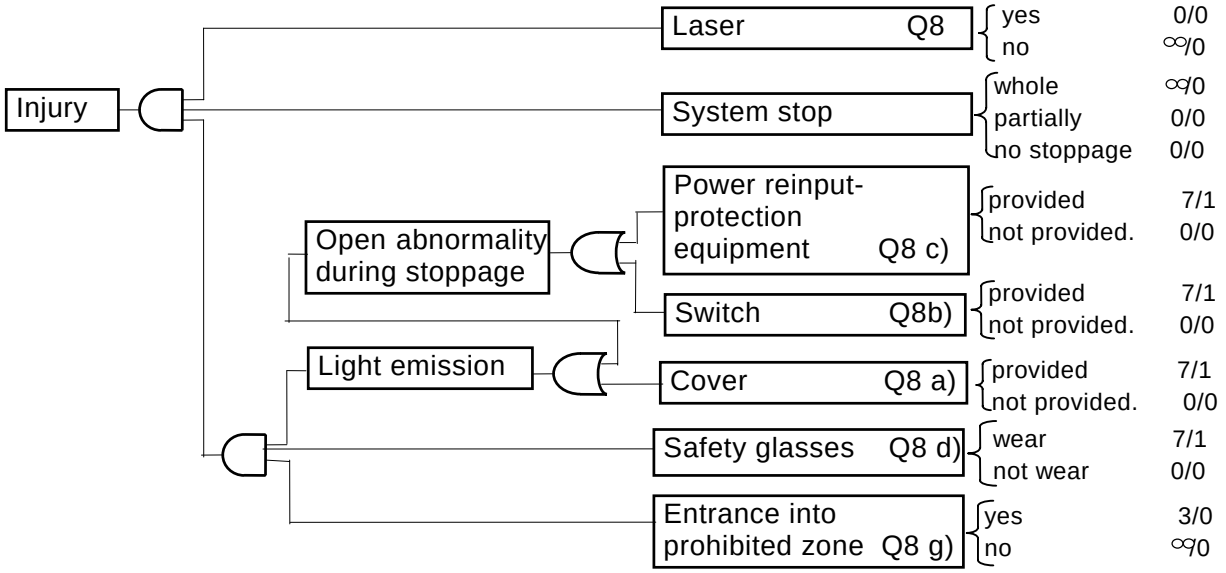
Q7: Are radioactive materials present in the system ?	
If yes to Q7	a) Is radioactive material enclosed or exposed ?
	b) Does an alarm sound in case of leakage of radioactive material ?
	c) Is maintenance work performed in a shield room when radioactive materials are exposed ?

Fig. 7 FTA for radioactive materials and Check list

a) Operation



b) Maintenance

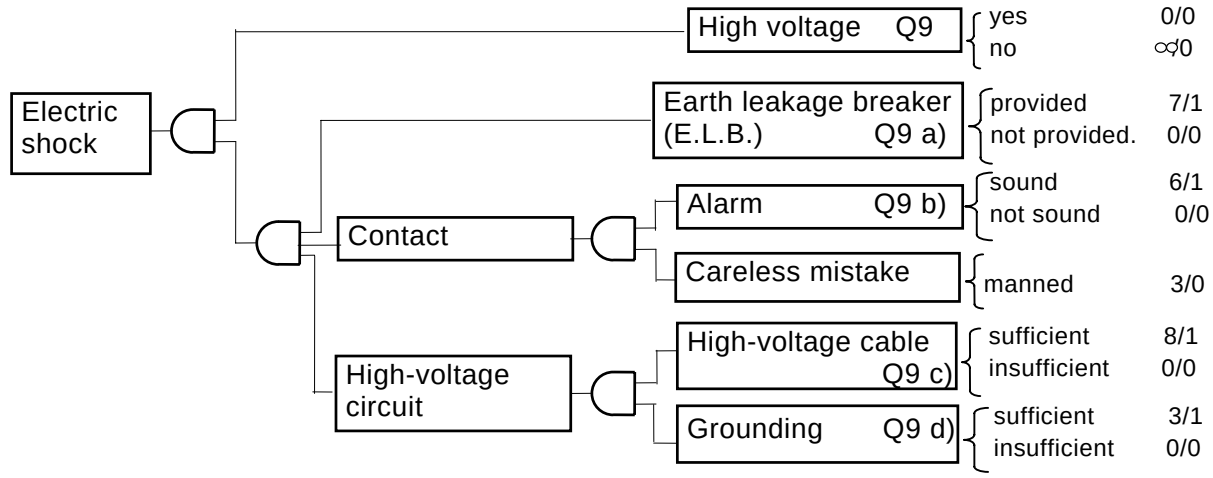


c)Check list for laser equipment

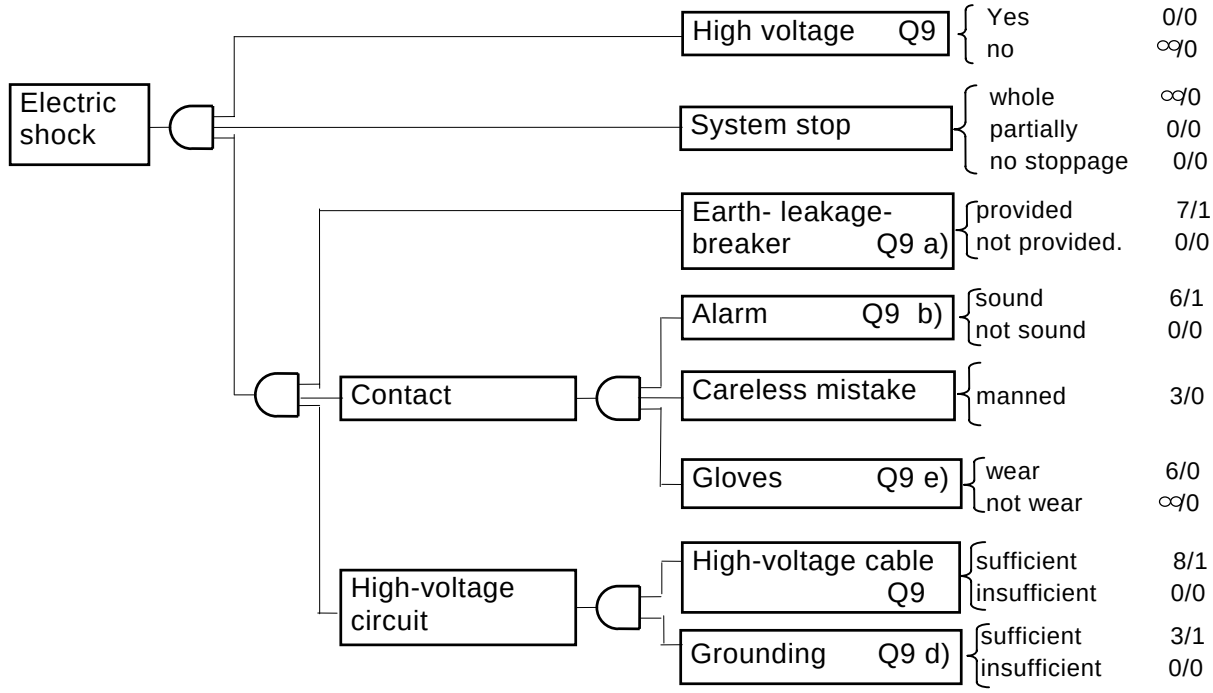
Q8: Is laser equipment (80mW or more) installed in the system ?	
If yes to Q8	a) Is a cover provided ?
	b) Is a switch provided to cut power when the cover is opened ?
	c) Can cut-off power be re-connected again when a cover is opened ?
	d) Does the operator have to wear safety glasses?
	e) Is a fence/barrier provided to prevent persons from approaching the laser equipment ?
	f) Does an alarm sound when person cross the fence ?
	g) Is work inside a fence/barrier required during maintenance ?

