

Introduction

- [Subject system] water-cooled chillers and air-cooled heat pumps
 [Refrigerants (A2L)] R32, R1234yf, R1234ze(E)
 [Risk assessment procedure]
1. Setup of an object product
 2. Analysis of risks
 3. Calculation of accident probability
 4. Planning of safety measures
 5. Establishment of the guideline

Conclusion

- With ventilation, the lower flammable refrigerants can be safely used for chillers

Table 1 Probability of accidental fire [1/(unit year)]

With ventilation	Without ventilation
3.89×10^{-12}	1.32×10^{-4}

System

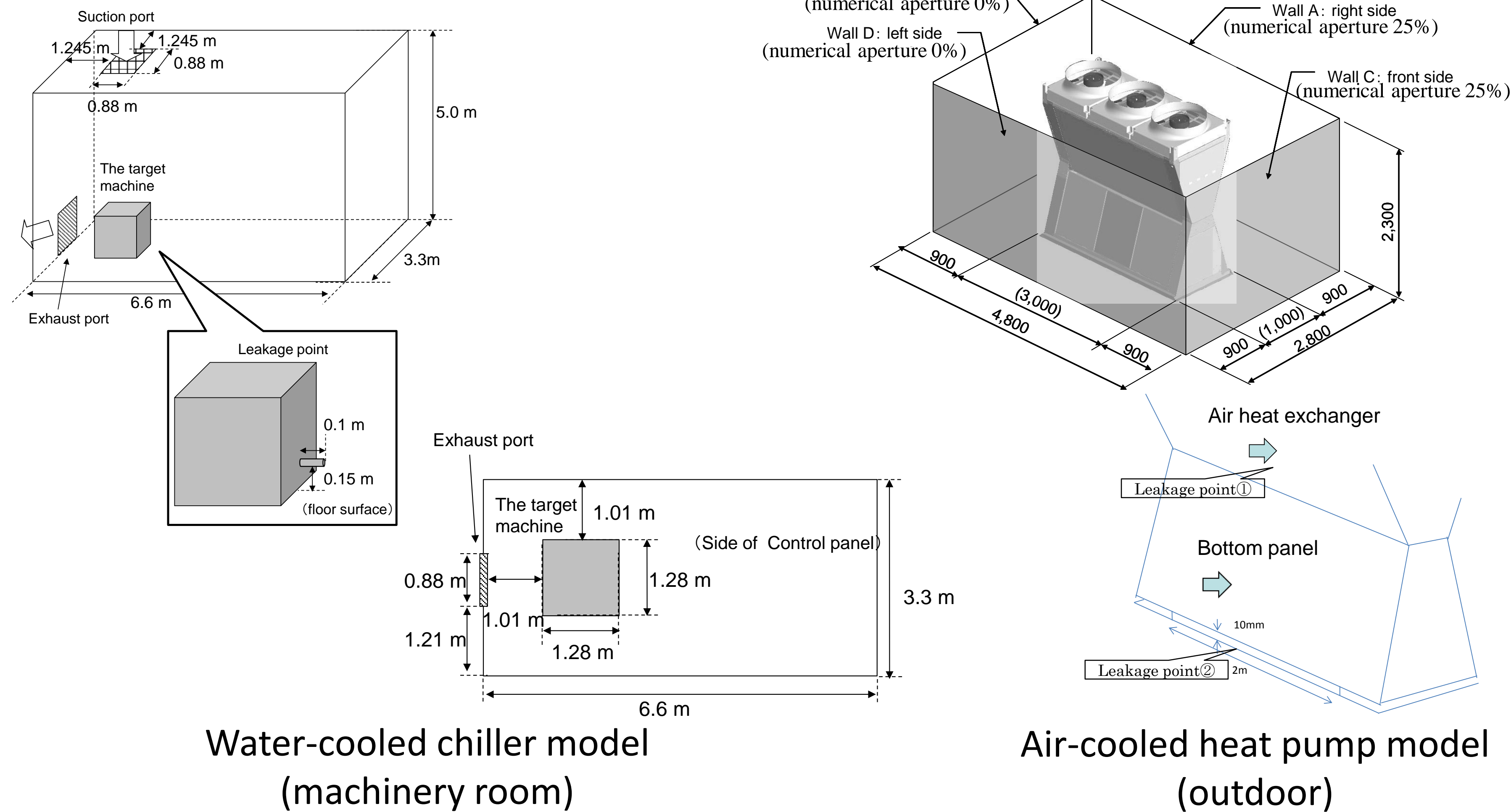
Table 2 Specification of a typical model

Type of chillers	Water-cooled	Air-cooled
Cooling capacity [kW]	170 kW	90 kW
Refrigerant charge [kg]	23.4 kg	11.7 kg *
Outer dimensions [m]	1.28 X 1.28 X 1.28	1.00 X 3.00 X 2.30
Installation location	Machinery room	Outdoors

