

Introduction

- Target is to make a proposal for safety measures which can achieve tolerable ignition risk for VRF with lower flammability refrigerants such as R32.
- Risk factors are identified to be a large charge amount and some severe installation cases in which flammable space appears easily.
- Ignition risk is evaluated using measurement results of leak rate and CFD results to calculate size and duration of flammable space.

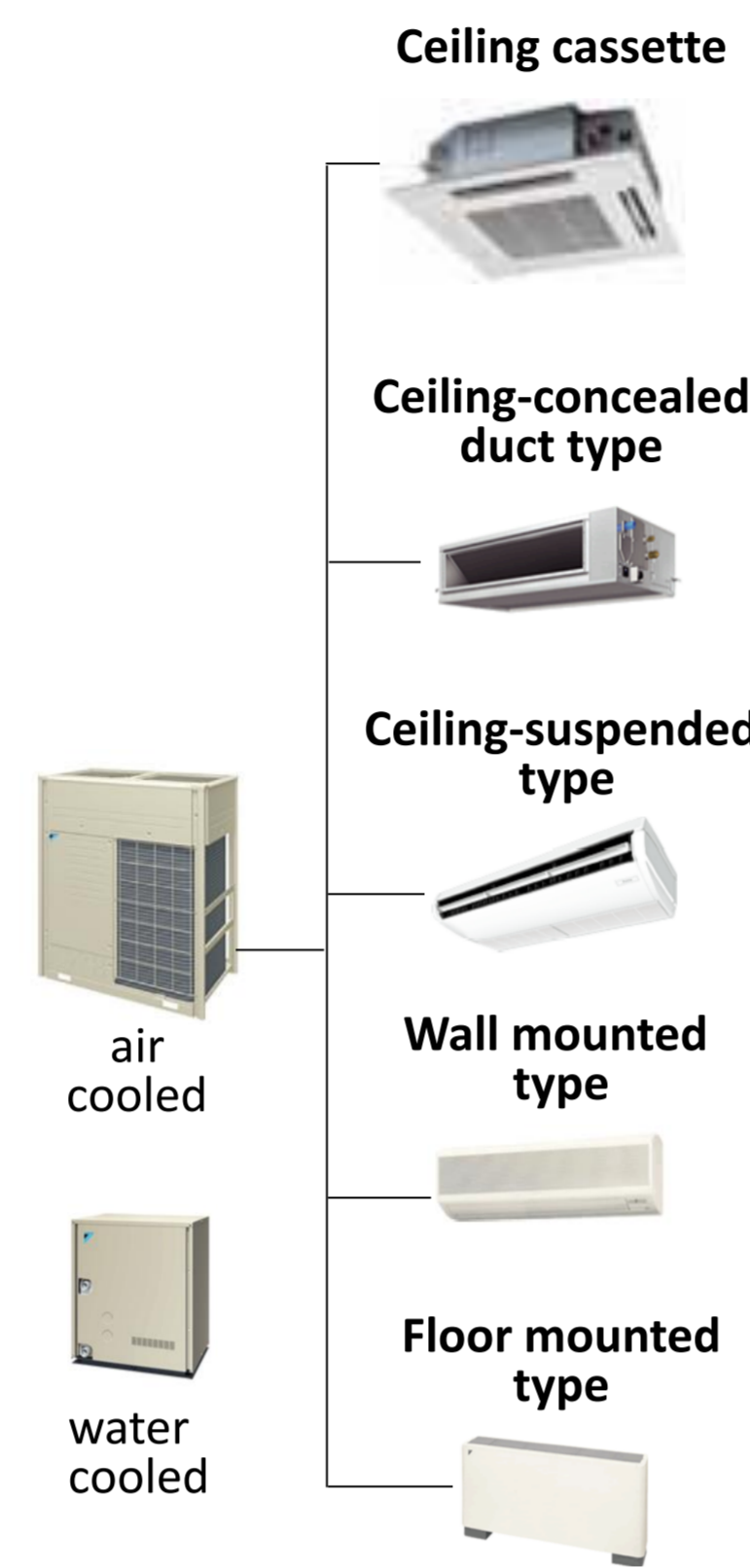
Conclusion

- In indoor operation, smoking with oil lighter by overtime worker in office at night after ventilation stops makes a non-tolerable risk. Shut-off valve, mechanical ventilation etc. can reduce risk to tolerable level.
- In outdoor operation, boiler ignition near outdoor unit in semi-underground makes a non-tolerable risk. Some measures to exhaust the leaked refrigerant can reduce risk to tolerable level.
- Safety measures are summarized in safety guidelines of JRAIA.

