VRF/VRV HVAC Systems and the Transition to Lower GWP Refrigerants

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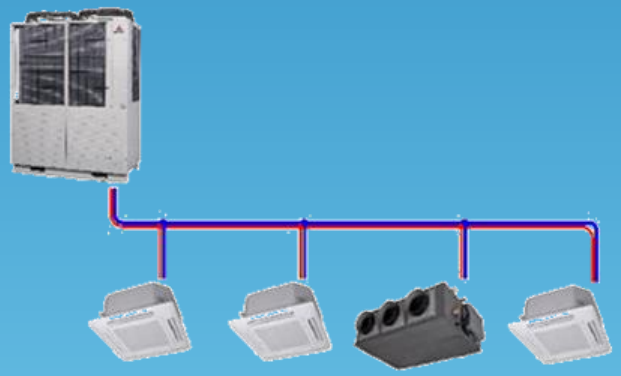
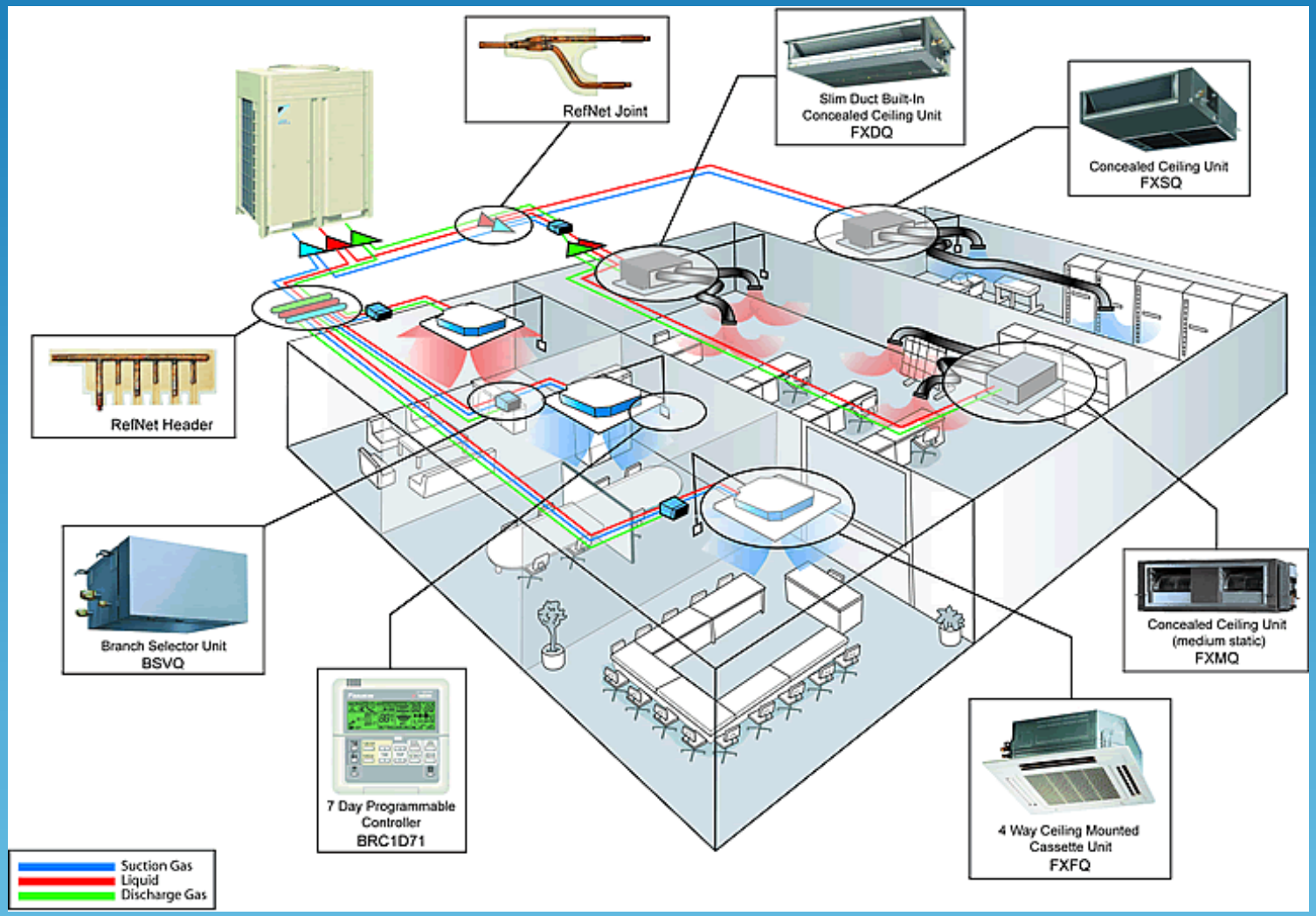
Variable Refrigerant Volume (VRV)
Variable Refrigerant Flow (VRF)



