

August 25, 2020

2020 VT RBES Mechanical Systems Requirements and System Design Options

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The following is a summary of **Chapter 3 – General Requirements** of the 2020 Vermont Residential Building Energy Standard (RBES), which covers General Requirements, Design Conditions, and Mechanical Systems and Equipment, and Design Criteria for Residential Ventilation Systems. This summary also includes mechanical system requirements in Section R403 of Chapter 4 – *Residential Energy Efficiency*.



Chapter 3 General Requirements

Sections R302 – R305 details design conditions and parameters of residential construction for:

- Building load design conditions
- Materials, systems, and equipment
 - Includes insulation and fenestration identification and default values
- Design criteria for whole-house ventilation systems
- Combustion Safety

Chapter 4 – Residential Energy Efficiency

Section R403 – Systems primarily deals with the application and requirements of mechanical systems installed in residential buildings.

Items covered include:

- Controls / thermostats
- Supplementary heat (disallowed) in heat pump systems other than for defrost
- Ducts: design/ installation/ testing
- Mechanical and DHW piping, including circulation systems
- Mechanical ventilation
- Equipment sizing – Manual S and Manual J or equivalent load calculations required for sizing heating and cooling equipment
- Snow melt systems
- Pools and spas

SECTION R302 DESIGN CONDITIONS



Design Conditions

R302.1 Interior design conditions.

The interior design temperatures used for heating and cooling load calculations shall be a maximum of 72°F (22°C) for heating and minimum of 75°F (24°C) for cooling.

R302.2 Climatic data.

The following design parameters in Table 302.2 shall be used for calculations required under this code

**TABLE 302.2
THERMAL DESIGN
PARAMETERS**

CONDITION	VALUE
Winter, Design Dry-Bulb	-11°F
Summer, Design Dry-Bulb	84°F
Summer, Design Wet Bulb	69°F
Degree Days Heating	7,665
Degree Days Cooling	489

“Heating and cooling equipment shall be sized in accordance with ACCA Manual S based on *building* loads calculated in accordance with ACCA Manual J or other *approved* heating and cooling calculation methodologies. New or replacement heating and cooling equipment shall have an efficiency rating equal to or greater than the minimum required by federal law for Climate Zone 6.

R403.7 Equipment sizing and efficiency rating (Mandatory).

What is Manual J?

ACCA (Air Conditioning Contractors of America) published guideline and procedure used to accurately define the total heating and cooling demand load for a residential building. Also called building *Block Load* or *Design Load*.

The Heating or Cooling Design Load defines the maximum heat loss or cooling demand on the coldest or hottest day of the year as referenced by local *design temperatures*

A full Manual J calculation will not only define the total building loads, but also the individual room-by-room loads which are crucial for distribution design

Apart from the load calculation being performed, the ducts must be sized and the correct size equipment must be selected.

- ACCA Manual D® is for duct sizing and
- ACCA Manual S® for residential equipment selection provide guidance here.

Implications of NOT doing a careful load calculation

Oversized equipment

Three main reasons for oversized equipment are:

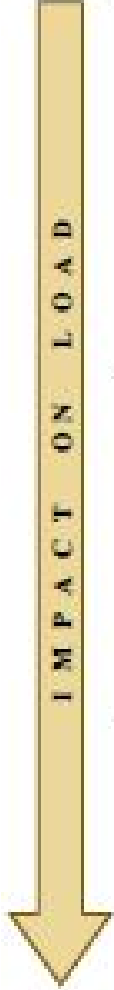
- (1) a guess is made on the load;
- (2) mistakes are made in the load calculation;
- (3) the equipment is selected for either unusual/extreme conditions such as abnormal temperatures or unusual occupancy loads.
- (4) Other reasons include the use of inappropriate and inadequate "rules of thumb" such as '500ft² /ton', '400CFM/ton', or 'total cooling capacity = 1.3 x sensible cooling capacity'.

Other trickle-down impacts of over-sized equipment

Uneven temperature control and discomfort

- While the temperature control at the thermostat may be satisfactory, equipment cycling may cause noticeable temperature swings in other rooms and larger temperature differences between rooms.
- Oversized equipment may cause degraded humidity control and increase the potential for mold growth, allergic reactions and respiratory problems. In these unfavorable conditions, occupants may experience additional discomfort and dissatisfaction.
- Other negative effects are higher installed costs, increased operating expenses, and increased maintenance costs.
- Furthermore, oversized equipment generally requires larger ducts, poses additional requirements on the power grid and may lead to more service calls.

Accurate Inputs



H I G H	<ul style="list-style-type: none">✓ Design Temperatures (Indoor and Outdoor)✓ Windows, Glass Doors and Large Skylights (shading, overhangs, etc.)✓ Ducts (location, leakage and duct wall R-values)✓ Ceilings under an attic (R-values, roof material, roof color)
M E D I U M	<ul style="list-style-type: none">✓ Small Skylights✓ Infiltration✓ Ventilation
L O W	<ul style="list-style-type: none">✓ Appropriately Insulated Floors✓ Appropriately Insulated Walls✓ Internal Gains

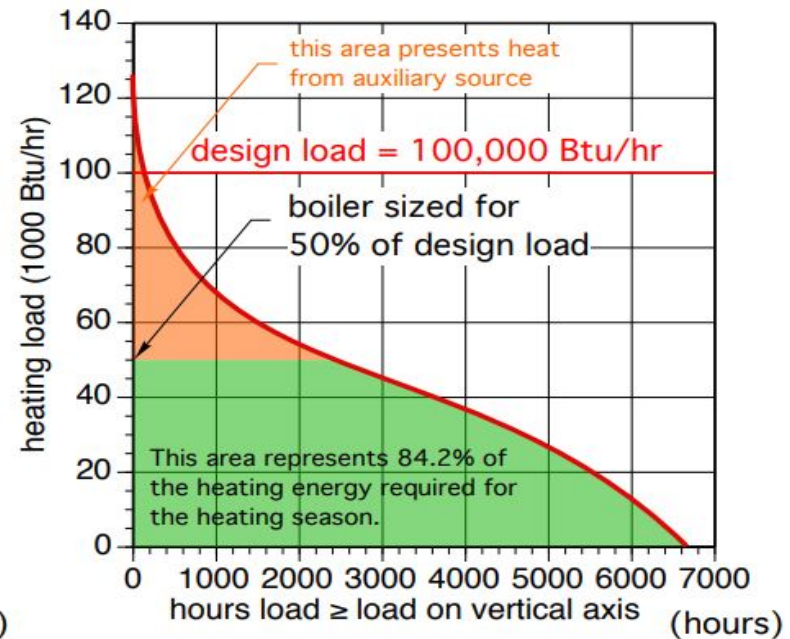
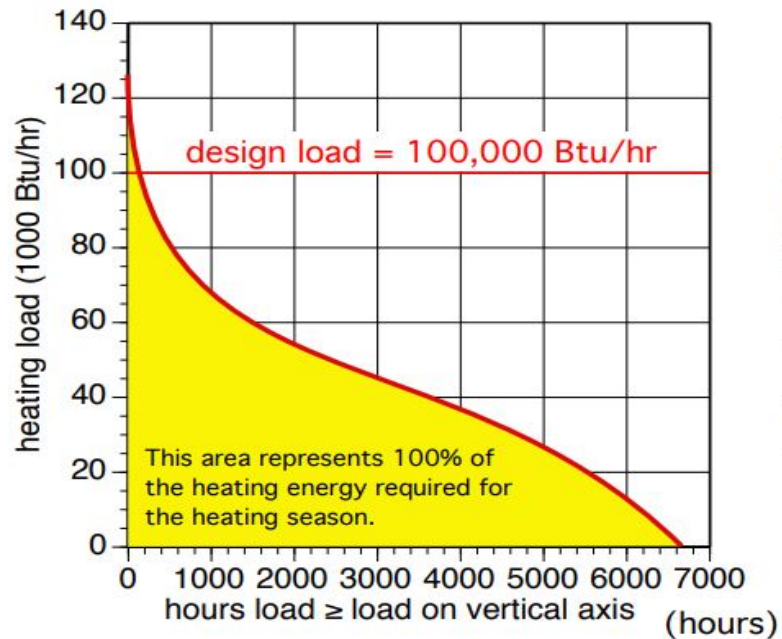
#	KEY ITEM	CHECK	QUESTIONS TO ASK
1	DESIGN TEMPERATURES	✓ Indoor Design Temperatures	Is the indoor design temperature for <i>Heating</i> : per Local Code OR 70°F (21°C) at 30% RH?
			Is the indoor design temperature for <i>Cooling</i> : per Local Code OR 75°F (24°C) at 50% RH? [or 55% for humid climate, 45% for dry climate?]
		✓ Outdoor Design Temperatures	Is the outdoor design temperature per Table 1 of MJ8 or Local Code?
2	WINDOWS & GLASS DOORS	✓ U-values and SHGC values	Are the SHGC and U-values reasonable for the window types and frame constructions? (see Table 2 of MJ8)
		✓ Shading Adjustments	Have window shading (curtains, drapes, insect screens, tinting, etc.) adjustments been made?
		✓ Overhang Adjustments	Have roof overhang adjustments been made?
		✓ Total Area	Is the total area for the windows & glass doors roughly equal to the area shown on the drawing plans?
		✓ Exposure Directions	Do the exposure directions [North (N), North-East (NE), etc.] appear correct?
3	SKYLIGHTS	✓ U-values and SHGC values	Are the SHGC and U-values appropriate for the skylight types and frame constructions? (see Table 2 of MJ8)
		✓ Shading Adjustments	Have adjustments been made for drapes, tinting and reflective coatings?
		✓ Total Area	Is the total area for the skylights roughly equal to the area shown on the drawing plans?
		✓ Exposure Directions	Do the exposure directions [North (N), North-East (NE), etc.] appear correct?
4	DOORS WOOD, METAL	✓ None	-----
5	WALLS ABOVE GRADE, BELOW GRADE	✓ Insulation	Are correct wall insulation R-values taken into account when the wall loads are calculated?
		✓ Total Area	Is the total area for the walls equal to the area shown on the drawing plans?
6	CEILINGS	✓ Insulation	Is correct ceiling insulation R-value taken into account when the ceiling load is calculated?
		✓ Radiant Barrier	If applicable, does the load calculation take credit for a radiant barrier?
		✓ Roof color and material	Is correct roof color and material taken into account when the ceiling load is calculated?
		✓ Total Area	Is the total area for the ceilings equal to the area shown on the drawing plans?
7	FLOORS	✓ Insulation	Is the floor insulation and type of construction representative of what is built/planned?
8	INFILTRATION	✓ Envelope Tightness	Is the listed envelope tightness (tight, semi-tight, average, semi-loose, loose) appropriate?
		✓ Above grade volume	Is the total above grade volume equal to what is shown on the drawing plans?



