VRF Technology and Application

AIR CONDITIONING TECHNOLOGIES

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Net-Zero Emissions by 2050

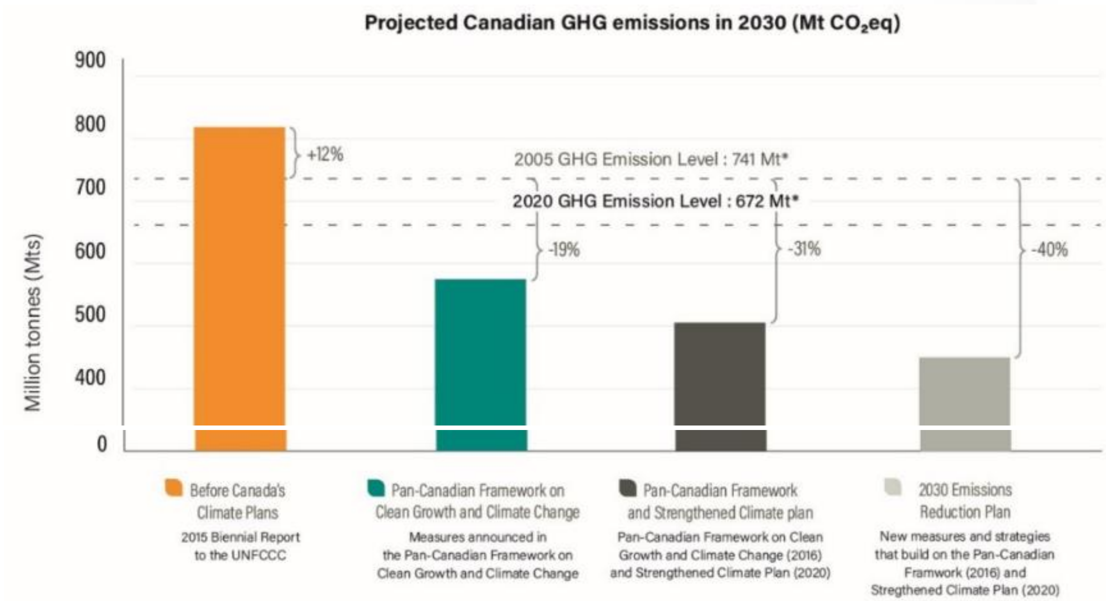
What is Net-Zero?

Achieving net-zero emissions means our economy either **emits no greenhouse gas emissions** or **offsets its emissions**, for example, through actions such as tree planting or employing technologies that can capture carbon before it is released into the air.

Canada has joined over 120 countries in committing to be net-zero emissions by 2050, including all other G7 nations (United Kingdom, United States, Germany, Italy, France, and Japan)

2030 Emissions Reduction Plan: Clean Air, Strong Economy

The Government of Canada **published the country's 2030 Emissions Reduction Plan in March 2022**. The plan reflects input from provinces, territories, Indigenous Peoples, the Net-Zero Advisory Body, and interested Canadians on what is needed to reach Canada's more ambitious climate **target of 40-45% emissions reductions by 2030.**

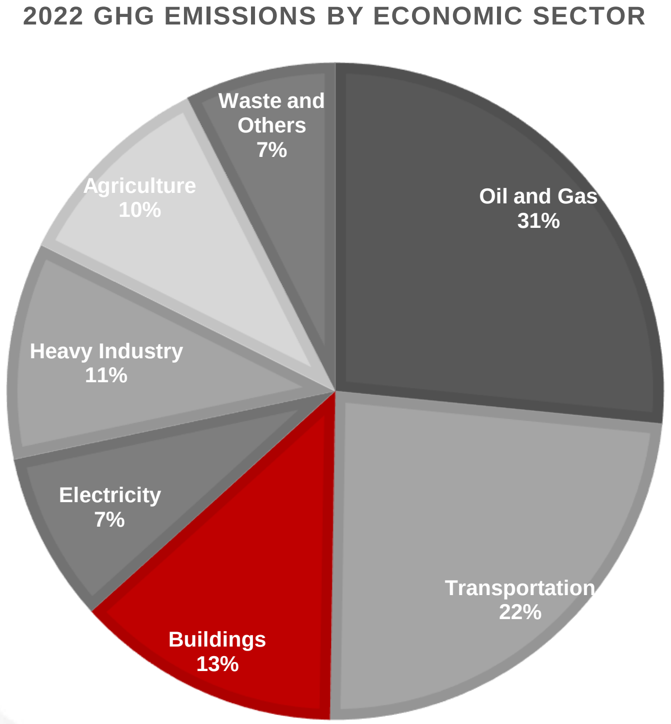


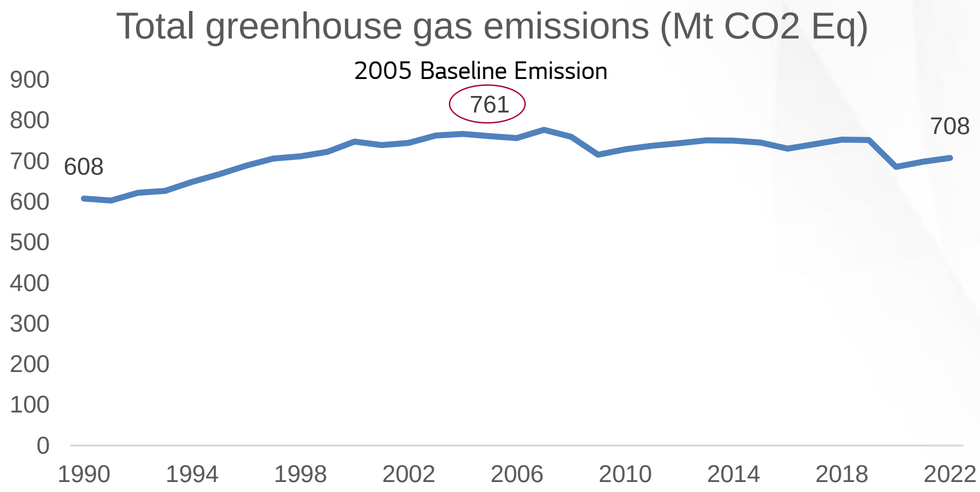
https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html

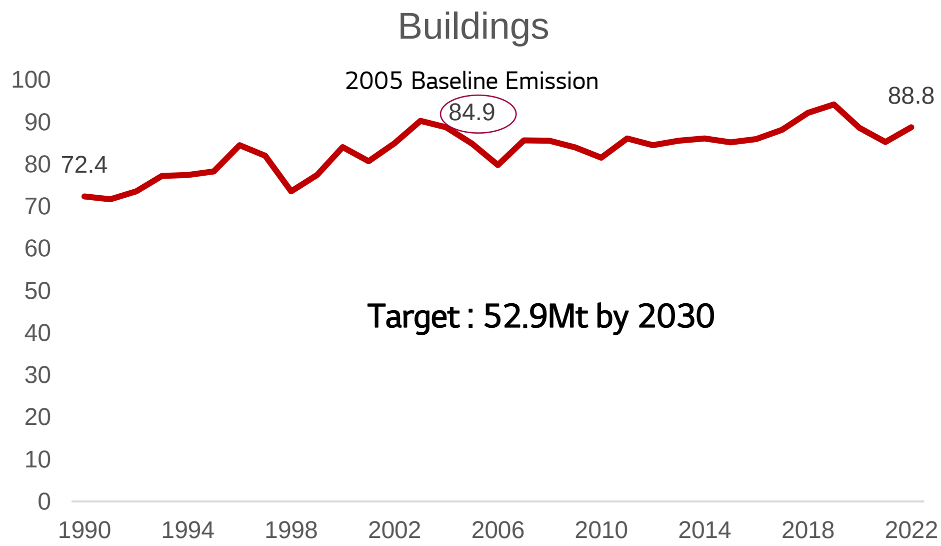
Electrification

National greenhouse gas emissions

- Canada's total GHG emissions in 2022 were 708 Mt CO2 eq, a 7% decrease from 761 Mt CO2 eq in 2005







https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html

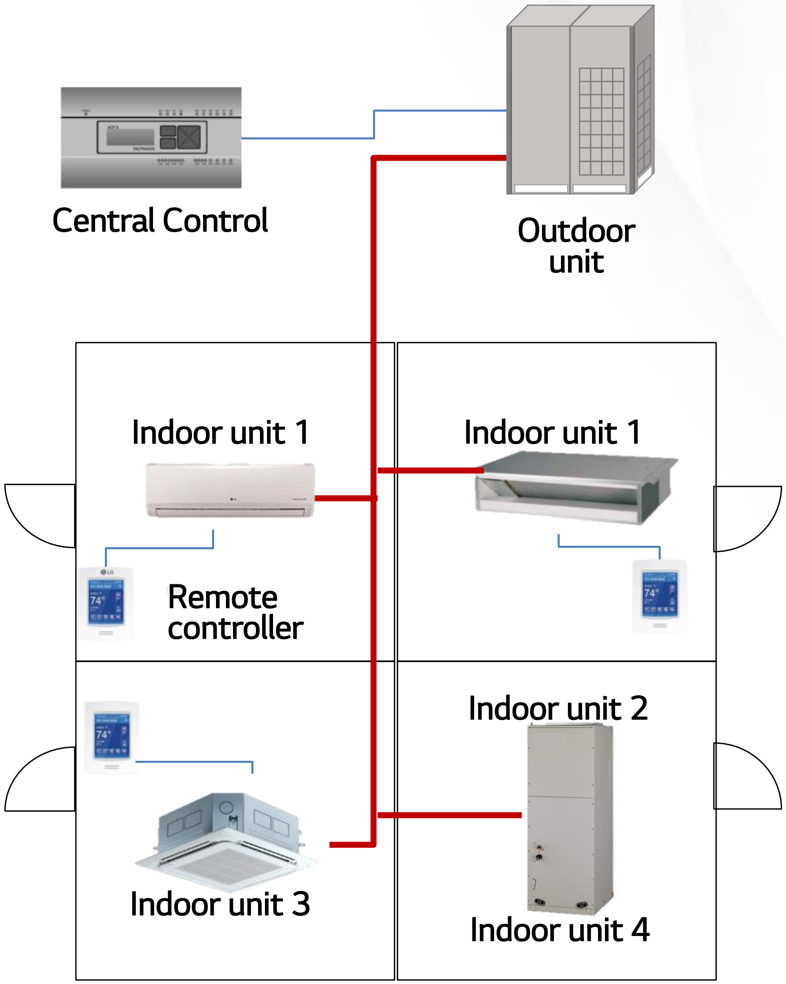
VRF OVERVIEW

Outline of System

VRF = Variable Refrigerant Flow

“A **VRF Multi split system** is a split-system air conditioner or heat pump with a single refrigerant circuit, one ore more outdoor units, at least one variable-speed compressor or other compressor combination that can vary system capacity by three or more steps, and multiple indoor fan-coil units that are individually metered and individually controlled by an integrated control device and common communication network”