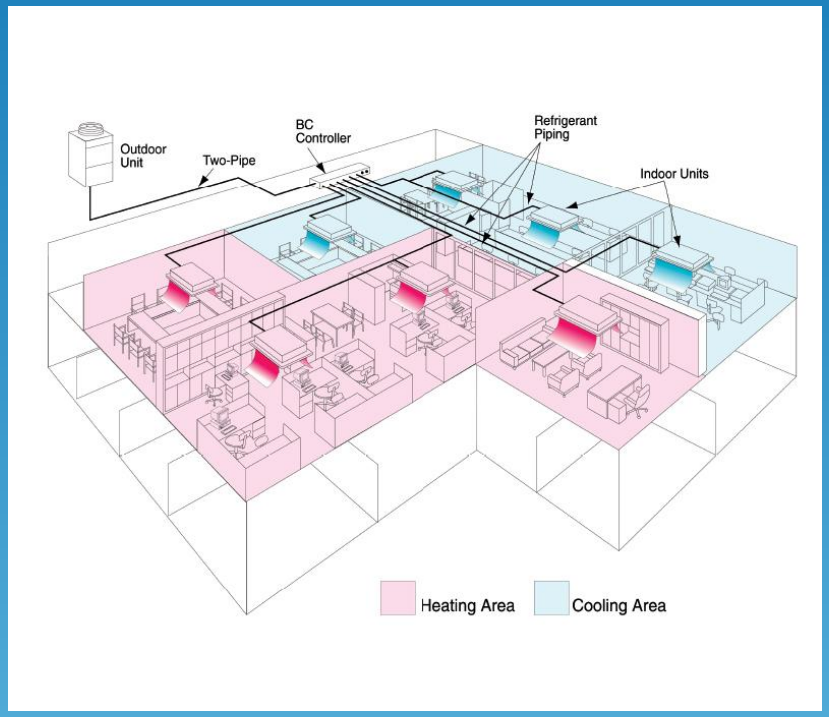
- VRV and VRF systems are popular for saving energy and allowing better control of the interior environment
- The Mechanical Code permits these systems using current refrigerants
- Newer systems will likely be using A2L refrigerants
- The use of A2L refrigerants is not economical based on current requirements, however changes are being considered
- Not all A2L refrigerants are suitable for comfort cooling equipment and must be evaluated to ensure performance, efficiency, safety, etc.

Components in VRF and VRV



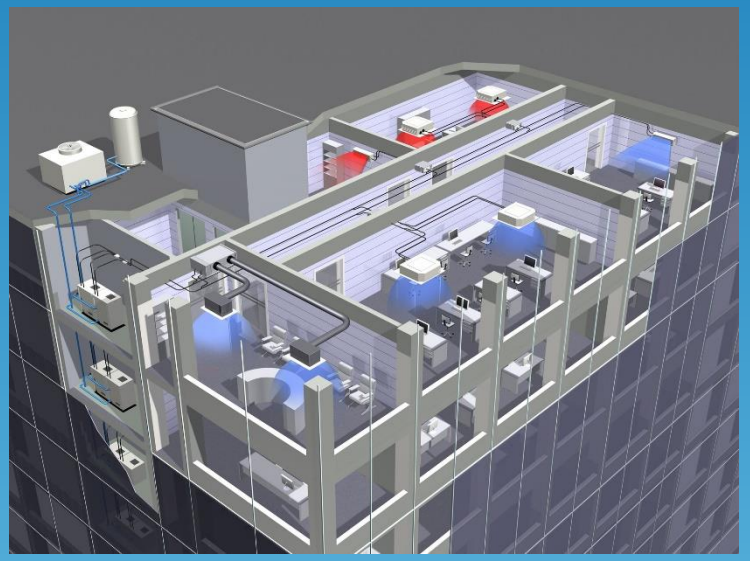
VRV and VRF Technology

- Both VRV and VRF use computer technology to control the heating and cooling in a building
- The system is considered a multi-split system (multiple indoor units) with refrigerant piping to an outdoor central unit
- Integrated controls determine when heating or cooling is required
- A system may be configured with different model types of Indoor Units to suit individual room requirements



Energy Efficiency Increases

- The purpose of a VRV or VRF system is to increase efficiency and comfort
- Heat recovery systems allow for cooling and heating simultaneously
- First costs can be higher than rooftop systems, but higher efficiencies can result in overall cost savings
- Individual rooms or zones may be turned on or off as may be needed without impacting comfort in other areas