Maximum over-sizing allowed under RBES:

Maximum Equipment Oversizing ACCA Manual S ~ Heating & Cooling Equipment Sizing Guide	
TYPE OF EQUIPMENT	MAXIMUM OVERSIZING
Air conditioners and heat pumps	15%
Fuel-fired heating equipment	40%

Partial load analysis:



Boiler sized @ 50% of design load provides about 84% of seasonal space heating energy.

Boiler sized @ 60% of design load provides about 90% of seasonal space heating energy.

Boiler sized @ 75% of design load provides about 96% of seasonal space heating energy.



The Importance of Integrated Design

2 Load Calcs

	Load Calc 1 (Btu/h-ft ²)	Load Calc 2 (Btu/h-ft ²)	Spec
Common Area	22*	11.5	38
Typical Apt	10*	4.0	23
Corner Apt	10*	8.8	23

Another item to note from Section R305 – Combustion Safety

Any home built to be compliant with the 2019 RBES shall be considered of *unusually tight construction*, as defined by NFPA 54 and NFPA 31.

Basically this means that any fuel-burning combustion appliances within the building need to be direct-vented (closed combustion) or have outdoor combustion air provided directly to the combustion appliance

Further detail and the full compliance language can be found in **Section R305 – Combustion Safety**

Electric Resistance Heat - Section R404

R404.2 Electric Resistance Heating Equipment

- Heat pumps having supplementary electric resistance heat shall be certified *cold-climate heat pumps* only and shall have controls that, except during defrost, prevent supplementary electric heat operation where the heat pump compressor can meet the heating load.
- Building heating with electric resistance heating equipment is prohibited.

Section R404.2 – Continued

Exceptions for use of electric resistance heating equipment:

Replacement of existing electrical resistance units.

Limited areas where other heating sources are cost prohibitive or impractical (e.g., a small interior space such as a bathroom or stairwell, which is distant from the distribution system).

Buildings with Cold-Climate Heat Pump(s) as the primary heating system, provided:

- a. The supplemental electric resistance heat is controlled to prevent it from operating at an outside air temperature of 5°F or higher; and
- b. The building has a tested air tightness of ≤ 2.0 ACH50.

4. Multifamily buildings with heating loads ≤ 6.0 Btu/hour/square foot at design temperature.

Mechanical Ventilation Requirements

Section R304

Design Criteria for Residential Ventilation Systems



R304.3 Whole House Ventilation – Mandatory

Every home and dwelling unit built to RBES shall be mechanically ventilated by a whole house ventilation system as defined in **Chapter 2 - Definitions**.

The whole house ventilation system shall be one of two types: “exhaust only” or “balanced.”

R304.1.1 Compliance.

- Compliance with **Section 304** shall be achieved Prescriptively by meeting the minimum requirements for fan selection provided in **Table R304.6** and complying with **Sections R304.2 through R304.11** (Installation Requirements)

**Table R304.6 –
Prescriptive Fan Capacity Requirements**

Number of Bedrooms	Minimum Rated Capacity (CFM)	Minimum Number of Fans
1	50	1
2	75	1
3	100	1
4	125	Centrally ducted systems: 1, All other systems: 2 or more
5	150	Centrally ducted systems: 1, All other systems: 2 or more
Homes over 3000 sq. ft.	0.05 x sq. ft. of conditioned space	Centrally ducted systems: 1, All other systems: 2 or more

Performance Option for Section R304 - Ventilation Requirements

As an alternative to meeting the requirements of **Section R304** by way of the Prescriptive approach, compliance may be demonstrated with one of the following alternatives:


- ASHRAE Standard 62.2-2016 (Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings)
- BSC Standard 01-2015 (Ventilation for New Low-Rise Residential Buildings)
- Passive house ventilation requirements (PHI or PHIUS)


ASHRAE-62.2.2016

Most common method used for determining ventilation requirements

Residential Energy Dynamics / RED Calc
<https://www.redcalc.com/ashrae-62-2-2016/>

Efficiency
Vermont



Reset Print 

ASHRAE 62.2-2016 Ventilation

New or existing construction Existing ▾
Dwelling unit is Detached ▾
Use infiltration credit Yes ▾

Closest weather station United States ▾
Vermont ▾
Springfield/Hartnes ▾

Weather and shielding factor [1/hr] = 0.51

Floor area [ft² ▾]
Number of occupants ▾
Dwelling height [ft ▾]
Measured leakage @ 50Pa [CFM ▾]

☐ Use Advanced Blower Door Inputs

☐ Use Local Ventilation Alternative Compliance

Dwelling-Unit Ventilation Results

Effective annual avg infiltration rate [CFM ▾] =
Total required ventilation rate, Q_{tot} [CFM ▾] =
Infiltration credit, Q_{inf} [CFM ▾] =
Required mechanical ventilation rate, Q_{fan} [CFM ▾] =

Dwelling-Unit Ventilation Run-Time Solver

Fan capacity [CFM ▾]
Fan run-time per hour [min ▾] =

Dwelling-Unit Leakage Rate Solver

Target mechanical ventilation rate [CFM ▾]
Corresponding measured leakage @ 50Pa [CFM ▾] =

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Local Ventilation Requirement

Section R304.2

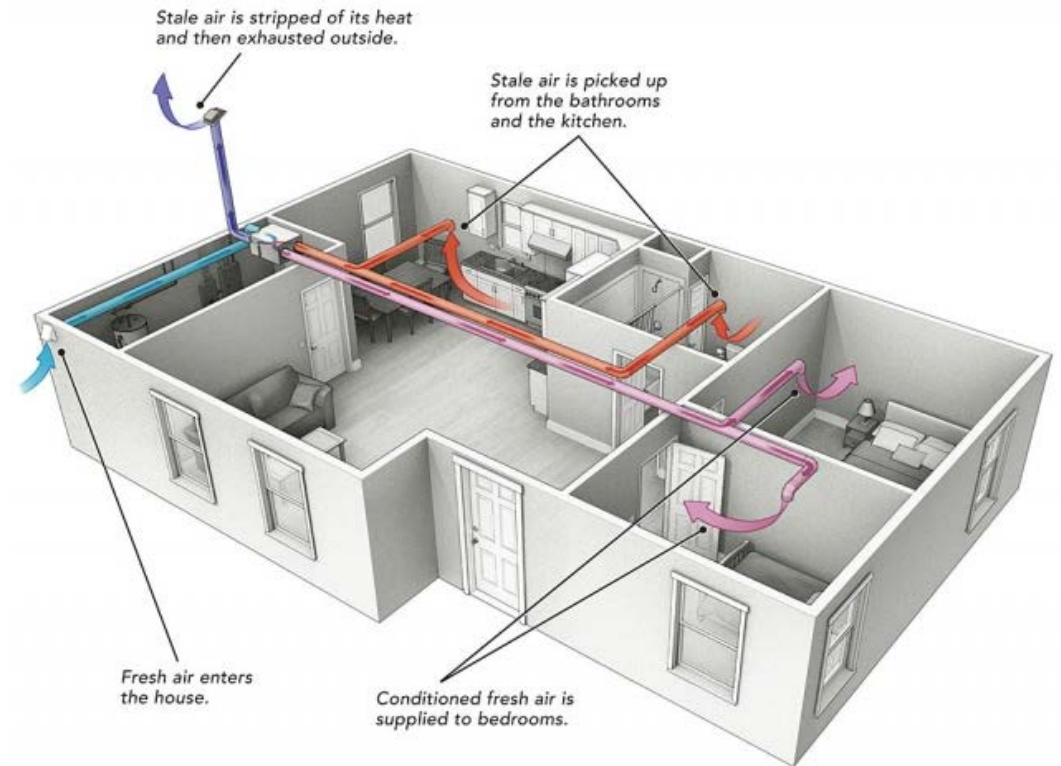
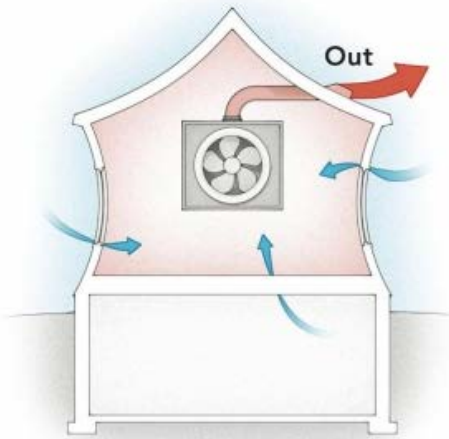
- Ventilation fans in bathrooms containing a bathtub, shower, spa or similar bathing fixture and not included in the whole house ventilation system shall be sized to meet the net capacity rates as required in **Table 304.2**. Whole house ventilation fans serving both localized and whole house ventilation functions shall be sized to meet the net capacity rates as required by **Section 304.6** and must meet all other requirements listed in **Section 304.3**, as applicable.