2020 ASHRAE Handbook – HVAC Systems and Equipment

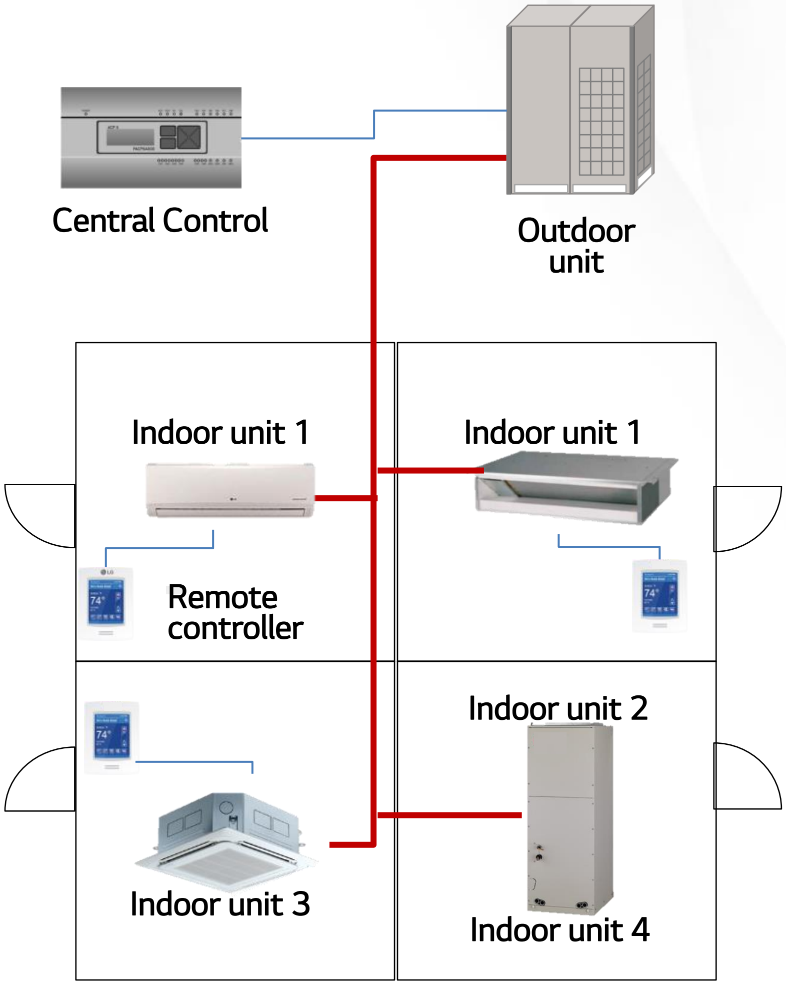


Outline of System

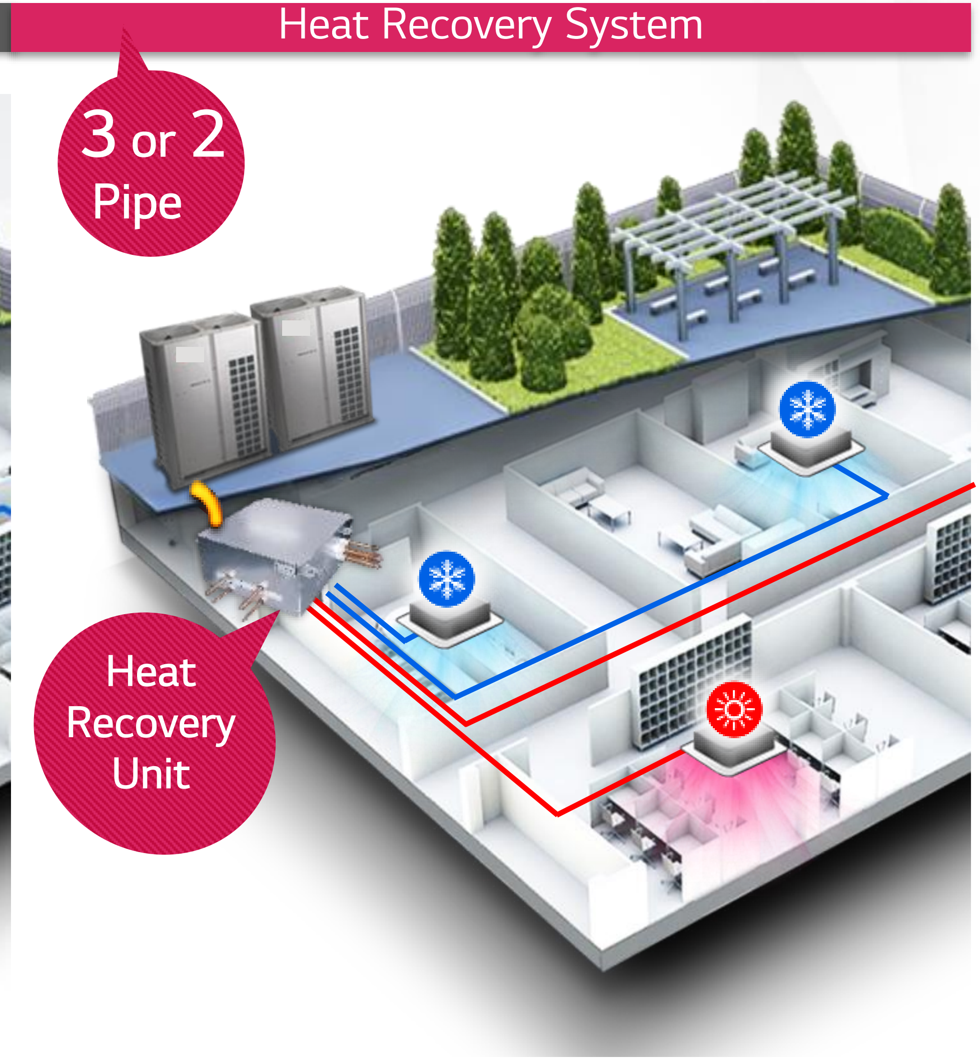
VRF = Variable Refrigerant Flow

A VRF system is a single refrigerant circuit with:

- One ODU connected to several IDUs
- IDU variety selection of styles and sizes
- Independent IDU operation
- Independent zone control
- Variable speed compressor(s) (adjusts to building load)
- Simple communication wiring between ODU and IDUs
- Long piping capabilities
- Simultaneous Heating and Cooling
- Built-in controls
- Energy efficient



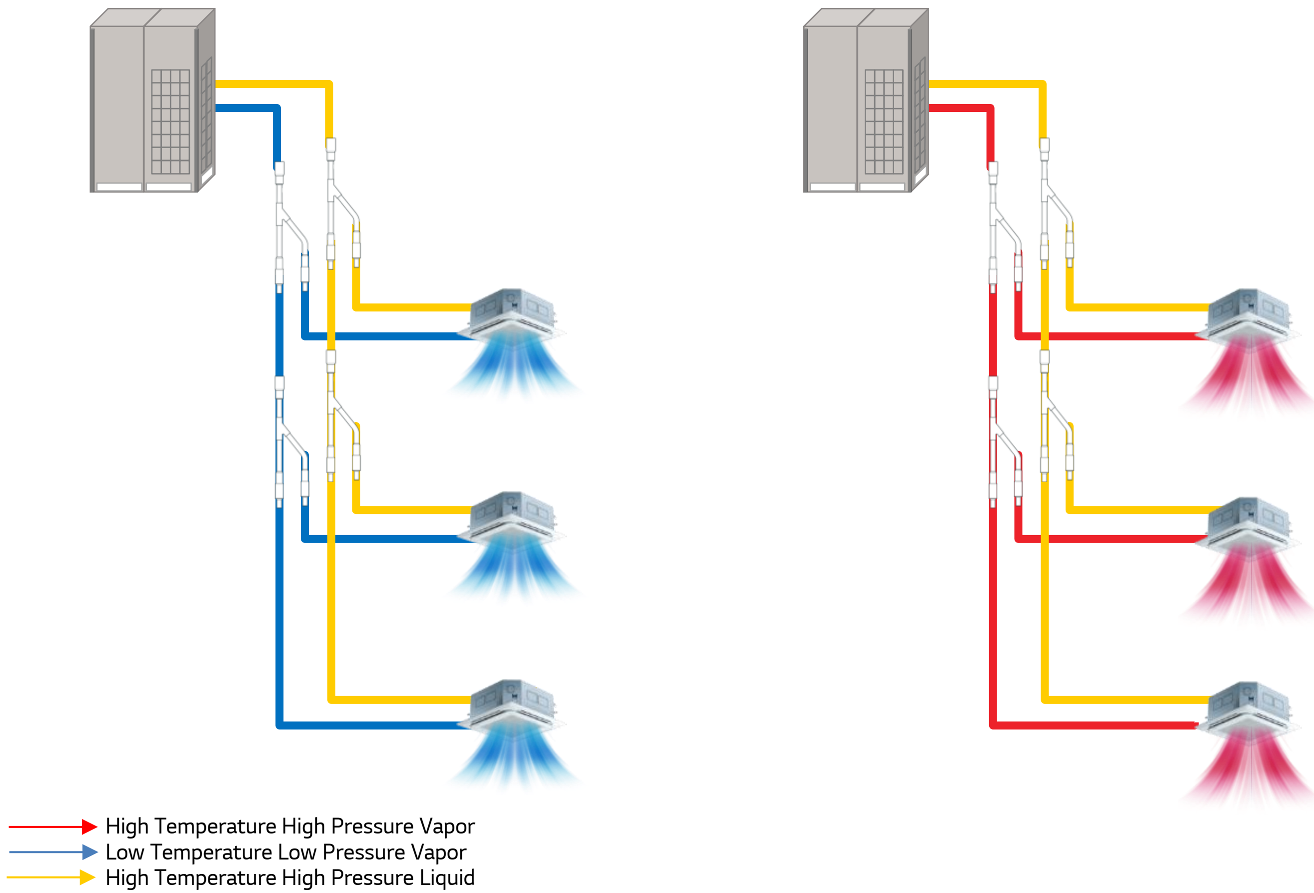
Type Changeover Outdoor Unit



Heat Pump System Concept

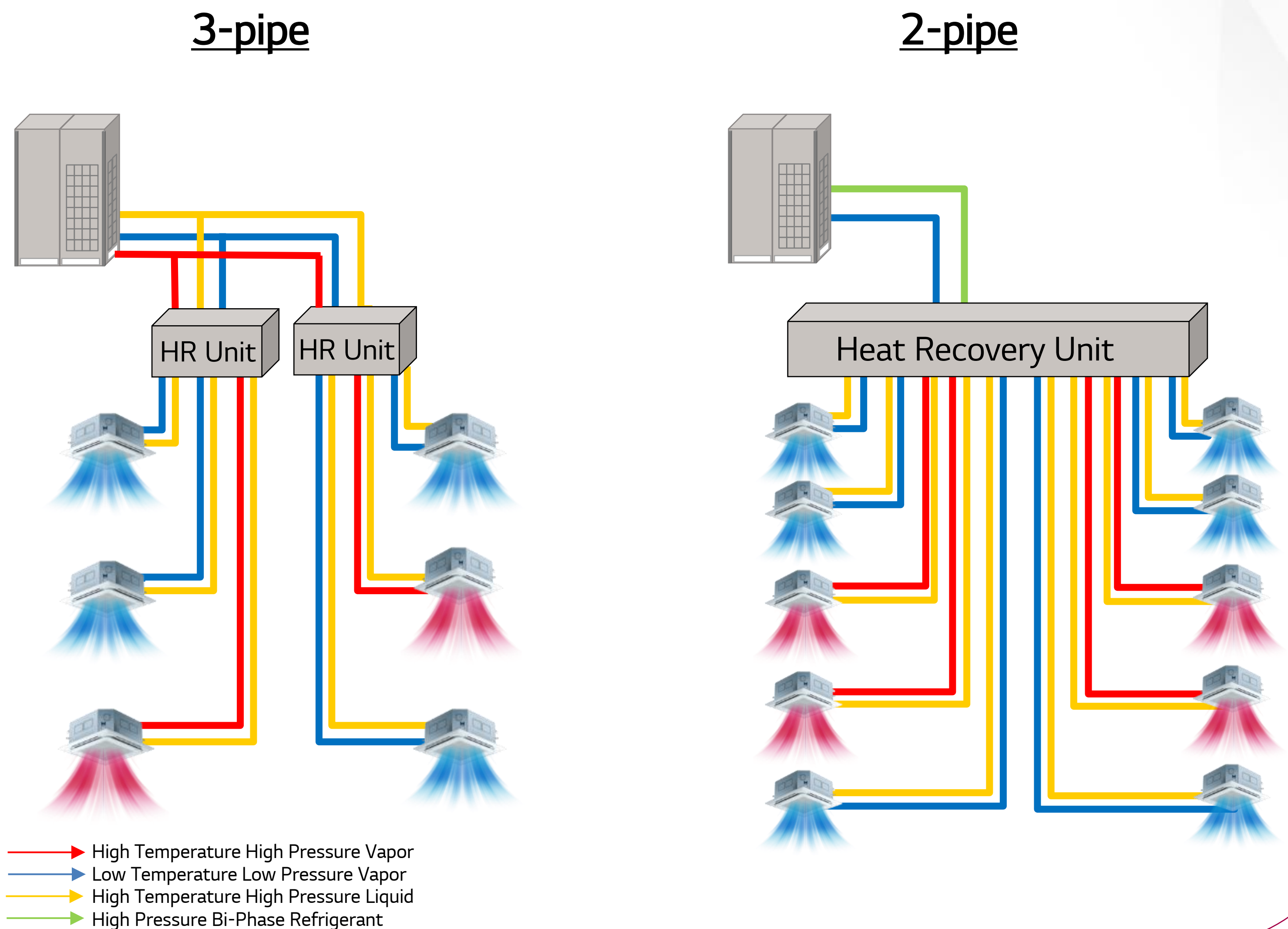
Heat Pump

Cooling | **Heating**



Heat Recovery System Concept

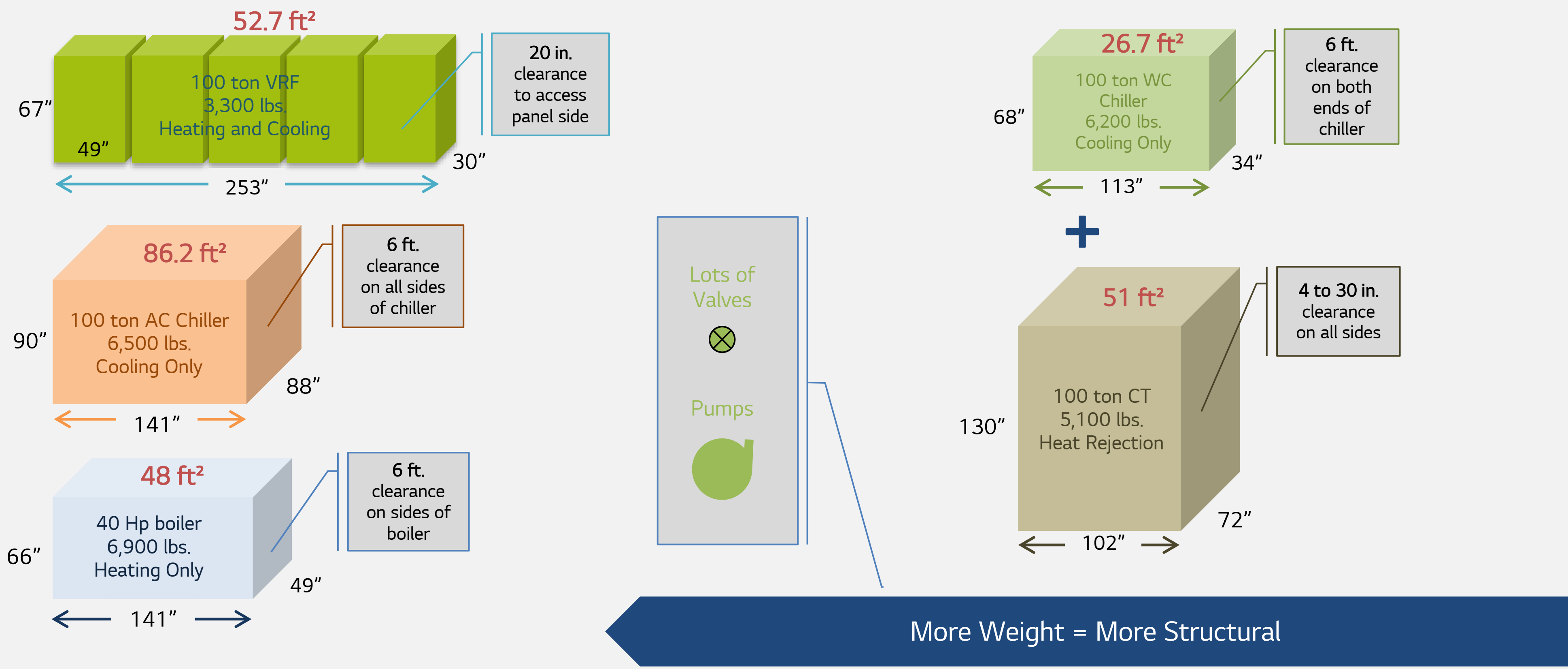
Heat Recovery



Sizing up VRF

At Least 32% Smaller Footprint
At Least 49% Lighter Weight

100 Ton System Comparison



Features of VRF System

Air-cooled VRF system serves various kind of benefits to the customers.

