VARIABLE REFRIGERANT FLOW APPLICATION AND DESIGN

Prepared for: New Jersey ASHRAE

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Agenda

- Thank You!
- Introduction to VRF
- Typical Applications
- Heat Pump vs. Heat Recovery
- ASHRAE 15

Initial Thoughts

What is VRF?

What is VRF?

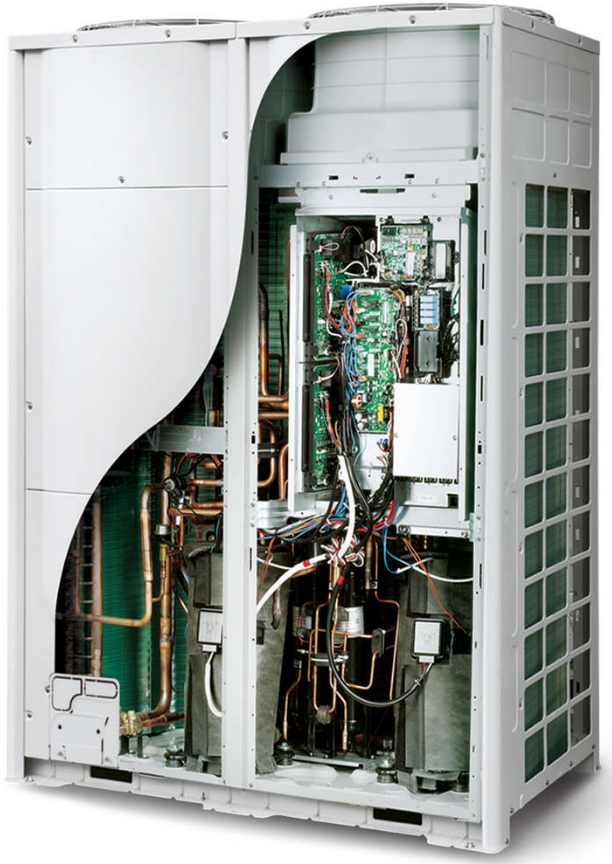
Basic Components

- Heat Pump Outdoor Unit or Water-Source Unit
- Indoor Unit(s)
- Refrigerant Piping
- Controls
- Heat Recovery Control Module (HR Only)

components

Typical Outdoor/Water-Source Unit

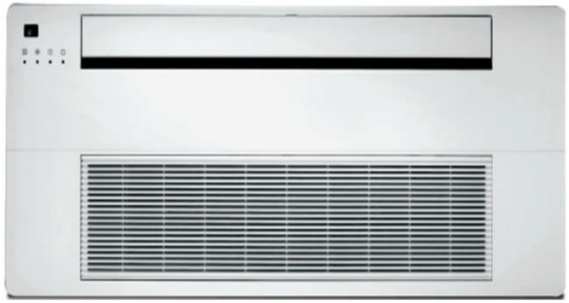
- Variable speed compressor(s)
- Condenser/Evaporator Coil
- Variable speed heat rejection fan(s)
- Heat exchanger (sub-cooler)
- Expansion device
- Oil separator

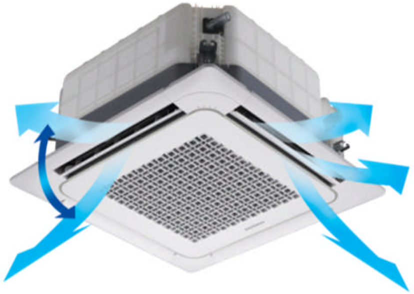


components

Indoor Unit

- Indoor coil and fans
- Expansion valve
- Diffusers



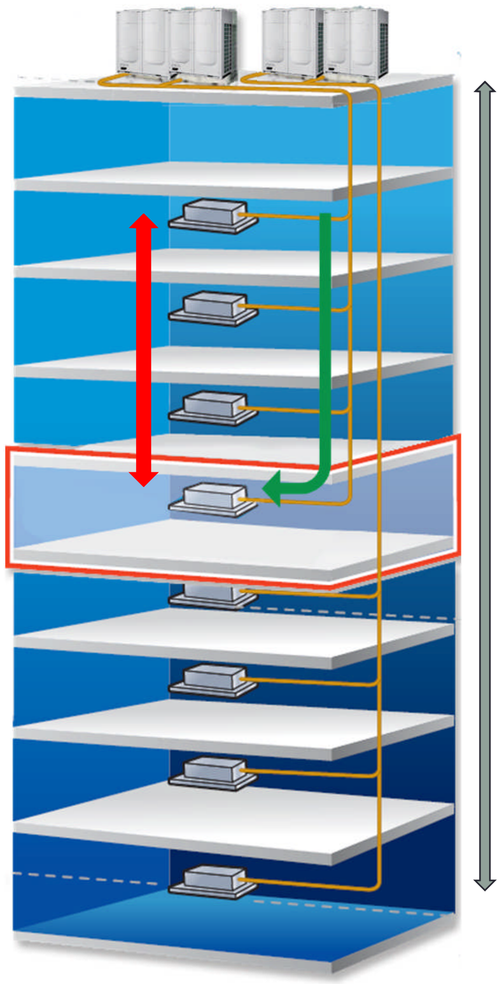


components

Refrigerant Piping

- Total elevation
- Maximum separation between indoor units
- Maximum distance between first branch and farthest indoor unit
- Total piping length

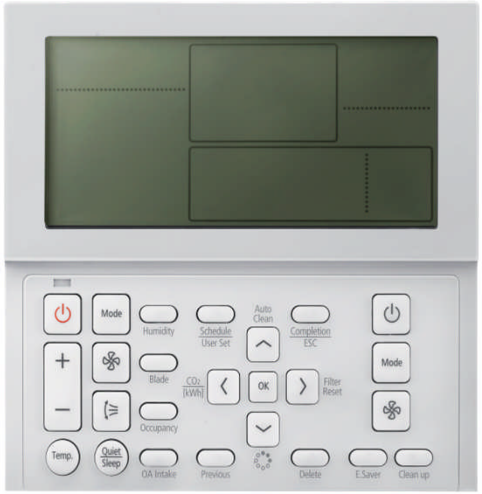
NOTE: All of these limits vary by manufacturer.



