2018 IECC Top 10 Commercial HVAC

1.29.2020

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- We are an applied research program at University of Illinois, working in collaboration with 360 Energy Group.

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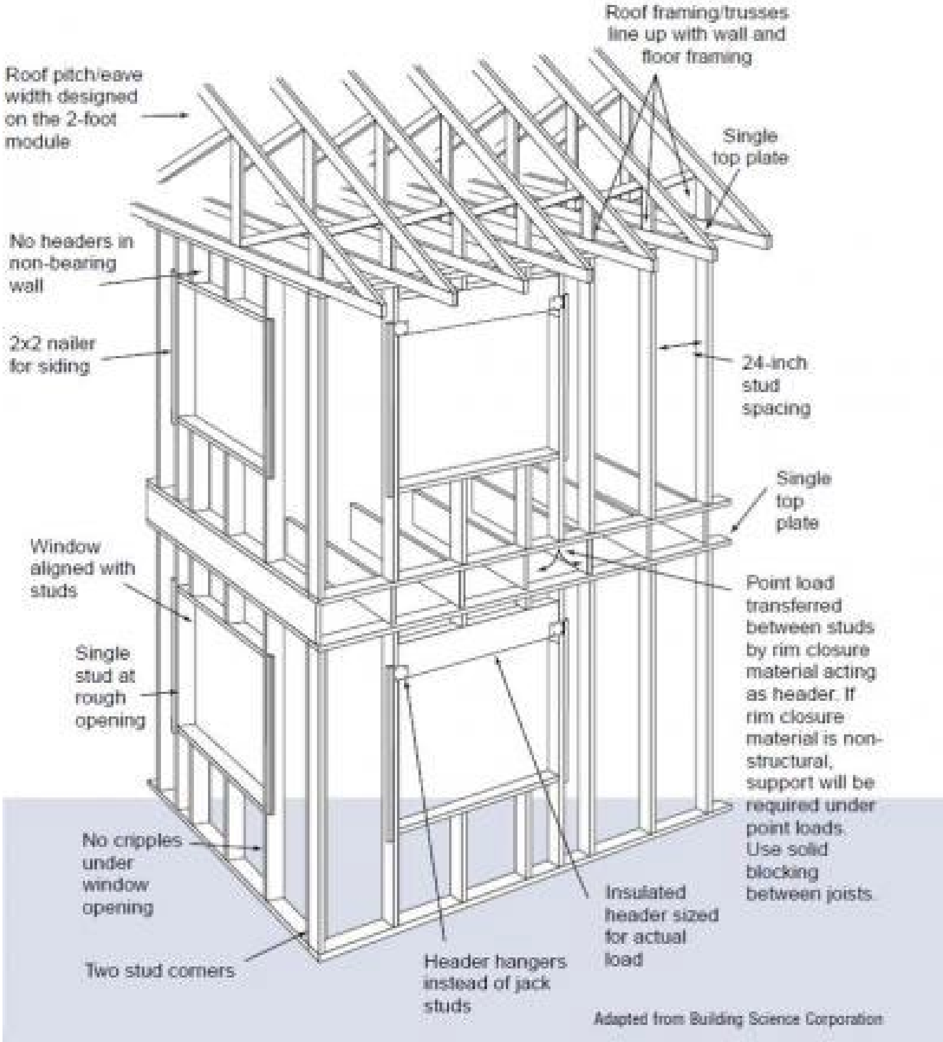
Top 10 Requirements: 2018 IECC Commercial HVAC

1. Missing Energy Recovery [C403.7.4]
2. Oversized Equipment [C403.3.1]
3. Missing Economizer Fault Detection [C403.5.5]
4. Lack of System Commissioning [C408]
5. Non-low leak dampers [C403.7.7]
6. Duct sealing [C403.11.1, C403.11.2]
7. No Demand Control Ventilation [C403.7.1]
8. Insulation not UV protected [C403.11.3.1]
9. Missing Circulation Controls [C404.6.1]
10. Freeze Protection System [C403.12.3]



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1.) C403.7.4 Energy Recovery Ventilation Systems

C403.7.4 Energy Recovery Ventilation systems

Where the supply airflow rate of a fan system exceeds the values specified in Tables C403.7.4(1) and C403.76.4(2), the system shall include an energy recovery system.

Table C403.7.4(1) and (2) CZ 4A and 5A

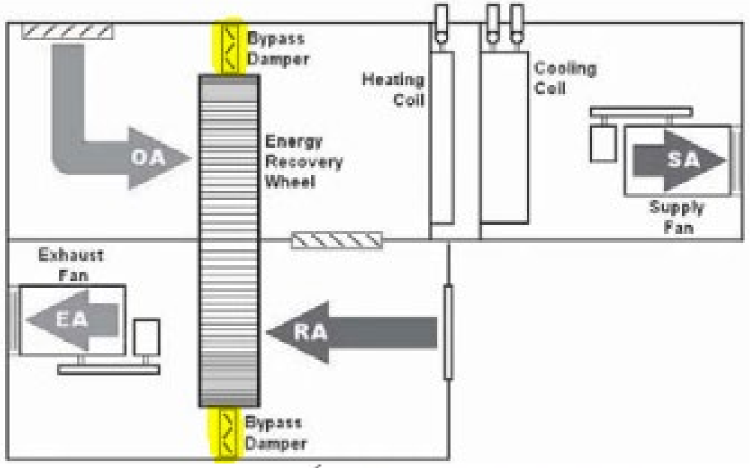
Operation	Percent (%) Outside Air at Full Design Airflow Rate (CZ 4A and 5A)							
	≥10% <20%	≥20% <30%	≥30% <40%	≥40% <50%	≥50% <60%	≥60% <70%	≥70% <80%	≥80%
<8,000 hr/yr	≥26,000	≥16,000	≥5,500	≥4,500	≥3,500	≥2,000	≥1,000	≥120
>8,000 hr/yr	≥200	≥130	≥200	≥200	≥200	≥200	≥200	≥200

Economizer must recover 50% of enthalpy difference between outside and return air streams at design conditions.

