BSR/ASHRAE Standard 221P

Public Review Draft

Test Method to Field-Measure and Score the Cooling and Heating Performance of an Installed Unitary HVAC System

Third Public Review (September 2019)
(Draft Shows Complete Proposed New Standard)

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ASHRAE, 1791 Tullie Circle, NE, Atlanta GA 30329-2305
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(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

FOREWORD

This standard provides a method to field-measure and estimate the capacity, efficiency, and score the performance of an installed Heating, Ventilating, and Air Conditioning (HVAC) system. An installed system’s performance deteriorates because of less than perfect design, installation practices, and poor maintenance. System airflow may be below the volume specified; system static pressures may be above the maximum allowable; duct systems may be undersized, poorly installed, or damaged; refrigeration circuits may be incorrectly charged; and combustion deficiencies may prohibit the delivery of equipment rated capacity.

The need for this field test method arose because laboratory rated equipment capacity and efficiency are not intended to represent actual system performance once the equipment is installed in a building. Equipment capacity and efficiency ratings are tightly regulated and accurately represent equipment performance under a specific set of test conditions. This standard does not validate or invalidate a manufacturer’s equipment energy rating or the laboratory testing performed on equipment at the time of manufacture; its purpose is to score the performance of a system, typically field-fabricated by the installing contractor which represents an end product different from the equipment it includes that has traditionally not been scored.

This test method estimates the system capacity being delivered through the supply registers for both heating and cooling systems. The Cooling and Heating System Performance Ratio (CSPr, HSPr) represent the ratio of the installed system delivered capacity divided by the expected equipment capacity under test conditions for a specific installation on a specific day in a specific geographical location. The denominator of the ratio represents the near-ideal equipment capacity given the environmental conditions present during the test. This provides a consistent, objective reference against which the system delivered capacity is compared.

For cooling systems, the standard also includes an efficiency metric. The Installed Cooling System Energy Efficiency Ratio (ICSeer) represents the installed system delivered capacity divided by the electrical power consumed by the system. This ratio is then multiplied by an adjustment factor to estimate the operating efficiency of the system under Standard Rating Conditions. The resulting metric is comparable to the rated Energy Efficiency Ratio (EER) of the equipment, but also accounts for system inefficiencies and losses.

The fundamental approaches described in this standard have been in regular use since at least 2001. The principles used in this test method are supported by numerous industry standards, which have been adapted for field measurement and taught to contractors and technicians by National Comfort Institute (NCI). These approaches formed the basis of the standard and were subsequently improved upon and vetted by a balanced committee to define consistent and repeatable test, measurement, and calculation procedures.

This test and scoring method may be used by field practitioners to score a system before and after system repairs and upgrades. The score before upgrades documents the deterioration caused by defects in the installed system and helps identify what may be done to improve the performance and efficiency of the system. The system is again tested and scored after system repairs and upgrades are completed using the same methodology. The difference between the before and after score provides an estimate of the improvement in performance and efficiency of the installed system.
BSR/ASHRAE Standard 221P, Test Method to Field-Measure and Score the Cooling and Heating Performance of an Installed Unitary HVAC System
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This standard is intended for field use to estimate the capacity and efficiency of installed systems. It is written in a language of and for field practitioners, enabling HVAC contractors, technicians, design engineers, balancing and Energy Measurement and Verification (EM&V) professionals, manufacturers, facility personnel, and commissioning agents to measure and score the installed performance of HVAC systems. It is not intended to replace, eliminate, or invalidate well-established product certification ratings or any other industry standard, but is intended to be used to augment other industry standards, codes, and regulations.

1. PURPOSE

The purpose of this standard is to prescribe a field evaluation and test method to measure and score the performance, in terms of delivered cooling or heating capacity, or cooling efficiency, of an installed unitary HVAC system.

2. SCOPE

This standard:

2.1. Defines performance scoring methods for cooling and heating system delivered capacity and cooling system efficiency;
2.2. Establishes uniform methods of measurements and testing procedures for airflow, temperature, enthalpy, and power;
2.3. Specifies test instruments, specifications, and calibration requirements for performing such measurements and tests;
2.4. Specifies data required and calculations to be used; and
2.5. Applies to single-zone unitary split and packaged direct expansion (DX) cooling, air-source heat pump, and combustion furnace HVAC systems of any capacity, and with forced-air distribution systems.

3. DEFINITIONS AND ACRONYMS

3.1. Definitions

accuracy: (1) degree of freedom from error, that is, the degree of conformity to truth or to a rule. (2) The ability of an instrument to indicate or record the true value of a measured quantity. (3) The error of indication, which is the difference between the indicated value and the true value of the measured quantity, expresses the accuracy of an instrument.

air density: the mass per unit volume of dry air.

air distribution: transportation of a specified airflow to or from the treated space, by ducts or plenums. Air-treatment devices can be added to the distribution system for the purpose of treating the air (e.g., cleaning, heating, cooling, humidifying, or dehumidifying).

air inlet: device or opening through which air is withdrawn from or a conditioned space or the outdoors (grilles, dampers, or other openings may be used as air inlets).

air velocity: rate of motion of air in a given direction, measured as distance per unit time. See also velocity.

ambient air: Air surrounding a building, the source of outdoor air brought into a building, etc. (Usually outdoor air or the air in an enclosure under study).
ambient temperature: temperature of the medium (such as air, water, or earth) into which the heat of equipment is dissipated.

balancing: the methodical proportioning of air and hydronic flows through the system mains, branches, and terminal devices using acceptable procedures to achieve the specified airflow or hydronic flow within testing, design, and installation limitations.

branch: (1) in ducts, piping, or conduit, another section of the same size or smaller, at an angle with the main. (2) section of pipe or duct from a main to a terminal device.

building official: the officer or other designated representative authorized to act on behalf of the authority having jurisdiction.

calibrate: the act of comparing an instrument of known or unknown accuracy with a standard of known accuracy to detect, correlate, report, or eliminate by adjustment any variation in the accuracy of the tested instrument.

calibration: comparison of the particular instrument with a primary standard, a secondary standard of higher accuracy than the instrument to be calibrated, or a known input source.

coil: cooling or heating element made of pipe or tube that may or may not be finned and formed into helical or serpentine shape.

compliance: act of complying with the rules or requirements of a standard.

contractor: in construction terminology, the person or entity responsible for performing the work and identified as such in an owner/contractor agreement.

cooling capacity: the rate of heat that the equipment removes from the conditioned space or heat transfer fluid in a defined interval of time, expressed in Btu/h (W).

damper: element inserted into an air-distribution system or element of an air-distribution system permitting modification of the air resistance of the system and consequently changing the airflow rate or shutting off the airflow.

design airflow: required airflow when the system is operating under assumed maximum conditions of design, including diversity.

design capacity: output capacity of a system or piece of equipment at design conditions.

design conditions: specified environmental conditions, such as temperature and light intensity, required to be produced and maintained by a system and under which the system must operate.

diffuser: circular, square, rectangular, or linear air-distribution outlet, generally located in the ceiling, and composed of deflecting members discharging supply air in various directions and planes and arranged to promote mixing of supply air with air in the treated space.

distribution system: conveying means, such as ducts, pipes, and wires, to bring substances or energy from a source to the point of use. The distribution system includes auxiliary equipment such as fans, pumps, and transformers.
**dry-bulb temperature:** temperature of air indicated by an ordinary thermometer shielded from solar and long wave radiation.

**duct system:** series of ducts, elbows, and connectors to convey air or other gases from one location to another.

**economizer:** device that, on proper variable sensing, initiates control signals or actions to conserve energy. A control system that reduces the mechanical heating and cooling requirement.

**fan or blower:** a machine used to create flow within a fluid, typically a gas, such as air.

**flow rate:** the mass or volumetric flow of a fluid per unit of time that moves past a given plane.

**forced-air distribution system:** a heating or combination heating and cooling system that uses motor-driven blowers to distribute heated, cooled, and otherwise treated air for the comfort of individuals or equipment.

**heat pump:** thermodynamic heating/refrigerating system to transfer heat. The condenser and evaporator may change roles to transfer heat in either direction. By receiving the flow of air or other fluid, a heat pump is used to cool or heat. Heat pumps may be the air source with heat transfer between the indoor air stream to outdoor air or water source with heat transfer between the indoor air stream and a hydronic source (ground loop, evaporative cooler, cooling tower, or domestic water).

**heating capacity:** the rate of heat that the equipment adds to the conditioned space or heat transfer fluid in a defined interval of time, expressed in Btu/h (W).

**HVAC system:** the equipment, distribution systems, and terminals that provide, either collectively or individually, the processes of heating, ventilating, or air conditioning to a building or portion of a building.

**model** a mathematical representation or calculation procedure that is used to predict the energy use and demand in a building or facility. Models may be based on equations that specifically represent the physical processes or may be the result of statistical analysis of energy use data.

**Pitot tube:** small bore tube inserted perpendicular to a flowing stream with its orifice facing the stream to measure total pressure. At present, the term is often used for a double-tube instrument from which the flow velocity can be calculated with one orifice facing the flowing stream to register total pressure and the other perpendicular to the stream to register static pressure.

**power factor:** (PF) a factor by which the product of voltage and current is multiplied to convert volt amperes to power in watts.

**psychrometer:** instrument with wet- and dry-bulb thermometers used to determine humidity content of air as a function of the measured value of wet- and dry-bulb temperatures.

**register:** combination grille and damper assembly over an air opening.

**relative humidity (rh, RH):** (1) ratio of the mole fraction of water vapor in air to the mole fraction of water vapor saturated at the same temperature and barometric pressure. (2) ratio of the partial pressure or density of water vapor to the saturation pressure or density, respectively, at the same dry-bulb temperature and barometric pressure of the ambient air.
residential: spaces in buildings used primarily for living and sleeping. Residential spaces include, but are not limited to, dwelling units, hotel/motel guest rooms, dormitories, nursing homes, patient rooms in hospitals, lodging houses, fraternity/sorority houses, hostels, prisons, and fire stations.

return air: air removed from a space to be recirculated or exhausted. Air extracted from a space and totally or partially returned to an air conditioner, furnace, or other heating, cooling, or ventilating system.

rh, RH: relative humidity (rh, RH).

rotating vane anemometer: device consisting of rotating-propeller-type vanes; the air velocity is indicated from the rotational speed of the vanes.

sensible heat: the energy exchanged by a thermodynamic system that relates to a change of temperature.

sensible heating capacity: the rate, expressed in Btu/h (W), at which the equipment raises the dry-bulb temperature (adds sensible heat) of the air passing through it under specified conditions of operation.

sequence of operation: an organized narration specifying how the integrated functions of a device, system, or facility will perform. It often incorporates energy efficiency and environmental concerns with detailed, comprehensive control strategies, i.e., how each individual piece of equipment will be controlled and what information and adjustment will be available to the user. These may be provided in a combination of narratives, diagrams, and point lists for every unique type of equipment and for each system.

specification: statement of a set of requirements to be satisfied by a material, product, system, or service that indicates the procedures for determining whether each of the requirements is satisfied. Informative Note: it is desirable to express the requirements numerically in terms of appropriate units, together with their limits.

standard air: dry air having a mass density of 1.2 kg/m^3 (0.075 lb/ft^3)

Standard Rating Conditions: rating conditions used as the basis of comparison of performance characteristics.

supply air: air delivered by mechanical or natural ventilation to a space, composed of any combination of outdoor air, recirculated air, or transfer air.

test port: an access hole installed by a trained and qualified testing agent into an HVAC system through which temperature, pressure, or velocity test instruments measure test data.

thermal anemometer: device that relies on the cooling effect of the airflow to change the temperature of a heated body in proportion to the air speed. Types include hot-wire anemometer, heated-bulb thermometer, heated-thermocouple anemometer, and heated-thermistor anemometer.

thermometer: instrument for measuring temperature.

thermostat: an automatic control device used to maintain temperature at a fixed or adjustable setpoint.

traverse: method of measuring air and fluid volumetric flow in ductwork and piping systems.

velocity: a measurement of the distance traveled per unit of time. This quantity is defined by its magnitude and direction at any point of the flow.
ventilation: (1) the process of supplying air to or removing air from a space for the purpose of controlling air contaminant levels, humidity, or temperature within the space. (2) the process of supplying or removing air by natural or mechanical means to or from any space. Such air is not required to have been conditioned.

ventilation air: the minimum amount of outdoor air required for the purpose of controlling air contaminant levels in buildings.

voltage: electric potential difference expressed in volts.

zone: (1) a separately controlled heated or cooled space. (2) one occupied space or several occupied spaces with similar occupancy category, occupant density, zone air distribution effectiveness, and zone primary airflow per unit area. (3) space or group of spaces within a building for which the heating, cooling, or lighting requirements are sufficiently similar that desired conditions can be maintained throughout by a single controlling device.

3.2. Abbreviations and Acronyms

AC                Alternating current
ADR<sub>e</sub>   Air Density Ratio as a function of elevation = 1.0 for sea level
AHJ              Authority having jurisdiction
AHRI             Air Conditioning, Heating and Refrigeration Institute
ANSI            American National Standards Institute
ASHRAE        American Society of Heating, Refrigerating and Air-Conditioning Engineers
Btu              British thermal unit
Btu/h            British thermal unit per hour
°C               Degrees Celsius
cfm              Cubic feet per minute (ft<sup>3</sup>/min) (L/s)
CSP-r           Cooling System Performance Ratio
<sub>C</sub>        Combustion Appliance Derating Factor
CO               Carbon Monoxide
COP              Coefficient of performance
DB               Dry bulb
DC/tdc          Direct current
EER              Energy efficiency ratio
°F               Degrees Fahrenheit
ft               Foot/feet
HVAC            Heating, ventilation, air conditioning
HSP-r           Heating System Performance Ratio
ICS-eer         Installed Cooling System EER
ICS-cop         Installed Cooling System COP
I-P             Inch-pound
in.             inch
kg               kilogram
kg<sub>da</sub>  kilograms of dry air
kPa             kilopascal
kW              kilowatt
kWh             kilowatt-hour
kJ              KiloJoules
L               liter
L/s             liters per second
lb              pound
lb<sub>da</sub>   pounds of dry air
m               meter
m³/s cubic meters per second
min minute
NCI National Comfort Institute
NIST National Institute of Standards and Technology
Pa pascal
TrueRMS True Root Mean Square
s second
SMACNA Sheet Metal and Air Conditioning Contractors National Association
VA volt-ampere
Var volt-ampere reactive
wb wet bulb

Informative Note: Symbols and Abbreviations used in formulae are described in greater detail in Informative Annex D, System Performance Calculation Background.

4. CLASSIFICATIONS

To comply with the requirements of this standard, one or more of the following installed system performance scoring methods shall be used.

4.1. Heating System Performance Ratio (HSP-r)
This test and calculation method produces an installed system heating capacity score based on the ratio of the sensible heating capacity delivered through the supply registers and return grilles divided into the manufacturer-specified gross sensible heating capacity of the equipment adjusted for ambient conditions.

4.2. Cooling System Performance Ratio (CSP-r)
This test and calculation method produces an installed system cooling capacity score based on the ratio of the total cooling capacity delivered through the supply registers and return grilles divided into the manufacturer-specified gross total cooling capacity of the equipment adjusted for ambient conditions.

4.3. Installed Cooling System EER (ICS-eer) (I-P) Installed Cooling System COP (ICS-cop) (SI)
This test and calculation method produces an installed system cooling efficiency score based on the ratio of the total cooling capacity delivered through the supply registers and return grilles divided into the measured total power consumed by the system and normalized to Standard Rating Conditions.

