2.2

Overview of the Risk Assessment for Residential Air-Conditioners

- **JRAIA：Japan Refrigerating and Air-conditioning Industry associations**
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1. Agenda

【1】Mildly flammable refrigerant risk assessment and the tolerance level for residential air-conditioners

【2】Study of mildly flammable refrigerant flammability

【3】Risk assessment result by fault tree analysis

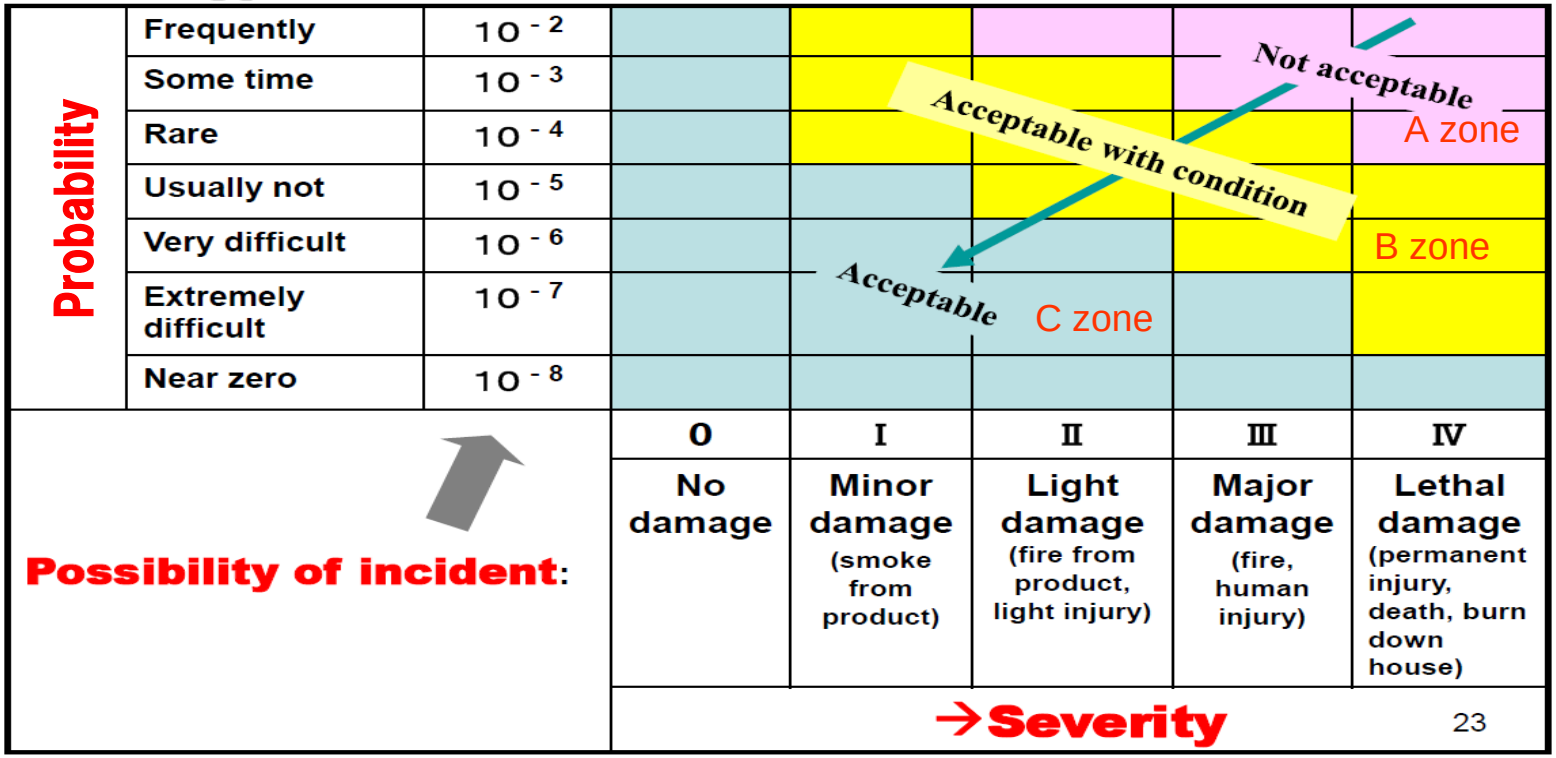
【4】Risk assessment of Multi-split type air conditioner for residential type

【5】Conclusion

2. Tolerance level of safety

Strategy of Risk Evaluation

ISO Guide 51



NITE：Home appliances tolerance level is required 1×10^{-8} per 1million in market

Amount of residential AC in Japan is 100 million

Tolerance level

Use 1×10^{-10}

Service etc. 1×10^{-9}

NITE：National Institute of Technology and Evaluation

3. Hazards of R32 and R1234yf

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Hazards of R32 & R1234yf

Pressure(50℃)	
R410A	3.07MPa
R32,yf	3.14MPa

toxicity	
R410A	None
R32,yf	**None**

yf:R1234yf

Flammability	
R410A	No
R32,yf	Mildly

Change Point

Ignition Source	
R410A	**None**
R32,yf	**Open flame**

Diesel explosion	
R410A	Yes
R32,yf	Yes

Contact flame	
R410A	Generation hydrofluoric acid
R32,yf	Generation hydrofluoric acid

