OAK RIDGE
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Existing and Past Methods of Test and Rating Standards Related to Integrated Heat Pump Technologies

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EXISITING AND PAST METHODS OF TEST AND RATING STANDARDS RELATED TO INTEGRATED HEAT PUMP TECHNOLOGIES

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CONTENTS

ACRONYMS

AHRI	Air-Conditioning, Heating and Refrigeration Institute
ANSI	American National Standards Institute
ARI	Air-Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CCPF	Combined Cooling Performance Factor
C_D	Degradation Coefficient
CHPF	Combined Heating Performance Factor
COP	Coefficient of Performance
CPF_{cs}	Combined Performance Factor cooling season
CPF_{hs}	Combined Performance Factor heating season
CPF_{ws}	Combined Performance Factor water-heating-only season
DOE	Department of Energy
EER	Energy Efficiency Ratio
EF	Energy Factor
ESP	External Static Pressure
HSPF	Heating Seasonal Performance Factor
HX	heat exchanger
ISO	International Organization for Standardization
NAECA	National Appliance Energy Conservation Act
SEER	Seasonal Energy Efficiency Ratio
SPF	Seasonal Performance Factor

EXECUTIVE SUMMARY

This report evaluates existing and past US methods of test and rating standards related to electrically operated air, water, and ground source air conditioners and heat pumps, 65,000 Btu/hr and under in capacity, that potentiality incorporate a potable water heating function. Two AHRI (formerly ARI) standards and three DOE waivers were identified as directly related. Six other AHRI standards related to the test and rating of base units were identified as of interest, as they would form the basis of any new comprehensive test procedure. Numerous other AHRI and ASHRAE component test standards were also identified as perhaps being of help in developing a comprehensive test procedure.

The review of the above standards and procedures revealed that there are 180 test condition variables that have to be specified in evaluating and rating the performance of a generic heat pump incorporating potable water heating, assuming no other functions such as thermal storage or ventilation, etc. There were no current or past test procedures found that dealt with water or ground source heat pumps with integrated potable water heating, European standard EN 15316 presents a procedure for calculating a Seasonal Performance Factor (SPF) for water source heat pumps for the heating season but not the cooling season. The Carrier and Nordyne waivers for air source heat pumps were found to be the most complete test procedures for equipment with integrated potable water heating.

In reviewing all of the pertinent standards, including those for just the base units, several near common test condition variables were found along with several differences. Two of the most common test condition variables were the nearly universal use of 80/67 (dry bulb temperature-^{o}F/wet bulb temperature-^{o}F) for the entering indoor air temperature during cooling, and 70 (dry bulb temperature-^{o}F) for the entering indoor air temperature during heating. The greatest disparity within the various standards is the use of a seasonal energy efficiency calculation involving cyclic performance for air source equipment, versus a simple steady state energy efficiency for water and ground source equipment. Other disparities occur in the calculation of fluid handling powers.

While it would be a major undertaking, development of a comprehensive test and rating procedure, specifying test conditions and procedures covering past and expected future system features, would ensure equal treatment for all system types, and hopefully eliminate the need for a variety of waivers. A suggested list of tasks, in priority order, that would be required should this be undertaken has been developed. Taking a less comprehensive and more piecemeal approach would be easier and faster in the near term, but would require continual revisions in the long term.

1. INTRODUCTION

It is generally acknowledged that the heat pump was invented by Lord Kelvin in 1852, with Peter Ritter von Rittinger, an Austrian engineer designing and installing the first known heat pump in 1855. The use of residential heat pumps in the U.S. dates back to the late 1920s, gaining both broad usage and a bad 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 water heaters, and various multifunction systems. One of the lesser known research projects involved a novel system designed and tested by Pennsylvania Power & Light, where the thermal output of the HVAC and all appliances were linked via a whole house water loop. Another of the lesser known research projects was sponsored by Niagara Mohawk Power Corporation with Carrier Corporation to develop a northern climate heat pump that resulted in a prototype system employing a unique series compression design. Two of the better known integrated systems that reached production were sponsored by the Electric Power Research Institute with Carrier Corporation and Nordyne developing their HydroTech and Powermiser systems respectively.

Prior to the National Appliance Energy Conservation Act (NAECA) of 1987, air-source heat pumps were tested under ARI standards, with the resulting performance data reported as system capacity, condensing unit power, and air handler power. While the ARI standards insured that all manufacturers tested to identical conditions, they left the installer to calculate the overall system performance at operating conditions of his choosing. With the passage of NAECA, air-source heat pumps became subject to minimum cooling and heating efficiencies specified as SEER and HSPF respectively, to be determined in accordance with “Uniform Test Method for Measuring the Energy Consumption of Central Air Conditioners and Heat Pumps” Appendix M to Subpart B of 10 CFR Part 430 incorporating ARI 210/240. Because this federal test and rating procedure did not adequately represent the performance of units including a potable water heating function, Carrier Corporation developed its own test and rating procedure, and in 1989 filed for a waiver to cover its unique microprocessor controlled variable speed HydroTech unit that included both potable water heating and a patented defrost cycle that extracted heat from the heated potable water. Nordyne followed suit, developing its own test and rating procedure, and in 1995 filed for a waiver to cover its unique single capacity Powermiser unit that included a potable water heating function.

At the present time numerous ASHRAE methods of test standards and AHRI methods of rating standards exist, covering Unitary Air-Conditioning & Air-Source Heat Pump Equipment, Water-Source Heat Pumps, Ground Water-Source Heat Pumps, Ground Source Closed-Loop Heat Pumps, and Direct GeoExchange Heat Pumps. AHRI also still has in place a rating standard for the Performance Rating of Desuperheater/Water Heaters, and the Carrier and Nordyne waivers appear to still be in effect but not presently used.

An overview of the key points of the various test and rating standards, and waivers is presented below.

2. METHODS OF TEST AND RATING PROCEDURES SUMMARIES

Only the key elements of the following test procedures are reported. Test voltages, variables tolerances, and instrumentation accuracies are generally the same between the various standards, and are not key to the comparison reported here.

The below summaries begin with AHRI 210/240 and the federal test procedure for water heaters as a base, and thereafter follow the other standards and waivers in approximately chronological order of their development.

2.1 AHRI 210/240, *PERFORMANCE RATING OF UNITARY AIR-CONDITIONING AND AIR-SOURCE HEAT PUMP EQUIPMENT*

Standard 210/240 has to be considered "the base standard", as it supports federal law and covers by far the largest sales volume of units sold in the US.

2.1.1 Ratings

Overall cooling performance is calculated in terms of Seasonal Energy Efficiency Ratio (SEER) with units of Btu/Wh. SEER is defined as the total heat, in Btu's, removed from the conditioned space in the cooling season divided by the total electrical energy consumed, in Wh. Heating performance is calculated in terms of Heating Seasonal Performance Factor (HSPF) with units of Btu/Wh. HSPF is defined as the total space heating, in Btu, required during the heating season divided by the total electrical energy consumed, in Wh.