components

Controls

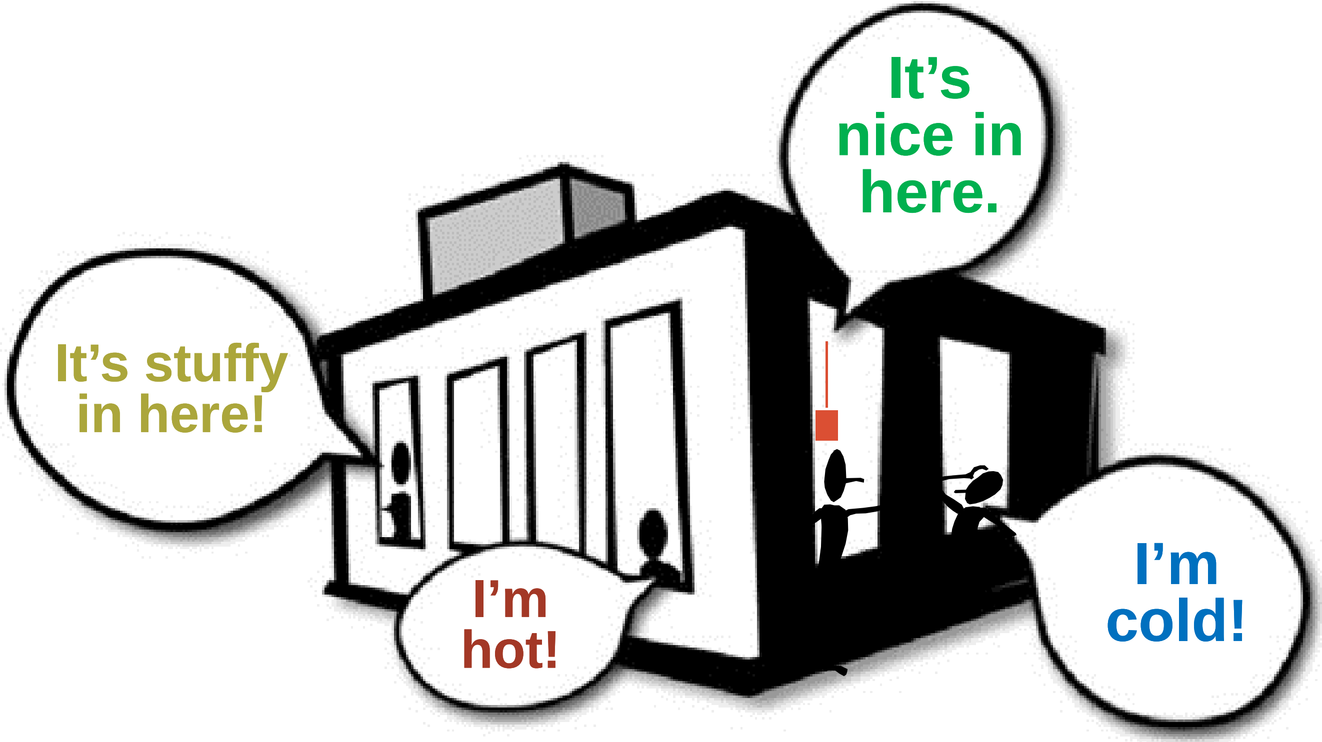
- Zone
- System
- Building



Scalable control options support many different application needs

Why VRF?

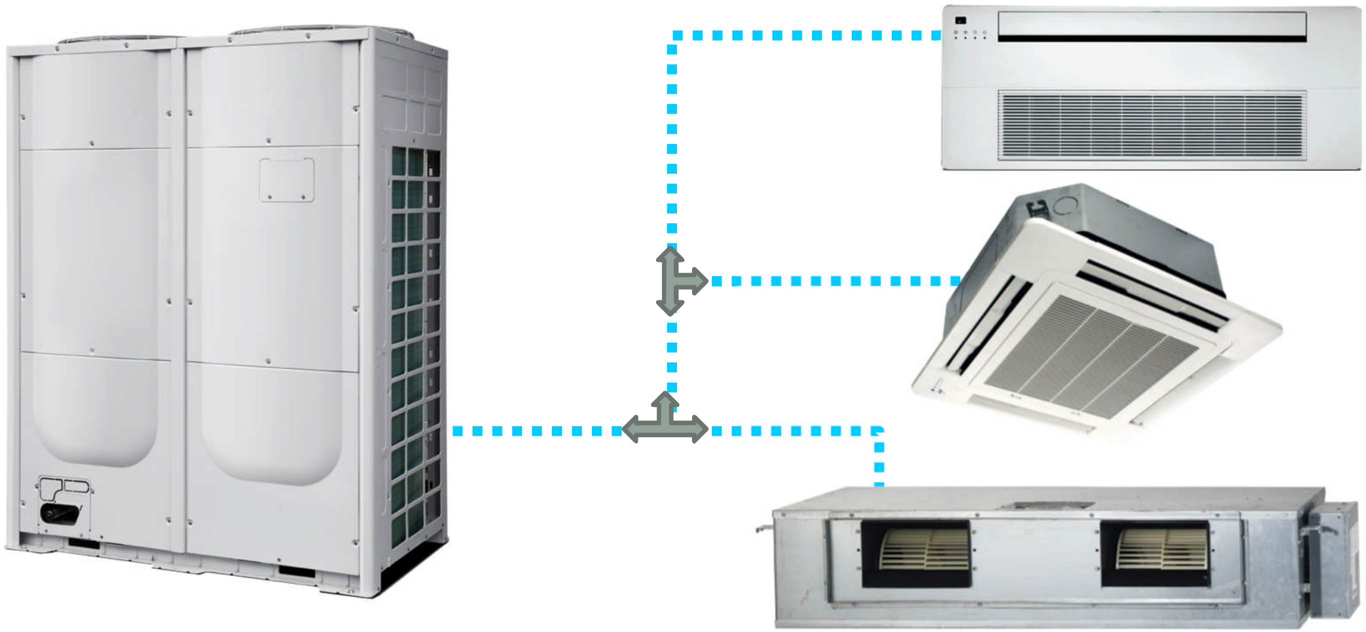
Traditional DX System Challenges



Single thermostats on traditional split systems may present a challenge…

What is VRF?

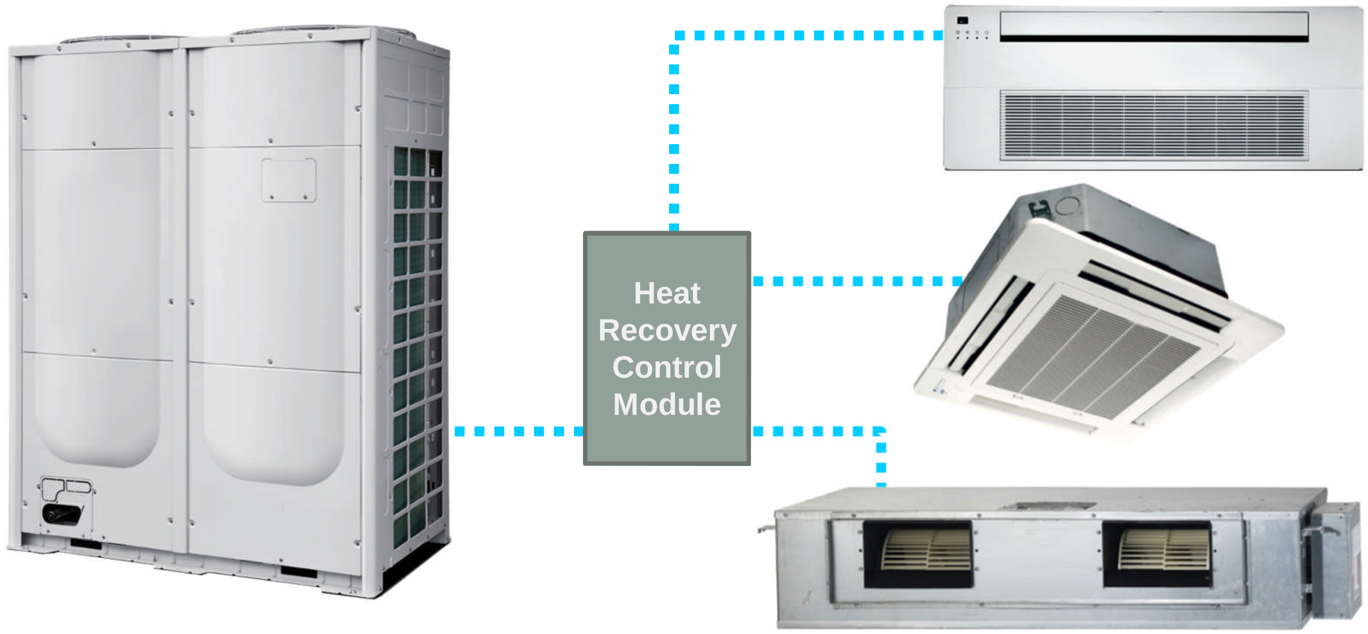
System Configuration



Two types of VRF: Heat Pump or Heat Recovery

What is VRF?