5. INSTALLED SYSTEM PERFORMANCE BASIC TEST AND CALCULATION PROCEDURES

This section of the standard provides an overview of the most basic forms of each of the three test and calculation methods required to score the installed system performance of a heating or cooling system with examples. Additional detail and instructions are included in Section 7 - Data Collection Procedures.

Informative note: Greater detail on the calculations used in the examples is included in Section 6, Performance Metric Calculations, and in Informative Annex D, Calculations Background. Greater detail on specific data collection and measurement requirements are included in Section 7 - Data Collection Procedures.

5.1. HSP-r Test Procedure
Heating System Performance Ratio - This test and calculation procedure as shown below describes the test procedure required to field measure and score the performance of an installed heating system, at elevations < 1000 ft (300m) having no outdoor air, or for residential systems with outdoor air inlet(s) blocked off. (See Section 6.2.1 for systems with outdoor air.)
a. Startup the system to call for maximum available heating capacity and allow the system to run for at least 15 minutes or until System Operating Requirements (see Section 7.8) are met.
b. Setup the test instrument to measure volumetric airflow corrected to CFM (L/s) of standard air. Measure the volume of airflow exiting the supply registers.
   i. Measure and record the airflow exiting each supply register.
   ii. Add together the airflow out of each supply register to find the total volume of airflow exiting the supply registers.

   Example:
   
   \[
   664 \text{ cfm} + 559 \text{ cfm} + 408 \text{ cfm} + 810 \text{ cfm} = 2441 \text{ cfm} \\
   (313 \text{ L/s} + 264 \text{ L/s} + 193 \text{ L/s} + 382 \text{ L/s} = 1152 \text{ L/s})
   \]

c. Measure the dry bulb temperature of the air exiting the supply registers and entering the return grilles.
   i. Measure and record the temperature of the air through a minimum of three or the total number of supply registers, whichever is less.
   ii. Find the average supply air temperature by adding together the measured temperatures and dividing by the number of temperatures measured.

   Example:
   
   \[
   109.4^\circ\text{F} + 108.5^\circ\text{F} + 109.1^\circ\text{F} = 327.0^\circ\text{F} \quad 327.0 ÷ 3 = 109.0^\circ\text{F} \\
   (43.0^\circ + 42.5^\circ + 42.8^\circ = 128.3^\circ) \quad 128.3 ÷ 3 = 42.8^\circ)
   \]
   iii. Measure and record the temperature of the air into a minimum of two or the total number of return grilles, whichever is less.
   iv. Find the average return air temperature by adding together the measured temperatures and dividing by the number of temperatures measured.
d. Calculate the system temperature change by subtracting the return grille average temperature from the supply register average temperature.

   Example:
   
   \[
   109.0^\circ\text{F} – 71.6^\circ\text{F} = 37.4 \, ^\circ\text{F} \\
   (42.8^\circ – 22.0^\circ = 20.8^\circ)
   \]
e. Calculate the system delivered capacity through the supply registers.
   i. Multiply the total supply register airflow by the system temperature change by 1.08 (I-P)\(^1\) or 1.206 (SI)\(^2\)

   Example:
   
   \[
   37.4^\circ\text{F} \times 2441 \text{ cfm} \times 1.08 = 98,597 \text{ Btu} \\
   (20.8^\circ \times 1152 \text{ L/s} \times 1.206 = 28,898 \text{ W})
   \]
f. Estimate the manufacturer-specified heating capacity of the equipment.

---

\(^{1}\) Informative note: 1.08 multiplier is equivalent to assumed density of 0.075 lb/ft\(^3\) x assumed specific heat of 0.24 Btu/lb\(^\circ\text{F}\) x 60 minutes per hour  

\(^{2}\) Informative note: 1.206 multiplier is equivalent to assumed density of 1.20 kg/m\(^3\) x assumed specific heat of 1.005 kJ/kg
i. When testing a gas furnace, read and record the rated equipment output.

ii. When testing a heat pump system, adjust capacity for current operating conditions using the manufacturer’s heating capacity table and the generic table in Annex E.

iii. Using the manufacturer’s heating performance data, find and record the manufacturer-specified heating capacity of the equipment under Standard Rating Conditions.

iv. Lookup the heating capacity adjustment factor for the outside air dry bulb at the time of the test in Annex E.

v. Multiply the manufacturer’s specified gross heating capacity by the heating capacity adjustment factor to find the estimated heating capacity under the test conditions.

g. Calculate the installed system performance score.

i. Divide the system delivered heating Btu/hr (W) by the equipment estimated heating capacity under test conditions to find the system HSP-r.

Example:
98,597 system delivered Btu/hr ÷ 143,000 estimated Btu/hr. = 69% HSP-r
(28,898 system delivered W ÷ 41,900 estimated W = 69% HSP-r)

5.2. CSP-r Test Procedure

Cooling System Performance Ratio - This test and calculation procedure below describes the test procedure required to field measure and score the performance of an installed cooling system having no outdoor air, or for residential systems with outdoor air inlet(s) blocked off.

a. Startup the system to call for maximum available cooling capacity and allow the system to run for at least 15 minutes or until System Operating Requirements (see Section 7.8) are met.

b. Setup the test instrument to measure volumetric airflow corrected to CFM (L/s) of standard air. Measure the volume of airflow exiting all supply registers.

i. Measure and record the airflow exiting each supply register.

ii. Add together the airflow out of each supply register to find the total volume of airflow exiting the supply registers.

Example:
664 cfm + 559 cfm + 408 cfm + 810 cfm = 2441 cfm
(313 L/s + 264 L/s + 193 L/s + 382 L/s = 1152 L/s)

c. Measure the enthalpy of the air exiting the supply registers and entering the return grilles.

i. Measure and record the temperature of the air through a minimum of three or the total number of supply registers, whichever is less.

ii. Find the average supply air enthalpy by adding the measured enthalpy values and dividing by the number of measurements.

Example:
(46.45 + 46.96 + 46.08 = 139.49 kJ/kg. 139.48 kJ/kg ÷ 3 = 46.50 kJ/kg)

iii. Measure and record the enthalpy of the air into a minimum of two or the total number of return grilles, whichever is less.
iv. Find the average return air enthalpy by adding together the measured enthalpy values and dividing by the number measurements.

d. Calculate the system enthalpy change by subtracting the supply register average enthalpy from the return grille average enthalpy.

```
Example:
26.21 Btu/lb. – 19.99 Btu/lb. = 6.22 Btu/lb
(60.96 kJ/kg – 46.50 kJ/kg = 14.46 kJ/kg)
```

e. Calculate the system delivered capacity through supply registers.
   i. Multiply the total supply register airflow by the system enthalpy change by 4.5 (I-P)³ or 1.2 (SI).

```
Example:
6.22 Btu/lb. x 2441 cfm x 4.5 = 68,323 total Btu/hr
(14.46 kJ/kg x 1152 L/s x 1.2 = 19,990 W)
```

f. Estimate the manufacturer-specified cooling capacity of the equipment.
   i. Measure and record the entering equipment wet bulb temperature.
   ii. Measure and record the outdoor air entering the condensing coil.
   iii. Using the manufacturer’s cooling performance data, find and record the manufacturer-specified gross cooling capacity of the equipment under Standard Rating Conditions.
   iv. Lookup the cooling capacity adjustment factor for the outside air dry bulb and evaporator entering wet bulb temperatures at the time of the test in Annex E.
   v. Multiply the manufacturer’s specified gross cooling capacity by the cooling capacity adjustment factor to find the estimated cooling capacity under the test conditions.

g. Calculate the installed system performance score (CSP-r)
   i. Divide the system delivered total capacity by the estimated cooling capacity under test conditions to find the system CSP-r.

```
Example:
103,056 system delivered Btu/hr ÷ 224,000 equipment rated Btu/hr = 46% CSP-r
(30,202 system delivered W ÷ 65,650 equipment rated W = 46% CSP-r)
```

5.3. ICS-eer (ICS-cop) Test Procedure

**Installed Cooling System EER (Installed Cooling System COP)** - This test and calculation procedure describes the tasks required to field measure and score the System EER of an installed cooling system EER having no outdoor air, or for residential systems with outdoor air inlet(s) blocked off.

a. Startup the system to call for maximum available cooling capacity and allow the system to run for at least 15 minutes or until System Operating Requirements (see Section 7.8) are met.

b. Setup the test instrument to measure volumetric airflow corrected to CFM (L/s) of standard air. Measure the volume of airflow exiting the supply registers.

---

3 Informative note: 4.5 multiplier is equivalent to assumed density of 0.075 lb/ft³ x 60 minutes per hour
4 Informative note: 1.20 multiplier is the assumed density of 1.20 kg/m³
i. Measure and record the airflow exiting each supply register.
ii. Add together the airflow out of each supply register to find the total volume of airflow exiting the supply registers.

Example:
664 cfm + 559 cfm + 408 cfm + 810 cfm = 2441 cfm  
(313 L/s + 264 L/s + 193 L/s + 382 L/s = 1152 L/s)

c. Measure the enthalpy of the air exiting the supply registers and entering the return grilles.
   i. Measure and record the enthalpy of the air through a minimum of three or the total number of supply registers, whichever is less.
   ii. Find the average supply air enthalpy by adding together the measured enthalpies and dividing by the number of enthalpies measured.

Example:
17.90 + 17.75 + 18.11 = 53.76 Btu/lb. ÷ 3 = 17.92 Btu/lb  
(41.64 + 41.29 + 42.12 = 125.05 kJ/kg, ÷ 3 = 41.68 kJ/kg)

   iii. Measure and record the enthalpy of the air into a minimum of two or the total number of return grilles, whichever is less.
   iv. Find the average return air enthalpy by adding together the measured enthalpies and dividing by the number of enthalpies measured.

d. Measure total equipment power and supply fan power.
   i. Measure and record the equipment power in Watts
   ii. Measure and record the fan power in Watts
   iii. Calculate the compressor and condenser outdoor fan power by subtracting the indoor fan power from the total equipment power. For split systems, the outdoor equipment power and indoor fan power shall be measured separately, eliminating the need to subtract to find compressor and condenser Watts.

Example:
5455 Total Watts – 765 Fan Watts = 4690 Compressor and Condenser Watts

e. Calculate the system enthalpy change by subtracting the supply register average enthalpy from the return grille average enthalpy.

Example
21.79 Btu/lb. – 17.92 Btu/lb. = 3.87 Btu/lb  
(50.68 kJ/kg – 41.68 kJ/kg = 9.00 kJ/kg).

f. Calculate the system delivered capacity through the supply registers.
   i. Multiply the total supply register airflow by the system enthalpy change by the total Btu/hr multiplier of 4.5 (I-P) or 1.2 (SI).  

---

5 Informative note: 4.5 multiplier is equivalent to assumed density of 0.075 lb/ft³ x 60 minutes per hour
6 Informative note: 1.20 multiplier is the assumed density of 1.20 kg/m³
g. Find the Efficiency Adjustment Factor.
   i. Measure and record the entering equipment wet bulb temperature.
   ii. Measure and record the outdoor air entering the condensing coil.
   iii. Using Appendix E find the Cooling Efficiency Adjustment Factor

Example:
For outside air dry bulb of 101°F (38.3°C) and evaporator entering wet bulb of 61°F (16.1°C), the cooling efficiency adjustment factor is 1.11

h. Calculate the Installed Cooling System EER (ICS-er) (Installed Cooling System COP (ICS-cop)).

Example:
1 ÷ [(4,690 W ÷ 42,510 Btu/h) x (1 ÷ 1.11) + (765 W ÷ 42,510 Btu/h)] = 8.5 ICS-er
(1 / [(4690 W ÷ 12,442 W) x (1 ÷ 1.11) + (765 W ÷ 12,442 W)] = 2.49 ICS-cop)

6. PERFORMANCE METRIC CALCULATIONS

6.1. Calculations for Systems without Outdoor Air Ventilation

6.1.1. Heating System Performance Ratio HSP-r without outdoor air for a gas furnace

   a. Obtain the following measurements:
   \( Q_{SN} \) = volumetric flow rate for each of \( n \) supply registers in the system (cfm) (L/s) of standard air
   \( T_{SN_{TS}} \) = dry bulb temperature for each of \( n_{TS} \) supply registers measured (°F) (°C)
   \( T_{R_{TR}} \) = dry bulb temperature for each of \( n_{TR} \) return grilles measured (°F) (°C)

   b. Calculate the total supply register flow rate
   Add all individual supply register airflow measurements to find the total airflow through the supply registers.
   \( Q_S = Q_{S1} + Q_{S2} + \cdots + Q_{Sn} \) = total volumetric flow rate for all supply registers (cfm) (L/s) of standard air

   Where:
   \( n \) = total number of supply registers in the system

   c. Calculate the average supply register and return grille temperature
   Add the supply register temperature measurements together, then divide by the number of measurements taken.
   \( T_S = \frac{T_{S1} + T_{S2} + \cdots + T_{SN_{TS}}}{n_{TS}} \) = average supply register temperature (°F) (°C)
   Add the return grille temperature measurements together, then divide by the number of measurements taken.
\[ T_R = \frac{T_{R1} + T_{R2} + \ldots T_{RnTR}}{n_{TR}} = \text{average return grille temperature (°F) (°C)} \]

Where:

- \( n_{TS} \) = total number of supply registers for which a measurement was made
- \( n_{TR} \) = total number of return grilles for which a measurement was made

d. **Calculate the heating system capacity**

\[
q_{H\text{system}} = q_{H\text{system(I-P)}} = 1.08 \times Q_s \times (T_S - T_R) \\
q_{H\text{system(SI)}} = 1.206 \times Q_s \times (T_S - T_R)
\]

Where:

- \( q_{H\text{system}} \) = measured system delivered heating capacity (Btu/hr) (W)
- 1.08 = Heating Btu/hr units Multiplier (I-P)\(^7\)
- 1.206 = Heating Watt units Multiplier (SI)\(^8\)
- \( Q_s(I-P) \) in units cfm
- \( Q_s(SI) \) in units L/s
- \( (T_S - T_R)(I-P) \) in units °F
- \( (T_S - T_R)(SI) \) in units °C

e. **Estimate the manufacturer-specified equipment capacity under measurement conditions**

Find the rated heating output capacity for the furnace.

\[ q_{H\text{rated}} = \text{rated gross heating output capacity (Btu/hr) (W)} \]

For sites at elevations less than 1000 ft (300 m) above sea level, assume that the manufacturer’s specified capacity under measurement conditions is the same as \( q_{H\text{spec}} \).

\[ q_{H\text{spec}} = q_{H\text{rated}} \]

For sites at elevations greater than 1000 ft (300 m) above sea level, de-rate the heating capacity of the equipment for elevations other than sea level using manufacturer specifications or **Table 1** (I-P) or **Table 2** (SI).

