Overview of ASHRAE Standard 206 - Method of Test for Rating of Multi-Purpose Heat Pumps for Residential Space Conditioning and Water Heating

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Abstract: ANSI/ASHRAE Standard 206 was developed to provide a uniform method of testing for rating the performance of multi-purpose heat pumps (combined appliances) which perform space conditioning and water heating in residential applications. The heat pumps may also provide additional functions, such as ventilation and/or dehumidification.

The standard provides a single comprehensive procedure for all existing and anticipated multi-purpose heat pumps, covering six, different, basic systems: single capacity air-source, dual capacity air-source, variable capacity air-source, single capacity liquid-source, dual capacity liquid-source, and variable capacity liquid-source systems.

The combined appliances may operate in up to 7 modes: A)space conditioning only; B)space conditioning + water heating; C)dedicated water heating; D)dehumidification + space conditioning; E)dehumidification; F)dehumidification + space conditioning + water heating; and G)dehumidification + water heating.

The standard specifies the test equipment for performing such tests, the physical arrangement of the interconnecting refrigerant and water lines, the data required and the calculations to be used.

The procedures in this standard may be used as a basis for establishing efficiency ratings for such equipment and for estimating annual energy consumption.

Key Words: heat pump, combined appliance, method of test, efficiency ratings

1 INTRODUCTION

The use of residential heat pumps in the U.S. dates back to the late 1920s, gaining both broad usage and a bad reliability reputation following the oil embargo of 1973. Since 1973 there has been much research and development of heat pumps, including air-source, ground-source, dedicated heat pump water heaters, and various multifunction systems.

The beginning of the multifunction heat pump was the addition of a simple compressor discharge line heat exchanger to transfer heat to the potable water system. Desuperheaters became popular in the 1980s and are still sold today as aftermarket add-ons and as original equipment.

By the mid-1980s there was enough interest in the use of heat pumps for combined space conditioning and water heating that ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) developed Standard 137-1995, “Methods of Testing for Efficiency of Space Conditioning/Water-Heating Appliances that Include a Desuperheater Water Heater”, that addressed the testing of combination space conditioning and potable water heating appliances. Integrated products being offered at that time were single stage air

conditioners and heat pumps with desuperheaters, and therefore Standard 137-1995 dealt with only single stage equipment with desuperheaters.

Later, in 1996, ARI (Air-Conditioning and Refrigeration Institute, now AHRI, Air-Conditioning, Heating, and Refrigeration Institute) introduced Standard 290-1996, “Air-Conditioning and Heat Pump Equipment Incorporating Refrigerant to Potable Water Heating Devices” that dealt with the performance rating of single capacity equipment providing desuperheating and full condensing capability.

These standards were then followed by requests for test and rating waivers to DOE (United States Department of Energy) by Carrier for their HydroTech integrated heat pump, and by Nordyne for their Powermiser integrated heat pump. The term “integrated heat pump” referred to heat pump systems that provided both space conditioning and water heating, and in both cases could provide water heating as needed, independent of the need for space conditioning.

Integrated heat pumps are continuing to evolve, with DOE, thru ORNL, working with several manufactures to develop quite advanced systems. As a result of this latest development activity, ORNL approached ASHRAE and asked that a new method of test be developed for these systems. ASHRAE established SPC206 to develop Standard 206, “Method of Test for Rating of Multi-Purpose Heat Pumps for Residential Space Conditioning and Water Heating”.

This standard has now been completed and issued, and is reviewed here.

2 EQUIPMENT COVERED

The standard covers six, different, basic systems: single capacity air-source, dual capacity air-source, variable capacity air-source, single capacity liquid-source, dual capacity liquid-source, and variable capacity liquid-source systems. For each of the six basic systems, the combined appliance may operate in up to 7 modes: A)space conditioning only; B)space conditioning + water heating; C)dedicated water heating; D)dehumidification + space conditioning; E)dehumidification; F)dehumidification + space conditioning + water heating; and G)dehumidification + water heating.

While the combined appliance may operate in up to 7 modes, the actual number of modes may be any number from 2 thru 7 depending on the design of the equipment.

For space conditioning only (mode A), the system operates either in space cooling or space heating with no water heating. If the system is performing space cooling, it will be at its normal sensible heat ratio. Space conditioning only occurs when there is a call for space conditioning and the hot water storage tank is fully recovered.

The space conditioning + water heating operation (mode B) is the same as the space conditioning only mode except that the hot water storage tank is not fully recovered. In addition to either space cooling or space heating, heat will be provided to the hot water storage tank per the equipment’s internal controls.