- Flammability and ignition source are studied in changing to R32 and R1234yf
- Diesel explosion and contact flame study are performed universities and AIST don't change

4. FTA indoor space assumption

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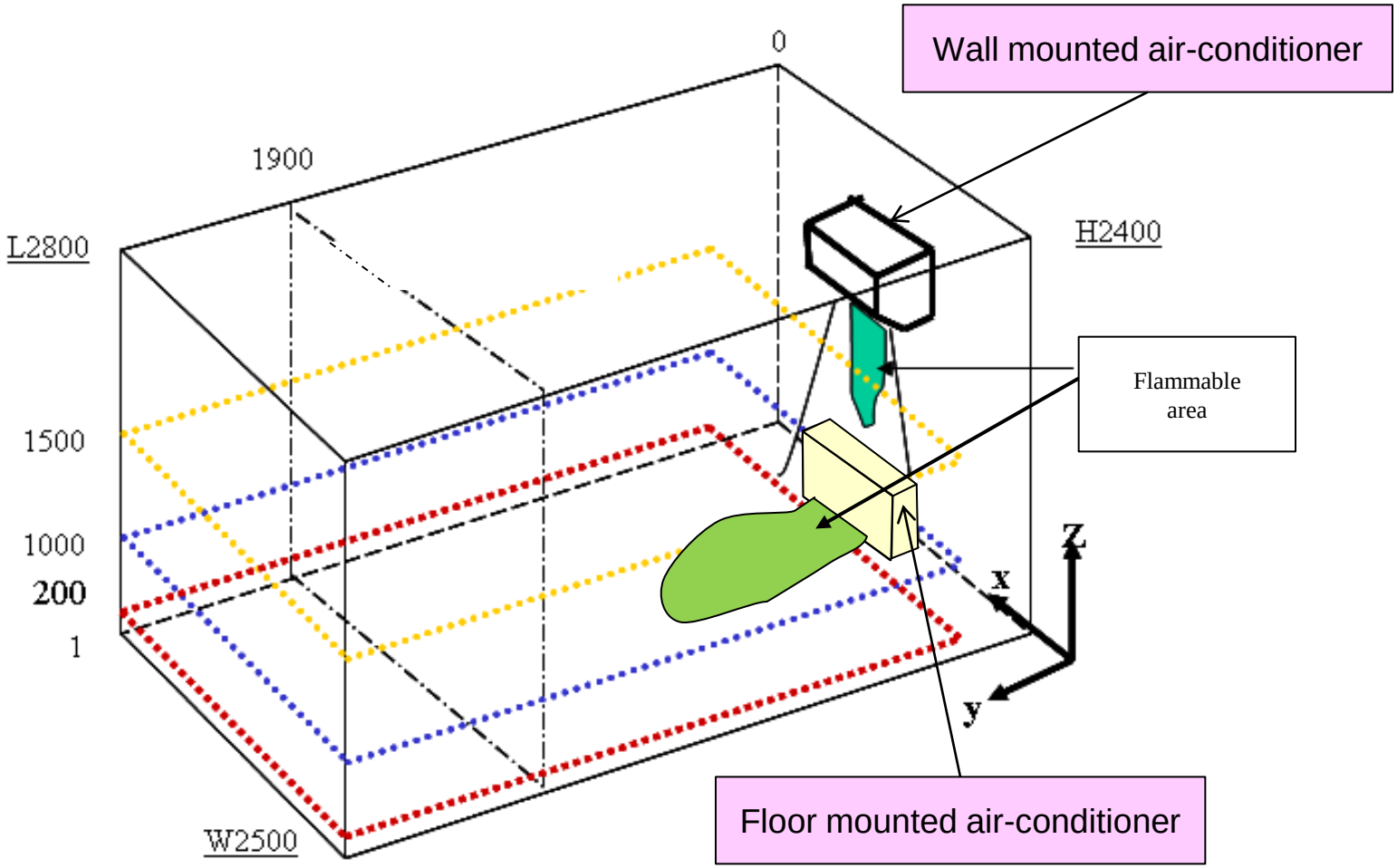
●Indoor space, the conditions of a simulation



5. Flammable volume and time integration

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●Flammable Volume and Time Integration

The rate of flammable volume being in certain space and certain time range

	R32	R1234yf	R290
1.1 Logistics	2.00×10^{-4}	2.20×10^{-4}	5.50×10^{1}
2.2 Installation	2.40×10^{-3}	2.50×10^{-4}	7.16×10^{2}
2.5 Mistakes	9.00×10^{-3}	1.30×10^{-2}	7.75×10^{-2}
2.10 Refrigerant charge	9.97×10^{1}	3.70×10^{2}	8.51×10^{3}
3.1 Indoor unit operation	5.00×10^{-4}	5.50×10^{-4}	1.41×10^{1}
3.5 Indoor unit stop	2.40×10^{-2}	2.50×10^{-2}	7.16×10^{3}
4.1 Outdoor unit	9.00×10^{-2}	1.30×10^{-1}	7.76×10^{-1}
5.1 Connecting pipe	9.97×10^{2}	3.70×10^{3}	8.51×10^{3}
7.8 Service/relief	9.07×10^{-3}	1.30×10^{-2}	7.75×10^{-2}
8 Disposal	Using similar situations and values		

6. Study of ignition：AIST

Ignition test of the magnetic contactor

Fig.5 The magnetic contractor (CLK65)

Extinction Diameter of Opening

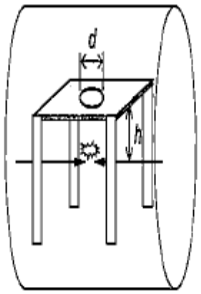

Fig.6 Apparatus for extinction diameter measurement.