---

\(^7\) Informative note: 1.08 multiplier is equivalent to assumed density of 0.075 lb/ft\(^3\) x assumed specific heat of 0.24 Btu/lb°C x 60 minutes per hour

\(^8\) Informative note: 1.206 multiplier is equivalent to assumed density of 1.20 kg/m\(^3\) x assumed specific heat of 1.005 kJ/kg
Table 1 Combustion Appliance Derating Factors by Elevation

<table>
<thead>
<tr>
<th>Z - Site elevation - ft above sea level</th>
<th>Combustion Appliance Derating Factor C_H</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>0.96</td>
</tr>
<tr>
<td>2000</td>
<td>0.93</td>
</tr>
<tr>
<td>3000</td>
<td>0.90</td>
</tr>
<tr>
<td>4000</td>
<td>0.86</td>
</tr>
<tr>
<td>5000</td>
<td>0.83</td>
</tr>
<tr>
<td>6000</td>
<td>0.80</td>
</tr>
<tr>
<td>7000</td>
<td>0.77</td>
</tr>
<tr>
<td>8000</td>
<td>0.74</td>
</tr>
<tr>
<td>9000</td>
<td>0.71</td>
</tr>
<tr>
<td>10000</td>
<td>0.69</td>
</tr>
<tr>
<td>11000</td>
<td>0.66</td>
</tr>
<tr>
<td>12000</td>
<td>0.64</td>
</tr>
<tr>
<td>13000</td>
<td>0.61</td>
</tr>
<tr>
<td>14000</td>
<td>0.59</td>
</tr>
<tr>
<td>15000</td>
<td>0.56</td>
</tr>
</tbody>
</table>

Table 2 SI Combustion Appliance Derating Factors by Elevation

<table>
<thead>
<tr>
<th>Z – Site elevation – meters above sea level</th>
<th>Combustion Appliance Derating Factor C_H</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>0.96</td>
</tr>
<tr>
<td>600</td>
<td>0.93</td>
</tr>
<tr>
<td>900</td>
<td>0.90</td>
</tr>
<tr>
<td>1200</td>
<td>0.86</td>
</tr>
<tr>
<td>1500</td>
<td>0.83</td>
</tr>
<tr>
<td>1800</td>
<td>0.80</td>
</tr>
<tr>
<td>2100</td>
<td>0.77</td>
</tr>
<tr>
<td>2400</td>
<td>0.74</td>
</tr>
<tr>
<td>2700</td>
<td>0.71</td>
</tr>
<tr>
<td>3000</td>
<td>0.69</td>
</tr>
<tr>
<td>3300</td>
<td>0.66</td>
</tr>
<tr>
<td>3600</td>
<td>0.64</td>
</tr>
<tr>
<td>3900</td>
<td>0.61</td>
</tr>
<tr>
<td>4200</td>
<td>0.59</td>
</tr>
<tr>
<td>4500</td>
<td>0.57</td>
</tr>
</tbody>
</table>

Use of Table 1 or Table 2 yields a gas heating elevation deration factor C_H. This factor is multiplied by q_Hrated to yield the estimated gross heating capacity under measurement conditions q_Hspec.

\[ q_{Hspec} = C_H \times q_{Hrated} \]

Use of the manufacturer specifications yields a value for q_Hspec directly. Some manufacturers and The National Fuel Gas Code (NFPA 54) specify a rule of thumb derating factor, for example: de-rate by 4% for every 1000 feet (300m) over 2000 feet (600m) above sea level. In cases where the manufacturer specifies a rule of thumb such as this, Table 1 or Table 2 shall be used.

f. Calculate Heating System Performance Ratio HSP-r

\[ HSP-r = \frac{q_{Hsystem}}{q_{Hspec}} \]

Express as a percentage rounded to the nearest 1%.

6.1.2. Cooling System Performance Ratio CSP-r Without Outdoor Air

a. Obtain the following measurements:

- Q_Sn = volumetric flow rate for each of n supply registers in the system (cfm) (L/s) of standard air
- h_{SnS} = enthalpy for each of n_{SnS} supply registers measured (Btu/lb) (kJ/kg)
- h_{RnR} = enthalpy for each of n_{RnR} return grilles measured (Btu/lb) (kJ/kg)
- T_{wb_emt} = wet bulb temperature of air entering the equipment from the return duct (°F) (°C)
- T_{oa} = outdoor air dry bulb temperature (°F) (°C)

b. Calculate the total supply register flow rate
Add all individual supply register airflow measurements to find the total airflow through the supply registers.

\[ Q_S = Q_{S1} + Q_{S2} + \cdots + Q_{Sn} = \text{total volumetric flow rate for all supply registers (cfm) (L/s)} \]

of standard air

Where:

\( n = \text{total number of supply registers in the system} \)

c. Calculate the average supply register and return grille enthalpy

Add the supply register enthalpy measurements together, then divide by the number of measurements taken.

\[ h_S = \frac{h_{s1} + h_{s2} + \cdots + h_{sn}}{n_{hs}} = \text{average supply register enthalpy (Btu/lb)(kJ/kg)} \]

Add the return grille enthalpy measurements together, then divide by the number of measurements taken.

\[ h_R = \frac{h_{r1} + h_{r2} + \cdots + h_{rnr}}{n_{hr}} = \text{average return grille enthalpy (Btu/lb)(kJ/kg)} \]

Where:

\( n_{hs} = \text{total number of supply registers for which an enthalpy measurement was made} \)

\( n_{hr} = \text{total number of return grilles for which an enthalpy measurement was made} \)

d. Calculate system capacity

\[ q_{c_{\text{system}}} = q_{c_{\text{system}(I-P)}} = 4.5 \times Q_S \times (h_R - h_S) \]

\[ q_{c_{\text{system}(SI)}} = 1.2 \times Q_S \times (h_R - h_S) \]

Where:

\( q_{c_{\text{system}}} = \text{measured system delivered cooling capacity (Btu/hr) (W)} \)

\( 4.5 = \text{Cooling Btu/hr units Multiplier (I-P)}^9 \)

\( 1.20 = \text{Cooling Watt units Multiplier (SI)}^{10} \)

\( Q_s(I-P) \text{ in units cfm of standard air} \)

\( Q_s(SI) \text{ in units L/s of standard air} \)

\( (h_R - h_S)(I-P) \text{ in units Btu/lb} \)

\( (h_R - h_S)(SI) \text{ in units kJ/kg} \)

e. Estimate the manufacturer-specified equipment capacity under measurement conditions

Use manufacturer’s performance data and the generic data provided in Annex E to estimate the expected equipment performance given the measured Toa and Twent temperatures.

Annex E provides a capacity adjustment factor. This factor must be multiplied by the manufacturer-specified gross cooling capacity of the equipment under Standard Rating Conditions to estimate the cooling capacity under measurement conditions.

\[ q_{\text{spec}} = C_c \times q_{\text{rated}} \]

Where:

\( q_{c_{\text{spec}}} = \text{estimated equipment gross cooling capacity under measurement conditions (Btu/hr) (W)} \)

\( C_c = \text{capacity adjustment factor (unitless)} \)

\( q_{\text{rated}} = \text{manufacturer-specified gross cooling capacity under Standard Rating Conditions (Btu/hr) (W)} \)

When using manufacturer data that includes airflow as an input, assume airflow equal to 400 cfm/ton [54 L/s per kW] of nominal cooling capacity, or the airflow that the equipment is specified at, if known. When using manufacturer’s data, the result will be a direct lookup of \( q_{\text{spec}} \) from a table.

---

9 Informative note: 4.5 multiplier is equivalent to assumed density of 0.075 lb/ft³ x 60 minutes per hour

10 Informative note: 1.20 multiplier is the assumed density of 1.20 kg/m³
f. Calculate Cooling System Performance Ratio CSP-r
\[
CSP-r = \frac{q_{\text{system}}}{q_{\text{spec}}} = \text{Cooling System Performance Ratio CSP-r (Btu/hr per Btu/hr) (W per W)}
\]
Express as a percentage rounded to the nearest 1%.

6.1.3. Installed Cooling System Energy Efficiency Ratio ICS-eer (Installed Cooling System COP ICS-cop) Without Outdoor Air

a. Obtain all measurements listed in 6.2.2 a. for CSP-r in addition to:
\[P_{\text{equip}} = \text{total equipment power (W)}\]
\[P_{\text{fan}} = \text{supply air fan power (W)}\]

b. Calculate cooling system delivered capacity
Use 6.1.2 b. through 6.1.2 d. for the Cooling System Performance Ratio CSP-r to calculate the cooling system delivered capacity \(q_{\text{system}}\).

c. Calculate compressor and condenser power
When the total system power measurement includes the supply fan power, the compressor and condenser power must be calculated to facilitate normalization of the ICS-eer metric to Standard Rating Conditions.
\[P_{\text{cc}} = P_{\text{equip}} - P_{\text{fan}} = \text{compressor and condenser power (W)}\]

d. Find the efficiency adjustment factor
Use the generic adjustment factors for \(C_E\) provided in Annex E to estimate the expected equipment efficiency relative to rated efficiency given the measured \(T_{oa}\) and \(T_{wbent}\) temperatures relative to the rated equipment efficiency.

Where:
\[C_E = \text{efficiency adjustment factor (unitless)}\]

e. Calculate Cooling System Installed Cooling System Energy Efficiency Ratio ICS-eer (Installed Cooling System COP ICS-cop)
\[
ICS_{EER}(ICS_{COP}) = \frac{1}{\frac{P_{\text{cc}}}{q_{\text{sys}}} \times \frac{1}{C_E} + \frac{P_{\text{fan}}}{q_{\text{sys}}}}
\]
Express in decimal notation rounded to the nearest tenth.

6.2. Calculations for Systems with Outdoor Air Ventilation

6.2.1. Heating System Performance Ratio HSP-r with outdoor air

a. Obtain the following measurements:
\[Q_{Sn} = \text{volumetric flow rate for each of n supply registers in the system (cfm) (L/s) of standard air}\]
\[Q_{oa} = \text{volumetric flow rate of outdoor air (cfm) (L/s) of standard air}\]
\[T_{SnTS} = \text{dry bulb temperature for each of n supply registers measured (°F) (°C)}\]
\[T_{RNTG} = \text{dry bulb temperature for each of n return grilles measured (°F) (°C)}\]
\[T_{ent} = \text{dry bulb temperature of air entering the equipment from the return duct before mixing with outdoor air (°F) (°C)}\]
\[T_{oa} = \text{outdoor air dry bulb temperature (°F) (°C)}\]

b. Calculate the total supply register flow rate
Add all individual supply register airflow measurements to find the total airflow through the supply registers. Add all individual return grille airflow measurements to find the total airflow through the return grilles.

\[ Q_S = Q_{S1} + Q_{S2} + \cdots + Q_{Sn} = \text{total volumetric flow rate for all supply registers (cfm) (L/s)} \]

Where:
- \( n \) = total number of supply registers in the system

c. Calculate the average supply register and return grille temperature

Add the supply register temperature measurements together, then divide by the number of measurements taken. Add the return grille temperature measurements together, then divide by the number of measurements taken.

\[ T_S = \frac{T_{S1} + T_{S2} + \cdots + T_{Sn}}{n_{TS}} = \text{average supply register temperature (°F) (°C)} \]
\[ T_R = \frac{T_{R1} + T_{R2} + \cdots + T_{Rn}}{n_{TR}} = \text{average return grille temperature (°F) (°C)} \]

Where:
- \( n_{TS} \) = total number of supply registers for which an enthalpy measurement was made
- \( n_{TR} \) = total number of return grilles for which an enthalpy measurement was made

d. Calculate system capacity

\[ q_{H\text{system}} = q_{H\text{system}(I-P)} = 1.08 \times Q_S \times (T_S - T_R) - 1.08 \times Q_{oa} \times (T_{oa} - T_{ent}) \]
\[ q_{H\text{system}(SI)} = 1.206 \times Q_S \times (T_S - T_R) - 1.206 \times Q_{oa} \times (T_{oa} - T_{ent}) \]

Where:
- \( q_{system} \) = measured system delivered capacity (Btu/hr) (W)
- 1.08 = Heating Btu/hr units Multiplier (I-P)\(^{11}\)
- 1.206 = Heating Watt units Multiplier (SI)\(^{12}\)

e. Estimate the manufacturer-specified equipment capacity under measurement conditions

Find the manufacturer-specified heating output capacity for the furnace.

\[ q_{H\text{rated}} = \text{rated gross heating output capacity (Btu/hr) (W)} \]

For sites at elevations less than 1000 feet above sea level, assume that the manufacturer’s specified capacity under measurement conditions is the same as \( q_{H\text{rated}} \).

\[ q_{H\text{spec}} = q_{H\text{rated}} \]

For sites at elevations greater than 1000 ft (300 m) above sea level, de-rate the heating capacity of the equipment for elevations other than sea level using manufacturer specifications or Table 1 or Table 2.

Use of Table 1 or Table 2 yields a gas heating elevation deration factor \( C_H \). This factor is multiplied by \( q_{H\text{rated}} \) to yield the estimated heating capacity under measurement conditions \( q_{H\text{spec}} \).

\[ q_{H\text{spec}} = C_H \times q_{H\text{rated}} \]

Use of the manufacturer specifications yields a value for \( q_{H\text{spec}} \) directly. Some manufacturers and The National Fuel Gas Code (NFPA 54) specify a rule of thumb derating factor, for example: de-rate by 4% for every 1000 feet (300m) over 2000 feet (600m) above sea level. In cases where the manufacturer specifies a rule of thumb such as this, Table 1 or Table 2. shall be used.

f. Calculate Heating System Performance Ratio HSP-r

\(^{11}\) Informative note: 1.08 multiplier is equivalent to assumed density of 0.075 lb/ft\(^3\) x assumed specific heat of 0.24 Btu/lb°F x 60 minutes per hour

\(^{12}\) Informative note: 1.206 multiplier is equivalent to assumed density of 1.20 kg/m\(^3\) x assumed specific heat of 1.005 kJ/kg
6.2.2. Cooling System Performance Ratio CSP-r with outdoor air

a. Obtain the following measurements:
\[ Q_{Sn} = \text{volumetric flow rate for each of } n \text{ supply registers in the system (cfm) (L/s) of standard air} \]
\[ Q_{oa} = \text{volumetric flow rate of outdoor air (cfm) (L/s) of standard air} \]
\[ h_{Snhs} = \text{enthalpy for each of } n \text{ supply registers measured (Btu/lb) (kJ/kg)} \]
\[ h_{Rnhs} = \text{enthalpy for each of } n \text{ return grilles measured (Btu/lb) (kJ/kg)} \]
\[ h_{oa} = \text{enthalpy of outdoor air (Btu/lb) (kJ/kg)} \]
\[ h_{ent} = \text{enthalpy of air entering the equipment from return duct before mixing with outdoor air (Btu/lb) (kJ/kg)} \]
\[ T_{wb_{oa}} = \text{outdoor air wet bulb temperature (°F) (°C)} \]
\[ T_{wb_{bent}} = \text{wet bulb temperature of air entering the equipment from the return duct before mixing with outdoor air (°F) (°C)} \]
\[ T_{oa} = \text{outdoor air dry bulb temperature (°F) (°C)} \]
\[ Z = \text{site elevation (ft) (m)} \]

b. Calculate the total supply register flow rate
Add all individual supply register airflow measurements to find the total airflow through the supply registers.
\[ Q_S = Q_{S1} + Q_{S2} + \cdots + Q_{Sn} = \text{total volumetric flow rate for all supply registers (cfm) (L/s) of standard air} \]
Where:
\[ n_{hs} = \text{total number of supply registers for which an enthalpy measurement was made} \]

c. Calculate the average supply register and return grille enthalpy
Add the supply register enthalpy measurements together, then divide by the number of measurements taken. Add the return grille enthalpy measurements together, then divide by the number of measurements taken.
\[ h_S = \frac{h_{S1} + h_{S2} + \cdots + h_{Sn}}{n_{hs}} = \text{average supply register enthalpy (Btu/lb) (kJ/kg)} \]
\[ h_R = \frac{h_{R1} + h_{R2} + \cdots + h_{Rn}}{n_{hr}} = \text{average return grille enthalpy (Btu/lb) (kJ/kg)} \]
Where:
\[ n_{hs} = \text{total number of supply registers for which an enthalpy measurement was made} \]
\[ n_{hr} = \text{total number of return grilles for which an enthalpy measurement was made} \]

d. Calculate system capacity
\[ q_{c_{system}} = q_{c_{system(I-P)}} = 4.5 \times Q_S \times (h_R - h_S) + 4.5 \times Q_{oa} \times (h_{oa} - h_{ent}) \]
\[ q_{c_{system(SI)}} = 1.2 \times Q_S \times (h_R - h_S) + 1.2 \times Q_{oa} \times (h_{oa} - h_{ent}) \]
Where:
\[ q_{c_{system}} = \text{measured system delivered cooling capacity (Btu/hr) (W)} \]
4.5 = Cooling Btu/hr units Multiplier (I-P)\(^{13}\)
1.20 = Cooling Watt units Multiplier (SI)\(^{14}\)

e. Calculate the average coil entering wet bulb temperature

---

\(^{13}\) Informative note: 4.5 multiplier is equivalent to assumed density of 0.075 lb/ft\(^3\) x 60 minutes per hour
\(^{14}\) Informative note: 1.20 multiplier is the assumed density of 1.20 kg/m\(^3\)
BSR/ASHRAE Standard 221P, Test Method to Field-Measure and Score the Cooling and Heating Performance of an Installed Unitary HVAC System
Subsequent Full Public Review Draft

\[
T_{wb_{coil}} = \frac{Q_{oa}}{Q_s} \times T_{wb_{oa}} + \left(\frac{Q_s - Q_{OA}}{Q_s}\right) \times T_{wb_{ent}}
\]