Table 304.2 –
Local Ventilation Requirements

TABLE 304.2
MINIMUM REQUIRED LOCAL EXHAUST

OCCUPANCY CLASSIFICATION	MECHANICAL EXHAUST CAPACITY (CFM)
Bathrooms	50 cfm intermittent or 20 cfm continuous

Base-code allows for exhaust-only ventilation, though Stretch-code, Rescheck compliance, UA Alternative, and points options *do require* balanced systems with minimum performance - ECM fan(s), plus minimum of $\geq 70\%$ SRE for HRV, or $\geq 65\%$ SRE for ERV



R304.8 Controls

Whole house ventilation systems (balanced or exhaust-only ventilation) shall be capable of being set remotely for continuous operation or shall be provided with an automatic control for intermittent operation. All whole house ventilation controls shall be readily accessible.

R304.8.1 Intermittent operation. Intermittently operated *whole house ventilation systems* shall be capable of being set remotely for continuous operation; or shall be provided with an automatic control capable of operating without the need for occupant intervention, such as a time switch or some other control device. Twist or crank-style timers are prohibited as control devices for *whole house ventilation systems*. Operation controlled solely by a humidity sensor (humidistat or dehumidistat) does not qualify.

R304.8.2 Continuous operation. Continuously operated *whole house ventilation systems* shall not be provided with local controls unless that control only operates the *whole house ventilation system* both intermittently at high speed and continuously at low speed.

R304.8.2.1 On/off switch for continuous operation. An on/off switch for continuously operated *whole house ventilation systems* shall be remotely installed and appropriately labeled.

What are we controlling with Mechanical Ventilation?

Occupant Indoor Air Quality

- Carbon monoxide-combustion appliances
- Carbon monoxide-humans off-gas..
- VOC's and indoor contaminants
- Pets and teenagers
- **Moisture**

Condensation Good.



Condensation Bad



Condensation Real Bad..



Wet funk comes in many flavors



To integrate or not to integrate..

Stand-alone duct system

- Ducts sized and designed specifically to airflow capacity of HRV/ERV unit
- Controlled flow rates with proper duct design
- Low operational cost utilizing ECM motor of HRV/ERV unit
- Quiet operation

Shared duct system

- Eliminates need for another set of ductwork
- Can help facilitate getting ventilation air through entire house
- Some potential installation cost savings

Potential pitfalls of integrated installations

- Overall higher operational costs due to utilizing H/AC air handler to move ventilation air
- Duct sizing and layout for heating/cooling does not align with flow rate and volume capacities of HRV/ERV units
- Without very careful design and controls ventilation air delivered can be much less than rooms require
- When air handler is running for heating/cooling demand without proper controls there can be negative implications to the HRV/ERV unit itself.
- Much less control on adjusting ventilation flow rates room by room

There is a performance requirement for integrated ventilation design in RBES

If ventilation is integrated into a furnace:

Per RBES R403.6.1: Where an air handler that is integral to tested or listed HVAC equipment is used to provide whole house mechanical ventilation, the air handler shall be powered by an electronically commutated motor (ECM).

Ventilator and air handler

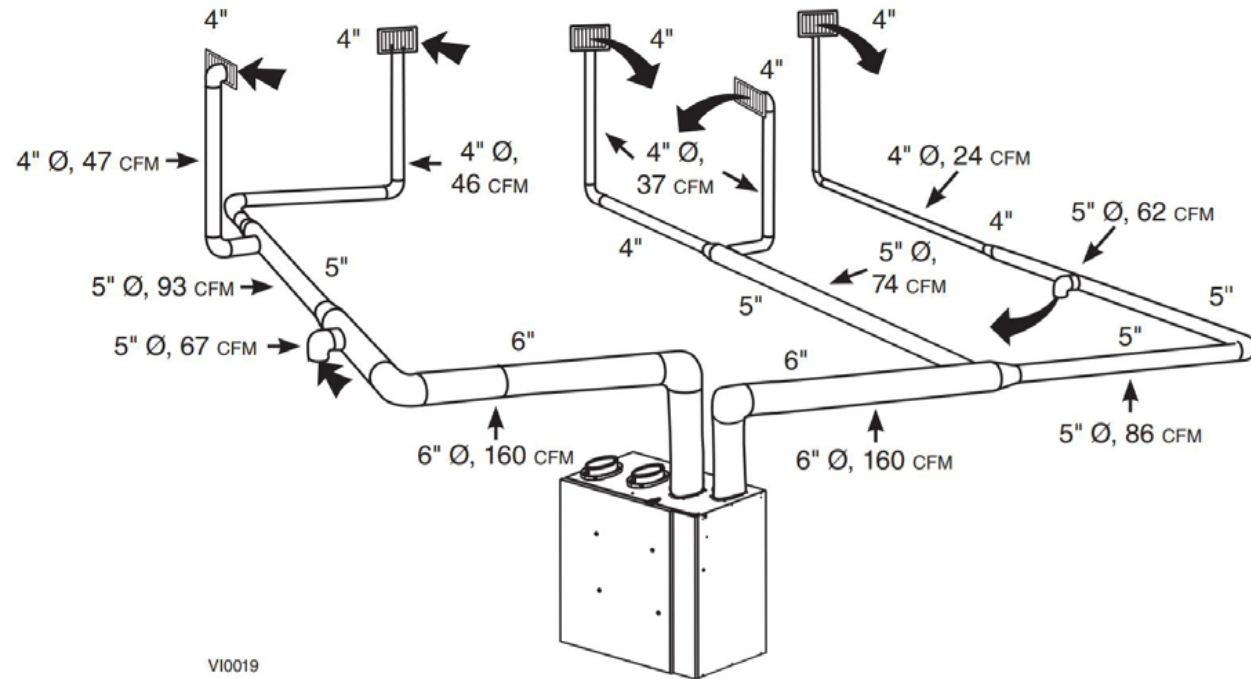
Operating continuously provides best air quality and is the simplest installation. But H/ERV must be able to operate at a low enough flow to avoid overventilation and air handler energy is significant with this operation strategy. With ECMs good duct design will minimize fan energy.

Operating intermittently requires motorized dampers that open only when the ventilator is on. Note that the air handler must be controlled by the ventilator so it is always on when the ventilator is on.

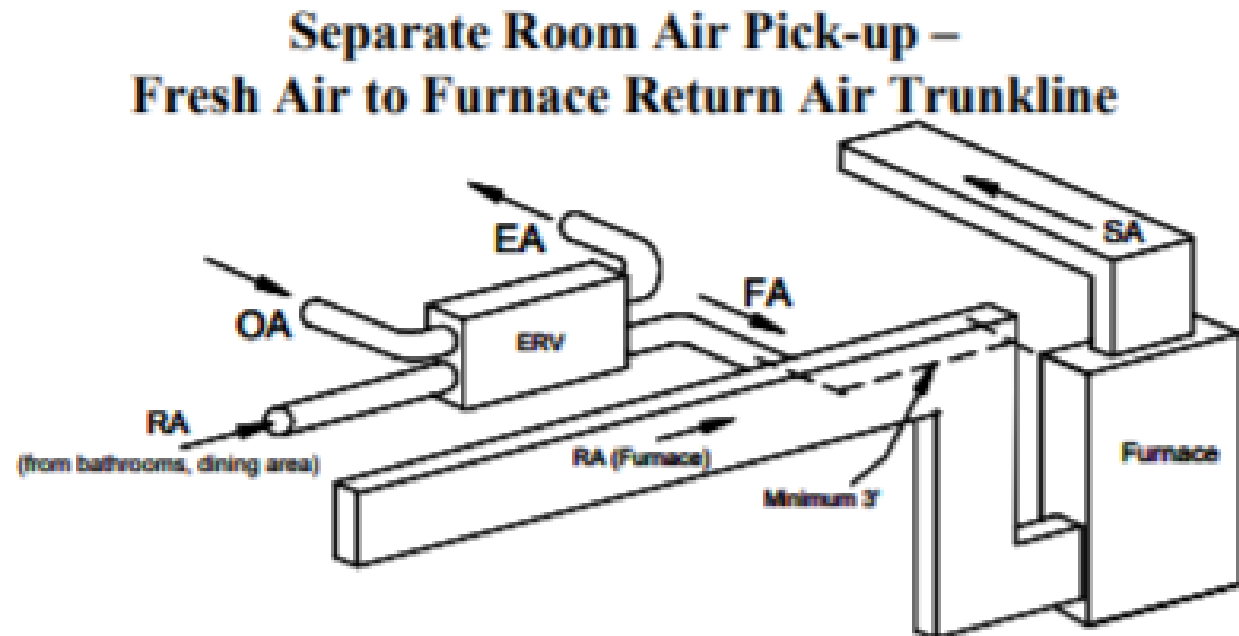
Most air handlers with an ECM have a ventilation mode or other very low speed that can be used when the ventilator is operating but there is no call for space conditioning. Air handler wattage at this speed varies depending on ductwork. Select air handler carefully to ensure the system can support integrated ventilation with minimal energy penalty.

Always measure flows!