2.1.2 Capacities

Test conditions are specified to accommodate single, dual, and variable capacity units. Single and dual capacity units are a subset of the more complicated variable speed. Cooling and heating capacities are net values, including the effects of circulating-fan heat, but not including supplementary heat. Net capacities of units which do not have indoor air-circulating blowers furnished as part of the model, i.e., split systems with indoor coil alone, are determined by subtracting from the total cooling capacity 1,250 Btu/h per 1,000 cfm (ft^3/min) and by adding the same amount to the heating capacity.

2.1.3 Entering Indoor Air Temperatures

The entering indoor air temperature conditions for all 210/240 testing is specified as 80 ^{o}F dry bulb (db) / 67 ^{o}F wet bulb (wb) for all tests to determine cooling capacities and efficiencies, and 70 ^{o}F dry bulb for all tests to determine heating capacities and efficiencies. The entering indoor air wet bulb temperature is decreased to 57 ^{o}F, or below, for tests to determine cooling cyclic degradation performance, to ease the testing burden by eliminating latent capacity considerations.

2.1.4 Entering Outdoor Air Temperatures

210/240 specifies 4 different entering dry bulb/wet bulb temperature combinations (95/75, 87/69, 82/65, & 67/53.5 ^{o}F) to cover cooling tests, and another 4 different entering dry bulb/wet bulb temperature combinations (62/56.5, 47/43, 35/33, & 17/15 ^{o}F) to cover heating tests. In both the cooling and heating tests, the 4 test temperatures were selected such that performance is quantified as a function of outdoor temperature for minimum and maximum compressor capacities. An intermediate compressor capacity test at an intermediate temperature then provides the data to interrelate the full map of unit performance as functions of outdoor temperature and compressor capacity.

2.1.5 Indoor Air Flow

210/240 covers both ducted and non-ducted systems. Ducted systems may be without blower, or with blower, or may apply to small ducts using high velocity flow. Simplified, non-ducted units use the air volume flow rate resulting when the unit operates at an external static pressure of zero at the lowest indoor fan setting. For ducted units without an indoor fan installed, the pressure drop across the indoor coil assembly must not exceed 0.30 in H_2O. For all ducted systems, the measured air volume cooling flow rate, when divided by the measured indoor air-side total cooling capacity, must not exceed 37.5 scfm per 1,000 Btu/h [450 scfm per ton], to ensure a minimum level of latent capacity. For ducted units with an indoor fan installed, the external static pressure must be equal to or greater than an AHRI specified minimum external static pressure. Small-duct, high-velocity systems must contain a blower and indoor coil combination that is designed for, and produces, at least 1.2 in H_2O of external static pressure when operated at the certified air volume rate of 220-350 cfm per rated ton [12,000 Btu/h] of cooling. The above requirements are for full capacity. Requirements are also set forth as to the specific air flows to be used for required tests of variable capacity equipment at reduced capacity.

2.1.6 Indoor Blower Power

Total actual blower power is used for those units with integral blowers. For units which do not have indoor air-circulating blowers furnished as part of the model, i.e., split systems with indoor coil alone, total power input for both heating and cooling is increased by 365 W per 1,000 cfm of indoor air circulated.

2.1.7 Outdoor Air Flow

For adjustable fan drives, the outdoor-coil airflow rate is as specified by the manufacturer. If the fan drive is non-adjustable, the outdoor-coil airflow rate is as inherent in the equipment when operated with all of the resistance elements associated with inlets, louvers, and any ductwork and attachments considered by the manufacturer as normal installation practice in place.

2.1.8 Defrost

Provides for defrost test at 35 ^{o}F db/ 33 ^{o}F wb outdoor temperature, with the heat for defrost taken from the indoor air.

2.1.9 Interconnecting Refrigerant Line Lengths

For equipment in which the outdoor section is separated from the indoor section, tests are performed with at least 25 ft of interconnection tubing. Equipment in which the interconnection tubing is furnished as an integral part of the machine not recommended for cutting to length is to be tested with the complete length of tubing furnished, or with 25 ft of tubing, whichever is greater. At least 10 ft of the interconnection tubing is to be exposed to the outside conditions. The line sizes, insulation, and details of installation are to be in accordance with the manufacturer’s published recommendation.

2.1.10 Cyclic Degradation Factor

Tests are specified to determine cooling and/or heating cyclic degradation coefficients. In lieu of conducting the cyclic tests, an assigned value of 0.25 may be used for either/or both the cooling or heating degradation coefficient.

2.1.11 Calculation Methodology

Cooling and heating performances for multi-stage equipment are based on temperature bin calculations, with bins above 65 ^{o}F being cooling. For single stage equipment, heating performance is based on temperature bins, but cooling performance is simplified to just the equipment performance at 82 ^{o}F and an assumed 50% load factor. For region IV (1 of 6 climate zones defined for the continental United States by 10 CFR 430; region IV extends from the east coast almost to the west coast, and is generally centrally located with respect to north-south), the simplified calculation at 82 ^{o}F provides a nearly identical result to the full bin calculation.

2.2 10 CFR PART 430, *ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS: TEST PROCEDURE FOR WATER HEATERS*

2.2.1 Ratings

Overall water heating performance is calculated in terms of Energy Factor (EF) which is dimensionless. The EF is calculated by computing the energy required to heat the amount of water removed during the test from its specified inlet temperature (58 ^{o}F) to the specified setpoint temperature (135 ^{o}F) and dividing that energy by the energy consumed by the water heater during the test. Unlike SEER and HSPF, the two energies being divided for the EF are to be expressed in like units, thus yielding a dimensionless parameter.

2.2.2 Products

Test conditions are specified to accommodate single and dual element electric storage units, along with gas and oil heated tank units and instantaneous units.

2.2.3 Storage Tank Ambient Temperature

May range between 65 and 70 ^{o}F. For heat pump water heaters, the dry bulb temperature must be maintained at 67.5 ^{o}F with a relative humidity maintained between 49% and 51%.

2.2.4 Supply Water Temperature

The temperature of the water supplied to the water heater is maintained at 58 ^{o}F.

2.2.5 Storage Tank Temperature Control

The operation of the water heating elements within the storage tank is under automatic control of the self contained thermostats.

2.2.6 Storage Tank Temperature

The temperature of the water within the storage tank is set to 135 ^{o}F cut-out. Cut-in is per the self contained thermostats.

2.2.7 Water Heater Mounting

A water heater designed to be freestanding is placed on a 3⁄4 inch thick plywood platform supported by three 2 x 4 inch runners.

2.2.8 Heat Pump Water Heater Storage Tank

The tank to be used for testing a heat pump water heater without a tank supplied by the manufacturer is an electric storage-type water heater having a measured volume of 47.0 gallons; two 4.5 kW heating elements controlled in such a manner as to prevent both elements from operating simultaneously; and an energy factor generally equal to the minimum energy conservation standard.

2.2.9 Water Draw Rate

During hot water draws, water is removed at a rate of 3.0 gallons per minute.

2.2.10 Total Water Draw

During the simulated use test, a total of 64.3 gallons are removed. This value is referred to as the daily hot water usage.

