100% Outside Air VRV Systems: A Sustainable, Hybrid Approach for Superior IEQ

Presented by: Dan Hahne
Varitec: Director of High-Performance HVAC Solutions

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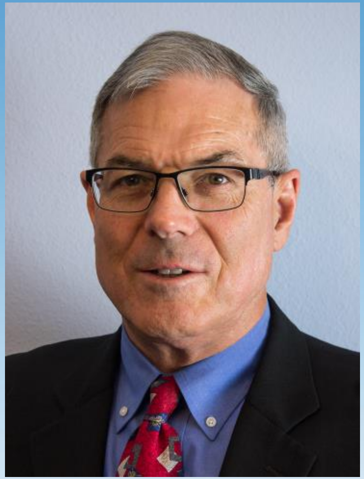
Introduction

- **Education:**
  - University of Arizona – Chemical Engineering
    - 1974 thru 1976
  - University College London – BFA Degree (Sculpture)
    - 1978 thru 1983
  - Boston University – MFA Degree (Sculpture)
    - 1983 thru 1985
- **Industry:**
  - **Norman S. Wright SW:** Estimator/Sales
    - 1985 thru 1999
  - **Air Specialty Products:** Outside Sales
    - 2000 thru 2008
  - **Air Specialty Products/ThermAir Systems:** Engineering Sales
    - 2009 thru 2016
  - **Varitec Solutions:**
    - Senior Sales Engineer
      - 2016 - 2022
    - Director of High-Performance HVAC Systems/Educator
      - 2022 thru present



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Introduction Publications:


Health Care Design: Beyond Code Minimum – Creating Healthier, More Efficient Environments

The technologies to reduce pathogenic infections exists — so why aren't we using them?

By Dan Hahne and Fletcher J. Clarcq, P.E., CEM, LEED AP BD+C


Health Care Design: FGI Guidelines, ANSI/ASHRAE/ASHE Standard 170, and Beyond

Engineers must design a space that responds to the needs and requirements of the building but also promotes an environment that is conducive to healing and well-being.

By Fletcher J. Clarcq, P.E., and Dan Hahne


Debunking Myths of Active Chilled Beams: What You Thought You Knew — But Were Wrong, Part 2

SmithGroup, Varitec, and Dadanco analyze the response time of an active chilled beam when the space's total load rapidly increases.

- **October 2021: Health Care Design:**
  - Beyond Code Minimum – Creating Healthier, More Efficient Environments
  - (Co-Authored with Fletcher Clarcq P.E.)
- **June 2021: Health Care Design:**
  - ANSI/ASHRAE/ASHE Standard 170, and Beyond
  - (Co-Authored with Fletcher Clarcq P.E.)
- **November 2019: Debunking the Myths of Active Chilled Beams: What You Thought You Knew But Were Wrong**
  - (Co-Authored with Eric Martin P.E., Fletcher Clarcq P.E. Steven Lamica, Engineer (Dadanco))
- **October 2019: Debunking the Myths of Active Chilled Beams: The Drip Test**
  - (Co-Authored with Eric Martin P.E., Fletcher Clarcq P.E. Steven Lamica, Engineer (Dadanco))

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Introduction

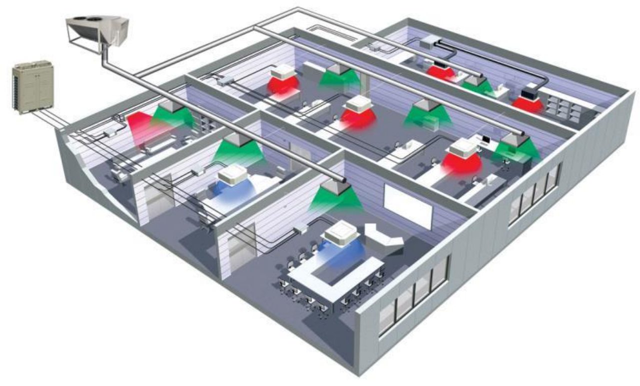
ES Magazine July 2022 Edition

Released July 6th

100% Outside Air VRF Systems: A Sustainable, Hybrid Approach for Superior IEQ

COOLING & CHILLERS

Increasing the amount of outside air to the occupied space and increasing ventilation air change rates are effective solutions for reducing concentrations of contaminants and the risk of infection.



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VARITEC:
The HVAC System Solution Resource

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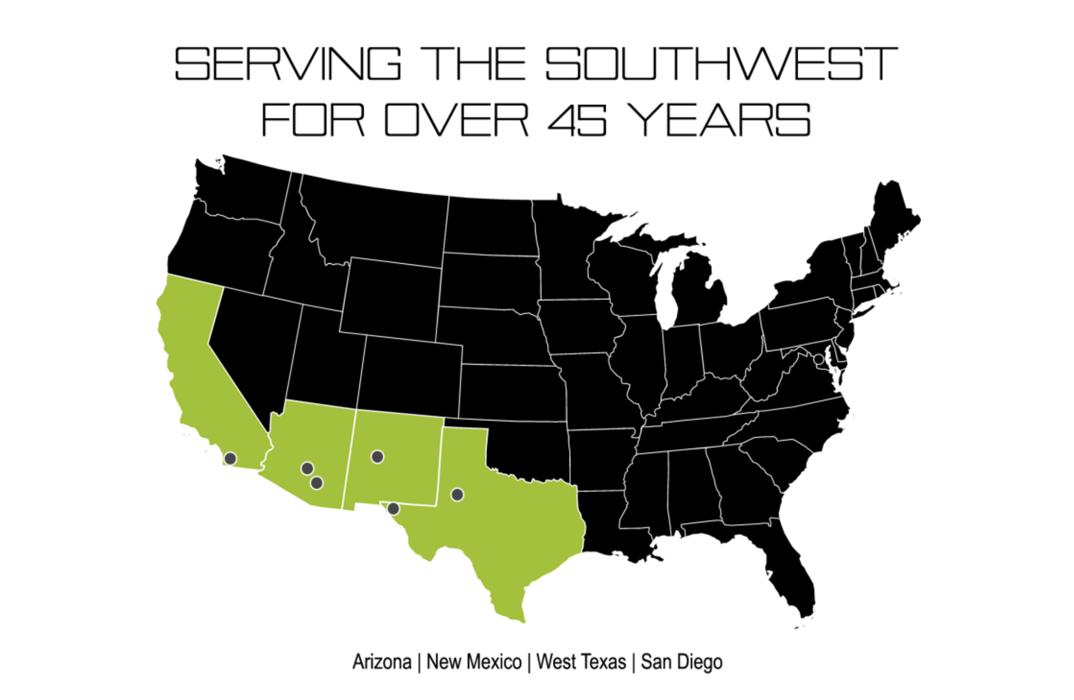
Varitec: The HVAC System Solution



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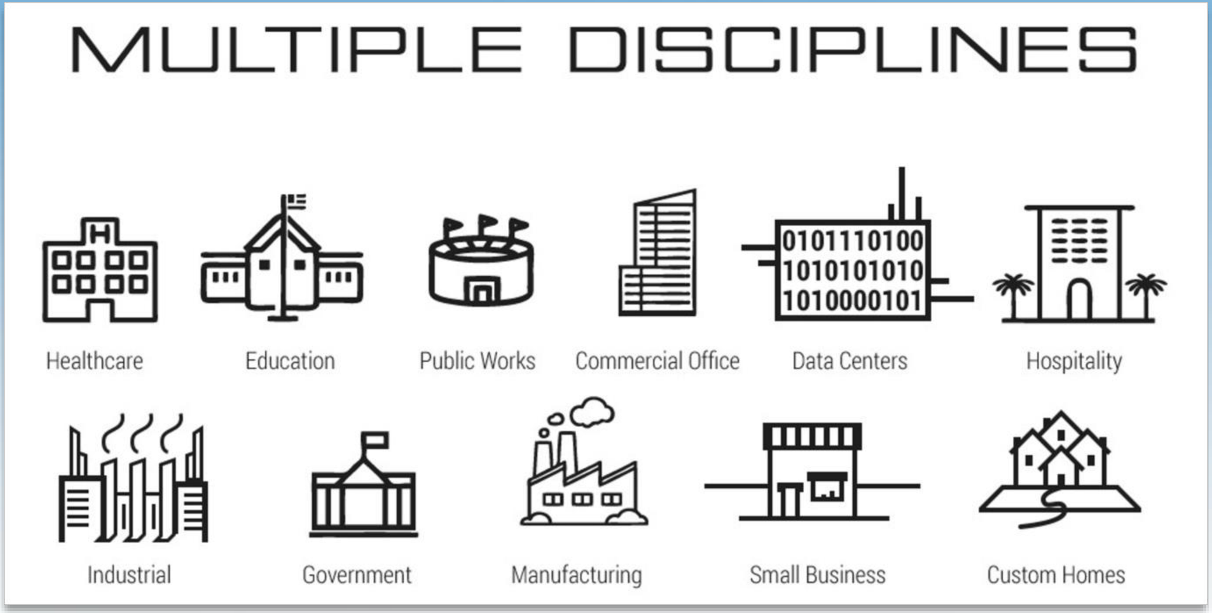
Varitec: The HVAC System Solution



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Varitec: The HVAC System Solution

System Solutions:

- Mixed Air VAV Systems
- Variable Refrigerant Systems
- Underfloor Air Systems
- 100% OSA Systems
    - DOAS Technology
    - Active Chilled Beams
    - Passive Hydronic Cooling & Heating Systems
- Humidity “Control”
- Package Central Plants for Air & Water Cooled Designs
- Cloud Based Controls

Varitec: The HVAC System Solution

Shaping
The Future
Of HVAC

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(New Horizons Launch, January 9, 2006)

Mission:

To provide an educational platform for continued learning in the HVAC industry with a focus on high performance buildings and innovative technologies for a better built environment.