Standard / Stand-Alone System Duct Schematic

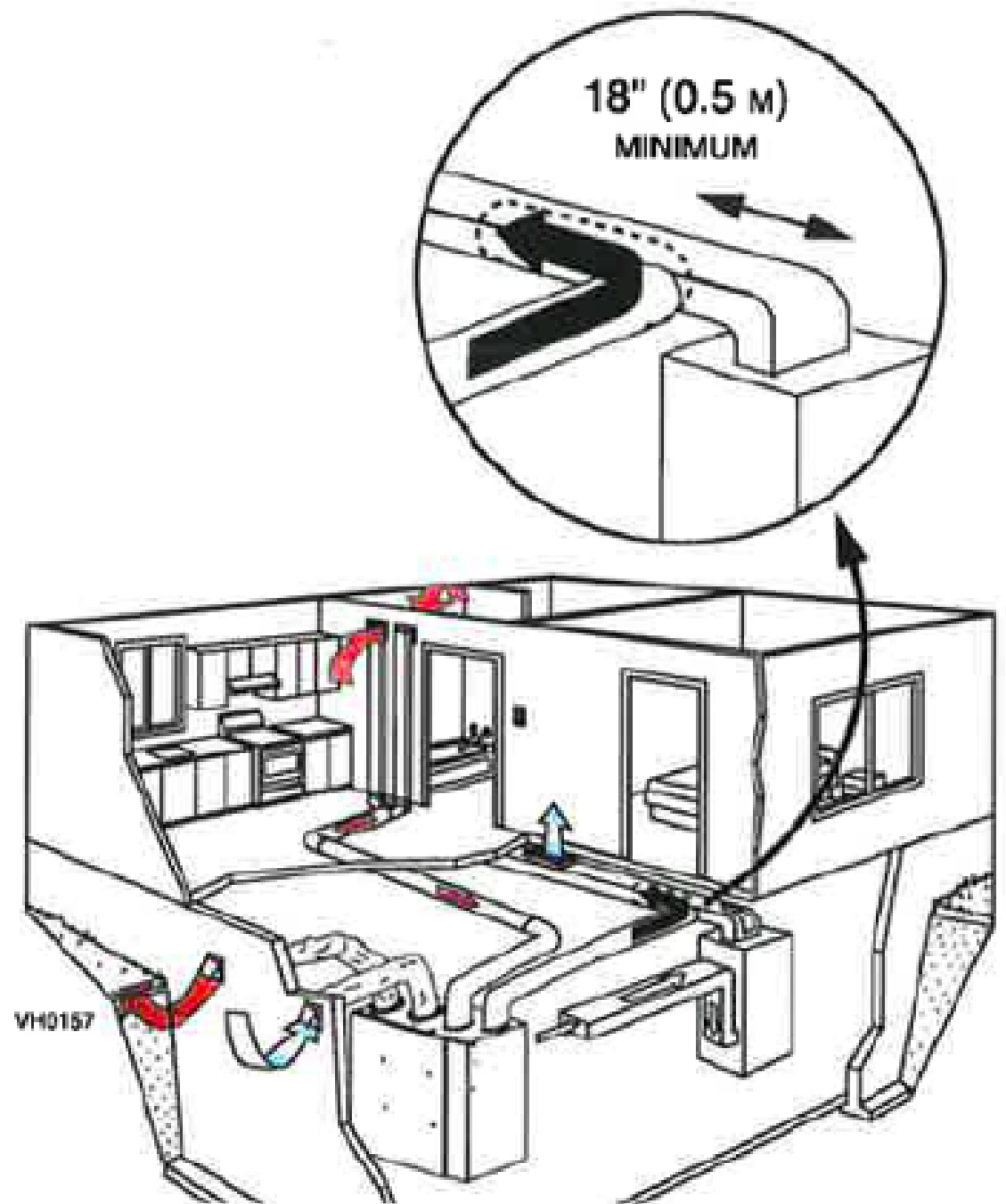


Method 1: "Return" (MOST COMMON) | Fresh air leaving H/ERV is injected into the return side of the furnace ductwork. Return air to H/ERV is via dedicated ductwork.

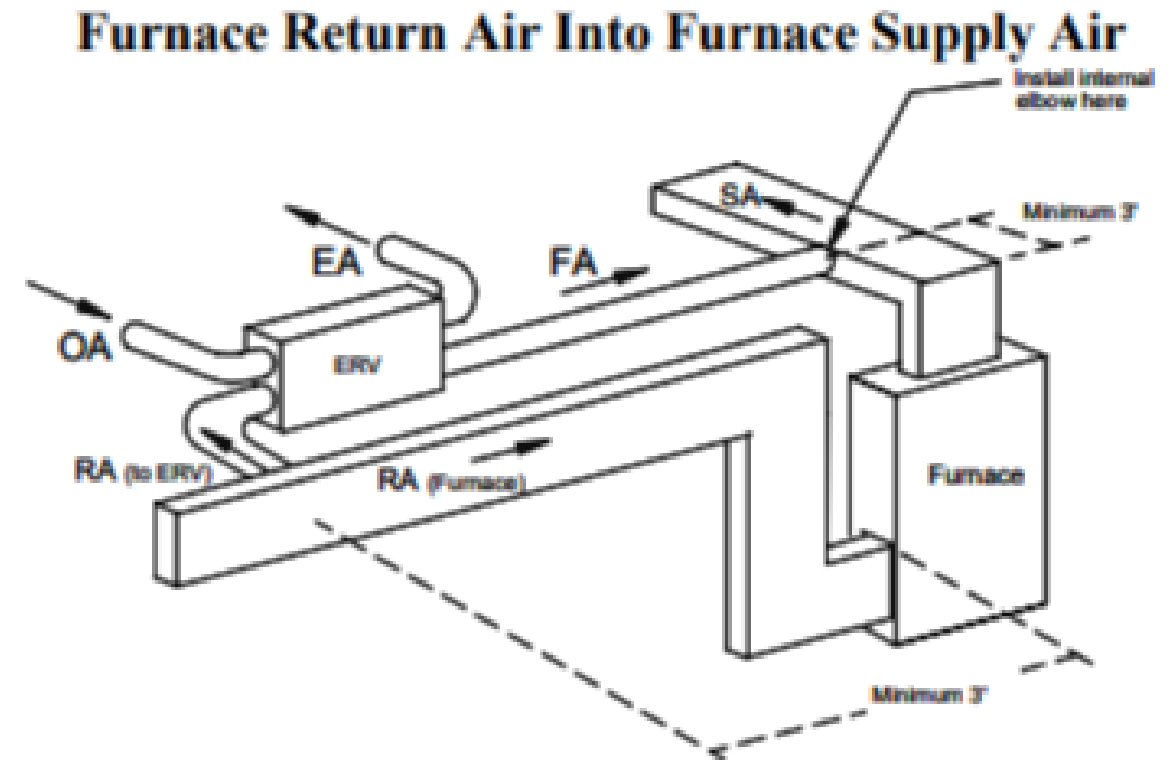


Note: ERV Blower may be operated separate from Furnace Blower

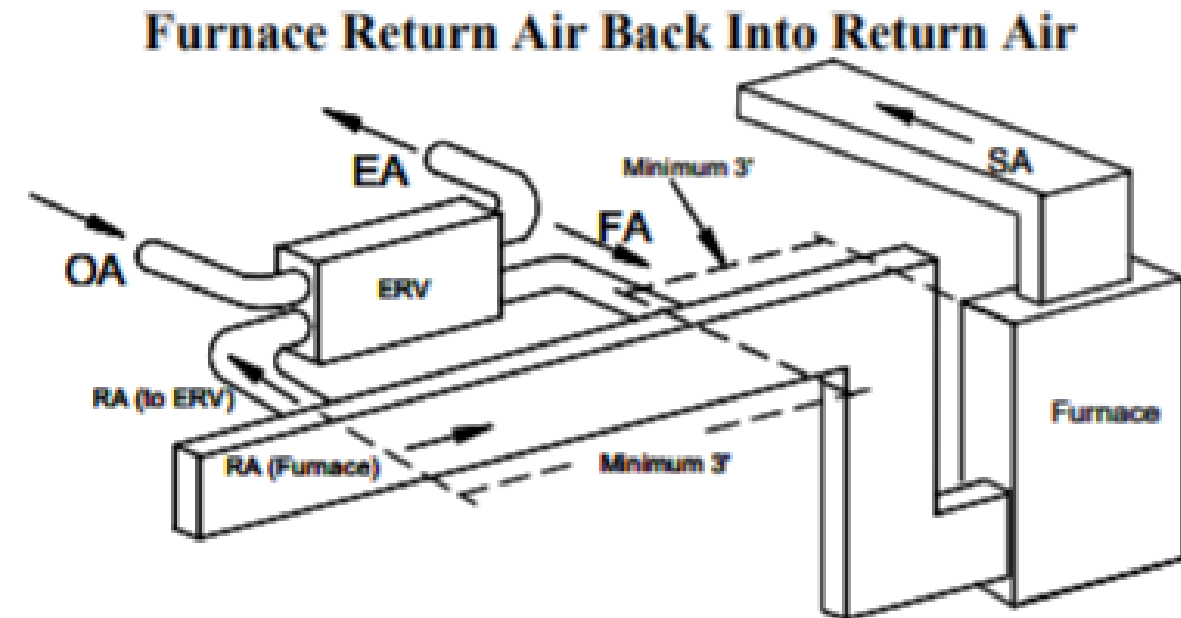
Method 2: "Supply" |
Fresh air leaving H/ERV
is injected into supply
side of the furnace
ductwork. Return air to
H/ERV is via dedicated
ductwork.



Method 3: "Return-supply"
| Fresh air leaving H/ERV is injected into supply side of the furnace ductwork AND exhaust air returning to H/ERV is drawn out from return side of furnace.



Method 4: "Return-return" |
Fresh air leaving H/ERV is injected into return side of the furnace ductwork AND exhaust air returning to H/ERV is drawn out from return side of furnace at a point at least 3' upstream of the fresh air injection.



Note: The Furnace Blower must be operated any time the ERV is operated. Use furnace fan "on" continuous low speed or optional FM control to cycle furnace fan on with ERV

Section R304 – Additional Mechanical Requirements

R304.10 Clothes dryer exhaust. Clothes dryers shall be exhausted in accordance with the manufacturer's instructions. Dryer exhaust systems shall be independent of all other systems and shall convey the moisture and any products of combustion to the outside of the building.

- Exception: This section shall not apply to listed and labeled condensing (ductless) clothes dryers

R304.11 Makeup air required. Exhaust hood systems capable of exhausting in excess of 400 cubic feet per minute shall be provided with makeup air at a rate approximately equal to the exhaust air rate. Such makeup air systems shall be equipped with a means of closure and shall be automatically controlled to start and operate simultaneously with the exhaust system.