Where:
\(T_{wb_{coil}}\) = average coil entering wet bulb temperature (°F) (°C)

f. **Estimate the manufacturer-specified equipment capacity under measurement conditions**

Use manufacturer’s performance data and the generic data provided in Annex E to estimate the equipment performance given the measured Toa and Twbcoil temperatures. Annex E provides a capacity adjustment factor. This factor must be multiplied by the manufacturer-specified gross cooling capacity of the equipment under *Standard Rating Conditions* to estimate the cooling capacity under measurement conditions.

\[
q_{system} = C_c \times q_{rated}
\]

Where:
\(q_{system}\) = estimated equipment gross cooling capacity under measurement conditions (Btu/lb) (kJ/kg)
\(C_c\) = capacity adjustment factor (unitless)
\(q_{rated}\) = manufacturer-specified gross cooling capacity under *Standard Rating Conditions* (Btu/lb) (kJ/kg)

When using manufacturer data that includes airflow as an input, assume nominal cooling airflow for the equipment (400 cfm/ton [54 L/s per kW] of nominal cooling capacity), or the airflow that the equipment is specified at, if known. When using manufacturer’s data, the result will be a direct lookup of the manufacturer-specified equipment total capacity under measurement conditions from a manufacturer provided table.

g. **Calculate Cooling System Performance Ratio CSP-r**

\[
CSP-r = \frac{q_{system}}{q_{spec}} = \frac{Cooling System Performance Ratio CSP-r}{unitless}
\]

6.2.3. **Installed Cooling System Energy Efficiency Ratio ICS-eer (Installed Cooling System COP ICS-cop) with outdoor air**

a. **Obtain all measurements listed in step 1. for CSP-r in addition to:**
\(P_{equip}\) = total equipment power (W)
\(P_{fan}\) = supply fan power (W)

b. **Calculate cooling system delivered capacity**

Use steps b through d for the Cooling System Performance Ratio CSP-r to calculate the cooling system delivered capacity \(q_{system}\).

c. **Calculate compressor and condenser power**

When the total system power measurement includes the supply fan power, the compressor and condenser power must be calculated to facilitate normalization of the ICS-eer metric to *Standard Rating Conditions*. \(P_{cc} = P_{equip} - P_{fan}\) = compressor and condenser power (W)

d. **Calculate the average coil entering wet bulb temperature**

\[
T_{wb_{coil}} = \frac{Q_{oa}}{Q_s} \times T_{wb_{oa}} + \left(\frac{Q_s - Q_{OA}}{Q_s}\right) \times T_{wb_{ent}}
\]

e. **Find the efficiency adjustment factor**
Use the generic adjustment factors for $C_E$ provided in Annex E to estimate the expected equipment efficiency relative to rated efficiency given the measured $T_{oa}$ and $T_{wb,coil}$ temperatures relative to the rated equipment efficiency.

Where:
$C_E = \text{efficiency adjustment factor (unitless)}$

f. Calculate Installed Cooling System Energy Efficiency Ratio ICS-eer (Installed Cooling System COP ICS-cop)

$$ICS_{BEE}(ICS_{COP}) = \frac{1}{\frac{p_{cc}}{q_{sys}} + \frac{1}{C_E} + \frac{p_{fan}}{q_{sys}}}$$

6.3. Variations for Different Types of Heat

6.3.1. HSP-r for Air Source Heat Pumps
In addition to the variables needed to calculate HSP-r for a gas furnace, collect $T_{oa}$ regardless of whether the unit provides outdoor air ventilation. $T_{oa}$ will then be used with Annex E to estimate the expected equipment performance given the measured $T_{oa}$ temperature.

Annex E provides a capacity adjustment factor. This factor must be multiplied by the manufacturer-specified heating capacity of the equipment under Standard Rating Conditions to estimate the heating capacity under measurement conditions.

$$q_{HSpec} = C_{HP} \times q_{Hrated}$$

Where:
$q_{HSpec} = \text{estimated equipment capacity under measurement conditions (Btu/lb) (kJ/kg)}$
$C_{HP} = \text{heat pump capacity adjustment factor (unitless)}$
$q_{Hrated} = \text{rated capacity under Standard Rating Conditions (Btu/lb) (kJ/kg)}$

When using manufacturer data that includes airflow as an input, assume nominal cooling airflow for the equipment (400 cfm/ton [54 L/s per kW] of nominal cooling capacity, adjusted for air density), or the airflow that the equipment is specified at, if known. When using manufacturer’s data, the result will be a direct lookup of the manufacturer-specified equipment heating capacity under measurement conditions from a table.

All other calculation procedures are consistent with the procedures for a gas furnace.

6.3.2. Electric Resistance Heat
Electric resistance heating capacities are published in terms of rated kW and are not meaningfully affected by airflow or temperature. To convert the rated kW to Btu/h for I-P, use the following formula:

$$\frac{Btu}{hr} = kW \times 3412$$

For SI convert kW to W:

$$W = kW \times 1000$$

7. DATA COLLECTION PROCEDURES

7.1. Test Technician Qualifications
Tests shall be conducted by a Qualified Individual, defined as personnel who possess the following:

a. Experiential knowledge of HVAC system installation, repair, service, troubleshooting, operation
b. Understanding of HVAC equipment and system configuration details for the system being tested
c. Ability to manipulate the control system of the system being tested, including ability to command the *supply air fan* to run at various speeds specified for heating or cooling, command outdoor air *dampers* to move to minimum position, and command heating or cooling to operate at full capacity
d. Knowledge of electrical system safety and specific procedures to safely take electrical measurements including *voltage*, amperage, and wattage on live circuits
e. Demonstrated skill in taking measurements with the various instrumentation required for all measurements, including electrical, airflow, temperature, and enthalpy
f. Proficiency in basic algebra, including named variable substitution, order of operations
g. Knowledge of relevant national, state, and local laws and industry standards and practices

This definition shall not supersede any additional qualifications required by national, state, and local laws.

7.2. Obtain Project Plans and Equipment Specifications.
This section sets forth the procedures and calculations required for compliance with this standard to complete the planning, preparation, tests, and calculations required to score the performance of an installed *HVAC system*.

7.2.1. Contact owner or owner’s representative
a. Request required plans and *specifications*.

7.2.2. Obtain and review project plans and equipment *specifications*
a. When plans and *specifications* are received, review and verify that the required design data is available within the documents. Required design data is listed in 7.3.
b. If plans are unavailable, a note shall be made indicating that fact, and the test practitioner shall draw a system schematic. Include at a minimum the following:
   1. The floor plan of the area served by the system,
   2. Equipment and control locations,
   3. The *distribution system* layout,
   4. Supply *register* locations,
   5. Return grille locations, and
   6. Document presence of factory or field-installed options and accessories, including economizers, other dampers, filters of a type or rating other than those specified by the manufacturer, humidifiers or dehumidifiers, auxiliary cooling or heating coils, and other auxiliary heating devices.
c. When equipment *specifications* are not provided by the owner or owner’s representative, *specifications* shall be obtained from manufacturer for cooling performance data and heating performance data.

7.3. Gather Customer and Project Information
The name and contact information of the customer, project, and testing company shall be recorded within the System Performance Scoring Report.

7.3.1. Record specified customer contact information. At a minimum, the following shall be recorded in the System Performance Scoring Report:
a. Customer name,
b. Customer address,
c. Customer phone number(s) and/or customer email.

7.3.2. Record project site data. At a minimum, the following shall be recorded in the System Performance Scoring Report:
a. Project site name,
b. Project site address,
c. Project site phone number, and
d. Project site elevation.

7.3.3. Testing Company and Technician. At a minimum, the following shall be recorded in the System Performance Scoring Report:
   a. Name of testing agency or company,
   b. Company address,
   c. Company phone number,
   d. Testing technician name, and
   e. List of instruments including make, model, and serial number used to gather test data.

7.4. Prepare design portion of System Performance Scoring Report
Prior to field testing, the test practitioner shall prepare a copy of the System Performance Scoring Report matching the type and mode of the system being tested. At a minimum, the following system design data shall be recorded in the design portion of the report.

7.4.1. Record equipment data. At a minimum, the following equipment data shall be recorded in the design portion of the report:
   a. Equipment manufacturer name
   b. Equipment model number
   c. Equipment serial number
   d. Nominal tonnage (outdoor unit)
   e. Rated heating output capacity
   f. Nominal rated fan airflow
   g. Rated cooling EER.

7.4.2. Record system data. At a minimum, the following system data shall be recorded in the design portion of the report:
   a. System mark, name, or identification number
   b. Name of area served by the system
   c. Room name containing each supply register
   d. Assign a name or number for each supply register and enter onto the report and onto the system schematic.

7.4.3. Variations to report preparation
   a. Split system equipment shall require data on both the indoor and outdoor equipment, including model number, serial number, and nominal tonnage.
   b. All equipment manufacturer, model, and serial numbers shall be listed within the System Performance Scoring Report.
   c. When system includes an economizer, the economizer manufacturer and model number shall be listed within the System Performance Scoring Report.

7.5. Inspect the system being tested
Prior to testing the system, the test practitioner shall inspect the system and note obvious installation defects within the System Scoring Report.

   a. Walk or crawl the system ensuring the installation is complete and functional.
   b. When testing a new system, verify the installation is complete and functional.
   c. When the system is existing, inspect and test the system in its as-found condition.
7.6. Install Test Ports
To provide access for the test instruments and probes into the fluid flow, test ports shall be installed into the system at locations meeting the requirements of the test procedures.

7.6.1. Air sampling test ports
a. Locate and install required temperature and/or traverse test ports in preparation for field testing of the system
b. Test ports shall be installed by drilling a hole appropriate for the diameter of the probe to be used into the duct or equipment where required by the test procedures.
c. Inspect behind any test sites before drilling to assure no damage will occur to any system components.
d. Use a drill bit sheath or drill stop to avoid over-penetration.
e. Each test port shall be sealed with a removable plastic or silicone hole-plug or other removable sealing device when testing is complete.

7.7. System Start-up Procedure
The system shall be started up in either full cooling or heating operation and shall be allowed to run until System Operating Requirements (Sections 5.1.1, 5.1.2) are met.

7.7.1. Heating mode system startup
a. The outdoor air temperature shall be less than or equal to 66°F (18.6°C) for all heating mode testing. When testing a heat pump, the outdoor air temperature shall also be greater than or equal to 35°F (1.7°C) unless the equipment is designed to operate in heat pump only mode without auxiliary heating at lower outdoor air temperatures. Manufacturer’s specifications must be used to determine manufacturer-specified heating capacity if the test is performed below 35°F (1.7°C).
b. The test practitioner shall manipulate the controls to call for all stages of heating operation
c. Auxiliary humidification or dehumidification devices shall not be in operation
d. When a system has an airside economizer, economizer controls shall be set to call for the damper motor to move the louvers to the position assigned for minimum ventilation airflow. If economizer controls, damper motor, or louvers are inoperable, the system shall be tested in as-found condition.
e. When testing a new system, the test practitioner shall ensure air filters and coils are clean.
f. Existing systems shall be tested in as-found condition.
g. During testing, exterior windows shall be closed and internal doors shall be in a typical use open or closed position. Any auxiliary exhaust fans not normally in use shall be off.
h. When the building includes a separate exhaust or dedicated outdoor air system, the system shall be turned off during the test procedure.
i. Allow the system to run until System Operating Requirements are met.
j. System temperatures shall be tested when the temperatures in the occupied space are between 65°F and 75°F or 18°C and 24°C.
k. Heat pump systems shall not be tested while operating in defrost mode.
l. Reset heating controls to as-found operating conditions at the completion of the testing

7.7.2. Heating start-up variations
When testing a hybrid system (for example, a heat pump and furnace combination), the test practitioner shall select the primary source of heating and test the system with only that source of heating operating. Score the system based on the capacity delivered into the conditioned space and the manufacturer-specified capacity of the selected heating mode.

7.7.3. Cooling mode system startup
a. The outdoor air temperature shall be greater than or equal to 63°F (17.2°C) and less than or equal to 105°F (40.6°C) for all cooling mode testing.
b. The test practitioner shall manipulate the controls to call for all stages of cooling operation.
c. When a system has an airside economizer, dampers shall be in the position assigned for minimum ventilation airflow.

d. When testing a new system, the test practitioner shall ensure air filters and coils are clean.

e. When testing an existing system, the test practitioner shall test the system in as-found condition.

f. During testing, exterior windows shall be closed and internal doors shall be in a typical use open or closed position. Any auxiliary exhaust fans not normally in use shall be off.

g. When the building includes a separate exhaust system, the system shall be turned off during the test procedure.

h. Allow the system to run until System Operating Requirements are met.

i. System temperatures shall be tested when the temperatures in the occupied space between 70°F and 80°F or 21°C and 27°C. Calculated coil entering wet bulb temperature shall be greater than or equal to 57°F (13.9°C) and less than or equal to 73°F (22.8°C).

j. Reset cooling controls to as-found operating conditions at the completion of the testing.

7.7.4. Variable fan and variable volume systems

a. As indicated in the data collection procedures in Sections 7.7.1 and 7.7.3, each system whether constant or variable volume fan and capacity shall have the controls calling for full capacity at the time each test is completed. (See ASHRAE Standard 111, Section 9.7 Verification of Control Operation).

b. For single zone variable air volume systems where the space temperature directly controls the heating and cooling functions, the fan and heating or cooling stages meeting maximum design conditions shall be calling, and the minimum ventilation position of the economizer dampers shall be called for by the system controls.