Simultaneous Heating and Cooling



Two types of VRF: Heat Pump or Heat Recovery

Why VRF?

Simultaneous Heating and Cooling

Dedicated Indoor Units

+

Dedicated Controllers/ Sensors

+

Heat Recovery Control Module

=

Individualized Zone Control

VRF technology allows for simultaneous heating and cooling

Why VRF?

Benefits and Advantages

- Energy Efficiency
- Comfortable Control
- Quiet Operation
- Small Footprint
- Scalable Capacity
- Ductless*
- Flexible Design

Why VRF?

Applications Suitable for VRF

- Buildings without ductwork
  - Historic buildings
  - Older homes being renovated
  - Buildings with hydronic heat
- Tenant finish and renovation
- Schools, day care facilities
- Banks & offices
- Extended care facilities
- Supplemental systems for off-season conditioning (e.g. school administrative wings)
- Upscale residences and condominiums

Why VRF?

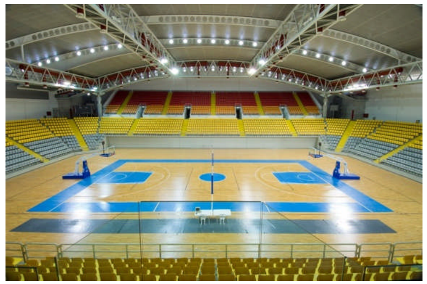
Applications Suitable for VRF

- Restaurants
- Small retail
- Boutique hotels
- Bed and Breakfast
- Multi-use commercial buildings

Why VRF?

Applications to Avoid VRF

- Buildings with large open spaces and high ceilings
  - Big box retail
  - Supermarkets
  - Arenas (other than box office and office areas)
- Applications incorporating data centers and server rooms



- Applications requiring superior air quality
  - Critical care facilities and surgical suites
- Applications with concerns about refrigerants within occupied spaces
- Applications requiring large amounts of outside air

System Configuration

Heat Pump vs. Heat Recovery

Goal:

Size and select indoor units and outdoor units to minimize the first cost and energy usage, while maintaining indoor comfort.

System Configuration

Heat Pump vs. Heat Recovery

Heat Pump

- Cooling OR heating at any given time
- Very little system diversity
  - Similar exposures/load profiles
- Indoor units connected to outdoor unit via refrigerant piping and branch joints

Heat Recovery

- Simultaneous heating and cooling
- Maximize system diversity
  - Requires a heat recovery control module between outdoor unit and indoor units

Without custom control logic, Heat Pump changeover is a challenge

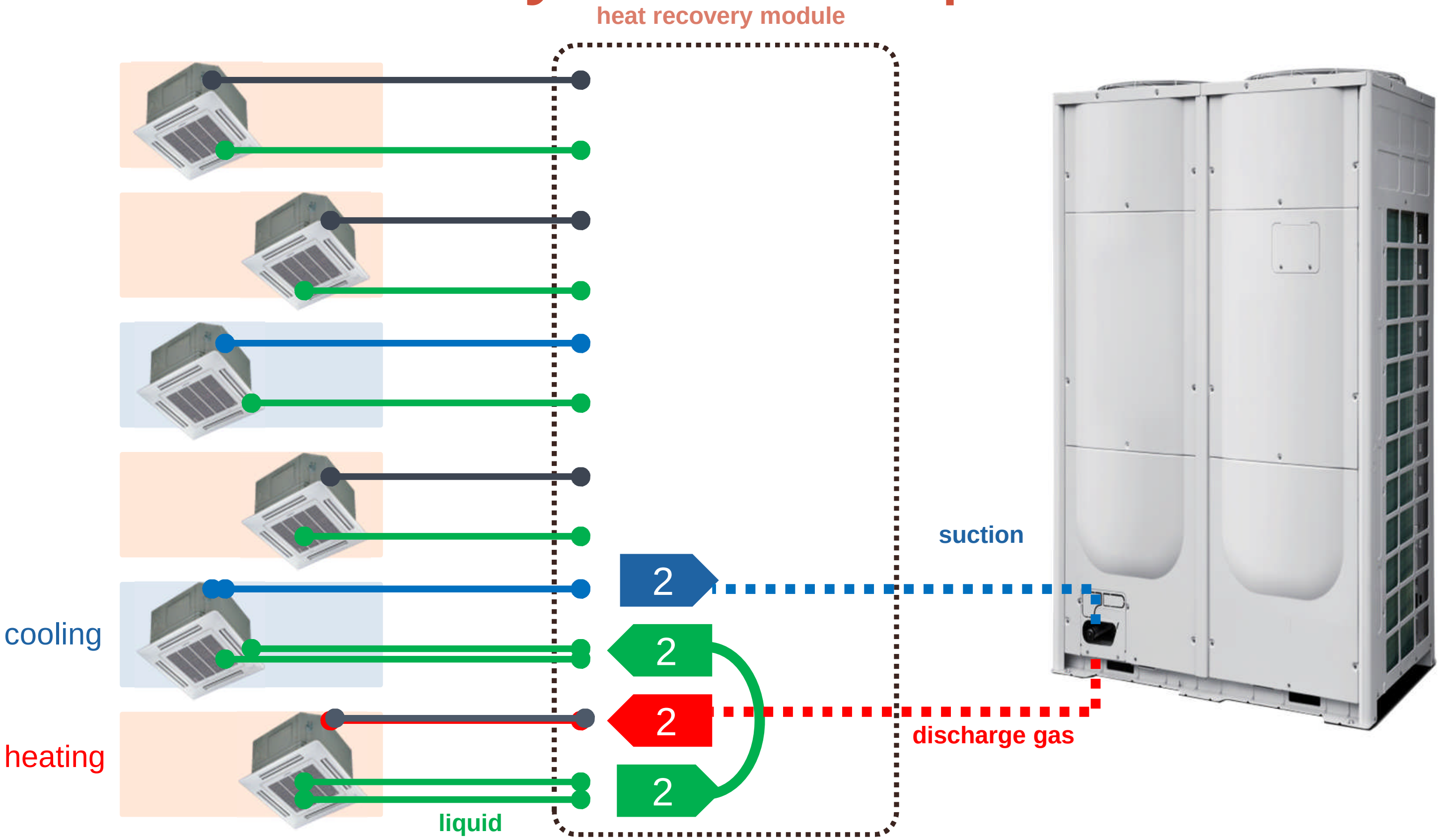
System Configuration

Heat Recovery Module Operation

- System control determines the type of refrigerant each indoor unit requires (liquid or hot gas), and supplies it using solenoid valves.
- Recycles waste product of heating zone to cooling zone