Fig. 8 FTA for laser equipment and Check list

a) Operation



b) Maintenance



c)Check list for high voltage

Q9: Is equipment with high voltage (250V or more) installed in the system ?	
If yes to Q9	a) Is an earth leakage breaker (E.L.B.) provided ?
	b) Does a breaker sound when the high-voltage portion is approached ?
	c) Does high-voltage cable correspond to the operating voltage used ?
	d) Is grounding sufficiently installed?
	e) Is the operator required to wear gloves during maintenance ?

Fig. 9 FTA for high voltage and Check list

ANNEX B Supplementary information on RANK-MATRIX method for safety evaluation of integrated manufacturing systems - General requirements-

1 Scope

The opinion has been expressed that including a third party would render the scope too wide for an evaluation of safety and that the safety evaluation of an integrated manufacturing system should be limited to manufacturing lines as well as the surrounding environment and space. Furthermore, ISO11161 does not clearly mention safety for such third party.

However, this RANK-MATRIX method takes into account the other (third party) in Table 2 - RANK-MATRIX for safety evaluation of integrated manufacturing systems, since the third party and visitors both in and outside a factory will be affected in the event that an accident occurs. Therefore, the safety considerations of the other (third party) meet fundamentally the concept of safety described in ISO 11161.

2 Normative references

Normative references are limited to International standards, i.e. ISO and IEC, since this RANK-MATRIX method aimes at supplementing ISO 1161.

3 Definitions

Definitions are limited to only special terms concerned with the RANK-MATRIX method for the safety evaluation. For other definitions, reference should be made to the specification of other relevant ISO.

4 Safety evaluation

4.1 General

Generally, the design and selection of machines, control devices and safety equipment of integrated manufacturing systems are dependent on manufacturing management policies, disaster countermeasure systems, and health, safety and environment (HSE) management systems of a factory/plant. A factory/plant should therefore prepare its own safety management standards in advance in consideration of design, construction, operation and maintenance to ensure the safety evaluation of integrated manufacturing systems.

However, individual standards for the safety of workstations, machines, control devices and safety equipment are not always available. Furthermore, such do not always comply with the safety evaluation of an integrated manufacturing system. In that case, an alternative appropriate safety evaluation method will be prepared separately in compliance with these requirements, depending on the application and operational conditions of the integrated manufacturing system.

Where specific points in these requirements are considered to be in conflict with the requirements of other international standards (now or in the future), these requirements will be adjusted to determine if they are to be included or deleted from the system safety evaluation.

4.2 Safety evaluation process

In order to obtain useful results from the safety evaluation by the RANK-MATRIX method, it is recommended that the evaluation be executed in appropriate phases for respective items together with own safety management standards and individual safety standards of workstations, machines, control devices and safety equipment in accordance with Table 1 -Safety evaluation process of integrated manufacturing systems.

[A] The safety design related to the whole integrated manufacturing system should be evaluated during the planning and design phases (safety design review) [1], since it is impossible to correct the basic design of a manufacturing system without the requirement for additional money and time after workstations, machines or control devices are fabricated.

[B] Safety measures related to safety functions for operation of workstations, machines and control devices are examined in the fabrication, and assembly and installation phases [1] and test operation phases [2], since it is important to verify and adjust all safety functions of an integrated manufacturing system prior to beginning normal operation.

[C] General safety for personnel to ensure long-term safety during normal operation or improved reliability, and maintenance, are evaluated periodically in accordance with each operation phase [3].

5 RANK-MATRIX method for safety evaluation

5.1 General

As a result of the 8-year period of investigation and research of some 300 companies in Japan, it was considered impossible to evaluate the safety of integrated manufacturing systems having many different factors by just the one index. Since most accidents in systems occurred when failure of the system and error by personnel occurred at the same time, it is important to evaluate the comprehensive safety of the whole system as well as the individual safety of equipment, machine, etc.

Therefore, it is recommended to apply the RANK-MATRIX method, as shown in Table 2 - RANK-MATRIX for safety evaluation of integration manufacturing systems, in order to describe the three types of factors which are safety design and measures, evaluation categories and safety rank based on the consequences potential factors each investigated in respect of system operation conditions.

5.2 Safety design and measures

General safety measures of integrated manufacturing systems are roughly divided into the safety design related to planning, design and safety management of a whole system, and safety measures to reduce consequencess and to limit emergencies, accidents and disasters of integrated manufacturing systems. If any special safety-related item corresponding to the characteristic of the system should be considered, it will be added to the matrix table.

5.3 Evaluation categories

Evaluation categories are set for the manufacturing system/facility itself (failure or trouble of hardware), normal operation (trouble of software involving personnel), maintenance work (maintenance trouble of hardware and software) and other who are not directly concerned with the manufacturing activity (e.g. HSE of visitors, third parties and other persons).

5.4 Classification of safety rank

Consequences potential factors are not problems themselves, and in fact are necessary to realize safety functions. Without control, these higher consequences potential factors expose persons to great dangers. These are therefore classified by ranks of consequences potential factors, as shown in Table 4 - Ranks of consequences potential factor.

A person may perform dangerous acts alone, but without special tools the danger posed may not be so great. This level is classified as rank 1. Where no danger exists, the rank given is 0.