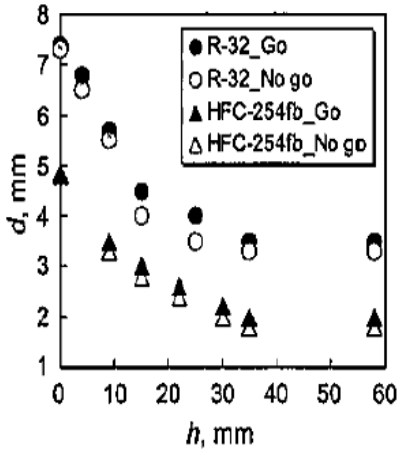

Fig.7 *d** vs. *h* for R-32 and HFC-254fb.

●Under 3mm of clearances in case cover
⇒ mildly flammable refrigerant no flame propagation through clearances

■Reference
Study on Minimum Ignition Energy of Mildly Flammable Refrigerant、2011

●Diameter of opening(d) and distances(h)
⇒ Estimating mildly flammable refrigerant flame can extinction

■Reference
THE INTERNATIONAL SYMPOSIUM on NEW REFRIGERANTS and ENVIRONMENTAL TECHNOLOGY 2012

7. Study of flammability Ⅰ：TUSS

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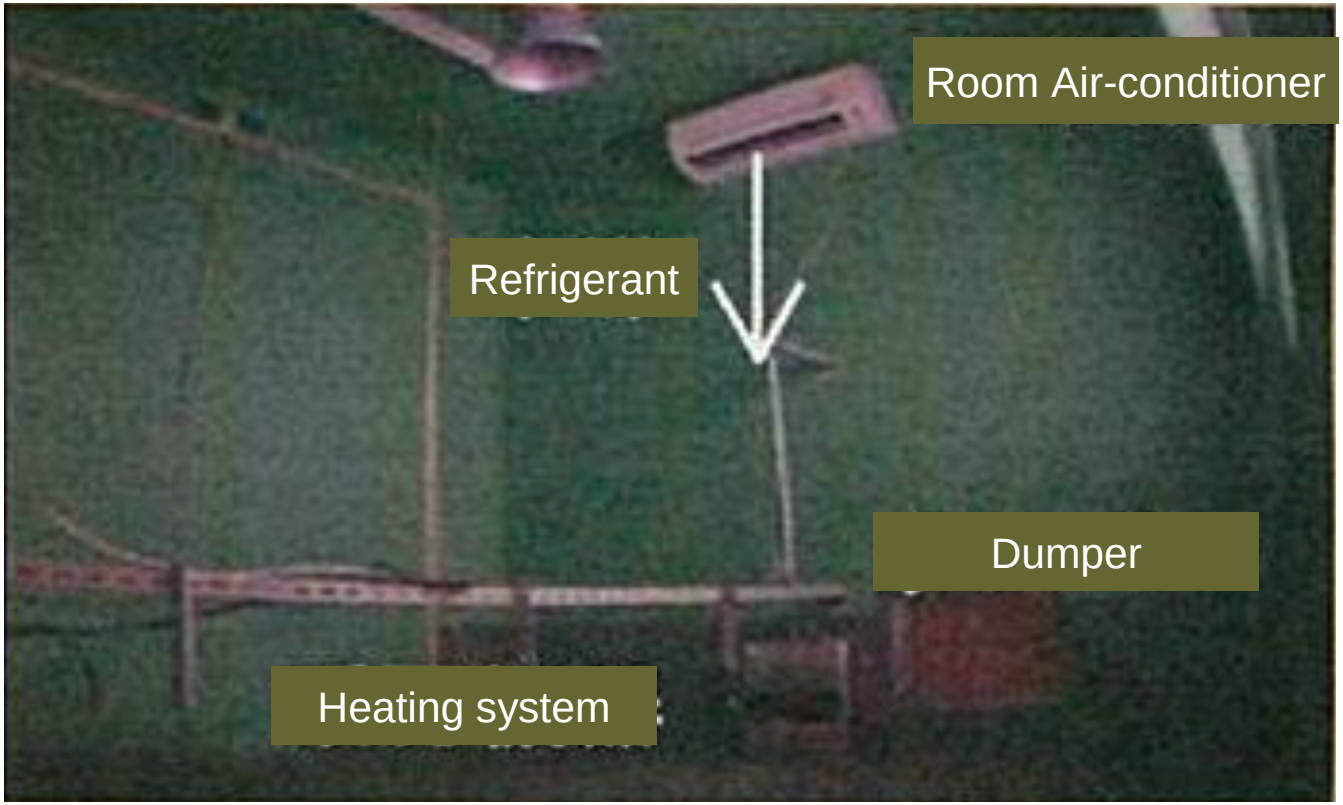
Evaluation of physical hazard

- Study of flammability with heating system, mildly flammable refrigerant leaked by room air-conditioner

