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Engineers Newsletter

volume 47–2

HVAC-related changes in

ASHRAE Standard 90.1-2016

Jurisdictions have begun to adopt ASHRAE 90.1-2013. We now look to the 2016 version for ideas on how to save energy over the 2013 version—for participating in above-code programs, preparing for the future, or simply as a design preference for energy and energy cost saving. This *Engineers Newsletter* describes important changes affecting HVAC systems and related equipment.

Since 1975, ANSI/ASHRAE/IES Standard 90.1 (hereafter referred to as 90.1 for brevity) has been the basis of many energy codes, and continues to be adopted directly or by reference in the International Energy Conservation Code (IECC). It is also the basis for determining compliance with the Energy Policy Act of 1992.

While harmony is desired and attempted between 90.1 and IECC, some requirements diverge. This newsletter identifies some of the areas and sections with the most differences between the two model codes, to help designers select a preferred path when there is a choice.

Look for this icon throughout this newsletter to indicate significant differences between 90.1-2016 and IECC-2018.

The most obvious change is the new formatting, which is better suited for digital use. More columns in the old version lead to more scrolling up and down in a digital document (ironically noted in this three-column document). And due to overwhelming hue and cry, italics that were removed in the 2013 version have been restored. Words in italics are defined in Chapter 3 of the standard. You'll also find that digital versions have hyperlinks and cross-references. There is also a new interactive tool for 90.1 available on the ASHRAE website.

Purchase a copy of Standard 90.1, and the accompanying User's Manual to better understand the requirements as they apply to specific systems, climates, buildings and design applications.

2016 HVAC Changes

121 addenda were incorporated in 2016. Of those, only 23 had energy savings which could be captured in any of the nearly 600 energy models created by the U.S. Department of Energy to determine energy saving impacts. Some types of equipment are not used in any of the prototype buildings, some changed the optional performance path only, and others simply added clarity to previous requirements.

According to these models, the 23 addenda save 34 percent energy versus the 2004 version, or 6.8 percent (weighted average) compared to the 2013 version. This is the energy consumed by the entire building, including equipment not regulated by 90.1.

The mechanical-related changes include:

- New climate zone assignments from ASHRAE Standard 169-2013
- Replacement equipment to follow some mandatory and prescriptive requirements (other than just efficiency)
- New coverage in equipment classes such as DOAS, CRAC and pool dehumidifiers
- Upgraded efficiency in packaged DX rooftops, PTAC and VRF
- Economizer fault detection in packaged DX equipment
- Variable airflow exhaust- and return-fan VFD control for building pressure control
- VFD threshold reductions (towers, pumps, fans)
- Fan system control 5 hp threshold moved to subsections
- Chilled-water plant monitoring
- 15°F minimum design delta T for cooling coil selections
- Chilled water reset alternative to pump pressure reset

Let's review these changes in more detail.

Revised climate classifications.

ASHRAE 90.1-2016 updated to the climate classifications published in ASHRAE Standard 169-2013 (Figure1). The methods and data used to develop the classifications are sufficiently arcane that this newsletter will only summarize and illustrate the significance of this change.

Some areas were quite affected (Figure 2). For example, 75 percent of the population of Wisconsin "moved" from climate 6A to 5A and 3 percent moved from 7 to 6A. Other states heavily reclassified are West Virginia (47%), North Carolina (43%), North Dakota (37%), Tennessee (36%), Indiana (30%) and Texas (24%). A few states reclassified as colder, such as Oklahoma (9% from 3A to 4A), New Hampshire (6% from 5A to 6A) and Washington (4% from 4C to 5C). Portions of 169 have been reprinted in the appendices of 90.1 for ease of reference.

These changes have ripple effects throughout the Standard. For example, requirements for insulation, glazing, the economizer tradeoff and high limit controls may change, all with potential impacts on energy savings calculations.