Varitec Technical Institute

May 12th: Varitec Sustainability Symposium

- Why Buildings Matter

June 15th: Refrigerants

- Why Buildings Matter

July 14th: 100% Outside Air Systems

- Part 1: Variable Refrigerant Systems

September 8th: 100% Outside Air Systems

- Part 2: Active & Passive Chilled Beams

October 13th : 100 Outside Air Systems

- Part 3: Passive Radiant Heating & Cooling Systems

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Acknowledgements

Smith Group: Phoenix

- Eric Martin: P.E., Senior Mechanical Engineer
- Huiyuan (Steven) Zhang: P.E., Mechanical Engineer

Daikin Comfort:

- Christopher Soh: VRV Product Engineer

Daikin Applied:

- Judith Peters: P.E. Energy Modeling Engineer

Varitec Solutions: Phoenix

- Zack Niemeyer: Sales Engineer
- Austin Vedder: Sales Support Engineer

Today’s Agenda:

- ASHRAE, CDC & EPA: Agency Statement Reviews
- IEQ, Decarbonization & Net-Zero: The Dilemma
- Spanning the Divide: 100% Outside Air Systems
- Variable Refrigerant Volume: The Technology
- 100% OSA VRV: System Concept Review
- Comparative Analysis and Review
- Equipment First Cost & Payback Review
- Concluding Remarks

ASHRAE, CDC & EPA: Agency Statement Reviews

ASHRAE, CDC & EPA: Agency Statements

ASHRAE: Epidemic Task Force

ASHRAE: April 5th 2021:

- **Updated Airborne Transmission Guidance**
  - “***Airborne transmission of SARS-CoV-2 is significant*** *and should be controlled. Changes to building operations, including the operation of heating,* ***ventilation, and air-conditioning systems, can reduce airborne exposures****.”*

ASHRAE News

FOR IMMEDIATE RELEASE

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ASHRAE Epidemic Task Force Releases Updated Airborne Transmission Guidance

Clarified guidance for evaluating and mitigating the spread of SARS-CoV-2

ATLANTA (April 5, 2021) – The ASHRAE Epidemic Task Force released an updated, unequivocal statement on the airborne transmission of SARS-CoV-2 in buildings.

ASHRAE has released the following statement:

> *"Airborne transmission of SARS-CoV-2 is significant and should be controlled. Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures."*

It replaces the April 2020 statement that said airborne transmission was "sufficiently likely" that airborne precautions should be taken. At that time both, the World Health Organization (WHO) and the Centers for Diseases Control (CDC), contended that transmission of SARS-CoV2 was by droplet and fomite modes, not airborne. Subsequently, both have acknowledged the risk of airborne transmission indoors.

(Figure #1: ASHRAE April 5th, 2021 Newsletter)

- **ASHRAE Task Force: Recommendation:**
- *“…Evaluate recirculation or* ***increase outside air fraction*** *from design levels* ***up to 100%...****”*

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ASHRAE, CDC & EPA: Agency Statements

Center for Disease Control (CDC):

- *May 7, 2021: "…**SARS-CoV-2 is transmitted by exposure to infectious respiratory fluids**."*
- *"…Infectious exposures to respiratory fluids carrying SARS-C0V-2 occur in three principle ways…deposition, touching, and **inhalation of air carrying very small droplets and aerosol particles that contain infectious virus**."*

CDC Website Subsequent Statement

- *"When indoors, **ventilation mitigation strategies** can help reduce viral particle concentration."*
- *"Open outdoor air damper beyond minimum settings to reduce or **eliminate HVAC air recirculation**."*

CENTERS FOR DISEASE™ CONTROL AND PREVENTION

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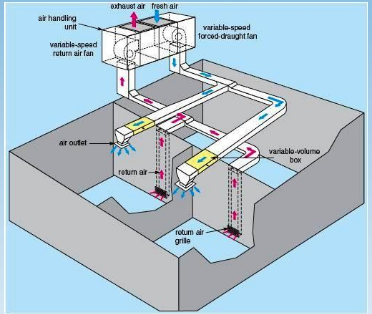
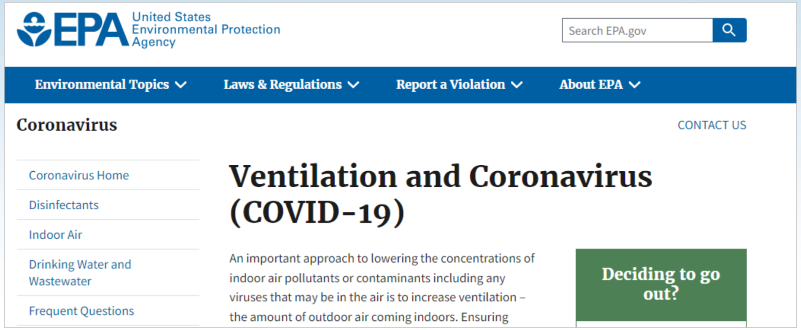
ASHRAE, CDC & EPA: Agency Statements

Environmental Protection Agency (EPA):

- *"An important approach to lowering the **concentrations of indoor air pollutants** or contaminants **including any viruses** that may be in the air is to **increase ventilation – the amount of outdoor air coming indoors**.."*





- *"**Ensuring proper ventilation with outside air** can help reduce the concentration of airborne contaminants, including viruses, indoors."*

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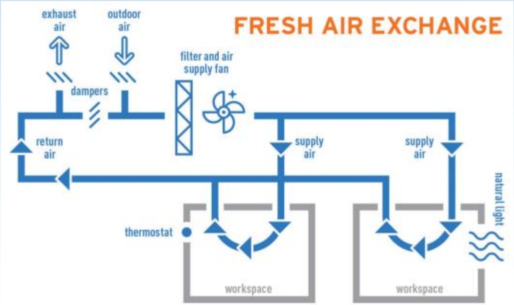
ASHRAE, CDC & EPA: Agency Statements

EPA: Clean Air in Buildings Challenge

- **Section #2: Optimize Fresh Air Ventilation…:**
  - "Ensure outdoor air is acceptably clean or is adequately filtered as it is brought into the building



Fact Sheet Guidelines:

- "Run HVAC systems during all occupied hours to ensure clean air enters and is distributed throughout the building."
- **"Increase volume of clean, outdoor air at times of higher risk. (e.g. at times of elevated risk of COVID-19).**
- "Consider running the HVAC system to refresh air before arrival and/or remove remaining particles at the end of the day (e.g., 1-2 hours before/after the building is occupied,) as needed."

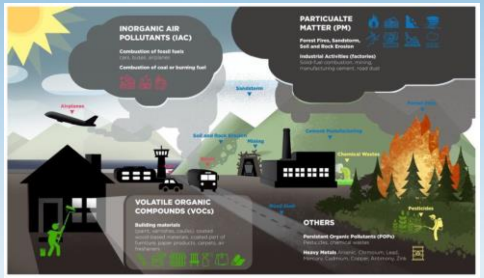
ASHRAE, CDC & EPA: Agency Statements

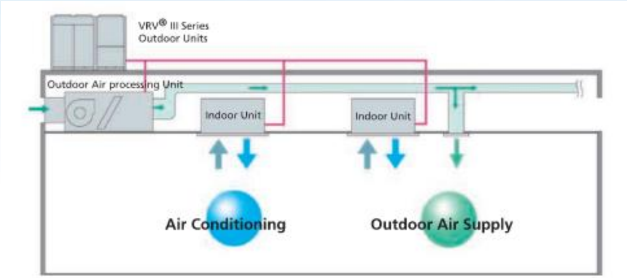
Environmental Protection Agency (EPA):

- **Outdoor Air and Indoor Contaminants: Comparison**

Indoor Air Pollutant

- Asbestos
- Biological Pollutants
- Carbon Monoxide
- Cook Stoves
- Formaldehyde/Pressed Wood Products
- Lead
- Nitrogen Dioxide
- Pesticides
- Radon
- Particulate Matter (PM)
- Volatile Organic Compounds
- Wood Smoke