■Reference
THE INTERNATIONAL SYMPOSIUM on NEW REFRIGERANTS and ENVIRONMENTAL TECHNOLOGY 2012



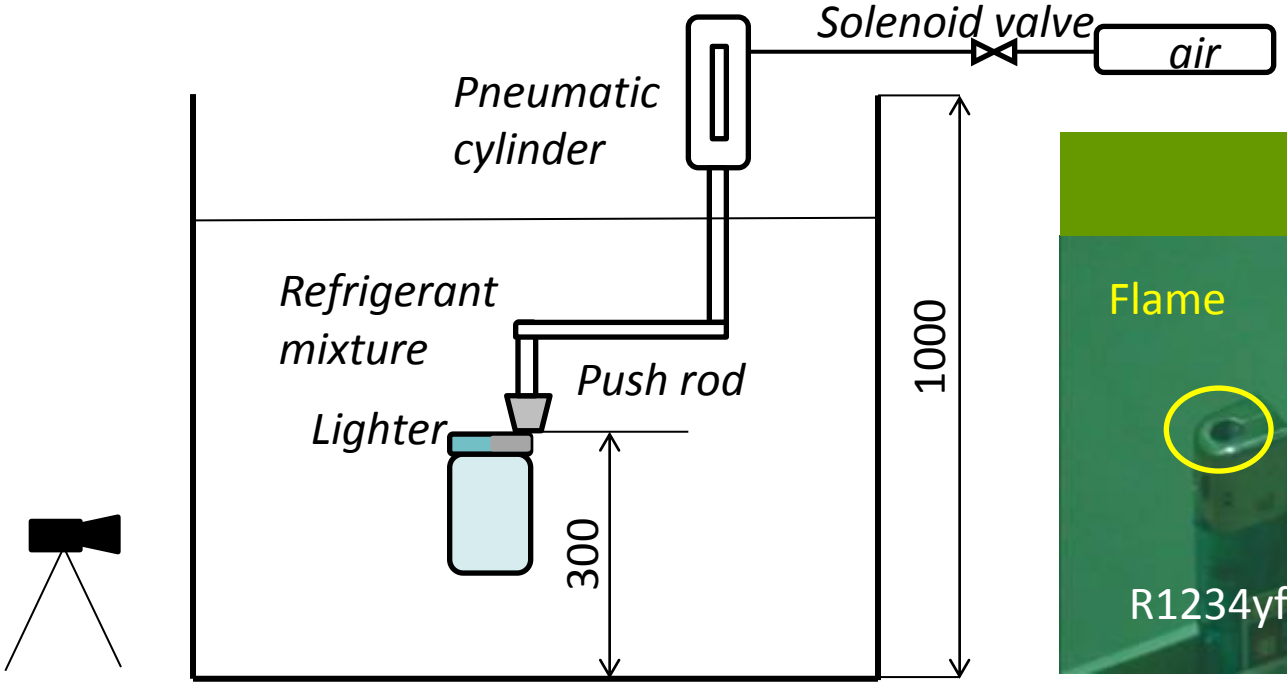
●No flame propagation across the whole space was observed

8. Study of flammability Ⅱ：TUSS

Evaluation of lighter

▪The refrigerant concentration at a height of 0.3 m was within ignitable range by a spark from a piezo lighter.

■Reference
THE INTERNATIONAL SYMPOSIUM on NEW REFRIGERANTS and ENVIRONMENTAL TECHNOLOGY 2012



- Ignition was observed when the button was pushed
- But flame propagation from the outlet of the lighter to the surrounding *n*-butane/mildly flammable refrigerant mixture

9. Risk assessment

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●reexamination of ignition source

●From study of R32

⇒mildly flammable refrigerant in a room air-conditioner leaked in the space, but no flame propagation across the whole space

⇒Ignition was observed at the outlet of piezo lighter, but no flame propagation of lighter to *n*-butane/mildly flammable refrigerant mixture

⇒Under 3mm of clearances in case cover, mildly flammable refrigerant no flame propagation through clearances

Ignition source	**R410**	**R32**	**R290** （Propane）
●Flame （Welding torch, Oil lighter, Candle）	No ignition	Ignition→ Rarely ignition	Ignition
●Electric spark	No ignition	Ignition→ Rarely ignition	Ignition
●Static electricity	No ignition	Ignition → No ignition	Occasionally Ignition