Since many integrated manufacturing systems with a consequences potential factor of rank 2

cause problems, troubles or accidents, this rank 2 is further broken down into three sub-levels.

A consequences potential factor of rank 4 refers to the potential to be fatal to numerous people and results in large-scale damage, such as in the case of an atomic bomb attack.

Although the term “rank” is applied, it should be noted that this rank of consequences potential factor is fundamentally different from the safety rank of the matrix table.

6 Evaluation procedure by RANK-MATRIX method

The integrated manufacturing system for the processing of parts incorporates the setting up of tools as a preparation work, parts transportation, mechanical processing, washing, and inspection after processing. An assembly system of products incorporates a stock of parts, installation, bolting, welding and inspection. Accordingly, in order to facilitate safety evaluation, the system may be divided into some appropriate size units such as workstations with each local control device.

6.1 Evaluation for a manufacturing system/facility

6.1.1 Safety rank of AS : Automation level

Since the safety evaluation purpose is whether or not a system exposes personnel to hazards in the event of failure or accident, a workstation subject to the evaluation of “automation rate” is limited to those with a consequences potential factor rank of 2 or higher in accordance with Table 4 - Rank of consequences potential factors.

The intention is to safeguard personnel from workstations with a consequences potential factor rank of 2 or higher. Specifically, an evaluation is made of the system design and fabrication in terms of ergonomics, for example, a safeguarding fence, guard cover, shield cover against radioactivity, high temperature and high pressure, and emergency devices.

According to a recent survey of integrated manufacturing systems in Japan:

- 3 mechanical processing lines and 1 assembly line for electronic parts were classified by the safety rank of “0”
- 1 mechanical assembly line and 1 electronic circuit board processing line were given the safety rank of “+1”

The automation level of parts processing lines was 80 percent on average, and the automation level of assembly lines was 80 percent or less. Therefore, safety considerations were applied in order to upgrade overall safety.

6.1.2 Safety rank of BS: Stress level

If “the comfort of personnel” is inadequate (difficult, odd or irritated), mental fatigue of personnel will increase which might lead to failures and accidents resulting from incorrect or careless operation. However, this will vary according to the size and complexity of the system as well as the experience and skill of personnel. It is therefore classified into four ranks.

The validation for “operability of a system/facility itself ”, that is “Operability tests requiring evaluation at the system level” evaluates comprehensive safety functions and performance of a system for mutual mechanical/electrical interference and outside disturbances between systems or mechanical devices in the environment of actual normal operation.

However, it is necessary to add or select evaluation items in accordance with the application, contents and size of an integrated manufacturing system and consequences potential factors. For example, it may be necessary to confirm the reliability of a control system as an important item to ensure the safety of a whole system, as follows:

(1) Higher reliability of control devices (e.g. back up)
(2) Degree of debugging of software
(3) Network change-over, protection circuit and stand-by redundancy system of control system
(4) Confirmation of operation at time of start and stop
(5) Safety of control circuit through noise
(6) Measures against power failure and immediately cut-off
(7) Other functions for handling abnormal operations

According to a recent survey on integrated manufacturing systems in Japan;

- 2 ordinary mechanical process lines were ranked "+1 and +3"
- 2 machine assembly lines were ranked "+1".
- 3 assembly lines of electronic machine were ranked "0 to +1".

In these above cases, it is estimated that "Operability tests requiring evaluation at system levels" of an integrated manufacturing system (especially, irregular tests) have not been fully conducted.

6.1.3 Safety rank of CS: Level of risk index

Since a professional capability is required to calculate this risk index, FTA and the check list shown in ANNEX A are recommended in order to facilitate the calculation of the index.

According to a recent survey of integrated manufacturing systems in Japan:

- Many systems, which were considered in good condition, were ranked "0"
- The risk index of five systems where accidents occurred under normal operation were ranked "+2 and +3". Some improvements were required.

6.1.4 Safety rank of DS: Diagnosis level

Since it is more important to diagnose failure than to monitor normal operation, "DS: diagnosis level" is combined with the detection rate and indication of failure/repair instruction.

According to a recent survey of integrated manufacturing systems in Japan:

- 5 out of 7 surveyed cases were ranked "0 and -1"
- 2 out of 7 cases were ranked "+2 and +3".

However, since one case with a ranking of "+3" was deemed a satisfactory system, its safety rank should be adjusted.

In accordance with the results of this survey, the detection rate of the diagnosis level of +1 was reduced from 80 at 60 percent or more. Additionally, the detection rate of the diagnosis level of 0 was reduced from 100 at 80 percent or more, in order that the classification of safety rank satisfied the actual conditions.

6.1.5 Safety ranks of ES: Interlock rate

The number of interlocking workstations in a system is of key importance, since it is not practical to count the number of interlocks of a workstation and it is considered appropriate to evaluate the interlock rate of a whole system.

Subject to interlocking systems are workstations with consequences potential factors of rank "1" or higher, since workstations with a consequences potential factor rank of "0" have little potential for danger.

In cases where a workstation contains several consequences potential factors, it is necessary to assign interlocking systems to all the factors. If an interlocking system is not provided for given a factor, the interlocking rate is calculated on the assumption that the workstation concerned has no interlocking system available.

The safety rank of “-2” is classified as 100 percent. At the beginning of the survey, the interlock rate of a system was expected to show a higher percentage, and the safety rank of “+2” was the interlock rate of 60 percent. However, as a result of a survey of several companies, it was deemed appropriate to reduce the safety rank of “+2” to 40 percent or more. Accordingly, the safety ranks for “0 and -1” were adjusted.

6.1.6 Safety rank of FS

“FS” that considers the fail-safe level for a system almost coincides with the purpose and content of “FW: fail-safe protection rate”. Please refer to paragraph 6.2.6. “FW”.

6.1.7 Safety ranks of GS

“GS” that considers the level of fault-tolerance for a system almost coincides with the purpose and content of “GW: level of fault tolerance”. Please refer to paragraph 6.2.7 “GW”.

6.1.8 Safety rank of HS

“HS” that considers the level of measures against emergencies almost coincides with the purpose and content of “HW: alarm and stop level”. Please refer to paragraph 6.2.8. “HW”.

6.1.9 Safety rank of IS: Backup level of power

Power failure of an integrated manufacturing system includes a momentary stop of within several milliseconds in duration. Measures against power failure include not only coping with accidents occurring during power failure, but also resuming power supply, as well as accumulating energy measures by inertia load of compressors and power supply systems with condensers.

Other structural measures for workstations or machines themselves are enclosure by means of covers and/or fences, and safeguarding persons from all workstations which might lead to injury or death of person by troubles in time of power failure.