In dedicated water heating (mode C) the system is responding to a call for water heating with no call for space conditioning. In the dedicated water heating mode there may or may not be attendant space conditioning depending on the season and design of the system. If the source of heat for water heating is from outdoor air, there is no indoor space conditioning. If the source of heat for water heating is from indoor air, there will be space cooling irrespective of the season. Depending on the system design, the source of heat for water heating may be either indoor or outdoor for either season.

When operating in dehumidification + space conditioning (mode D) there will be space cooling at a lower sensible heat ratio than for the space cooling only mode. How the system achieves the lower sensible heat ratio, and its associated indoor airflow, is solely dependent on the equipment's design and internal controls.

The dehumidification mode (mode E) is the same as for dehumidification+space conditioning mode, except that the system operates at a lower sensible heat ratio than for the dehumidification+space conditioning mode. There will likely still be some sensible space cooling, but the sensible heat ratio will be the lowest possible for the combined appliance.

The dehumidification + space conditioning + water heating mode (mode F) is the same as the dehumidification + space conditioning mode except that the hot water storage tank is not fully recovered. In addition to space cooling at a lower sensible heat ratio, heat will be provided to the hot water storage tank per the equipment internal controls.

The dehumidification + water heating mode (mode G) is the same as the dehumidification only mode except that the hot water storage tank is not fully recovered. In addition to space cooling at the equipment's lowest possible sensible heat ratio, heat will be provided to the hot water storage tank per the equipment internal controls.

3 SENSIBLE LOAD

Because the standard accounts for equipment that can operate at various sensible heat ratios it was necessary to develop separate sensible and latent loads for use with the combined appliance performance calculation.

ASHRAE Standard 116-2010, which is the test standard for standalone heat pumps, establishes the total cooling load as 0 W (0 Btu/h) at 18.3°C (65°F) outdoor temperature and increases linearly to equal the unit test total cooling capacity at 35°C/26.7°C/19.4°C (95°F/80°F/67°F) (outdoor dry bulb/indoor dry bulb/indoor wet bulb temperature respectively), multiplied by 1.1 at 95°F outdoor temperature. Standard 206 multiplies this total capacity by 0.76 to establish the space sensible cooling load for the combined appliance.

ASHRAE Standard 116-2010 establishes the sensible heating load as 0 W (0 Btu/h) at 18.3°C (65°F) outdoor temperature and increases linearly to equal 0.77 times the unit test heating capacity at 8.33°C/6.11°C/21.1°C (47°F/35°F/70°F) (outdoor dry bulb/outdoor wet bulb/indoor dry bulb temperature respectively). Standard 206 also uses this as the space sensible heating load for the combined appliance.

4 LATENT LOAD

The latent cooling load for the combined appliance in Standard 206 is made up of an internal latent gain and a ventilation latent gain.

The internal latent gain consists of 52.7 W (180 Btu/h) of direct moisture per person and 105.5 W (360 Btu/h) of indirect (showers, cooking, etc.), moisture per person. The number of people is one per ton of total unit cooling capacity at 35°C/26.7°C/19.4°C (95°F/80°F/67°F), with a lower limit of 1 person and an upper limit of 5 persons.

The ventilation latent heat gain due to natural and forced ventilation is based on a total ventilation air flow of 18.9 L/s, (40 cfm) per 3.52 kW, (1 ton) of total unit cooling capacity at 35°C/26.7°C/19.4°C (95°F/80°F/67°F). The ventilation air flow is then multiplied by the

difference in enthalpy between the moist air for the outdoor average relative humidity in combination with each outdoor temperature bin and the indoor return air. For the cooling season the enthalpy of the indoor cooling return air is based on 26.7°C/19.4°C (80°F /67°F), and for the heating season the enthalpy of the indoor heating return air is based on 21.1°C /14.6°C (70°F /58°F).

5 WATER HEATING LOAD

For purposes of the seasonal bin analysis used in Standard 206, the water heating load is assumed evenly distributed over the hours of the year. The hot water usage is taken as 243.4 liters/day (64.3 gallons/day) from ASHRAE 118.2-2006, which is the test standard for standalone residential water heaters. Using inlet and outlet water temperatures from ASHRAE 118.2-2006 of 14.2°C (58°F) and 57.2°C (135°F) respectively and a water heater energy factor of 0.90 yields an hourly water heating load of 496.9 W (1696 Btu/h).

6 VENTILATION FUNCTION

Other than the latent load from the ventilation air, no other impact due to ventilation air is included in the standard.

Early in the development of the standard it was intended to have an integrated ventilation function impact the system return air dry and wet bulb temperatures, but this was dropped after it was concluded that the function would have little influence and would add much calculation complexity.