Recovery devices need to have bypass or controls to allow economizer operation as per C403.5

- Bypass can be VFD on wheel that stops rotation, or bypass dampers

Annual energy reduction potential of 25%-50%



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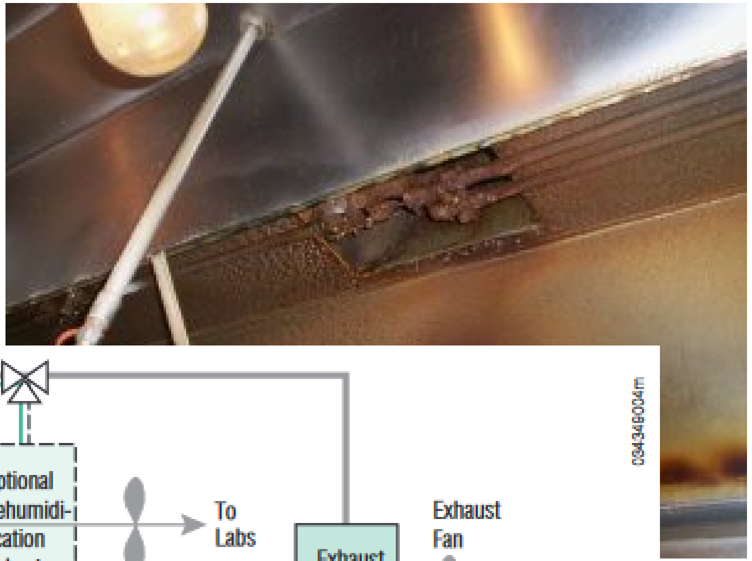
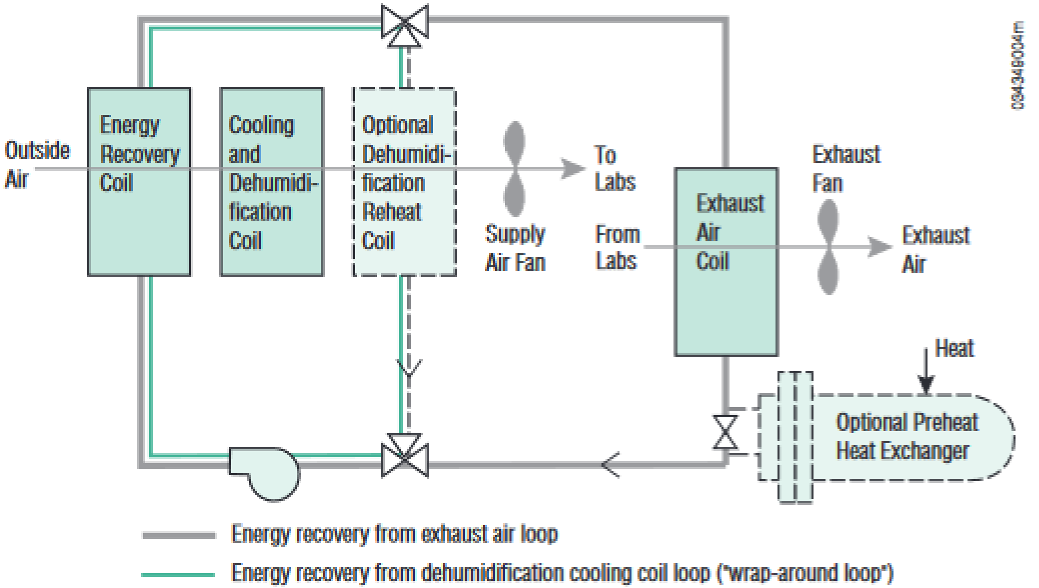
C403.7.4 Energy Recovery Ventilation System

Exceptions to ERV Requirement

- Where prohibited by IMC - primarily only limits energy wheel use, not loops or exchangers (heat-only recovery)
    - IMC restrictions duplicated in exception for hazardous fumes, grease, etc… in IECC
- Laboratory fume hoods with VAV control configured to reduce exhaust and make-up volume by 50%, and/or direct make-up air is supplied within specific conditions
- Semi-conditioned spaces served (no cooling and heating <60 °F
- >60% heating supplied by renewables or site-recovered energy
- Systems requiring dehumidification with energy recovery in series with cooling coil
- Systems operating <20 hrs/wk as OA rate from table C403.7.4(1)
- Where the largest source of air exhausted at a single location at the building exterior is <75% of design outdoor air flow rate.





Exceptions to ERVs don't prevent use of HRVs

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2.) C403.3.1 Equipment Sizing

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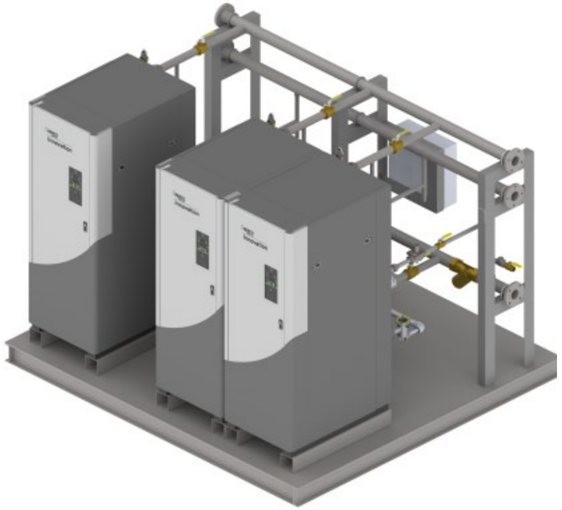
C403.3.1 Equipment Sizing

The output capacity of heating and cooling equipment shall not be greater than that of the smallest available equipment size that exceeds the loads calculated in accordance with Section C403.1.1.

- Code allows for installation of stand-by equipment (N+1)
- Code allows for multiple units exceeding capacity provided controls limit operation based on load.
  - Modular systems are a good example of this compliance method, providing redundancy and built-in staging controls



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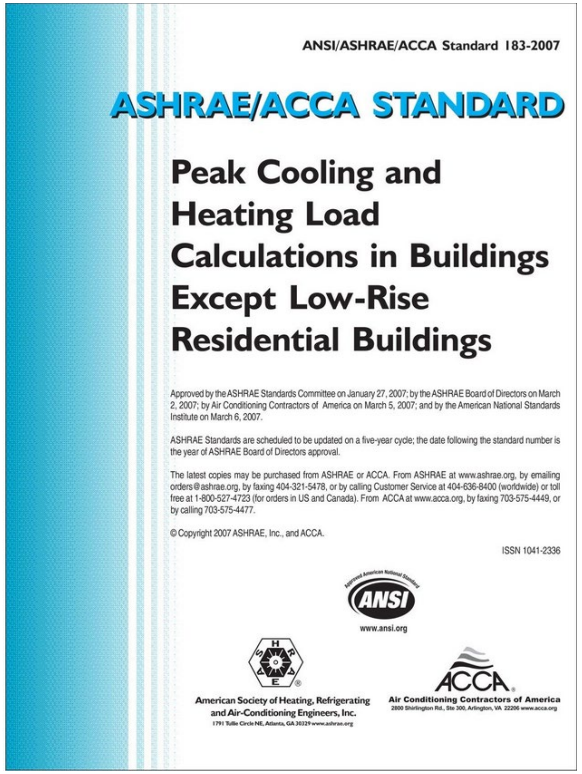
C403.3.1 Equipment Sizing

- Over-sizing issues
  - Unnecessary increased capital costs
  - Continual low part-load can reduce equipment life and efficiency
- Under-sizing issues
  - Unmet loads and comfort issues
- Right-size using load calculation software or sheets
  - ASHRAE/ANSI/ACCA Standard 183
  - eQuest/Energy Plus/Trane Trace/Carrier and others



ANSI/ASHRAE/ACCA Standard 183-2007

ASHRAE/ACCA STANDARD

Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings

Approved by the ASHRAE Standards Committee on January 27, 2007; by the ASHRAE Board of Directors on March 2, 2007; by Air Conditioning Contractors of America on March 5, 2007; and by the American National Standards Institute on March 6, 2007.