Outdoor Air Pollutant

- Carbon Monoxide
- Lead
- Nitrogen Dioxide
- Ozone
- Particulate Matter (PM):Various Sizes
- Sulfur Dioxide)

(Note: Outdoor air contains other pollutants not regularly monitored by the EPA)

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IEQ, Net-Zero & Decarbonization: The Dilemma

IEQ, Decarbonization & Net-Zero: The Dilemma

What is Indoor Environmental Quality (IEQ):

- **CDC Definition:** "…refers to the **quality of a building's environment related to the health of occupants** with it."
- "…research shows that building-related symptoms are associated with building characteristics:
    - **Dampness**
    - **Cleanliness**
    - **Ventilation**

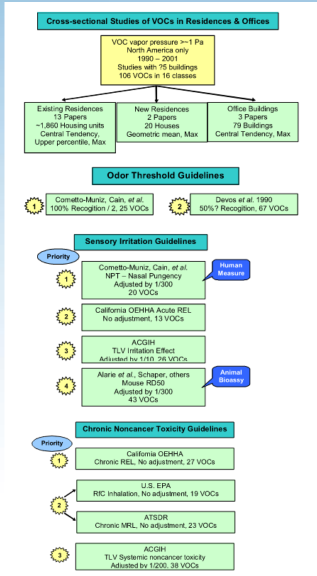
Note: Though related, IAQ is not IEQ

- **USGBC Definition:** "…encompasses the conditions inside a building – **air quality**, lighting, **thermal conditions**, ergonomics – and their effects on occupants or residents."
- "IEQ goals often focus on providing stimulating and comfortable environments for occupants and **minimizing the risk of building-related health problems**."

IEQ, Decarbonization & Net-Zero: The Dilemma

EPA: (2010) Document Release

- National Programs to Assess IEQ Effects of Building Materials and Products



Organizations and Statements:

- **IEQ - Global Alliance (IEQ-GA):**
  - "…to provide an acceptable indoor environmental quality…to occupants in buildings and places of work around the world…"
- **Whole Building Design Guide**
  - **IEQ and Occupant Productivity Dynamic**
  - "Salary expenses are…a high proportion of the operational expenses…Even a small percentage gain in productivity,…can result in considerable savings…"

IEQ, Decarbonization & Net-Zero: The Dilemma

Building Health Monitoring: Growing International Trends

- **Building4Health (B4H)**
- **Dr. Stephanie Taylor:**
  - Founder & CEO
  - Physician & Cellular Biologist
  - Harvard Medical School (MD)
  - Norwich University (M.Arch)
  - ASHRAE
    - Distinguished Lecturer
    - Epidemic Task Force Board Member

https://www.b4hinc.com/

- **B4H: Monitor Building Health Score**
  - Integrates (4) Areas of Research to determine the **real-time health influence of the indoor environment on the human body**
    - Physiology
    - Disease Drivers
    - Immunity
    - Indoor Ecology

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IEQ, Decarbonization & Net-Zero: The Dilemma

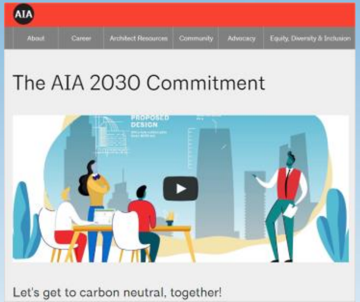
The Dilemma:

The Energy Burden

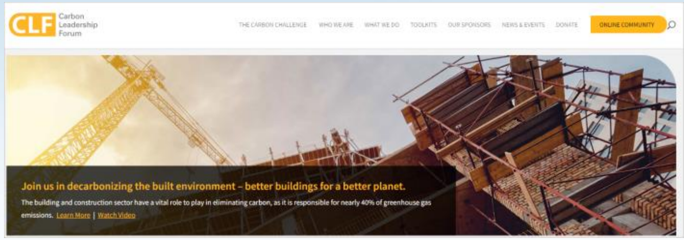
IEQ, Decarbonization & Net-Zero: The Dilemma

Decarbonization: National Movements

AIA 2030 Commitment:



- “The built environment creates a **staggering 40% of the world’s CO_2 emissions**, architects, engineers, and owners play a key role.”
- We must all commit to net-zero emissions by 2030.”



Carbon Leadership Forum:

- “All systems engineers shall advocate for and achieve **net-zero carbon** in their projects…”

“Operational carbon by 2030, embodied carbon by 2040”

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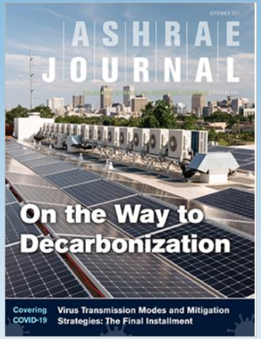
IEQ, Decarbonization & Net-Zero: The Dilemma

Decarbonization: National Movements

ASHRAE Standard 90.1-2019 & DOE:



- **ASHRAE Journal September 2021;**
  - "…the **U.S. Department of Energy (DOE)** issued a **determination** that **ANSI/ASHRAE/IES Standard 90.1-2019** for buildings except Low-Rise Residential Buildings, improves energy efficiency in commercial buildings…

What's Next for Standard 90.1

ATLANTA—In late July, the U.S. Department of Energy (DOE) issued a determination that ANSI/ASHRAE/IES Standard 90.1-2019, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, improves energy efficiency in commercial buildings compared to the 2016 standard.

The final determination makes the 2019 version of the standard the reference energy-efficiency standard for buildings other than low-rise residential buildings, said Standing Standard Project Committee 90.1 Chair Don Brundage, P.E., Member ASHRAE; Co-Vice Chair Thomas Culp, Ph.D., Member ASHRAE; and

special status as the model energy code for buildings within the 90.1 scope."

Now What?

DOE analysis shows the updated standard could cause national savings in commercial buildings of about 4.7% site energy, 4.3% source energy and 4.3% energy cost. States and other jurisdictions are now required to review their commercial building code regarding energy efficiency and update their codes to meet or exceed Standard 90.1-2019. Each state or jurisdiction has their own process for considering updates

  - The **final determination** makes the 2019 version of the standard **the reference energy-efficiency standard**…"

US Department of Energy

IEQ, Decarbonization & Net-Zero: The Dilemma

Decarbonization: The National Movement

ASHRAE Journal September 2021:


TECHNICAL FEATURE

How Building Decarbonization Can Transform HVAC


FIGURE 2 VRF heating and cooling system.

How Building Decarbonization Can Transform HVAC

- By Peter Rumsey, P.E., Fellow ASHRAE; Jorlyn Le Garrec, Assoc Member ASHRAE; Avril Levasseur, P.E., Assoc. Member ASHRAE
  - “Buildings in the U.S. account for 40% of carbon emissions.”
  - **“An all-electric building coupled with a renewable or carbon-free source of electricity is considered to be decarbonized in its operation.”**
  - **“Heat Pumps: Variable Refrigerant Flow:”**
    - “…the **most cost-effective option** is where a compressor system is designed to provide both heating and cooling, as is the case with **variable refrigerant flow (VRF) systems**.”
- **“Dedicated outdoor air systems (DOAS) and their associated benefits couple well with VRF systems.”**

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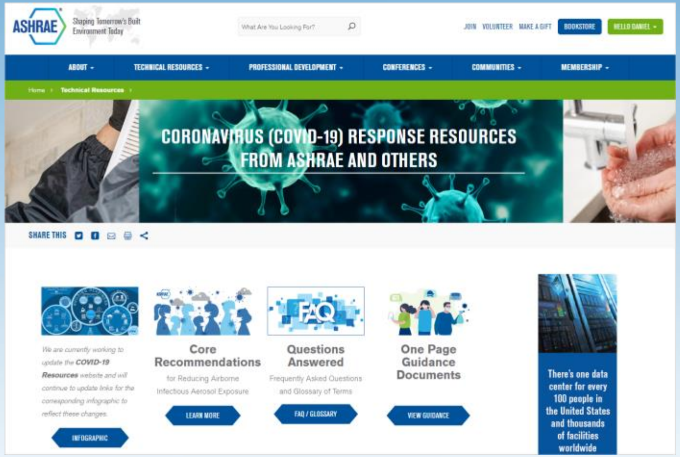
IEQ, Decarbonization & Net-Zero: The Dilemma

The Dilemma: Efficiency vs. Occupant Health



At the Same Time:

ASHRAE's Epidemic Task Force:
Strategies to Reduce the Risk of Infection

- **Minimum Filtration:** MERV13, MERV14 (preferable), HEPA filtration ideal
- **Increase outside air fraction rates** up to 100% OSA where possible
- **Maintain building humidity:**
  - Between 40-60%

Impact System Performance & Increase Operating Costs!!!