2.2.11 Water Draw Schedule

Six equal draws totaling the above 64.3 gallons are utilized at 1 hour intervals.

2.3 ASHRAE 137-1995, *METHODS OF TESTING FOR EFFICIENCY OF SPACE CONDITIONING/WATER-HEATING APPLIANCES THAT INCLUDE A DESUPERHEATER WATER HEATER*

2.3.1 Background

ASHRAE 137 was the first standard developed that addressed combination space conditioning and potable water heating appliances. Integrated products being offered prior to the Carrier HydroTech in the early 90s were single stage air conditioners and heat pumps with desuperheaters, and a variety of field applied “add on” desuperheaters. 137 therefore dealt with only single stage equipment with desuperheaters.

2.3.2 Ratings

137 provides for the standard SEER and HSPF, along with CPFcs (Combined Performance Factor cooling season), and CPFhs (Combined Performance Factor heating season), the combined performance factors being dimensionless. The CPFcs was defined as the sum of the total space cooling provided and the useful portion of the total water-heating load divided by the total electrical energy consumed by the combined appliance (heat pump or air conditioner, electric water heater, and, if applicable, desuperheater water pump) The phrase “useful portion of the total water-heating load” refers to the fact that tank standby losses are excluded. The CPFhs is defined precisely the same except for the heating season. A CPFws (Combined Performance Factor water heating only season) was defined as that part of the year when neither space cooling or heating was required, and set equal

to the water heater EF. 137 specified that SEER and HSPF were to be determined in the normal manner, but with the desuperheater installed and filled with water. Appendix A then went on to provide a procedure for calculating Seasonal Annual Energy Consumption and Operation Costs for the Combined Appliance; Appendix B provided a procedure for calculating Seasonal and Annual Energy Consumption and Operating Costs for the Separate Heat Pump (or Air Conditioner) and Electric Water Heater of the Combined Appliance; Appendix C provided a procedure for calculating Seasonal and Annual Energy and Cost Credits for the Combined Appliance; Appendix D provided a procedure for Calculation of an Equivalent Seasonal Energy Efficiency Ratio and an Equivalent Heating Seasonal Performance Factor or an Equivalent Energy Factor; and Appendix E provided a procedure for Determination of Seasonal Combined Performance Factors for Installations Using a Separate Heat Pump (Air Conditioner) and an Electric Water Heater.

2.3.4 Calculation Methodology

Both combined cooling and heating performance were based on temperature bin calculations, with bins above 65 ^{o}F being cooling.

2.3.5 Tests and Test Conditions

The test procedure specifies 10 required tests and 3 optional tests for C_D determination. The test conditions are the same as those for AHRI 210/240.

2.3.6 Water Heater Mounting

Same as for the standard Federal water heater test procedure.

2.3.7 Standard Components

If the manufacturer neither supplied nor specified the heat pump (air conditioner), water heater, or water pump (if required), then components meeting the following criteria were to be used for testing. A first standard air conditioner was to have a space-cooling capacity of 30,000 ± 1500 Btu/h when tested at an outdoor temperature of 95 °F and indoor temperature conditions of 80 °F dry-bulb and 67 °F wet-bulb. A second standard air conditioner was to have a space-cooling capacity of 48,000 ± 2000 Btu/h at the 95 °F, 80 °F/67 °F rating conditions. These capacities were to be determined using procedures described in *ANSI/ASHRAE Standard 116-1995*. Each standard air conditioner was to be a single-speed, split system and have a seasonal energy efficiency ratio (SEER), as determined by *ANSI/ASHRAE Standard 116-1995*, that was either equal to or no more than 0.5 greater than the SEER specified as the minimum efficiency standard. The standard heat pumps were to comply with the space-cooling capacities and SEER requirements specified for the standard air conditioner. Each heat pump was to be a single-speed, split system and have a heating seasonal performance factor (HSPF), as determined by *ANSI/ASHRAE Standard 116-1995*, that was equal to or no more than 0.4 greater than the HSPF specified as the minimum efficiency standard.

2.3.8 Water Heater Storage Tank

A standard water heater was specified as an electric water heater with a vertical tank having a measured volume of 47±2 gallons. The water heater was to have an energy factor (EF), as determined by *ASHRAE Standard 118.2-1993*, that was either equal to or no more than 0.05 greater than the EF specified as the minimum efficiency standard for 52-gallon electric water heaters. The water heater was to include two heating elements that were nominally rated at 4.5 kW each. Ports for the cold-water inlet and the hot-water outlet were to be located on the top of the tank.

2.3.9 Interconnecting Potable Water Line Lengths

Where the water piping between the water heater and the desuperheater was to be field-installed, unless supplied with the desuperheater, the piping was to have the smallest diameter recommended in the manufacturer-supplied installation instructions for the total piping. If a (minimum) diameter was not specified, the diameter of the added piping was to be the same size as the fitting/ports on the desuperheater or the water heater, whichever was smaller. When adding the piping, a full-port ball or gate valve was to be installed in one of the water lines to prevent thermosiphoning when the combined appliance was tested in a space-conditioning- only mode. The total length of water piping used to connect the water heater and desuperheater was to be a minimum of 30 ft (round trip).

2.3.10 Refrigerant Line Lengths Compressor to Water HX

Additional refrigerant tubing was to be used to connect a field-installed desuperheater within the refrigeration circuit, between the compressor discharge and the heat pump reversing valve (or between the compressor and the outdoor coil of an air conditioner). A minimum of 20 to 50 ft (round trip) of additional tubing was to be used, depending on system type. The diameter of the tubing and the tubing insulation was to be selected in accordance with the installation instructions provided by the manufacturer. If not specified, tubing was to have the same diameter as the compressor discharge line. If not specified, the added tubing was to be insulated using a material having a thermal resistance (when measured flat) that was not less than 4 $h \cdot ft^2 \cdot °F/Btu$.

2.3.11 Storage Tank Temperature Control

The operation of the supplemental water heating elements within the storage tank was under manual control.

2.3.12 Storage Tank Temperature

The temperature of the water within the storage tank was to be controlled to 135 ^oF or above cut-out / 115 ^oF or lower cut-in for the upper element, and 110 ^oF or above cut-out / 100 ^oF or lower cut-in for the lower element.

Note that with manual control of the storage tank supplemental heater elements, the upper element cut-out temperature along with the lower element cut-in and cut-out temperatures were specified, as opposed to the as supplied automatic operation of the elements in the water heater test procedure.

2.3.13 Water Draw Schedule

Three consecutive draws, of 5.4, 16.1, and 10.7 gallons, starting at t=0, 68, and 118 minutes were specified. The seemingly strange water draw timing was selected so as to not coincide with the following unit operation.

2.3.14 Unit Operation

The unit was to be operated at 50% load, with 10 minutes on, 10 minutes off. The unit was to begin an on cycle at t=10 minutes.

2.3.15 Supply Water Temperature

Same as for the standard Federal water heater test procedure at 58 ^{o}F.

2.3.16 Water Draw Rate

Same as for the standard Federal water heater test procedure at a rate of 3.0 gallons per minute.