Climate zone 1 has been divided to include a new climate zone 0, to allow for more discerning requirements and their justifications for even hotter locations. Several areas outside of North America have begun to use 90.1 as the basis of their own energy codes—some of which are in climate zone 0.

Figure 1. ASHRAE climate zone map.

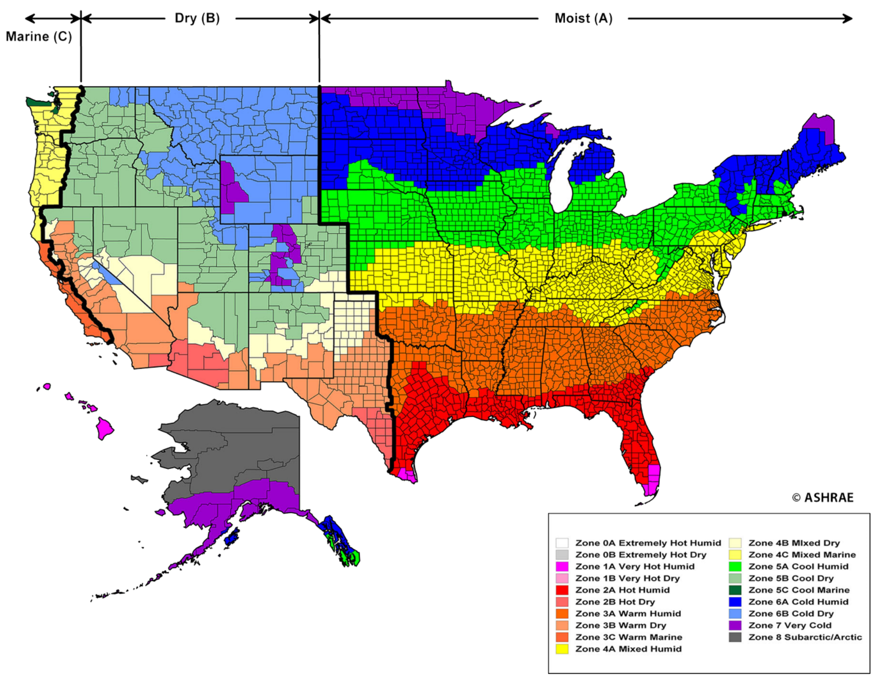
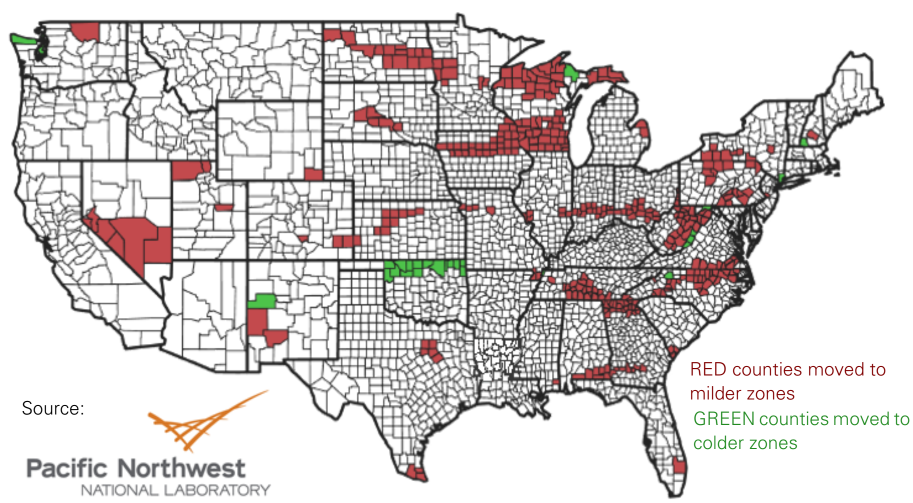


Figure 2. Counties where climate zone classification has changed.