IEQ, Decarbonization & Net-Zero: The Dilemma

ES Magazine Article: Purpose

- **Demonstrate: Improved Building IEQ and HVAC System Efficiency are NOT contradictory design objectives.**

By: Dr. Stephanie Taylor

- **High Efficiency HVAC Designs resulting in superior building IEQ can be accomplished**
- **To Create Healthier Buildings:**
  - Fewer sick days
  - Greater productivity
  - Reduction of health risks after prolonged Periods of exposure

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Spanning the Divide: 100% Outside Air Systems

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Spanning the Divide: 100% Outside Air Systems

What is a 100% Outside Air (OSA) System: Objective

- **Design Intent: Decouple outside air (ventilation load)** from HVAC system
- **Designed Parallel to** heating and cooling components

100% Outside Air Unit Considerations:

- **Heat Recovery:** Building **exhaust air** used to **pre-condition OSA (summer or winter)**
  - **Sensible:** (Plate & Frame, Heat-Pipe Technology, Sensible Wheel, Run-Around Coil Loop)
  - **Enthalpy:** (Enthalpy Wheel (Sensible or Latent Exchange), Plate & Frame Technology)
- OSA and exhaust air ratio calculated to:
  - **Supply minimum OSA per code or more** to create even healthier environments
  - Maintain ~0.01” w.g. positive building pressure

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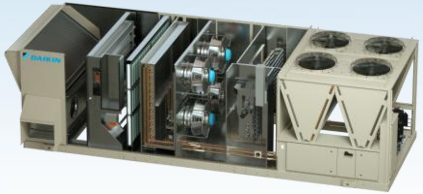
Spanning the Divide: 100% Outside Air Systems

100% Outside Air Advantages:

- **Control OSA (ventilation) rates to each zone:**
  - Design increased OSA air change rates to higher levels as desired: **NOT CODE MINIMUM.**
- Building **CO_2 concentrations** controlled to 600-800 PPM
- Building **humidity controlled** through **lower dew point supply Air**
- **Heat Recovery:**
  - Pre-Conditioning OSA **Improved Energy Efficiency**
  - **Variable refrigerant system significantly downsized**
- **100% OSA Unit: Various cost points**

(Courtesy: Oxygen 8)



(Courtesy: Daikin Applied)

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Variable Refrigerant Volume: The Technology

Variable Refrigerant Volume: The Technology

HVAC System: Objectives

- Meet **Occupant Thermal Comfort Needs**
- Create **Healthy Building Environments**
- Healthy Environments Require **Humidity Control**

- **Energy Efficiency: What is it?**
  - **Department of Energy (DOE)**: “Energy efficiency is the use of less energy to perform the same task (work) or produce the same result.”

- **High-Performance Building: ASHRAE Standard 189.1-2021**
  - High-Performance Green Building: “A building designed, constructed, and capable of being operated in a manner that increases environmental performance and economic value over time,…

Variable Refrigerant Volume: The Technology

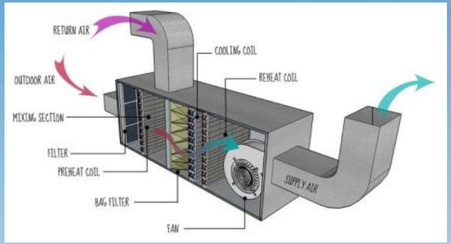
HVAC System: Objectives

- **High-Performance Building: ASHRAE Standard 189.1-2021**
  - **(Continued):** "…seeks to establish an indoor environment that supports the health of occupants, and enhances satisfaction and productivity of occupants … and **energy efficient systems.**"

- **High-Performance Building: An Observation**
  - Buildings **consume only that amount of energy required** to maintain thermal comfort and IEQ system demand at any given time of day and year to do so**.**

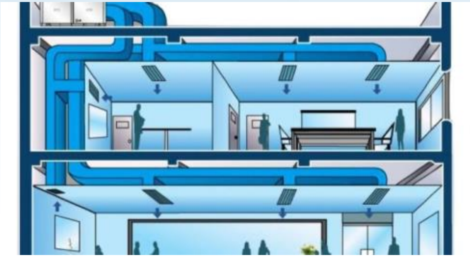
Variable Refrigerant Volume: The Technology

Conventional Mixed-Air Systems:



- **Thermal Comfort:**
  - **Cooling & Dehumidification:** Move thermal energy (heat) from a building to outdoors
  - **Heating & Humidification:** Supply thermal energy (heat) and/or moisture (where applicable) to a building

- **Heat Transfer Media: Air**
  - Air carries energy from inside a building to an AHU cooling coil
  - **Air is not a dense heat transfer media.**
  - It takes a lot of air to move thermal energy from a building to outdoors: **More Horsepower**



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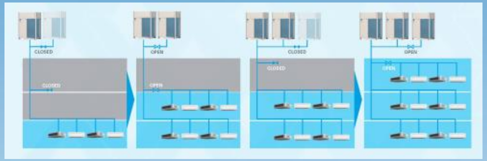
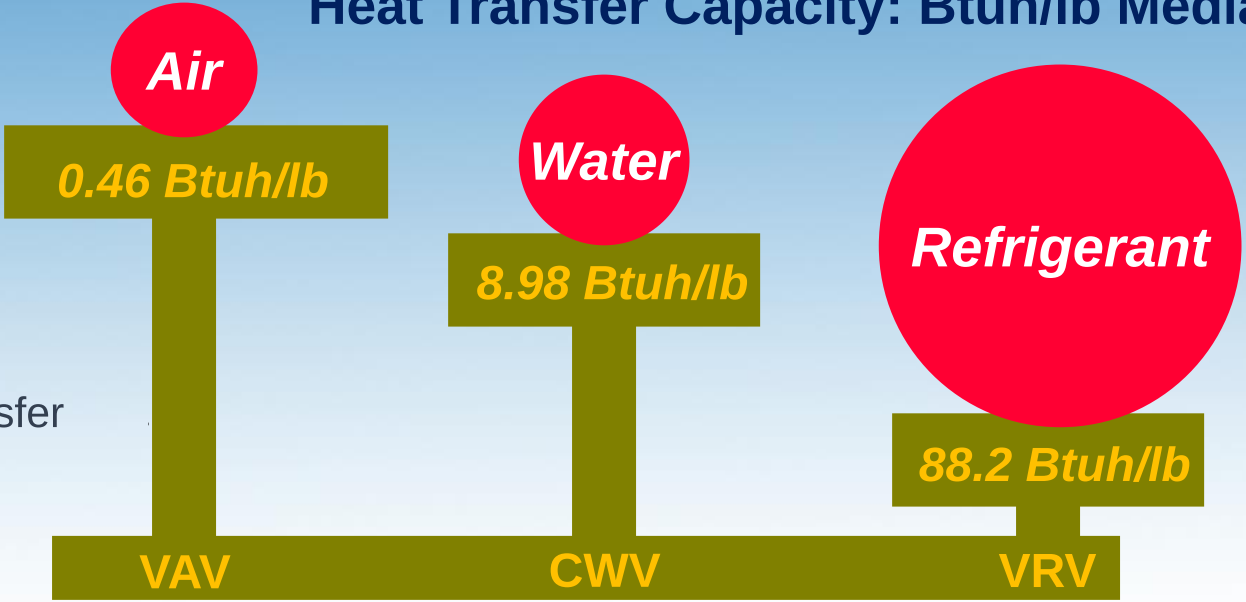
Variable Refrigerant Volume: The Technology

Heat Transfer Medium and Efficiency



Heat Transfer Capacity: Btuh/lb Media



Refrigerant:

- More Dense Than Air
- More Efficient Heat Transfer Medium

Airside Systems:

- **More horsepower (energy)** to remove heat & moisture loads in lieu of water or refrigerant.

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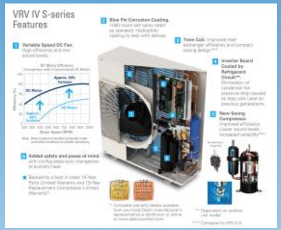
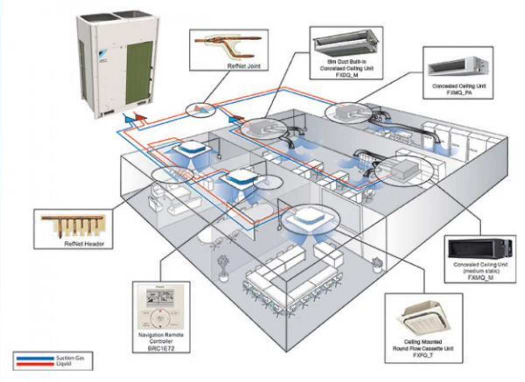
Variable Refrigerant Volume: The Technology



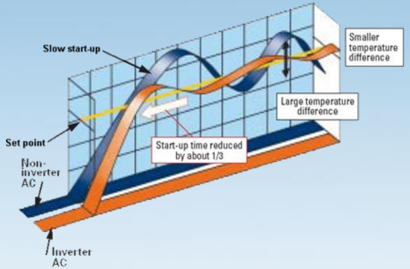
Variable Refrigerant Technology: What is it?