System

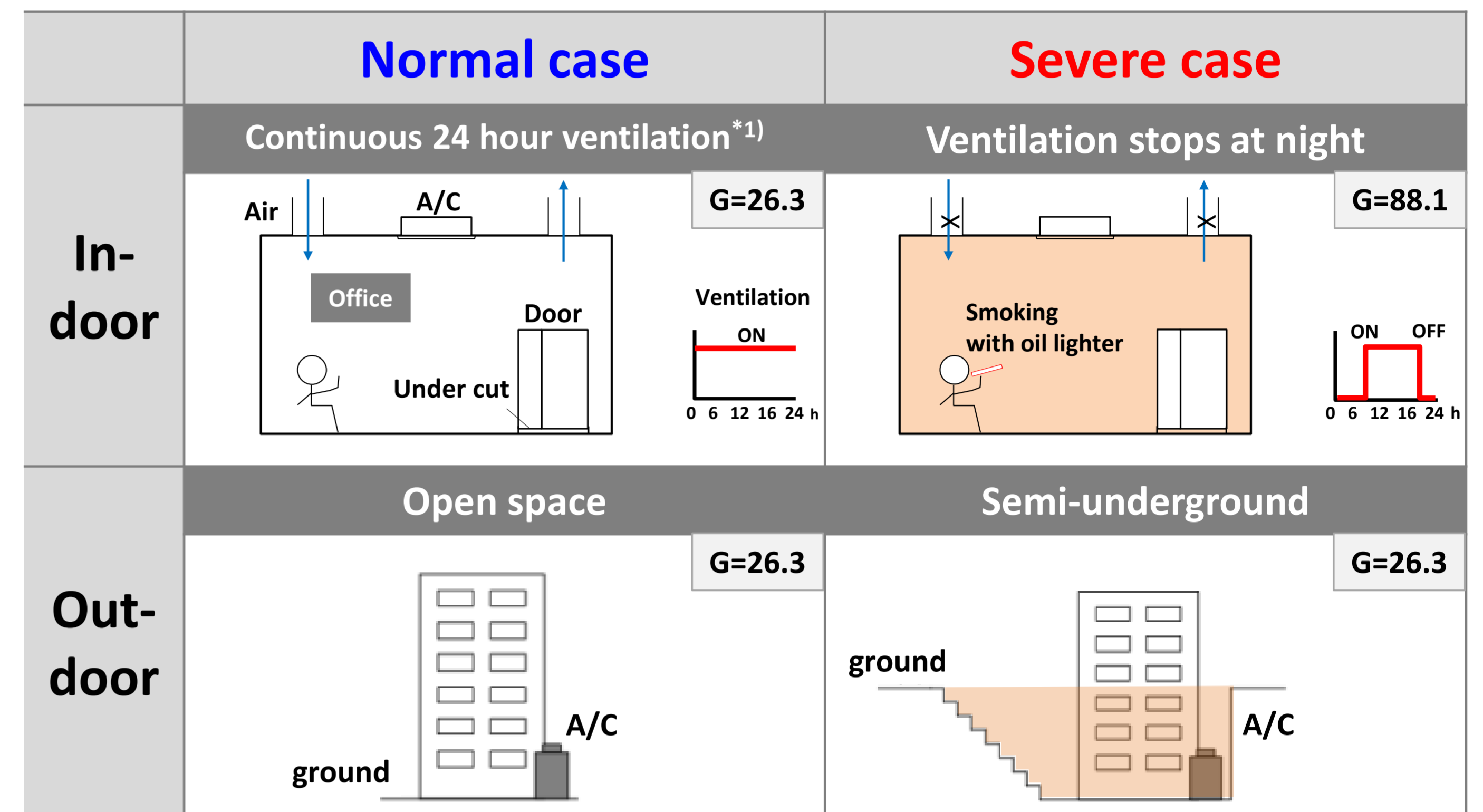
- Large charge amount and many types of units.