2.3.17 Water Heating Coincidence

Assumed water heating was distributed evenly over the total hours per year.

2.4 CARRIER CORPORATION HYDROTECH WAIVER, *ELECTRICALLY-DRIVEN, VARIABLE SPEED COMPRESSOR AIR-TO-AIR HEAT PUMP THAT INCLUDES AN INTEGRAL HEAT EXCHANGER AND WATER PUMP FOR THE HEATING OF DOMESTIC WATER, AND EMPLOYING A WATER SOURCE DEFROST FEATURE.*

2.4.1 Ratings

Carrier requested "Equivalent SEER" and "Equivalent HSPF", but was denied. The HydroTech 2000 was required to be rated in terms of standard SEER and HSPF and to state the (positive) difference between the annual operating cost of a stand alone water heater and the energy cost for providing the annual requirement for domestic hot water using the HydroTech 2000 connected to the stand alone water heater.

2.4.2 Indoor Air Flow & Indoor Blower Power

As specified in 210/240.

2.4.3 Water Heater Mounting

Same as for the standard Federal water heater test procedure.

2.4.4 Water Heater Storage Tank

The tank to be used for testing is an electric storage-type water heater having a measured volume of 47.0 gallons; two 4.5 kW heating elements controlled in such a manner as to prevent both elements from operating simultaneously; and an energy factor equal to 0.87.

2.4.5 Interconnecting Potable Water Line Lengths

The piping used was the same size as the connections on the water heater. Each water line between the HydroTech 2000 and the electric water heater was specified as 8 feet or less in length. All water lines were insulated with a material having a thermal resistance (R) value of not less than 4 $h \cdot ft^2 \cdot °F/Btu$.

2.4.6 Storage Tank Temperature Control

Unlike the standard Federal water heater test procedure, the operation of the supplemental water heating elements within the storage tank are under manual control.

2.4.7 Storage Tank Temperature

The control temperature for the supplemental heating elements within the storage tank are set to 135 ^{o}F cut-out / 113 ^{o}F cut-in for the upper element, and 110 ^{o}F cut-out / 100 ^{o}F cut-in for the lower element. Control temperatures for the heat pump are as supplied by the heat pump manufacturer.

Note that the upper element cut-in temperature above is specified as 113 ^{o}F, which is different from the 115 ^{o}F specified in the above ASHRAE 137-1995. This would appear to be the result of a typo someplace, but that is unknown.

2.4.8 Water Draw Schedule

Four consecutive draws, of 15, 6, 6, and 6 gallons, starting one hour apart.

Note that this is different from the EF draw schedule of 10.72 gallons each hour for 6 hours. Carrier stated in its waiver request that this draw profile was determined based on comparisons using a computer simulation of the HydroTech 2000. Using their simulation, Carrier determined that the proposed abbreviated draw schedule gave results that adequately duplicated results of a distributed draw profile. NIST evaluated the two alternatives and believed both to be satisfactory and for the purpose of a waiver DOE should allow Carrier to use the Carrier method.

2.4.9 Supply Water Temperature

Same as for the standard Federal water heater test procedure at 58 ^{o}F.

2.4.10 Water Draw Rate

Same as for the standard Federal water heater test procedure at a rate of 3.0 gallons per minute.

2.4.11 Defrost

Provides for a defrost test at 35 ^{o}F db/ 33 ^{o}F wb outdoor temperature, with the heat for defrost taken from the potable hot water tank.

2.5 NORDYNE POWERMISER WAIVER, *ELECTRICALLY-DRIVEN, SINGLE SPEED COMPRESSOR AIR-TO-AIR HEAT PUMPS HAVING A NOMINAL COOLING CAPACITY OF 65,000 BTU/HR OR LESS THAT INCLUDE AN INTEGRAL HEAT EXCHANGER AND WATER PUMP FOR THE HEATING OF DOMESTIC WATER, EITHER CONCURRENT WITH OR SEPARATE FROM THE SPACE HEATING AND COOLING MODES.*

2.5.1 Ratings

Nordyne requested, and was permitted to rate the Powermiser in terms of Combined Cooling Performance Factor (CCPF), and Combined Heating Performance Factor (CHPF). CCPF is the sum of the total space cooling load and the total domestic water heating load during the cooling season, divided by the sum of the total energy consumption used for space cooling and water heating over the same period, expressed in Btu/Wh. Similarly, CHPF is the sum of the total space heating load and the domestic water heating load during the heating season, divided by the sum of the total energy consumption used for space heating and water heating over the same period, expressed in Btu/Wh. Note that both of these factors use the same units as SEER and HSPF, rather than consistent units for energy in both the numerator and denominator (as does, for example, EF), which would have yielded dimensionless quantities. In addition the Powermiser was also required to be rated in terms of standard SEER and HSPF.

2.5.2 Calculation Methodology

Both cooling and heating performance are based on temperature bin calculations, with bins above 65 ^{o}F being cooling.

2.5.3 Tests and Test Conditions

The test procedure specifies 12 required tests and 3 optional tests for C_D determination. The test conditions are the same as those for AHRI 210/240, except for a heating test at 67 ^{o}F db / 61 ^{o}F wb versus 67 ^{o}F db / 56.5 ^{o}F wb for AHRI 210/240. The reason for this difference has not been investigated.

2.5.4 Water Heater Mounting

Per ASHRAE Standard 137, which is the same as for the standard Federal water heater test procedure.

2.5.5 Water Heater Storage Tank

As with the Carrier HydroTech waiver, the tank to be used for testing is an electric storage-type water heater having a measured volume of 47.0 gallons, with two 4.5 kW heating elements controlled in such a manner as to prevent both elements from operating simultaneously, and an energy factor equal to 0.87.

2.5.6 Interconnecting Potable Water Line Lengths

The piping size was not specified. Each water line between the Powermiser and the electric water heater was specified as 15 feet in length. All water lines were to be insulated with a material having a thermal resistance (R) value of not less than 4 $h \cdot ft^2 \cdot °F/Btu$.

2.5.7 Storage Tank Temperature Control

As with the Carrier HydroTech waiver, the operation of the supplemental water heating elements within the storage tank is under manual control.

2.5.8 Storage Tank Temperature

The temperature of the water within the storage tank is set to 135 ^{o}F cut-out / 115 ^{o}F cut-in for the upper element, and 110 ^{o}F cut-out / 100 ^{o}F cut-in for the lower element, consistent with ASHRAE 137-1995.

2.5.9 Water Draw Schedule

Three consecutive draws, of 5.4, 16.1, and 10.7 gallons, starting at t=0, 68, and 118 minutes, consistent with ASHRAE 137-1995.

2.5.10 Supply Water Temperature

Same as for the standard Federal water heater test procedure at 58 ^{o}F.

2.5.11 Water Draw Rate

Same as for the standard Federal water heater test procedure at a rate of 3.0 gallons per minute.

2.5.12 Water Heating Coincidence

Assumes water heating is distributed evenly over the total hours per year.