Low Initial Investments

- Simple components and refrigerant piping work saves initial cost

Lower Maintenance cost

- Simple maintenance saves maintaining labor cost and the person.

Maximize Available Space

- Smaller equipment's installation space increases available space

Low Operation Costs

- High efficient inverter heat pump system decreases operation costs

Total Air Conditioning

- Individual cooling & heating
- Ventilation & humidification & pressurization (AHU)
- Air quality control (Filter, CO_2 sensor)

Environmental Friendly

- High energy efficient Inverter control
- Lower electricity consumption lowers CO2 emission amount
- "0" ODP refrigerant R410A system

User Convenience

- Individual indoor unit's operation is controllable according to the user's comfort
- Integrated Control control is possible through central control or BMS system

Reasonable Payment

- Using cost is calculated precisely by checking each unit's detail operation

VRF PRODUCT APPLICATION

- Air source Systems
- Water Source Systems

VRF Outdoor Unit Equipments

Air Source	Water Source

- Modular
- 3 Phase High Capacity
- Top Discharge
- Airflow required

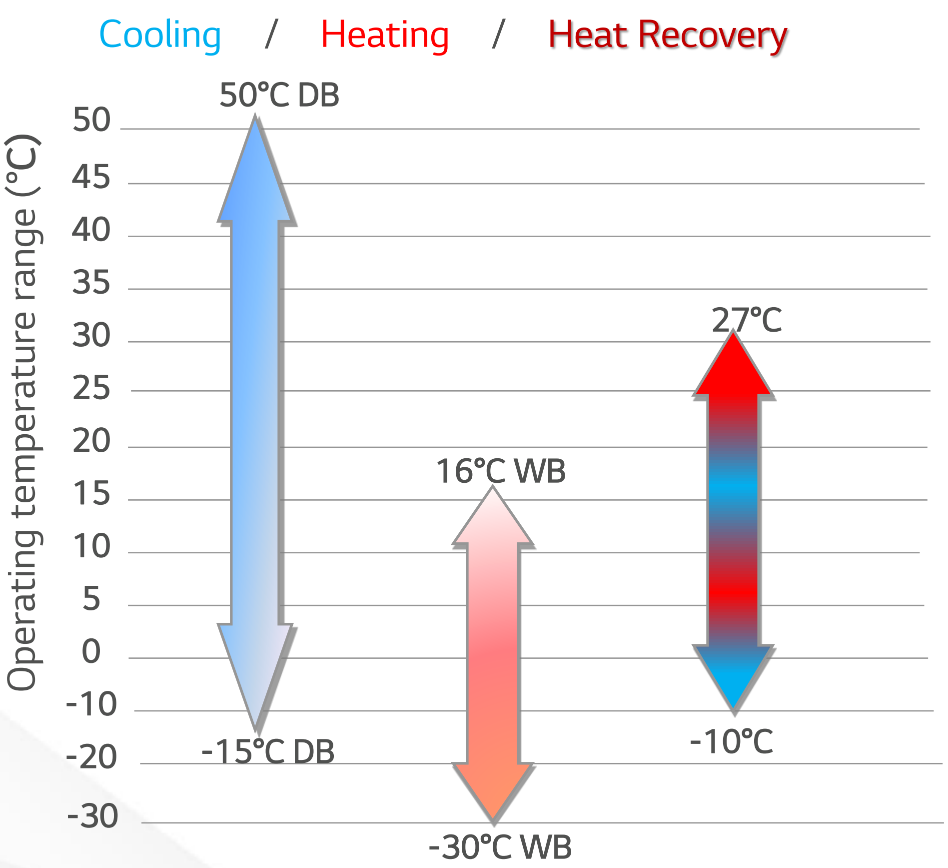
- Non Modular
- 1 Phase Low Capacity
- Side Discharge
- Airflow Required

- Modular
- 3 Phase High Capacity
- Waterflow Required
- Indoor Install

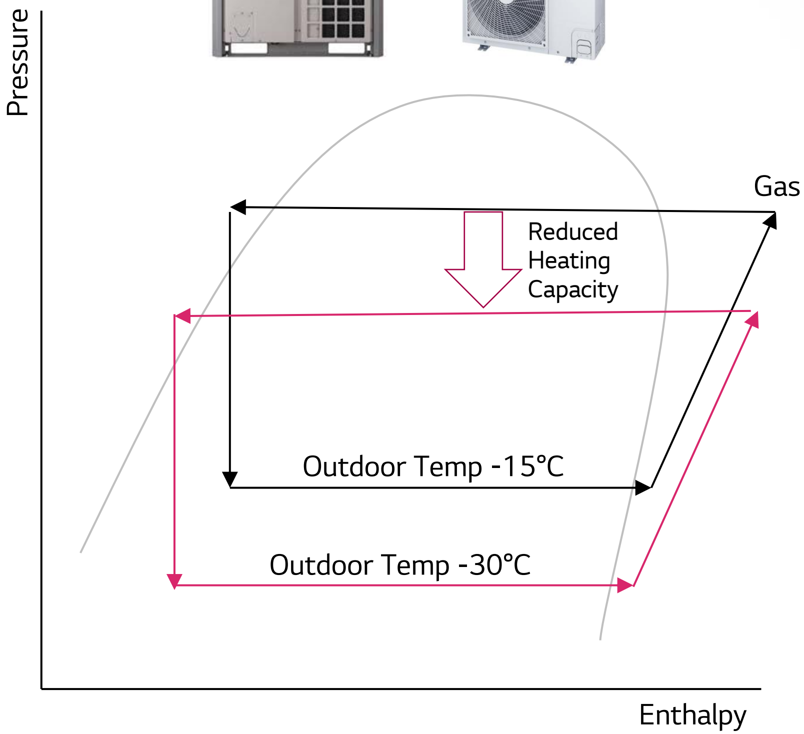
Air Source VRF

Operating Range

- AC VRF can be operated down to **-30 ℃.**



Cycle

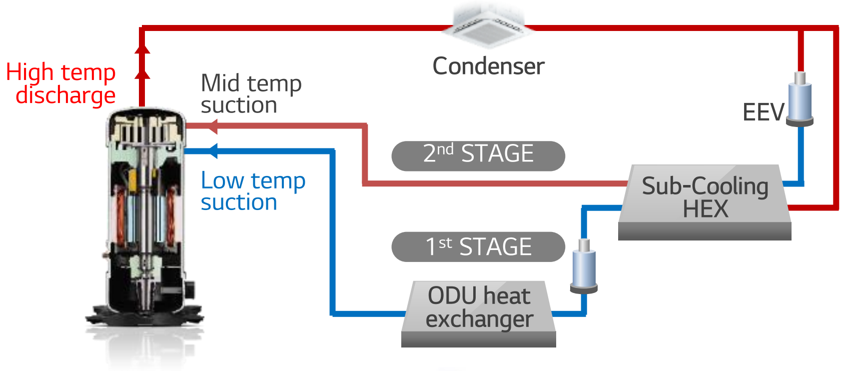


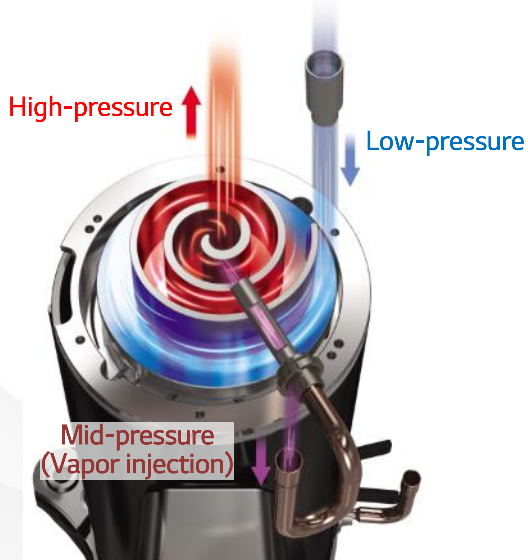
Air Source VRF

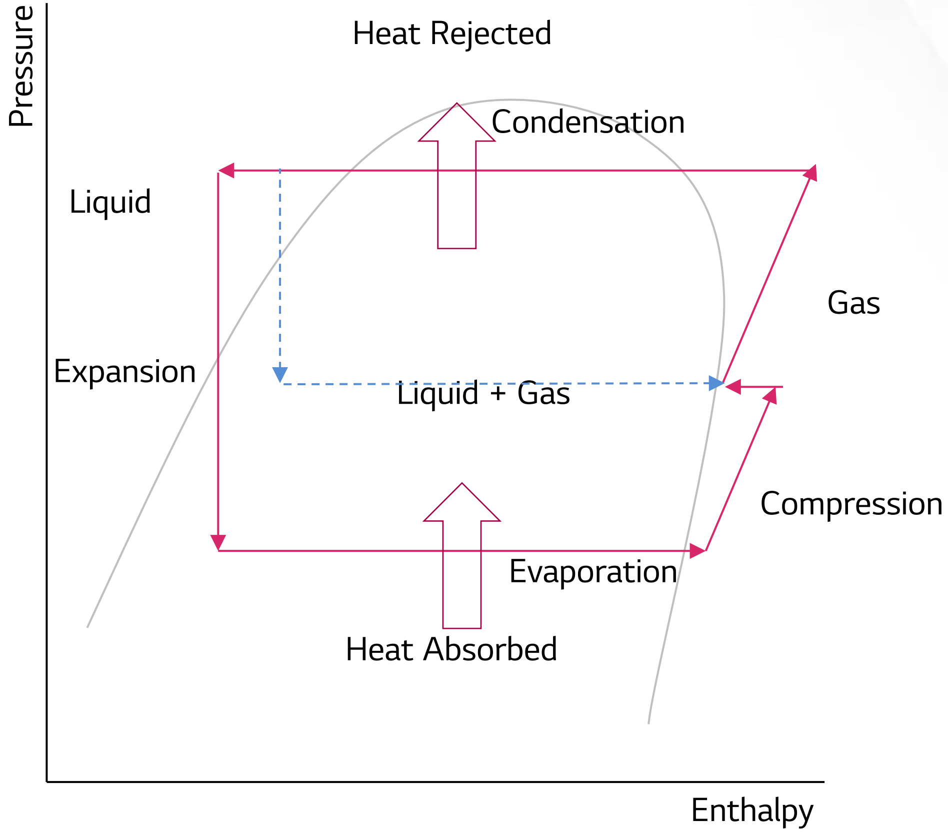
- Vapor Injection

Technologies for High Heating Capacity

➢ Vapor Injection uses a two-stage compression effect, which provide efficient heating in extremely cold environment.







Heating- New Technologies

VRF systems may be stopped heating operation by several reasons, such as oil recovery and defrost. Heating operation down time can be reduced by several advanced technologies.