10. FTA of indoor unit using（Reexamination）

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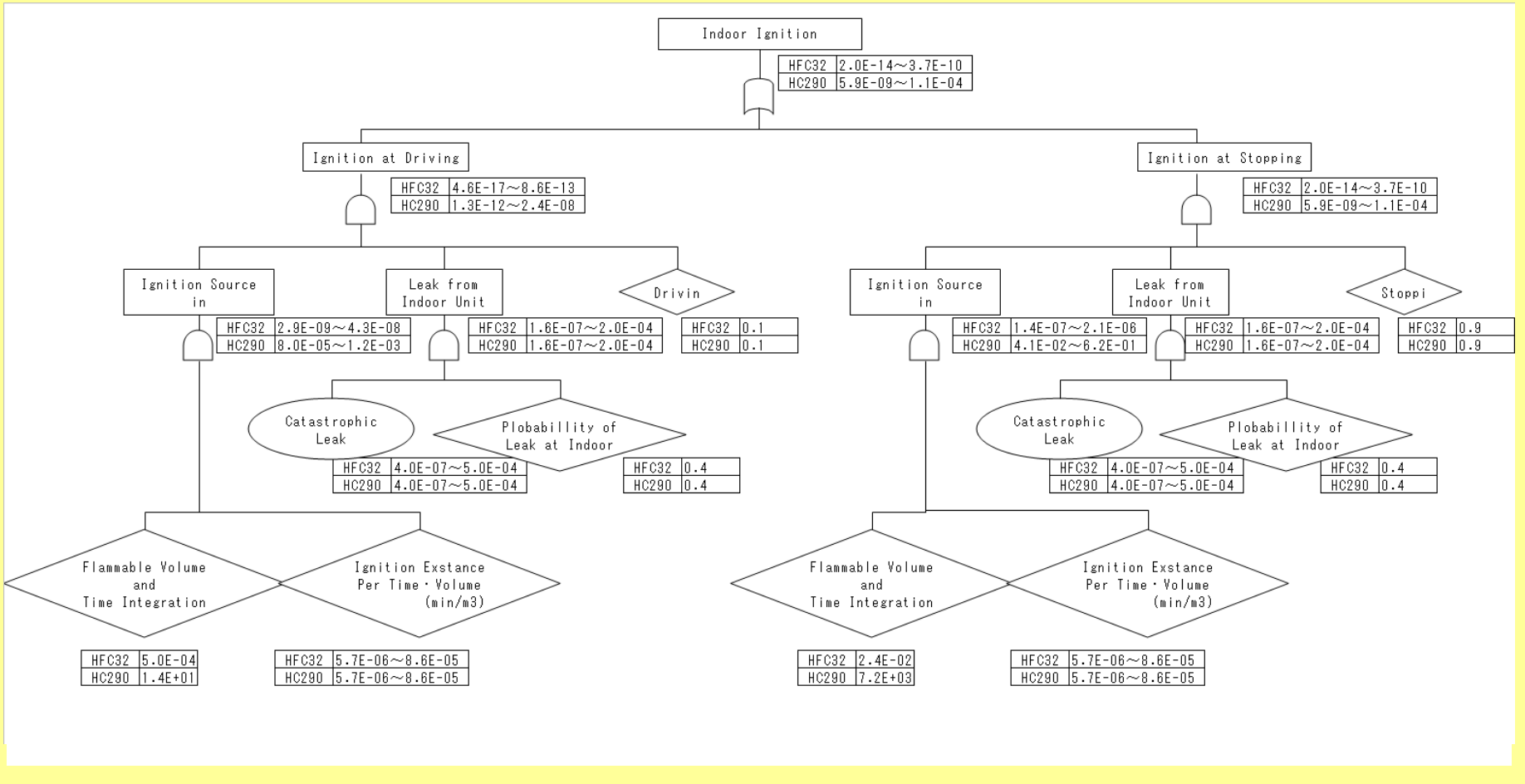
・FTA ignition probability

＝（Existence of Ignition source）×（Existence of flammable volume）



11. FTA of life cycle stage（Reexamination）

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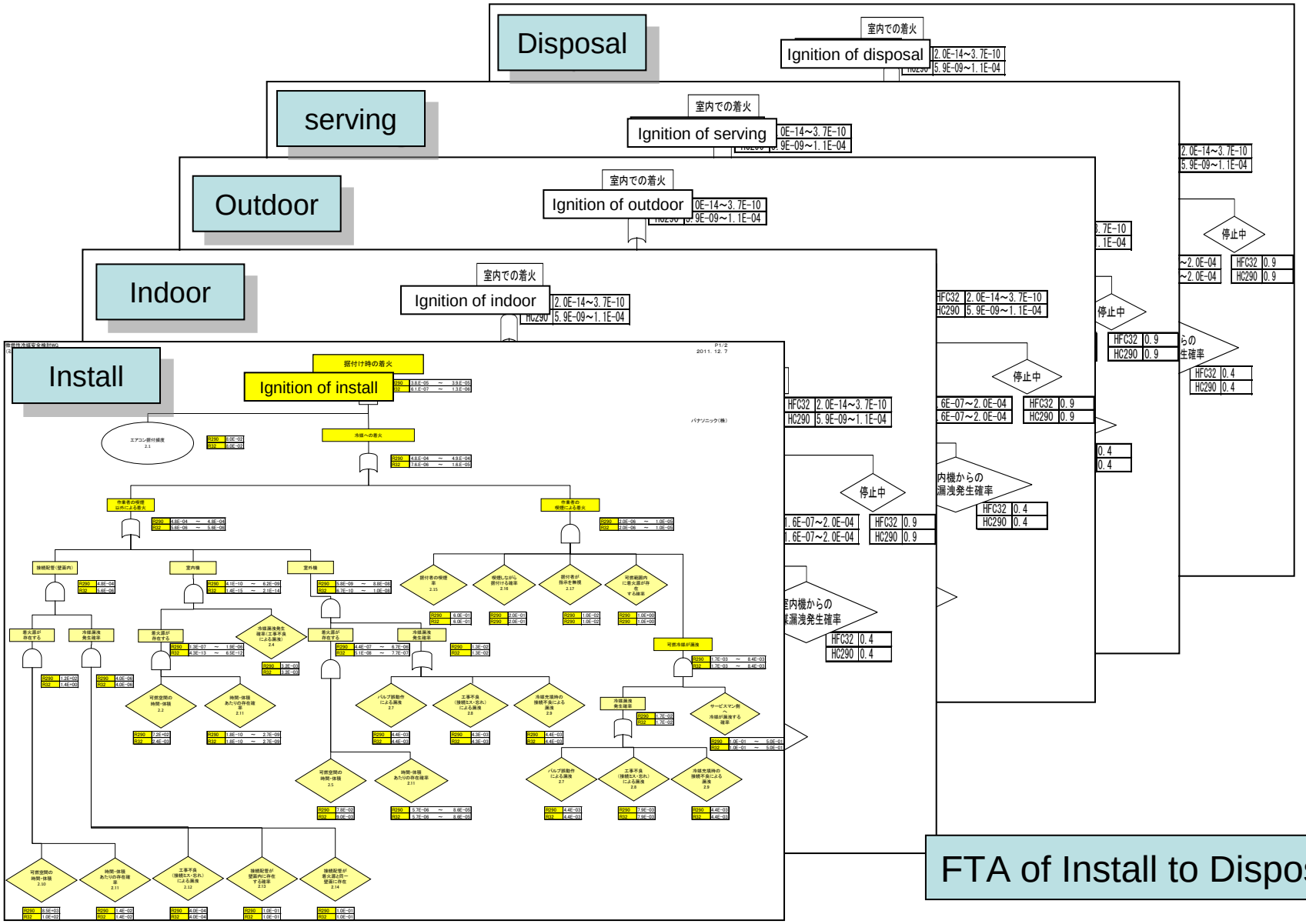