2.5.13 Defrost

Provides for defrost test at 35 ^{o}F db/ 33 ^{o}F wb outdoor temperature, with the heat for defrost taken from the indoor air.

2.6 ARI 290-96, *AIR-CONDITIONING AND HEAT PUMP EQUIPMENT INCORPORATING REFRIGERANT TO POTABLE WATER HEATING DEVICES*

2.6.1 General

This standard, now withdrawn, was supplemental to ARI Standard 210/240, for the purpose of evaluating the water heating and/or combined space conditioning and water heating capability of equipment covered by 210/240. While the standard identified numerous possible future equipment configurations, they are only "reserved" place holders, with the full details presented only for single stage equipment, lifted from the Nordyne waiver.

2.6.2 Ratings

The standard cooling and heating performance was calculated in terms of SEER and HSPF, respectively, per Standard 210/240, along with calculations of Combined Cooling Performance Factor (CCPF), and Combined Heating Performance Factor (CHPF), both having units of Btu/Wh, and taken from the Nordyne waiver.

2.6.3 Capacities

Ten water heating test conditions are specified to accommodate single, dual, and variable capacity units. Single and dual capacity units are a subset of the more complicated variable speed.

2.6.4 Test Conditions

The test conditions for the above tests are the same as those for AHRI 210/240.

2.6.5 Potable Water Circulating Pump Power

The water heating device may or may not have the potable water circulating pump supplied. If the pump is not supplied but is required for proper operation, the water pressure drop was required to be stated, not to exceed 2 psi. A penalty of 40 watts per gpm of recommended water flow rate was added to units where no water circulating pump was furnished, but was required for proper operation of the water heating function.

2.6.6 Interconnecting Refrigerant Line Lengths Between Compressor and Potable Water HX

For a water heating device installed remote from the component containing the compressor, it was to be tested with 15 feet of interconnection refrigerant tubing on each line, with 10 feet on each line exposed to the outside conditions. Refrigerant to water heat exchangers applied integral with the water storage tank were to be tested with 25 feet of interconnecting refrigerant tubing on each line, with 10 feet of each line exposed to the outside conditions. The line sizes, insulation and details of installation were to be in accordance with the manufacturer's published recommendations. The combined line length of both refrigerant tubing from the outdoor unit and the water piping to the water storage tank was to be 25 feet each way. The difference between 25 feet total each way and the amount of refrigerant tubing was to be made up of water piping.

2.6.7 Water Heater Storage Tank

The water heating device may or may not have a storage tank. If the storage tank was not provided by the manufacturer, the tank was to be an electric storage type water heater having a measured volume of 47.0 gallons, with two 4.5 kW heating elements controlled in such a manner as to prevent both elements from operating simultaneously, and an energy factor equal to 0.87.

2.7 DAIKIN WAIVER, *ELECTRICALLY DRIVEN, VARIABLE SPEED, CASCADE COMPRESSOR, AIR-TO-WATER HEAT PUMP WITH INTEGRATED DOMESTIC WATER HEATING.*

2.7.1 General

Daikin requested, and was permitted to rate their Altherma air-to-water heat pumps in terms of cooling energy efficiency ratio (EER) and heating coefficient of performance (COP) per European standard EN 14511. The EER is defined as the ratio of the total cooling capacity in W to the effective power input of the unit, also in W, so the result is dimensionless. COP is defined similarly – the ratio of the heating capacity in W to the effective power input of the unit, also in W. In addition the Altherma is rated in terms of a seasonal performance factor (SPF) per European standard EN 15316 for combined space heating and water heating. SPF is defined as the ratio of the total annual energy delivered to the distribution subsystem for space heating and/or domestic hot water to the total annual input of driving energy (electricity in case of electrically-driven heat pumps and fuel/heat in case of combustion engine-driven heat pumps or absorption heat pumps) plus the total annual input of auxiliary energy.

EN 14511 relates to the rating of air and water cooled air conditioners, liquid chilling packages, air-to-air, water-to-air, air-to-water and water-to-water heat pumps with electrically driven compressors when used for space heating and/or cooling. It states that it does not specifically apply to heat pumps for sanitary hot water. It goes on to state that it applies to: factory-made units that can be ducted; factory-made liquid chilling packages with integral condensers or for use with remote condensers; factory-made units of either fixed capacity or variable capacity by any means; packaged units, single split and multi split systems; single duct and double duct units; and air-to-air air conditioners which evaporate the condensate on the condenser side. EN 14511 states that it does not apply to units having their condenser cooled by air aided by the evaporation of external additional water, and to units using transcritical cycles, e.g. with CO_2 as refrigerant.

EN 15316 relates to methods for "calculation of system energy requirements and system efficiencies", consisting of thirteen sections, totaling over 600 pages. EN 15316 is a series of "systems standards, i.e. they are based on requirements addressed to the system as a whole and not dealing with requirements to the products within the system….The requirements are mainly expressed as functional requirements, i.e. requirements dealing with the function of the system and not specifying shape, material, dimensions or the like."

2.7.2 Ratings

Cooling performance is calculated in terms of EER, but as a dimensionless number as opposed to having units of Btu/Wh as used in the U.S. Heating performance is calculated in terms of COP. Cooling EER and heating COP are full load values as determined under EN 14511. Seasonal Performance Factor (SPF) for space heating plus water heating is calculated as a dimensionless number through a bin analysis presented in EN 15316. No representation is made for a Seasonal Performance Factor for the space cooling plus water heating operation.

2.7.3 Capacities

Test conditions are specified to determine full load rated capacity and efficiency. No mention is made of multi or variable capacity units. Cooling and heating capacities are termed "net values", including the effects of a portion of the indoor fan or pump power, but not including supplementary heat.

2.7.4 Entering Indoor Air Temperatures

The entering indoor air temperature conditions for EN 14511 standard rating tests of air-to-air and water-to-air equipment is specified as 80.6 ^{o}F dry bulb / 66.2 ^{o}F wet bulb for tests to determine cooling capacity and efficiency, and 68 ^{o}F dry bulb for all tests to determine heating capacity and efficiency. While these values are close to those of 210/240, they differ slightly because they have been converted from hard metric integral values.

2.7.5 Entering Outdoor Air Temperatures

EN 14511 specifies 95 ^{o}F dry bulb temperature for cooling and 44.6 / 42.8 entering dry bulb/wet bulb temperature for heating for standard rating tests of air-to-air and air-to-water equipment.

2.7.6 Entering Indoor Fluid Temperatures

For air-to-water and water-to-water systems cooling tests, EN 14511 specifies 53.6 ^{o}F entering fluid temperatures for water based equipment, and 32 ^{o}F entering fluid temperatures for brine based equipment. For heating tests, the entering fluid temperature is specified as 104 ^{o}F, except for floor heating systems, where 86 ^{o}F is used.

2.7.7 Entering Outdoor Fluid Temperatures

For water-to-air and water-to-water systems cooling tests, EN 14511 specifies a single 86 ^{o}F entering fluid temperature. Four different temperatures; 32, 50, 59, and 68 ^{o}F are used for heating, depending on system characteristics. 32 ^{o}F is used for water-to-air and water-to-water brine systems, 50 ^{o}F is used for water-to-water water systems, 59 ^{o}F is used for water-to-air water systems, and 68 ^{o}F is used for water-to-air water loop systems.

