

# Real World Application of ANSI/ASHRAE Standard 221

Monday, February 6<sup>th</sup>  
1:00 PM – 2:00 PM



**Ben Lipscomb, P.E.**

Director of Engineering & Utility Services  
National Comfort Institute, Inc.

*Content and illustrations © NCI, Inc. 2023*

# About NCI

*If you don't measure, you're just guessing™*

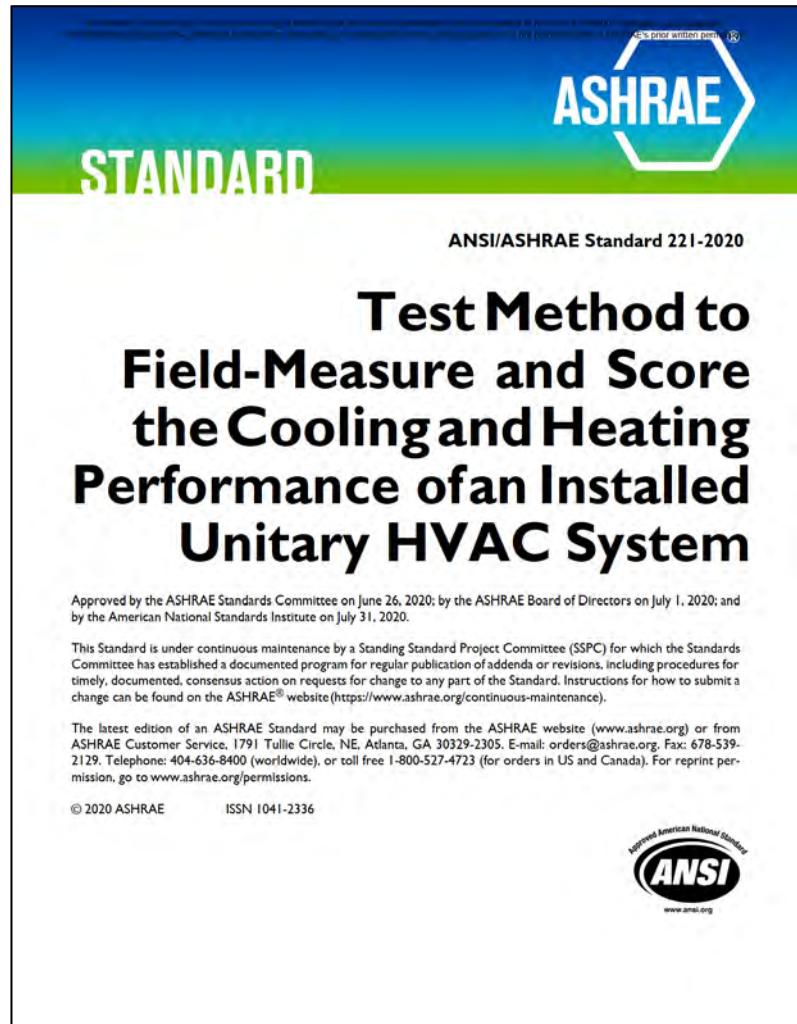
## Who we are

- Founded in 1993
- Our core purpose is helping people survive and thrive
- We want to help elevate HVAC contractors to craftsmen who make buildings comfortable, healthy safe and efficient
- We do this by providing training, certification, and support to HVAC contracting companies large and small

## NCI High Performance Philosophy

- NCI promotes performance-based HVAC contracting
- Field measured performance metrics inform diagnostics and ensure success of new installations, retrofits, renovations, and maintenance
- ASHRAE 221 is the industry standard approach for measuring installed system performance that we teach in our Residential and Commercial System Performance classes

# What is Standard 221?



- Method for field measurement and calculation of
  - Heating System Performance Ratio
  - Cooling System Performance Ratio
  - Installed Cooling System EER
- Applies to single-zone unitary split and packaged DX cooling, air-source heat pump, and combustion furnace systems of any capacity and with forced-air distribution systems