- **Split DX (refrigerant) System:**
  - Condensers remote from fan coil units
  - Fan coil units (refrigerant coils) located **local to each zone of control**



(Courtesy: Daikin Comfort)

- **Condensers:** Variable speed scroll compressor technology **modulates refrigerant flow to meet zone load** at each fan coil
- **NO ON/OFF start, stop cycling**
- Energy consumed **rides the curve of system load**



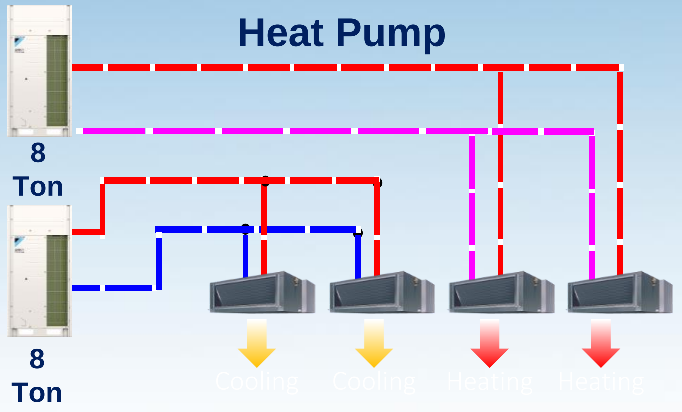
(Courtesy: Daikin Comfort)

Variable Refrigerant Volume: The Technology

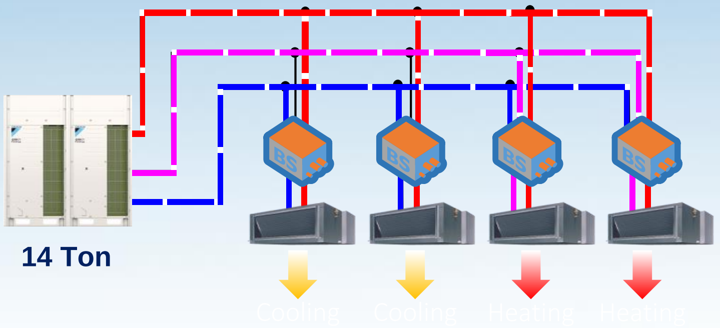
Variable Refrigerant Technology:

- **Heat Transfer Media: Refrigerant**
  - **Refrigerant flow modulates local to each zone** transfers heat energy from inside a building to outdoors (condensers). **NOT AIR**

Heat Pump



Heat recovery



- **Refrigerant flow modulates to meet demand**

Heating or Cooling
(Efficient)

Simultaneous Heating & Cooling
(More Efficient)

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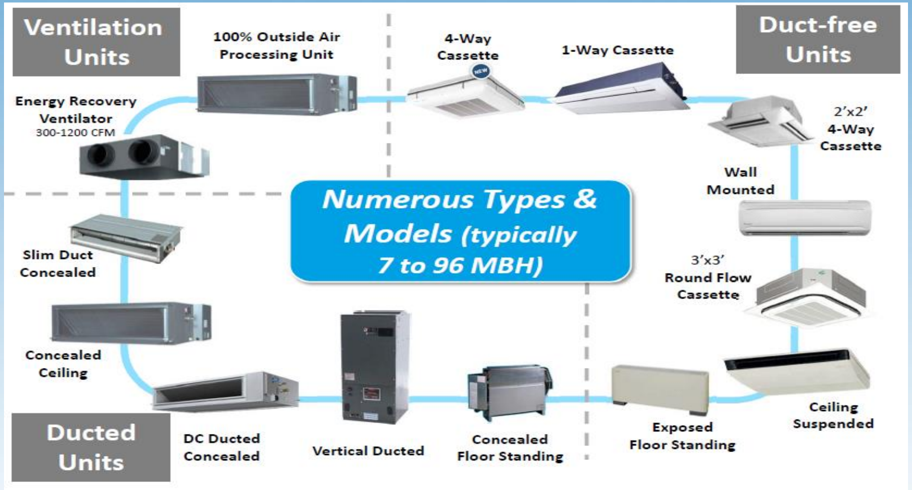
Variable Refrigerant Volume: The Technology

Variable Refrigerant Technology



Refrigerant Flow Control Local To Each Zone

Enhanced Thermal Comfort & Quiet Operation

Improved Thermal Comfort, Energy Efficiency

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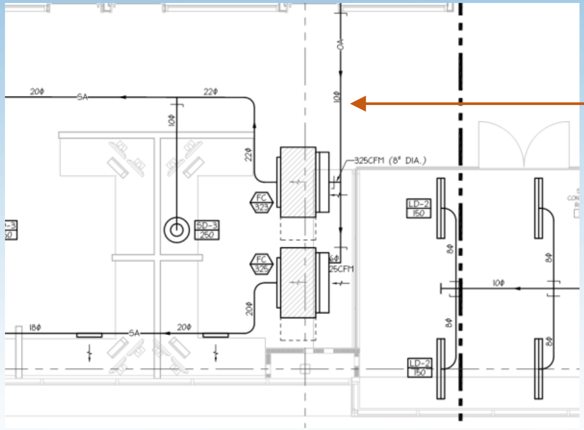
Variable Refrigerant Volume: The Technology

Variable Refrigerant Technology: Ventilation Air

- **Outdoor Air (Ventilation) Requirements:**
  - **ASHRAE 62.1:** Standard assigns minimum building outdoor air flow rates requirements



(VRV Indoor Fan Coil Units)

Conventional Design: Unconditioned Outside Air Ducted to Fan Coil Units

The Load: Terms

- **Total Building Load** = Sensible Load (Thermal "heat" energy) + Latent Energy* (water vapor)
- **Total Load** = Total Energy BTUs **= Enthalpy**
- **Total Load Occurs at Fan Coil Cooling Coil**

***Latent Energy:**

- Amount of energy to maintain water vapor in a vapor state (gas)

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Variable Refrigerant Volume: The Technology

Variable Refrigerant Technology: Sonoran Desert

- Outdoor Air Design Conditions: Peak Loads

Location: Maricopa County - Design Conditions: (EL: 1100 Feet)

- Summer Dry: 115F DB / 72F WB = ~49F DP (dew point) = **Enthalpy: 38.69 BTUs/lb (air)**
- Summer Monsoon: 97F DB / 78F WB = ~71F DP (dew point) = **Enthalpy: 42.36 BTUs/lb (air)**

GREATEST OSA LOAD DURING THE YEAR:
SUMMER MONSOON!!!

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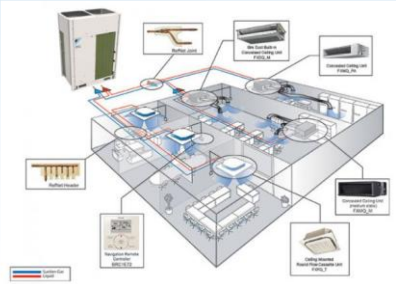
Variable Refrigerant Volume: The Technology

Variable Refrigerant Technology: Common Designs

- **Conventional Design Objective: Meet Peak Demand**
  - Eliminate **thermal comfort complaints** at **PEAK LOAD** (Phoenix: Summer Conditions)**
  - Dehumidification occurs at fan coil unit cooling coil
  - Drain pans pool with water

The IEQ Factor:

- Drain pan **bio-growth** exposed to supply air



VRV Efficiency at Peak Load:

- Similar to High SEER Package Rooftop Units
- Efficiency achieved at part-load conditions

**Phoenix buildings often designed to 115F peak load conditions.

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Variable Refrigerant Volume: The Technology

Variable Refrigerant Technology: Untempered OSA

- **The Problem: Sizing to Peak Load Demand**
  - Higher OSA Condition (DB/WB) = **Higher Mixed-Air Conditions (DB/WB)**
  - Higher Mixed-Air Conditions = **Greater Cooling Coil Total Load (enthalpy)**
  - Greater Loads = **Larger Condensers**

- **VRV Condenser Capacity: System Impact**
  - Greater Capacity = Larger & Heavier Condensers
  - Larger Condensers = Reduced Turndown
  - Reduced Turn Down = **Reduced Efficiency**
  - **Owner Penalty: Higher operating cost throughout the life of the system**

System Efficiency Potential: Compromised

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Variable Refrigerant Volume: The Technology

Variable Refrigerant Technology: System Layout Note

- **Designing to Peak Sensible Load: ASHRAE Handbook 2017**
  - Phoenix, Arizona: Peak Load: **110F DB / 69.5 MCWB**
    - **0.4% Annualized Hours**
  - Phoenix, Arizona: 108.3F DB / 69.3 MCWB
    - 1.0% Annualized Hours
  - Phoenix, Arizona: 106.4F DB / 69.0 MCWB
    - 2.0% Annualized Hours