7 TESTS REQUIRED

While certain additional tests are required for the combined appliance, compared to a space conditioning only unit, the standard builds on the test conditions of ANSI/AHRI 210/240-2008, ANSI/ARI/ASHRAE ISO Standard 13256-1:1998, and ANSI/AHRI Standard 870-2005, which are the rating standards for air-source, liquid-source, and direct geoexchange systems respectively, as the basis of the tests.

In order to minimize the laboratory test burden, all or part of some of the additional tests are conditional or optional. The optional test is at the manufacturer's discretion, but if the test is not conducted, it is expected that the default value will result in a slight performance penalty.

The number of tests required to describe a given mode of operation increases as that mode of operation is expected to operate over a greater portion of the season. The number of tests also depends on the type and complexity of the system design, with air-source systems requiring more tests than liquid-source, and variable capacity systems requiring more tests than single capacity.

As a specific high detail example, the space conditioning + water heating mode is expected to operate over the entire season, so for air-source systems two tests in both the cooling and heating seasons are required to define the basic linear interpolation of performance as a function of outdoor temperature. This base performance is then applied with the cyclic degradation factor of the space conditioning only mode for both cooling and heating, and the defrost degradation factor of the space conditioning only mode for heating.

A low detail example would be the dehumidification mode, which is only expected to operate during the mild temperatures of the cooling and heating seasons. Therefore, the performance

of the dehumidification mode is based on only one test, and a change in performance as a function of outdoor temperature is assumed equal to that of the space conditioning + water heating mode. Even that test is optional, and the performance of the dehumidification only mode may be assumed equal to that of the space performance portion of the dehumidification + water heating mode if the manufacturer so chooses.

8 CALCULATION PROCEDURE

In order to keep the performance calculation for the standard as simple as possible, the standard uses a bin procedure based on the number of hours in 2.78°C (5°F) outdoor temperature bins, similar to that of ASHRAE Standard 116-2010. Because the standard takes into account the performance of combined appliances having multiple modes of operation, the standard requires a number of bin calculations in a specific sequence. The most complex example is a variable capacity system having all seven modes of operation, requiring twelve sequential bin calculations of varying complexity.

Because there is no way to easily predict the coincidence of space cooling (or heating), space dehumidification, and water heating loads, the standard assumes they all exist at the initiation of each hours calculation. Thus, the first calculation is for the dehumidification + water heating mode (G), and operates to meet either the initial latent load, the initial space sensible cooling load, or the initial water heating load.

The second calculation is then for the space conditioning + dehumidification + water heating mode (F), and operates to meet either the residual latent load, the residual space sensible cooling load, or the residual water heating load.

The third through fifth calculations are for the space conditioning + water heating mode (B) in sequence of low, variable, and high capacity, and operates to meet either the residual space sensible cooling load, or the residual water heating load.

The sixth calculation is for the dehumidification mode (E), and operates to meet either the residual latent load, or the residual space sensible cooling load.

The seventh calculation is for the space conditioning + dehumidification mode (D), and operates to meet either the residual latent load, or the residual space sensible cooling load.

The eighth calculation is for the dedicated water heating mode (C), and operates to meet the residual water heating load.

The ninth calculation is then for auxiliary dehumidification, and operates to meet any residual space latent load.

The tenth thru twelfth calculations are for the space conditioning only mode (A) in sequence of low, variable, and high capacity, and operates to meet any residual space sensible load.

It should be noted that the dedicated dehumidification mode, either with or without water heating, only operates if the space latent load is greater than can be met by the dehumidification + space conditioning + water heating, or dehumidification + space conditioning mode. Similarly, the dehumidification + space conditioning mode, either with or without water heating, only operates if the space latent load is greater than can be met by the space conditioning + water heating, or space conditioning only mode.

A last requirement is that the combined appliance can only operate for one hour of each bin hour. Auxiliary dehumidification, auxiliary space heating, and/or auxiliary water heating is

assumed to operate as required within any given bin hour to exactly meet any residual space sensible heating load, residual space latent cooling load, and/or residual water heating load. An unmet residual sensible cooling load is possible at high outdoor temperatures where the space cooling load exceeds the cooling capacity of the unit, just as in ASHRAE Standard 116-2010.

Because the space conditioning + water heating mode, during space heating, can result in increased use of auxiliary space heat due to heat pump system heat being diverted to water heating, the standard allows the manufacturer to specify a priority to space conditioning. With a priority on space conditioning, the run times in heating modes that include water heating are limited such that the ending space conditioning only mode can exactly meet the space heating load.