Cooling capacity	14.0 – 168 kW
Refrigerant charge	5 – 104 kg (R410A)
Operation	Indoor units, max 64units, can be operated individually
Type of indoor unit	<ul style="list-style-type: none"> • Ceiling mounted cassette • Ceiling-concealed duct type • Ceiling-suspended type • Wall mounted type • Floor mounted type
Type of outdoor unit	<ul style="list-style-type: none"> • Heat Pump • Heat Recovery • Water cooled unit



Typical risk case

- Both of normal and severe cases are evaluated.



*1) Air flow rate is assumed to be adequate.

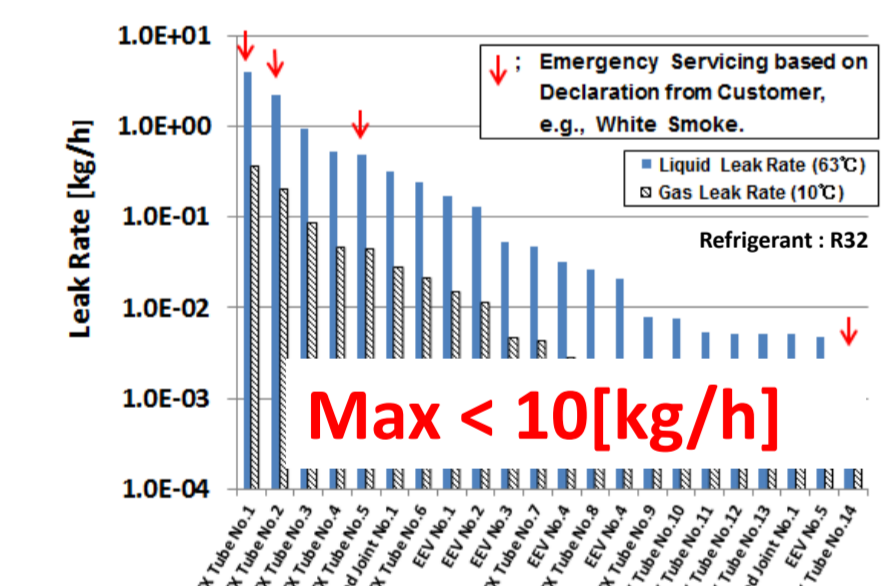
R32 charge amount : G [kg]

Leak rate and probability

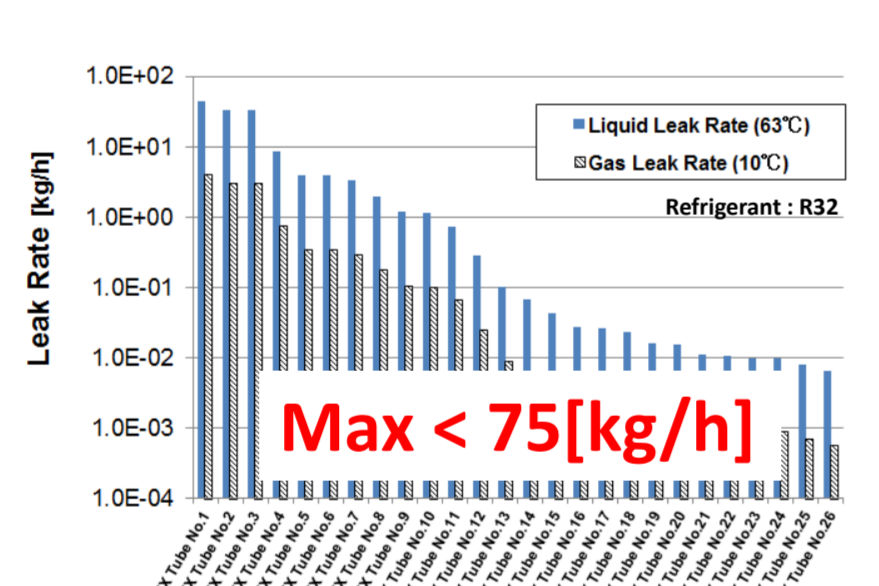
- Measured leak rate and probability based on service data.

