The Experience of Risk Assessment and its Future Utilization at Rokkasho Reprocessing Plant

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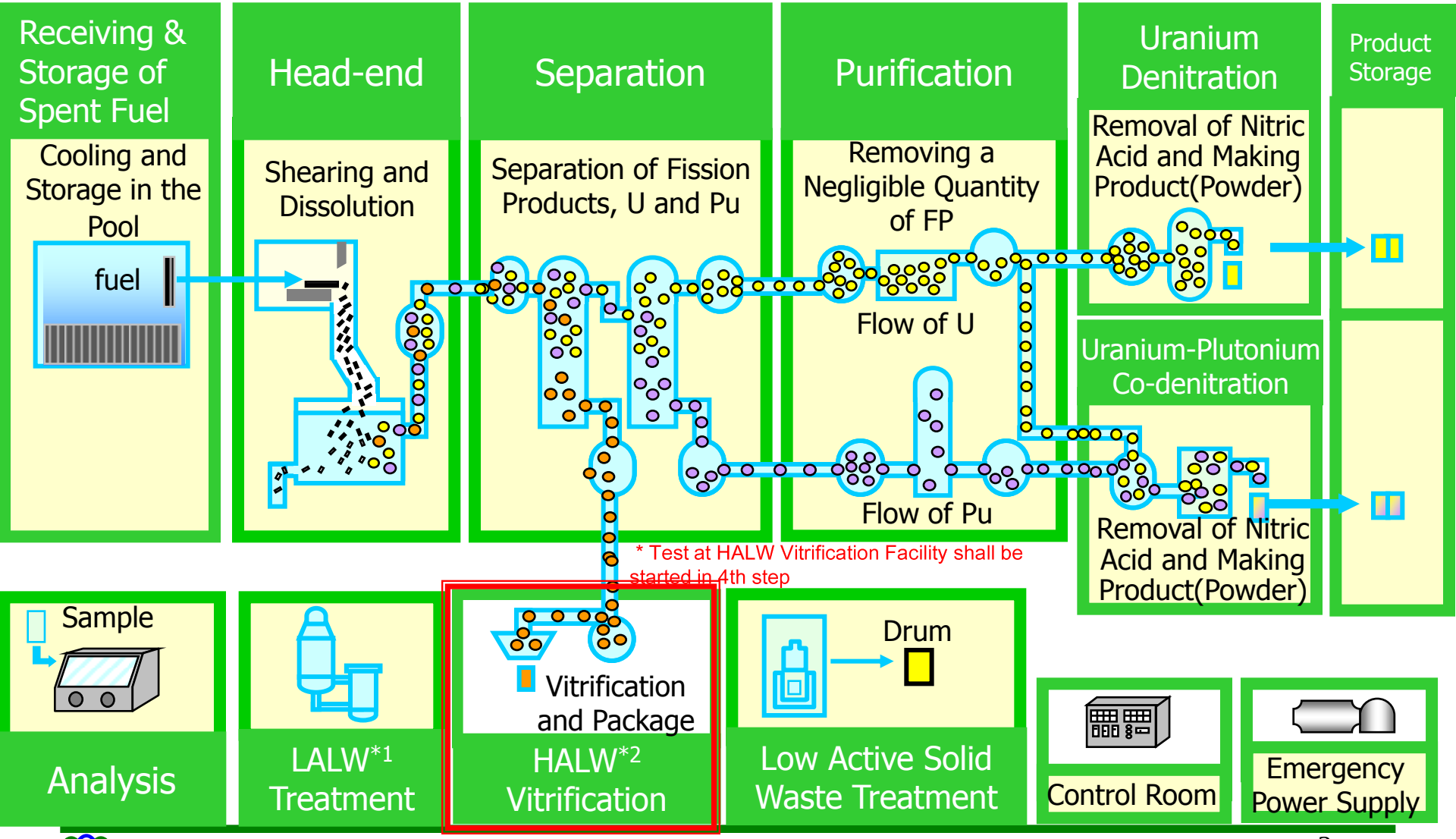
Contents

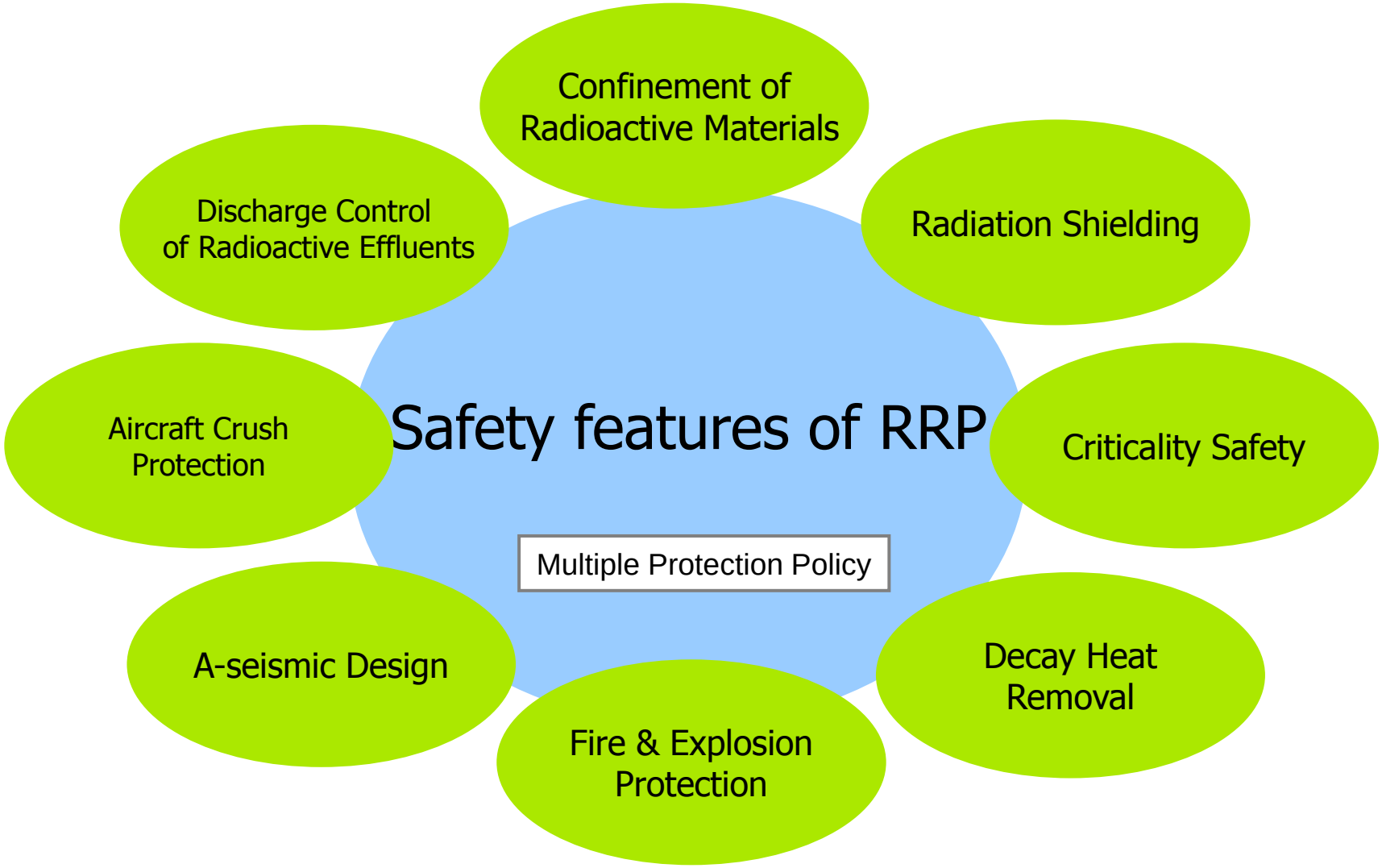
- Safety features of Rokkasho Reprocessing Plant (RRP)
- Identification of events and PSA of RRP
- An example of detailed PSA
- Development and application of the Simplified PSA
- Possible utilization of risk information
- Conclusion