Source: Pacific Northwest NATIONAL LABORATORY

Mandatory Section (6.4) Changes

Requirements in this section are mandatory, meaning they cannot be traded off using any of the other compliance paths. All paths include the mandatory sections.

Replacement equipment. Previously, like-for-like replacement equipment only had to meet the minimum efficiency requirements, and not all other prescriptive and mandatory requirements. In the new version, replacement equipment is now obliged to also meet several mandatory (as well as prescriptive) requirements. This includes off-hour controls, demand-controlled ventilation for single-zone systems, and setpoint controls. Other prescriptive requirements for replacement equipment will be discussed later.

DOAS equipment. A new class of product has been added for direct-expansion (DX), dedicated outdoor air systems (DOAS). This includes a reference to the recently created AHRI Standard 920, which reflects the different conditions a 100 percent outdoor-air unit is expected to experience. The rating is based on moisture removal efficiency (MRE) with an off-design rating of ISMRE for cooling and/or ISCOP for heating. Standard 920 and its use by 90.1 was the subject of a previous *Engineers Newsletter*.

Pool dehumidifiers and CRAC units are newly covered in the scope of 90.1. The scope of 90.1 is written so that coverage for new equipment can be added over time. In this case, pool dehumidifiers and CRAC units now have minimum efficiency requirements.

VRF equipment. The 2013 version had the first efficiency requirements for VRF systems with a corresponding AHRI certification program and test procedure. The 2016 version changes some of the part-load requirements, effective either January of 2017 or 2018, depending on the product. Part of this is due to a change in the test procedures and part from an actual improvement in stringency. The table is quite large due to many different temperature conditions for the various cooling and heating sources.

Chiller-plant monitoring and reporting. Another mandatory requirement is for new chiller plants to have efficiency and energy use measurement and reporting. This requirement is invoked based on climate and chiller-plant size (Table 1).

Table 1. Chiller-plant monitoring requirements

Climate zone	Water-cooled plant	Air-cooled plant
3C,4C,5,6,7,8	>1500 tons	>860 tons
0,1,2,3A,3B, 4A,4B	>1000 tons	>570 tons

The data must be recorded and trended every 15 minutes and graphically displayed to include hourly, daily, monthly and annual information. The data must be maintained for at least three years.

Economizer fault detection and diagnostics. This mandatory requirement applies to packaged unitary DX air-conditioners and heat pumps, regardless of condensing type, if they have an air economizer. The purpose is to identify when sensors and controls on the equipment are not economizing (bringing in more than minimum outdoor air) when outdoor conditions are favorable, or conversely if the economizer is active when conditions are unfavorable. Permanent sensors, economizer status, fault detection, reporting and provisions for test modes are specified by 90.1. This requirement has been in place for several years in California; manufacturers have already developed equipment options that meet the requirements (Figure 3).

Figure 3. Automatic fault detection implemented in a rooftop unit controller

Prescriptive Section (6.5) Changes

Prescriptive requirements may be traded off using one of the performance or alternative compliance paths. If you have a situation where you can't or don't wish to comply with a prescriptive requirement, you may switch to the performance path (Chapter 11) or the new Energy-Cost-Budget (Appendix G) based compliance option.

Replacement equipment prescriptions. In addition to the previously mentioned mandatory requirements, the following prescriptive requirements must also be met when replacing like-for-like equipment.

- Economizers (outdoor units)
- Integrated economizer control
- Economizer heating impact
- Fan efficiency
- Fan airflow control
- Ventilation optimization (multiple-zone VAV systems)
- Parallel, fan-powered VAV controls
- Fractional horsepower fan motors
- Fan speed control (heat rejection equipment)
- Chiller and boiler isolation
- Boiler turndown

Chilled-water reset. This is a new alternative to pump-pressure reset based on critical valve position. You may now choose to reset chilled-water temperatures to keep one valve nearly wide open or until equipment limits are reached. Or, you may continue to use pump-pressure reset based on critical valve. Exceptions are provided for district cooling, thermal storage and process cooling. The Trane ENL in 2015 included a table comparing the energy performance of the two options. Generally speaking, pump-pressure reset saves more energy at higher load (flow) conditions, or when constant-speed chillers are used, and when system design delta T is less than 15° F. You can also choose to do both resets in sequence. That is, do one until it reaches a limit and then the other.