System Configuration

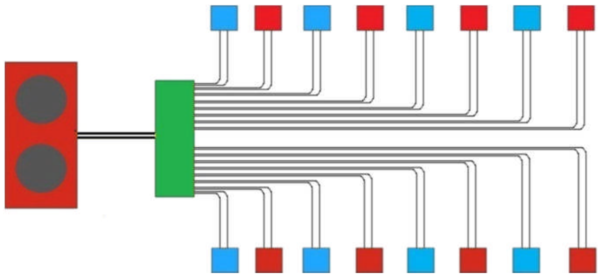
Heat Recovery Module Operation



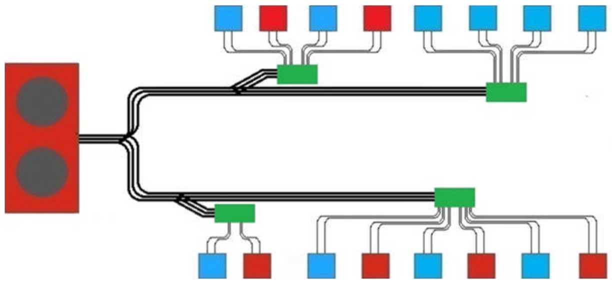
System Configuration

Heat Recovery Piping Architectures

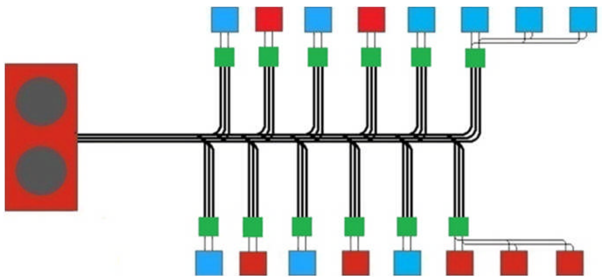
Home Run



Hybrid System



Independent Zones

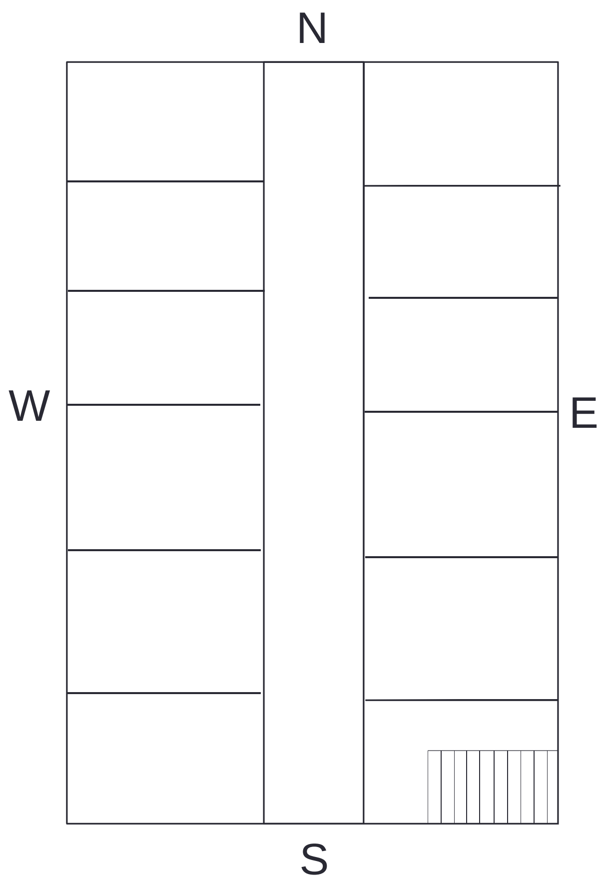


Key Differences

- Amount of refrigerant pipe required
- Number of zones on each heat recovery module
- Localized vs. centralized energy exchange
- Location of branch selectors