7.8. System Operating Requirements

System Operating Requirements shall be met to help ensure methodological consistency between tests conducted at different times on the same system and ensure performance scores reflect system performance relative to manufacturer-specified performance.

7.8.1. Airflow Measurements

At the time when volumetric airflow rate measurements are recorded, the system shall be calling for the highest cooling or heating capacity available with the current equipment configuration, and the supply air fan shall be allowed to operate at the speed currently set for that configuration. The test technician shall ensure that this condition is met through direct manipulation and evaluation of control system signals, in conjunction with knowledge of the control system sequence of operations, accounting for any staged or delayed fan speed ramp up algorithms present.

7.8.2. Temperature, Humidity, Enthalpy Measurements

At the time that temperature, humidity, or enthalpy values are recorded, the controls shall be calling for the supply air fan and all heating or cooling functions of the system to be operating at highest cooling or heating capacity available with the current equipment configuration.

For combustion heating systems, the control system shall be calling for the highest heating capacity available with the current equipment configuration, and burners shall be operating at full fire.

For heat pump heating systems, the control system shall be calling for the highest heating capacity available with the current equipment configuration, and all compressors intended to be operating in full heating shall be operating at their maximum available capacity.

For direct expansion cooling systems, the control system shall be calling for the highest cooling capacity available with the current equipment configuration, and all compressors intended to be operating in full cooling shall be operating at their maximum available capacity.
Prior to measuring temperature, humidity, or enthalpy, either a maximum rate of temperature change or a minimum run time requirement shall be met.

a. Maximum rate of temperature change: The rate of supply register temperature change shall not exceed 0.5°F (0.3°C) degrees in 60 seconds, as verified by test technician based on observation of temperature readings. The rate of temperature change is defined as the absolute value of the difference between two temperature readings taken 60 seconds apart.

b. Minimum run time: The system shall run for at least 15 minutes after a call for full heating or cooling has been initiated and the supply air fan has reached full speed.

7.9. Airflow Measurement Procedures

The volume of airflow shall be measured and recorded for each supply register in a system. When the system includes an economizer or outdoor air ventilation, the volume of airflow through the airside economizer or ventilation inlet shall be measured and recorded. All airflow measurements shall be recorded in terms of CFM (L/s) of standard air.

a. Supply register airflow shall be measured from each terminal. Include any registers that are intended to supply air to unoccupied spaces. Do not include gaps or holes in ducts that are not intentional in the design of the system.

b. Because an airside economizer or outdoor air inlet contributes to the load on the HVAC system, the volume of airflow through the economizer shall be measured and recorded. When an economizer is included in a system, economizer air volume shall be used to calculate the economizer impact on system capacity.

7.9.1. Required airflow test instruments, tools, and accessories

This section provides a brief introduction to required airflow test instruments, tools, and accessories. Section 8 details the names and specifications of the required test instruments that shall be used during testing. All measurement instruments shall be maintained and calibrated in accordance with manufacturer specifications. A table detailing the calibration dates of each test instrument used shall be attached to the report. Current calibration certificates shall be made available upon request.

a. Air balancing hood – A capture device to measure airflow into supply registers that are accessible and within range of the hood. The hood shall be set up to read in actual volumetric airflow. The air balancing hood shall be set to measure in CFM (L/s) of standard air.

b. Thermal or rotating vane anemometer – A programmable measuring device that is used to traverse airflow by reading velocities out of a register or within an airstream and convert velocity readings to volumetric airflow in cfm (L/s).

i. Thermal anemometers shall be set to measure in CFM (L/s) of standard air.
ii. Rotating vane anemometers cannot typically display measurements in CFM (L/s) of standard air, in which case, a separate barometric pressure and temperature measurement at the measurement location shall be made if the site is located more than 1,000 feet above sea level. The measurement from the instrument shall then be corrected to CFM (L/s) of standard air using the following equations:

\[ Q_{\text{standard}} = Q_{\text{displayed}} \times \frac{530}{460 + T_{\text{amb}} - 32} \times \frac{P_{\text{actual}}}{29.92} \]

Where:
- \( Q_{\text{standard}} \) = Airflow in CFM of standard air
- \( Q_{\text{displayed}} \) = Nominal airflow displayed on vane anemometer
- \( P_{\text{actual}} \) = Barometric pressure at the measurement location inHg
- \( T_{\text{amb}} \) = Ambient temperature at the measurement location °F
- 29.92 = Standard pressure inHg

\[ Q_{\text{standard SL}} = Q_{\text{displayed SL}} \times \frac{293}{273 + T_{\text{amb SL}}} \times \frac{P_{\text{actual SL}}}{101.325} \]

Where:
- \( Q_{\text{standard SL}} \) = Airflow in L/s of standard air
- \( Q_{\text{displayed SL}} \) = Nominal airflow displayed on vane anemometer
- \( P_{\text{actual SL}} \) = Barometric pressure at the measurement location kPa
- \( T_{\text{amb SL}} \) = Ambient temperature at the measurement location °C

c. Digital manometer – A test instrument used with a Pitot tube and pressure hoses to traverse airflow by reading velocities of out of a register or within an airstream and converts velocity readings to volumetric airflow in cfm (L/s) of standard air.
d. Pitot tube – A pressure capturing device inserted into an airstream reading air velocity and other air pressures.
e. Measuring tape – A measurement device to document the dimensions of an airstream to identify its cross-sectional area, necessary for calculating volumetric flow in cfm (L/s).
f. Calculator – A digital calculator or spreadsheet calculation tool is required to complete the calculations in this section of the standard. The calculator may also be software-based.

7.9.2. Airflow testing safety requirements
When performing field testing on an operating HVAC system, all safety requirements by applicable codes and standards shall be adhered to when any of the following occur:

a. Operating live equipment,
b. Using ladders, scaffolding, harnesses, and man lifts,
c. Operating motorized or battery driven tools,
d. Using required test instruments, or
e. Handling fluids, materials, or hazardous waste.

7.9.3. Preparation for the airflow measurement test

a. Start up the system as described in Section 7.7, System Start-up Procedure.
b. The system airflow shall be measured when the system controls are calling for airflow at full system capacity.
c. Supply registers inaccessible to an air balancing hood shall be traversed. When the traverse location is within a duct, traverse test ports shall be installed in an acceptable test location per ASHRAE Standard 111.
d. Existing systems shall be tested in as-found operating condition while the controls are actively calling for full heating or cooling capacity.

e. New systems shall be tested while the controls are actively calling for full heating or cooling capacity.

f. Ensure all System Operating Requirements are met.

7.9.4. **Supply register airflow test procedure**

a. Set the instrument to display volumetric airflow in CFM(L/s) of standard air.

b. With the system calling for full available heating or cooling capacity and the fan set to operate in the speed configured for full available capacity, begin reading and recording field measured airflows. The fan shall continue to operate in this state throughout the airflow testing.

c. Where the register is accessible and within the published test instrument parameters, measure airflow using the air balancing capture hood meeting instrument specifications. (see ASHRAE Standard 111)

d. When testing a register that is not accessible or within air balancing capture hood parameters, an airflow traverse and a field created correction factor shall be used. Record traverse data and correction factor method (See ASHRAE Standard 111).

e. Measure and record the airflow of each supply register in the order specified on the report.

7.9.5. **Economizer Airflow Measurement Procedure**

a. Set the instrument to display volumetric airflow in CFM(L/s) of standard air.

b. With the system calling for full heating or cooling, measure and record economizer airflow.

c. Ensure the fan continues in full operation throughout the economizer airflow testing.

d. Traverse economizer airflow with an anemometer or with a manometer meeting the requirements specified in Section 8. (See ASHRAE Standard 111).

e. Measure and record the airflow through the economizer onto the System Performance Scoring Report.

7.10. **Temperature and Enthalpy Measurement Procedures**

A series of air temperature and/or enthalpy measurements, depending upon the required measurements for the test being performed as specified in Section 6, shall be taken and recorded across the system. System temperature and enthalpy measurement shall be taken in the precise locations as described in this standard.

a. Temperatures shall be taken and recorded to the nearest tenth of a degree Fahrenheit or Celsius.

b. Enthalpy measurements shall be taken and recorded to the nearest hundredth of Btu/lb (kJ/kg).
c. When measuring and calculating the performance of a heating system, dry bulb readings shall be taken and recorded.
d. When measuring and calculating the performance of a cooling system, enthalpy readings shall be taken and recorded.
e. Wet bulb temperature measurement is required where the return air enters the equipment.
f. The temperature and/or enthalpy measurements required to score the performance of an HVAC system shall include:
   i. The average air temperature (for heating) or enthalpy (for cooling) exiting the system supply registers.
   ii. The average air temperature (for heating) or enthalpy (for cooling) entering the system return grilles.
   iii. The ambient outdoor air dry bulb temperature entering the outdoor heat exchanger shall be taken under shaded conditions and reflect the air temperature entering the outdoor equipment.
   iv. The air temperatures entering the equipment from the return air duct.
   v. When systems have an airside economizer, the economizer entering air temperatures shall be measured at the inlet of the economizer under shaded conditions.

7.10.1. Required temperature instruments and tools
This section provides a brief introduction to required airflow test instruments, tools, and accessories. Section 8 details the names and specifications of the required test instrument that shall be used during testing.

a. For heating system tests: Multi-sensor Thermometer - A dry bulb temperature measurement and display instrument capturing dry bulb temperatures and having the capacity of measuring a minimum of 7 readings at different locations simultaneously and displaying and recording each value.
b. For cooling system testing: Multi-sensor digital psychrometer - A temperature and humidity measurement and display instrument having the capacity of measuring a minimum of 7 readings at different locations simultaneously and displaying or recording each value in enthalpy Btu per pound (kJ/kg), including wet bulb and dry bulb temperatures.
c. Reference to a reliable online map or GPS reference or the use of an altimeter or an elevation meter used to measure and document the elevation of a location.
d. Calculator - A digital calculator or spreadsheet calculation tool is required to complete the calculations in this section of the standard. The calculator may be software-based.

7.10.2. Temperature testing safety requirements
When performing field testing on an operating HVAC system, all safety requirements by applicable codes and standards shall be adhered to when any of the following occur:

a. Operating live equipment,
b. Using ladders, scaffolding, harnesses, and man lifts,
c. Operating motorized or battery driven tools,
d. Using required test instruments, or
e. Handling fluids, materials, or hazardous waste.

7.10.3. Preparation for the temperature test

a. Start up the system as described in Section 7.7, System Start-up Procedure.
b. System temperatures shall be measured when the system controls are calling for cooling or heating to operate at full available system capacity with the fan speed set to operate at the speed configured for full capacity and System Operating Requirements shall be met. The system shall continue functioning in this state throughout the entire length of the temperature testing.
c. When there is an airside economizer on an existing system in a test-in scenario, the economizer shall be left in as-found position.
d. When there is an airside economizer on a new or recently upgraded system in a test-out scenario, the economizer shall be adjusted to minimum ventilation position prior to completing the temperature testing.

e. All temperatures documenting indoor and outdoor and return duct temperature values shall be captured simultaneously using the multi-probe test instruments described in Section 8.

f. Existing systems shall be tested in as-found operating condition and while the controls are actively calling for full available heating or cooling capacity.

g. New systems shall be balanced prior to the installed system being tested while the controls are actively calling for full available heating or cooling capacity. New systems that do not have the necessary dampers to support balancing shall be tested in as-found operating condition.

7.10.4. Test location requirements

a. When testing registers and grilles, each register and grille has openings between the louvers allowing access directly into the airstream by inserting the probe through the louvers. When access into the airstream is not accessible, test ports shall be installed according to Section 7.6 into the airstream in the boot immediately upstream from registers and into the airstream in the boot immediately downstream from grilles.

b. Select a minimum of three or the total number of supply registers, whichever is less.

c. Select a minimum of two or the total number of return grilles, whichever is less.

d. When selecting a sample or registers or grilles, select registers and grilles located near the halfway point between the equipment and the most distant registers and grilles in the system.

e. Select registers and grilles that provide 50% of the average airflow or higher relative to all registers or grilles in the system. Do not select registers or grilles that provide low airflow relative to the other registers or grilles in the system.

Figure 4 Use of a digital thermometer or psychrometer probe to measure air temperature or enthalpy
BSR/ASHRAE Standard 221P, Test Method to Field-Measure and Score the Cooling and Heating Performance of an Installed Unitary HVAC System
Subsequent Full Public Review Draft

Figure 5 Example commercial building temperature and enthalpy measurement locations

Figure 6 Example residential building temperature and enthalpy measurement locations
f. A temperature measurement shall also be taken within the return air duct at a point where the air enters the equipment at a point where the return air temperature is not affected by the temperature of the outdoor air entering the system.

g. The outdoor air temperature representing the ambient temperature sensed by the outdoor equipment shall be measured at a location reflecting the average air temperature entering the outdoor unit.

h. When an airside economizer is included in the system, the temperature measurement representing the air temperature entering the economizer or outdoor air inlet shall be taken and recorded. Additionally, the temperature of the air entering the equipment from the return duct prior to mixing with the outdoor air shall be taken and recorded.

7.10.5. Timing and Test Sequencing
The timing and sequence of the temperature testing described in this section shall be as follows.

a. Prior to measuring temperature or enthalpy, the System Operating Requirements shall be met.

b. Throughout the temperature testing, an HVAC system must be in constant operation with the controls actively calling for full available heating or cooling capacity and the fan operating at the speed configured for full available capacity.

c. Temperature and/or enthalpy measurements shall be captured simultaneously using an instrument capable of displaying or capturing all measurements simultaneously.
7.10.6. Heating system temperature test procedure
The following test procedure shall be followed when scoring the performance of a system operating in heating mode.

a. Prior to measuring temperature, System Operating Requirements shall be met.
b. The following measurements shall be taken and recorded:
   i. The dry bulb air temperatures of a minimum of three supply registers located near the center of the air distribution system and meeting the test location requirements.
   ii. The dry bulb air temperatures of a minimum of two return grilles located near the center of the air distribution system and meeting the test location requirements.
   iii. The dry bulb temperature of the return air entering the equipment (Fahrenheit or Celsius).
   iv. The outdoor air dry bulb ambient temperature (Fahrenheit or Celsius) accurately representing the average temperature that is entering the outdoor equipment.
   v. When an airside economizer is included in the system, the dry bulb temperature (Fahrenheit or Celsius) accurately representing the average air temperature entering the economizer or outdoor air inlet.

7.10.7. Cooling system temperature test procedure
The following test procedure shall be followed when scoring the performance of a system operating in cooling mode.

a. Prior to measuring temperature, System Operating Requirements shall be met.
b. The following temperature and enthalpy measurements shall be taken and recorded:
   i. The enthalpy of the air through a minimum of three supply registers located near the center of the air distribution system and meeting the test location requirements.
   ii. The enthalpy of the air through a minimum of two return grilles located near the center of the air distribution system and meeting the test location requirements.
   iii. The wet bulb temperature of the return air entering the equipment.
   iv. The outdoor air dry bulb and wet bulb air temperature accurately representing the average temperature that is entering the outdoor equipment.
   v. When an airside economizer is included in the system, the enthalpy and wet bulb temperatures accurately representing the average air temperature entering the economizer or outdoor air inlet.