Outline of Rokkasho Reprocessing Plant



JNFL *1LALW: Low Activite Liquid Waste
*2HALW: High Activite Liquid Waste

Safety features of RRP



Identification of events and PSA of RRP

HAZOP study
at basic design phase

AT: about 450 events
BAT: about 600events

Detailed PSA
15 events selected

Detail design

3 events up-dated
reflecting detail design
and operation procedure

results incorporated

A Simplified PSA developed
655 events to be assessed

Output

- Risk Profile
- The Risk Importance

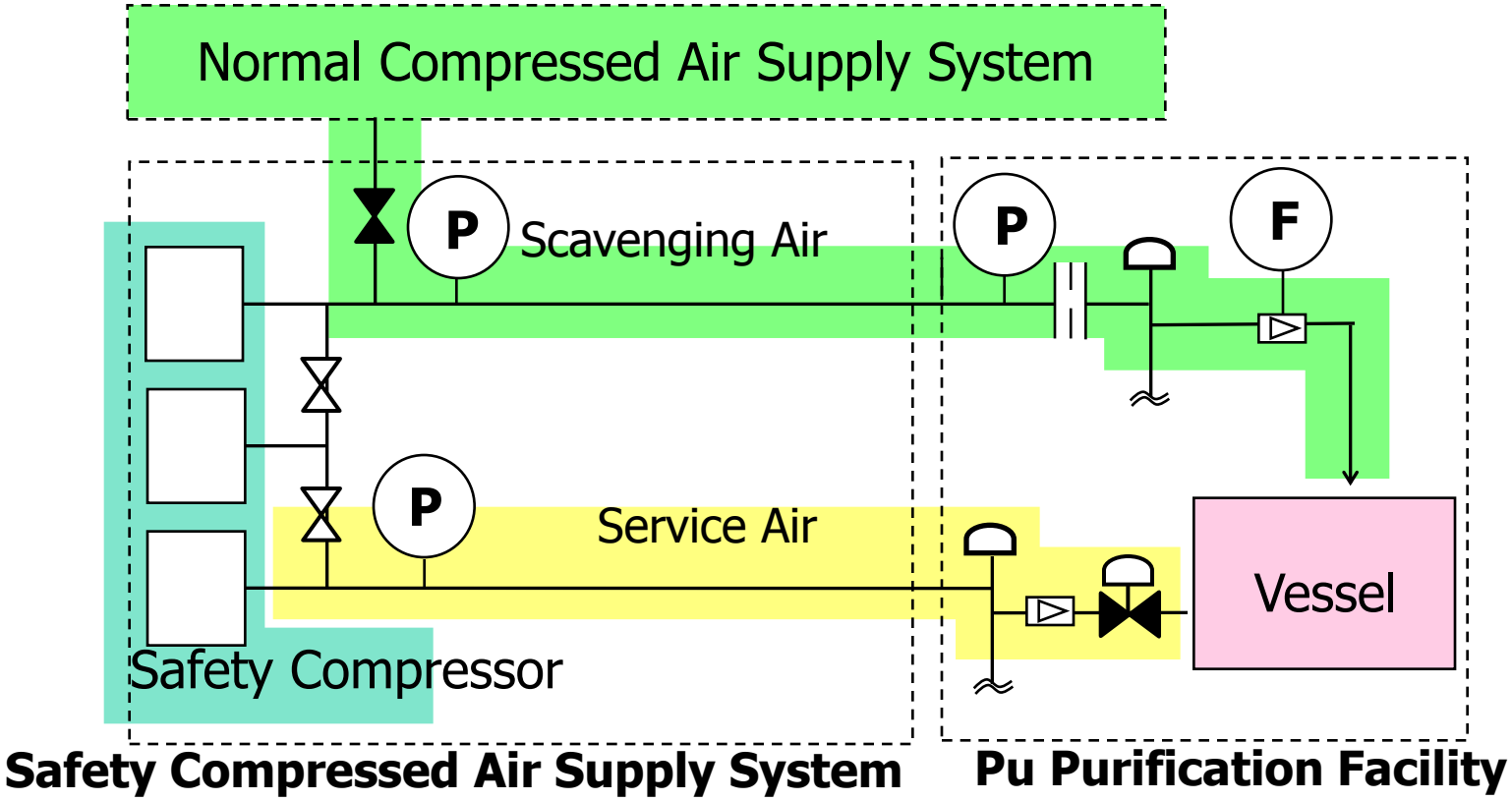
Utilization of Risk Information

An example of detailed PSA

Loss of Hydrogen Gas Scavenging Function in Plutonium Solution vessels

ref.4) Tamauchi, Y. et al., "Application of Probabilistic Safety Assessment to Rokkasho Reprocessing Plant (1); The Occurrence Frequency of Loss of H_2 Scavenging Function in Pu Solution Vessel," *Nihon- Genshiryoku-Gakkai Shi* (*J. At. Energy Soc. Jpn.*), **4**[5], 334-346 (2006), [in Japanese].