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3.) C403.5.5 Economizer Fault Detection and Diagnostics

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C403.5.5 Economizer Fault Detection and Diagnostics

Air-cooled unitary DX units listed in Tables C403.3.2(1) – (3) and VRF units that are equipped with an economizer in accordance with C403.5-C403.5.4 shall include a fault detection and diagnostics system…

- Monitor supply, return, and outside air temperatures
- Provide status on free cooling availability, enable status of economizer, cooling and heating, low-limit cycle for mixed air, and value of each sensor in system
- Report air temperature sensor faults, improper economizing, damper malfunctions, and excess OA flow.
- Previous code text stated systems shall be _capable_ of fault detection, 2018 IECC states shall be _configured_
- Failed economizers can dramatically increase energy consumption for heating/cooling.

Figure 6. California's Title 24 Economizer Dashboard

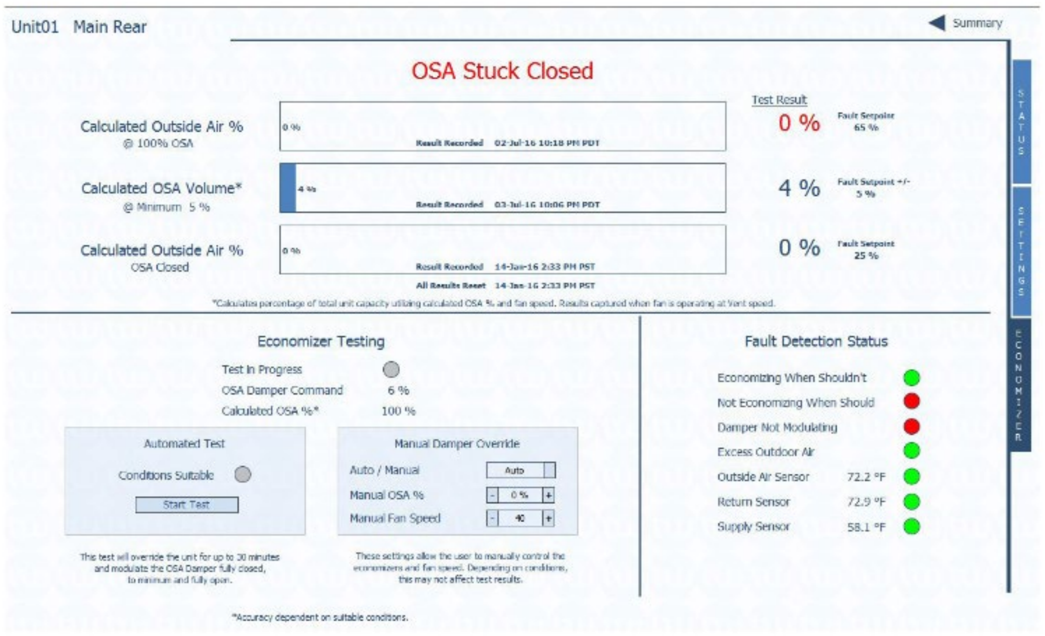

Image source: https://transformativewave.com/docs/default-source/default-document-library/ebook_afdd.pdf?sfvrsn=4

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Example Economizer Issues

Damper Height in. and (mm)	FACE VELOCITY TORQUE Damper Width in. and (mm)				PRESSURE TORQUE Damper Width in. and (mm)				SEALING TORQUE Damper Width in. and (mm)			
	12" (305)	24" (610)	36" (914)	48" (1219)	12" (305)	24" (610)	36" (914)	48" (1219)	12" (305)	24" (610)	36" (914)	48" (1219)
12" (305)	1 (1)	1 (1)	2 (1)	3 (1)	1 (1)	3 (1)	4 (1)	5 (1)	21 (3)	31 (4)	41 (5)	52 (6)
18" (457)	1 (1)	3 (1)	4 (1)	6 (1)	2 (1)	4 (1)	5 (1)	7 (1)	30 (4)	44 (5)	58 (7)	71 (9)
24" (610)	1 (1)	2 (1)	5 (1)	6 (1)	2 (1)	5 (1)	8 (1)	11 (2)	38 (5)	56 (7)	73 (9)	90 (11)
30" (762)	2 (1)	4 (1)	6 (1)	8 (1)	3 (1)	7 (1)	10 (2)	14 (2)	47 (6)	68 (8)	89 (11)	109 (13)
36" (914)	2 (1)	4 (1)	7 (1)	9 (2)	4 (1)	8 (1)	12 (2)	16 (2)	56 (7)	80 (10)	104 (12)	129 (15)
42" (1067)	2 (1)	5 (1)	8 (1)	11 (2)	4 (1)	9 (2)	14 (2)	19 (3)	65 (8)	93 (11)	120 (14)	148 (17)
48" (1219)	3 (1)	6 (1)	9 (2)	13 (2)	5 (1)	10 (2)	16 (2)	22 (3)	74 (9)	105 (12)	136 (16)	167 (19)
54" (1372)	4 (1)	10 (2)	15 (2)	20 (3)	6 (1)	12 (2)	19 (3)	26 (3)	85 (10)	122 (14)	159 (19)	197 (23)
60" (1524)	4 (1)	10 (2)	15 (2)	20 (3)	6 (1)	12 (2)	19 (3)	26 (3)	91 (11)	128 (15)	165 (19)	203 (23)
66" (1676)	5 (1)	11 (2)	17 (2)	23 (3)	6 (1)	14 (2)	22 (3)	29 (4)	101 (12)	143 (17)	185 (21)	226 (26)
72" (1829)	6 (1)	12 (2)	19 (3)	26 (3)	7 (1)	16 (2)	25 (3)	33 (4)	111 (13)	157 (18)	204 (24)	250 (29)

Above values based on 1000 fpm (5 m/s) face velocity. Use multipliers below for other face velocities.

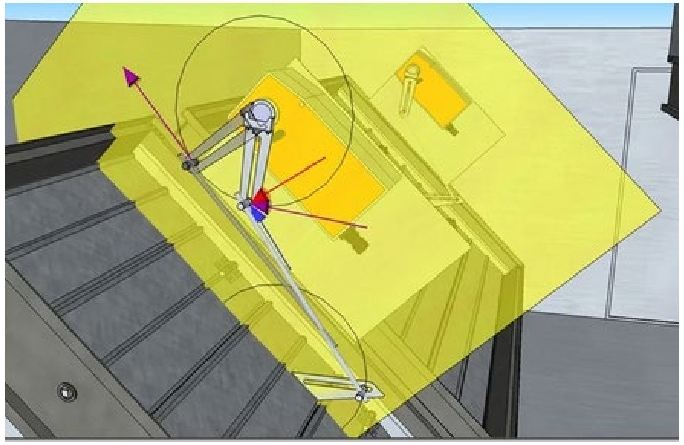
Above values based on differential pressure of 1 in. wg. (250 Pa). Use multipliers below for other differential pressures.