Defrost by Humidity

- Target outdoor temperature is adjusted to minimize frost accumulation by temperature sensor and humidity sensor

Oil Recovery by Oil Sensor

- Heating downtime can be reduced by an oil sensor

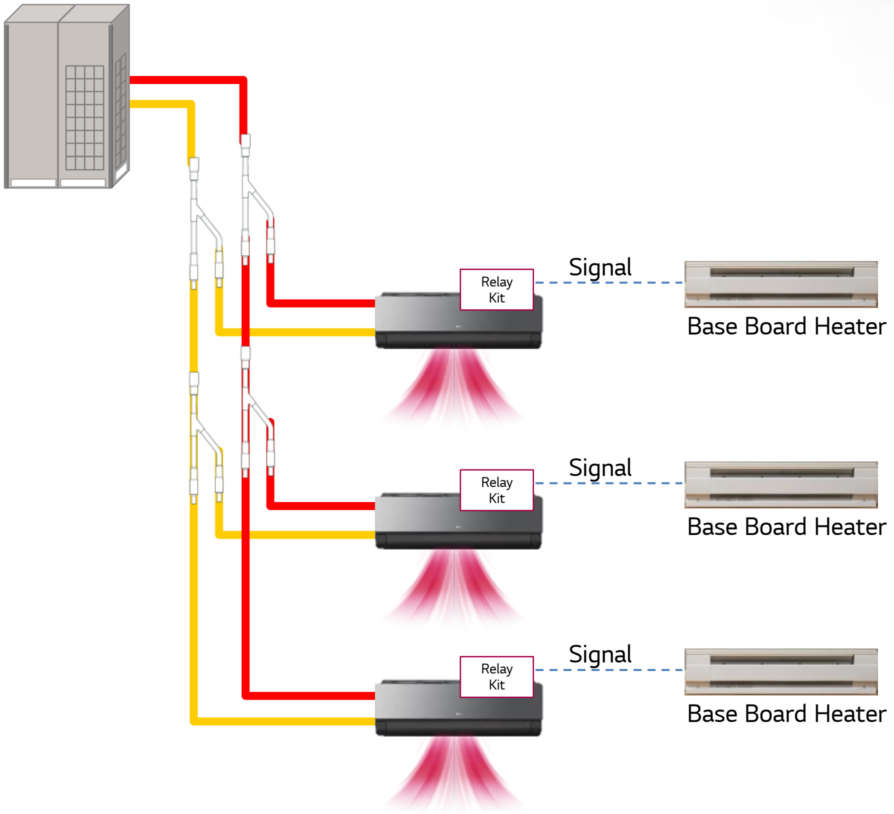
Hot Gas (Linear Bypass)

Auxiliary Heater Control

Auxiliary heater can be connected to each indoor unit to provide additional heating while heating capacity of heat pump is decreased

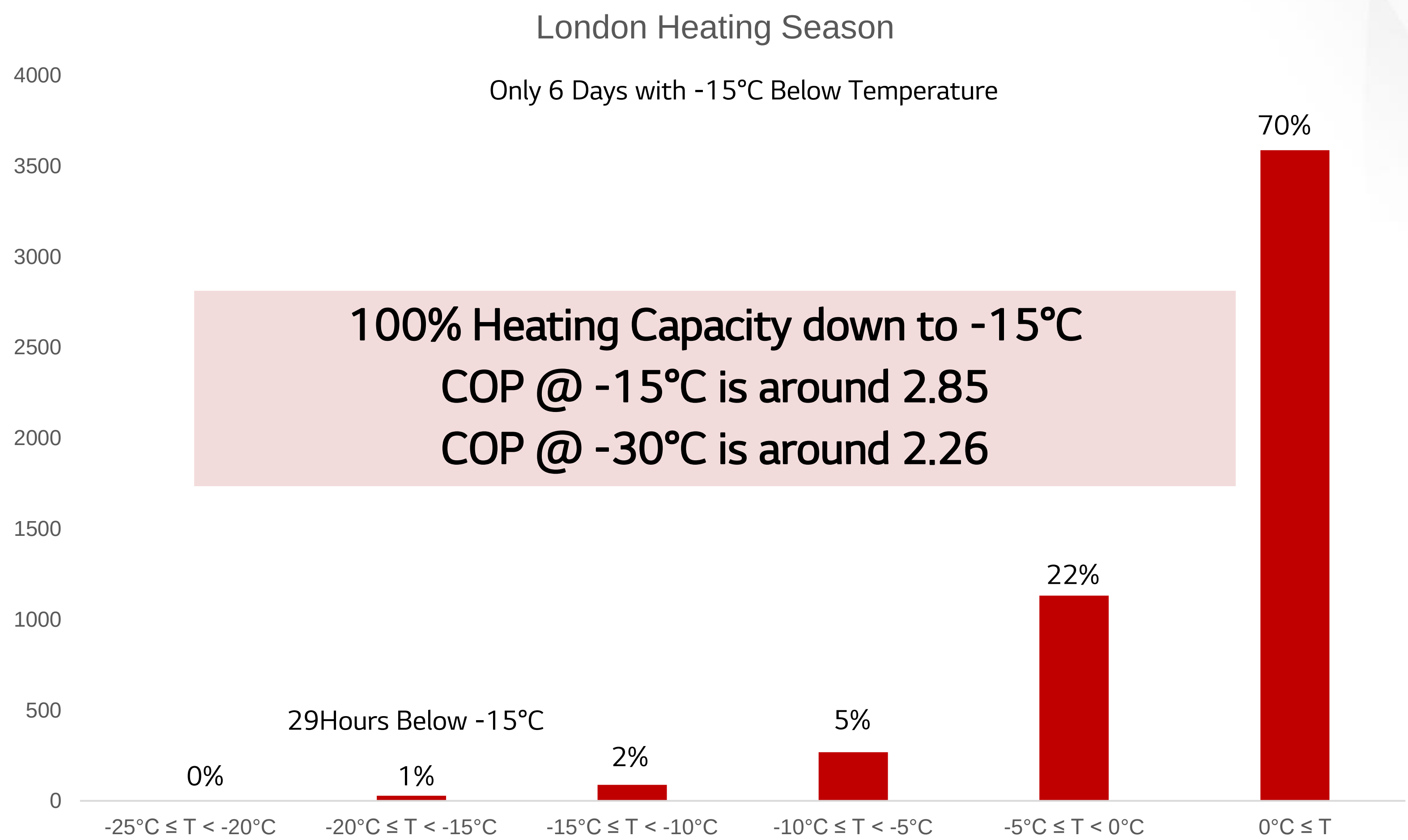
Type 1:
Built in E-Heater with V.AHU Type

Type 2 :
Aux Heater Relay Kit with External Heater



Air Source VRF

- Heating Season Temperature Hours (October 2023 – April 2024)



https://climate.weather.gc.ca/index_e.html

Performance of 12T "L" company VRF unit at 70°F Indoor Temp @ 100% combination ratio

Water Source VRF

Chiller system

Cons

- Large mechanical room requirement
- Need to additional device for individual room control and proper operation cost distribution
- Inefficient in low part-load

Pros

Stability

- Free from the external environment
- No need the defrosting operation

Applicability

- Applicable to large buildings
- Aesthetic façade design

Pros

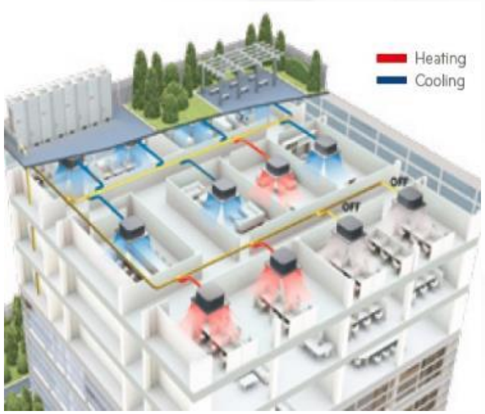
Convenience

- Able to control individual room without additional device
- Easy to distribute proper operation cost to each room than chiller system

Economic

- Expandability of mechanical system
- Reduce installation area
- Efficient in low part-load
- Energy saving by simultaneous operation

Air-cooled VRF system



Cons

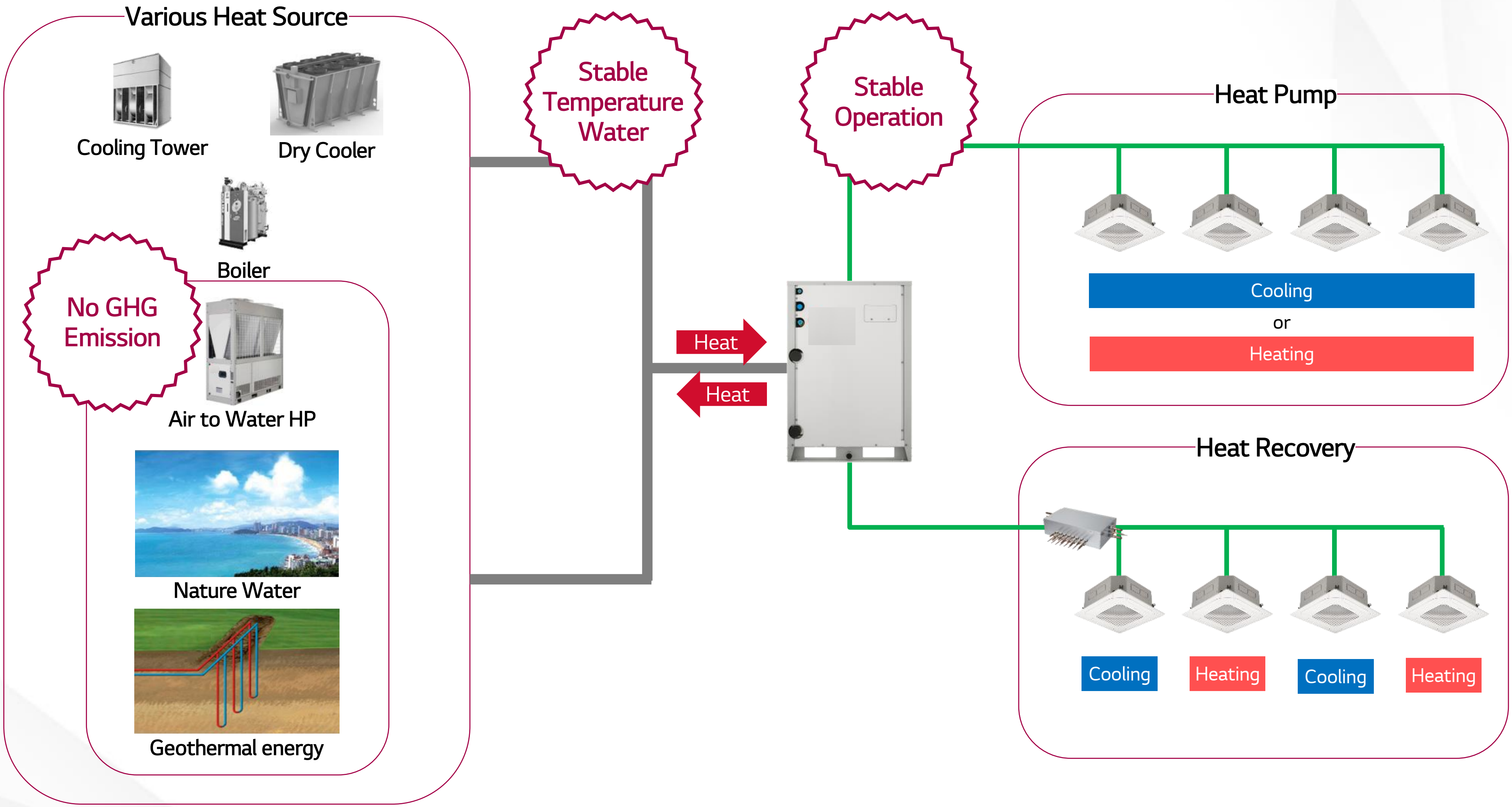
- In case of installing indoor, require louvers.
- Influenced by external environment