2017 ASHRAE Handbook - Fundamentals (IP)

PHOENIX SKY HARBOR INTL, AZ, USA WMO#: **722780**

Lat: **33.428N** Long: **112.004W** Elev: **1107** StdP: **14.12** Time Zone: **-7.00 (NAZ)** Period: **90-14** WBAN: **23183**

Annual Heating and Humidification Design Conditions

	Coldest Month	Heating DB		Humidification DP/MCDB and HR 99.6%			Humidification DP/MCDB and HR 99%			Coldest month WS/MCDB 0.4%		Coldest month WS/MCDB 1%		MCWS/PCWD to 99.6% DB		
		99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	
(1)	12	39.2	41.8	2.6	6.5	65.0	7.1	8.2	65.4	18.9	57.4	16.7	59.0	3.6	100	(1)

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

	Hottest Month	Hottest Month DB Range	Cooling DB/MCWB 0.4%		Cooling DB/MCWB 1%		Cooling DB/MCWB 2%		Evaporation WB/MCDB 0.4%		Evaporation WB/MCDB 1%		Evaporation WB/MCDB 2%		MCWS/PCWD to 0.4% DB		
			DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(2)	7	20.8	110.3	69.5	108.3	69.3	106.4	69.0	75.7	95.0	74.9	94.6	74.0	94.4	9.4	260	(2)

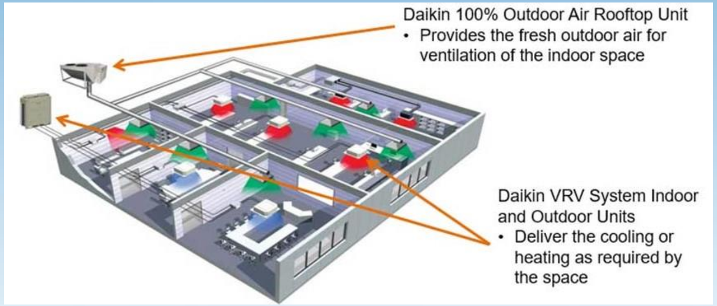
Buildings often designed to:
115F DB / 72F WB

Do Phoenix commercial buildings see **maximum occupancy during summer months?**

Variable Refrigerant Volume: The Technology

The Outdoor Air Question: Is There a Better Design?

- **100% OSA / VRV Hybrid Approach: Decouple & Condition OSA**



(Courtesy: Daikin Applied)

The Concept:

- 100% Outside Air AHU (**Dedicated Outside Air System (DOAS)**) only conditions and supplies outside air required for building ventilation
- DOAS to control building humidity supplying air at **appropriate DEW POINT**
- Supply air dry bulb temperature is supplied at between 70-75F (LOAD NEUTRAL)

Variable Refrigerant System Impact:

- Reduce VRV System Load
- Reduce condensing load at fan coil cooling coils; less condensate

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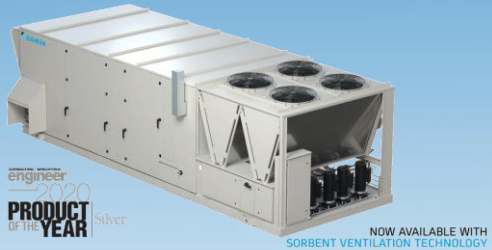
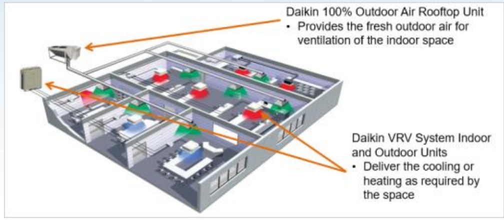
Variable Refrigerant Volume: The Technology

The Outdoor Air Question: Is There a Better Design?

- **Decouple Outside Air from the VRV System**
  - **Dedicated Outside Air Units (DOAS)**
    - Outside air **parallel to VRV system**
    - Outside air delivered directly to each space
    - Heat Recovery (Sensible or Enthalpy)
    - Hot Gas Reheat Coil
      - Heat dehumidified supply air off cooling coil using compressor heat of rejection

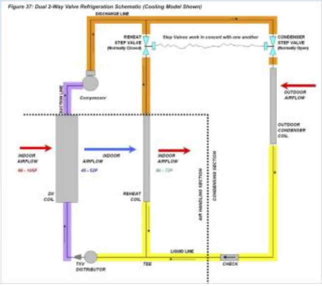


(Courtesy: Daikin Applied)



(Courtesy: Daikin Comfort)

- Dehumidified **Load Neutral OSA** Supplied to Each Zone
- **Fan Coil Inlet Air Condition = Return Air Condition ~75F - 78F**



(Hot Gas Reheat Loop: Courtesy of Daikin)

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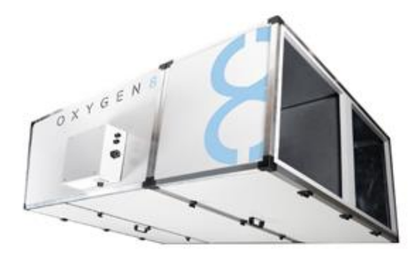
Variable Refrigerant Volume: The Technology

Peak Efficiency at Peak Design Conditions

Outdoor DOAS Units

(Courtesy: Daikin Comfort)



Indoor DOAS Units

(Courtesy: Oxygen 8)

100% OSA / VRV Hybrid Design:

- Outside air treated to load neutral condition
- Lower entering air temperature at fan coil cooling coil
- Improved condenser efficiency
- Lower condenser tonnage for VRV first cost savings
- Smaller VRV dimensional footprint
- Parallel OSA delivery to zones for enhanced system efficiency and assured IAQ is maintained & validated
- Improved system dehumidification (Reduced Risk of Condensation)
- **Depressed Dew Point Supply Air for true humidity control and increased system efficiency**

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100% OSA Variable Refrigerant Concept: Project Review

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100% OSA Variable Refrigerant Concept

Project Review: Sonoran Desert Climate Zone

- **Type of Building Used & Why**
  - Common Commercial Building Type & Size
    - Evaluate practical application of system
  - A building designed for **enhanced indoor air quality (IAQ)**

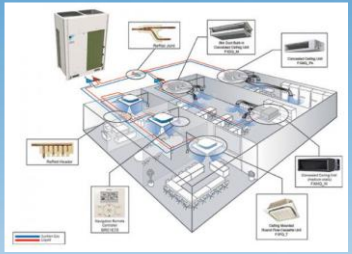
Building Selected: Medical Office Building*

- Single Story Medical Office Building: **~28,000 SQFT**
- Location: Maricopa County
- Elevation: ~1100 feet
- Load calculations generated in Trane Trace

***Project floor plan and load calculations by Smith Group, Phoenix**

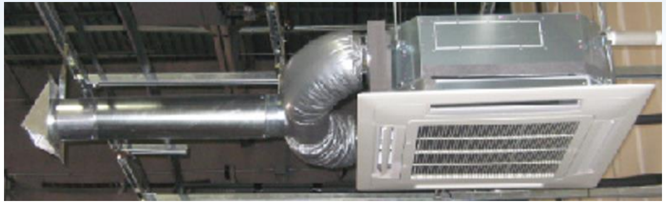
100% OSA Variable Refrigerant Concept

Project Review: Layout & Conditions



(Courtesy: Daikin Comfort)

- **Design #1:**
    - **VRV System: Primary**
        - **Untempered outside air mixed with return air** at fan coil unit
            - Summer Outdoor Air Condition: **97F DB/78F WB**
            - Return Air Condition: ~**75F / 62.36 WB (50% RH and 55F Dew Point)**
            - Winter Outdoor Air: 38F

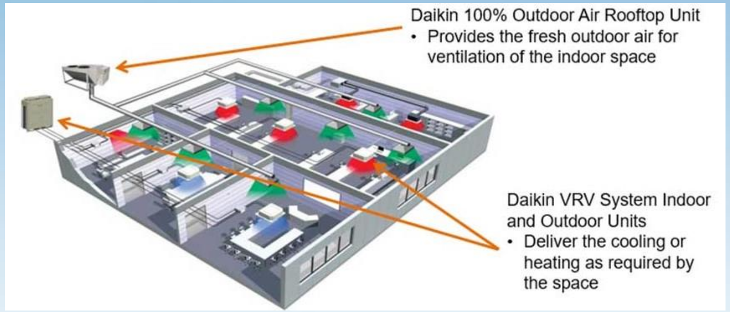


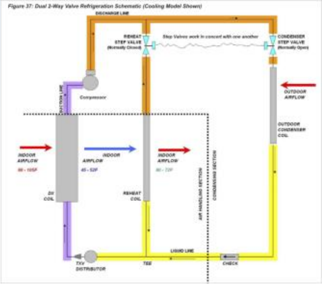
(Courtesy: Daikin Comfort)

100% OSA Variable Refrigerant Concept

Project Review: Layout & Conditions

- **Design #2: VRV System - Primary, OSA System - Secondary**
  - 100% DOAS with enthalpy wheel supplying **53.32F dew point LAT**.