Above values based on the use of dual durometer vinyl seals on the blade and metallic compression seals at the jambs.

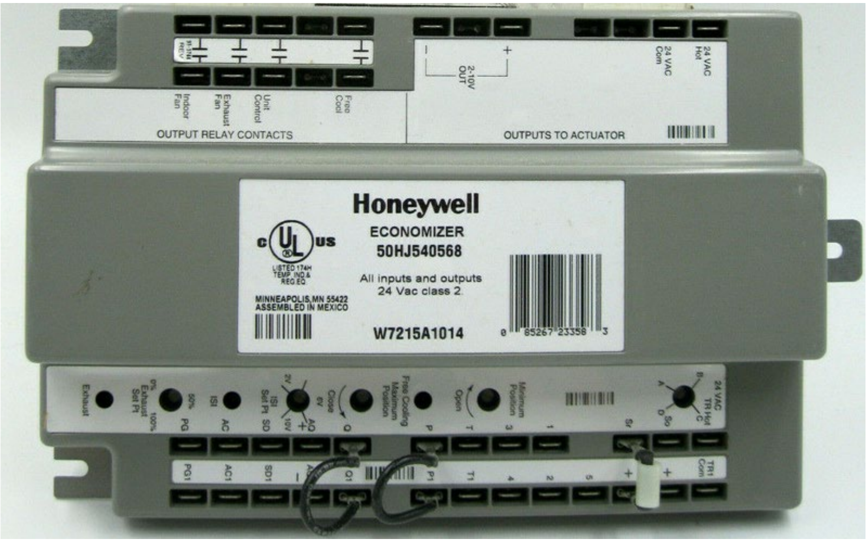
Face Velocity fpm (m/s)	Multiplier	Diff. Pressure in. wg (Pa)	Multiplier
1500 (8)	2.25	1 (250)	1
2000 (10)	4.00	2 (500)	2
2500 (13)	6.25	3 (750)	3
3000 (15)	9.00	4 (1000)	4

See page 6 for multi-panel jackshafting arrangements.

Mesteksa.com



[Economizers–The Physics of Linkage Systems](#)- **David Sellers, Facility Dynamics Engineering**



Common economizer controller for RTUs above.

- Common errors include incorrect settings on this controller, which is hard to read.
- Modern controllers have LCD readouts explaining settings to reduce incorrect setting errors in set-up.

Damper linkages need to be properly set up geometrically to provide proper closure torque and full range of motion for dampers.

- Incorrect geometry can prevent full seal and increase leakage.
- All should be checked during commissioning of the building.

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4.) C408 Maintenance Information and System Commissioning

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C408 Maintenance Information and System Commissioning

- Current code requires much more automation control to increase efficiency
  - Thermostat deadbands
  - Unoccupied setback and optimized start/stop
  - Equipment modulation to match current loads (fan speed/pressure, temperature resets, etc…)
  - Economizer and energy recovery optimization
  - Demand-controlled ventilation
  - And More!

Commissioning often cut from construction budgets as other line-items exceed projected costs, or delays occur.

Often leads to long-term energy costs and occupant complaints

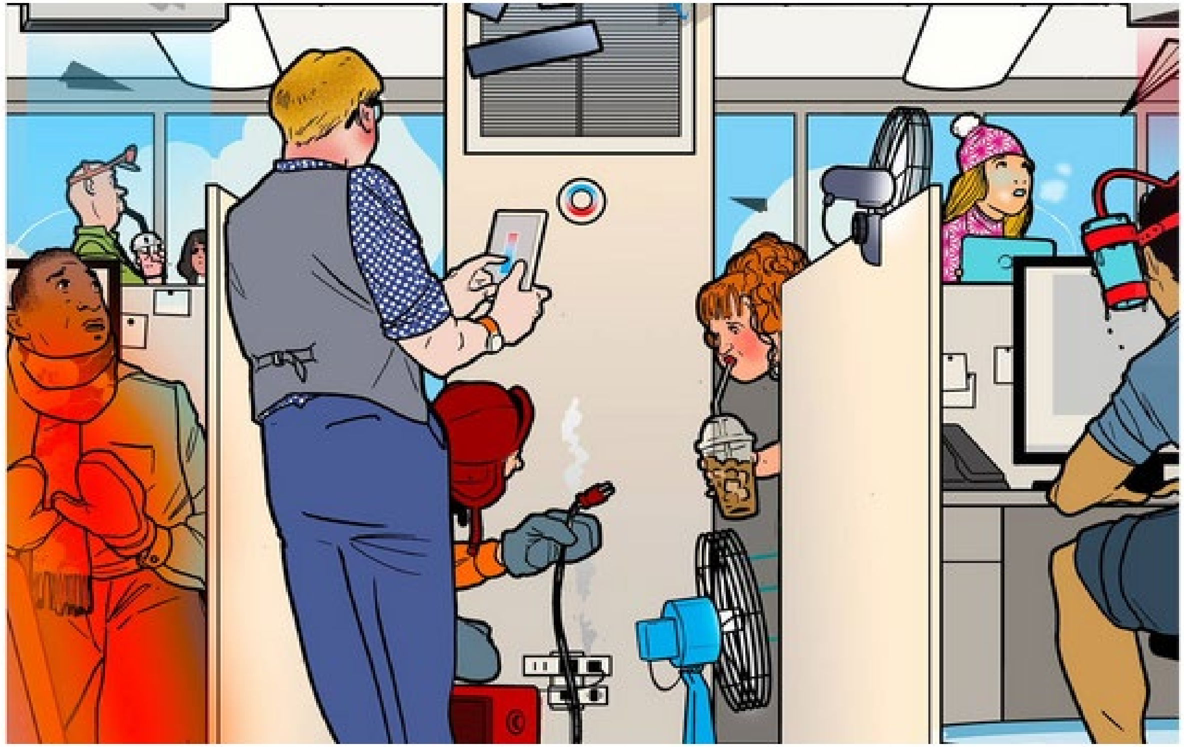

ILLUSTRATION: JASON SCHNEIDER [WSJ - Let the Thermostat Wars Begin]

C408 Maintenance Information and System Commissioning

- LBL report found that commissioning new construction reduced energy $0.18/sf-yr at a cost of $1.16/sf
  - existing buildings saved $0.29/sf-yr on average at a cost of $.30/sf on average.
- Also improves building safety, prolongs service life, reduces comfort complaints from occupants.
- Evidence of commissioning should be submitted before final mech./plumbing inspections

- C408.2.5 – Documentation Requirements. Construction documents (and information for code officials) shall specify commissioning reports are due to building owner within 90 days of certificate of occupancy.