Water Sources vs. Air Source

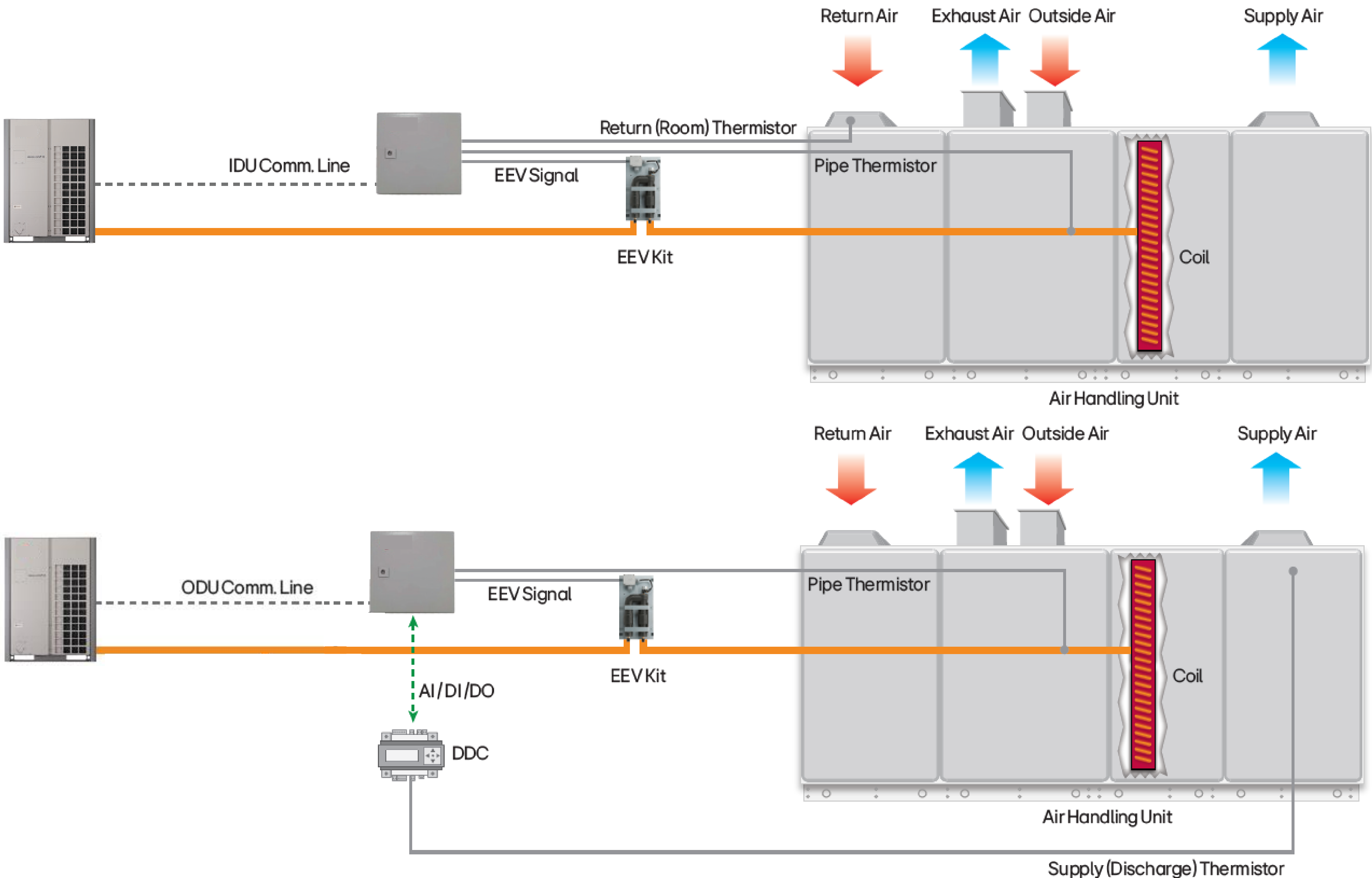
Comparison	Water Source VRF	Air Source VRF
Defrost	Not required	Required
Performance Derating	N/A	Applicable
Install location	Indoor Only	Outdoor (recommended) or Indoor with certain conditions
Water Systems	Required	Not Required
Efficiency	Typical Higher COPs (depends on water system)	Typically lower at colder temperatures
Auxiliary Heat	Not Required	Required
Heat Recovery	Indoor Unit / Outdoor Unit	Indoor Unit only
Geothermal	Yes	No
Refrigerant Amount	Less	More

Stable Operation from Various Heat Sources

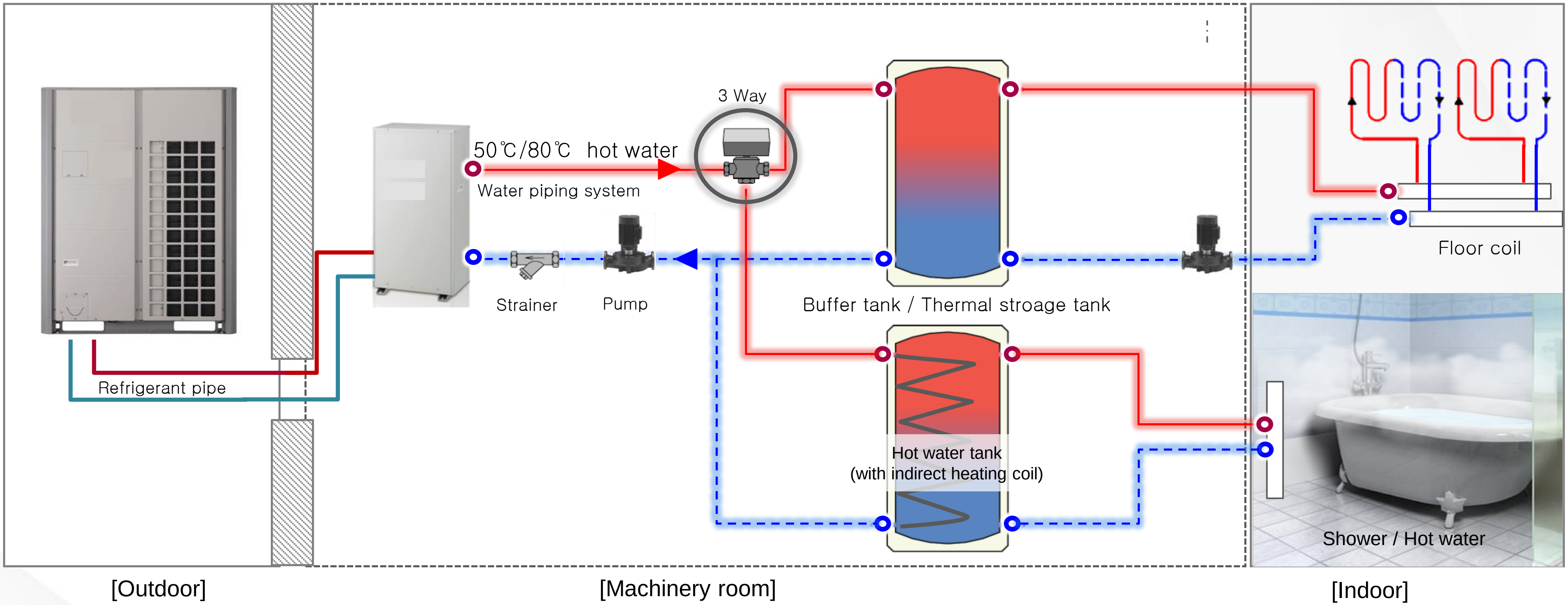
Multi V Water 5 can obtain stable temperature water from various heat sources.



Integration with AHU



Water Heating Options



VRF Controls

Dry Contact

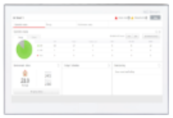
External Contact Signal Control

Dry Contact Controller

- Single Contact Point
- Dual Contact Point
- 3rd Party Thermostat
- Modbus Control

Central Controller

Monitor Entire VRF system



- BMS Integration (BACnet, Modbus TCP)
- Interlock using DI / DO port
- Manage groups of VRF system

Programmable Thermostat

Individual Indoor Unit Control

- Individual Indoor Unit Control
- Indoor unit scheduling

Special Application

Special Control Applications

Power Distribution

3rd Party DX Coil Control

Auxiliary Heater Relay

Contact Module for ODU

A2L Refrigerant

New Refrigerant Changes

Air Solution

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Why ?

The Montreal Protocol (1987)

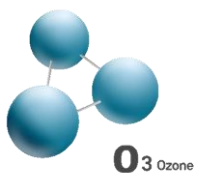
Montreal Protocol

	Ozone Depletion Potential (ODP)	Global Warming Potential (GWP)
R12 (CFC)	1.0	10,900
R22 (HCFC)	0.05	1,810
R410A (HFC)	0	2,088

Montreal Protocol was created to phase down hydrochlorofluorocarbons (HCFCs)

- HCFCs are broken down by strong ultraviolet radiation within stratosphere and releases chlorine atoms which reacts with ozone molecules.

One chlorine atom can destroy over 100,000 ozone molecules.



Kigali Amendment (2016)

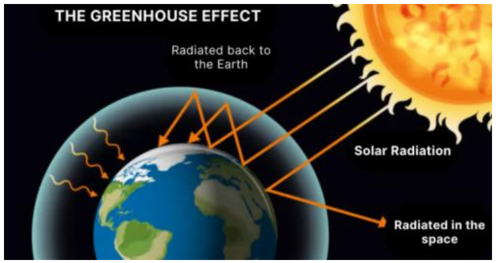
Kigali Amendment

	Ozone Depletion Potential (ODP)	Global Warming Potential (GWP)
R410A (HFC)	0	2,088

New Refrigerant with Lower GWP!

Kigali Amendment was created to phase down HFCs that have high GWP

- High Global Warming Potential causes Greenhouse effect



CO_2 has GWP rating of 1
R410a has GWP rating of 2,088

North America R410a Phase out Timeline (EPA & ECCC)

EPA

Refrigeration, Air Conditioning, and Heat Pump Systems*			
Subsector	**Systems**	**Global Warming Potential Limit or Prohibited Substances**	**Installation Compliance Date[5]**
Stationary air conditioning and heat pumps	Residential and light commercial air conditioning and heat pump systems	700	January 1, 2025[6]
	Variable refrigerant flow systems	700	January 1, 2026
Chillers	Industrial process refrigeration with exiting fluid below -50 °C (-58 °F)	Not covered	Not covered
	Industrial process refrigeration with exiting fluid from -50 °C (-58 °F) to -30 °C (-22 °F)	700	January 1, 2028
	Industrial process refrigeration with exiting fluid above -30 °C (-22 °F)	700	January 1, 2026
	Comfort cooling	700	January 1, 2025

[6]New systems with a GWP above 700 can be installed until January 1, 2026, so long as all components are manufactured or imported prior to January 1, 2025 (refer to the Interim Final Rule for additional details).

HRAI proposed following dates to ODSHAR (Ozone-Depleting Substance sand Halocarbon Alternatives Regulations) for R410a phase out in Canada

- Comfort Heating / Cooling excluding VRF : **Jan 1st 2026**
- VRF / VRV : **Jan 1st 2027**

Additional Notes

- Unlimited sell – through period after date of manufacture
- No restrictions for components servicing existing equipment in the Canadian market
- Unlimited manufacture and sale of replacement parts marked with “For Service Only”

A2L Refrigerant Specification

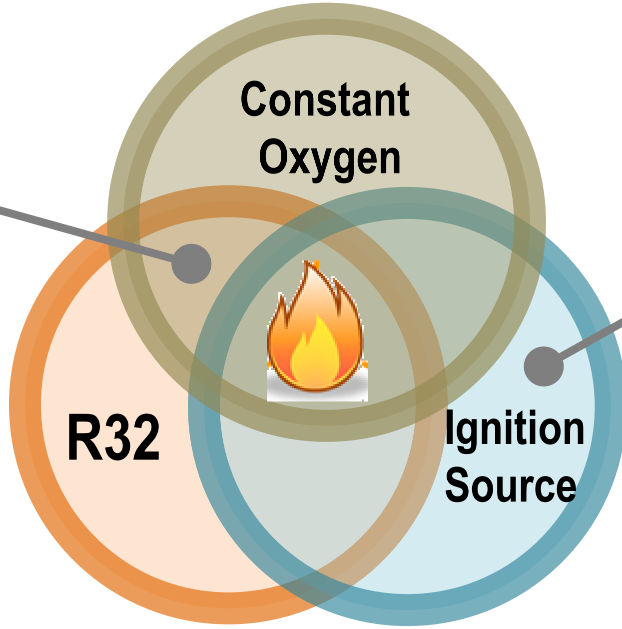
	R410A	R32	R454B
Composition	R32 50% / R125 50%	R32 100%	R32 68.9% / R1234yf 31.1%
Refrigerant classification	A1	A2L	A2L
Global Warming Potential	2088	675	466
Direct emissions (kg CO_2 eq.)	6,368	1,793 (↓72%)	1,468 (↓77%)
Indirect emissions (kg CO_2 eq.)	74,496	70,775 (↓5%)	73,009 (↓2%)
Total emissions [LCCP] (kg CO_2 eq.)	80,865	72,568 (↓10%)	74,478 (↓8%)
Charge amount (%)	100	75	92
Discharge Temperature (%)	100	110 - 119	105 - 107
Lower Flammability Limit (lb/1000 ft^3)	-	19.1	22.0
Refrigerant Concentration Limit (lb/1000 ft^3)	26	4.81	3.06
Consumer Cost ($/lb)	$10.14	$10.52	$28.36

Direct Emissions : Refrigerant Leak / Atmospheric degradation of refrigerants
Indirect Emissions : Energy Consumption, Material / Refrigerant manufacturing, material / refrigerant recycling

A2L Refrigerant

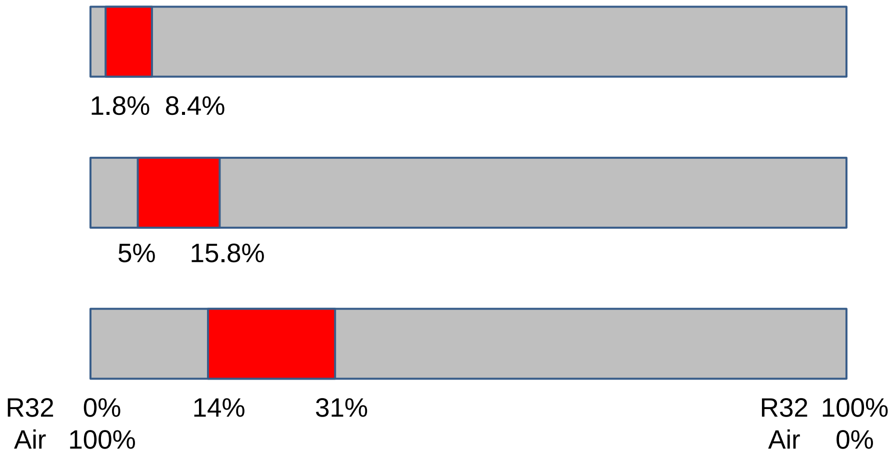
Lower Flammable Limit
R32
14%

- Propane : 1.8%
- Natural Gas : 5%
- Acetylene : 2.3%
- Hydrogen : 4.3%



Minimum Ignition Energy
R32
30 to 100 mJ
(Static electricity : 1.25mJ)

- Propane : 0.25mJ
- Natural Gas : 0.28mJ
- Acetylene : 0.017mJ
- Hydrogen : 0.011mJ

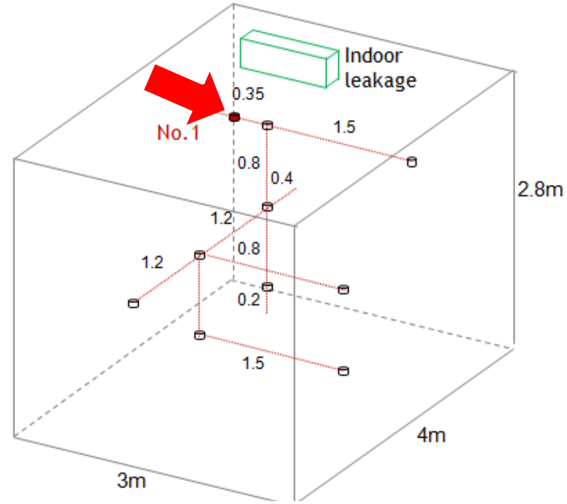


Type	Mixture ratio	Ignition Velocity
Iso-butane	1.8% 8.4%	3,000 m/s
Natural Gas	5% 15.8%	2,000 m/s
R32	14% 31%	0.07 m/s

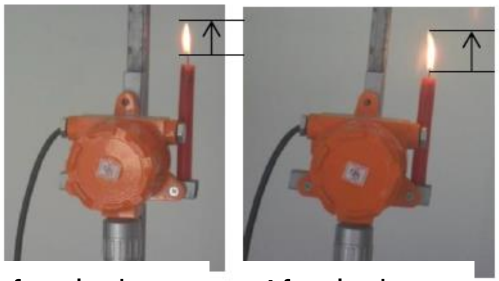
Safety Analysis

-**Result : Only No.1's fire size is increased a little during in a brief space of time.**

→ No Explosion , Flame.