A safety function against power failure is a system ensuring safe stoppage by a control circuit incorporating a safety circuit using slow-response relay, and/or springs used for brakes. Safety functions for short-time or partial stoppage are provided by safety circuits using batteries, as well as independent power source for a security/safety circuit.

According to a recent survey on integrated manufacturing systems in Japan, all 7 cases ranked “-1” were close to the ideal rank. This was due to the view that power failure measures are directly related to manufacturing activities, rather than to safety.

6.1.10 Safety rank of JS: Disaster-proof level

It is recommended that Table B - 1, the Japanese seismic intensity standard, be applied for evaluating seismic intensity. The scale has been reviewed in the wake of the Great Hanshin Earthquake on January 17, 1995. The new standards will take effect in fiscal 1997. For general requirements, conventional standards were used.
According to a recent survey of integrated manufacturing systems in Japan:

- 3 cases were ranked “-2”, 3 cases “+1” and one case “+2”.
- some cases showed problems, other cases were ideal.

Table B - 1 Seismic Intensity of the Meteorological Agency and Corresponding Seismic Acceleration (Gal)

Intensity		Explanation	Seismic acceleration (gal)	
			Horizontal	Vertical
0	Unfelt earthquake	Unfelt tremor only recorded in a seismograph	0.8 or less	No standard
1	Slight shock	Tremor felt by people sitting still or those sensitive to earthquakes	0.8 to 2.5	
2	Weak earthquake	Tremor felt by many people with shoji screens moving slightly	2.5 to 8.0	
3	Minor earthquake	Houses shaken, shoji screens rattling, electric lights and other hanging items shaken, and the water surface in a glass moving	8.0 to 25	
4	Moderate earthquake	Houses shaken violently, and unstable vases fall. People walking can feel tremors and many people rush outside.	25 to 80	
5	Strong earthquake	Cracks seen in walls. Tombstones and stone garden lanterns fall, and chimneys and stone hedges damaged.	80 to 250	
6	Violent earthquake	30% or less of houses collapse, landslides occur, and cracks appear in the ground. Many people cannot stand.	250 to 400	
7	Severe earthquake	30% or more of houses collapse, landslides occur, cracks in the ground appear and faults are caused.	400 or more	

6.2 Evaluation for normal operation (Working)

6.2.1 Safety rank of AW: Amenity level

The factors in a comfortable environment include lighting, air conditioning, ventilation, as well as sound insulation and vibration resistance, which will directly cause physical fatigue or pain to personnel. If all items are satisfactory, the level of the environment is equivalent to “-2”. In Japan, it is desirable to conduct the evaluation while using the “requirements for measures businesses should take to create good amenity workplace design” promoted by the Labor Standards Bureau of the Ministry of Labor for reference purposes.

The factors governing a comfortable working space include working positions, obstacles like wiring and piping around workplaces, work at a high location or space for physical distribution and monitoring of a system, in-house layout regarding escape passages, color tones and space to ensure the safety of personnel.

According to a recent survey of integrated manufacturing systems in Japan:

- 3 ordinary mechanical processing lines were ranked “+1, +2 and +3”
- assembly lines of precision machines or electronic machines were all given “-2”

The results showed the characteristics of types of industries. It is therefore better to evaluate amenity while adding and adjusting in-house standards concerning health and safety.

6.2.2 Safety rank of BW: Working safety management level

Reducing stress (mental and physical fatigue) of personnel from unfamiliar or excess workload (longer working hours and fewer staff members) prevent incorrect operations as well as failure and accidents resulting from carelessness.

The educational level evaluates the expertise level of personnel who receive sufficient instructions on system operation, in order to reduce stress and to ensure that systems are operated safely.

The working safety management system is also an important item subject to evaluation. This is because it involves organizational activities to maintain safe work programs such as the arrangement of personnel, operation data management and operation manuals, while using a working safety management organization and safe operation manuals.

According to a recent survey of integrated manufacturing systems in Japan, all 7 cases were ranked “0.” This showed that safe operation manuals were insufficient, although education of personnel and working safety management organizations were available.

Mechatronics technology changes integrated manufacturing systems that have many black boxes and difficult-to-understand operational characteristics as well as abnormal phenomena. It is therefore predicted that professional personnel will be needed to manage safe operation manuals, including operation data management.

6.2.3 Safety rank of CW: Stopping rate

Since frequent stoppage of an integrated manufacturing system will increase the chances of personnel coming into contact with a system, the stopping rate shall be evaluated.
According to a recent survey of integrated manufacturing systems in Japan, 6 out of 7 cases were ranked “0 or +1” and the remaining case was ranked “+2”.

6.2.4 Safety rank of DW: Warning level

According to a recent survey of integrated manufacturing systems in Japan, 3 out of 7 cases were ranked “+1 or +3”, and 4 were ranked “-2”.

At the beginning of the survey, it was thought that abnormal conditions would be detected and notified at a considerably high rate, but this turned out to be not true. This means that some excellent offices with emphasis on safety did not necessarily handle monitoring and diagnosis in earnest.

6.2.5 Safety rank of EW: Rate of interlock manual cancellation

In view of the original purpose of installing interlocks, interlocks should not be canceled, whether automatically or manually, and a system is needed so that measures for troubles can be taken without interlock cancellation.

However, when trouble occurs in a system, it is often necessary to cancel an interlock in order to solve the trouble. Therefore, in many cases, interlocks are designed so as to cancel manually in the system design phase.

6.2.6 Safety rank of FW: Fail-safe protection rate

As the interlocking rate, the fail-safe protection rate counts the number of workstations with fail-safe protection of a system.

Subject to evaluation are the existence of consequences potential factors (high-temperature materials and high-speed motion mechanisms) as well as the fail-safe design for such factors; namely, the existence of safety design. In addition, a fail-safe system ensures safety even if an interlock does not work when an accident happens.

According to a recent survey of integrated manufacturing systems in several countries, “FW” varied from “-2 to +2”, displaying great differences in fail-safe measures among companies. There is a greater need to raise the fail-safe protection rate at the time of system design.

6.2.7 Safety rank of GW: Level of fault tolerance

If multiple workstations are installed and faulty components can easily be changed, work can be continued without interruption. Additionally, even if multiple workstations are not installed, adequate buffer of intermediate parts or materials can continue works in following workstations.

No relationship appears to exist between the continuity of works and the extent of danger for workstation with a consequences potential factor 0. Therefore, in calculating the rate of multiple function with backup, workstations with a consequences potential factor of rank 2 or higher are subject to evaluation.