Table 2. Updated requirements for pump VFD control

Chilled-water pumps	Heating-water pumps	Nameplate hp
0, 1, 2B	no requirement	≥ 2 hp
2A, 3B	no requirement	≥ 3 hp
3A, 3C, 4A, 4B	7,8	≥ 5 hp
4C, 5, 6	3C, 5A, 5C, 6B	≥ 7.5 hp
	4A, 4C, 5B	≥ 10 hp
7,8	4B	≥ 15 hp
	2, 3A, 3B	≥ 25 hp
	1B	≥ 100 hp
	0, 1A	≥ 200 hp

Pump VFD control by climate zone, now includes heating. During the evaluation of lowering the chilled-water pump VFD threshold, it was discovered that the existing requirements were not universally cost justified. The result of this evaluation prompted a new table, which also creates VFD requirements on heating-water pumps in many climate zones. Unsurprisingly, hot climates use drives on smaller pumps in their cooling system and cold climates use drives on smaller pumps in their heating systems (Table 2).

Waterside economizer for induction and/or fan-free systems. Aggregating coil capacity rather than looking at the fan-plus-coil terminal size is something that's new and starting to affect more codes, but not 90.1. Thresholds based on terminal size were used so that chilled-water systems were not disadvantaged compared to other small-terminal DX systems, such as PTACs or VRF. Small units (<54,000 Btu/h) have traditionally been exempt from economizers and still are. However, chilled-beam and induction units now are not. When multiple chilled-water terminals are connected to the same chiller, especially sensible-cooling-only terminals using relatively warm water, it's difficult to ignore the potential savings by using the water-economizer cycle.

Two changes were made. The word "fan" was struck from the threshold, as sometimes these units do not have a fan. Then, when their total cooling load is *large enough*, an economizer is required. "Large enough" varies by climate zone.

The new requirement applies to chilled-water cooling systems without a fan or that use induced airflow when the sum of the cooling loads not served by another type of economizer is

- ≥ 1,000,000 Btu/h (83 tons) in climates 0, 1B, 2, 3, and 4
- ≥ 1,400,000 Btu/h (116 tons) in climates 5-8
- Any size in climate 1A

Water economizer requirement in IECC.
Unlike 90.1, the IECC now has a system size aggregation (not just for induction units but for all chilled-water coils) when water economizers are required (Table 3). The equipment performance exception may be used instead in climates 2A/B, 3A/B and 4A/B (Table 6).

Table 3. Minimum chilled-water system cooling capacity for determining economizer cooling requirements

Climate zone	Total chilled-water system capacity less capacity of cooling units with air economizers	
	Local water-cooled chilled-water systems	Air-cooled chilled-water systems or district chilled-water systems
1A	Economizer not required	Economizer not required
1B, 2A, 2B	≥ 960,000 Btu/h	≥ 1,250,000 Btu/h
3A, 3B, 3C, 4A, 4B, 4C	≥ 720,000 Btu/h	≥ 960,000 Btu/h
5A, 5B, 5C, 6A, 6B, 7,8	≥ 1,320,000 Btu/h	≥ 1,720,000 Btu/h

Ventilation optimization despite ERV. The 2010 standard introduced the requirement for ventilation optimization in multiple-zone VAV systems. It was thought that systems required to use exhaust air energy recovery should be exempt from this requirement. However, energy use increased with this exception, so it has been removed. All multiple-zone VAV systems must use ventilation optimization unless their exhaust is too high (>70%) relative to outdoor-air intake, or if zone-to-zone transfer fans are used, as in fan-powered VAV systems. The first exception is because less turndown of outdoor air is available, and the second exception is because the ventilation effectiveness of systems meeting that exception cannot be easily determined.