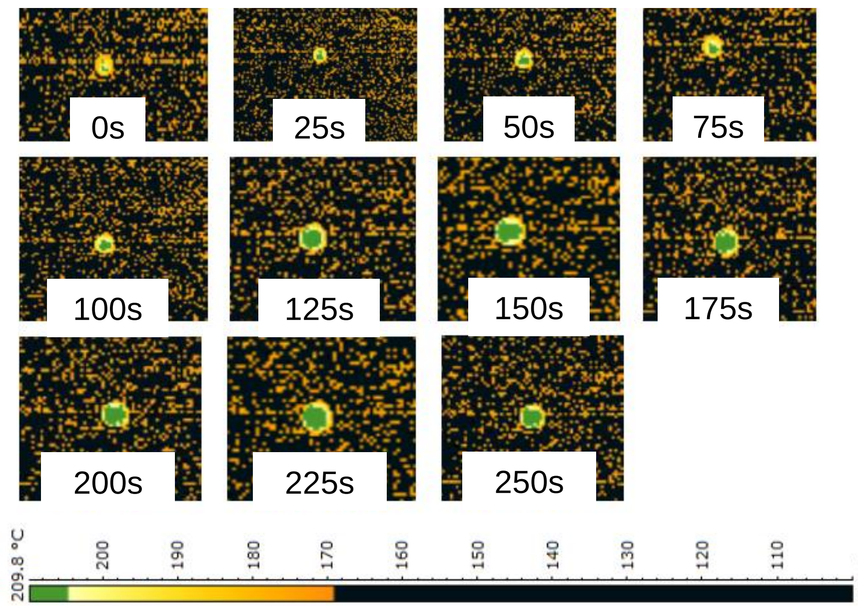


1) Flame length just increase in case of leakage at check position



Before leakage After leakage

2) Data on No.1 location. R32 concentration exceeds LFL level between 110s and 125s which increases the flame size but does not cause chain reaction



Standard

Standard	Detailed Standard	The moment you need this standard
UL 60335-1 UL 60335-2-40	- Safety regulation for the air conditioner - Mandatory for customs, sales in US and Canada. - Contains requirements for construction, installation, service and transportation of flammable refrigerants	Product / ✓Installing
ASHRAE 15	- For USA procedures made by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) - Procedures for operating equipment and systems when using refrigerants	Product / Installing
CSA B52	- For Canada A minimum requirements made by CSA group - It is indicated for the design, construction, installation, and maintenance of mechanical refrigeration systems	Product / Installing

Standard

CSA B52:23

Mechanical Refrigeration Code

CSA B52 : 23

Major Update on A2L Refrigerant usage for human comfort

4.5.5 High-probability systems using A2L refrigerants for human comfort

4.5.5.2 Refrigerant systems with air circulation (ASHRAE 15 : 7.6.1.1)

$$EDVC = V_{eff} \times LFL \times CF \times F_{occ}$$

$\mathrm{E}DVC = Effective\ disperal\ volume\ charge\ (lb)$

$V_{eff} = Effective\ disperal\ volume\ (ft^3)$

$CF = Concentration\ factor, value\ of\ 0.5$

$F_{occ} = Occupancy\ adjustment\ factor\ (Non\ institutional : 1, Institutional : 0.5)$

This is an equation to calculate the Effective Dispersal Volume Charge (EDVC) when there is either

a. Air circulation initiated by a refrigerant detector
b. Continuous air circulation

Ex) 1,000ft^3 Room

$$EDVC = V_{eff} \times LFL \times CF \times F_{occ}$$

$$EDVC = 1{,}000ft^3 \times 19.1\ lb/1000ft^3 \times 0.5 \times 1$$

$$EDVC = 9.55lb/1{,}000ft^3$$

If there is an air circulation initiated by a refrigerant detector, A2L refrigerant amount allowed in a room is now doubled

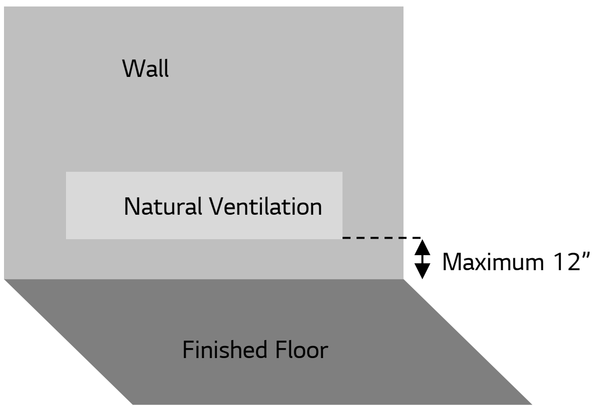
Major Update on A2L Refrigerant usage for human comfort

Annex N Effective Dispersal Volume Calculation

N2.3 Natural ventilation opening for Group A2L, A2, or A3 refrigerants (ASHRAE 15 : 7.2.3.2.2)

$$A_{vent} = \frac{m_{rel} - m_{room}}{LFL \times 0.417} \times \sqrt{\frac{A}{g \times m_{room}} \times \frac{M}{M-29}}$$

A_{vent} = minimum area of a permant opening (ft^2)
m_{rel} = releasable refrigerant charge (lb)
m_{room} = allowable refrigerant charge of an individual room (lb)
LFL = Lower flammability limit $(lb/1000ft^3)$
A = actual area of the indiviual room(ft^2)
g = acceleration due to gravity, (32.2ft/s^2)
M = mrelative molar mass of the refrigerant (R32 = 52)



CSA-B52 & ASHRAE Standard 15

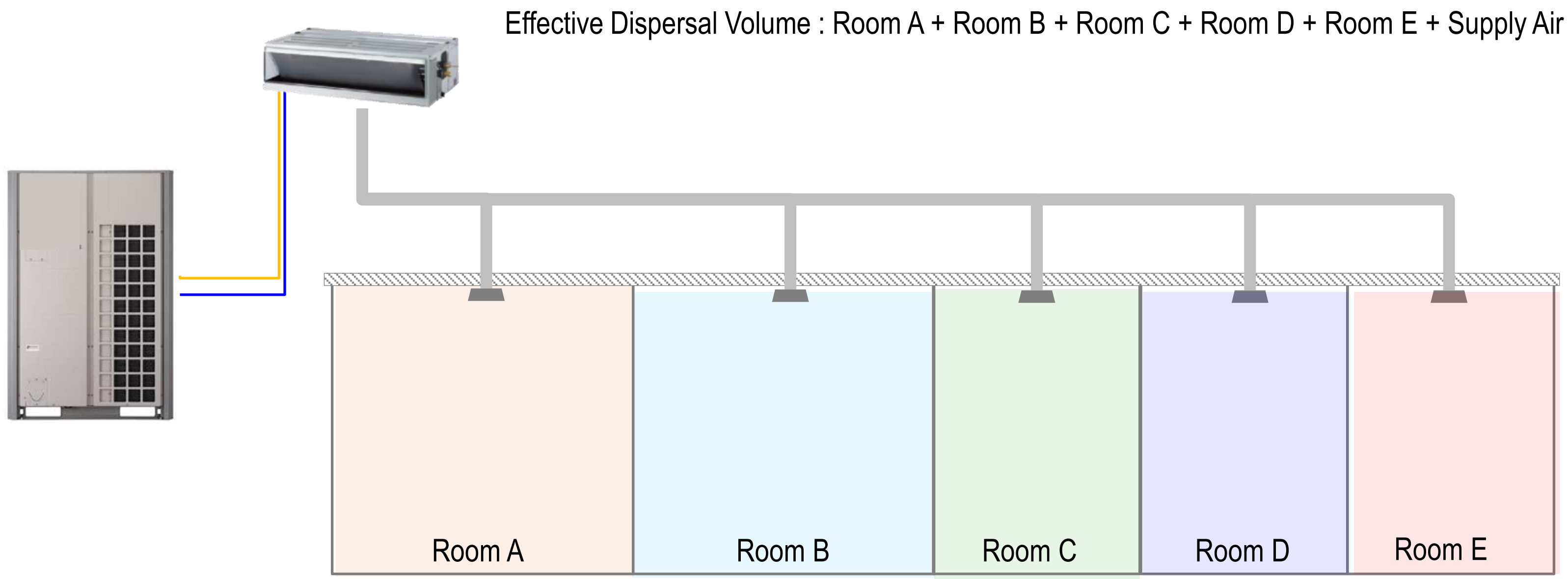
Annex N.3 Connected spaces via ducted air distribution system

ASHRAE15 : 7.2.3.3 Connected spaces via ducted air distribution system

N.3.1 General
Where a refrigeration system, or a part therof, is located within an air distribution duct system, or in a space served by an air distribution duct system, the entire air distribution system shall be analyzed to determine the worst-case distribution of leaked refrigerant. The effective dispersal volume in which the leaked refrigerant disperses shall be used to determine the EDVC in the system, subject to the criteria in Clauses N.3.1 to N.3.4

N.3.3 Plenum : The volume of an air ceiling plenum or floor plenum shall be included when calculating the EDV where the plenum space is a part of the refrigeration system air distribution system

N.3.4 Supply and return ducts : The volume of the supply and return ducts shall be included when calculating the effective dispersal volume



Annex Q Mechanical ventilation for high probability systems using A2L

ASHRAE15 : 7.6.4 Mechanical Ventilation

$$Q_{min} = \frac{Q_{req}}{C_{LFL}}$$ Must refer to table Q.1 & Q2 (ASHRAE 15 Table 7-4 & 7-5)

$$Q_{Req} = \frac{m_s - EDVC}{4 \times LFL} \times SF_{vent}$$ If m_s and EDVC value is known, does not have to refer to table Q1

$Q_{min} = Required\ minimum\ mechanical\ ventilation\ airflow\ rate\ (CFM)$

$Q_{req} = Required\ ventilation\ as\ determined\ from\ table\ Q1 (ASHRAE\ 15\ Table\ 7-4)$

$Q_{LFL} = lower\ flammability\ limit\ conversion\ factor\ as\ determined\ from\ table\ Q2\ (ASHRAE\ 15\ Table\ 7-5)$

$m_s = largest\ system\ refrigerant\ charge\ from\ independent\ circuit\ (lb)$

$4 = Assumed\ leak\ time\ (4\ minutes)$

$SF_{vent} = Safety\ factor, value\ of\ 2$

Example

If the total charge of the system is 60lbs

EDVC of the room is 27.5lbs (2,880ft^3)

$$Q_{Req} = \frac{60 - 27.5}{4 \times 19.1} \times 2$$

$$Q_{Req} = 850CFM$$

It requires **850CFM** mechanical fan to comply with CSA B52

Table 7-4 Required Ventilation for A2L Systems [a]