7.10.8. Variations to the system temperature and enthalpy test procedures
a. When less than the minimum number of supply registers exist in a system, the minimum number of supply register temperature or enthalpy measurements shall be decreased to include all of the supply register temperatures within the system.
b. When less than the minimum number of return grilles exist in a system, the minimum number of return grille temperature or enthalpy measurements shall be decreased to include all of the supply register temperatures within the system.
c. When the system serves multiple floors of a building, a minimum number of one supply register and one return grille temperature or enthalpy measurement shall be taken on each floor served by the system. The minimum total number of measurements shall be 3 supply registers and 2 return grilles, or the number of supplies and returns in the system, whichever is less.

7.11. System Electrical Consumption Measurement Procedures
When scoring the installed system performance in cooling mode using the ICS-eer (ICS-cop), electrical consumption measurements are required to be measured and recorded. Total system and supply fan watt measurements shall be measured and recorded. Power measurements shall be taken and recorded under full cooling capacity operating conditions and System Operating Requirements shall be met.
7.11.1. **Required electrical instruments and tools**

This section provides a brief introduction to required airflow test instruments, tools, and accessories. Section 8 details the names and specifications of the required test instruments that shall be used during testing.

a. Electrical power meter satisfying the specifications and calibration requirements and having the capability of displaying true power in Watts, where true power is apparent power (VA) less reactive power (VAr), or apparent power (VA) multiplied by the power factor.

b. Hand tools required to gain access to the specified test locations within the system.

c. All required electrical testing safety devices and accessories.

7.11.2. **Electrical testing safety requirements**

When performing field testing on an operating HVAC system, all safety requirements by applicable codes and standards shall be adhered to when

a. Operating on live equipment.

b. Using ladders, scaffolding, harnesses, and man lifts.

c. Operating motorized or battery driven tools.

d. Using required test instruments.

7.11.3. **Preparation for the electrical testing**

a. Start up the system as described in Section 7.7, System start-up procedure.

b. Allow the system to run until System Operating Requirements are met throughout the entire length of the electrical testing.

c. When there is an airside economizer on an existing system in a test-in scenario, the economizer shall be left in as-found position. Existing systems shall be tested in as-found operating condition and while the controls are actively calling for full available heating or cooling capacity.

d. Existing systems shall be tested in as-found operating condition and while the controls are actively calling for full available cooling capacity.

e. New systems shall be balanced prior to the installed system being tested while the controls are actively calling for full available cooling capacity.

7.11.4. **Electrical test timing and test sequencing**

To comply with the requirements of this standard, the timing and sequence of the electrical testing described in this section is mandatory.

a. Throughout the electrical testing, the HVAC system must be constant operation with the controls actively calling for full capacity cooling with the System Operating Requirements being met.

b. Record electrical measurements within three minutes after capturing system temperature measurements, assuring the system remains in specified operating mode.

7.11.5. **Electrical test procedure**

The following test procedure shall be followed when scoring the performance system operating in cooling mode. Each requirement included in this section shall be adhered to as the watt measurement is gathered and recorded.

7.11.5.1. **Single phase power measurement (115-120 Volt Systems)**

a. Set TrueRMS, auto calculating power meter to read AC watts.

b. Insert the black probe to the meter’s Common (COM) port and the red probe in the port intended for the live wire when performing voltage measurements.

c. While testing, ensure that no physical contact is made with the live electrical circuit or the metal end of the probe. Touch only the plastic or insulated handles of the probe.

d. Place the black probe on an exposed common wire or to ground.

e. Place the red probe on an exposed and energized incoming bus, lug, or wire marked L1.

f. Place the current clamp of the power meter onto the L1 conductor.
g. Measure and record the operating wattage displayed on the electrical multi-meter.

h. Do not touch any energized surfaces when withdrawing probes and power meter from the test locations.

7.11.5.2. Single phase power measurement (208-230 Volt Systems)

a. Set the TrueRMS auto calculating power meter to read “AC” or to the V Watt or W with the wavy line.

b. Insert the black probe to the meter’s Common (COM) port and the red probe in the port intended for the live wire when performing voltage measurements.

c. While testing, ensure that no physical contact is made with the live electrical circuit or the metal end of the probe. Touch only the plastic or insulated handles of the probe.

d. Place black probe to the exposed and energized incoming L1 lug or terminal.

e. Verify the measured voltage is within the required voltage of the equipment

f. Place red probe to the exposed and energized incoming line 2 lug or terminal.

g. Place the power meter clamp onto the L1, L2 conductors while following the specific steps of the particular meter to complete the wattage calculation.

h. Measure and record the system watts displayed on the power meter

7.11.5.3. Measure three-phase power

a. When taking power measurements on a three-phase piece of equipment, the voltage between each leg and current through each leg is measured. The instrument then calculates active true RMS power. Always read measurements from left to right.

b. Set the TrueRMS, auto calculating 3 phase power meter to read AC Watts. Insert all the probes into the meter.

c. When testing, ensure that no physical contact is made with the live electrical circuit or the metal end of the probe. Touch only the plastic or insulated handles of the probe.

d. Connect all power meter probes to each of the L1, L2, L3, and ground terminals.

e. Place the current clamps onto the L1, L2, and L3 conductors while following the proper steps of the particular meter to complete the three-phase wattage calculations.

f. Measure and record the power displayed on the power meter in watts.

7.11.5.4. Variations to the system electrical test procedure

a. When measuring the power consumption of a split system, power consumption shall be measured at each piece of equipment following the specified test procedures above. The watt consumption of each piece of equipment shall be totaled and recorded as the system watt consumption.

b. When the source for heating is an electric resistance heater, multiply the rated capacity in kilowatts of the electric heater 3412 to calculate the rated capacity in Btu/h and by 1000 to calculate the rated capacity in watts.
c. When testing a hybrid system (for example, a gas furnace with a heat pump system included), determine the desired mode for the testing and disable the other heat source during the testing. Test only one heat source at a time.

8. TEST INSTRUMENTS

Test instruments shall meet the specifications of this section. Specifications include the functions required of each instrument, minimum accuracy, resolution, and range and for each instrument used as well as the required calibration period. Where range is specified, multiple instruments, each meeting the accuracy and resolution requirements, may be used to cover the full range.

8.1. Air Balancing (capture) Hood Assembly
a. Digital balancing hoods with the capability of compensating for local air density and displaying the air velocity or flow in terms of standard air, shall be used. Balancing hoods are used to capture airflow into and out of registers and grilles.

b. Balancing hood requirements include a minimum accuracy of ±3% of reading ± 7 cfm (3.3 L/s), a minimum resolution of 1 cfm (0.5 L/s), and a minimum range of 30 cfm to 1750 cfm (15 to 825 L/s). Each instrument shall be calibrated against a NIST-traceable or international equivalent reference instrument by a qualified testing laboratory within the past 12 months.

c. Field accessories include fabric skirts and frames matching the size of registers or grilles to be measured.

8.2. Digital Anemometer
a. Two types of anemometers meet the requirements of this standard, a thermal anemometer or a rotating vane anemometer.

b. Thermal anemometers shall have the capability of compensating for local air density and displaying the air velocity or flow in terms of standard air.

c. Digital anemometer requirements include a minimum accuracy of ±5% of the reading +/- 1 foot per minute, a minimum resolution of 1 foot per minute or 0.01 m/s, and a minimum range of 50 to 3750 feet per minute or 0.25 to 19.00 m/s. Each anemometer shall be calibrated against a NIST-traceable or international equivalent reference instrument by a qualified testing laboratory within the past 12 months.

d. Field accessories include a 3/8” (10 mm) drill bit, drill bit sheath, or protection and test port plugs.

8.3. Pressure Measurement, Manometers.

a. Manometers shall have the capability of compensating for barometric pressure effects on the air being measured and displaying the reading in terms of velocity or volumetric flow of standard air.

b. Digital manometer requirements include a minimum accuracy of ±5% of reading or ±0.01 in. of water, a minimum resolution of 0.01 in. of water (2.5 Pa), and a minimum range of 0” to 1 in. of water (0 to 2,500 Pa) Each instrument shall be calibrated against a NIST-traceable or international equivalent reference instrument by a qualified testing laboratory within the past 12 months.

c. Field accessories include pressure hoses, a Pitot tube, and velocity grid device.

8.4. Multi-sensor Thermometer/Psychrometer

a. Two types of test instruments are permitted. Both tests shall include a minimum of 7 remote probes that have the ability to simultaneously capture and record temperatures across the HVAC system being tested.

b. Multi-sensor thermometer - A dry bulb temperature measurement and display instrument capturing dry bulb temperatures and displaying each value in dry bulb readings.

c. Multi-sensor digital psychrometer - A temperature and humidity measurement and display instrument having the capacity of capturing and displaying each value in enthalpy (Btu/lb(kJ/kg), wet bulb, and dry bulb temperatures and displaying each value. Alternatively, software may be
used to calculate enthalpy from any two measurable psychrometric properties from the following list: dry bulb temperature, wet bulb temperature, dew point temperature, relative humidity. Software documentation shall specify or reference the algorithms used to calculate enthalpy from the two measured properties.

d. Multi-sensor thermometer and psychrometer requirements include a minimum accuracy for dry bulb and wet bulb temperature of ±1°F, a minimum resolution of 0.1°F or 0.1°C, and a minimum temperature range of 20 to 180 degrees F or -7°C to 82°C. The minimum accuracy for relative humidity is ±2.5%RH, with a minimum humidity range of 5% to 95% relative humidity. Each is to be calibrated against a NIST-traceable or international equivalent reference instrument by a qualified testing laboratory within the past 12 months.

e. Field accessories include a 3/8” (10 mm) drill bit, drill bit sheath, or protection and test port plugs.

8.5. Electrical Power Meter

a. Digital electrical power meter shall be used to measure the operating true power wattage of an HVAC system being scored using the ICS-eer (ICS-cop) test and calculation method.

b. Electrical power meters are to measure and interpret system watt consumption including TrueRMS, and an auto calculating power factor shall be used to perform this testing.

c. Digital power meter requirements include a minimum accuracy of ±3% and a minimum resolution of 10 watts. Minimum range shall be 0-600 Volts and 0-100 Amps. Each electrical power meter is to be calibrated against a NIST-traceable or international equivalent reference instrument by a qualified testing laboratory within the past 12 months.

d. Field accessories include a minimum of 1 power clamp and a minimum of 2 voltage probes and leads.

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE ANNEX A – BIBLIOGRAPHY


(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)
### Table 1 Measurement Units and Conversions

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<th>By To Obtain SI</th>
<th>Multiply I-P</th>
<th>By To Obtain SI</th>
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*Conversion factor is exact.

Notes: 1. Units are U.S. values unless noted otherwise.
2. Liter is a special name for the cubic decimeter. 1 L = 1 dm³ and 1 mL = 1 cm³.
ANNEX C – CALCULATIONS BACKGROUND

C.1. Introduction
This document is intended to capture the theoretical basis, field application, and historical evolution of field-measured HVAC performance calculations.

C.2. Theoretical Basis

C.2.1. Assumptions and Simplifications
In field measurement applications, there are a number of challenges related to instrumentation accuracy, accessibility of measurement locations, physical configuration of systems, and technician time constraints. These challenges suggest a number of assumptions and simplifications that reduce the number of measurements required and reduce calculation complexity. The system delivered capacity equation is based on measurements that can be taken in the field. The calculation expresses the instantaneous total cooling capacity delivered to the zone under the tested conditions.

C.2.2. System Delivered Capacity
An energy balance on the airside of the system can be expressed as:

\[ q_{coil} = q_{zone} + q_{OA} + q_{loss} \]  

where:
- \( q_{coil} \) = the load presented to the evaporator coil of the unit
- \( q_{zone} \) = the zone load satisfied by the system
- \( q_{OA} \) = the outdoor ventilation air load
- \( q_{loss} \) = conduction and leakage losses from the duct system.

The coil and zone load terms in equation (1) can be calculated as follows:

\[ q_{coil} = \dot{m}_e(h_{mix} - h_e) \] \hspace{1cm} (2)
\[ q_{zone} = \dot{m}_s(h_r - h_s) \] \hspace{1cm} (3)

where:
- \( \dot{m}_e \) = mass flow rate of the air exiting the HVAC unit
- \( h_{mix} \) = enthalpy of the mixed air entering the evaporator coil
- \( h_e \) = enthalpy of the air exiting the HVAC unit
- \( \dot{m}_s \) = mass flow rate of the supply air entering the zone
- \( h_r \) = enthalpy of the zone air entering the return grill
- \( h_s \) = enthalpy of the supply air entering the zone

To calculate the outdoor air load, an energy balance on mixing box can be expressed as:

\[ \dot{m}_e h_{mix} = \dot{m}_{oa} h_{oa} + (\dot{m}_e - \dot{m}_{oa}) h_{ent} \] \hspace{1cm} (4)

where:
- \( \dot{m}_{oa} \) = mass flow rate of the outdoor air entering the HVAC unit
- \( h_{oa} \) = enthalpy of the outdoor air entering the unit
- \( h_{ent} \) = enthalpy of the air entering the HVAC unit

Combining equations (4) and (2) gives:
\[ q_{coil} = m_{oa} h_{oa} + (m_{ex} - m_{oa}) h_{ent} - m_{ex} h_{ex} \]  \hspace{1cm} (5)

Combining equations (5) and (1) gives:
\[ m_{oa} h_{oa} + (m_{ex} - m_{oa}) h_{ent} - m_{ex} h_{ex} \\
= m_s (h_r - h_s) + q_{oa} + m_{ex}(h_{ent} - h_{ex}) - m_s (h_s - h_r) \]  \hspace{1cm} (6)

Simplifying equation (6) gives:
\[ q_{oa} = m_{oa} \times (h_{oa} - h_{ent}) \]  \hspace{1cm} (7)

Solving equation (1) for \( q_{loss} \):
\[ q_{loss} = q_{coil} - q_{zone} - q_{OA} \\\n= m_{oa} h_{oa} + (m_{ex} - m_{oa}) h_{ent} - m_{ex} h_{ex} - m_s (h_r - h_s) - m_{oa} (h_{oa} - h_{ent}) \]  \hspace{1cm} (8)

Simplifying equation (8) gives:
\[ q_{loss} = m_{ex} (h_{ent} - h_{ex}) - m_s (h_r - h_s) \]  \hspace{1cm} (9)

The net system delivered capacity can be expressed as:
\[ q_{system} = q_{coil} - q_{loss} \]  \hspace{1cm} (10)

Substituting equation (10) into equation (1):
\[ q_{system} = q_{zone} + q_{oa} \]  \hspace{1cm} (11)
\[ q_{system} = m_s (h_r - h_s) + m_{oa} \times (h_{oa} - h_{ent}) \]  \hspace{1cm} (12)

The mass flow of the outdoor air, the return air entering the grills, and the supply air leaving the registers is calculated from:
\[ m_s = Q_s \times 4.5 \times ADR \]  \hspace{1cm} (13)

where:
\[ Q_s = Q_{S1} + Q_{S2} + \cdots + Q_{Sn} \]  \hspace{1cm} total volumetric flow rate for all supply registers (cfm)
\[ n = \] total number of supply registers in the system
\[ 4.5 = \text{constant (lbm/cfm at standard conditions)} \]
\[ ADR = \text{air density ratio (actual air density / standard air density)} \]

The average enthalpy of the return air entering the grills and the supply air leaving the registers is calculated from:
\[ h_S = \frac{h_{S1} + h_{S2} + \cdots + h_{Sn}}{n} \]  \hspace{1cm} (14)
\[ h_R = \frac{h_{R1} + h_{R2} + \cdots + h_{Rn}}{n} \]  \hspace{1cm} (15)
(This is a normative annex and is part of this standard)