Image courtesy WBDG.org

Examples from field experience:

- HVAC fans turned off on schedule, but back on at midnight instead of morning start-up
- Non-functional economizer/dampers on AHUs

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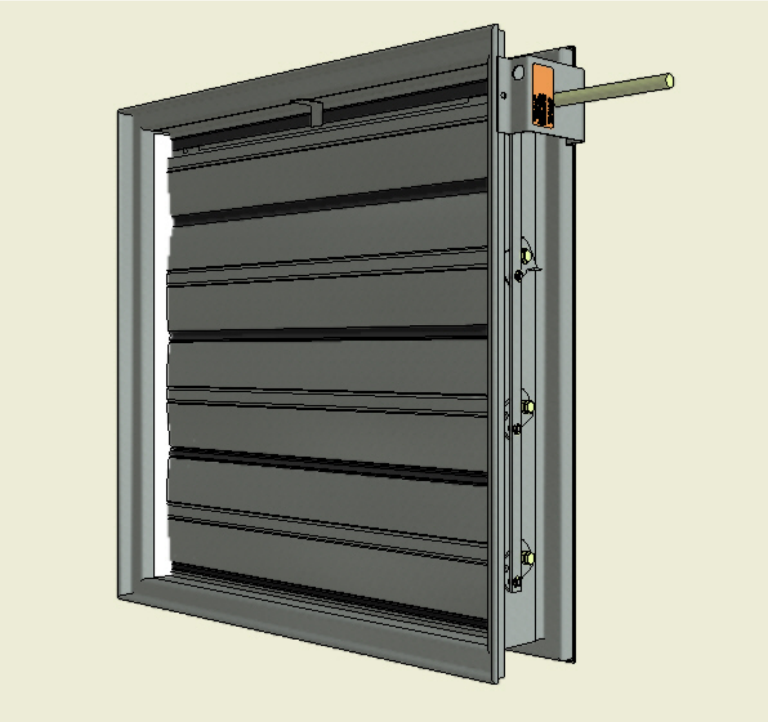
5.) C403.7.7 Shut-off Dampers

C403.7.7 Shut-off Dampers

Outdoor air intake and exhaust openings and stairway and shaft vents shall be provided with Class 1 motorized dampers. The dampers shall have an air leakage rate of not greater than 4cfm/sf of damper surface area at 1” w.g. and shall be labeled by an approved agency when tested in accordance with AMCA 500D for such purpose.

- This section is not referencing fire dampers, but pressurization ventilation dampers.
  - Fire dampers are covered in the fire code.
- Commonly find these dampers are not sealed dampers, and leak more than code requirements.
- Very important for stopping/reducing stack effect in buildings.
- Low-rise buildings can have non-motorized gravity dampers with leakage rates <20cfm/sf if >24” in either dimension or <40 cfm/sf if <24” in either dimension



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6.) C403.11.1 Duct and Plenum Sealing and Insulation

C403.11.1 Duct and Plenum Insulation and Sealing

Supply and return dusts and plenums shall be insulated with not less than R-6 insulation where located in unconditioned spaces and where located outside the building with not less than…R-12 insulation…Ducts, air handlers and filter boxes shall be sealed.

- While testing has forced sealing to be commonplace in residential markets, commercial often is not properly sealed, and rarely tested.
- Particularly bad for unducted returns above ceilings where return depressurizes surrounding space, amplifying supply leakage.
- Duct joints often covered by insulation, left unsealed, or sealant applied over insulation, which leaves an air gap.

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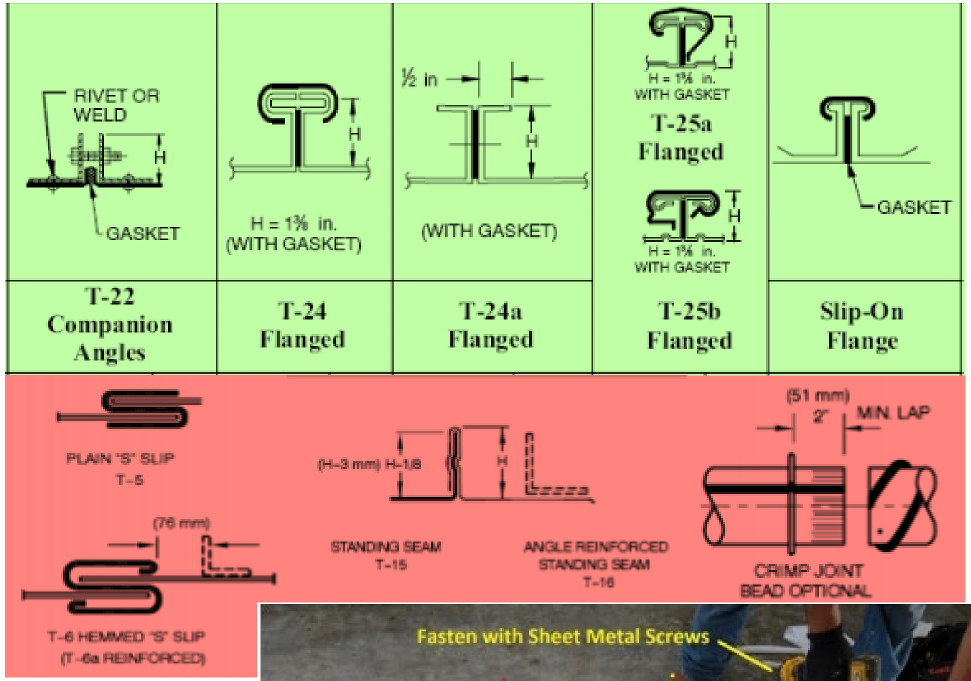
C403.11.1 Duct and Plenum Insulation and Sealing

- Gasketed joints are ideal, but not always used or properly applied.
- Ungasketed joints should be sealed with UL-181 mastic or tape.
- Gasketed joints should be applied to duct surface, not insulation wrap.



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7.) C403.7.1 Demand Control Ventilation

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C403.7.1 Demand Control Ventilation

DCV shall be provided for spaces larger than 500 sf and with an average occupant load of 25 people or greater per 1,000 sf of floor area…and served by systems with (1.) air-side economizer, (2.) automatic modulating control of OA damper, and/or (3.) design OA of >3,000cfm.

- Exceptions:

1. Systems with energy recovery complying with C403.7.4
2. Multiple-zone systems without direct digital control of individual zones communicating with a central control panel
3. Systems with a design outdoor airflow less than 1,200 cfm
4. Spaces where the supply airflow rate minus any makeup or outgoing transfer air requirements is less than 1,200 cfm
5. Ventilation provided only for process loads.