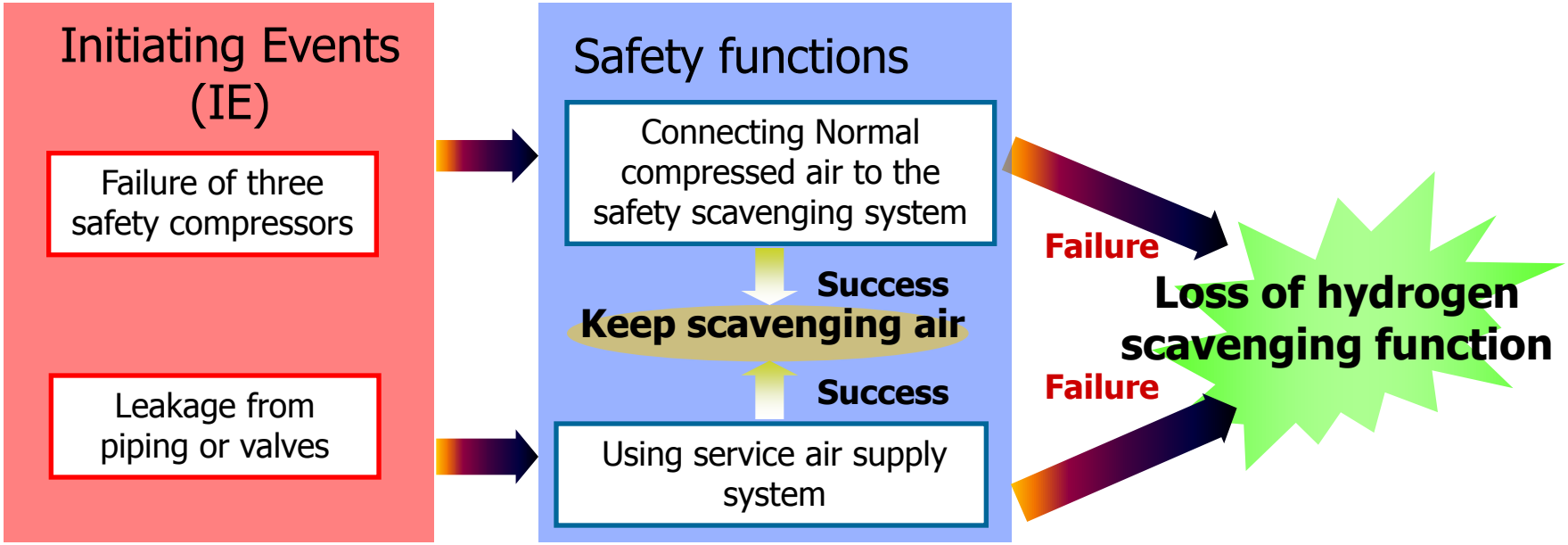
Outline of scavenging air supply system



P:Pressure gauge
F:Flow meter

Schematic diagram of the scavenging air supply system

Accident scenarios and evaluation method



- Evaluation Method and Database

Accident frequency assessment : ET/FT method

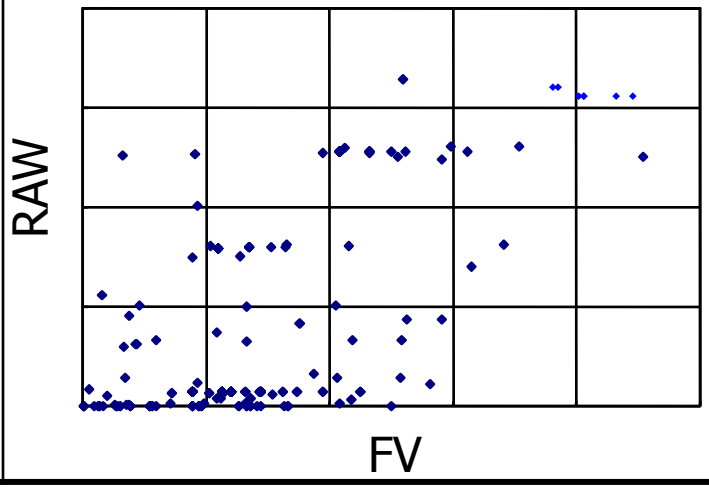
Human error probability : THERP method

Failure rate of equipment : Selected from Published literatures

Failure rate of air compressor, air operated valve, etc.:

→referred from database of THORP and Tokai Reprocessing Plant

Results of the assessment

Items	Results
Summation of occurrence frequencies of IE	4×10^{-3} per year
Occurrence frequency of loss of hydrogen scavenging function	8×10^{-6} per year
Uncertainty of the frequency at 90% reliability level	$1 \times 10^{-6} \sim 2 \times 10^{-5}$ per year EF=4
Importance evaluation of each basic input events ●Operator action of valve open for service air supply ●Leakage from piping and valves ●Operator action of valve open for normal compressed air supply	

Development and application of the Simplified PSA

ref.3) Tatsuo SHOUJI, Yuuji KOHATA, Kazumi TAKEBE, Yoshikazu TAMAUCHI, Kazuya HAYASHI, Katsuya KUROSU, "A Study on Graded Approsch for Risk Assessment of the Rokkasho Reprocessing Plant", Paper No. 460, Proceedings of GLOBAL 2005, Tsukuba, Japan, Oct. 9-13, 2005

Development of Simplified PSA

Detailed PSA

- FTA results of utility facilities
- Human reliability Analysis, etc.