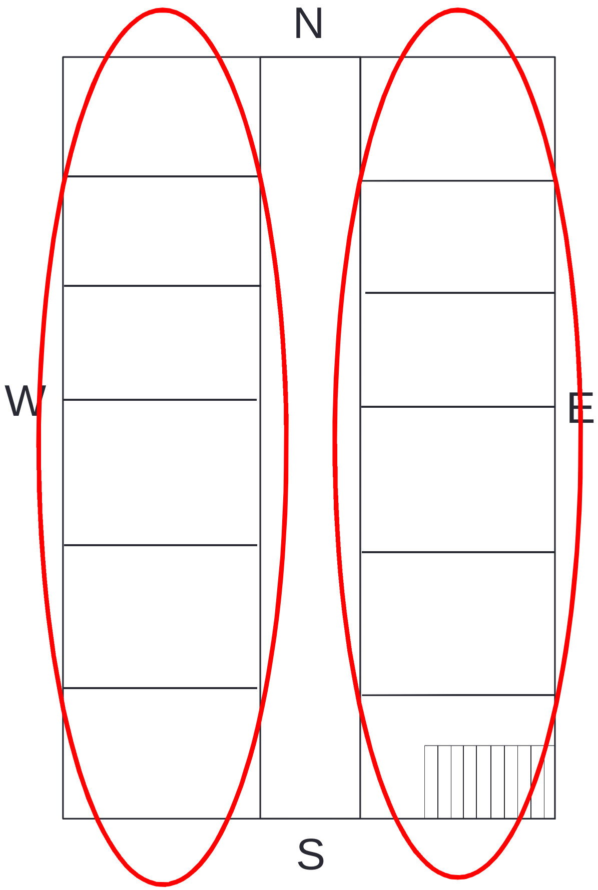
System Configuration

Heat Pump vs. Heat Recovery



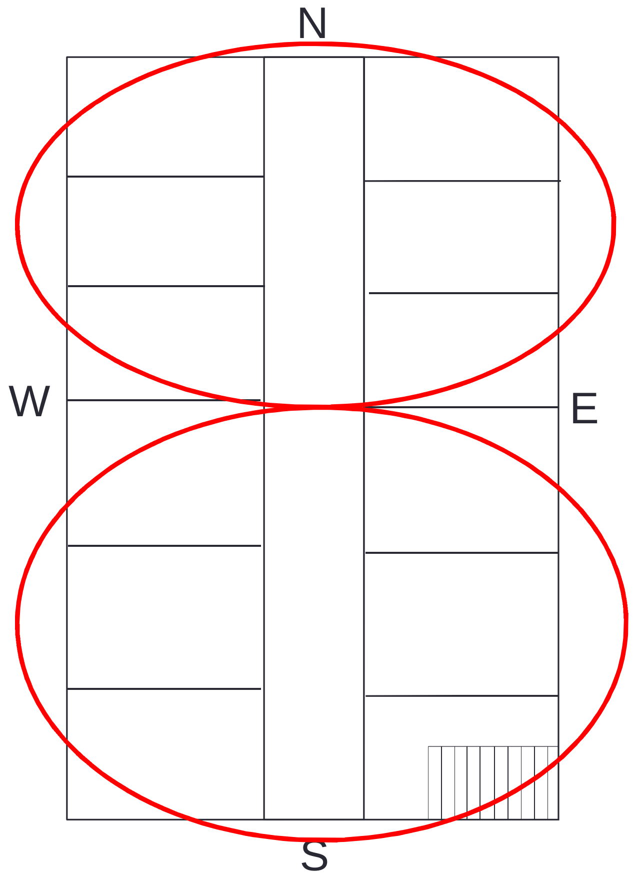
System Configuration

Heat Pump



System Configuration

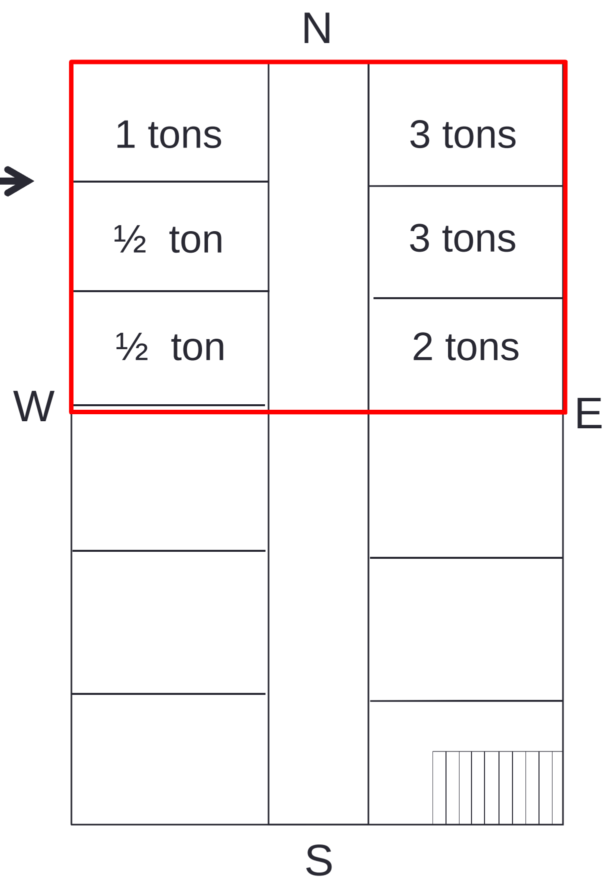
Heat Recovery



System Configuration

Combination Ratio

Zone Peak Loads →



Combination Ratio = $\frac{\text{Indoor Capacity}}{\text{Outdoor Capacity}}$

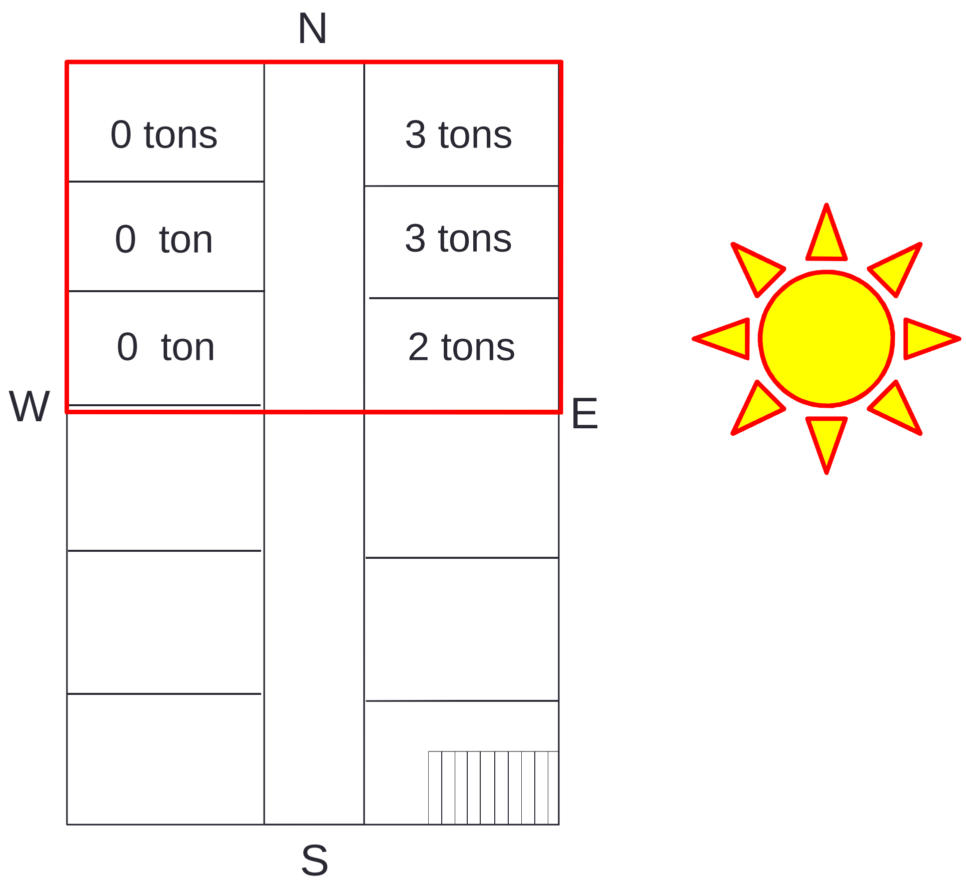
= $\frac{\text{10 tons}}{\text{10 tons}}$

= 100% CR

System Configuration

Combination Ratio

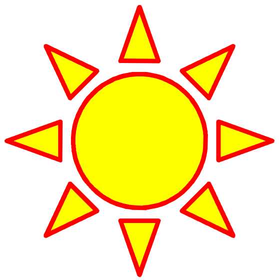
Morning Load:
8 tons

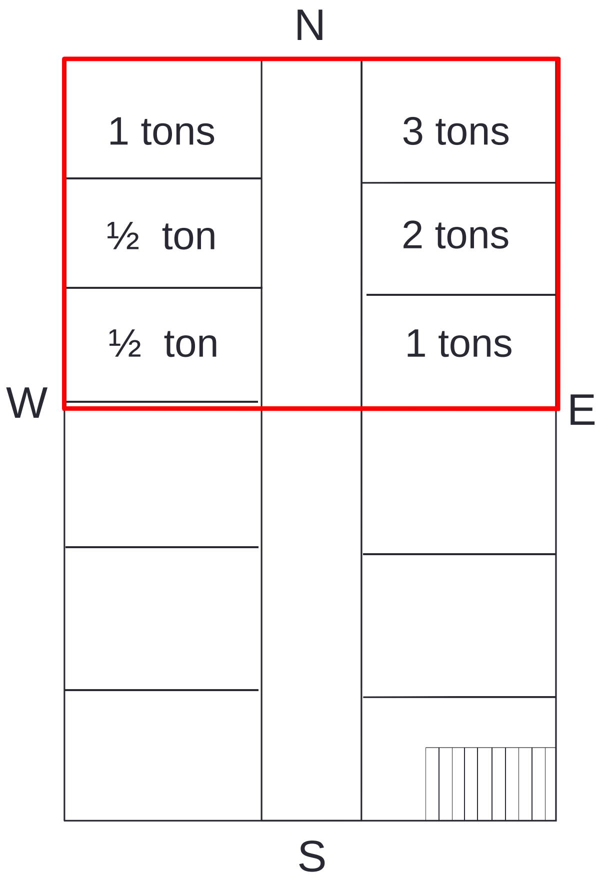


System Configuration

Combination Ratio

Afternoon Load:
8 tons





Combination Ratio = Indoor Capacity / Outdoor Capacity

$= \frac{10 \text{ tons}}{8 \text{ tons}}$

= 125% CR

Size indoor unit for individual zone peak loads, and outdoor unit for block load

But use caution!

Heat Pump vs. Heat Recovery

Summary

- System Diversity
- Zoning
- Combination Ratio

Remember….

Goal:

Size and select indoor units and outdoor units to minimize the first cost and energy usage, while maintaining indoor comfort.

ASHRAE Standard 15

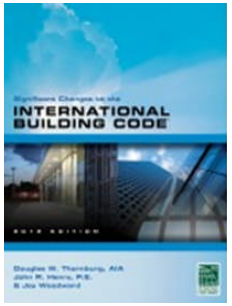
- Applicability
- Overview
- Example

International Mechanical Code

2015 IMC section 1101.6 General.

“Refrigeration systems shall comply with the requirements of this code and, except as modified by this code, ASHRAE 15. Ammonia-refrigerating systems shall comply with this code and, except as modified by this code, ASHRAE 15 and IIAR 2.”

standard



model code

state law

Standard 15

Purpose and Scope

"… specifies safe design, construction, installation, and operation of refrigeration systems"

"… establishes safeguards for life, limb, health, and property and prescribes safety requirements"

Keep refrigerants contained within their systems. In the event of a refrigerant leak, mitigate its impact on people.