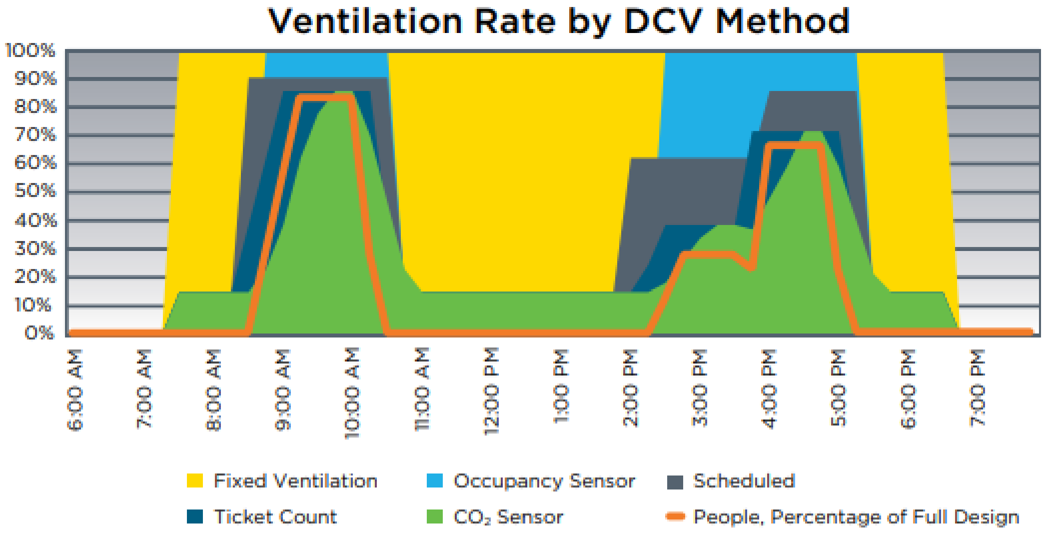


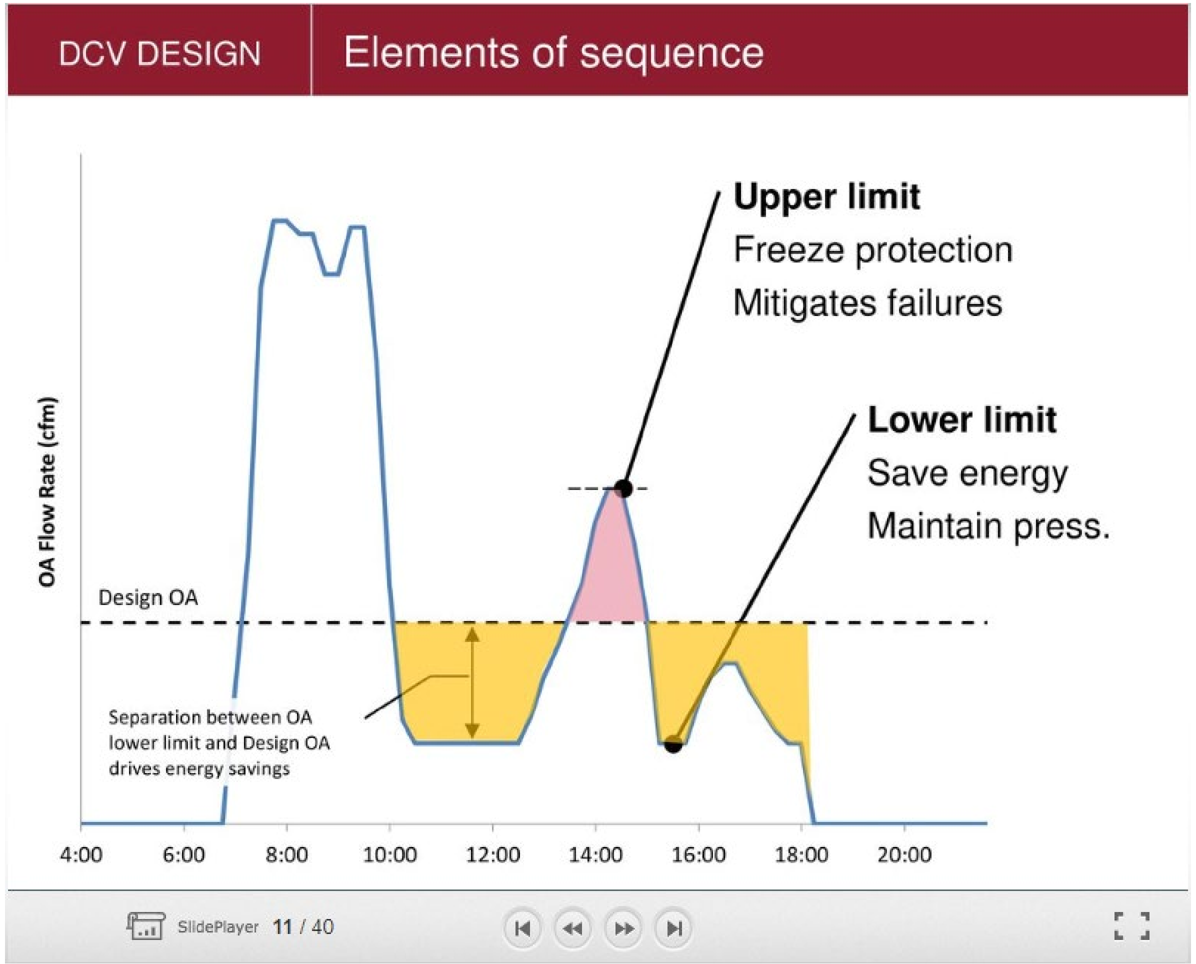
Figure 1. Ventilation rates provided with fixed ventilation and DCV alternatives

Chart courtesy Energycodes.gov: Note that all methods of DCV reduce airflow over a fixed ventilation rate.

C403.7.1 Demand Control Ventilation

Common issues:

- Economizer not set-up to override DCV, resulting in loss of economizing ability
- Confusion on CO_2 sensor setpoints (too low/high) depending on sensor type (differential or total CO_2 setpoint)
- Minimum area ventilation and maximum occupant ventilation limits are not set at the AHUs controls, resulting in incorrect ventilation levels.