Section 402.4.2 – Fireplaces

New wood-burning fireplaces shall have tight-fitting doors and outdoor combustion air. Where using tight-fitting doors on factory-built fireplaces *listed* and *labeled* in accordance with UL 127, the doors shall be tested and *listed* for the fireplace. Where using tight-fitting doors on masonry fireplaces, the doors shall be listed and labeled in accordance with UL 907.

Full detail on requirements for solid-fuel (wood/pellet) burning appliances and fireplaces can be found in **Section R305.4 / Subsections R305.4.1 – R305.4.3.7**

Heating and Cooling Duct System Requirements



Duct System Requirements per RBES

Sections R403.3 - R403.3.7

R403.3 Ducts. Ducts and air handlers for space conditioning shall be in accordance with Sections R403.3.1 through R403.3.5.

R403.3.1 Insulation (Prescriptive). All supply and return ducts shall be insulated to meet the same *R*-value requirement that applies to immediately proximal surfaces.

Exception: Ducts or portions thereof located completely inside the *building thermal envelope*.

R403.3.2 Sealing (Mandatory). Ducts, air handlers and filter boxes shall be sealed. Joints and seams shall comply with either the *International Mechanical Code* or *International Residential Code*, as applicable.

R403.3.2.1 Sealed air handler. Air handlers shall have a manufacturer's designation for an air leakage of no more than 2 percent of the design air flow rate when tested in accordance with ASHRAE 193.

Duct Testing Requirements

R403.3.3 Duct testing. Ducts shall be pressure tested to determine air leakage by one of the following methods:

Rough-in test: Total leakage shall be measured with a pressure differential of 0.1 inch w.g. (25 Pa) across the system, including the manufacturer's air handler enclosure if installed at the time of the test. All registers shall be taped or otherwise sealed during the test.

Rough-in test: The total leakage shall be less than or equal to 3 cubic feet per minute (85 L/min) per 100 square feet (9.29 m²) of conditioned floor area.

Postconstruction test: Total leakage shall be measured with a pressure differential of 0.1 inch w.g. (25 Pa) across the entire system, including the manufacturer's air handler enclosure. Registers shall be taped or otherwise sealed during the test.

Postconstruction test: Total leakage shall be less than or equal to 4 cubic feet per minute (113.3 L/min) per 100 square feet (9.29 m²) of conditioned floor area.

Exceptions:

- A structure where the ducts and air handlers are located entirely within the *building thermal envelope*.
- Ducts serving heat or energy recovery ventilators that are not integrated with ducts serving heating or cooling systems.

If you keep your ductwork within the thermal envelope and follow duct sealing procedures duct testing is not required

R403.3.5 Building cavities (Mandatory). *Building* framing cavities shall not be used as ducts or plenums.

R403.3.7 Ducts located in conditioned space. For ducts to be considered as inside a *conditioned space*, such ducts shall comply with either of the following:

The duct system shall be located completely within the continuous air barrier and within the building thermal envelope.

The ducts shall be buried within ceiling insulation in accordance with Section R403.3.6 and all of the following conditions shall exist:

- The air handler is located completely within the *continuous air barrier* and within the building thermal envelope.
- The ceiling insulation *R*-value installed against and above the insulated duct is greater than or equal to the proposed ceiling insulation *R*-value, less the *R*-value of the insulation on the duct.

If ducts will be outside of the thermal envelope they need to be sealed and insulated

R403.3.6 Ducts buried within ceiling insulation. Where supply and return air ducts are partially or completely buried in ceiling insulation, such ducts shall comply with all of the following:

- The supply and return ducts shall have an insulation R -value not less than R-8.
- At all points along each duct, the sum of the ceiling insulation R -value against and above the top of the duct, and against and below the bottom of the duct, shall be not less than R-40, excluding the R -value of the duct insulation.

Some Best Practice Principals for Duct Design

- **Go for predictability.** A straight run of hard pipe is more predictable than a straight run of flex. A straight run of flex pulled tight is more predictable than the typical flex installation. Turning air with fittings is more predictable than turning air with flex.
- **Know your limits.** The blower you choose limits the static pressure you have to work with. The components you add and the duct system you design must work with that limit. If you overspend on a restrictive duct system, you won't get the amount of air flow you need.
- **A good duct system needs more space than you might imagine.** Especially near the air handler, ducts generally need to be bigger and have longer runs than they're usually designed for.
- **Place the air handler in the center of the house if possible.** Running trunk lines away from the air handler in two directions makes it easier to get good air flow because of fewer downstream branches than a single trunkline.
- **Design to minimize equivalent length but build in some cushion.**
- Make sure your design will work even if the installers make a few substitutions or mistakes.

No one likes spiders in their attic.





Ducted Distribution Systems

-Heat Pump Equipment options



Centrally Ducted Heat Pump

Whole House system

Mitsubishi multi-position air handler with outdoor unit PUZ/PVA 36KBtu

Vertical or horizontal installation

Higher static pressure capability – can work with “standard” ducts

ECM motor

NEEP cold climate air source heat pump





Compact Ducted AKA “ducted mini split”

Minimal ducting, low static pressure systems

Good for adjacent rooms

Slightly lower performance vs mini split

Connect to HRV? Yes or no?

Can create individual zones within a home

Great turn-down ratios compared to multi-zone condenser units

Compact Ducted Mini Split



Indoor Unit: SEZ-KD18NA



Remote Controller: PAR-21MAA



Outdoor Unit: SUZ-KA18NA

Indoor Unit

MCA	1 A
Fan Type x Quantity	Sirocco Fan x 4
Fan Motor Type	Direct-driven DC Brushless Motor
Fan Motor Output	96 W
Fan Motor	0.74 F.L.A.
Airflow (Lo - Med - Hi)	423 - 529 - 635 Dry CFM 381 - 476 - 572 Wet CFM
Air Filter	Polypropylene Honeycomb
External Static Pressure	0.02 - 0.06 - 0.14 - 0.20" WG
Sound Pressure Level (Lo - Med - Hi)	30 - 34 - 38 dB(A)



Static pressure in a duct system

Manuf. sells you the heating appliance, but they don't sell you the distribution system.
Manuf. is not responsible for the design of the distribution system.

Engineer has to design the system, and the HVAC contractor has to install the system according to the mechanical engineer's specifications.

You can see why ductless mini splits are so popular, can't you?

Static pressure in a duct system

Ducts may need to be larger than you'd think.


Duct runs must be short, with minimal fittings.

ACCA Manual D is a good place to start.

Compact ducted systems range in allowable static pressure from 0.2"-0.6" wg

As a rule of thumb, it's not a good idea to use rules of thumb for HVAC design. -John Semmelhack

Static Pressure Calculator

 Total Environmental Conditioning Solutions™		STATIC PRESSURE CALCULATOR		10793 St. Rt. 37 West Sunbury, Ohio 43074 Phone: 740.965.2974 Toll Free: 877.427.9247 Fax: 740.965.5470 Email: bryair1@bry-air.com www.bry-air.com	
TO FIND DUCT DIAMETER AND FRICTION LOSS		TO FIND DUCT DIAMETER AND DUCT VELOCITY		TO FIND DUCT VELOCITY AND FRICTION LOSS	
Enter Velocity, Air Flow & Length		Enter Friction Loss, Airflow & Length		Enter Friction Loss, Airflow & Length	
Duct Velocity (FPM)	<input type="text" value="230"/>	Available Pressure - (Inches W.C.)	<input type="text" value="0.36"/>	Duct Diameter Round (inches)	<input type="text" value="12"/>
Duct Airflow (CFM)	<input type="text" value="383"/>	Duct Airflow (CFM)	<input type="text" value="383"/>	Duct Airflow (CFM)	<input type="text" value="383"/>
Duct Length (Feet)	<input type="text" value="30"/>	Duct Length (Feet)	<input type="text" value="30"/>	Duct Length (Feet)	<input type="text" value="20"/>
Enter Number of Bends		Enter Number of Bends		Enter Number of Bends	
45° Bends (QTY)	<input type="text" value="2"/>	45° Bends (QTY)	<input type="text" value="2"/>	45° Bends (QTY)	<input type="text" value="2"/>
90° Bends (QTY)	<input type="text" value="6"/>	90° Bends (QTY)	<input type="text" value="6"/>	90° Bends (QTY)	<input type="text" value="6"/>
180° Offset (QTY)	<input type="text" value="0"/>	180° Offset (QTY)	<input type="text" value="0"/>	180° Offset (QTY)	<input type="text" value="0"/>
Results		Results		Results	
Duct Diameter (in)	<input type="text" value="17.5"/>	Duct Diameter (in)	<input type="text" value="7.6"/>	Duct Velocity (FPM)	<input type="text" value="488"/>
Friction Loss - (Inches W.C.)	<input type="text" value="0.00"/>	Duct Velocity (FPM)	<input type="text" value="1,216"/>	Friction Loss - (Inches W.C.)	<input type="text" value="0.03"/>

Compact Ducted Mini Split

Performance Specs

Heating / Cooling	Outdoor Dry Bulb	Indoor Dry Bulb	Unit	Min	Rated	Max
Heating	5°F	70°F	Btu/h	12,500	-	25,000
			kW	1.6	-	3.82
			COP	2.29	-	1.92
Heating	17°F	70°F	Btu/h	13,100	14,000	25,000
			kW	1.5	1.62	3.56
			COP	2.56	2.53	2.06
Heating	47°F	70°F	Btu/h	11,400	25,000	25,000
			kW	0.93	1.72	1.72
			COP	3.59	4.25	4.25
Cooling	82°F	80°F	Btu/h	15,060	-	23,600
			kW	0.68	-	3.77
			COP	6.49	-	1.84
Cooling	95°F	80°F	Btu/h	12,600	22,000	23,600
			kW	0.53	1.63	3.77
			COP	6.97	3.96	1.84