12. Results of risk assessment

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Wall mount type air conditioner

Risk: Ignition Probability			
	R32	R1234yf	(ref. R290)
Logistic	4.1×10^{-17}	4.5×10^{-17}	$1.9 \times 10^{-8} \sim 1.2 \times 10^{-6}$
Installation	2.7×10^{-10}	3.1×10^{-10}	$1.5 \times 10^{-6} \sim 1.7 \times 10^{-5}$
Use (Indoor)	3.9×10^{-15}	4.3×10^{-15}	$5.9 \times 10^{-9} \sim 1.1 \times 10^{-4}$
(Outdoor)	1.5×10^{-10}	2.1×10^{-10}	$9.7 \times 10^{-13} \sim 1.9 \times 10^{-8}$
Service	3.2×10^{-10}	3.6×10^{-10}	$9.3 \times 10^{-6} \sim 1.7 \times 10^{-5}$
Disposal	3.6×10^{-11}	5.3×10^{-11}	$1.8 \times 10^{-5} \sim 1.3 \times 10^{-4}$

- Probability of indoor use is lower than tolerance level 10^{-10}.
- Tolerance level 10^{-9} in service, installation and others is satisfied in all stages.

- The ignition probability of R32 and R1234yf is nearly same.
  (Attention : R1234yf is extended flammable range in high humidity condition.

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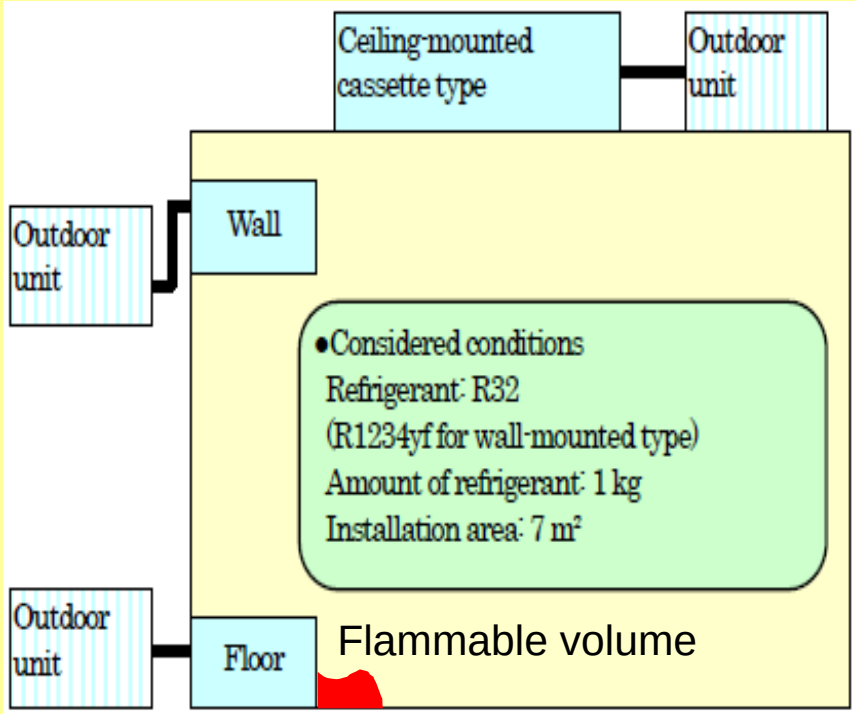
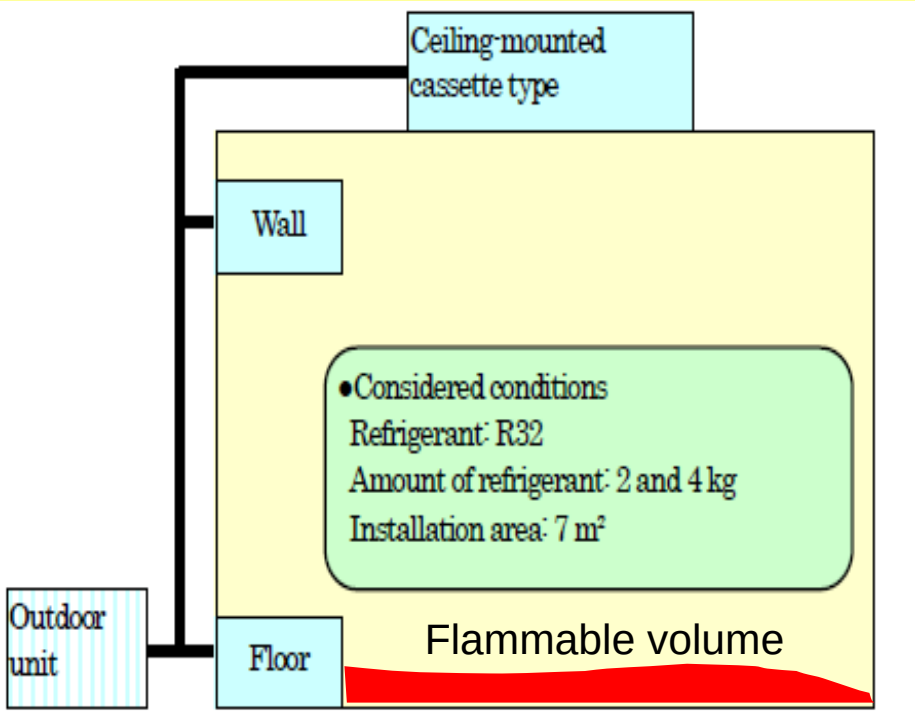
Difference of ordinary and multi-split type air conditioner