DCV presentation MN Energy Expo, Scott Hackel, Senior Energy Engineer

8.) C403.11.3.1 Protection of Piping Insulation

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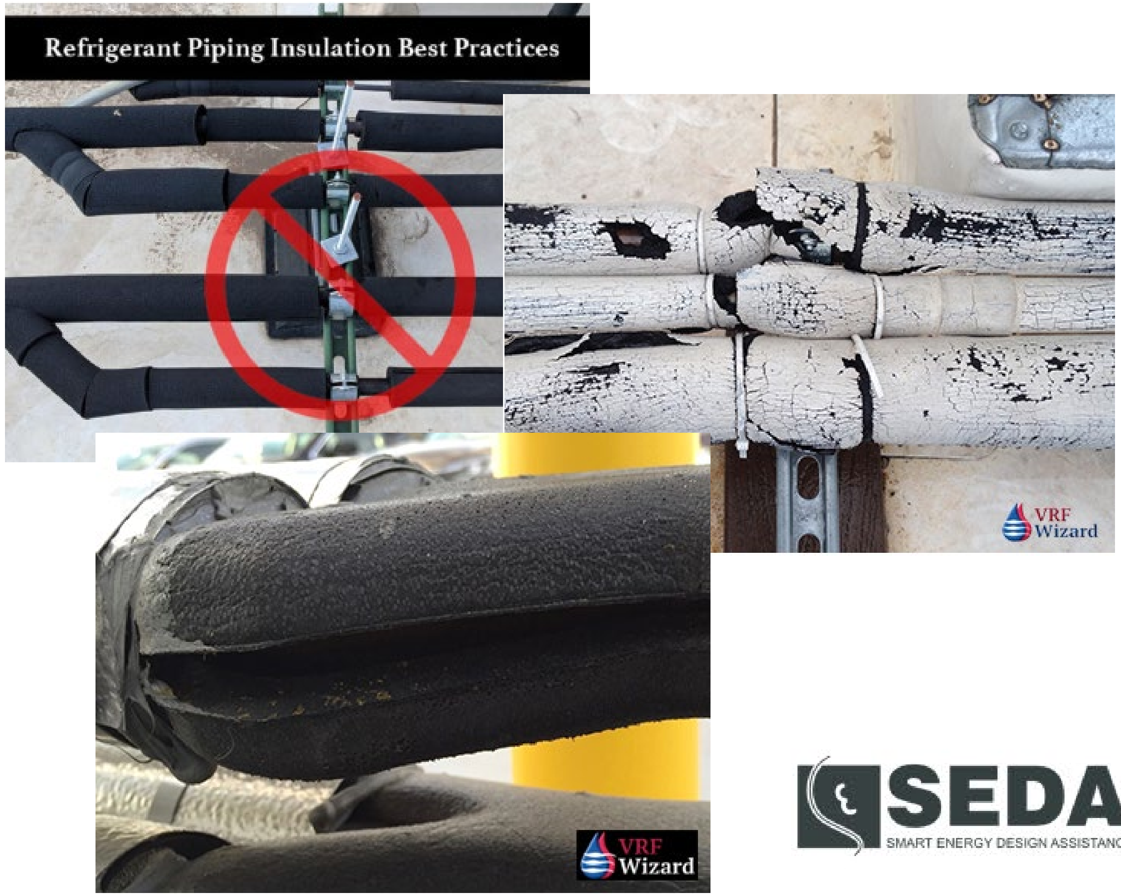
C403.11.3.1 Protection of Piping Insulation

Piping insulation exposed to the 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.

- Commonly an issue with small refrigeration units (residential-style DX, small diameter pipes)
  - Wrapped with foam pipe wrap, and nothing else
  - UV-degradation turns insulation to dust after a few years
  - Crimped by zip-ties
  - Gaps/incomplete insulation



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C403.11.3.1 Protection of Piping Insulation

- Failed insulation significantly increases parasitic loads on refrigeration systems (DX, VRF, CHW, etc…) On heat pumps, also impacts heating capacity.
- Failed insulation also exposes underlying pipe to corrosion damage

Results for Piping @ +20°F

Properly Maintained Insulation Estimate

Pipe Size [in]	Insulation Thickness [in]	Annual Heat Gain [ton-hrs per 100 ft]	Annual Cost per 100 ft
8”	**3”**	540	$36
4”	**3”**	224	$22
2”	**2.5”**	165	$16

Assumptions

- Madison, WI
- 0.9 HP/ton
- $0.10/kWh

Failed Insulation Estimate†

Pipe Size [in]	Insulation Thickness [in]	Annual Heat Gain [ton-hrs per 100 ft]	Annual Cost per 100 ft
8”	**3”**	1,826	$120

† Factor of 2 loss of insulation thermal conductivity on top, factor of 6 on the bottom

www.irc.wisc.edu – Presentation by Todd Jekel, Ph.D., P.E. Back to Basics: Pipe Insulation

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9.) C404.6.1 Circulation Systems & C404.7 Demand Recirculation Controls

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C404.6.1 Circulation Systems & C404.7 Demand Recirculation

C404.6.1: "Controls…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 not a demand for hot water."

C404.7: "The controls shall start the pump upon receiving a signal from the action of a user of a fixture or appliance…The controls shall limit the temperature of the water entering the cold-water piping to ≤ 104 °F."

Both code sections essentially have a demand-based component to circulation pump "ON" command. The shut-off method is the difference between the two.

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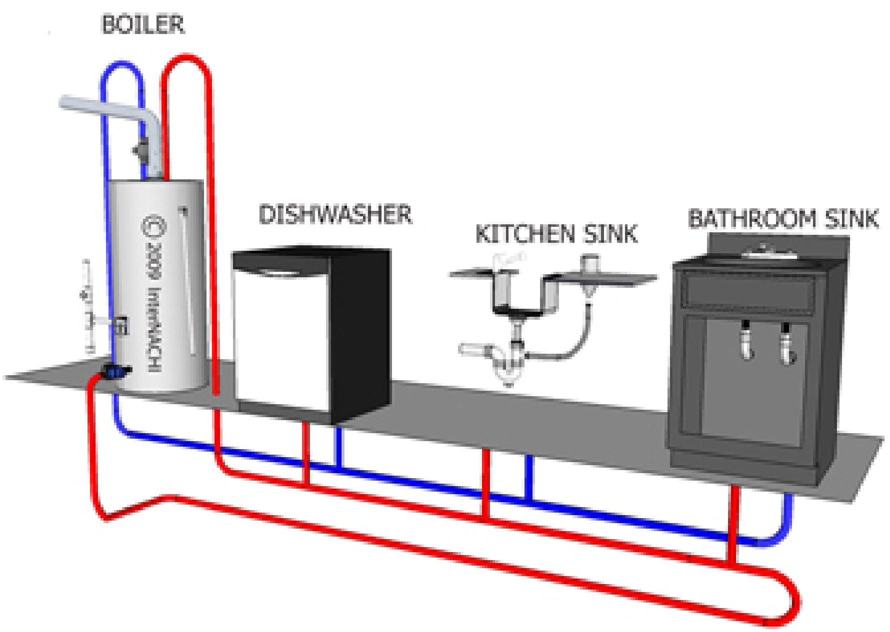
C404.6.1 Circulation Systems & C404.7 Demand Recirculation