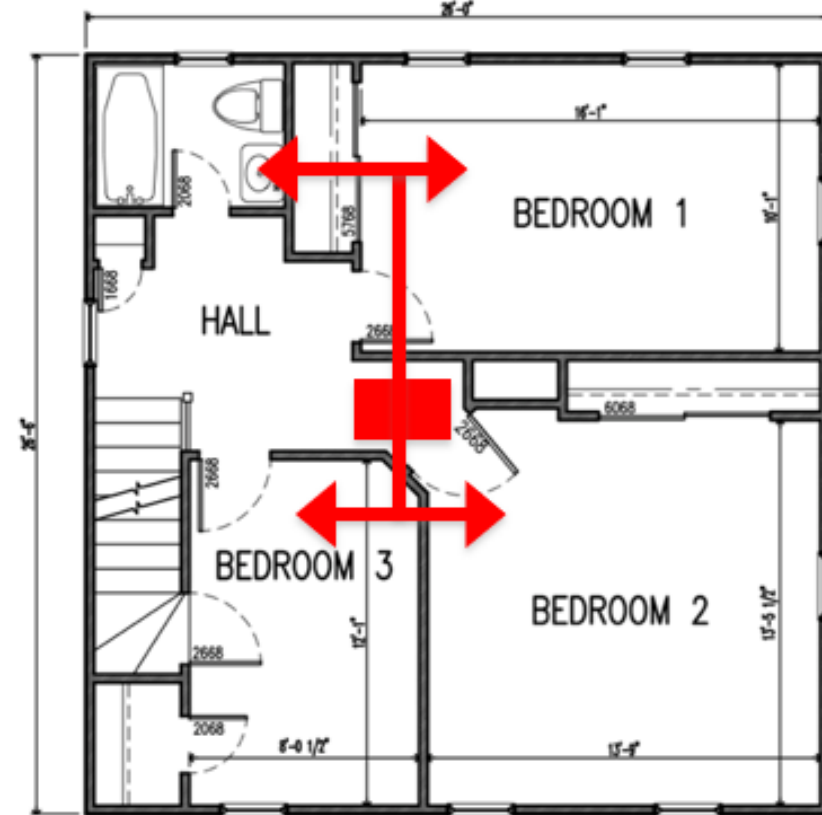
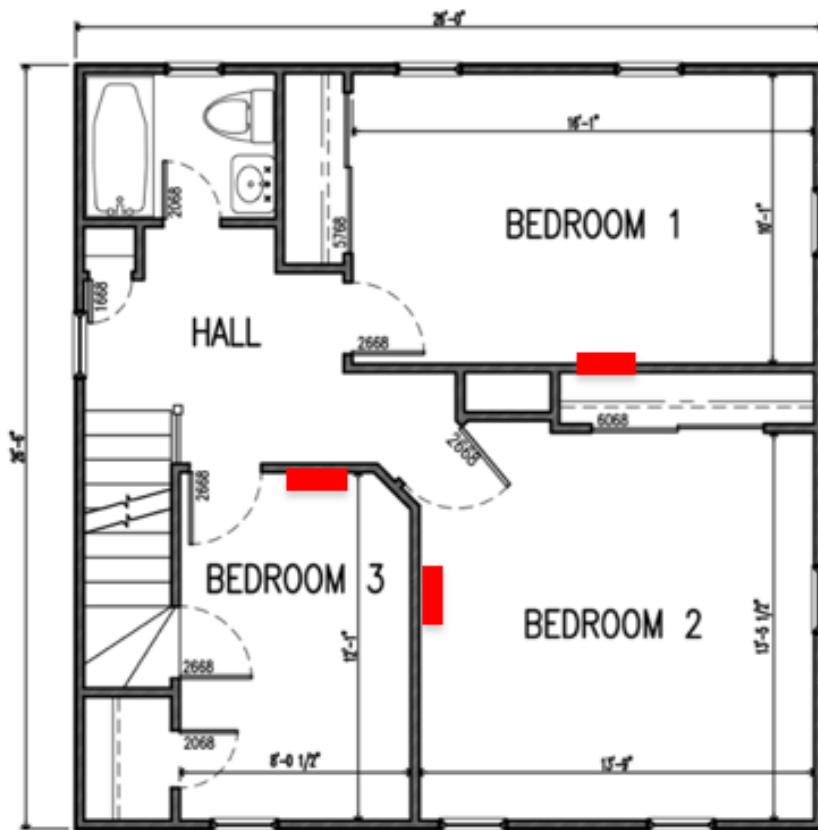
MXZ-3C24NAHZ2
Multi Zone Ductless

Performance Specs

Heating / Cooling	Outdoor Dry Bulb	Indoor Dry Bulb	Unit	Min	Rated	Max
Heating	5°F	70°F	Btu/h	3,800	-	12,000
			kW	0.25	-	1.22
			COP	4.46	-	2.88
Heating	17°F	70°F	Btu/h	4,900	13,900	13,900
			kW	0.31	1.42	1.42
			COP	4.63	2.87	2.87
Heating	47°F	70°F	Btu/h	8,100	21,600	25,600
			kW	0.43	1.58	2.12
			COP	5.52	4.01	3.54
Cooling	82°F	80°F	Btu/h	6,700	-	18,900
			kW	0.25	-	1.1
			COP	7.85	-	5.04
Cooling	95°F	80°F	Btu/h	6,100	18,000	18,000
			kW	0.32	1.31	1.31
			COP	5.59	4.03	4.03

SUZ-KA18NA2 / SEZ-KD18NA
Compact Duct

Compact Ducted vs Multi Split



Images courtesy of Mike Duclos, DEAP Energy Group



Compact ducted Bottom Line

Better option than
multi-split

Use a ducted single
zone to match load
to capacity

Careful, creative duct
layout keeps ducts
short: essential with
compact ducted

Provide access to air
handler and filter

DO NOT OVERSIZE
(more info on this
later in the program)

Hydronic Distribution Systems



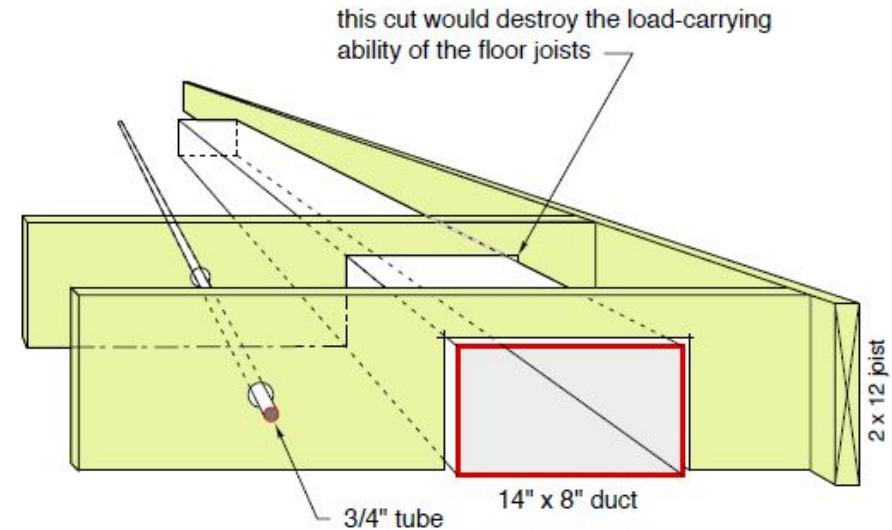


Future-proofing with low-temp hydronic design

- **Almost any heating device/source can be used for hydronic distribution:**
 - Air-source heat pump
 - Ground-source heat pump
 - Condensing gas boiler
 - Biomass
 - District heating
- **Distribution efficiency is superior in comparison to forced-air heating/cooling systems**
 - More btu output for volume, and less embodied distribution energy (fans/motors)
- **Properly designed and installed hydronic distribution systems can last for many decades and outlast by many iterations the primary heat source**
 - Only underscores the importance of low temperature distribution design, no matter the heat source being installed now

Water is vastly superior to air for conveying heat

Material	Specific heat (Btu/lb/°F)	Density* (lb/ft³)	Heat capacity (Btu/ft³/°F)
Water	1.00	62.4	62.4
Concrete	0.21	140	29.4
Steel	0.12	489	58.7
Wood (fir)	0.65	27	17.6
Ice	0.49	57.5	28.2
Air	0.24	0.074	0.018
Gypsum	0.26	78	20.3
Sand	0.1	94.6	9.5
Alcohol	0.68	49.3	33.5



$$\frac{62.4}{0.018} = 3467 \approx 3500$$

A given volume of water can absorb almost 3500 times as much heat as the same volume of air, when both undergo the same temperature change

A brief look @ distribution efficiency/energy-use

*with thanks to John Sigenthaler for this breakdown

Defining DISTRIBUTION EFFICIENCY

$$\text{Efficiency} = \frac{\text{desired OUTPUT quantity}}{\text{necessary INPUT quantity}}$$

Distribution efficiency for a space heating system.

$$\text{distribution efficiency} = \frac{\text{rate of heat delivery}}{\text{rate of energy use by distribution equipment}}$$

Consider a system that delivers 120,000 Btu/hr at design load conditions using four circulators, (with PSC motors) operating at 80 watts each. The distribution efficiency of that system is:

$$\text{distribution efficiency} = \frac{120,000 \text{ Btu/hr}}{320 \text{ watts}} = 375 \frac{\text{Btu/hr}}{\text{watt}}$$



Taco 007



Grundfos
UPS15-58



Bell & Gossett
NFR-22

Forced-air vs. Hydronic Pumping Energy

So is a distribution efficiency of 375 Btu/hr/watt good or bad?

To answer this you need something to compare it to.