Ordinary air conditioner
(1 indoor unit: 1 outdoor unit)



Residential-use multi-split type air conditioners
(1 outdoor unit: multiple indoor units)

- Issue : 4kg refrigerant amount and floor standing unite not satisfy to tolerance level

14. Multi-split type air conditioner

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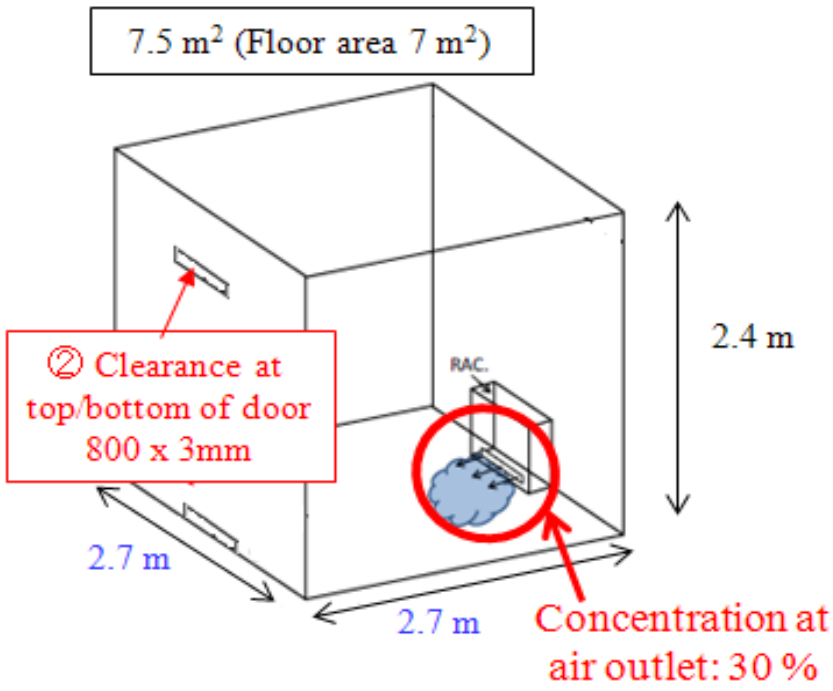
New simulation condition for floor mounted unite of multi-split type air conditioner



Item	Practical house conditions
① Air exhaust opening in upper space	No
② Clearance at top/ bottom of a door	Yes (W800 * H3 mm)
③ Leak point (internal)	100 %
④ Concentration at air outlet (external)	30 % (initial)
⑤ Space size (W*D*H)	2.7*2.7*2.4