Evaluation of RCL For VRF/VRV Systems

- The refrigerant concentration limit (RCL) becomes an important calculation for A2L refrigerants
- RCL is based on the LFL for flammable refrigerants
- Each space with an indoor unit must be evaluated for compliance with the RCL

Refrigerant Concentration Limit (RCL)

Refrigerant Concentration Limit (RCL): "*the refrigerant concentration limit, in air, determined in accordance with this standard and intended to reduce the risks of acute toxicity, asphyxiation and flammability hazards in normally occupied, enclosed spaces*"

Expressed in pounds of refrigerant charge per 1000 cubic feet

AHRI Low-GWP AREP

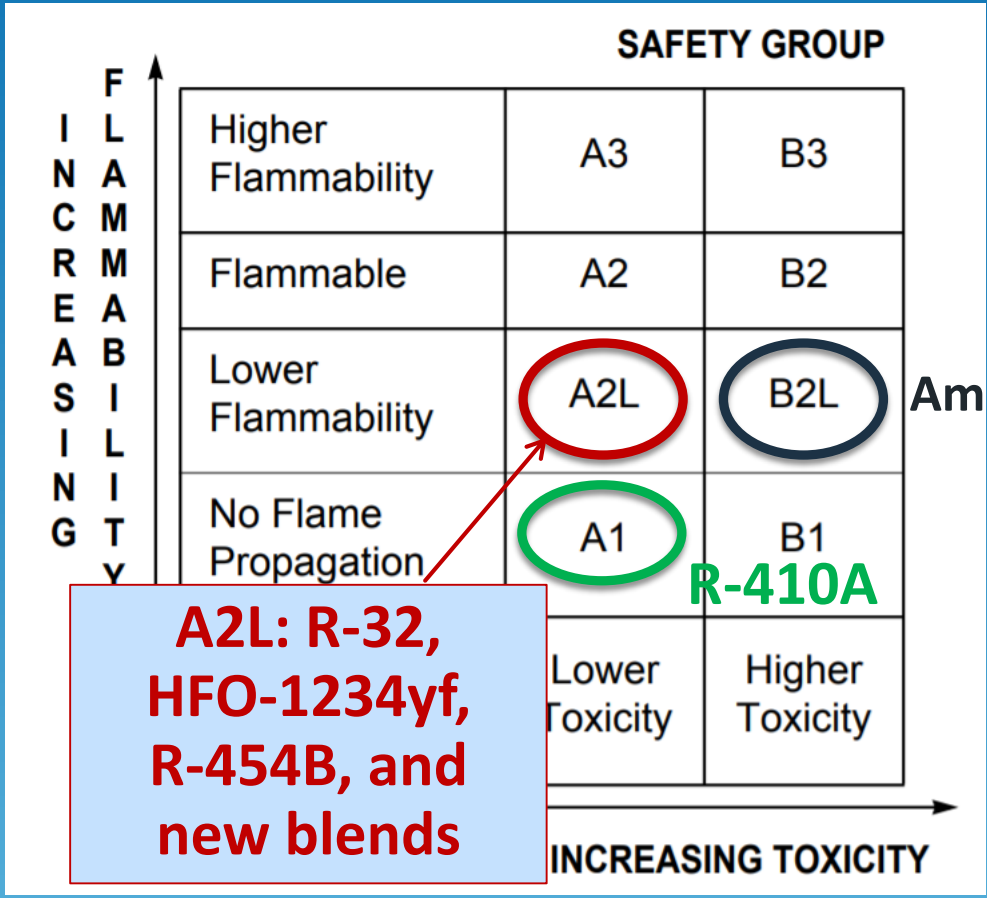
List of Low GWP Candidates in Phase I

Baseline	Refrigerant	Composition	(Mass%)	Classification (Note 1)	GWP_{100} (Note 2)
R410A	ARM-70a	R-32/R-134a/R-1234yf	(50/10/40)	A2L	482
	D2Y60	R-32/R-1234yf	(40/60)	A2L	272
	DR-5	R-32/R-1234yf	(72.5/27.5)	A2L	490
	HPR1D	R-32/R-744/R-1234ze(E)	(60/6/34)	A2L	407
	L41a	R-32/R-1234yf/R-1234ze(E)	(73/15/12)	A2L	494
	L41b	R-32/R-1234ze(E)	(73/27)	A2L	494
	R32	R32	100	A2L	675
	R-32/R-134a	R-32/R-134a	(95/5)	A2L	713
	R-32/R-152a	R-32/R-152a	(95/5)	A2L	647