Compare this to a 4-ton rated **geothermal water-to-air heat pump** delivering 48,000 Btu/hr (using a 1 HP/ ECM blower) operating on published 746 watts. The distribution efficiency of this delivery system is:

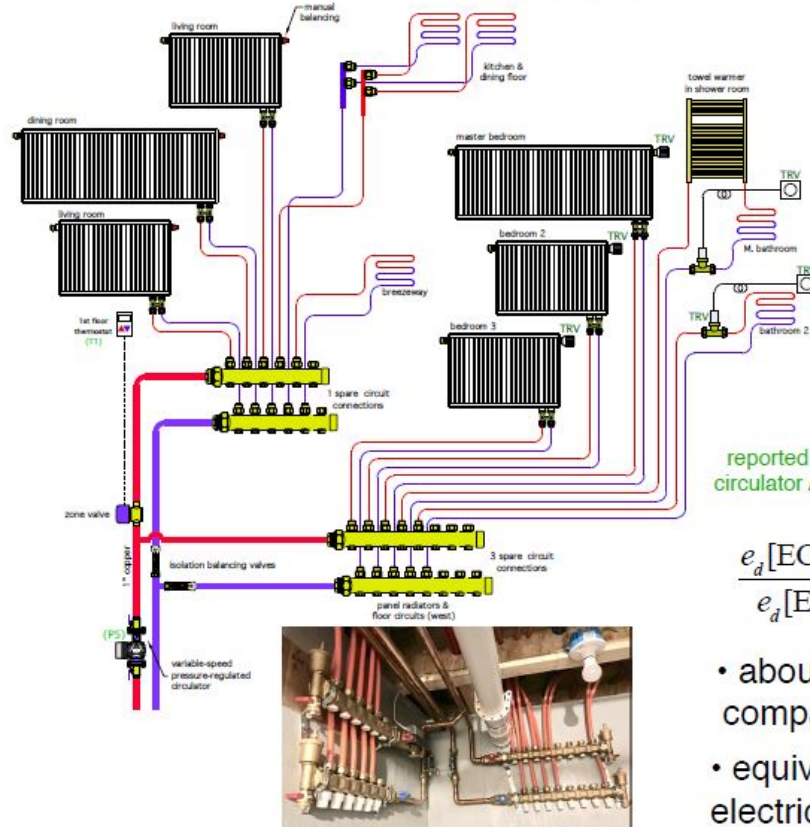
$$n_d = \frac{Q}{w_e} = \frac{48,000 \text{ Btu} / \text{hr}}{746 \text{ watt}} = 64.3 \frac{\text{Btu} / \text{hr}}{\text{watt}}$$

The previous hydronic system (w/ PSC circulators) had a distribution efficiency 5.8 times higher than the forced air system (w/ ECM blower).

Water is vastly superior to air as a conveyor belt for heat.

11 zones of heating with one circulator consuming 27 watts = 1,604 btu/hr/watt

A single variable speed high efficiency circulator supplies this distribution system @ design load with a power draw of about 27 watts.



4.3 gpm @ 20°F ΔT = 43,000 Btu/hr

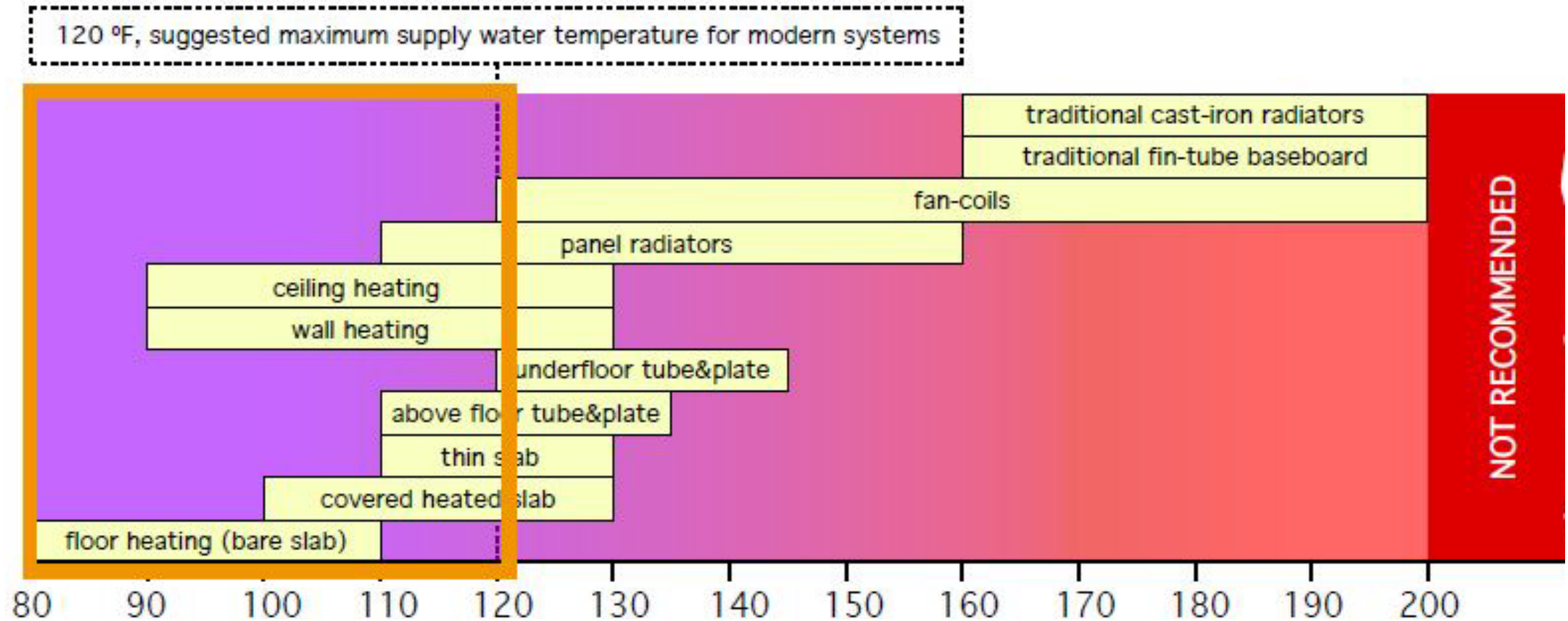
reported by circulator APP

$$\text{distribution efficiency} = \frac{43,000 \frac{\text{Btu}}{\text{hr}}}{26.8 \text{ watt}} = 1,604 \frac{\text{Btu / hr}}{\text{watt}}$$

$$\frac{e_d[\text{ECM circulator}]}{e_d[\text{ECM blower}]} = \frac{1604}{64.3} = 24.95$$

- about 25 times more heat delivery per watt compared to the previous forced air system
- equivalent heat delivery (Btu/hr/watt) using about 4% of the electrical power input of the previous forced air system.

What do we mean when we say “low-temp” distribution?



Equipment Sizing

Performance Tables **ATW-65-HACW-P-1T** *R410a, 60 Hz, ZPS51K5E-PFV*

OUTDOOR			ELECTRICAL		INDOOR						
Outdoor Air Temperature	Evaporating Temperature	Heat Absorbed (Btu/hr)	Compressor Current (A)	Input Power (W)	ELT	Condensing Temperature	Liquid Flow (gpm)	LLT	Delta T	Heating (Btu/hr)	COP _H
-5°F	-16°F	7,600	20.7	4730	102°F	110°F			3°F	23,400	1.45
5°F	-8°F	13,600	19.3	4410	101°F	109°F			4°F	28,300	1.88
15°F	1°F	19,200	17.8	4100	100°F	109°F			5°F	32,900	2.35
25°F	9°F	24,900	17.1	3950	100°F	109°F			5°F	37,900	2.81

Performance Tables **ATW-55-HACW-P-1T** *R410a, 60 Hz, ZPS40K5E-PFV*

OUTDOOR			ELECTRICAL		INDOOR						
Outdoor Air Temperature	Evaporating Temperature	Heat Absorbed (Btu/hr)	Compressor Current (A)	Input Power (W)	ELT	Condensing Temperature	Liquid Flow (gpm)	LLT	Delta T	Heating (Btu/hr)	COP _H
-5°F	-16°F	6,810	16.7	3870	102°F	110°F			3°F	19,800	1.50
5°F	-8°F	11,800	15.7	3670	101°F	109°F			4°F	24,100	1.93
15°F	1°F	16,200	14.8	3470	100°F	109°F			5°F	27,800	2.35
25°F	9°F	21,400	14.0	3290	100°F	109°F			5°F	32,400	2.89

Hydronic Distribution and equipment



Site-built radiant floors, walls, or ceilings

- Consistent low temperature heat
- Lag time in recovery or cooling with changes in occupant settings



Photo credits: John Siegenthaler



Low temperature / high output baseboard

Looks like normal baseboard but works with lower water temperatures

Examples:

- [Mestek Synergy](#)
- [Smith HE2 Heating Edge](#)
- [Smith HE3 Silent Fin](#)



Image: <http://www.mesteksa.com/fileuploads/Literature/DesignLine/DL-SG-3.pdf>

Panel Radiators

- Common worldwide
- Many manufacturers
- Room-by-room control
- No power needed
- Large surface area



Image: <https://www.bosch-thermotechnology.us/us/en/ocs/residential/buderus-panel-radiators-1098983-p/>

Fan coil units

Kinda like a mini-split

- Fan moves air across hydronic coil
- Additional fan energy use beyond pumping energy for hot water coil
- Can be controlled room by room



Image:

<http://spacepak.com/ThinWall.html>

Panel radiators + fan assist

Higher output

Needs 24V

Additional fan energy

Can be controlled room by room



Images:

https://runtalnorthamerica.com/pdfs/RuntaL_NEO_Brochure.pdf



Hydronic Designs
do not need to be
complex to work
well. In fact the less
complex the better
the performance
(and maintenance..)