- **Design #3: VRV system designed parallel to:**
  - 100% DOAS with enthalpy wheel supplying **48.8F dew point LAT**.

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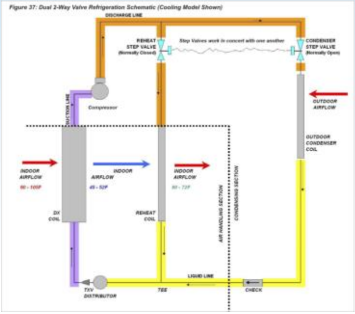
100% OSA Variable Refrigerant Concept

Project Review: Layout & Conditions

- **Design #2: VRV System - Primary, OSA System - Secondary**
  - **Cooling Coil Conditions:**
    - **55° DB / 54° WB LAT:** Dew Point = **53.32°F**
  - **Hot Gas Reheat Coil:**
    - 70° DB/59.58° WB: Dew Point = **53.32°F (Heating, System Part-Load Cooling)**
    - 55° DB/ 53.89° WB: Dew Point = **53.32°F** DP LAT (System 100% cooling)

- **Design #3: VRV System - Primary, OSA System - Secondary**
  - Cooling Coil Conditions:
    - **52° DB / 50° WB LAT**: Dew Point = **48.8°F**
  - Hot Gas Reheat Coil:
    - 70° DB/57.4° WB: Dew Point = **48.8°F DP LAT (Heating, System Part-Load Cooling**
    - 55° DB/ 51.0° WB: Dew Point = **48.8°F DP LAT (System 100% cooling)**



(Hot Gas Reheat Loop: Courtesy: Daikin Comfort)

100% OSA Variable Refrigerant Concept

Project Review: Layout & Conditions

- **Daikin VRV: Performance Observations**
  - Daikin's **VRV Series IV-X Condenser** Technology Applied
  - **Daikin's New EMERION Condenser** Technology (currently available) **NOT APPLIED***.
    - **30% greater efficiency with Emerion**

- **Design Layout Clarifications:**
  - **Room layouts & peak loads the same** for all
  - **Fan coil sizing remained the same** for all rooms
  - **Condenser capacity changed per design**; space latent loads varied per DOAS supplied OSA condition
  - **TMY3 weather data ending in 2005 applied.**

* Emerion performance curves not uploaded into Trane Trace to evaluate

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100% OSA Variable Refrigerant Concept

Project Review : Humidity Control???

Conventional Supply Air Design Conditions:

- 55F DB / 54F WB = **(53.3F Dew Point)**

The Challenge:

- Maintain a room at 75F 50% RH
  (55.13F Dew Point)

Condensation Problem

"CONTROL" Building Humidity at a **dew point depression of 1.83F?**
Physics say you can, but at what airflow rate?

Comparative Analysis & Review

Comparative Analysis & Review

Conventional VRV Design: Untempered Outside Air:

Zone VRV Design: OSA and Zone Total Loads

- Zone Total Load (Sensible + Latent Energy)**: Fan Coil Cooling Coil
- **VRV Condensers to be Sized for Total Load**

Leaving Air Dry Bulb Temperature

Name	FCU	Cooling							
		Tmp C °F (DBT/WBT)	Rq TC BTU/h	Rv TC BTU/h	Max TC BTU/h	Rq SC BTU/h	Tevap °F	Tdis C °F	Max SC BTU/h
FCU-3	FXMQ30PBVJU	79.8/65.0	27,175	27,273	27,944	22,899	42.8	60.7	23,176
FCU-CC1A	FXAQ18PVJU	78.0/63.5	12,000	14,422	15,781	12,000	42.8	56.1	12,593
FCU-CC1B	FXAQ18PVJU	78.0/63.5	12,000	14,422	15,781	12,000	42.8	56.1	12,593
FCU-CC1C	FXAQ18PVJU	78.0/63.5	12,000	14,422	15,781	12,000	42.8	56.1	12,593
FCU-6	FXMQ07PBVJU	85.0/69.4	7,122	7,122	7,614	4,015	42.8	73.5	7,614
FCU-7	FXMQ18PBVJU	81.7/66.7	16,445	16,445	17,808	12,507	42.8	63.8	16,393
FCU-5	FXMQ30PBVJU	87.3/71.2	28,960	28,960	30,817	15,587	42.8	74.4	29,055
FCU-8	FXMQ48PBVJU	80.8/65.9	42,403	42,403	46,193	33,208	42.8	58.9	36,121
FCU-4	FXMQ96MVJU	87.3/71.2	83,971	83,971	98,676	46,228	42.8	70.9	79,821
FCU-9	FXMQ54PBVJU	80.2/65.5	46,841	46,841	51,067	33,992	42.8	61.2	39,858
			288,917						

OSA & Room Air Dehumidification:

- **Fan Coil Unit Cooling Coil**
- **Condenser Capacity Increase**
- Condensate Pans Hold Water
- **Space Humidity Control?**

** HVAC 101:

- **Sensible Energy:** Amount of heat energy present in air sample
- **Latent Energy:** Amount of energy required for water to exist as a vapor (gas)

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Comparative Analysis & Review

DOAS VRV Design: 100% Conditioned Outside Air

Zone VRV Design : Zone Total Load Only

- Zone Total Load (Sensible + Latent Energy): Fan Cooling Coil
- **VRV Condensers: Reduced Size for Zone Total Load (No OSA Load)**

Leaving Air Dry Bulb Temperature

Name	FCU	Cooling							
		Tmp C °F (DBT/WBT)	Rq TC BTU/h	Rv TC BTU/h	Max TC BTU/h	Rq SC BTU/h	Tevap °F	Tdis C °F	Max SC BTU/h
FCU-3	FXMQ30PBVJU	77.2/63.1	23,440	23,440	25,899	20,154	42.8	60.4	21,918
FCU-4	FXMQ48PBVJU	74.0/61.6	30,880	30,880	38,917	21,567	42.8	59.7	31,153
FCU-5	FXMQ12PBVJU	74.0/61.6	8,631	8,631	9,743	6,158	42.8	61.5	8,422
FCU-6	FXMQ07PBVJU	75.0/62.1	2,586	2,586	6,198	1,842	42.8	69.7	5,789
FCU-7	FXMQ15PBVJU	76.4/62.8	11,045	11,045	12,755	9,621	42.8	60.7	11,048
FCU-8	FXMQ48PBVJU	76.8/62.9	32,008	32,008	41,181	27,147	42.8	58.8	32,678
FCU-9	FXMQ48PBVJU	77.0/63.0	37,782	37,782	41,352	28,228	42.8	58.3	32,818
FCU-CC1A	FXAQ18PVJU	78.0/63.5	12,000	14,422	15,781	12,000	42.8	56.1	12,593
FCU-CC1B	FXAQ18PVJU	78.0/63.5	12,000	14,422	15,781	12,000	42.8	56.1	12,593
FCU-CC1C	FXAQ18PVJU	78.0/63.5	12,000	14,422	15,781	12,000	42.8	56.1	12,593
FCU-10	FXMQ15PBVJU	76.2/62.8	11,214	11,214	12,791	8,072	42.8	63.1	10,924
FCU-14	FXMQ24PBVJU	75.7/62.4	15,339	15,339	20,143	12,238	42.8	59.5	16,964
FCU-15	FXMQ48PBVJU	76.7/62.9	32,324	32,324	41,062	27,121	42.8	58.7	32,630
FCU-17	FXMQ30PBVJU	76.0/62.6	20,732	20,732	25,350	16,156	42.8	62.6	21,428
FCU-19	FXMQ48PBVJU	76.6/62.8	32,504	32,504	40,994	27,797	42.8	58.2	32,584
FCU-20	FXMQ48PBVJU	76.7/62.9	32,324	32,324	41,062	27,121	42.8	58.7	32,630
FCU-21	FXMQ48PBVJU	76.6/62.8	32,504	32,504	40,994	27,797	42.8	58.2	32,584
FCU-CC4A	FXAQ18PVJU	78.0/63.5	12,000	14,422	15,781	12,000	42.8	56.1	12,593
FCU-CC4B	FXAQ18PVJU	78.0/63.5	12,000	14,422	15,781	12,000	42.8	56.1	12,593
			383,313						

VRV Dehumidification Load Reduced:

- Fan Coil Unit Cooling Coil
- Condenser Size Reduced
- Space Humidity Load Reduced
- Reduced Coil Condensation
- Space Humidity Control

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Comparative Analysis & Review