2.7.8 Indoor Air Flow

EN 14511 covers both ducted and non-ducted systems, and ducted systems may be with blower, or without blower. For non ducted units, the adjustable settings such as louvers and fan speed are set for maximum air flow. For ducted systems, the rated airflow rate given by the manufacturer is set and the resulting external static pressure (ESP) measured. The ESP is to be greater than a minimum value, which closely follows the AHRI required minimum, but not greater than 80 % of the maximum external static pressure specified by the manufacturer. If the fan of the unit has an adjustable speed, it is to be adjusted to the lowest speed that provide the minimum ESP or greater. If the maximum ESP of the unit is lower than the minimum required value, then the air flow rate is lowered to achieve an ESP equal to 80 % of the maximum ESP of the manufacturer. In case this ESP is lower than 25 Pa, the unit can be considered as a free delivery unit and be tested as a non ducted unit with an ESP of 0 Pa.

2.7.9 Indoor Blower Power

EN 14511specifies that for units which are not designed for duct connection, i.e. which do not permit any external pressure differences, and which are equipped with an integral fan, the power absorbed by the fan is to be included in the effective power absorbed by the unit. For ducted units which have indoor air-circulating blowers furnished as part of the model, a fan power adjustment is to be included in the effective power using a specified formula that considers both air flow and external static pressure differential, such that the power penalty is assessed at zero external static. For units which do not contain integral air-circulating blowers furnished as part of the unit, only the fan power required to overcome the internal resistance is included in the effective power input to the heat pump. At an internal static pressure differential of 0.30 in H_2O, the formula would require only 118 W per 1,000 cfm of indoor air circulated, or less than 33% of that required by 210/240. As with 210/240, the values calculated for blower powers are to be added to the heating capacity and subtracted from the cooling capacity.

2.7.10 Outdoor Air Flow

No mention was found related to outdoor air flow.

2.7.11 Outdoor Fan Power

No clear specification was found related to outdoor air flow fan power. Outdoor fan power is clearly included in the “total power”, and should be included in the “effective power”, which is used to calculate EER and COP, based on the wording for non ducted fan power for indoor blowers.

2.7.12 Indoor Fluid Flow

EN 14511 specifies a 9 ^{o}F temperature differential for the indoor fluid in both cooling and heating.

2.7.13 Outdoor Fluid Flow

EN 14511 specifies a 9 ^{o}F temperature differential for the outdoor fluid in cooling and 5.4 ^{o}F for heating.

2.7.14 Indoor and Outdoor Fluid Power

EN 14511 specifies that if a liquid pump is an integral part of the unit, only a fraction of the input to the pump motor is to be included in the effective power absorbed by the unit, using a specified formula that considers both fluid flow and external static pressure differential, such that the power penalty is assessed at zero external static. If no liquid pump is provided with the unit, the proportional power input which is to be included in the effective power absorbed by the unit, is calculated using the same formula. In the case of appliances designed especially to operate on a distributing network of pressurized water without water-pump, no correction is to be applied to the power input.

2.7.15 Units For Use With Remote Condenser

The power for the auxiliary liquid pump of a remote condenser is not taken into account in the effective power input.

2.7.16 Heat Recovery

EN 14511 defines heat recovery as the recovery of heat rejected by the unit(s) whose primary control is in the cooling mode by means of either an additional heat exchanger (e.g. a liquid chiller with an additional condenser) or by transferring the heat through the refrigerating system for use to unit(s) whose primary control remains in the heating mode (e.g. variable refrigerant flow) The heat recovery capacity of air-to-water and water-to-water heat pumps and liquid chilling packages is determined by measuring the output water side for the recovered heat.

2.7.17 Defrost

No specific defrost test.

2.7.18 Interconnecting Refrigerant Line Lengths

EN 14511 states, that in the case of a unit consisting of several parts, the refrigerant lines are to be installed in accordance with the manufacturer's instructions with a minimum length of 16.4 ft and a greater length to a maximum of 24.6 ft if the constraints of the test installation make 16.4 ft not possible. Further, the lines are to be installed so that the difference in elevation does not exceed 8.2 ft. The thermal insulation of the lines is to be applied in accordance with the manufacturer's instructions. Unless constrained by the design, at least half of the connecting lines are to be exposed to the outside conditions, with the rest of the lines exposed to the inside conditions.

2.7.19 Cyclic Degradation Factor

All tests are steady-state, with no consideration of cyclic performance.

2.7.20 Potable Water Heating

Daikin requested, and was permitted to rate their Altherma heat Pumps in terms of SPF per European standard EN 15316 for combined space heating and water heating. EN 15316 does not contain values for specific test condition variables, but does provide examples that use 56.3 ^{o}F as a water supply temperature, and a 140 ^{o}F water delivery temperature. Example hot water usages are also provided, with the largest being 52.8 gallons per day for a family of 3 in a dwelling with a bath and shower.

2.8 ANSI/ARI/ASHRAE ISO 13256-1:1998, *WATER-SOURCE HEAT PUMPS -- TESTING AND RATING FOR PERFORMANCE -- PART 1: WATER-TO-AIR AND BRINE-TO-AIR HEAT PUMPS*

2.8.1 Background

Prior to January 1, 2000 ground and water source heat pumps were rated in accordance with ARI Standards 320, Water-Source Heat Pumps; 325, Ground Water-Source Heat Pumps; and 330, Ground Source Closed-Loop Heat Pumps. At that time ARI and ASHRAE jointly adopted ISO Standard 13256-1-1998, "Water-Source Heat Pumps -Testing and Rating for Performance: Part 1 - Water-to-Air and Brine-to-Air Heat Pumps" as their official testing and rating standard for these equipment types.

2.8.1.1 ARI 320

Defined water-source heat pump as “typically one of multiple units using fluid circulated in a common piping loop as a heat source/heat sink. The temperature of the loop fluid is usually mechanically controlled within a moderate range of 60 ^{o}F to 90 ^{o}F.”

Testing was conducted in accordance with ASHRAE Standard 37, and did NOT include a penalty for the water side pump power. Water flow rate was set to achieve a 10 ^{o}F rise in temperature during the cooling rating test, and was held at that flow rate for the heating rating test.

2.8.1.2 ARI 325

Defined ground water-source heat pump as “typically uses water pumped from a well, lake, or stream as a heat source/heat sink. The temperature of the water is related to climatic conditions and usually ranges from 45 ^{o}F to 75 ^{o}F for deep wells.”

Testing was conducted in accordance with ASHRAE Standard 37, and did include a penalty for the water side pump power. Water flow rate was set at the manufacturers recommended flow rate, and held constant between the cooling rating test, and the heating rating test.