List of Low GWP Candidates in Phase II

Baseline	Refrigerant	Composition	(Mass%)	Classification (Note 1)	GWP_{100} (Note 2)
R410A	ARM-71a	R-32/R-1234yf/R-1234ze(E)	68/26/6	A2L	460
	DR-5A (R-454B)	R-32/R-1234yf	68.9/31.1	A2L	466
	DR-55	R-32/R-125/R-1234yf	67/7/26	A2L	698
	HPR2A	R-32/134a/1234ze(E)	76/6/18	A2L	600
	L-41-1 (R-446A)	R-32/R-1234ze/Butane	68/29/3	A2L	461
	L-41-2 (R-447A)	R-32/R-1234ze/R-125	68/28.5/3.5	A2L	583

2L "Lower Flammability" Class



The 2L safety group was introduced to differentiate the lower-GWP HFC refrigerants within class 2 based on *burning velocity*.

RCL Applicable to VRF/VRV

TABLE 1102.3
REFRIGERANT GROUPS, PROPERTIES, AND ALLOWABLE QUANTITIES[8]
[ASHRAE 34: TABLE 4-1, TABLE 4-2]

REFRIGERANT	CHEMICAL FORMULA	CHEMICAL NAME[1] (COMPOSITION FOR BLENDS)	SAFETY GROUP[7]	OEL[2] (ppm)	POUNDS PER 1000 CUBIC FEET OF SPACE
R-11	CCl_3F	Trichlorofluoromethane	A1	C1000	0.39
R-12	CCl_2F_2	Dichlorodifluoromethane	A1	1000	5.6
R-13	$CClF_3$	Chlorotrifluoromethane	A1	1000	8.5
R-13B1	$CBrF_3$	Bromotrifluoromethane	A1	1000	12
R-14	CF_4	Tetrafluoromethane	A1	1000	11
R-20	$CHCl_3$	Trichloromethane	A1	10	0.12
R-21	$CHCl_2F$	Dichlorofluoromethane	B1	10	0.19
R-22	$CHClF_2$	Chlorodifluoromethane	A1	1000	13
R-23	CHF_3	Trifluoromethane	A1	1000	7.3
R-30	CH_2Cl_2	Dichloromethane (methylene chloride)	B1	—	—
R-31	CH_2ClF	Chlorofluoromethane	—	—	—
R-32	CH_2F_2	Difluoromethane (methylene fluoride)	A2L	1000	4.8
R-40	CH_3Cl	Chloromethane	B2	50	0.63
R-41	CH_3F	Fluoromethane (methyl fluoride)	A2	1000	2.3
R-50	CH_4	Methane	A3	1000	0.28
R-113	CCl_2FCClF_2	1, 1, 2-trichloro-1, 2, 2 – t	A1	1000	0.78
R-114	$CClF_2CClF_2$	1, 2-dichloro-1, 1, 2, 2 tet	A1	1000	1.7
R-115	$CClF_2CF_3$	Chloropentafluoro	A1	1000	3.2
R-116	CF_3CF_3	Hexafluoroeth	A1	1000	3.4
R-123	$CHCl_2CF_3$	2, 2-dichloro-1, 1, 1, - trifluoroethane	B1	50	3.5
R-124	$CHClFCF_3$	2-chloro-1, 1, 1, 2 - tetrafluoroethane	A1	1000	3.5
R-125	CHF_2CF_3	Pentafluoroethane	A1	1000	23
R-134a	CH_2FCF_3	1, 1, 1, 2-tetrafluoroethane	A1	1000	13
R-410A	zeotrope	R-32/125 (50.0/50.0)	A1	1000	26

Charge size of an A2L refrigerant is 18.5% the charge size of an A1

Risk Mitigation Methods

A1

- Refrigerant Concentration Limit is based on either the Oxygen Deprivation Limit (ODL) or the Acute Toxicity Exposure Limit (ATEL)
- Maximum Refrigerant Concentration [System Charge divided by the volume of the space] must not exceed the RCL

A2L

- RCL = Flammable Concentration Limit = 25% of the Lower Flammability Limit (ASHRAE 34)
- Leak tightness
- Limits on charge size
- Refrigerant detection
- Air circulation & ventilation
- Shut-off valves
- Eliminate or reduce proximity to sources of ignition
- Warnings and signage
- Operation, Installation and Service Manuals

Doug Tucker, ASHRAE Webcast (2019)