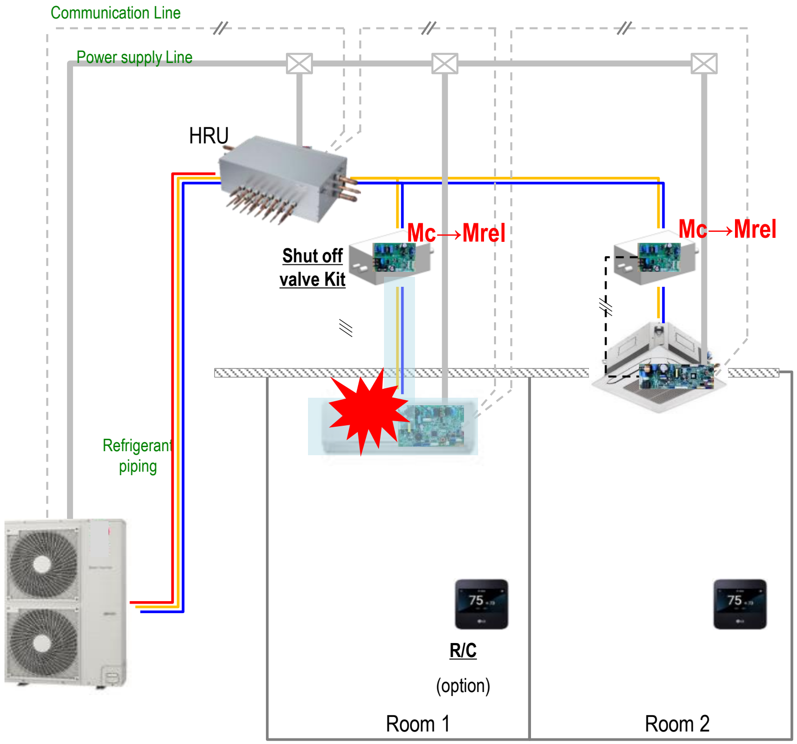
Excluded Charge ($m_s - EDVC$)[b]		Q_{req}		Excluded Charge ($m_s - EDVC$)[b]		Q_{req}	
lb	kg	ft^3/min	m^3/h	lb	kg	ft^3/min	m^3/h
3.8	1.7	100	170	91.8	41.6	2400	4080
7.6	3.5	200	340	95.6	43.4	2500	4250
11.5	5.2	300	510	99.4	45.1	2600	4420
15.3	6.9	400	680	103.2	46.8	2700	4590
19.1	8.7	500	850	107.1	48.6	2800	4760
22.9	10.4	600	1020	110.9	50.3	2900	4930
26.8	12.1	700	1190	114.7	52.0	3000	5100
30.6	13.9	800	1360	118.5	53.8	3100	5270
34.4	15.6	900	1530	122.4	55.5	3200	5440
38.2	17.3	1000	1700	126.2	57.2	3300	5610
42.1	19.1	1100	1870	130.0	59.0	3400	5780

Annex O Releasable Refrigerant Charge Calculation

O.1 Releasable refrigerant charge calculation (ASHRAE 15 : 7.3.4.3)

M_{rel} = Releasable Refrigerant Charge

- A portion of the system refrigerant charge that can be released into a space as a result of a single point failure



$$m_{rel} = (t_{r1} \times 0.0062) + m_{r2} + m_{r3}$$

t_{r1} = time before the leak is detected

0.0062 = leakage rate in lb/s

m_{r2} = leakage between the detection of the leak and the closing of the safety shutoff valve (lb)

$$m_{r2} = t_{close} \times 0.0062$$

t_{close} = time from when a leak is detected until the saftey shutoff valve closes

m_{r3} = leakage in the piping downstream of the safety shutoff valve after the valve is closed (lb)

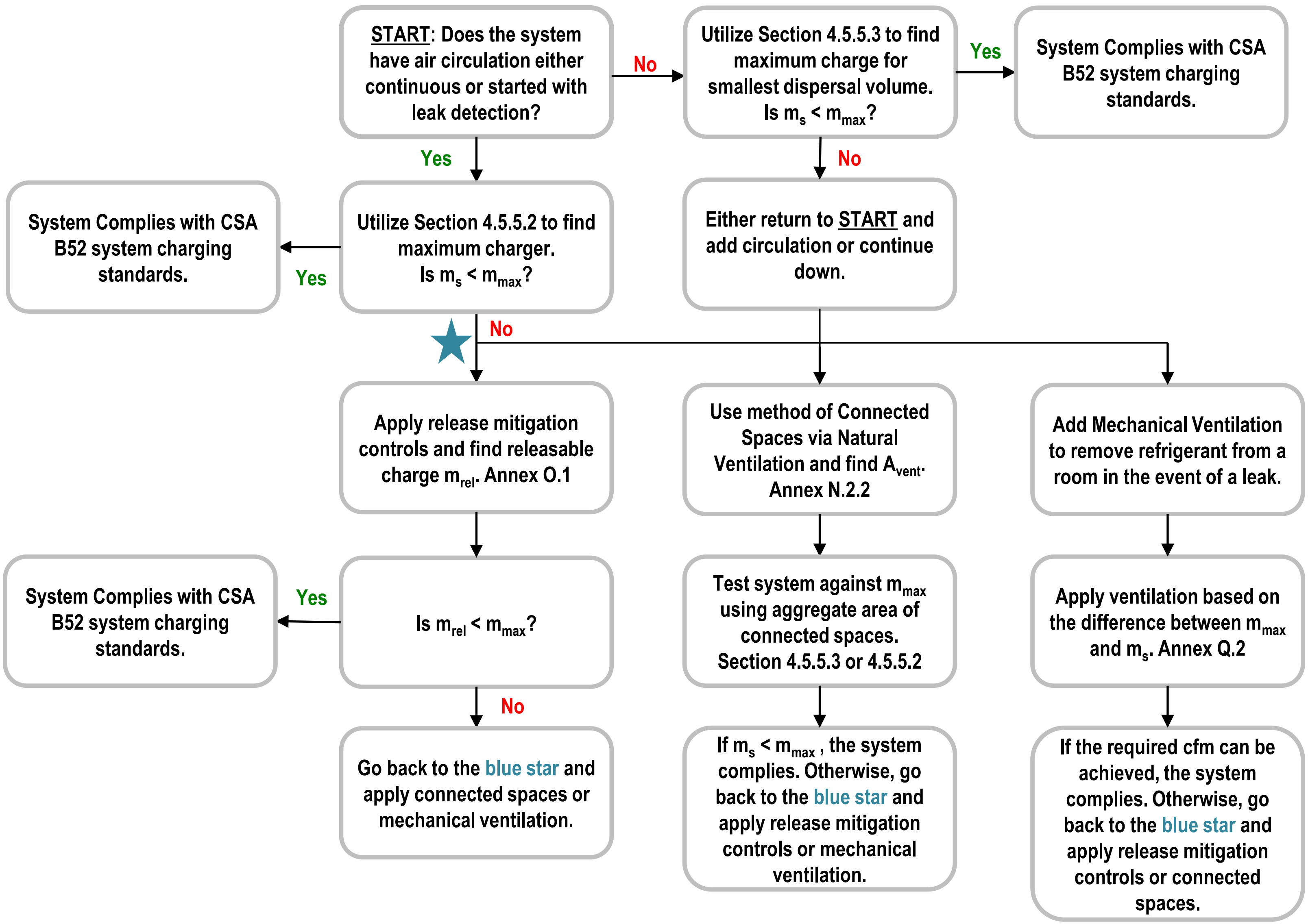
$$m_{r3} = \sum V_{pipe} \times \rho_{ref}$$

V_{pipe} = internal volume of each section of the piping and HEX downstream (ft^3)

ρ_{ref} = density of the refrigerant in each section of pipe downstream (lb/ft^3)

Depending on the m_{rel} amount, design may not require any natural ventilation

CSA B52 : 23


START: Does the system have air circulation either continuous or started with leak detection?
No
Utilize Section 4.5.5.3 to find maximum charge for smallest dispersal volume. Is $m_s < m_{max}$?
Yes
System Complies with CSA B52 system charging standards.
Yes
No
System Complies with CSA B52 system charging standards.
Yes
Utilize Section 4.5.5.2 to find maximum charger. Is $m_s < m_{max}$?
Either return to START and add circulation or continue down.
No
Apply release mitigation controls and find releasable charge m_{rel}. Annex O.1
Use method of Connected Spaces via Natural Ventilation and find A_{vent}. Annex N.2.2
Add Mechanical Ventilation to remove refrigerant from a room in the event of a leak.
System Complies with CSA B52 system charging standards.
Yes
Is $m_{rel} < m_{max}$?
Test system against m_{max} using aggregate area of connected spaces. Section 4.5.5.3 or 4.5.5.2
Apply ventilation based on the difference between m_{max} and m_s. Annex Q.2
No
Go back to the blue star and apply connected spaces or mechanical ventilation.
If $m_s < m_{max}$, the system complies. Otherwise, go back to the blue star and apply release mitigation controls or mechanical ventilation.
If the required cfm can be achieved, the system complies. Otherwise, go back to the blue star and apply release mitigation controls or connected spaces.

Standard

UL60335-2-40

International Standard

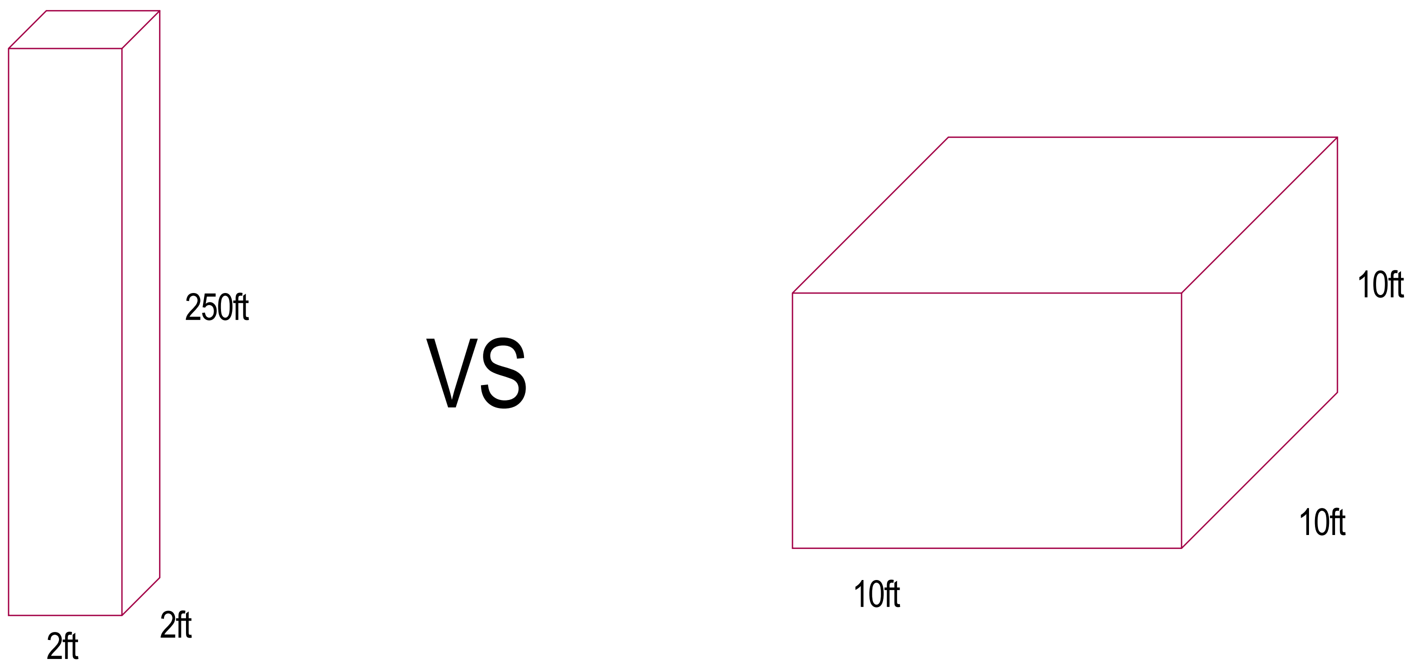
UL60335-2-40

CSA B52 code regulates the refrigerant based on the volume.

UL60335-2-40 regulates the refrigerant based on the area.