NORMATIVE ANNEX D – GENERIC EXPANDED EQUIPMENT PERFORMANCE TABLES

All tables are based on the equations for default equipment performance in the California Energy Commission Nonresidential Alternative Calculation Method Reference Manual for the 2016 Building Energy Efficiency Standards\textsuperscript{15}.E.1 Generic Cooling Capacity and Efficiency Tables

\textsuperscript{15} http://www.energy.ca.gov/2015publications/CEC-400-2015-025/CEC-400-2015-025-CMF.pdf Cooling Capacity: Table 32, Air Source (Other DX) Column; Cooling Efficiency: Table 38, Air Source (Other) Column; Heating Capacity: Table 44, Air Source Column; Heating Efficiency Table 45, Air Source EIR-FT Column
## Table 1 Generic cooling capacity adjustment

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<th>59°F (15°C)</th>
<th>61°F (16.1°C)</th>
<th>63°F (17.2°C)</th>
<th>65°F (18.3°C)</th>
<th>67°F (19.4°C)</th>
<th>69°F (20.6°C)</th>
<th>71°F (21.7°C)</th>
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<td>0.95</td>
<td>0.98</td>
<td>1.01</td>
<td>1.04</td>
<td>1.07</td>
<td>1.11</td>
<td>1.14</td>
<td>1.18</td>
</tr>
<tr>
<td>83°F (28.3°C)</td>
<td>0.91</td>
<td>0.94</td>
<td>0.97</td>
<td>1.00</td>
<td>1.03</td>
<td>1.06</td>
<td>1.10</td>
<td>1.13</td>
<td>1.17</td>
</tr>
<tr>
<td>85°F (29.4°C)</td>
<td>0.90</td>
<td>0.93</td>
<td>0.96</td>
<td>0.99</td>
<td>1.02</td>
<td>1.05</td>
<td>1.09</td>
<td>1.12</td>
<td>1.16</td>
</tr>
<tr>
<td>87°F (30.6°C)</td>
<td>0.89</td>
<td>0.92</td>
<td>0.95</td>
<td>0.98</td>
<td>1.01</td>
<td>1.04</td>
<td>1.07</td>
<td>1.11</td>
<td>1.15</td>
</tr>
<tr>
<td>89°F (31.7°C)</td>
<td>0.88</td>
<td>0.91</td>
<td>0.94</td>
<td>0.97</td>
<td>1.00</td>
<td>1.03</td>
<td>1.06</td>
<td>1.10</td>
<td>1.14</td>
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<td>91°F (32.8°C)</td>
<td>0.87</td>
<td>0.90</td>
<td>0.93</td>
<td>0.96</td>
<td>0.99</td>
<td>1.02</td>
<td>1.05</td>
<td>1.09</td>
<td>1.12</td>
</tr>
<tr>
<td>93°F (33.9°C)</td>
<td>0.86</td>
<td>0.89</td>
<td>0.92</td>
<td>0.95</td>
<td>0.98</td>
<td>1.01</td>
<td>1.04</td>
<td>1.08</td>
<td>1.11</td>
</tr>
<tr>
<td>95°F (35°C)</td>
<td>0.86</td>
<td>0.88</td>
<td>0.91</td>
<td>0.94</td>
<td>0.97</td>
<td><strong>1.00</strong></td>
<td>1.03</td>
<td>1.07</td>
<td>1.10</td>
</tr>
<tr>
<td>97°F (36.1°C)</td>
<td>0.85</td>
<td>0.87</td>
<td>0.90</td>
<td>0.93</td>
<td>0.96</td>
<td>0.99</td>
<td>1.02</td>
<td>1.06</td>
<td>1.09</td>
</tr>
<tr>
<td>99°F (37.2°C)</td>
<td>0.84</td>
<td>0.86</td>
<td>0.89</td>
<td>0.92</td>
<td>0.95</td>
<td>0.98</td>
<td>1.01</td>
<td>1.05</td>
<td>1.08</td>
</tr>
<tr>
<td>101°F (38.3°C)</td>
<td>0.83</td>
<td>0.85</td>
<td>0.88</td>
<td>0.91</td>
<td>0.94</td>
<td>0.97</td>
<td><strong>1.00</strong></td>
<td>1.04</td>
<td>1.07</td>
</tr>
<tr>
<td>103°F (39.4°C)</td>
<td>0.82</td>
<td>0.85</td>
<td>0.87</td>
<td>0.90</td>
<td>0.93</td>
<td>0.96</td>
<td>0.99</td>
<td>1.03</td>
<td>1.06</td>
</tr>
<tr>
<td>105°F (40.6°C)</td>
<td>0.81</td>
<td>0.84</td>
<td>0.86</td>
<td>0.89</td>
<td>0.92</td>
<td>0.95</td>
<td>0.98</td>
<td>1.02</td>
<td>1.05</td>
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</tbody>
</table>
### Table 2 Generic cooling efficiency adjustment

<table>
<thead>
<tr>
<th>Outside Air DB °F (°C)</th>
<th>Evaporator Entering WB °F (°C)</th>
<th>57°F (13.9°C)</th>
<th>59°F (15°C)</th>
<th>61°F (16.1°C)</th>
<th>63°F (17.2°C)</th>
<th>65°F (18.3°C)</th>
<th>67°F (19.4°C)</th>
<th>69°F (20.6°C)</th>
<th>71°F (21.7°C)</th>
<th>73°F (22.8°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>63°F (17.2°C)</td>
<td>0.69</td>
<td>0.69</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>65°F (18.3°C)</td>
<td>0.71</td>
<td>0.71</td>
<td>0.72</td>
<td>0.72</td>
<td>0.72</td>
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<td>0.72</td>
<td>0.72</td>
<td>0.72</td>
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</tr>
<tr>
<td>67°F (19.4°C)</td>
<td>0.73</td>
<td>0.74</td>
<td>0.74</td>
<td>0.74</td>
<td>0.74</td>
<td>0.73</td>
<td>0.73</td>
<td>0.73</td>
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<td></td>
</tr>
<tr>
<td>69°F (20.6°C)</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
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</tr>
<tr>
<td>71°F (21.7°C)</td>
<td>0.77</td>
<td>0.77</td>
<td>0.77</td>
<td>0.77</td>
<td>0.77</td>
<td>0.77</td>
<td>0.77</td>
<td>0.76</td>
<td>0.76</td>
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<tr>
<td>73°F (22.8°C)</td>
<td>0.79</td>
<td>0.79</td>
<td>0.79</td>
<td>0.79</td>
<td>0.79</td>
<td>0.79</td>
<td>0.78</td>
<td>0.78</td>
<td>0.77</td>
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</tr>
<tr>
<td>75°F (23.9°C)</td>
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<td>0.81</td>
<td>0.81</td>
<td>0.81</td>
<td>0.81</td>
<td>0.80</td>
<td>0.80</td>
<td>0.79</td>
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<tr>
<td>77°F (25°C)</td>
<td>0.83</td>
<td>0.83</td>
<td>0.83</td>
<td>0.83</td>
<td>0.83</td>
<td>0.82</td>
<td>0.82</td>
<td>0.81</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>79°F (26.1°C)</td>
<td>0.86</td>
<td>0.86</td>
<td>0.86</td>
<td>0.86</td>
<td>0.86</td>
<td>0.84</td>
<td>0.84</td>
<td>0.83</td>
<td>0.83</td>
<td>0.82</td>
</tr>
<tr>
<td>81°F (27.2°C)</td>
<td>0.88</td>
<td>0.87</td>
<td>0.87</td>
<td>0.87</td>
<td>0.86</td>
<td>0.86</td>
<td>0.86</td>
<td>0.84</td>
<td>0.84</td>
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<tr>
<td>83°F (28.3°C)</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.89</td>
<td>0.88</td>
<td>0.88</td>
<td>0.87</td>
<td>0.86</td>
<td>0.85</td>
<td></td>
</tr>
<tr>
<td>85°F (29.4°C)</td>
<td>0.93</td>
<td>0.92</td>
<td>0.92</td>
<td>0.91</td>
<td>0.90</td>
<td>0.89</td>
<td>0.89</td>
<td>0.88</td>
<td>0.88</td>
<td>0.87</td>
</tr>
<tr>
<td>87°F (30.6°C)</td>
<td>0.95</td>
<td>0.95</td>
<td>0.94</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
<td>0.92</td>
<td>0.91</td>
<td>0.90</td>
<td>0.88</td>
</tr>
<tr>
<td>89°F (31.7°C)</td>
<td>0.97</td>
<td>0.97</td>
<td>0.96</td>
<td>0.95</td>
<td>0.95</td>
<td>0.94</td>
<td>0.93</td>
<td>0.91</td>
<td>0.90</td>
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</tr>
<tr>
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<td>1.00</td>
<td>0.99</td>
<td>0.99</td>
<td>0.98</td>
<td>0.97</td>
<td>0.96</td>
<td>0.95</td>
<td>0.93</td>
<td>0.92</td>
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<td>1.02</td>
<td>1.02</td>
<td>1.01</td>
<td>1.00</td>
<td>0.99</td>
<td>0.98</td>
<td>0.97</td>
<td>0.95</td>
<td>0.94</td>
<td></td>
</tr>
<tr>
<td>95°F (35°C)</td>
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<td>1.04</td>
<td>1.03</td>
<td>1.02</td>
<td>1.01</td>
<td>1.00</td>
<td>0.99</td>
<td>0.97</td>
<td>0.96</td>
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<tr>
<td>97°F (36.1°C)</td>
<td>1.08</td>
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<td>1.06</td>
<td>1.05</td>
<td>1.03</td>
<td>1.02</td>
<td>1.01</td>
<td>0.99</td>
<td>0.98</td>
<td></td>
</tr>
<tr>
<td>99°F (37.2°C)</td>
<td>1.10</td>
<td>1.09</td>
<td>1.08</td>
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<td>1.06</td>
<td>1.04</td>
<td>1.03</td>
<td>1.01</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>101°F (38.3°C)</td>
<td>1.13</td>
<td>1.12</td>
<td>1.11</td>
<td>1.09</td>
<td>1.08</td>
<td>1.07</td>
<td>1.05</td>
<td>1.03</td>
<td>1.02</td>
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</tr>
<tr>
<td>103°F (39.4°C)</td>
<td>1.16</td>
<td>1.15</td>
<td>1.13</td>
<td>1.12</td>
<td>1.11</td>
<td>1.09</td>
<td>1.07</td>
<td>1.06</td>
<td>1.04</td>
<td></td>
</tr>
<tr>
<td>105°F (40.6°C)</td>
<td>1.18</td>
<td>1.17</td>
<td>1.16</td>
<td>1.14</td>
<td>1.13</td>
<td>1.11</td>
<td>1.10</td>
<td>1.08</td>
<td>1.06</td>
<td>1.06</td>
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</table>
Table 3 Generic heat pump capacity adjustment

<table>
<thead>
<tr>
<th>Outside Air DB °F (°C)</th>
<th>C&lt;sub&gt;HP&lt;/sub&gt;</th>
<th>Outside Air DB °F (°C)</th>
<th>C&lt;sub&gt;HP&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>35°F (1.7°C)</td>
<td>0.78</td>
<td>51°F (10.6°C)</td>
<td>1.07</td>
</tr>
<tr>
<td>36°F (2.2°C)</td>
<td>0.80</td>
<td>52°F (11.1°C)</td>
<td>1.09</td>
</tr>
<tr>
<td>37°F (2.8°C)</td>
<td>0.82</td>
<td>53°F (11.7°C)</td>
<td>1.11</td>
</tr>
<tr>
<td>38°F (3.3°C)</td>
<td>0.84</td>
<td>54°F (12.2°C)</td>
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</tr>
<tr>
<td>39°F (3.9°C)</td>
<td>0.85</td>
<td>55°F (12.8°C)</td>
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</tr>
<tr>
<td>40°F (4.4°C)</td>
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<td>56°F (13.3°C)</td>
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</tr>
<tr>
<td>41°F (5°C)</td>
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<td>57°F (13.9°C)</td>
<td>1.18</td>
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<tr>
<td>42°F (5.6°C)</td>
<td>0.91</td>
<td>58°F (14.4°C)</td>
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<td>43°F (6.1°C)</td>
<td>0.93</td>
<td>59°F (15°C)</td>
<td>1.21</td>
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<td>44°F (6.7°C)</td>
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<td>60°F (15.6°C)</td>
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<tr>
<td>45°F (7.2°C)</td>
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<td>61°F (16.1°C)</td>
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</tr>
<tr>
<td>46°F (7.8°C)</td>
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<td>62°F (16.7°C)</td>
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<tr>
<td>47°F (8.3°C)</td>
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<td>63°F (17.2°C)</td>
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<td>48°F (8.9°C)</td>
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<td>64°F (17.8°C)</td>
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<td>49°F (9.4°C)</td>
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<td>50°F (10°C)</td>
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<td>66°F (18.9°C)</td>
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</tbody>
</table>
(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

ANNEX E – DATA COLLECTION FORMS

E.1. I-P Cooling System Performance Ratio and Installed Cooling System EER Data Collection Form
### Cooling System Performance Ratio and Installed Cooling System EER Data Collection Form

#### Airflow Data

<table>
<thead>
<tr>
<th>Fan shall be operating at full speed for cooling. Using capture hood, measure airflow through each supply register. For systems with outside air, set dampers to minimum position for ventilation. Perform traverse with anemometer or pitot tube. For systems with too many registers to fit in provided spaces, use supplementary form.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supply Airflow</strong></td>
</tr>
<tr>
<td>$Q_{S1}$</td>
</tr>
<tr>
<td>$Q_{S2}$</td>
</tr>
<tr>
<td>$Q_{S3}$</td>
</tr>
<tr>
<td>$Q_{S4}$</td>
</tr>
<tr>
<td>$Q_{S5}$</td>
</tr>
<tr>
<td><strong>Outside Airflow</strong></td>
</tr>
<tr>
<td>$Q_{OA}$</td>
</tr>
<tr>
<td>$Q_{\text{OA}}$</td>
</tr>
<tr>
<td>$% \text{ OA}$</td>
</tr>
<tr>
<td><strong>Total Supply Airflow CFM</strong></td>
</tr>
</tbody>
</table>

#### Thermal Data

<table>
<thead>
<tr>
<th>Fan shall be operating at the full speed intended for cooling. Controls shall be calling for all stages of cooling, equipment shall be operating with all compressors running. Operate for at least 15 minutes, or until the rate of supply register temperature change is no more than 0.5°F in 60 seconds. Capture all enthalpy measurements simultaneously.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supply Register Enthalpy</strong></td>
</tr>
<tr>
<td>$h_{S1}$</td>
</tr>
<tr>
<td>$h_{S2}$</td>
</tr>
<tr>
<td>$h_{S3}$</td>
</tr>
<tr>
<td># measured</td>
</tr>
<tr>
<td>$h_s$</td>
</tr>
<tr>
<td><strong>Return Grille Enthalpy</strong></td>
</tr>
<tr>
<td>$h_{R1}$</td>
</tr>
<tr>
<td>$h_{R2}$</td>
</tr>
<tr>
<td>$h_{R3}$</td>
</tr>
<tr>
<td># measured</td>
</tr>
<tr>
<td>$h_r$</td>
</tr>
<tr>
<td><strong>Outside Air Dry Bulb Temp °F</strong></td>
</tr>
<tr>
<td>$T_{OA}$</td>
</tr>
<tr>
<td>$h_{OA}$</td>
</tr>
<tr>
<td>Equipment Entering Enthalpy Btu/lb</td>
</tr>
<tr>
<td><strong>Outside Air Wet Bulb Temp °F</strong></td>
</tr>
<tr>
<td>$T_{WbOA}$</td>
</tr>
<tr>
<td>$T_{Wb_{ent}}$</td>
</tr>
<tr>
<td>$T_{Wb_{coil}}$</td>
</tr>
<tr>
<td>$% \text{ OA}$</td>
</tr>
<tr>
<td>$\text{WB °F}$</td>
</tr>
<tr>
<td><strong>Equipment Entering WB °F</strong></td>
</tr>
<tr>
<td><strong>Coil Entering WB °F</strong></td>
</tr>
</tbody>
</table>