9 PERFORMANCE DESCRIPTORS

Three performance descriptors are used to completely describe the performance of the combined appliance: a combined appliance space conditioning performance for the cooling season; a combined appliance space conditioning performance for the heating season; and a combined appliance water heating performance on an annual basis.

In all cases, the descriptor ends in a subscript “ca” to designate “combined appliance”.

For air-source systems the cooling season space conditioning descriptor is termed $SEER_{ca}$, and the heating season space conditioning descriptor is termed $HSPF_{ca}$, where SEER and HSPF stand for seasonal energy efficiency ratio and heating seasonal performance factor, respectively, just as it does for the space conditioning only equipment covered by ASHRAE Standard 116-2010.

For liquid-source and direct geoexchange systems the cooling season space conditioning descriptor is termed EER_{ca}, and the heating season space conditioning descriptor is termed COP_{ca}, where EER and COP stand for energy efficiency ratio and coefficient of performance, respectively, just as it does for the space conditioning only equipment covered by ANSI/ARI/ASHRAE ISO Standard 13256-1:1998, and ANSI/AHRI Standard 870-2005. While the liquid-source and direct geoexchange system performance descriptors do not contain an “S” for seasonal, and the unit capacity does not change as a direct function of outdoor temperature, the bin calculation does account for the change in load as a function of outdoor temperature.

EF_{wca} is the annual water heating energy factor, and is defined identically to EF in ASHRAE 118.2-2006. In addition to the “ca” being added, there is also a “w” added to differentiate between the energy factor for water heating and the energy factor for the auxiliary dehumidifier designated as EF_d in the standard.

$SEER_{ca}$ and EER_{ca} are defined as the total space cooling energy delivered to the space divided by the total energy used, with units of Btu/Wh.

$HSPF_{ca}$ and COP_{ca} are defined as the total space heating energy delivered to the space divided by the total energy used, with units of Btu/Wh, and Wh/Wh respectively.

EF_{wca} is defined as the total hot water energy delivered divided by the total energy used to heat the water, and is dimensionless.

In all cases the energy consumed by the combined appliance is debited proportionally by function to the useful energy provided. As an example, if the combined appliance provides 10

Wh (34.13 Btu) for space conditioning, either cooling or heating, and simultaneously provides 2 Wh (6.83 Btu) for water heating while consuming 3 Wh (3 Wh) of energy, excluding the potable water pump energy, 10/12 or 2.5 Wh (2.5 Wh) of the energy consumed is debited to space conditioning, and 2/12 or 0.5 Wh (0.5 Wh), plus all of the potable water pump energy, is debited to water heating.

Because the combined appliance and space conditioning only equipment are not meeting identical space conditioning loads (the combined appliances must address sensible+latent loads, while the single function equipment only meets sensible loads), an energy adjustment is deducted from the combined appliance energy use to bring $SEER_{ca}$, EER_{ca}, $HSPF_{ca}$, and COP_{ca} into alignment with SEER, EER, HSPF, and COP respectively. The calculation of the energy adjustment requires two additional bin calculations.

First, the performance of the space conditioning only mode is calculated using the data from the space conditioning only tests (mode A)against the total load with the bin procedure presented in ASHRAE Standard 116-2010. The results will be the total capacity supplied and total energy used.

Second, the performance of the space conditioning only mode is again calculated using the data from the space conditioning only tests (mode A), but against the separate sensible and latent loads as determined for Standard 206 load and with the bin procedure presented in ASHRAE Standard 206 with an auxiliary dehumidifier included. The results will be the net total capacity supplied and total energy used.

The difference between the net total capacity of the space conditioning only plus auxiliary dehumidifier system and the total capacity of the space conditioning only system multiplied by the energy consumed by the space conditioning only system provides the energy adjustment to be subtracted from the total combine appliance system energy consumed to make SEERca, EERca, HSPFca, and COPca directly comparable to the SEER, EER, HSPF, and COP values respectively that the consumer is familiar with.

10 CONCLUSION

ASHRAE Standard 206 represents a major step forward in testing and describing the performance of combined appliances. Standard 206 covers a very wide range of equipment because it is intended to address not only those configurations currently being developed, but also other possible configurations that might arise in the foreseeable future. It has introduced the concept of specific latent loads and implemented a means of accounting for them in a seasonal performance descriptor.

Development of a uniform method-of-test along with performance descriptors understandable by the consumer, followed by establishment of a rating standard, will facilitate market penetration of energy saving combined appliances, by allowing consumers to make informed comparisons of the energy performance of combined appliances to that of a suite of separate-function appliances.

11 REFERENCES

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