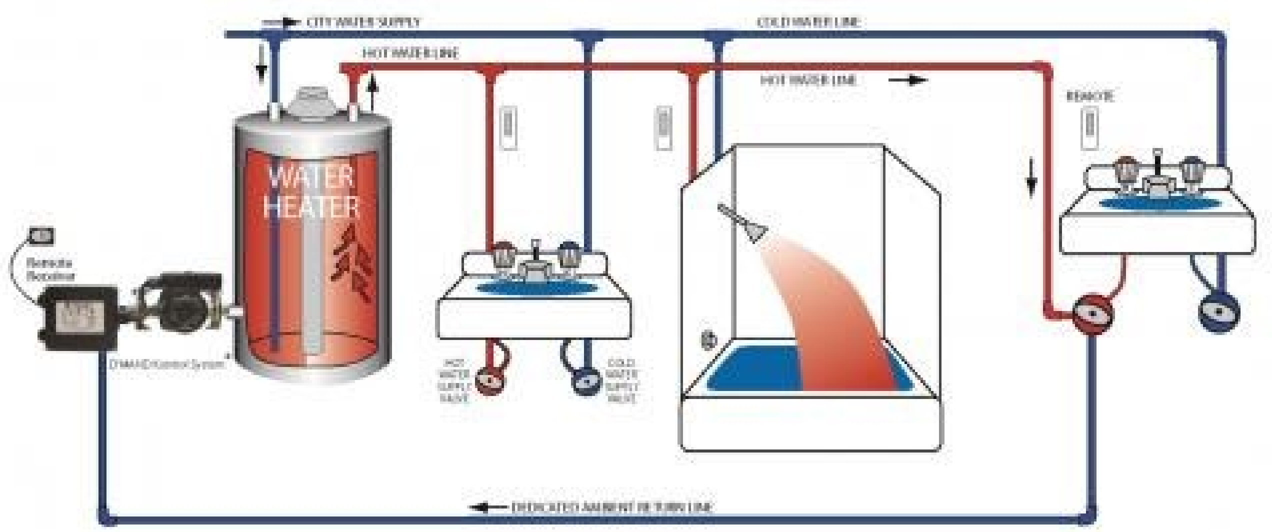
Commonly find circulation systems that circulate water continuously to ensure entire loop is always hot. Should cycle to maintain loop temperature.

DEDICATED LOOP HOT WATER RECIRCULATION SYSTEM



https://www.nachi.org/hot-water-recirculation-systems.htm

INTEGRATED LOOP HOT WATER RECIRCULATION SYSTEM



https://basc.pnnl.gov/images - Integrated hot water recirculation loop

10.) C403.12.3 Freeze Protection System Controls

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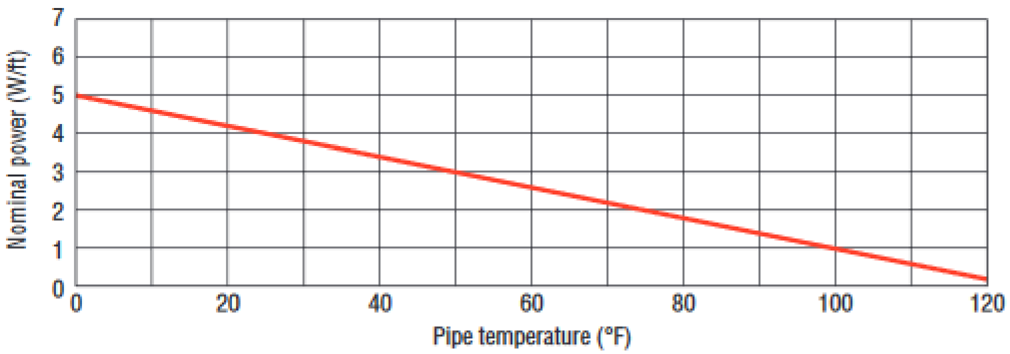
C403.12.3 Freeze Protection System Controls

Freeze protection systems, such as heat tracing or outdoor piping and heat exchangers… shall include automatic controls configured to shut off the systems when outdoor air temperatures are >40 °F or when the conditions of the protected fluid will prevent freezing.

- Common for heat-trace to be active year-round
- Self regulating heat trace uses continuous power, does not automatically shut off.

Graph 1 Nominal power output rating

This graph shows the self-regulating characteristics of Frostex heating cable. The conductive polymer core automatically adjusts its heat output as depicted in the graph at each point along the pipe, with no need for thermostats.



Source: Frostex® freeze protection system

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C403.12.3 Freeze Protection System Controls

- Freeze protection pumps on CHW coils for AHUs running year-round is typical finding as well
  - Pumps are in parallel with system supply loop, allowing pump to circulate flow in coil alone for freeze protection
  - Often confused with series booster pumps, which are in series with system loop.
- Cooling tower sumps often set to 45F, wasting heating energy for sump freeze protection in milder weather (WB>32 °F).
  - Sumps are often electric heat, but can also include HW heat exchangers.

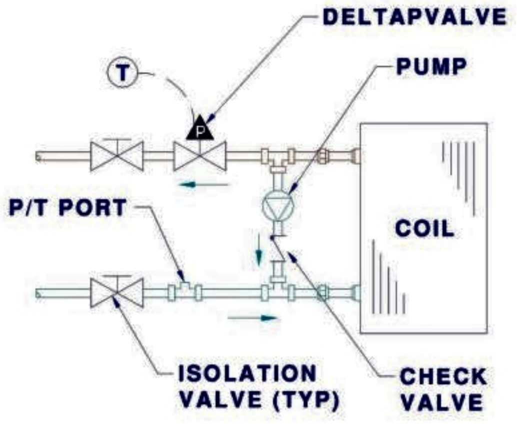
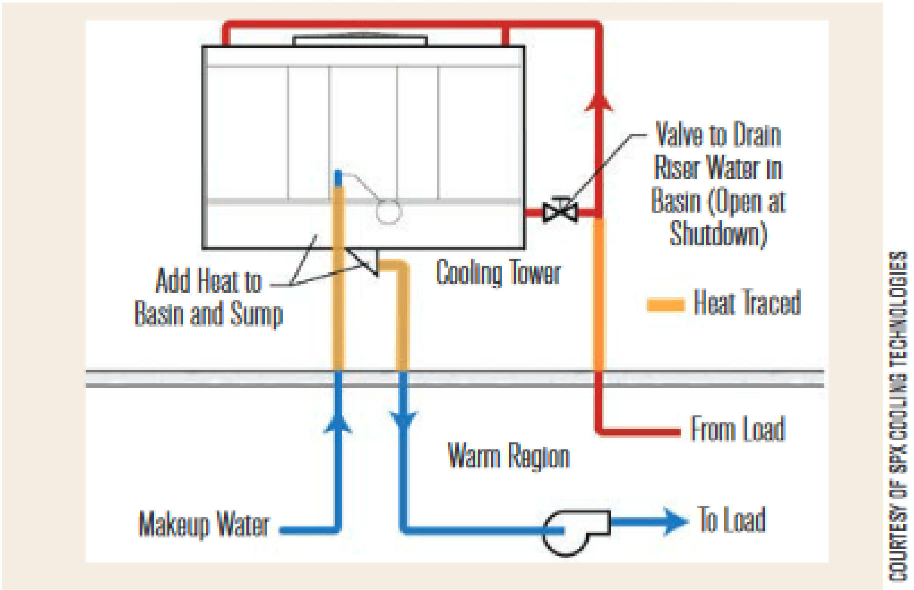


Figure 10: Pumped Coil Schematic
Pump 25% of coil design flow for freeze protection.



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