Safety Standard for Refrigeration Systems

Standard 15-2013

Applicability

New construction:

" … the design, construction, test, installation, operation and inspection of mechanical and absorption refrigeration systems, including heat pumps systems used in stationary applications"

Certain replacements:

"… modifications including replacement of parts or components if they are not identical in function and capacity …"

Certain conversions:

"… and to substitutions of refrigerant having a different designation"

ANSI/ASHRAE Standard 15-2013

Classification Criteria

- **Building occupancy**
  - Speed of evacuation
- **Refrigerating system**
  - Probability of occupant exposure
- **Refrigerant safety**
  - Permissible human exposure level

ANSI/ASHRAE Standard 15-2013 Classification Criteria

Building Occupancy

- Institutional
- Public assembly
- Residential
- Commercial
- Large mercantile
- Industrial

Share rules

ANSI/ASHRAE Standard 15-2013 Classification Criteria

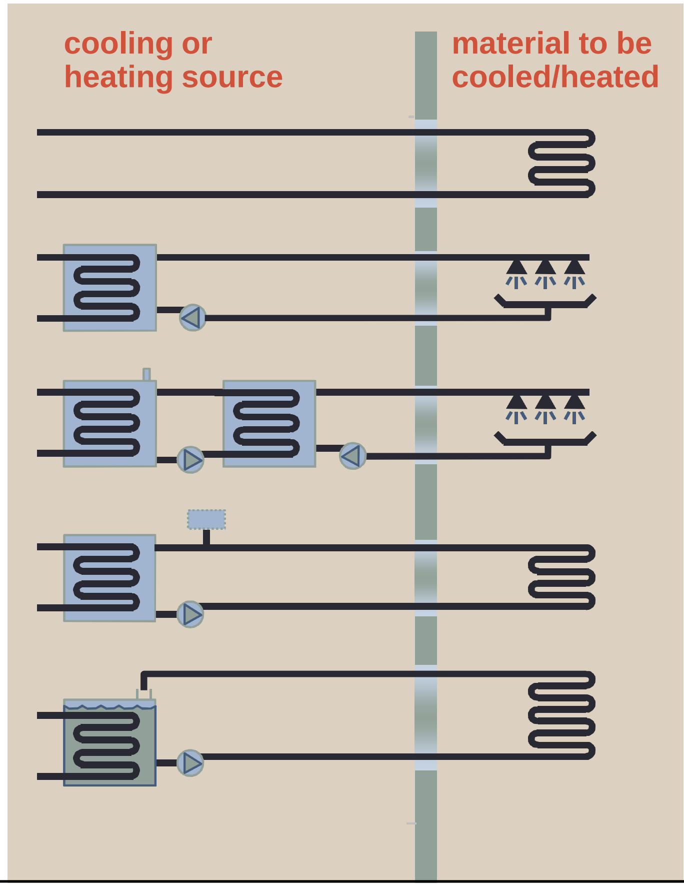
Building Occupancy

- **Institutional**
  - Occupant impairment prevents quick exit
- **Industrial**
  - Restricted access and worker training
- **Mixed**
  - Two or more occupancy types within the same building
  - Requires system isolation

Safety Standard for Refrigeration Systems

ANSI/ASHRAE Standard 15-2013 Classification Criteria

Refrigerating System



SYSTEM TYPE	SYSTEM CLASSIFICATION
direct	**high probability**
indirect open spray	**high probability (conditional)**
double indirect open spray	**low probability**
indirect closed	**low probability**
indirect vented closed	**low probability**

ANSI/ASHRAE Standard 34-2013 Classification Criteria

Refrigerant Safety Criteria

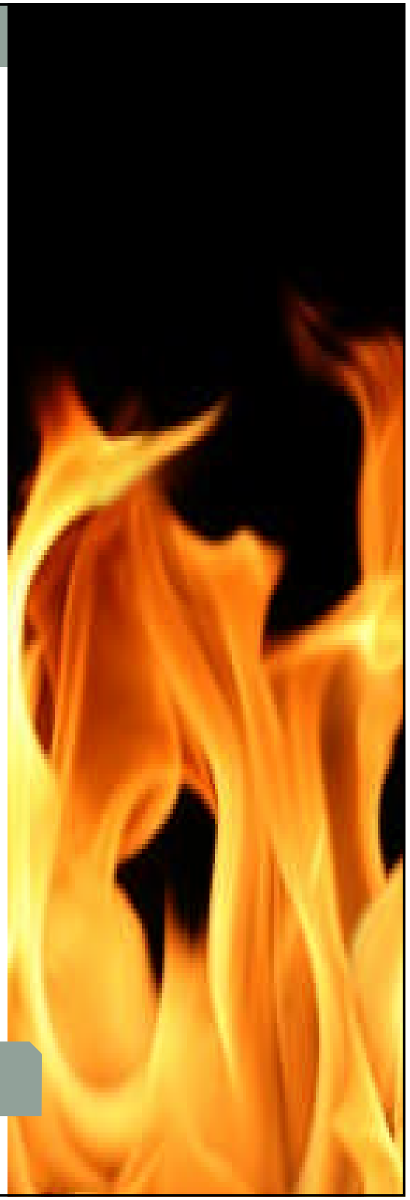
- Flammability:
  3 classes
  (plus one subclass)
- Toxicity:
  2 classes

Designation and Safety Classification of Refrigerants

ANSI/ASHRAE Standard 34-2013 Classification Criteria

Refrigerant Flammability Criteria

- Class 1
  No flame propagation
- Class 2
  Flammable, high LFL
  - Class 2L (low flame speed)
- Class 3
  Flammable, low LFL



Designation and Safety Classification of Refrigerants

LFL: Lower Flammability Limit

ANSI/ASHRAE Standard 34-2013

Refrigerant Toxicity Criteria

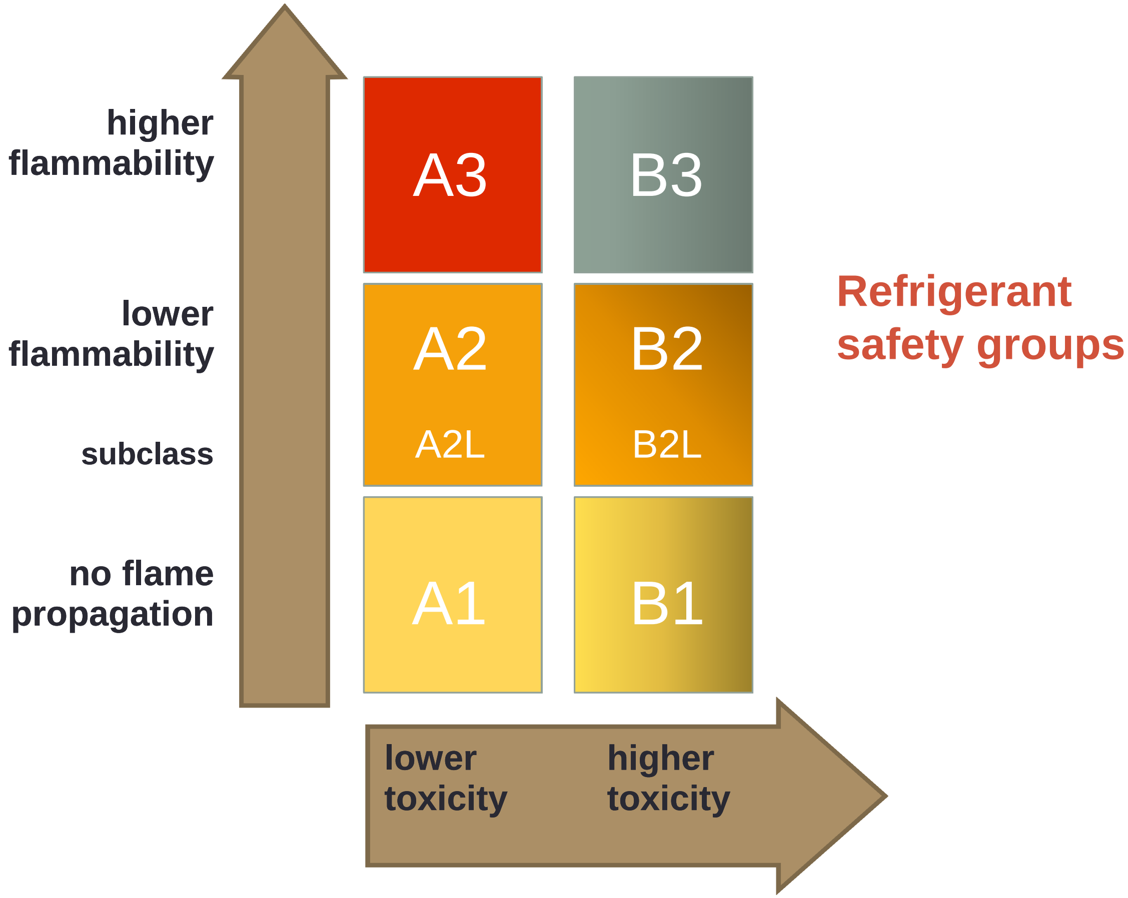
Occupational Exposure Limit (OEL)