According to a recent survey of integrated manufacturing systems in Japan, the rate of multiple function with backup or the amount of buffer stock for 7 systems ranged from “-2 to +2” for an average of - 0.2. This therefore appeared to be reasonable.

6.2.8 Safety rank of HW: Alarm and stop level

The emergency stop mentioned here is a physical stop and not necessarily failure of power supply.

According to a recent survey of integrated manufacturing systems in Japan, the safety rank varied from “-2 to +3” for an average of +0.14. This safety rank therefore seemed to be reasonable.

6.2.9 Safety rank of IW: Backup level for personnel

Backup of power supply is indispensable for an integrated manufacturing system. However, in principle, mechanical measures rather than electrical measures ensure safety. It is necessary to evaluate mechanical measures separately for safety of personnel, if available.

6.2.10 Safety rank of JW: Escape system level

Evaluation of the escape system concerns the availability of escape facilities and frequency of escape training.

In Japan, escape equipment is stipulated in the Building Standard Law of Japan, which provides for structures and functions of such facilities as escape passages, staircases and gangways.

6.3 Evaluation for maintenance work

6.3.1 Safety rank of AM: Maintenance frequency degree

In general, the life cycle of integrated manufacturing systems is from several years up to 10 years in view of market trends. Therefore, the achievable safety rank of “0” is one year and the preferred rank “-1” is five years. A system which requires some maintenance (repair) within one month is ranked “+2 or +3”, because improvement or proper measures are considered necessary.

“Occupational hour” of one hour or one day causes inspection and maintenance difficulties. However, since this differs greatly according to the size of a system, and the contents and objectives of work - preventive maintenance or emergency maintenance - the occupational hour is adjusted in accordance with the actual situation of system.

For example, if preventive maintenance or scheduled maintenance is available, spare parts are procured and maintenance manuals prepared in advance to conduct work in a short period, and safety is guaranteed. In the case of emergency maintenance for sudden stoppage, one day or more is required to inspect and confirm troubles as well as plan repair work. In such case, safety is regarded as considerably low.

According to a recent survey of integrated manufacturing systems in Japan, five cases were ranked “+1” and the remaining two ranked “ 0 “ and “+2,” respectively.

6.3.2 Safety rank of BM: Maintenance educational level

Reducing stress (mental and physical fatigue) caused by “unfamiliarity” or excess workload (longer work hours and insufficient staff) of personnel prevents incorrect operations, as well as failure and accidents resulting from carelessness.

Educational level is an important item subject to evaluation in terms of safety management, since qualified and skilled personnel who receive sufficient instructions on system maintenance and have expertise suffer less stress and are capable of repairing systems safely.

The availability of manuals is also an important item subject to evaluation in terms of safety management. This is because the safety of maintenance work is guaranteed by easy-to-understand instructions or manuals, and safety management is easily conducted with the use of manuals, such as maintenance programs (preventive maintenance program, arrangement of staff and preparation of work schedule).

According to a recent survey of integrated manufacturing systems in Japan, five cases were ranked “0 to +1” and one case was ranked “+3”.

Mechatronics technology changes integrated manufacturing systems that have many black boxes as well as difficult-to-understand operational characteristics and abnormal phenomena. Therefore, it is predicted that professional personnel will be needed to manage safe operation manuals, including operation data management.

6.3.3 Safety rank of CM: Risk index of maintenance

According to a recent survey of integrated manufacturing systems in Japan, 5 of 7 cases were ranked “-1 to +1”, and the remaining 2 were ranked “+3”. The ranking “+3” needs improvement in view of the current safety technology level.

6.3.4 Safety rank of DM

In many cases, power supply is cut off during maintenance. Therefore, it is necessary to confirm that monitoring and diagnosis functions remain effective during maintenance.

“DM” almost coincides with the purpose and content of “DW: warning level”. Please refer to paragraph 6.2.4. “DW”.

6.3.5 Safety rank of EM: Interlocking level of maintenance

Of paramount importance is how the power supply for a system is cut off during maintenance to ensure safety of maintenance work.

This classification has been based on the assumption that power sources for a workstation or a machine subject to maintenance are often cut off for maintenance work.

According to a recent survey of integrated manufacturing systems in Japan:

- 2 out of 7 systems were ranked “-2”
- 4 out of 7 systems were ranked “+1”
- 1 out of 7 systems was ranked “+3”

This result showed the differences in attitudes toward the safety of system planning.

6.3.6 Safety rank of FM

“FM”: the safety rank of fail-safe for maintenance work is almost identical to “FW”: fail-safe protection rate in normal operation. Please refer to paragraph 6.2.6 “FW”.

However, since the power supply is often cut off during maintenance, it should be guaranteed that fail-safe functions will work effectively and a system can be operated both automatically and manually for the system maintenance work.

6.3.7 Safety rank of GM: Self-repairing level

According to a recent survey of integrated manufacturing systems in Japan, all 7 cases were ranked “+1”. This showed that measures for possible consequences potential factors concerning maintenance work were inadequate.

6.3.8 Safety rank of HM: Modulability rate

Before the recent survey of integrated manufacturing systems in Japan, a modulability rate of 100 percent was given rank “-2”, and that of 30 percent was given rank “+3”. However, it was found that the average exceeded “+1”, which was considered unrealistic. Therefore, rank “-2” was adjusted to a modulability rate of 90 percent and 10 percent for rank “+3”, and rates in-between have been classified into five levels.

6.3.9 Safety rank of IM

“IM”: measures for power failure during maintenance are almost identical to the purpose and content of “IW: Backup level”. Please refer to paragraph 6.2.9 “IW”.

6.3.10 Safety rank of JM

“JM”: measures for disasters during maintenance are almost identical to the “JW: Escape system level”. Please refer to paragraph 6.2.10 “JW”.

6.4 Evaluation for other (Third party)

6.4.1 Safety rank of AO: Safe-guarding rate

If a third party is protected from dangerous or manufactured products having a consequences potential factor rank 2 or higher, safety will be enhanced.

According to a recent survey of integrated manufacturing systems in Japan:

- 6 out of 7 cases were ranked “-2”
- 1 (part processing line) out of 7 cases was ranked “+2”

Generally, thorough safety management was enforced at the factory.

6.4.2 Safety rank of BO: Pollution control level

According to a recent survey of integrated manufacturing systems in Japan, 5 out of 7 cases were ranked “-2”, and 2 out of 7 were ranked “+1”. This reflects the fact that restrictions based on domestic laws work effectively in Japan.

6.4.3 Safety rank of CO: Protection level

According to a recent survey of integrated manufacturing systems in Japan, 3 out of 7 cases were ranked “-2” and 4 out of 7 cases were ranked “0”. This shows that efforts were made for the safety of third parties.