#### Adjustments for Altitude and Test Conditions

<table>
<thead>
<tr>
<th>Determine manufacturer's specified gross capacity under rating conditions referring to mfg. literature. Determine capacity adjustment factor using Table 4 in Annex D. Determine efficiency adjustment factor using Table 5 in Annex D.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rated Capacity Adjustment</strong></td>
</tr>
<tr>
<td>$q_{\text{Rated}}$</td>
</tr>
<tr>
<td>$C_{C}$</td>
</tr>
<tr>
<td>$q_{\text{Spec}}$</td>
</tr>
<tr>
<td><strong>Rated Efficiency Adjustment</strong></td>
</tr>
<tr>
<td>$C_{E}$</td>
</tr>
</tbody>
</table>

#### Electrical Data

<table>
<thead>
<tr>
<th>Fan shall be operating at the full speed intended for cooling. Controls shall be calling for all stages of cooling, equipment shall be operating with all compressors running. Operate for at least 15 minutes, or until the rate of supply register temperature change is no more than 0.5°F in 60 seconds.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Equipment and Fan Power</strong></td>
</tr>
<tr>
<td>$P_{\text{equip}}$</td>
</tr>
<tr>
<td>$P_{\text{fan}}$</td>
</tr>
<tr>
<td>$P_{CC}$</td>
</tr>
<tr>
<td><strong>Compressor and Condenser Power</strong></td>
</tr>
</tbody>
</table>
ASHRAE 221P

Cooling System Performance Ratio and Installed Cooling System EER Data Collection Form

Measured System Delivered BTU/hr

\[ 4.50 \times Q_s \times h_R - h_S + 4.5 \times Q_{OA} \times h_{OA} - h_{ENT} = q_{system} \]

Cooling System Performance Ratio

\[ \frac{q_{system}}{q_{spec}} = CSPr \]

Installed Cooling System EER Btu/hr/W

\[ P_{cc} + q_{system} \times C_{e} + P_{fan} + q_{system} = 1 = ICSeer \]
### ASHRAE 221P

**Cooling System Performance Ratio and Installed Cooling System EER Data Collection Form**

<table>
<thead>
<tr>
<th>Supply #</th>
<th>Area Served</th>
<th>Airflow CFM</th>
<th>Enthalpy Btu/lb</th>
<th>Return #</th>
<th>Area Served</th>
<th>Enthalpy Btu/lb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

**Total Airflow CFM** | **Total Btu/lb** | **Total Btu/lb**
|----------------------|------------------|------------------|

**# Registers**

**Avg Supply Enthalpy Btu/lb** | **Avg Return Enthalpy Btu/lb**
|-------------------------------|-----------------------------|
E.2. I-P Heating System Performance Ratio Data Collection Form
**ASHRAE 221P**

## Heating System Performance Ratio Data Collection Form

### Airflow Data

**Instructions**
Fan shall be operating at full speed for heating. Using capture hood, measure airflow through each supply register. For systems with outside air, set dampers to minimum position for ventilation. Perform traverse with anemometer or pitot tube. For systems with too many registers to fit in provided spaces, use supplementary form.

<table>
<thead>
<tr>
<th>Supply Airflow CFM</th>
<th>Q_{s1}</th>
<th>Q_{s2}</th>
<th>Q_{s3}</th>
<th>Q_{s4}</th>
<th>Q_{s5}</th>
<th>Σ Q_{s}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside Airflow CFM</td>
<td>Σ Q_{oa}</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Total Supply CFM

### Thermal Data

**Instructions**
Fan shall be operating at the full speed intended for heating. Controls shall be calling for all stages of heat. Combustion burners shall be operating at full fire. Heat pumps shall be operating with all compressors running. Operate for at least 15 minutes, or until the rate of supply register temperature change is no more than 0.5°F in 60 seconds. Capture all temperature measurements simultaneously.

<table>
<thead>
<tr>
<th>Supply Register Temp °F</th>
<th>T_{s1}</th>
<th>T_{s2}</th>
<th>T_{s3}</th>
<th>Σ Measured</th>
<th>Σ T_{s}</th>
<th>Average Supply °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return Grille Temp °F</td>
<td>T_{r1}</td>
<td>T_{r2}</td>
<td>T_{r3}</td>
<td>Σ Measured</td>
<td>Σ T_{r}</td>
<td>Average Return °F</td>
</tr>
<tr>
<td>Outside Air Temp °F</td>
<td>T_{oa}</td>
<td>T_{ent}</td>
<td></td>
<td></td>
<td></td>
<td>Equipment Entering Temp °F</td>
</tr>
</tbody>
</table>

### Adjustments for Altitude and Test Conditions

**Instructions**
Determine manufacturer's specified capacity under rating conditions referring to mfg. literature. For combustion appliances if site is greater than 1,000 ft above sea level, see Table 1 for CH. For heat pumps use Table 6 to find C_{hp}. For electric resistance use rated capacity without adjustment.

\[
q_{\text{rated}} \times C_{R(P)} = q_{\text{hp,spec}}
\]

- \( q_{\text{rated}} \): Mfg. Rated BTU/h
- \( C_{R(P)} \): Combustion Appliance Derating Factor (Table 1)
- \( q_{\text{hp,spec}} \): Heat Pump Capacity Adjustment Factor (Table 6)
ASHRAE 221P

Heating System Performance Ratio Data Collection Form

Performance Score Calculations

Measured System Delivered BTU/hr

\[ Q_{system} = 1.08 \times Q_s \times \frac{T_s - T_R}{T_{ENT} - T_{OA}} + 1.08 \times Q_{OA} \]

Heating System Performance Ratio

\[ \text{HSPR} = \frac{Q_{system}}{q_{spec}} \]

Key

<table>
<thead>
<tr>
<th></th>
<th>Direct measurement</th>
<th>Calculated value</th>
<th>Previously calculated value</th>
</tr>
</thead>
</table>
### ASHRAE 221P

#### Heating System Performance Ratio Data Collection Form

<table>
<thead>
<tr>
<th>Supplemental Supply and Return Airflow and Thermal Data</th>
<th>of</th>
<th>Use multiple pages as required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply #</td>
<td>Area Served</td>
<td>Airflow CFM</td>
</tr>
<tr>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Airflow CFM</th>
<th>Total °F</th>
<th>Total °F</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th># Registers</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>Avg Supply Temperature °F</th>
<th>Avg Return Temperature °F</th>
</tr>
</thead>
</table>
E.2. SI Cooling System Performance Ratio and Installed Cooling System EER Data Collection Form
### ASHRAE 221P

#### Cooling System Performance Ratio and Installed Cooling System EER Data Collection Form

**Airflow Data**

<table>
<thead>
<tr>
<th>Supply Airflow</th>
<th>Q_{01}</th>
<th>Q_{02}</th>
<th>Q_{03}</th>
<th>Q_{04}</th>
<th>Q_{05}</th>
<th>Total Supply Airflow L/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside Airflow</td>
<td>Q_{OA}</td>
<td>Q_{3}</td>
<td>% OA</td>
<td></td>
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</tr>
</tbody>
</table>

Fan shall be operating at full speed for cooling. Using capture hood, measure airflow through each supply register. For systems with outside air, set dampers to minimum position for ventilation. Perform traverse with anemometer or pitot tube. For systems with too many registers to fit in provided spaces, use supplementary form.

**Thermal Data**

<table>
<thead>
<tr>
<th>Supply Register Enthalpy</th>
<th>h_{11}</th>
<th>h_{22}</th>
<th>h_{32}</th>
<th># measured</th>
<th>h_s</th>
<th>Average Supply Enthalpy kJ/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return Grille Enthalpy kJ/kg</td>
<td>h_{R1}</td>
<td>h_{R2}</td>
<td>h_{R3}</td>
<td># measured</td>
<td>h_r</td>
<td>Average Return Enthalpy kJ/kg</td>
</tr>
<tr>
<td>Outside Air Dry Bulb Temp °C</td>
<td>T_{OA}</td>
<td></td>
<td></td>
<td></td>
<td>h_{OA}</td>
<td>Equipment Entering Enthalpy kJ/kg</td>
</tr>
<tr>
<td>Outside Air Wet Bulb Temp °C</td>
<td>T_{w,OA}</td>
<td>% OA</td>
<td>T_{w,ent}</td>
<td>% OA</td>
<td>T_{w,col}</td>
<td></td>
</tr>
</tbody>
</table>

Fan shall be operating at the full speed intended for cooling. Controls shall be calling for all stages of cooling, equipment shall be operating with all compressors running. Operate for at least 15 minutes, or until the rate of supply register temperature change is no more than 0.5°C in 60 seconds. Capture all enthalpy measurements simultaneously.

**Adjustments for Altitude and Test Conditions**

Determine manufacturer’s specified gross capacity under rating conditions referring to mg. literature. Determine capacity adjustment factor using Table 4 in Annex D. Determine efficiency adjustment factor using Table 5 in Annex D.

<table>
<thead>
<tr>
<th>Rated Capacity Adjustment</th>
<th>q_{rated}</th>
<th>C_{C}</th>
<th>q_{spec}</th>
<th>Rated Efficiency Adjustment</th>
<th>C_{E}</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

**Electrical Data**

<table>
<thead>
<tr>
<th>Equipment and Fan Power</th>
<th>P_{equipment}</th>
<th>P_{fan}</th>
<th>P_{CC}</th>
</tr>
</thead>
</table>

Fan shall be operating at the full speed intended for cooling. Controls shall be calling for all stages of cooling, equipment shall be operating with all compressors running. Operate for at least 15 minutes, or until the rate of supply register temperature change is no more than 0.5°C in 60 seconds.
ASHRAE 221P

Cooling System Performance Ratio and Installed Cooling System EER Data Collection Form

Measured System Delivered Watts

\[ 1.2 \times Q_s \times (h_s - h_r) + 1.2 \times Q_{OA} \times (h_{OA} - h_{ENT}) = q_{system} \]

Cooling System Performance Ratio

\[ q_{system} / q_{spec} = CSPr \]

Installed Cooling System EER W/W

\[ P_{cc} / q_{system} + C_E \times 1 + P_{tan} / q_{system} = 1 = ICSeer \]

Key

- Direct measurement
- Calculated value
- Previously calculated value
### ASHRAE 221P

**Cooling System Performance Ratio and Installed Cooling System EER Data Collection Form**

<table>
<thead>
<tr>
<th>Supply #</th>
<th>Area Served</th>
<th>Airflow L/s</th>
<th>Enthalpy kJ/kg</th>
<th>Return #</th>
<th>Area Served</th>
<th>Enthalpy kJ/kg</th>
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<thead>
<tr>
<th>Total Airflow L/s</th>
<th>Total kJ/kg</th>
<th>Total kJ/kg</th>
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<tbody>
<tr>
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<tr>
<td># Registers</td>
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<tr>
<td>Avg Supply Enthalpy kJ/kg</td>
<td>Avg Return Enthalpy kJ/kg</td>
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</tbody>
</table>
E.3. SI Heating System Performance Ratio Data Collection Form
### ASHRAE 221P

**Heating System Performance Ratio Data Collection Form**

#### Airflow Data

**Instructions**

Fan shall be operating at full speed for heating. Using capture hood, measure airflow through each supply register. For systems with outside air, set dampers to minimum position for ventilation. Perform traverse with anemometer or pitot tube. For systems with too many registers to fit in provided spaces, use supplementary form.

<table>
<thead>
<tr>
<th>Supply Airflow L/s</th>
<th>$Q_{S1}$</th>
<th>$Q_{S2}$</th>
<th>$Q_{S3}$</th>
<th>$Q_{S4}$</th>
<th>$Q_{S5}$</th>
<th>$Q_{S6}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside Airflow L/s</td>
<td>$Q_{OA}$</td>
<td>$Q_{O1}$</td>
<td>$Q_{O2}$</td>
<td>$Q_{O3}$</td>
<td>$Q_{O4}$</td>
<td>$Q_{O5}$</td>
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</tbody>
</table>

Total Supply L/s

### Thermal Data

**Instructions**

Fan shall be operating at the full speed intended for heating. Controls shall be calling for all stages of heat. Combustion burners shall be operating at full fire. Heat pumps shall be operating with all compressors running. Operate for at least 15 minutes, or until the rate of supply register temperature change is no more than 0.5°C in 60 seconds. Capture all temperature measurements simultaneously.

| Supply Register Temp °C | $T_{S1}$ | $T_{S2}$ | $T_{S3}$ | $T_{S4}$ | $T_{S5}$ | $T_{S6}$ | $T_{S7}$ |
|--------------------------|----------|----------|----------|----------|----------|---------|
| Return Grille Temp °C    | $T_{R1}$ | $T_{R2}$ | $T_{R3}$ | $T_{R4}$ | $T_{R5}$ | $T_{R6}$ | $T_{R7}$ |
| Outside Air Temp °C      | $T_{OA}$ | $T_{ENT}$ | $T_{OUT}$ | $T_{INT}$ | $T_{IN}$ | $T_{OUT}$ | $T_{IN}$ |

### Adjustments for Altitude and Test Conditions

**Instructions**

Determine manufacturer’s specified capacity under rating conditions referring to mfg. literature. For combustion appliances if site is greater than 1,000 ft above sea level, see Table 1 for CH. For heat pumps use Table 6 to find $C_{HP}$. For electric resistance use rated capacity without adjustment.

\[
q_{\text{Rated}} \times C_{R(P)} = q_{\text{Spec}}
\]

- **$q_{\text{Rated}}$**: Mfg. Rated W
- **$C_{R(P)}$**: Combustion Appliance Derating Factor (Table 1)
- **$q_{\text{Spec}}$**: Heat Pump Capacity Adjustment Factor (Table 6)
ASHRAE 221P
Heating System Performance Ratio Data Collection Form

Performance Score Calculations

Measured System Delivered Wr

\[ Q_{\text{system}} = 1.206 \times (T_s - T_R) + 1.206 \times (T_{\text{ENT}} - T_{\text{OA}}) \]

Heating System Performance Ratio

\[ \text{HSPR} = \frac{q_{\text{system}}}{q_{\text{base}}} \]
ASHRAE 221P
Heating System Performance Ratio Data Collection Form

<table>
<thead>
<tr>
<th>Supply #</th>
<th>Area Served</th>
<th>Airflow L/s</th>
<th>Temperature °C</th>
<th>Return #</th>
<th>Area Served</th>
<th>Temperature °C</th>
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<th>Total Airflow L/s</th>
<th>Total °C</th>
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<th># Registers</th>
<th>Avg Supply Temperature °C</th>
<th># Registers</th>
<th>Avg Return Temperature °C</th>
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