Comparison of results of Simplified PSA and Detailed PSA Method

Results Incorporated

A Simplified PSA has been developed

- It can evaluate systematically evaluate the risk of RRP
- It can evaluate the importance of systems, components and Human action
- It is possible to use the MS Excel sheet for all evaluation
- The formula corresponding FTA are inputted in the sheet

Outline of simplified PSA procedure 1

Simplified PSA consist of several MS Excel sheet as follow,

Input sheets
(a) Safety function/System Matrix
(b) Utilities/Systems datasheet
(c) Consequence evaluation sheet

Output sheets
(d) Event tree display sheet for each event
(e) Consequence evaluation result display sheet for each event
(f) Importance evaluation result display sheet for each event
(g) Risk of all events display sheet
(h) Importance related to risk of reprocessing plant

Outline of simplified PSA procedure 2

Identification of hazards and accident sequences

Identification of safety functions

Identification of systems, components and human actions essential to the safety functions

Design information

Design and Operation Information input and summarized in (a) Safety function/System Matrix

Outline of simplified PSA procedure 3

Excerpt from (a) Safety function/System Matrix

Component	Pu Concentrate Vessel			Time margin (h)
Event	Loss of H_2 scavenging function			1
	The contents of safety functions	Time to operate (h) start	operation	Release sequence
PS-1	Continuous feeding of scavenging air from "Safety Compressed Air Supply System"	-	-	-
-2	—	-	-	Increasing of H_2 density
MS-1	Emergency feeding of service air from "Safety Compressed Air Supply System" by low warning of flow rate	0	0.01	
-2	Compressed air feeding from "Normal Compressed Air Supply System" by low alarm of pressure	0	0.01	
-3	Compressed air feeding from "Normal Compressed Air Supply System" by low warning of flow rate	0	0.01	Loss of scavenging function
-4				

Systems, components and human actions related to safety functions	Prevention	Safety function							Function of on-duty		Function of on-demand		The value considering time margin	
								MS-5	Failure rate (/h)	MTTR (h)	Unavailability (/d)	MTTR (h)	Failure rate (/h)	Unavailability (/d)
Active comp.														
											3.00E-03	0		3.00E-03
											1.00E-04	0		1.00E-04
Passive comp.									1.00E-08	24			9.59E-09	2.40E-07
									1.00E-08	24			9.59E-09	2.40E-07
									1.00E-08	24			9.59E-09	2.40E-07

Input the component and kind of event for evaluation

safety functions

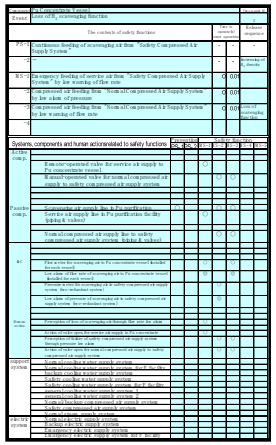
safety function

A list "Database of system, component and human action" have been set conservatively based on the published documents. Human error rate was determined based on detailed PSA.

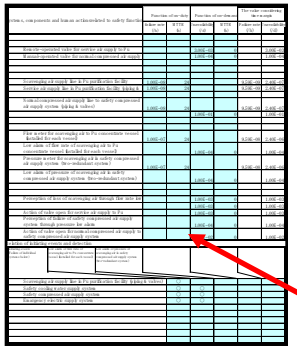
Outline of simplified PSA procedure 4

Unavailability of redundant system

Analyst enters the operating information such as component type, redundancy, maintenance period and test interval, etc.



(a) Safety function/System Matrix



Calculated result is entered

(b) Utilities/Systems datasheet

Systems and components	Alarm, warning
Explaination of system and components	Two redundant system of Alarm
Boundary of systems and components	
Remarks	safety-related equipments

The operation information of systems and components

Items		Info	Remarks
Number of systems		2	
Number of needed systems of On-duty equipment	N1		
Number of systems of On-duty equipment	N2		
Number of needed systems of stand-by equipment	N3	1	
Number of systems of stand-by equipment	N4	2	
failure rate (per systems) (/h)	λ	3.00E-06	IEEE-std-500 failure rate of reley 4E-7/h
Maintenance frequency of On-duty equipment (/yr)	F1		
Maintenance frequency of stand-by equipment (/yr)	F2	0	It was assumed the one to execute only the proof test.
Test frequency of stand-by equipment (/yr)	F3	1	The test frequency was assumed once per year.
	T1	0	
	T2	24	The equipment which located out of the cell takes 24 hours for repair.
	β2	0.01	Beta factor apply to 0.1 for stand-by dinamic apparatus. 0.01 for running dinamic apparatus.
	q*	0	
failure rate (On-duty)(/h)	λeff	-	
unavailability of stand-by system (On-demand)(/demand)	q	4.62E-04	
Unabailability of the component considering the backup, etc.	qeff	4.62E-04	q*+q

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Outline of simplified PSA procedure 5

Excerpt from (a) Safety function/System Matrix

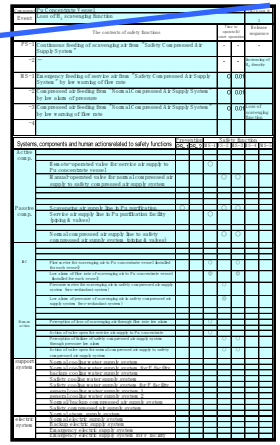
Systems, components and human actions related to safety functions		Prevention		Safety function				
		PS-1	PS-2	MS-1	MS-2	MS-3	MS-4	MS-5
Support system	Normal cooling water supply system							
	Normal cooling water supply system for F facility				○	○		
	backup cooling water supply system							
	Safety cooling water supply system	○		○				
	Safety cooling water supply system for F facility							
	General cooling water supply system 1							
	General cooling water supply system 2							
	Normal/buckup compressed air supply system				○	○		
	Safety compressed air supply system	○		○				
	Normal steam supply system							
Electric system	Normal electric supply system							
	Backup electric supply system				○	○		
	Emargency electric supply system	○		○				
	Emargency electric supply system for F facility							

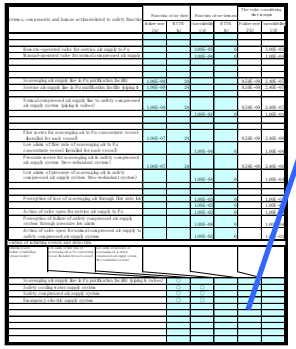
Unavailability of such support s
related to many events, has bee
fault tree equation based o