		Slow	Rapid	Burst	Evidence
Leak rate [kg/h]		< 1	1 - 10	10 - 75	a, b
Cause of leakage		Pin-hole /Corrosion of pipe	Corrosion of heat exchanger	Breaking of pipe	Observation of leakage hole
Probability [ppm/(unit·year)]	indoor	345	5	None (no compressor)	N x 10
	outdoor	6130	1340	134 (with compressor)	

a. Indoor leak rate



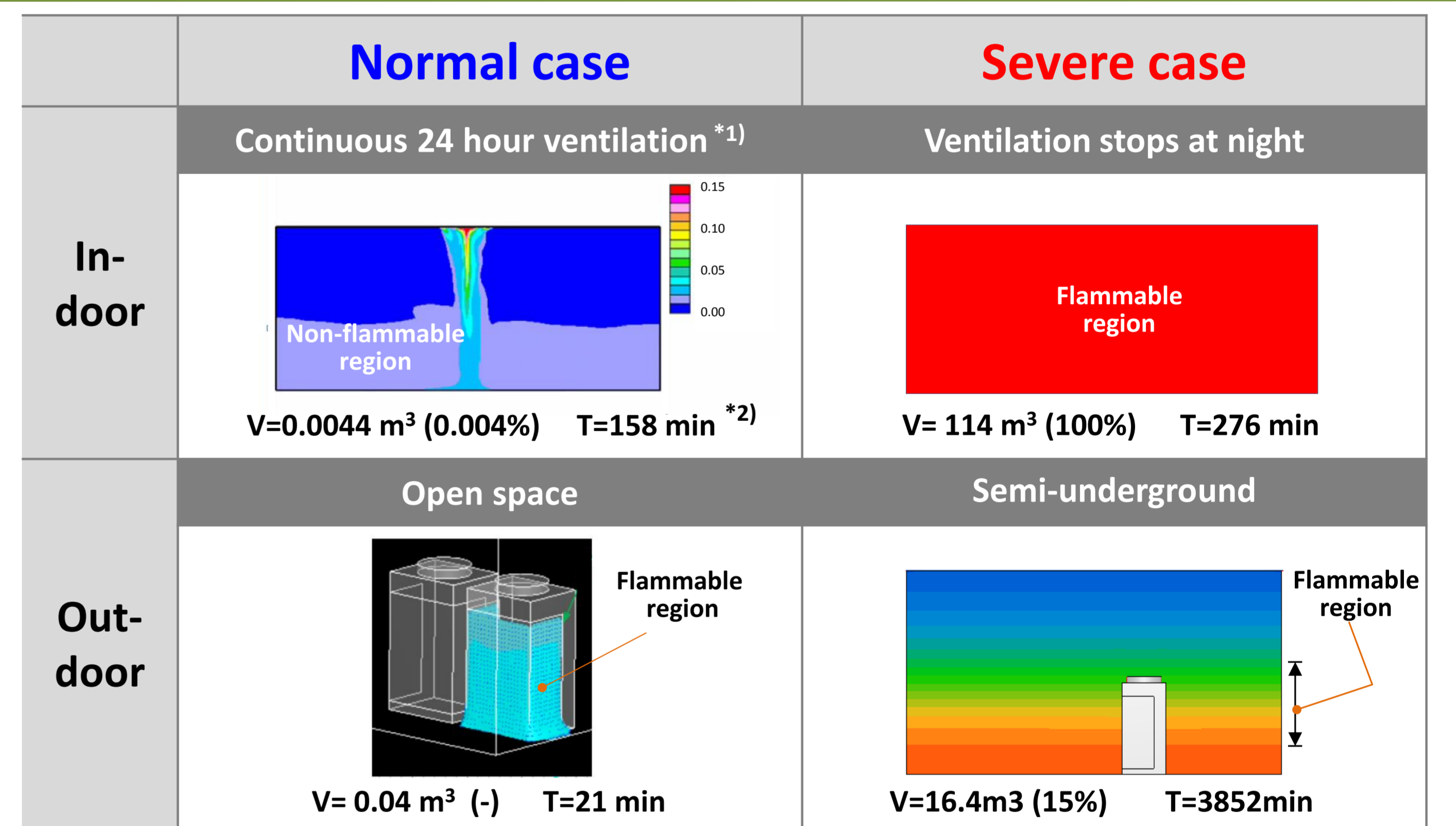
b. Outdoor leak rate



c. Number of servicing report indicating rapid leak

		2010, Manufacturer B [number/year]			
unit	White smoke	Burnt smell	Holes in pipe	N (total)	
Indoor	0	1	0	1	
Outdoor	1	3	3	7	

Flammable region



V : Mean volume size of flammable region [m³], (ratio to all volume) [%]
T : Duration of flammable region [min]

*1) Air flow rate is assumed to be adequate.

*2) Hihara et al., Progress at the University of Tokyo, JSREA, Progress report, 2013, pp.16

Results of risk assessments

- In severe cases, the ignition risks exceed tolerable risk.

not tolerable | tolerable [time/(unit·year)]

		Normal case	Severe case	
Indoor	Life stage		without measure	with measure
	Operation	3.5×10^{-12}	7.6×10^{-9}	3.5×10^{-12} Ventilation
	Installation	1.9×10^{-9}	1.5×10^{-10}	Shut off valve
	Repairing	8.7×10^{-11}	7.6×10^{-10}	Safety alarm
	Disposal	2.9×10^{-14}		
Outdoor	Operation	1.9×10^{-11}	1.7×10^{-6}	2.5×10^{-13} Ventilation
	Installation	1.9×10^{-9}	1.1×10^{-8}	1.9×10^{-6} Carring of portable leak detector, and education
	Repairing	1.4×10^{-9}	3.6×10^{-7}	
	Disposal	2.4×10^{-10}	4.2×10^{-6}	6.1×10^{-6}