- Class A
  Lower toxicity
  OEL ≥ 400 ppm
- Class B
  Higher toxicity
  OEL < 400 ppm

Designation and Safety Classification of Refrigerants

ANSI/ASHRAE Standard 34-2013

Safety Classifications



ANSI/ASHRAE Standard 34-2013

Refrigerant Concentration Limit

RCL based on:

- Toxicity
- Flammability
- Oxygen deprivation

ANSI/ASHRAE Standard 34-2013

Refrigerant/Blend Data

Refrigerant Number	Composition (Mass %)	Composition Tolerances	OEL[h], ppm v/v	Safety Group	RCL[a] (ppm v/v)	RCL[a] (lb/Mcf)	RCL[a] (g/m^3)
Zeotropes							
407F	R-32/125/134a (30.0/30.0/40.0)	(±2.0/±2.0/±2.0)	1000	A1	95,000	20	320
408A[g]	R-125/143a/22 (7.0/46.0/47.0)	(±2.0/±1.0/±2.0)	1000	A1	95,000	21	340
409A	R-22/124/142b (60.0/25.0/15.0)	(±2.0/±2.0/±1.0)	1000	A1	29,000	7.1	110
409B	R-22/124/142b (65.0/25.0/10.0)	(±2.0/±2.0/±1.0)	1000	A1	30,000	7.3	120
410A[i]	R-32/125 (50.0/50.0)	(+0.5, –1.5/+1.5, –0.5)	1000	A1	140,000	26	420
410B[i]	R-32/125 (45.0/55.0)	(±1.0/±1.0)		A1	140,000	27	430

$$RCL = \frac{26\ lbs}{1000\ ft^3}$$

**Institutional Occupancy is 50% of this!

Designation and Safety Classification of Refrigerants

ANSI/ASHRAE Standard 15-2013

Review

- Occupancy, system type, and refrigerant safety classification determine rules for the application
- Rules provide guidance
- Standard 15 is not a design manual

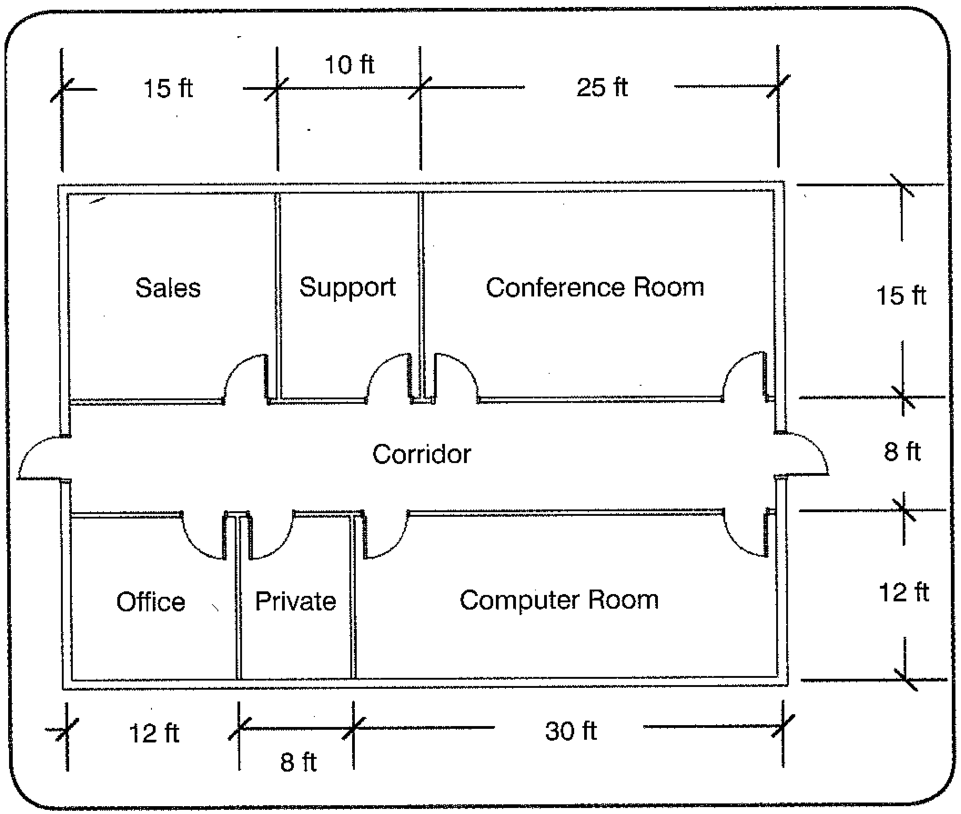
Let’s walk through an example…

Standard 15-2013

Applied to VRF

Example building

9ft ceilings



Standard 15-2013

Applied to VRF

Example building parameters:

- 10 Ton System: One outdoor unit, 6 indoor units
- Commercial occupancy
- Direct (high probability) system
- Total Charge: 40 lbs (factory charge + field piping)
- Refrigerant R410A
  - Safety group A1
  - RCL = 26lbs /1000 ft^3 per Standard 34-2013

Safety Standard for Refrigeration Systems

ANSI/ASHRAE Standard 15-2013

Quantity of Refrigerant

Refrigerant quantity for calculation:

- RCL check done prior to installation
- Requires accurate charge estimate
  - Charge in condensing unit plus
  - Charge in refrigerant pipe
- Estimated charge for example building is 40 lb

Safety Standard for Refrigeration Systems

ANSI/ASHRAE Standard 15-2013

Refrigerant Quantity Limit

Compliance with RCL:

Step 1: Determine proper RCL
(lb per 1000 cubic feet)

Step 2: Calculate total lb of refrigerant that could leak

Step 3: Determine space volume available for dilution

Safety Standard for Refrigeration Systems

ANSI/ASHRAE Standard 15-2013

Occupied Volume

Nonconnecting spaces (Section 7.3.1)
(Refrigeration system components in occupied space)

- Volume = height x width x length
- Ignore furniture
- Exclude space that can be isolated
  - Closets
  - Hotel bathroom

Safety Standard for Refrigeration Systems

ANSI/ASHRAE Standard 15-2013

Occupied Volume

Ventilated spaces (Section 7.3.2)
(Refrigeration system components in air handler/ductwork)

- Sum occupied space volumes served
- Include plenums and ductwork if applicable
- Omit spaces that can be isolated