. Therefore, analysts should select the support system essential to the safety functions and mark the symbols

Outline of simplified PSA procedure 6

Input time margin to accident occurrence from initiating event

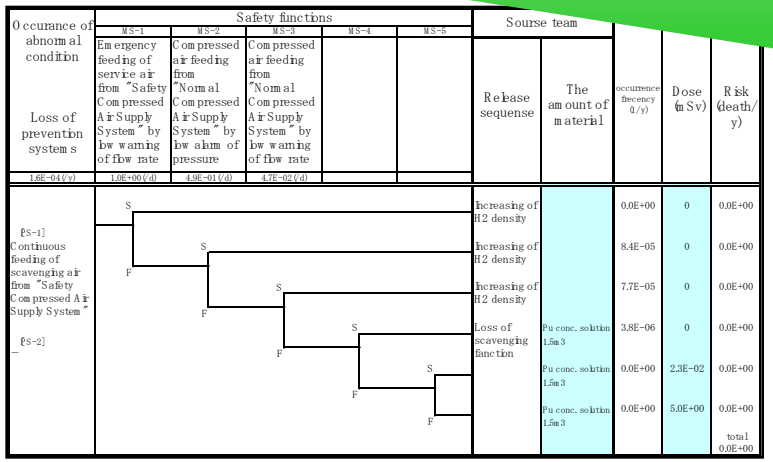




Input relation of initiating events and detection

(a) Safety function/System Matrix

Running macro program



Calculated occurrence frequency is automatically shown in form of ET (d)

Outline of simplified PSA procedure 7

Quantification of consequence

- In the simplified PSA, consequence is represented as radiation dose to the public
- The radiation dose is calculated in (c) Consequence evaluation sheet
- The result is showed on (e) Consequence evaluation result display sheet based on five-factors formula *

$$ST = MAR*DR*ARF*RF*LPF$$
$$Di=ST*R*X/Q*H$$

Where,

MAR:Material At Risk
DR:Damage Ratio
ARF:Airborne Release Fraction
RF:Respirable Fraction
LPF: Leak path Factor

ST:Source Team
Di:Effective Dose due to inhalation
R:Inhalation ratio
X/Q:Relative concentration
H:Coefficient for ingestion and inhalation

JNFL*ref.7) *Nuclear Fuel Cycle Facility Accident Analysis Handbook*, NUREG/CR-6410, (1998).

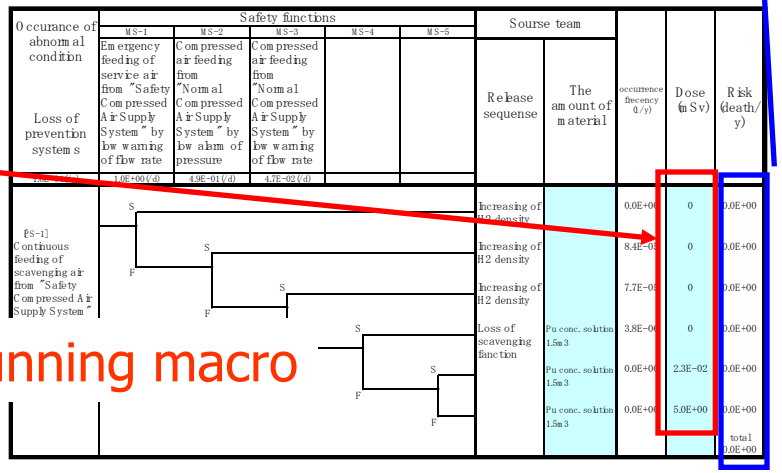
Outline of simplified PSA procedure 8

Consequence evaluation result

Event	No.	Release path No	Release sequence	MAR	Element group of MAR	MAR (Bq)	DR	ARF	LPF	Bq	X/Q	effective dose inhalation (mSv)	effective dose deposited on the ground surface
Hydrogen explosion at the Pu solution vessel	171Aa1	4	Stack release		Ru/Rh	1.48E+10	1.00E+00	1.00E-04	1.00E-03	1.48E+03	1.30E-06	2.12E-11	1.87E-12
					Cs/Ba	2.84E+09		1.00E-04	1.00E-03	2.84E+02		3.52E-13	8.84E-13
					Other FP	2.50E+09		1.00E-04	1.00E-03	2.50E+02		6.92E-12	1.87E-13
					Pu	6.59E+15		1.00E-04	1.00E-03	6.59E+08		1.96E-02	3.94E-09
					Am/Cm	0.00E+00		1.00E-04	1.00E-03	0.00E+00		0.00E+00	0.00E+00
					U	7.14E+07		1.00E-04	1.00E-03	7.14E+00		3.00E-11	1.17E-14
					Np	1.07E+07		1.00E-04	1.00E-03	1.07E+00		1.06E-11	7.68E-14
Hydrogen explosion at the Pu solution vessel	171Aa1	6	Ground release		Ru/Rh	1.48E+10	1.00E+00	1.00E-04	1.00E-02	1.48E+04	7.00E-05	1.14E-08	1.01E-09
					Cs/Ba	2.84E+09		1.00E-04	1.00E-02	2.84E+03		1.90E-10	4.76E-10
					Other FP	2.50E+09		1.00E-04	1.00E-02	2.50E+03		3.73E-09	1.01E-10
					Pu	6.59E+15		1.00E-04	1.00E-02	6.59E+09		1.06E+01	2.12E-06
					Am/Cm	0.00E+00		1.00E-04	1.00E-02	0.00E+00		0.00E+00	0.00E+00
					U	7.14E+07		1.00E-04	1.00E-02	7.14E+01		1.62E-08	6.30E-12
					Np	1.07E+07		1.00E-04	1.00E-02	1.07E+01		5.74E-09	6.12E-14
Hydrogen explosion at the Pu solution vessel	172Ab1	3	Stack release		Ru/Rh	9.60E+09	1.00E+00	1.00E-04	1.00E-03	9.60E+02	1.30E-06	1.37E-11	1.21E-12
					Cs/Ba	1.83E+09		1.00E-04	1.00E-03	1.83E+02		2.28E-13	5.72E-13
					Other FP	1.62E+09		1.00E-04	1.00E-03	1.62E+02		4.47E-12	1.21E-13
					Pu	4.26E+15		1.00E-04	1.00E-03	4.26E+08		1.27E-02	2.55E-09
					Am/Cm	0.00E+00		1.00E-04	1.00E-03	0.00E+00		0.00E+00	0.00E+00
					U	4.61E+07		1.00E-04	1.00E-03	4.61E+00		1.94E-11	7.57E-15
					Np	6.89E+06		1.00E-04	1.00E-03	6.89E-01		6.86E-12	4.96E-14
Hydrogen explosion at the Pu solution vessel	172Ab1	6	Ground release		Ru/Rh	9.60E+09	1.00E+00	1.00E-04	1.00E-02	9.60E+03	7.00E-05	7.38E-09	6.52E-10
					Cs/Ba	1.83E+09		1.00E-04	1.00E-02	1.83E+03		1.23E-10	3.08E-10
					Other FP	1.62E+09		1.00E-04	1.00E-02	1.62E+03		2.41E-09	6.52E-11
					Pu	4.26E+15		1.00E-04	1.00E-02	4.26E+09		6.83E+00	1.37E-06
					Am/Cm	0.00E+00		1.00E-04	1.00E-02	0.00E+00		0.00E+00	0.00E+00
					U	4.61E+07		1.00E-04	1.00E-02	4.61E+01		1.05E-08	4.08E-12
					Np	6.89E+06		1.00E-04	1.00E-02	6.89E+00		3.70E-09	2.67E-11
Hydrogen explosion at the Pu solution vessel	173Ab1	3	Stack release		Ru/Rh	9.70E+09	1.00E+00	1.00E-04	1.00E-03	9.70E+02	1.30E-06	1.39E-11	1.22E-12
					Cs/Ba	1.85E+09		1.00E-04	1.00E-03	1.85E+02		2.30E-13	5.77E-13
					Other FP	1.63E+09		1.00E-04	1.00E-03	1.63E+02		4.52E-12	1.22E-13
					Pu	4.31E+15		1.00E-04	1.00E-03	4.31E+08		1.28E-02	2.57E-09
					Am/Cm	0.00E+00		1.00E-04	1.00E-03	0.00E+00		0.00E+00	0.00E+00
					U	4.66E+07		1.00E-04	1.00E-03	4.66E+00		1.96E-11	7.65E-15
					Np	6.96E+06		1.00E-04	1.00E-03	6.96E-01		6.93E-12	5.01E-14