6.4.4 Safety rank of DO

It is possible for the third party to escape from a hazard by detecting and notifying of abnormal conditions in an integrated manufacturing system.

“DO” is almost identical to the purpose and content of “DW: the warning level”. Please refer to paragraph 6.2.4 “DW”. However, in the case of “DO”, since the third party is subject to monitoring, priority must be given to escape passages, etc.

6.4.5 Safety rank of EO

“EO” is almost identical to the purpose and content of “ES: interlock rate”. Please refer to paragraph 6.1.5 “ES”.

However, regarding the third party, interlocks are generally necessary against careless access or contact, rather than interlocks against incorrect operation. In cases where such interlocks are available, it should be noted that the ranks of “EO” will differ from those of “ES”.

6.4.6 Safety rank of FO

“FO” is almost identical to the purpose and content of “FW: rate of interlock manual cancel”. Please refer to paragraph 6.2.6 “FW”.

Even if a third party is involved in an integrated manufacturing system by accident, fail-safe functions for personnel are expected to be effective.

6.4.7 Safety rank of GO

“GO” is almost identical to the purpose and content of “GW: level of fault tolerance”. Please refer to paragraph 6.2.7 “GW”.

6.4.8 Safety rank of HO

“HO” is almost identical to the purpose and content of “HW: alarm and stop level”. Please refer to paragraph 6.2.8 “HW”.

6.4.9 Safety rank of IO

“IO”: measures against power failure for a third party are “display and guides of escape passages”, in order to prevent power failure from threatening the safety of the third party.

“IO” is almost identical to the purpose and content of “IW: backup level for personnel”. Please refer to paragraph 6.2.9 “IW”.

6.4.10 Safety rank of JO: Disaster measure level

“JO” is to confirm whether safety against disaster of an integrated manufacturing system for a third party, including local residents, etc., is ensured.

According to a recent survey of integrated manufacturing systems in Japan, all 7 cases were ranked “-2”. This was mainly because of the high-frequency equipment and radioactive materials in the systems concerned. These results differed from the definition of the ranks of this method. However, since it will require great effort to raise the rank of special equipment, for the purpose of the evaluation this method is allowed.

7 ANNEX **A** FTA for calculation of risk index and check list

TAS (tree analysis for safety) technology is necessary for the calculation of the risk index of “CS” and “CM”.

This check list was initially prepared so that personnel without TAS technology could carry out calculations. Nevertheless, even with a check list, calculations proved difficult. Accordingly, a much-easier FTA and check list were prepared - ANNEX A Figures 1 to 9 “FTA and Check List”. Using the figures, it is relatively easy to calculate the risk index. This method, however, is designed for approximation and may contain some errors. Furthermore, it is desirable for personnel with TAS technology to conduct occasional checks.

7.1 Checklist for safety rank concerned with a total system

1 System Identification		
1.1	Product name	Name:
1.2	Number of processes	
1.3	Number of non operator processes	
1.4	Number of workstations	
2 Removal of accident objects		
2.1	Does the system have safety and protection devices for the consequences potential factors of rank 2 or higher and protect person from the hazard?	Yes No
2.2	How long does repair interval of the system? (example: once a year, once 10 years)	
2.3	How long does repair time of the system? (example: 8 hours, one day)	
3 Working safety management		
3.1	Is working safety management organization established? (If your answer is no, go to 3.5.)	Yes No
3.2	Is working safety management organization joined by all staff concerned? (If your answer is no, go to 3.5.)	Yes No
3.3	Are safety management activities conducted mainly by staff responsible for safety management? (If your answer is no, go to 3.5.)	Yes No
3.4	Are manuals and data necessary for judgment established? (1) Manuals and data necessary for judgment are established. (2) Manuals and data necessary for judgment are insufficient. (3) Means to collect data necessary for judgment is not established.	Put a mark on the number (1) (2) (3)
3.5	What kind of feeling is a worker working by? (1) Feeling comfortable. (2) Not feeling odd or irritated. (3) Feeling somewhat difficult, odd or irritated. (4) Feeling difficult, odd or irritated.	Put a mark on the number (1) (2) (3) (4)
3.6	What kind of education for safety is there? (1) Education requiring acquisition of qualifications by authority (2) Education and training for safe maintenance work by internal authority without qualifications (3) Education and training for safe maintenance work with manual alone (4) No special education or training, with only on-the-job training	Put a mark on the number (1) (2) (3) (4)

7.1 Checklist for safety rank concerned with a total system(continue)

3.7	How about availability of manuals ? (1) Maintenance work is instructed directly by a system without the use of manuals. (2) Availability of manuals enabling personnel to become familiar with maintenance work within one week. (3) Availability of manuals enabling personnel to become familiar with maintenance work in more than a week. (4) Manuals for maintenance work are not prepared.	Put a mark on the number (1) (2) (3) (4)
3.8	Does the system's operating noise reach the boundary of the plant site? (1) The system's operating noise does not reach the boundary of the plant site. (2) The system's operating noise reaches the boundary of the plant site, but it is at the same level as the noise in the surrounding area. (3) Except the above things.	Put a mark on the number (1) (2) (3)
3.9	Are there facilities that use high frequencies in the system? Have anti-noise measures been introduced if the facilities exist?	Yes No Measure No measure
4 Reliability design		
4.1	Is power to the entire system cut off during maintenance? (1) Power to the entire system is cut off during maintenance. (2) Power to the processes under maintenance is cut off. (3) Power to the processes under maintenance is not cut off.	Put a mark on the number (1) (2) (3)
4.1	How many times does each equipment in system stop by machine troubles? (1) Less than a time/100 years (2) Less than a time/5 years, More than a time/100 years (3) Less than a time/a year, More than a time/5 years (4) Less than a time/a month, More than a time/a year (5) Less than a time/a day, More than a time/a month (6) More than a time/a day	Put a mark on the number (1) (2) (3) (4) (5) (6)
5 Fault tolerance		
5.1	Does the system have a self-restoring function? (1) Self-repairing function without any intervention of personnel (2) Failed parts are replaced by remote instruction of personnel with confirmation of safe normal operation. (3) Failed parts are replaced by remote instruction of personnel with temporary stoppage . (4) Failure/trouble of workstations is displayed automatically, and all repairs are performed manually within one hour. (5) Failure/trouble of workstations is displayed automatically, and all repairs are performed manually in over one hour. (6) Failure/trouble of workstations is identified by personnel, and all repairs are performed manually.	Put a mark on the number (1) (2) (3) (4) (5) (6)