Building Loads: VRV Equipment Selection Review

Design Scenarios: Condenser Capacities per Designs #1, #2 & #3

Condenser Sizing and Energy Savings Review

Design #	Design Type	Condenser Tag	Total Peak Load	Condenser Model #	Total Condenser Nominal Tonnage	Diversity Factor	Capacity - Peak Load (Tons)	VRV System (Cooling: kWh)	VRV System (Heating: kWh)	Fans: (Total: kWh)	VRV System (Total: kWh)	kWh (Total Energy Savings)	Percentage Savings
#1	Untempered OSA	CU-1A	80.56	REYQ288AAYDA	105.6	80%	3.92	76,751	919	30,424	108,084		0.00%
		CU-1B		REYQ288AAYDA									
		CU-2		REYQ480AAYDA									
#2	DOAS with ERW @ 53.13 F Dew Ppoint	CU-1	80.56	REYQ432AAYDA				53,447	485	34,040	87,972	20,112	19.00%
		CU-2		REYQ312AAYDA	74.4	80%	-6.16						
#3	DOAS with ERW @ 48.8F Dew Ppoint	CU-1	80.56	REYQ360AAYDA				44,833	551	34,720	80,104	27,980	26.00%
		CU-2		REYQ28.8AAYDA	64.8	80%	-15.76						

- **Design VRV Condenser Sizing: Nominal Tonnage Review:**
  - Design #1: Untempered Mixed-Air: **105.6 Tons**
  - Design #2: 100% OSA DOAS: **53.32F Dew Point Supply Air: 74.4 Tons**
  - Design #3: 100% OSA DOAS: **48.8F Dew Point Supply Air: 64.8 Tons**

Comparative Analysis & Review

Building Loads, VRV Equipment Selection Review:

Design Scenarios: Condenser Capacities per Designs #1, #2 & #3

- **Design Condenser Sizing: Nominal Tons:**
  - Design #1: Untempered Mixed-Air: Condensers Sized for **105.6 Tons**
  - Design #2: 100% OSA DOAS: **53.32F DP Supply Air: Reduced 31.2 Tons**
  - Design #3: 100% OSA DOAS: **48.8F Dew Point Supply Air: Reduced 40.8 Tons**

Supplying 48.8F Dew Point OSA:

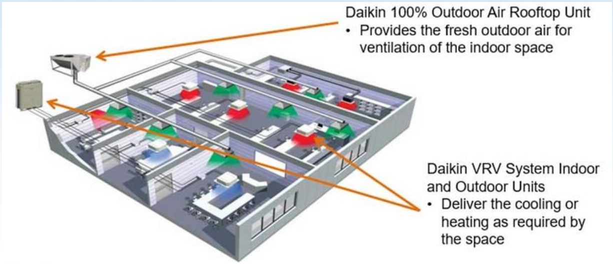
- VRV System Predominantly a **Sensible Cooling System**
- **Reduced Condensate**, If Any, In Drain Pans
- **Reduced Bio-Mass Growth** @ Coil & Drain Pan
- Improved IEQ

Comparative Analysis & Review

Building Loads, VRV Equipment Selection Review:

Design Scenarios: Condenser Capacities per Designs #1, #2 & #3

- **VRV Performance: System (DOAS & VRV) Energy Savings**
  - Design #1: Untempered Mixed-Air: **VRV System Total Energy – 108,084 kW/h**
  - Design #2: 100% OSA DOAS: **53.32F DP SA: VRV Total Energy – 87,972 kW/h**
  - Design #3: 100% OSA DOAS: **48.8F DP SA: VRV Total Energy – 80,104 kW/h**



Percentage of Energy Savings:

- Design #1: Base Line Design – 0.0%
- **Design #2: Energy Savings = 19%**
- **Design #3: Energy Savings = 26%**

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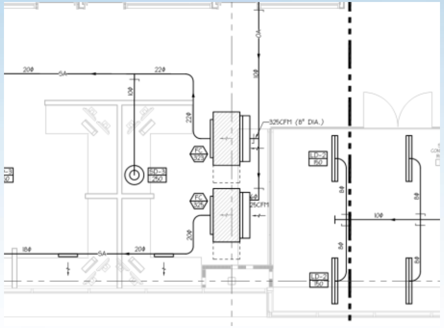
Equipment First Cost & Payback Review

Equipment First Cost & Payback Review

Building Loads, VRV Equipment Selection Review

VRV Design Equipment First Cost & Projected Payback Analysis:

- **Design #1:**
  - Daikin VRV Series IV Condenser Layout with **untempered outside air**: Total Budget Cost: ……………………………... $239,875.00
  - Daikin Rebel DOAS Budget Cost: ………… $0.00 NA
    - **Total System Equipment Cost: …... $239,875.00**



- **Design Considerations:**
  - **100% building dehumidification at VRV fan coil units**
  - Larger condenser sizing and heavier
  - Larger mechanical foot print
  - Drain pans fill with condensate; building humidity source
  - OSA validation to building not validated

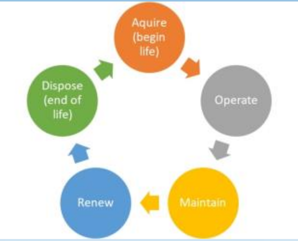
**Payback would vary between local utility rates, climate zone, regional market values, contractor installation costs…etc.

Equipment First Cost & Payback Review

Building Loads, VRV Equipment Selection Review

VRV Design Equipment First Cost & Projected Payback Analysis:

- **Design #2:**
  - Daikin VRV Series IV Condenser Layout with untempered outside air: Total Budget Cost: ………………………………….. $184,090.00
  - Daikin Rebel DOAS Budget Cost: …………. $73,055.00 NA
    - **Total System Equipment Cost: …..…. $257,145.00**
    - **Total Premium: ……………………….. +$17,270.00**
    - **Projected Payback: ………………..…. 5-10 Years****



- **Owner Benefits:**
  - Better Building Humidity Control
  - Enhanced System Energy Efficiency
  - Reduced condensation
  - **Outdoor air delivered to each zone & validated for IEQ**

**Payback would vary between local utility rates, climate zone, regional market values, contractor installation costs…etc.

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Equipment First Cost & Payback Review

Building Loads, VRV Equipment Selection Review

VRV Design Equipment First Cost & Projected Payback Analysis:

- **Design #3:**
  - Daikin VRV Series IV Condenser Layout with untempered outside air: Total Budget Cost: ……………... $173,051.00
  - Daikin Rebel DOAS Budget Cost: ………… $93,280.00 NA
    - **Total System Equipment Cost: ….. $266,331.00**
    - **Total Premium: …………………..…. +$26,456.00**
    - **Projected Payback: …………………. 6-11 Years****

- **Owner Benefits:**
  - **Building Humidity Control** at Industry Recommended levels (40-60% RH)
  - Premium System Energy Efficiency
  - Significantly Reduced Risk of Building Condensation
  - Outdoor Air Delivered to Each Zone & **Validated for IEQ**

**Payback would vary between local utility rates, climate zone, regional market values, contractor installation costs…etc.

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Concluding Remarks

Concluding Remarks

Opening Statements: Market Existential Pressures

Market Forces: The Dilemma

- Pandemic Awareness: The Risk of Infection in Built Environments
- Importance of **Building IEQ**: Global Movement
- CDC, EPA and ASHRAE Positions
  - Ventilation & Indoor air quality
- Net-Zero Initiatives
  - AIA 2030 Commitment
  - Carbon Leadership Forum

What's Next for Standard 90.1

ATLANTA—In late July, the U.S. Department of Energy (DOE) issued a determination that ANSI/ASHRAE/IES Standard 90.1-2019, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, improves energy efficiency in commercial buildings compared to the 2016 standard.

The final determination makes the 2019 version of the standard the reference energy-efficiency standard for buildings other than low-rise residential buildings, said Standing Standard Project Committee 90.1 Chair Don Brundage, P.E., Member ASHRAE; Co-Vice Chair Thomas Culp, Ph.D., Member ASHRAE; and

special status as the model energy code for buildings within the 90.1 scope."

Now What?

DOE analysis shows the updated standard could cause national savings in commercial buildings of about 4.7% site energy, 4.3% source energy and 4.3% energy cost. States and other jurisdictions are now required to review their commercial building code regarding energy efficiency and update their codes to meet or exceed Standard 90.1-2019. Each state or jurisdiction has their own process for considering updates

Concluding Remarks

The Dilemma: A Proposed Solution

- **100% Outside Air / Variable Refrigerant Systems**

Spanning the Divide:

- **Enhanced Energy Efficiency**:
  - A Hybrid VRV / OSA System approach
- **Enhanced IEQ:**
  - Outside air supplied directly to each zone
  - Outside air supplied monitored and validated
- **Building humidity control**
- **Premium Energy Efficiency Goals:**
  - Decarbonization
  - Electrification

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Questions?

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Thank you.

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