(e) Consequence evaluation result display sheet for each event

Risk of each accident scenarios



Running macro

(d) Event tree display sheet for each event

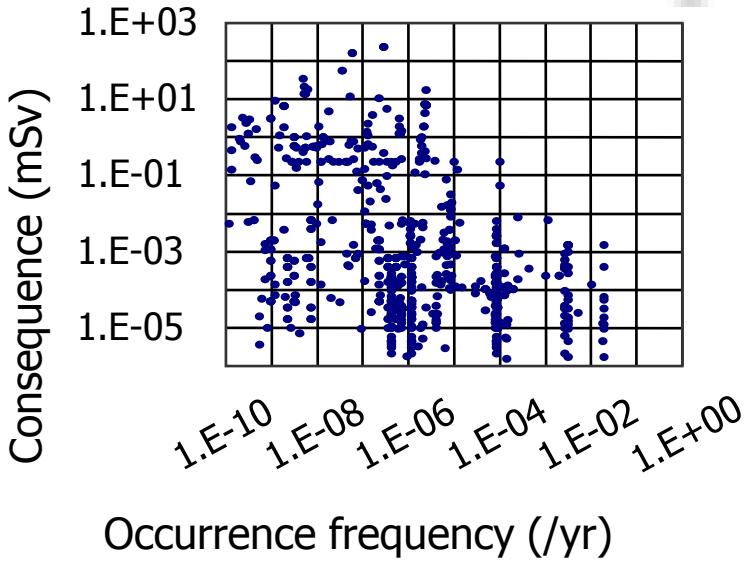
Comp.	Pu Concentrate Vessel			Risk	
Event	Loss of H2 scavenging fanction			9.9E-11 (death/y)	
Systems, components and human actionsrelated to safety functions		Risk and increasment of risk (death/			
		R (A=0)	R (A=1)	FV	RAW
Remote-operated valve for service air supply to Pu concentrate vessel		9.2E-11	2.3E-09	6.7E-02	2.3E+01
Manual-operated valve for normal compressed air supply to safety compressed air		9.8E-11	2.1E-09	2.0E-03	2.1E+01
Scavenging air supply line in Pu purification facility (piping & valves)		8.7E-11		1.1E-01	