7.1 Checklist for safety rank concerned with a total system(continue)

6 Measures for emergency		
6.1	Can all workstations or a system can stop immediately and safely when an emergency is notified through an alarm (1) Notify an emergency through an alarm and stop all workstations or a system immediately and safely. (2) Notify an emergency through an alarm and stop a workstation concerned, and other workstations are stopped after completion of work. (3) Notify an emergency through an alarm and stop system after completion of sequential operations. (4) Notify an emergency through an alarm and system is stopped manually . (5) Emergency stop function (manual) is available, but no device to notify an emergency is available. (6) No device to notify an emergency and no emergency stop functions are available.	Put a mark on the number (1) (2) (3) (4) (5) (6)
7 Measures for power failure		
7.1	Does the system use electrical power?	Yes No
7.2	Does power failure threaten human safety? (1) No usage of electric power supply from outside of the system, except for the control system and safety functions. (2) Full electric power supply backed-up by an emergency power source in order to maintain system operation without failure (3) System designed for prevention of troubles such as damage to machines, leading to injury or death by power failure. (4) Electric power for safety functions backup by other independent electric power source, etc. (No failure of control device-related safety functions). (5) Safety functions for a short period of time or during partial power failure. (6) No consideration made for power failure.	Put a mark on the number (1) (2) (3) (4) (5) (6)
7.3	Does the system have electric power supply back up during a power failure? (1) No usage of electric power supply from outside of the system, except for the control system and safety functions. (2) Full electric power supply backup with an emergency power source are available in order to maintain system operation without failure . (3) Backup power sources for a certain period to maintain safe operation are available. (4) Backup power sources for control devices are available in order to confirm the system safety and re-running of a system. (5) Working records remain and the system can easily be put into operation again after electricity is recovered (6) No consideration for power failure.	Put a mark on the number (1) (2) (3) (4) (5) (6) no influence

7.1 Checklist for safety rank concerned with a total system(continue)

8 Measures for disaster		
8.1	Are there any escape equipment help personnel to more easily escape; for example, emergency exits and emergency lights, in addition to escape? (1) Escape equipment fully installed. (2) Escape by worker alone possible. (3) Notification possible. (4) Two (2) escape passages (5) One (1) escape passage	Put a mark on the number (1) (2) (3) (4) (5)
8.2	Are there any special equipment when access of personnel is restricted; for example, a clean room, a shield room for radioactivity and working space exclusively used for automatic machines?	Yes No
8.3	Has the system a structure resistant to earthquakes, fires, storms and floods? (1) Not damaged by earthquake (7 or less on the Japanese scale of 7), fires (all surrounding directions), storms and floods (typhoons). (2) Not damaged by earthquakes (5 or less on the Japanese scale of 7) and fires (one direction). (3) Temporary shutdown and possible early recovery. (4) Automatic shutdown at time of disaster. (5) No secondary disaster (radioactivity, poison gas, explosion, etc.) . (6) Only conventional measures in event of emergency without special measures.	Put a mark on the number (1) (2) (3) (4) (5) (6)
8.4	Are causes of accidents which could affect the surrounding area eliminated? (1) No consequences potential factor of rank 2 or higher. (2) Pollution of consequences potential factors of rank 2 or higher are measured completely against huge disaster. (3) Pollution of consequences potential factors of rank 2 or higher is measured completely against disaster. (4) Pollution of consequences potential factors of rank 2 is measured against disaster within the legal permissible limit. (5) Pollution of consequences potential factors of rank 2 are for the most part measured against disaster within the legal permissible limit. (6) Consequences potential factors are not measured against disaster.	Put a mark on the number (1) (2) (3) (4) (5) (6)

7.2 Checklist for safety rank concerned with each process in the system

	Process Number	1	2
	Name of the Process		
A-1	Is this process automated? (If yes, go to B.)		
A-2	Does the luminous intensity of this process keep 300lux or more (600lux or more for precision work)?		
A-3	Does the noise of this process keep 80dB(A) or lower?		
A-4	Does this process keep the temperature at 17-28 degrees Celsius?		
A-5	Does this process keep the humidity at 40-70%?		
A-6	Does a worker feel displeased by odor or dust?		
B	Does this process contain a consequences potential factor? And have you got any good ideas which visitor can't touch tools and/or products in the process? a) high-temperature (60degrees Celsius or over) b) heavy component (50kg or over) c) high speed machine (5km/h or over) d) sharp shape e) laser (80mW or higher) f) gas or poisonous substance g) radioactive substance h) high voltage (250V or higher) i) explosives or combustibles substance		
C-1	Does a high-temperature object (60degrees Celsius or over) exist in the system? (If no, go to D-1.)		
C-2	What temperature is it in the system? (#)		
C-3	Is there a cover on the high-temperature object?		
C-4	Is there a fence protecting against a high-temperature object?		
C-5	Does an alarm sound on approach to a high-temperature object?		
C-6	Is there an automatic power disconnecting device?		
C-7	Is a high-temperature object cooled down to 60degrees Celsius or lower within a few seconds after cutting off power?		
C-8	Does the system design to keep out of reach of human body when an accident break out? (*)		

Question for finding level of potential rank
* Question for calculating FW
** Question for calculating CO

7.2 Checklist for safety rank concerned with each process in the system (continue)

	Process Number	1	2
D-1	Does a heavy object (50kg or over), which could become detached, exist in the system? (If no, go to D-5.)		
D-2	How much does it weigh in the system? (#)		
D-3	Is the heavy object fixed with bolts or others to endure a seismic intensity of 5?		
D-4	How many fixing points does it have?		
D-5	Is slinging work required?		
D-6	Is slinging work required also during maintenance?		
D-7	Is there work at a high location?		
D-8	Is there work at a high location also during maintenance?		
D-9	Does the system design to keep out of reach of human body when a heavy object fall down? (*)		
E-1	Is a machine moving at a high speed (5km/h or over) in the system? (If no, go to E-7.)		
E-2	What speed is it in the system? (#)		
E-3	Is a bumper provided for a machine with high-speed motion?		
E-4	Is an interlock provided for stopping the high-speed machine in case of contact?		
E-5	Does the interlock work during maintenance?		
E-6	Does an alarm sound?		
E-7	Does a machine (component) moving at high-speed (5km/h or over) in the system? (If no, go to E-12.)		
E-8	What speed is it in the system? (#)		
E-9	Is a fence provided to keep persons out of the operation area?		
E-10	Is an interlock provided to stop the machine when a person enters the operation area?		
E-11	Does an alarm sound when a person enters the operation area?		
E-12	Does a machine capable of pinching or trapping a person exist the operation area? (If no, go to F-1.)		
E-13	Is a cover provided to prevent pinching or trapping a person?		
E-14	Is an interlock provided to stop the machine when pinching or trapping occurs?		
E-15	Does the interlock also work during maintenance?		
E-16	(If E-1 and E-7 are no, go to F-1.) Does the system design to shut down when these come into contact with human body? (*)		
E-17	What kind of partition is it installed to keep visitors out? 1.concrete, 2.steel or stainless steel, 3.Wooden or glass, 4.No partition (**)		