ASHRAE Standard 15-2019

- Refrigerant concentration limits must not be exceeded, whether A1 or A2L
- For A2L systems, refrigerant detectors required when system charge >0.212 x LFL (in lb.)
- Example, detector required for systems with charge of R-32 > 4 lb.
- When detector senses concentration above 25% LFL, minimum supply fan airflow rate must be Qmin=1000 x M/LFL, where M=system charge
- Detector must be located in the indoor unit for ducted products

UL 60335-2-40 3rd Edition

Safety mitigation for systems with flammable refrigerants are based on the system refrigerant charge within three charge-level classifications: m1, m2, and m3, based on the lower flammability limit of the refrigerant. m1 is the lowest charge designation and m3 the maximum possible charge allowed for most systems with A2L-classified refrigerant. The charge designation determines which safety mitigation method must be provided with the system from the factory or during installation.

Unitary air conditioning systems with a charge less than m1 don’t require safety controls, but from charges greater than m1, up to and including m3, it must have a mitigation safety control in the event a refrigerant leak occurs.

UL 60335-2-40 3rd Edition

Annex 101.DVG – Additional requirements for multi-split system appliances, provides stricter requirements for multi-split systems due to larger charge quantities that could leak from a single indoor unit.

Mitigation options do exist: natural ventilation, circulation airflow, mechanical ventilation, enhanced tightness, and limiting the releasable charge.

Mitigation options will likely be required in most multi-split application which will increase cost from design through installation.

UL 60335-2-40 3rd Edition

- Three forms of mitigation available for multi-split equipment:
  - **Mechanical Ventilation**: operate continuously or initiated by the refrigerant detection system
  - **Alarm Systems**: turn on with refrigerant detection; 70dBA at 3m; visible and audible in the occupied space
  - **Safety Shut-off Valves**: normally closed; close within 30 seconds; seat leakage requirements; Body leakage test

- Additional requirements specific to Multi-Split Systems
  - Maximum refrigerant charge is restricted
  - Larger Charge Size allowed with mitigation (see below)
  - Mitigation test and design requirements
  - More stringent strength tests
  - Specific installation design requirements
- Larger Charge Size: Enough to have a meaningful impact when factoring in mitigation costs?
  - 101.DVG.3.4 defines maximum refrigerant charge, below m_{max} no mitigation required.

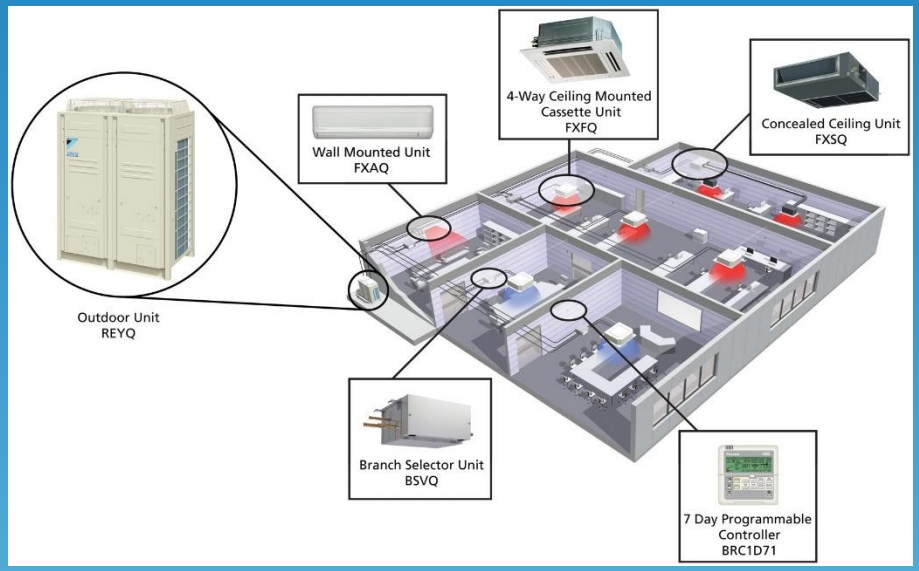
$$m_{max} = 0.25 * LFL * H * A$$

  - 101.DVG.3.5 defines maximum refrigerant charge, below m_{max} one form of mitigation is required.

$$m_{max} = 0.5 * LFL * H * A$$

    - H = room height (2.2m max)
    - A = floor area (250m^2 max)

UL/CSA 60335-2-40 Allowances When Exceeding RCL in Room



- If a room or space with refrigerant piping exceeds the RCL, detection and ventilation are required when using Group A2L refrigerant
- Safety shut off valves can also be used to isolate the refrigerant piping
- The ventilation of the space maintains the refrigerant concentration below the lower flammable limit (LFL)

Questions???