(f) Importance evaluation result display sheet for each event

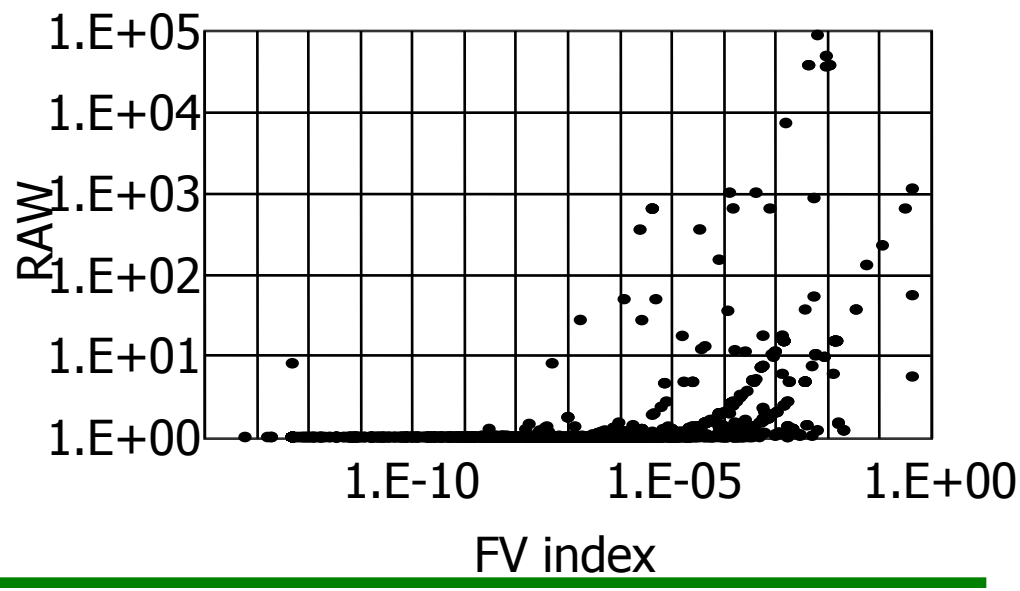
Running macro

Outline of simplified PSA procedure 9

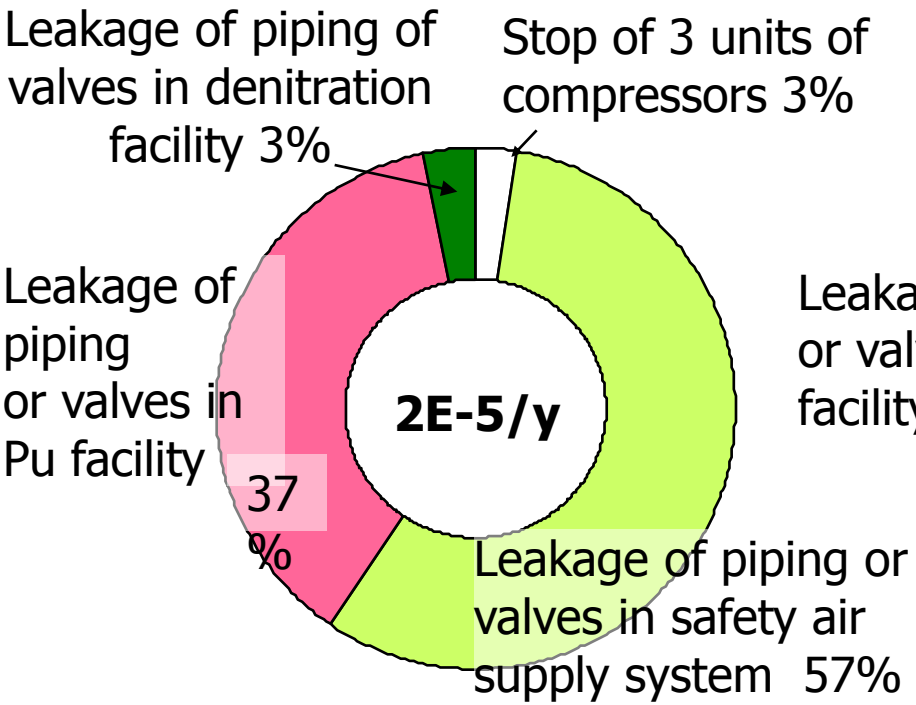
- (g) Risk of all events display sheet



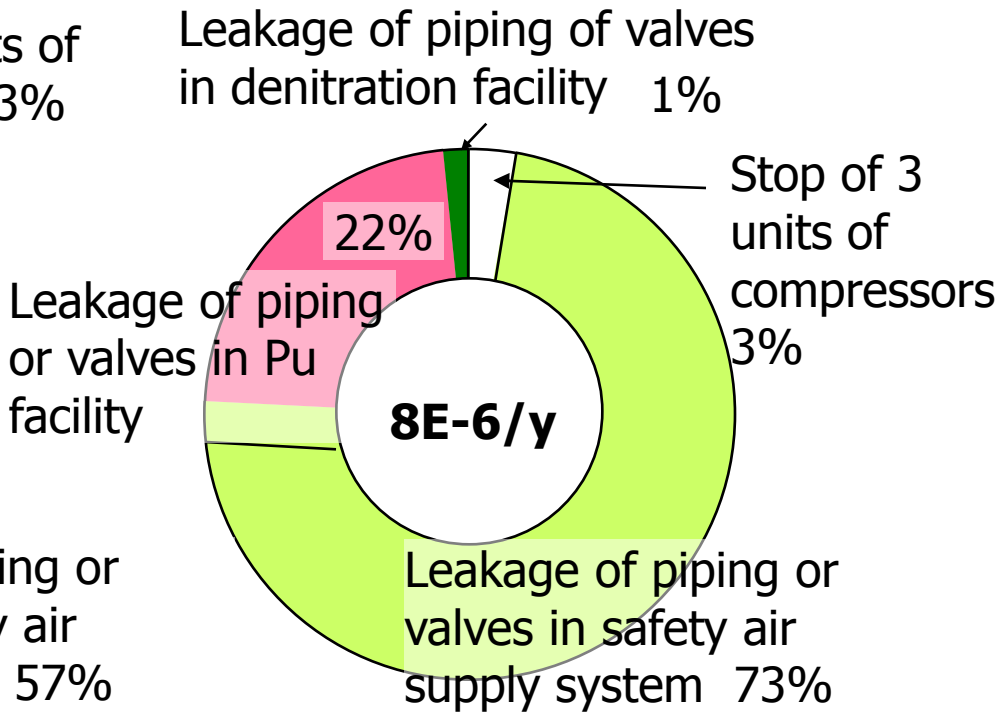
- (h) Importance related to risk of reprocessing plant.