7.2 Checklist for safety rank concerned with each process in the system (continue)

	Process Number	1	2
F-1	Does equipment or material having sharp edge exist in the system? (If no, go to G-1.)		
F-2	Which is the sharp object, (1)sharp product or (2)cutting tool? (#)		
F-3	Is a fence or a cover provided?		
F-4	Does an interlock work when a person crosses the fence or cover?		
F-5	Does an alarm sound when a person crosses the fence or cover?		
F-6	Do personnel wear gloves?		
F-7	Can an interlock be released during maintenance?		
F-8	Does the system design to shut down when these come into contact with human body? (*)		
G-1	Do explosive or combustible materials exist in the system? (If no, go to G-14.)		
G-2	What kind of explosive or combustible materials is it in the system? And, What quantity is it? (#)		
G-3	Is an appropriate distance secured between flammable combustible materials and thermal source?		
G-4	Are grounding devices, countermeasures for static electricity and temperature control secured?		
G-5	Are countermeasures against short-circuits secured?		
G-6	Does an alarm sound when explosive or combustible materials are released?		
G-7	Is there a ventilation or exhaust hole?		
G-8	Is rubber used for equipment?		
G-9	Is an O-ring provided?		
G-10	Is a solenoid valve provided?		
G-11	Is the double check for the leak test executed?		
G-12	Does the system design to prevented from being ignited in the event of leakage? (*)		
G-13	What kind of partition is it installed to keep visitors out? 1.concrete, 2.steel or stainless steel, 3.Wooden or glass, 4.No partition (**)		
G-14	Is there high-pressure equipment in the system? (If no, go to H-1.)		
G-15	Is the high-pressure equipment provided with a relief valve?		
G-16	Is an interlock provided to be actuated at abnormally high pressure?		
G-17	Does an alarm sound in abnormally high pressure?		
G-18	What kind of partition is it installed to keep visitors out? 1.concrete, 2.steel or stainless steel, 3.Wooden or glass, 4.No partition (**)		

7.2 Checklist for safety rank concerned with each process in the system(continue)

	Process Number	1	2
H-1	Are toxic materials present in the system? (If no, go to I-1.)		
H-2	What kind of toxic materials are there in the system? And, What quantity are there? (#)		
H-3	Is rubber used for equipment?		
H-4	Does an alarm sound in case of container leakage?		
H-5	Is a gas detection sensor provided?		
H-6	Is equipment for gas control provided?		
H-7	Are managers and operators for handling toxic materials assigned separately?		
H-8	Does the system design to prevent from affecting human body in the event of leakage? (*)		
H-9	What kind of partition is it installed to keep visitors out? 1.concrete, 2.steel or stainless steel, 3.Wooden or glass, 4.No partition (**)		
I-1	Are radioactive materials present in the system? (If no, go to J-1.)		
I-2	How is radiological dosage? (#)		
I-3	Is radioactive material enclosed or exposed?		
I-4	Does an alarm sound in case of leakage radioactive materials?		
I-5	Is maintenance work performed in a shield room when radioactive materials are exposed?		
I-6	Does the system design to prevent from affecting human body in the event of leakage? (*)		
I-7	What kind of partition is it installed to keep visitors out? 1.concrete, 2.steel or stainless steel, 3.Wooden or glass, 4.No partition (**)		
J-1	Is laser equipment (80mW or higher) installed in the system? (If no, go to K-1.)		
J-2	How is full power of the laser? (#)		
J-3	Is a cover provided?		
J-4	Is a switch provided to cut power when the cover is opened?		
J-5	Can cut-off power be re-connected again when a cover is opened?		
J-6	Does the operator have to wear safety glasses?		
J-7	Is a fence/barrier provided to prevent persons from approaching the laser equipment?		
J-8	Does an alarm sound when person cross the fence?		
J-9	Is work inside a fence/barrier required during maintenance?		
J-9	Is there an operation within the fence during maintenance?		
J-10	Does the system design to protect eyes of operator when an accident break out? (*)		

7.2 Checklist for safety rank concerned with each process in the system(continue)

	Process Number	1	2
K-1	Is equipment with high voltage (250V or higher) installed in the system? (If no, go to L-1.)		
K-2	How is the voltage? (#)		
K-3	Is an earth leakage breaker (E.L.B.) provided?		
K-4	Does breaker sound when the high-voltage portion is approached?		
K-5	Does high-voltage cables correspond to the operating voltage used?		
K-6	Is grounding sufficiently installed?		
K-7	Is the operator required to wear gloves during maintenance?		
K-8	Does the system design to keep out of reach of human body when operator come into contact with the part of high-voltage?(*)		
L-1	Is an interlock provided for each consequences potential factor? (If no, go to M.)		
L-2	Can this process can cancel the interlock by manual operation?		
M	How many times can this process stock products before moving next process? A: one month or more B: one day or more C: one hour or more D: one minute or more E: less than one minute or automatic delivery to a following station		

7.3 Checklist for safety rank concerned with each station in the system

	Station number	1	2
	Station name		
A	Which test the station was taken when the station arrived? (1) Irregular test I : Examine safety under irregular operations (2) Irregular test II: Examine safety under supposed failure based on FTA evaluation and simulation (3) Noise immunity test: Examine safety under electromagnetic noise over the specified level (4) Noise electric intensity test: Examine electric wave noise within the specified values (5) Safety verification test for moving elements: Examine interlock functions before person touches a dangerous moving element (6) Power safety test: Examine insulation resistance, insulation resisting pressure and leakage currents within the specified values (7) Installation environment and power source test: Examine installation environment and power source conditions within the specified		
B-1	Is this station able to detect and give a warning an emergency condition?		
B-2	Does this station have a diagnosis?		
B-3	Which is the diagnosis level? (1) Possible to predict failure with a detection rate of 100% and records of failure (2) Detection rate of 100% with indication of instructions for failure repair (3) Detection rate of 80% with indication of failure and contents (4) Detection rate of 60% or more (5) Detection rate of less than 60% (6) No diagnosis device		
C	Is the station able to detach or put in modules?		