2.8.1.3 ARI 330

Defined ground source closed-loop heat pump as “typically uses fluid circulated through a subsurface piping loop as a heat source/heat sink. The heat exchange loop may be placed in horizontal trenches or vertical bores, or submerged in a body of surface water. The temperature of the fluid is related to climatic and operating history conditions and usually varies from 25 ^{o}F to 100 ^{o}F.”

Testing was conducted in accordance with ASHRAE Standard 37, and did include a penalty for the water side pump power. Water flow rate was set at the manufacturers recommended flow rate, and held constant between the cooling rating test, and the heating rating test.

2.8.2 Ratings

13256-1:1998 defines EER and COP but specifies that both cooling and heating performance be calculated in terms of COP. AHRI reports ratings in terms of EER for cooling and COP for heating.

2.8.3 Capacities

Test conditions are specified to accommodate single, dual, and variable capacity units. Single and dual capacity units are a subset of the more complicated variable speed. Cooling and heating capacities are termed “net values”, including the effects of a portion of the circulating-fan heat, but not including supplementary heat.

2.8.4 Entering Indoor Air Temperatures

The entering indoor air temperature conditions are specified as 80.6 ^{o}F dry bulb / 66.2 ^{o}F wet bulb for all tests to determine cooling capacities and efficiencies, and 68.0 ^{o}F dry bulb for all tests to determine heating capacities and efficiencies. While these values are close to those of 210/240, they differ slightly because they have been converted from hard metric integral values.

2.8.5 Entering Outdoor Fluid Temperatures

13256-1:1998 specifies different entering fluid temperatures for water-loop, ground-water, and ground-loop system equipment. Entering equipment conditions for water-loop systems are specified as water at 86 ^{o}F and 68 ^{o}F for cooling and heating tests respectively. Entering equipment conditions for ground-water systems are specified as water at 59 ^{o}F and 50 ^{o}F for cooling and heating tests respectively. Entering equipment conditions for ground-loop systems are specified for a test fluid of 15% sodium chloride brine at 77 ^{o}F and 32 ^{o}F for cooling and heating tests respectively at full capacity, and as 68 ^{o}F and 41 ^{o}F for cooling and heating tests respectively at part load capacity.

2.8.6 Indoor Air Flow

13256-1:1998 covers both ducted and non-ducted systems, and ducted systems may be with or without blower. Simplified, non-ducted units use the air volume flow rate resulting when the unit operates at an external static pressure of zero at an indoor fan setting specified by the manufacturer. For ducted units the air volume used is the flow rate resulting when the unit operates at an external static pressure of zero or at an indoor fan setting specified by the manufacturer, whichever is lower. For ducted units without an indoor fan installed, the pressure drop across the indoor coil assembly must not exceed 0.30 in H_2O. While the maximum permitted pressure drop across the indoor coil is identical to that for 210/240, 13256-1:1998 permits testing at zero external static pressure, which is less than that of 210/240, and not representative of actual field installations.

2.8.7 Indoor Blower Power

13256-1:1998 specifies that for units which do not have indoor air-circulating blowers furnished as part of the model, a fan power adjustment is to be included in the effective power using a specified formula that considers both air flow and internal static pressure differential. At an internal static pressure differential of 0.30 in H_2O, the formula would require only 118 W per 1,000 cfm of indoor air circulated, or under 33% of that required by 210/240. 13256-1:1998 specifies that for units which do contain integral air-circulating blowers furnished as part of the unit, only the portion of the fan power required to overcome the internal resistance is to be included in the effective power input to the heat pump. The fraction which is to be "excluded" from the total power consumed by the fan is calculated using the same formula as for the calculation of power to be "included" for units which do not have indoor air-circulating blowers furnished as part of the model, such that the power penalty is assessed at zero external static pressure. The preceding blower power calculations are identical to those in European standard EN 14511. As with 210/240, the values calculated for blower powers are to be added to the heating capacity and subtracted from the cooling capacity.

2.8.8 Outdoor Fluid Flow

31256-1:1998 specifies that heat pumps with integral liquid pumps are to be tested at the liquid flow rates specified by the manufacturer or that obtained at zero external static pressure difference, whichever provides the lower liquid flow rate. Heat pumps without integral liquid pumps are to be tested at the flow rates specified by the manufacturer. The manufacturer is to specify a single liquid flow rate for all of the tests required unless automatic adjustment of the liquid flow rate is provided by the equipment.

2.8.9 Outdoor Fluid Power

31256-1:1998 specifies that if no liquid pump is provided with the heat pump, a pump power adjustment is to be included in the effective power consumed by the heat pump, using the same formula as for the indoor air side, where pump power is proportional to flow rate and pressure drop. If a liquid pump is an integral part of the heat pump, only the portion of the pump power required to overcome the internal resistance is included in the effective power input to the heat pump. The fraction which is to be "excluded" from the total power consumed by the pump is calculated using the same formula as above. The pump power calculated by the formula seems to provide for a very nominal value. An example provided in the old ARI Standard 325 calculated 919 Watts for a pump operating at 10 gpm and 10 psi pressure differential. The ISO standard calculates 145 Watts for the same condition.

2.8.10 Interconnecting Refrigerant Line Length

31256-1:1998 specifies that for heat pumps consisting of separate matched assemblies, each refrigerant line is installed in accordance with the manufacturer's instructions with the maximum stated length or 24.6 ft, whichever is shorter. If the interconnecting tubing is furnished as an integral part of the equipment and not recommended for cutting to a shorter length, the equipment is tested with the complete length of tubing furnished. The lines are to be installed without more than 6.56 ft difference in elevation. There is no reference to line insulation.

2.8.11 Cyclic Degradation Factor

All tests are steady-state, with no consideration of cyclic performance.

2.8.12 Potable Water Heating

13256-1:1998 mentions that the equipment covered may include potable water means, but does not provide any comment as to how it would be enabled, disabled, or otherwise accounted for.

2.9 ANSI/ARI/ASHRAE ISO 13256-2:1999, *WATER-SOURCE HEAT PUMPS -- TESTING AND RATING FOR PERFORMANCE -- PART 2: WATER-TO-WATER AND BRINE-TO-WATER HEAT PUMPS*

2.9.1 General

The 13256-2:1999 requirements are generally identical to the above 13256-1:1998, except that the indoor fluid is water as opposed to air.

2.9.2 Entering Indoor Water Temperatures

The entering indoor water temperatures are specified as 53.6 ^{o}F for all tests to determine cooling capacities and efficiencies, and 104 ^{o}F for all tests to determine heating capacities and efficiencies.

2.9.3 Indoor Water Flow

13256-2:1999 covers systems both with and without indoor water pumps. Heat pumps with integral liquid pumps are tested at the liquid flow rates specified by the manufacturer or those obtained at zero external static pressure difference, whichever provides the lower liquid flow rates. Heat pumps without integral liquid pumps are tested at the flow rates specified by the manufacturer. The manufacturer is to specify a single liquid flow rate for all of the tests required unless automatic adjustment of the liquid flow rate is provided by the equipment.