Ventilation design. This new requirement sets an upper limit on ventilation of 135 percent of the minimum outdoor airflow rate using the prescriptive path. If additional ventilation is part of the design, the building would have to comply using one of the performance options.

Limits on reheating in dedicated outdoor-air systems (DOAS). When zones demand cooling, it doesn't make sense for the DOAS to reheat dehumidified air to space neutral dry-bulb temperatures, because zone cooling and fan energy increase. This requirement sets a limit of no higher than 60°F supply air from the DOAS when a majority of the zones are in cooling mode. Any energy (even site-sourced or recovered energy) is prohibited from being used for this purpose. This implies system-level coordination: the DOAS is operated differently, depending on the mode (heating or cooling) of the majority of the zones served by the other cooling/heating systems. A previous Trane *Engineers Newsletter* and application guide (SYS-APG001-EN) discuss the merits of non-neutral DOAS air delivery in more detail.

Parallel-flow, fan-powered VAV (PFPVAV) air termination control. This new requirement specifies the method of controlling the fan in a parallel, fan-powered VAV terminal. The fan is only permitted to run during heating mode, or if required for ventilation, and as the first stage of heat before any heating coil is activated. Additionally, during warmup or during setback the controller must either stop the primary air or reverse the logic so that when the primary air is warmer rather than colder than the zone, the damper actuates to open (for more heat) rather than close to its minimum as it does in cooling mode when the zone is being overcooled.

Variable airflow exhaust- and return-fan controls. Building pressurization is critical for conserving energy, not to mention moisture control. When exhaust fans are out of sync with the ventilation system, buildings don't perform well. This can lead to doors that stand open (positive pressure) or to moisture intruding into the envelope (negative pressure). Moisture in the insulation layer reduces its effectiveness at reducing heat gains or losses across the envelope. Buildings with poor pressurization control are also more likely to have operators who disable or limit airside economizer operation.

Compliance requires two things: control and capability. The return/relief fan control must either directly manage building pressure control or indirectly through supply-return airflow tracking. The second part of the requirement is for VFDs on fans ½ hp and larger or at least four stages of control.

Fan system control threshold moved to subsections. Previous versions only required compliance with all of Section 6.5.3 *Air System Design and Control* once the total system motor nameplate exceeds 5 hp. This meant that requirements such as the system fan-power limit effectively did not apply to small, unitary packaged equipment. Requirements specifically addressing products below the threshold (such as fan control down to 65,000 Btu/h, supply- air-temperature reset, VAV setpoint sensing) perversely did not apply in some cases anyway. The system size threshold was replaced with individual thresholds within the specific requirements (Table 4).

Table 4. Size thresholds for Section 6.5.3.

Section	Name	Threshold
6.5.3.1	Fan System Power and Efficiency	> 5 hp
6.5.3.1.3	Fan Efficiency	All, with exceptions
6.5.3.2	Fan Control	DX >= 65,000 Btu/h chilled water >= 1/4 hp
6.5.3.2.2	VAV Static Pressure Sensor Location	All or meet 6.5.3.2.3 instead
6.5.3.2.3	VAV Setpoint Reset	> 5 hp and DDC
6.5.3.2.4	Return and Relief Fan Control	>1/2 hp in total (exception) or 4+ stages
6.5.3.3	Multiple-zone VAV Ventilation Optimization	All, with exceptions
6.5.3.4	Parallel-flow, Fan-powered VAV Control (new requirement)	All
6.5.3.5	Supply-Air-Temperature Reset	All, with exceptions for climate zones 0, 1A, 2A, 3A (and other cases
6.5.3.6	Fractional Horsepower Fan Motors	1/12 to 1/2 hp motors, exception for heating-only fans, others
6.5.3.7	Ventilation Design (new requirement)	All

Economizer comfort cooling efficiency tradeoff. This requirement is not new, but many locations may have switched climate zones. The option compares the efficiency of compressor-bearing equipment to the minimum requirements for that same equipment in Section 6.4.1. If the unit meets the full-load efficiency required in Section 6.4.1 and its rated part-load efficiency is better than the minimum requirement by the fraction in the tradeoff table (Table 5), an economizer is not required.