Efficiency
Vermont

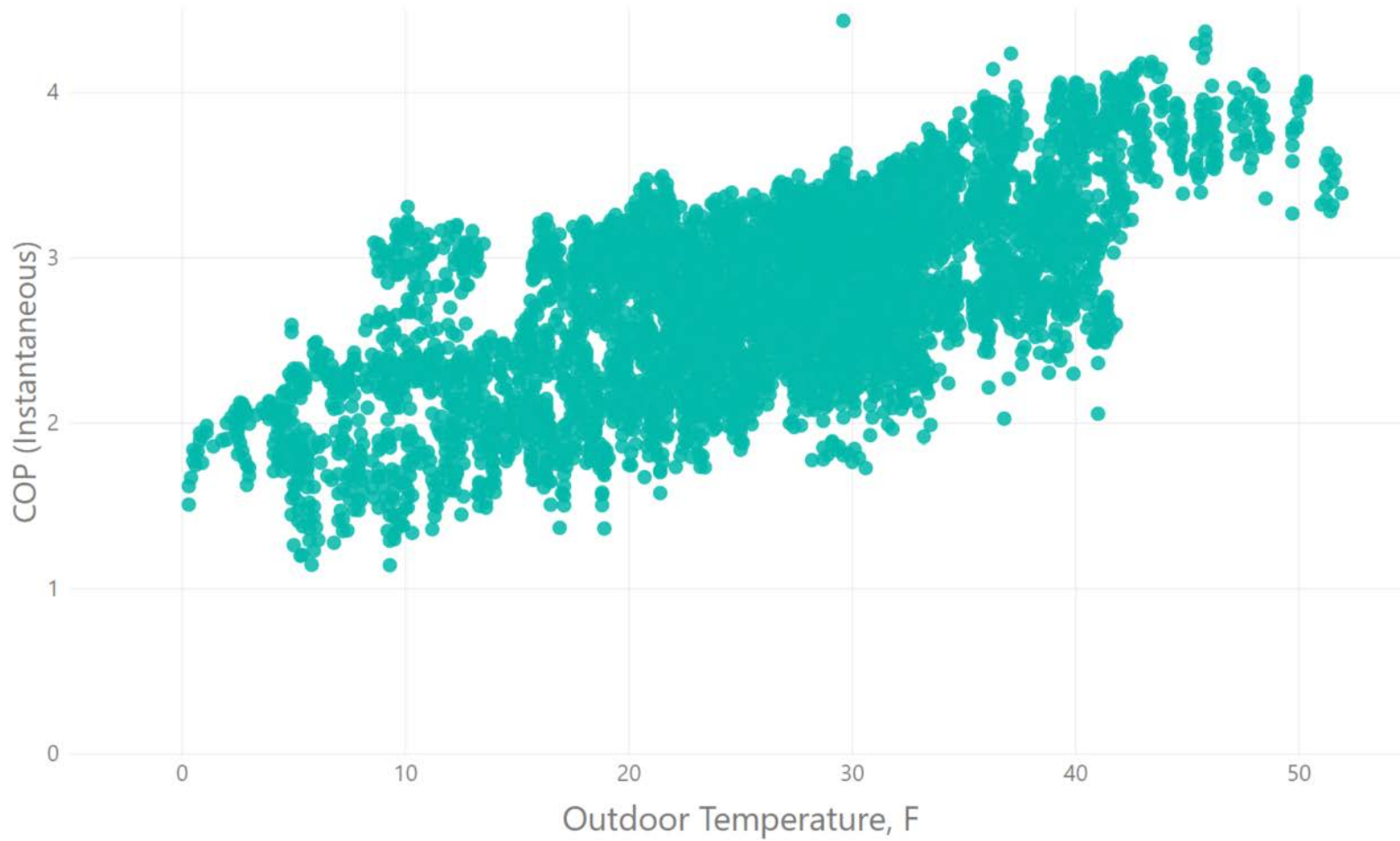


Simple

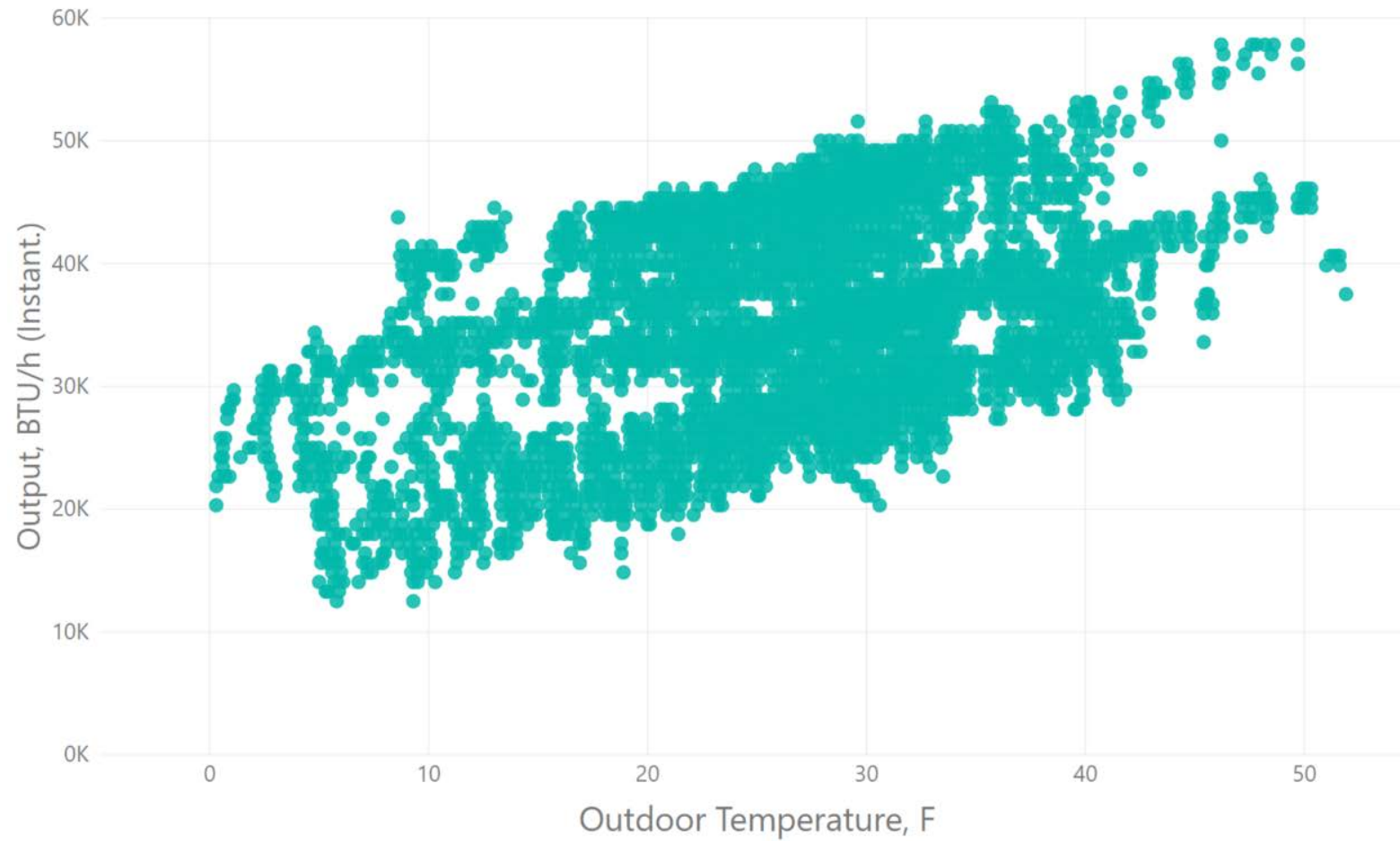


*images B.Just

COP, instant. (Nov 2019-Jan 2020)



Output, instant. (Nov 2019-Jan 2020)



Hot Water Pipe Insulation

R403.4 Mechanical system piping insulation (Mandatory). Mechanical system piping designed to carry fluids above 105°F (41°C) or below 55°F (13°C) shall be located within the building thermal envelope and insulated to a minimum of R-3.

R403.4.1 Protection of piping insulation. Piping insulation exposed to weather shall be protected from damage, including that caused by sunlight, moisture, equipment maintenance and wind, and shall provide shielding from solar radiation that can cause degradation of the material. Adhesive tape shall not be permitted.

Domestic Hot Water System Requirements

R403.5.1 Heated water circulation and temperature maintenance systems (Mandatory). Heated water circulation systems shall be in accordance with Section R403.5.1.1. Heat trace temperature maintenance systems shall be in accordance with Section R403.5.1.2. Automatic controls, temperature sensors and pumps shall be *accessible*. Manual controls shall be readily *accessible*.

R403.5.1.1 Circulation systems. Heated water circulation systems shall be provided with a circulation pump. The system return pipe shall be a dedicated return pipe or a cold water supply pipe. Gravity and thermosyphon circulation systems shall be prohibited. Controls for circulating hot water system pumps shall start the pump based on the identification of a demand for hot water within the occupancy. The controls shall automatically turn off the pump when the water in the circulation loop is at the desired temperature and when there is no demand for hot water.

Domestic Hot Water System Requirements Cont.d

R403.5.2 Demand recirculation systems. A water distribution system having one or more recirculation pumps that pump water from a heated water supply pipe back to the heated water source through a cold water supply pipe shall be a *demand recirculation water system*. Pumps shall have controls that comply with both of the following:

The controls shall start the pump upon receiving a signal from the action of a user of a fixture or appliance, sensing the presence of a user of a fixture or sensing the flow of hot or tempered water to a fixture fitting or appliance.

The controls shall limit the temperature of the water entering the cold water piping to 104°F (40°C).

Domestic Hot Water Pipe Insulation

R403.5.3 Hot water pipe insulation (Prescriptive). Insulation for hot water pipe with a minimum thermal resistance, *R*-value, of R-3 shall be applied to the following:

1. Piping $\frac{3}{4}$ inch (19.1 mm) and larger in nominal diameter.
2. Piping serving more than one dwelling unit.
3. Piping located outside the *conditioned space*.
4. Piping from the water heater to a distribution manifold.
5. Piping located under a floor slab.
6. Buried piping.
7. Supply and return piping in recirculation systems other than demand recirculation systems.

Who's got your
back?

Efficiency
Vermont



Questions?

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