Example with R410a

RCL : 26lbs / 1000ft^3



NOT TO RATIO

UL60335-2-40 4th

Regulation with shutoff valve

4th Edition

shut-off valve : $m_{rel} < 0.5 \times LFL \times H_r \times A$

Before leak is detected / Detection-closing the valve / After closing the valve

$$m_{rel} = t_{rl} \times 0.0062 + 0.0062 \times t_{cl} + \sum V_{part,i} \times \rho_{part,i}$$

Or

m_{rel} =Max(Releasable charge in heating/cooling /off mode)

Releasable charge in heating/cooling mode

$=L_{valve\sim IDU} x TD_{tube\ volume/length} x \rho_{density} + L_{valve\sim IDU} x TD_{tube\ volume/length} x \rho_{density} + V x \rho_{mix} + 0.204$

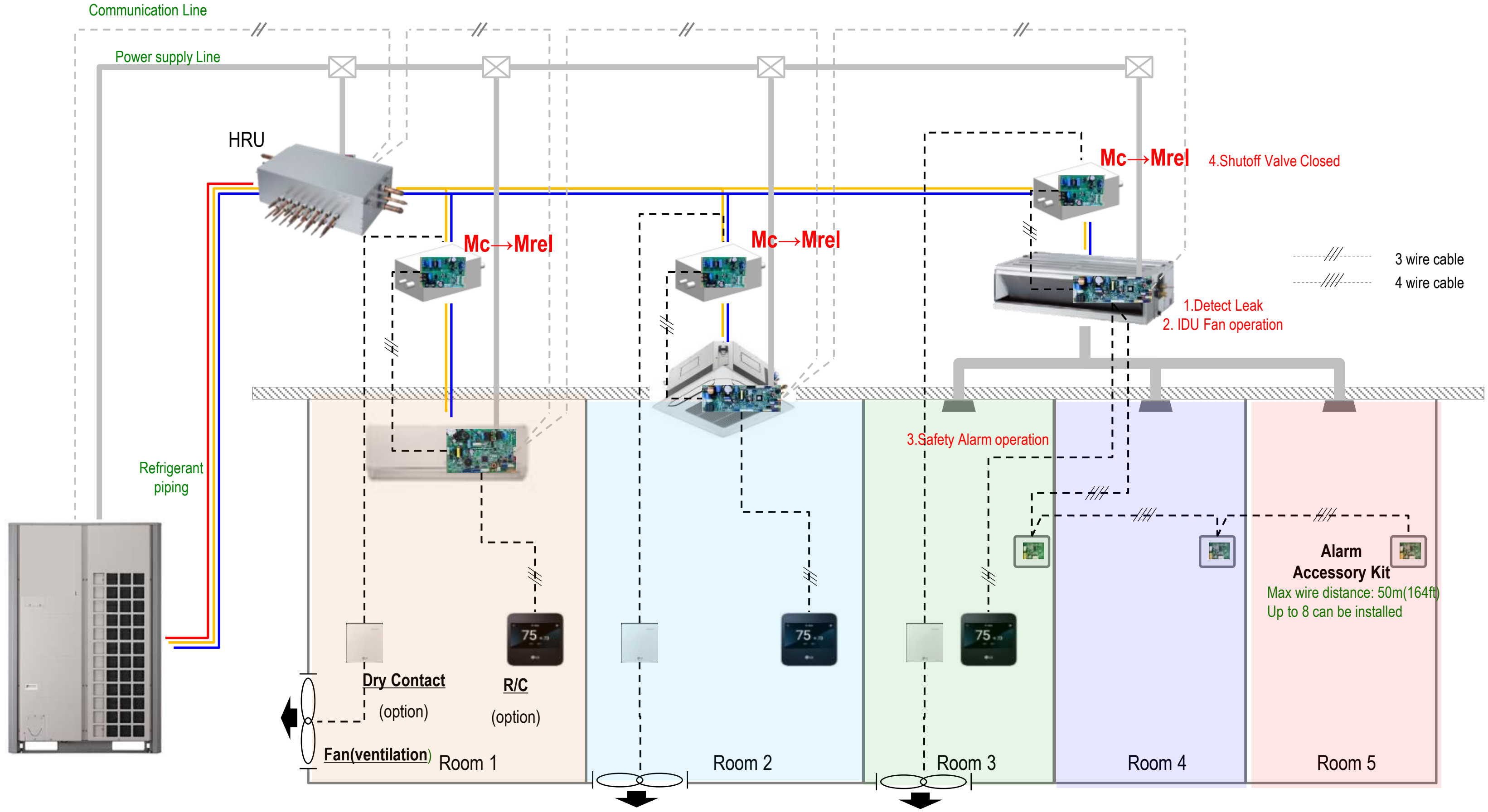
Releasable charge in off mode

$= L_{valve\sim IDU} x\ TD_{tube\ volume/length} + L_{valve\sim IDU} x\ TD_{tube\ volume/length} x \rho_{density} + V\ x\ \rho_{mix} + 0.204]$

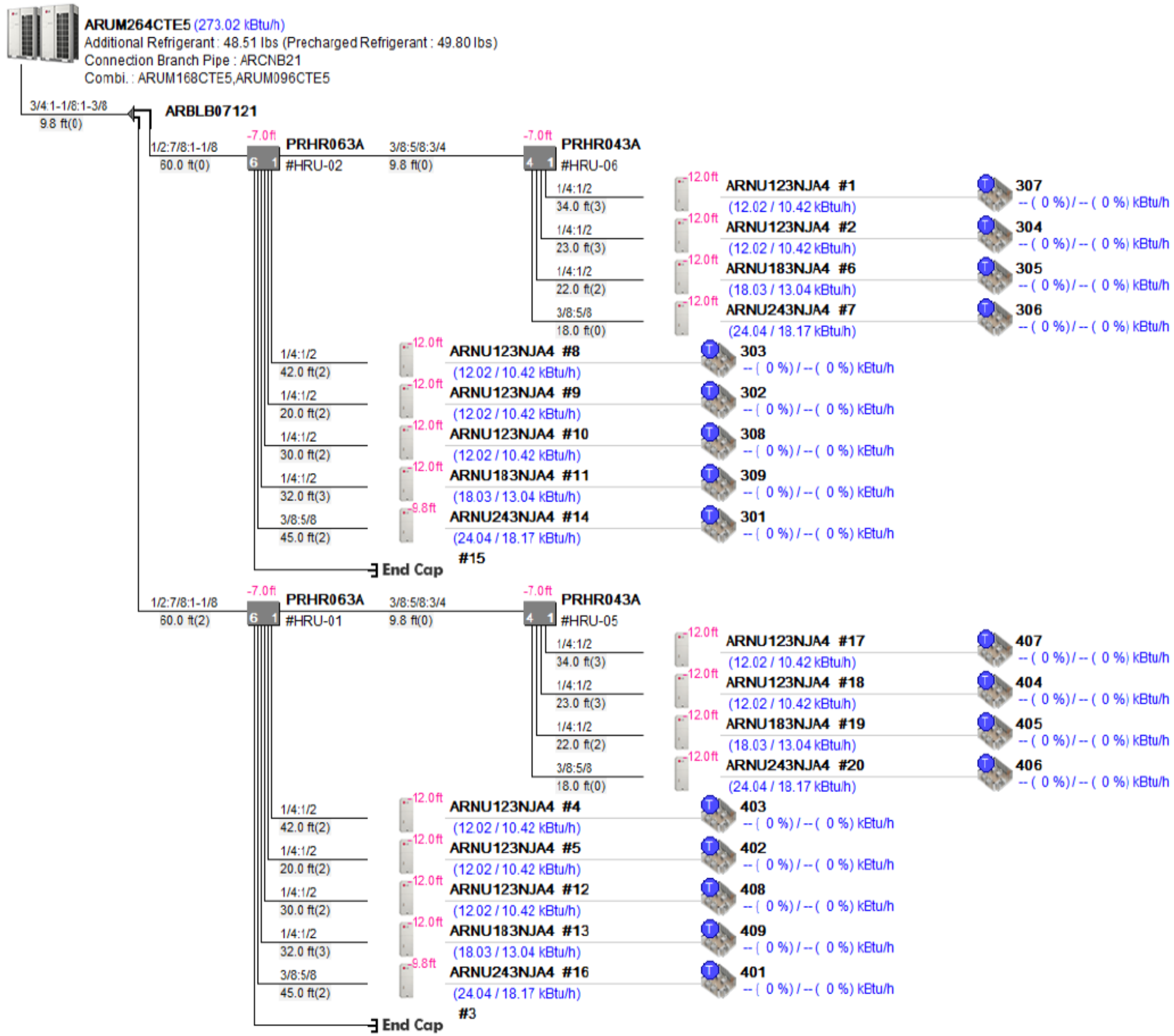
[cooling /Off mode] $\rho_{mix} = 0.2 \times \rho_{LIQ} + 0.8 \times \rho_{vap}$

[Heating mode] $\rho_{mix} = 0.4 \times \rho_{LIQ} + 0.6 \times \rho_{vap}$

Safety device installation



Example system with R32 VRF system



Assumption
Ceiling height : 10ft
Minimum room sqft : 378ft^2

Indoor Units	**: 18 of 42**
Combination Ratio	**: 288.0 of 264.0 (109%)**
Total Pipe	**: 681.5 of 3280.8 ft**
ODU factory charge	**: 49.80 lbs**
Additional Refrigerant	**: 48.51 lbs**
Total refrigerant	**: 98.32 lbs**
Minimum room volume	**: 3781.44 ft³**
(Based on 26.0 lbs / 1000.0 ft³)	

UL603325-2-40 4th

[cooling mode] $\rho_{mix} = 0.2 \times \rho_{LIQ} + 0.8 \times \rho_{vap}$

[Heating /OFF mode] $\rho_{mix} = 0.4 \times \rho_{LIQ} + 0.6 \times \rho_{vap}$

Releasable charge

$= L_{valve\sim IDU} x TD_{tube\ volume/length} x \rho_{density} + L_{valve\sim IDU} x TD_{tube\ volume/length} x \rho_{density} + V x \rho_{mix}$ +0.00045 (Leak during response time)

Heating Releasable Charge

= 45ft x 0.000205ft^3/ft x 55.75lbs/ft^3 + 45ft x 0.00108ft^3/ft x 4.57lbs/ft^3 + 0.056ft^3 x 45.51lbs/ft^3 + 0.0045

= 0.514lbs + 0.222lbs + 1.402lbs + 0.00045

= **2.14lbs**

Cooling Releasable Charge

= 45ft x 0.000205ft^3/ft x 63.68lbs/ft^3 + 45ft x 0.00108ft^3/ft x 1.89lbs/ft^3 + 0.056ft^3 x 38.96lbs/ft^3 + 0.0045

= 0.506lbs + 0.092lbs + 0.798lbs + 0.00045

= **1.40lbs**

Off Releasable Charge

= 45ft x 0.000205ft^3/ft x 60.26lbs/ft^3 + 45ft x 0.00108ft^3/ft x 2.87lbs/ft^3 + 0.056ft^3 x 48.78lbs/ft^3 + 0.0045

= 0.556lbs + 0.139lbs + 0.803lbs + 0.00045

= **1.50lbs**

m_{rel} = Max(Releasable charge in heating/cooling /off mode)

m_{rel} = 2.14lbs

Assumptions

R32 Refrigerant amount = R410a amount : 98.32lbs

Pipe diameter and length are identical to R410a

Ceiling height : 9ft

V.AHU sitting on 3ft stand

Shutoff Valve Kit is installed at the Heat Recovery Unit (45ft)

Liquid Pipe : 1/4”

Gas Pipe : 1/2”

Type L Copper

Volume per feet

Liquid : 0.00021ft^3/ft

Vapor : 0.00108 ft^3/ft

IDU : ARNU123NJA4

Coil Volume : 0.056ft^3 (1600.9cm^3)

Refrigerant Type	Operation	State	Temperature (°C)	Density (lbs/ft^3)
R32	Heating	Vapor	40.6	4.57
R32	Heating	Liquid	40.6	55.75
R32	Heating	Mix	-	25.04
R32	Cooling	Vapor	10	1.89
R32	Cooling	Liquid	43.3	54.8
R32	Cooling	Liquid	10	63.68
R32	Cooling	Mix	-	14.25
R32	Off	Vapor	23.9	2.87
R32	Off	Liquid	23.9	60.26
R32	Off	Mix	-	14.35

Area calculation for a room with safety alarm

$A_{min} = m_c / (0.50 \times LFL \times H_{IDU})$

A_{min} = 2.14lbs / (0.50 x 19.1 lbs/1000ft^3 x 3ft)

$A_{min} = 74.7ft^2$

CSA B52 : 23

Assumptions
R32 Refrigerant amount = R410a amount : 98.32lbs
Pipe diameter and length are identical to R410a
Ceiling height : 9ft
V.AHU sitting on 3ft stand
Shutoff Valve Kit is installed at the Heat Recovery Unit (45ft)
Liquid Pipe : 1/4”
Gas Pipe : 1/2”
Type L Copper

Volume per feet
Liquid : $0.00021 ft^3/ft$
Vapor : $0.00108 ft^3/ft$

IDU : ARNU123NJA4
Coil Volume : $0.056ft^3$ ($1600.9cm^3$)

Releasable charge

$= (t_{r1} \times 0.0062) + m_{r2} + m_{r3}$

Issue with CSA B52 code : It does not mention the ratio between Liquid and Gas at Mixed condition

Assumption : Use the same mix condition as UL60335-2-40 3rd or 4th (worst case)

[3rd]	[4th]
$\rho_{mix.heating}$ = 45.51lbs/ft^3	$\rho_{mix.heating}$ = 25.04lbs/ft^3
$\rho_{mix.cooling}$ = 38.96lbs/ft^3	$\rho_{mix.cooling}$ = 14.25lbs/ft^3
$\rho_{mix.off}$ = 48.78lbs/ft^3	$\rho_{mix.off}$ = 14.35lbs/ft^3

For this example, we will use the heating density of UL 60335-2-40 3rd Edition

Total Refrigerant Leaked
$m_{rel}=(t_{r1} \times 0.0062) + m_{r2} + m_{r3}$
t_{r1} = 30 secs as per CSA B52 : 23 Annex P P.1 g)
t_{r1} = 15 secs as per CSA B52 : 23 Annex P P.2
m_{rel}=(30s x 0.0062lbs/s) + (15s x 0.0062lbs/s) + (45ft x 0.000205ft^3/ft x 55.75lbs/ft^3 + 45ft x 0.00108ft^3/ft x 4.57lbs/ft^3 + 0.056ft^3 x 45.51lbs/ft^3)
m_{rel}= 0.186lbs + 0.093lbs + 0.514lbs + 0.222lbs + 2.549lbs
m_{rel}= 3.564lbs

EDVC Calculation
EDVC = V_{eff} x LFL x CF x F_{occ}
3.564lbs = V_{eff} x 19.1lbs/1000ft3 x 0.5 x 1

With condition of fan initiating when leak is detected

$V_{eff} = 373.2ft^3$

Thank you