2.9.4 Indoor Fluid Power

31256-2:1999 specifies that if no liquid pump is provided with the heat pump, a pump power adjustment is to be included in the effective power consumed by the heat pump, using the same formula as for outdoor fluid side of 31256-1:1998, where pump power is proportional to flow rate and pressure drop. If a liquid pump is an integral part of the heat pump, only the portion of the pump power required to overcome the internal resistance is included in the effective power input to the heat pump. The fraction which is to be “excluded” from the total power consumed by the pump is calculated using the same formula as above.

2.10 AHRI 870-2005, *PERFORMANCE RATING OF DIRECT GEOEXCHANGE HEAT PUMPS*

2.10.1 Ratings

870-2005 specifies that cooling and heating performance is calculated in terms of EER and COP respectively.

2.10.2 Capacities

Test conditions are specified to accommodate single, and multi capacity units. Cooling and heating capacities are net values, including the full effects of the circulating-fan heat, but not including supplementary heat.

2.10.3 Entering Indoor Air Temperatures

The entering indoor air temperature conditions are specified as 80 ^oF dry bulb / 67 ^oF wet bulb for all tests to determine cooling capacities and efficiencies, and 70 ^oF dry bulb for all tests to determine heating capacities and efficiencies, which is identical to 210/240.

2.10.4 Outdoor Fluid Temperatures

Because it is not practical to actually bury the outdoor refrigerant ground loop for certification testing, 870-2005 specifies that the ground loop is placed in heat exchange contact with a water bath containing 15% methanol, by weight, and controlled in temperature such that the refrigerant leaves the ground loop at 77 ^oF and 32 ^oF for full load cooling and heating tests, respectively. Refrigerant is to leave the ground loop at 70 ^oF and 41 ^oF for part load cooling and heating tests, respectively. For the heating tests, the leaving refrigerant temperatures are not specified as to whether they are saturated or actual temperature. Also, note that the 70 ^oF above for the part load cooling test is different from the 68 ^oF specified in section 2.8.5 for ground-loop systems, while the other three temperatures are identical. The reason for this is unknown.

2.10.5 Indoor Air Flow

870-2005 covers both ducted and non-ducted systems, and ducted systems may be with or without blower. Simplified, non-ducted units use the air volume flow rate resulting when the unit operates at an external static pressure of zero at an unspecified indoor fan setting. For ducted units without an indoor fan installed, the pressure drop across the indoor coil assembly must not exceed 0.30 in H_2O. Ducted systems are to be rated at the indoor-side air quantity delivered when operating against the standard AHRI minimum external, or at a lower indoor-side air quantity if so specified by the manufacturer.

2.10.6 Indoor Blower Power

870-2005 specifies that total actual blower power is used for those units with integral blowers. For units which do not have indoor air-circulating blowers furnished as part of the model, total power input for both heating and cooling is increased by 365 W per 1,000 cfm of indoor air circulated. As with 210/240, the values calculated for blower powers are to be added to the heating capacity and subtracted from the cooling capacity.

2.10.7 Interconnecting Refrigerant Line Length

870-2005 specifies that for heat pumps consisting of separate matched assemblies, ratings are to be determined with at least 25.0 ft of interconnecting tubing on each line. Heat pumps, in which the interconnecting tubing to the direct geoexchange heat exchanger is furnished as an integral part and a recommended length is furnished, are to be tested with the complete length of tubing furnished, or with 25.0 ft of tubing, whichever is greater. The line sizes, insulation and details of installation are to be in accordance with the manufacturer's published recommendations.

2.10.8 Cyclic Degradation Factor

All tests are steady-state, with no consideration of cyclic performance.

2.10.9 Potable Water Heating

870-2005 mentions that the equipment covered may include potable water means, but does not provide any comment as to how it would be enabled, disabled, or otherwise accounted for.

3. METHODS OF RATINGS SUMMARY

In reviewing all of the pertinent standards, including those for just the base units, several nearly common test condition variables were found along with several differences. Two of the nearest common test condition variables were the near use of 80/67 (dry bulb temperature- ^{o}F /wet bulb temperature- ^{o}F) for the entering indoor air temperature during cooling, and 70 (dry bulb temperature- ^{o}F) for the entering indoor air temperature during heating. The greatest disparity within the various standards is the use of a seasonal energy efficiency calculation involving cyclic performance for air source equipment, versus a simple steady state energy efficiency for water and ground source equipment. Other disparities occur in the calculation of fluid handling powers.

In reviewing the above standards and procedures, 180 test condition variables were identified that relate to rating the performance of a generic heat pump incorporating potable water heating, assuming no other functions such as thermal storage or ventilation, etc.

Certain temperature variations occur because one standard incorporated integral inch-pound numbers, versus another standard using integral metric units. Other variations occur, probably because the standards were written at different times by different organizations and/or groups of people.

The differences in the calculation of fluid handling powers are the most puzzling. It would appear that certain standards understate the indoor air handling power, and it is curious that they have not been challenged.

There were no current or past test procedures found that dealt with water or ground source heat pumps with integrated potable water heating. European standard EN 15316 presents a procedure for calculating a Seasonal Performance Factor (SPF) for water source heat pumps for the heating season but not the cooling season. The Carrier and Nordyne waivers for air source heat pumps were found to be the most complete test procedures for equipment with integrated potable water heating.

Overall, the above identified waivers, and current and past standards identify the important ratings variables, and form an excellent basis for any future, more encompassing standard.

As multiple functions are incorporated in a single piece of equipment, it would appear that the coincidence of use of those functions represents a major need for thought in the development of a test and rating standard for that equipment.

4. CONCLUSIONS

Development of a comprehensive test procedure with specified test conditions encompassing past and expected future system features would ensure equal treatment for all system types, and hopefully eliminate the need for a variety of waivers.

If this is undertaken, the following specific tasks would form a logical basis for proceeding:

1) Develop a list of system features and functions to be covered by the test procedure,
2) Develop the suggested performance metrics,
3) Develop the suggested coincidence of use patterns for the covered system functions,
4) Determine the possible implementation schemes to be covered for each of the system functions, such as for defrost; defrost heat from indoor air, defrost heat from potable water heat, defrost heat from thermal storage, defrost from direct mechanical frost harvesting, etc.,
5) Develop the suggested performance metric calculation methodology,
6) Determine the test points required to fulfill the calculation methodology,
7) Develop a uniform set of test point conditions,
8) Develop a uniform set of component operating requirements in response to compressor part load operation,
9) Develop a uniform set of fluid flow rate requirements,
10) Develop test point condition tolerances,
11) Develop instrumentation requirements,
12) Develop a uniform methodology for incorporating parasitic power, including supplemental heat, outdoor fan power, indoor blower power, outdoor pump power, indoor pump power, potable water pump power, etc.,
13) Develop a uniform set of parasitic power default values,
14) Develop system setup conditions, such as interconnecting line lengths, etc.,
15) Develop test sequence details, such as when various components begin operation in relationship to other components,
16) Develop a data reduction program to generate the performance metrics from the determined test points data,
17) Lastly, provide selected example data sets and results for the above program.

Taking a less comprehensive and more piecemeal approach would be easier and faster in the near term, but would require continual revisions in the long term.