Comparison of the Results of it and Detailed PSA



Results of Simplified PSA method

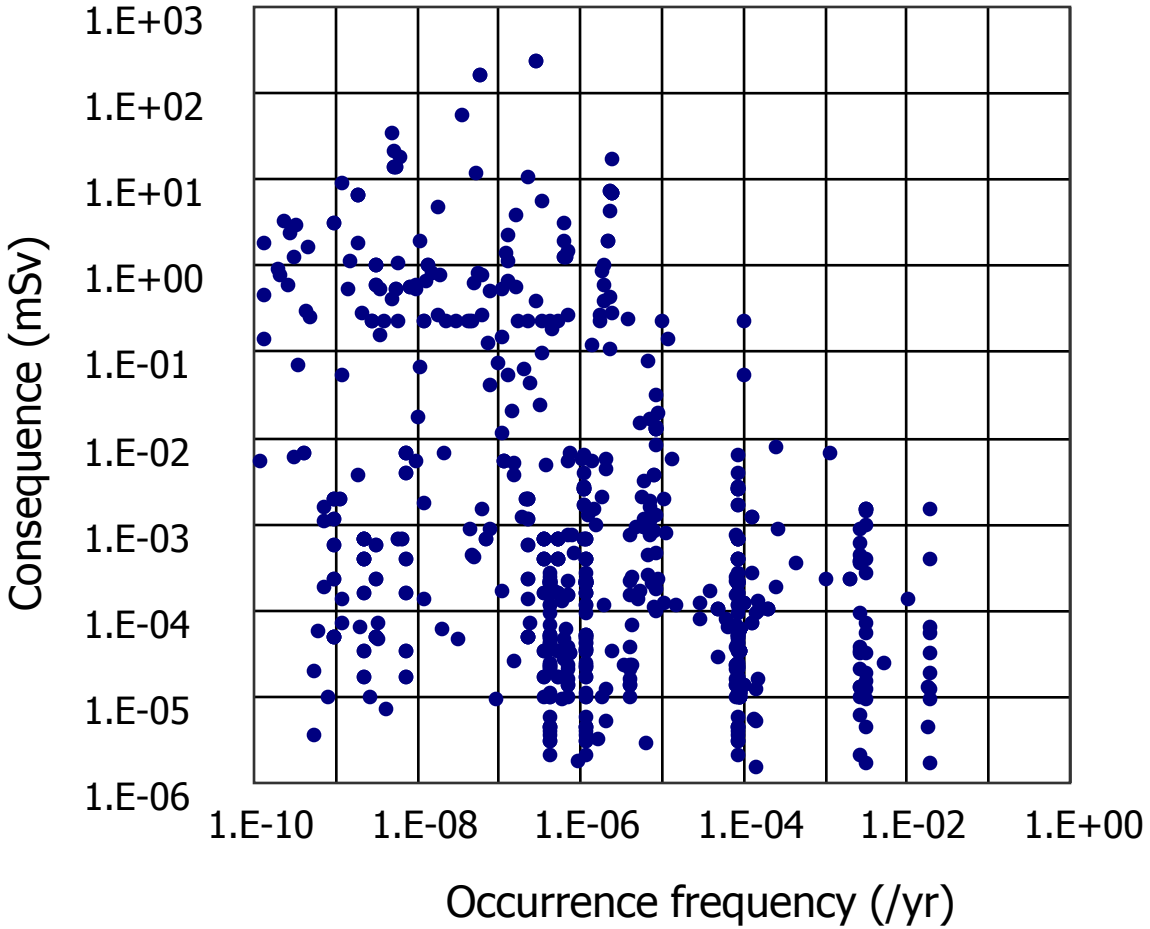


Results of detailed PSA method

The frequency calculated by the simplified PSA method well agrees with the result of detailed PSA with the reliability of 90%

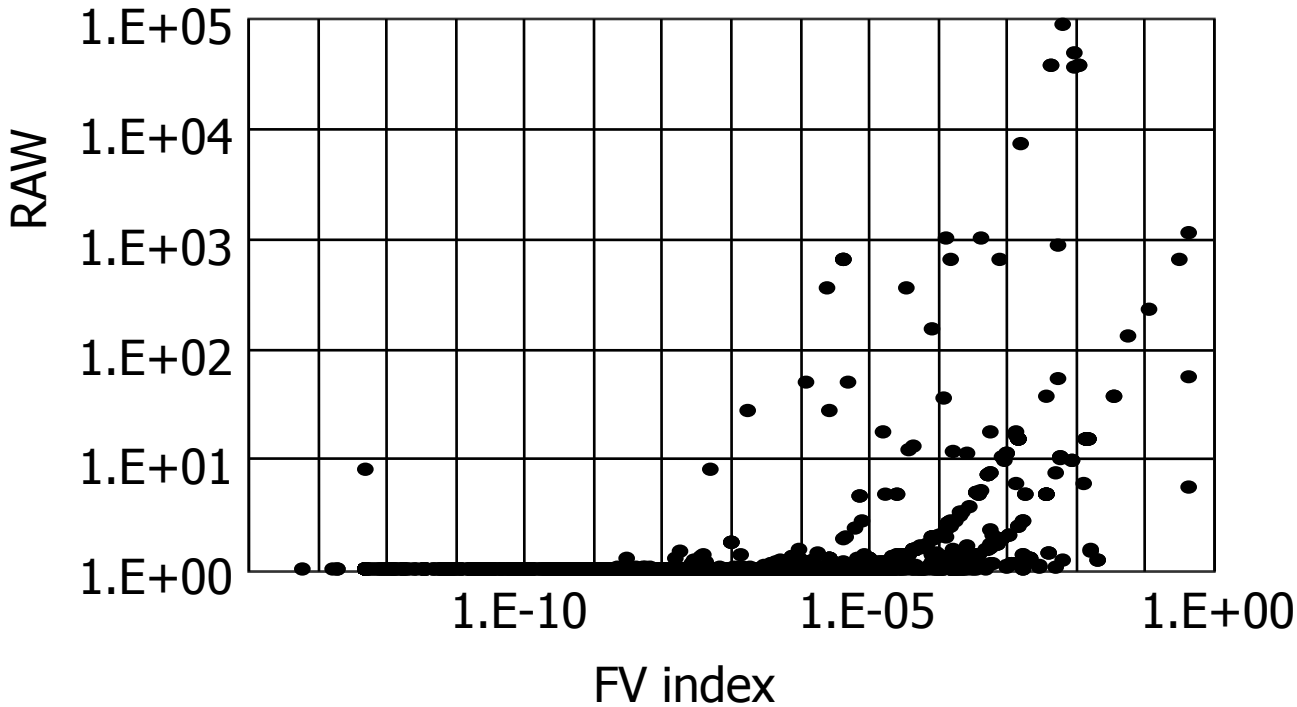
Possible utilization of risk information

A risk profile



An example of risk profile dotted according to the calculated results as of September 2007

Risk importance for each components



An example of risk importance dotted according to the calculated results as of September 2007

Utilizing the risk information- future plan

- Risk profile in 2 years
- Classification of components and systems into three classes of risk importance
- Determination of allowable outage time (AOT), examination of on-line maintenance and inspection period

- "Residual risk" and seismic PSA

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Shizuoka, Yamanashi Prefectures

Mts. Hakkouda-san **<1600m**

Aomori Prefecture

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