*single refrigeration circuit



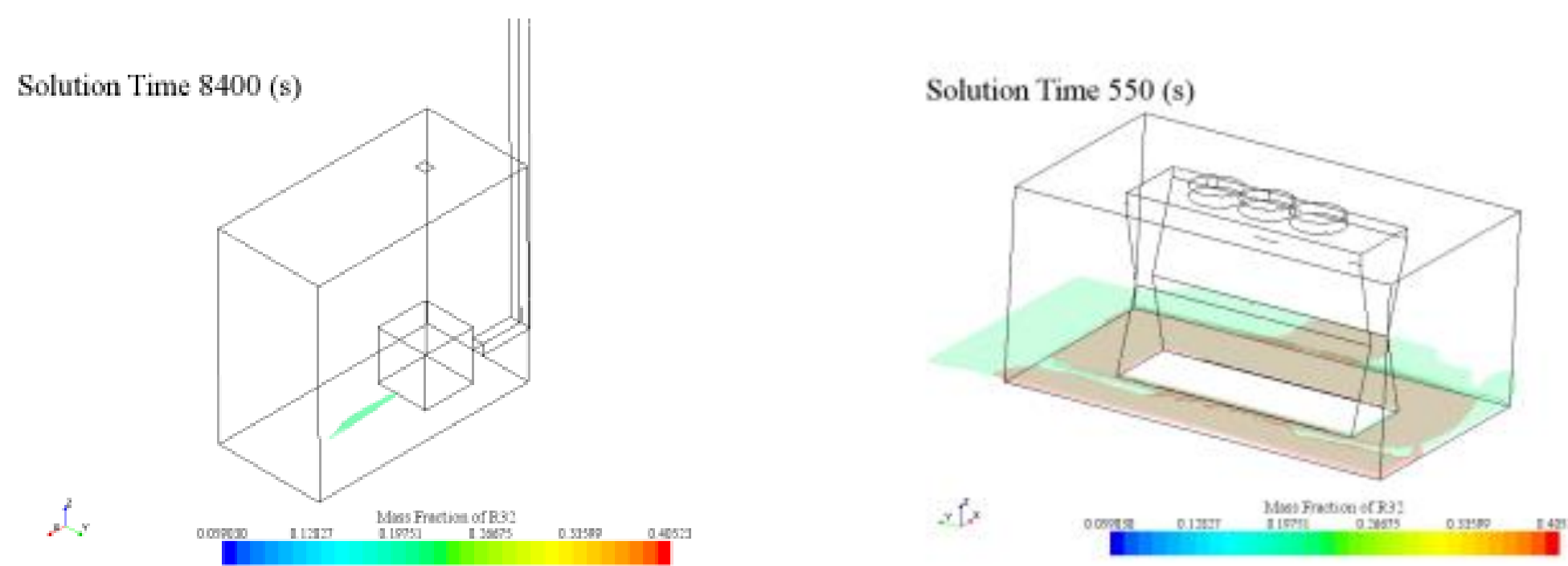
Installation



Occurrence of refrigerant leakage

Table 3 Probability of the occurrence of refrigerant leakage [case/(unit year)]

2004-2011FY	Water-cooled Chiller	Air-cooled heat pump	Centrifugal chiller
Burst leakage	5.83×10^{-6}	1.35×10^{-5}	0
Rapid leakage	1.07×10^{-4}	1.87×10^{-4}	0
Slow leakage	1.64×10^{-3}	2.21×10^{-3}	7.09×10^{-3}



Flammable region

The probability of existence of a flammable space
 = the time-dependent volume of the flammable space [m³ min]
 / (target space [m³] X 8760 [h] X 60 [min])

Table 4 Probability of existence of a flammable space [1/year]

Life Stage (LS)	Burst leakage	Rapid leakage	Slow leakage
Logistics	2.64×10^{-10}	5.46×10^{-7}	0
Installation [carry-in]	7.84×10^{-8}	8.26×10^{-6}	0
Installation [trial]	7.84×10^{-8}	2.33×10^{-7}	0
Usage [machinery room]	2.64×10^{-10}	5.46×10^{-7}	0
Usage [outdoor]	1.12×10^{-7}	9.84×10^{-8}	0
Repair / Service	7.84×10^{-8}	2.33×10^{-7}	0
Overhaul	7.84×10^{-8}	2.33×10^{-7}	0
Disposal	7.84×10^{-8}	8.26×10^{-6}	0

Ignition source

- [Spark]
- Electrical part inside equipment (solenoid switch with 5kVA or above)
 - Metal spark (by forklift)
- [Open flame]
- Match, Oil lighter (open fire once ignited)
 - Burning appliance
 - Electric radiant heater
 - Gas water heater
 - Gas cooking appliance

Probability of accidental fire

Table 5 Probability of accidental fire [1/(unit year)]

Target	LS	LS ratio	Without ventilation		With ventilation	
			Probability	Probability under user	Probability	Probability under user
Supplier	Logistics	0.0517	4.28×10^{-6}	-	1.51×10^{-13}	-
User	Installation [carry-in]	0.0517	4.66×10^{-6}	1.32×10^{-4}	2.39×10^{-12}	3.89×10^{-12}
	Installation [trial]	(0.0023)				
	Usage [machinery room]	0.2144				
	Usage [outdoor]	0.5002				
	Repair / Service	0.1207				
Supplier	Overhaul	0.0098	6.51×10^{-5}	-	1.00×10^{-12}	-
	Disposal	0.0517	1.72×10^{-5}	-	9.22×10^{-12}	-

Technical requirements for safety

1. Ventilation:
 - Mechanical ventilation is always indispensable
 - In this risk assessment, it has proved that **4 times/h** ventilation is required for the standard machinery room
 - In JRA GL-15, the ventilation frequency, **$n=380/V$** , is adopted in accord with RA for other products in the machinery rooms
2. Refrigerant detector and refrigerant leakage alarm (n: ventilation frequency [times/h], V: machinery room volume[m³])
3. Open flame prohibition

Documentation

1. Guideline of design construction for ensuring safety against refrigerant leakage from chiller using lower flammability (A2L) refrigerants JRA GL-15 : 2016