This option is quite different in IECC-2018, where it is less stringent but only covers six climates: 2A/B, 3A/B, 4A/B. The "A" climates are new in the 2018 version (Table 6).

Table 5. Eliminate required economizer for comfort cooling by increasing cooling efficiency (90.1)

climate zone	efficiency improvement
2A	17%
2B	21%
3A	27%
3B	32%
3C	65%
4A	42%
4B	49%
4C	64%
5A	49%
5B	59%
5C	74%
6A	56%
6B	65%
7	72%
8	77%

Minimum 15°F delta T chilled-water cooling coil selections. Chilled-water coils now must be selected for at least a 15°F delta T with at least a 57°F leaving coil water temperature. Exceptions include:

- Sensible-only cooling coils,
- Fan-cooling units with 5000 cfm or less,
- Constant volume systems,
- Coils selected at 50°F or higher entering water or 65°F or lower entering air dry-bulb temperatures, or coils selected at the maximum temperature difference allowed by the chiller.

An extensive analysis was submitted to 90.1 showing system energy consumption and first costs are reduced when chilled-water coils are selected for higher delta Ts (lower water flow rates). The analysis included the impacts on fan, pump and chiller energy and costs. The rationale is explained in detail in a new course, ""Fundamentals of Design and Control of Central Chilled-Water Plants," from the ASHRAE Learning Institute.

Table 6. Table C403.5 (2) Equipment Efficiency Performance Exception for Economizers (IECC)

climate zones	cooling equipment performance improvement (EER or IPLV)
2A, 2B	10% efficiency improvement
3A, 3B	15% efficiency improvement
4A, 4B	20% efficiency improvement

Where to Learn More

ASHRAE 90.1-2016 incorporated many changes in this cycle. This newsletter summarized only the HVAC-related mandatory and prescriptive changes. In 2017, ASHRAE launched a 90.1 portal which you may find useful for learning more about these and other changes. It brings together the Standard, the Users' Manual, and a *redline* version that shows changes from one version to the next. Visit https://901portal.ashrae.org.

The International Code Council (ICC) has also provided free online view-only access to the IECC Model Code. Chapter 4 (commercial) can be viewed at https://codes.iccsafe.org/public/document/iecc2018/chapter-4-ce-commercial-energy-efficiency.

By Susanna Hanson, Trane. To subscribe or view previous issues of the *Engineers Newsletter* visit trane.com/EN. Send comments to ENL@trane.com.

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Demand-Controlled Ventilation. The mobility of a building's occupants poses a ventilation challenge: To bring enough outdoor air into the building to help ensure good indoor air quality without wasting energy by bringing in (and conditioning) too much. This ENL will discuss various methods used to vary outdoor airflow based on actual demand. It also reviews the related requirements for compliance with ASHRAE Standards 62.1 and 90.1. (November)

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Cooling Towers and Condenser-Water System Design and Operation
Sometimes overlooked, the cooling towers and condenser water loop play and important role in the first cost, function, and efficiency of the chilled-water systems. A fundamental understanding of how the cooling tower affects chiller performance can provide opportunities to reduce both capital cost and operating expense. (Recorded 2005)

Chilled-water System Design Trends This program reviews recent advancements in technology and trends due to these developments, system strategies that can take advantage of the latest technology and when various system strategies should be used. Consideration will be given to: variable primary, primary secondary, constant flow, series chillers, chilled water reset, pump pressure optimization, flow rates and turndown, heat exchanger types, and the components of air- and water-cooled systems.

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