	Storage	7.8×10^{-17} ~ 1.8 x		

Refrigerant : R32

Safety measures

- In severe cases, each safety measures are defined. These measures are effective also for R1234yf & ze in high moisture condition.

Installation case	Safety measures
Choose one of measures shown below	
Indoor Other than floor mounted type	A) Ref. charge $M \leq 1/4 \times LFL \times A \times \text{height_of_leak_position}$ B) Mechanical ventilation with adequate air flow rate C) Shut-off valve
Indoor Floor mounted type	A) Ref. charge $M \leq 1/4 \times LFL \times A \times \text{reaching_height_with_air_circulation}$ B) Mechanical ventilation with adequate air flow rate C) Shut-off valve
Outdoor Semi-underground	A) Ref. charge $M \leq 1/2 \times LFL \times A \times \text{depth}$ B) Mechanical ventilation C) Air circulation
Outdoor Machinery room	A) Mechanical ventilation operated at all times with adequate air flow rate

Documentation

- JRAIA : VRF Sub working, Risk Assessment for VRF System, 2015 Final report, JSREA, 2016
- JRAIA : VRF Sub working, Risk assessment for VRF system with mildly flammable refrigerants, JSREA, Refrigeration, 2016/5
- JRAIA, JRA GL-16:2016, Guideline of design construction for ensuring safety against refrigerant leakage from commercial air conditioners using lower flammability (A2L) refrigerants
- JRAIA, JRA 4070:2016, Requirements for ensuring safety against refrigerant leakage from commercial air conditioners using lower flammability (A2L) refrigerants