Safety Standard for Refrigeration Systems

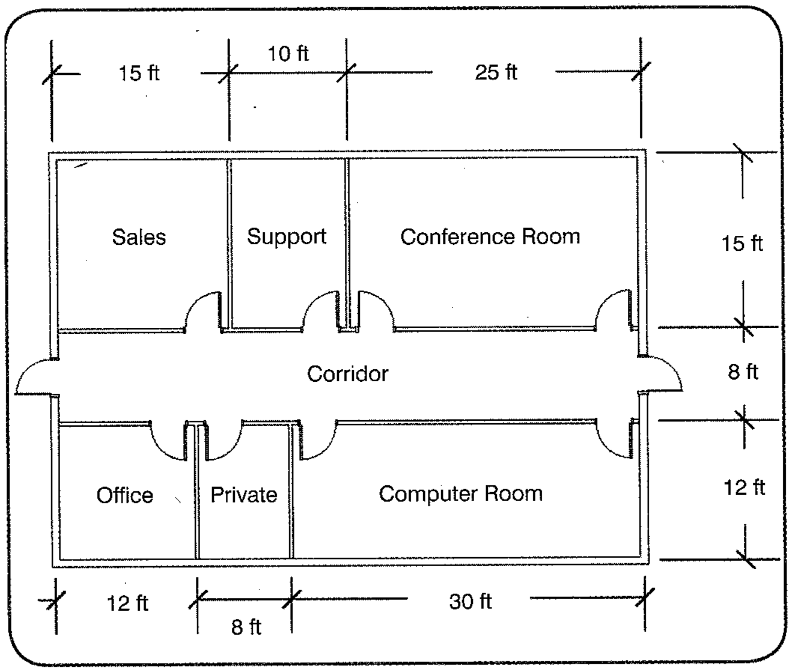
Standard 15-2013

Applied to VRF

Use Volume of Smallest Space

↓

Worst Case Scenario

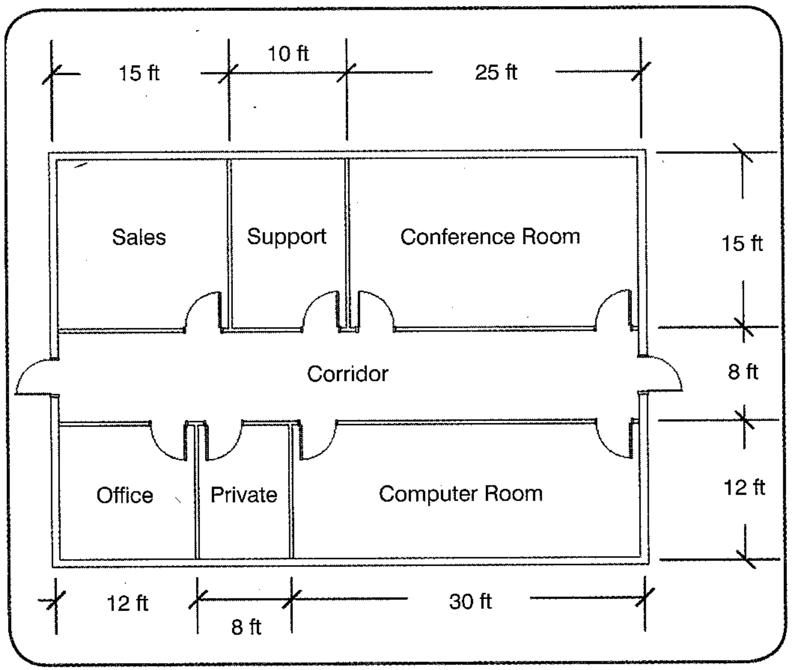


For Private office:

$$\frac{\text{lbs in system} \times 1000}{\text{Room volume}} = \frac{40 \times 1000}{8 \times 12 \times 9} = 46\ \text{lbs}/1000\text{ft}^3 \quad > \quad 26\ \text{lbs}/1000\ \text{ft}^3$$

Standard 15-2013

Applied to VRF



Method 2

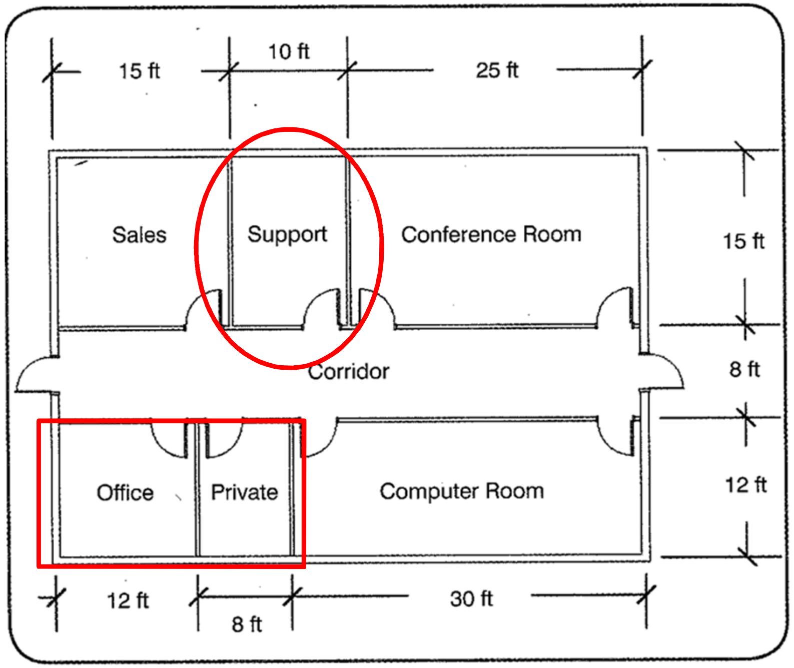
For Private office:

$$\frac{26 \text{ lbs}}{1000 \text{ ft}^3} = \frac{X}{8 \times 12 \times 9} \qquad X = 22.46 \text{ lbs MAX} \quad < \quad 40 \text{ lbs}$$

applying Standard 15-2013

Meeting the RCL

- Reduce refrigerant quantity
  - Computer room
  - Serve building with two systems
- Increase dilution volume
  - Office 2 + Private Office



For Support:

$$\frac{\text{lbs in system} \times 1000}{\text{Room volume}} = \frac{40 \times 1000}{10 \times 15 \times 9} = 29.6\ \text{lbs}/1000\text{ft}^3$$

applying Standard 15-2013

Meeting the RCL

Quote from July 2012 *ASHRAE Journal* article titled, “Applying VRF? Don’t Overlook Standard 15”

Does an undercut door or a transfer opening qualify as a permanent opening? If so, how large an undercut or transfer opening would be needed to qualify? These questions are not specifically addressed in Standard 15, neither to affirm nor disqualify. Clearly, undercut doors or transfer openings would *eventually* permit a large leak of refrigerant in one small room to disperse to adjacent rooms. However, without detailed study or modeling, we do not know that this will occur quickly enough to protect the safety of the room’s occupants. Keep in mind that the driving force expelling R-410A from a ruptured refrigerant pipe is on the order of 450 psi (3.1 MPa), but the driving force pushing transfer air under a door or through a transfer opening is five or six orders-of-magnitude less. Ceiling-mounted transfer ducts are even more suspect, since most commonly-used refrigerants are heavier than air.

Also see Interpretation IC 15-2010-1 of ANSI/ASHRAE Standard 15-2010

Standard 15-2013 and VRF

ASHRAE Summary

Standard 15:

- Applies to all refrigeration equipment
- VRF requirements are not new
- Promotes safety for all systems

Safety Standard for Refrigeration Systems

VRF Design

Key Takeaways

- VRF Benefits/Applications
- Load analysis and careful zoning
- Be cognizant of refrigeration safety

Thank You!

Questions