15. Multi-split type air conditioner

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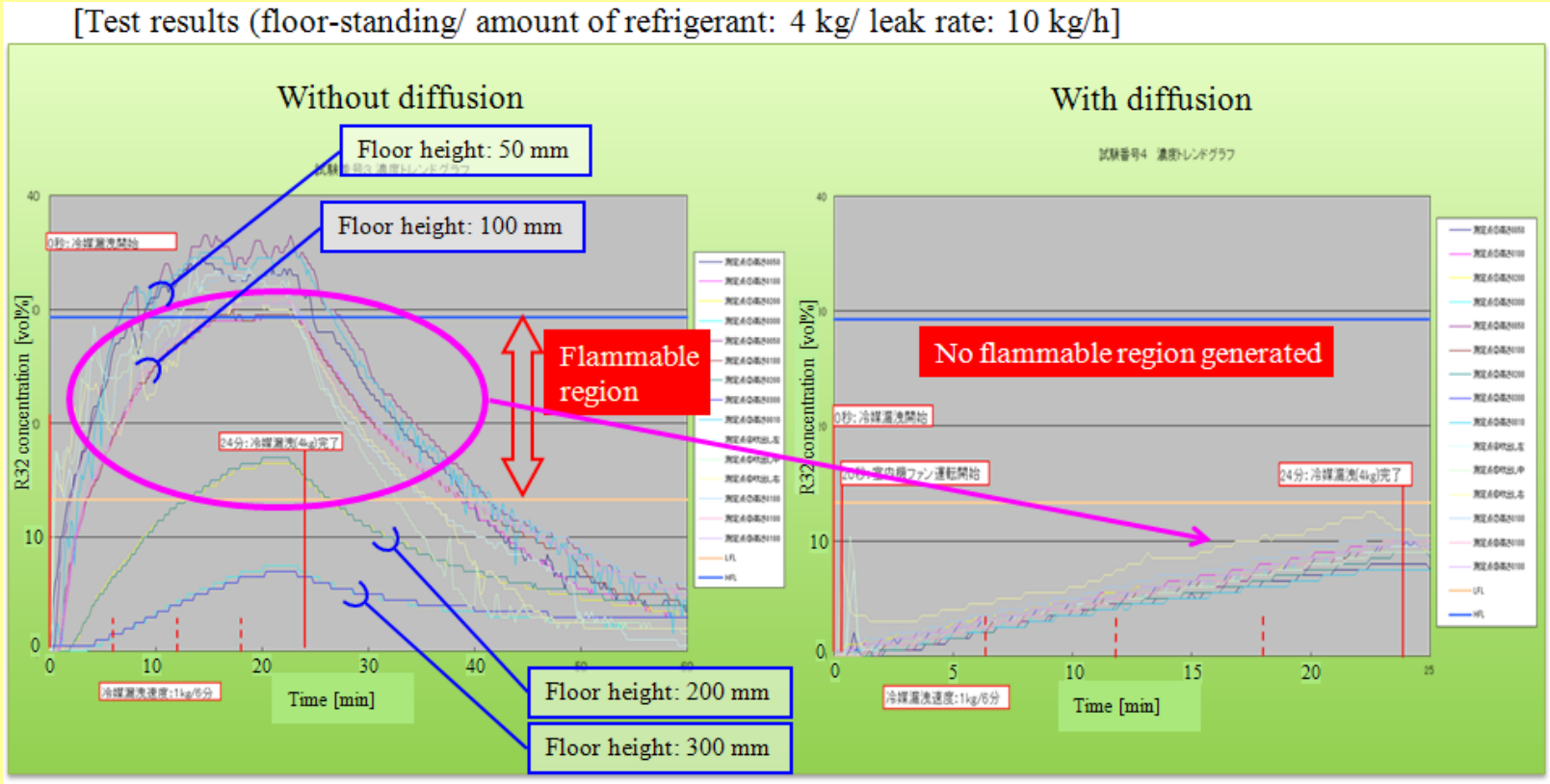
Test results of refrigerant leakage inside room(approx. 7.5m^2 room)



- Using the indoor unit fan to diffuse the refrigerant
- In the case of 4 kg refrigerant leakage, LFL was not reached.

16. Multi-split type air conditioner

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- Ratio of occurrence patterns and their ignition probabilities in indoor use

Pattern		[Method 2]		Power	Operation / Stop	Parts fault	Occurrence ratio	Ignition risk probability
		Diffusion with I.U. fan	Breaker OFF countermeasure					
General	1	Diffusion possible	In order to avoid breaker OFF, add caution label to unit	Breaker ON	Operating (indoor fan ON)	No	48.80%	7.7^{-12}
	2				Stop → indoor fan ON	No	50.91%	8.1^{-12}
Not general	3	Diffusion not possible	Same as above	Breaker ON	Stop	Yes	0.04%	5.6^{-11}
	4			Power outage		No	0.002%	2.4^{-12}
	5			Breaker OFF		No	0.25%	3.9^{-10}
							Sum. ignition risk probability:	4.7^{-10}

- The ignition risk is 4.7×10^{-10} when patterns 1 to 5 are combined

17. Multi-split type air conditioner

Amount of multi-split AC in Japan → Use Criteria10^{-9}
Service etc.10^{-8}

Risk: Ignition Probability		
Type	Representative model	R32
Logistics (for each warehouse)	Middle-size warehouse	1.1×10^{-09}
Installation	3.24 m^2 veranda	9.0×10^{-09}
Use (indoor)	7 m^2 room	4.7×10^{-10}
Use (outdoor)	3.24 m^2 veranda	1.1×10^{-09}
Service	3.24 m^2 veranda	4.3×10^{-09}
Disposal	3.24 m^2 veranda	4.1×10^{-10}

- In using the value of 10^{-9} estimate safety
- Probabilities of installation and servicing is acceptable

18. Conclusion

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Single wall mount AC Risk Assessment

- Calculate the ignition probability values by FTA through life cycle and reexamination by study results of universities and AIST
- Result of single wall mounted air conditioner with R32 and R1234yf

Using :1×10^{-10} Service & Install :1×10^{-9} ⇒ Those values are acceptable

★Using of R1234yf , be attention to the humidity and the HEX design

Multi-split type AC Risk Assessment

- Result of Multi-split type air conditioner

With countermeasure of fun diffusion make value of Using :1×10^{-9} and service and install :1×10^{-8} ⇒ Those vales are acceptable

Universities : Tokyo university, Tokyo university of science Suwa

AIST : The National Institute of Advanced Industrial Science and Technology

Thank you very much