# Key Measurements and Data

## HSP-r

- Total Heating Airflow through Supply Registers
- Average Temperature through Supply Registers and Return Grilles
- Outdoor Air Temperature
- Outdoor Airflow and Temperature of Air Entering Equipment from Return (Systems with outside air supply only)
- Manufacturer Specified Heating Capacity at AHRI Rating Conditions

## CSP-r

- Total Cooling Airflow through Supply Registers
- Average Enthalpy through Supply Registers and Return Grilles
- Outdoor Air Temperature
- Wet-bulb Temperature of Air Entering Equipment from Return
- Outdoor Airflow, Enthalpy, Wet-Bulb, and Equipment Entering Enthalpy (Systems with outside air only)
- Manufacturer Specified Cooling Capacity (Gross) at AHRI Rating Conditions

## ICS-eer

- CSP-r values plus:
- Total Equipment Power
- Supply Fan Power

# CSP-r Calculation

## Basic Concept

Measured System Btu/h = 4.5 x  
Total Supply Airflow x  
(Return Enthalpy – Supply Enthalpy)

$$CSP_r = \frac{\text{Measured System Btu/h}}{\text{Rated Btu/h}}$$

$$CSP_r = \frac{29,400}{36,000} = 82\%$$

## Actual Standard 221 Method

- Accounts for non-standard air density through instrumentation adjustments
- Accounts for outdoor air impacts to return air and indoor coil entering air (when outdoor air ventilation is provided by the system)
- Provides standardized adjustment factors for rated capacity under the test conditions (adjusts for outdoor temperature and equipment entering wet bulb)

# Instrumentation

## Bare Minimum

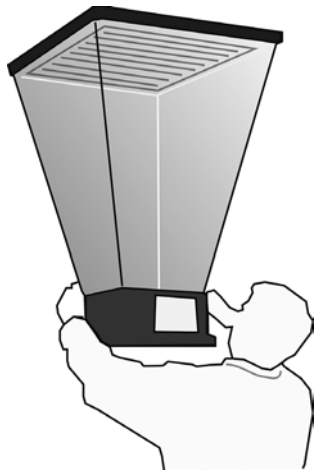


Illustration © 2017 National Comfort Institute, Inc.

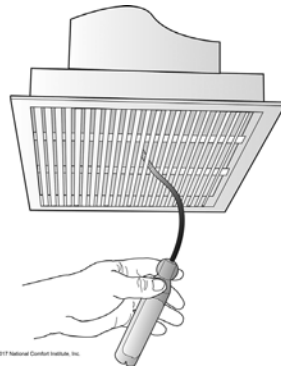


Illustration © 2017 National Comfort Institute, Inc.

## Full Suite

- Air Balancing (Capture) Hood
- Multisensor Thermometer/Psychrometer
- Digital Vane Anemometer
- Digital Thermal Anemometer
- Manometer, Pitot Tube, & Velocity Grid
- Electrical Power Meter

# ASHRAE Standard 221 Cooling Test Report - BETAv0.1

## KEY

Required input, unless *noted*

Optional input

Input Error

This calculator was developed to comply with ASHRAE Standard 221-2020 by the SSPC-221 Committee. Tool has not yet been approved by ASHRAE for full compliance. Users of this tool must refer to the standard and meet test technician qualifications for full compliance.

Calculated Value

Calculated Value Error

Result

Result Error

## PROJECT INFORMATION

Test Technician	Benjamin Lipscomb	Site Name	Lipscomb Residence
Test Date	12/14/2021	Site Elevation ft	3179
Testing Company	National Comfort Institute	Site Address	999 Deer Trl
Company Address	999 Deer Trl	City	Whitefish
City	Whitefish	State	MT
State	MT	Zip Code	59900
Zip Code	59900	Site Telephone	555-555-1212
Company Telephone	555-555-1212	Customer Name	Ben Lipscomb
Customer Name	Ben Lipscomb	Owner/Rep Tel.	555-555-1212
Owner	Ben Lipscomb	Owner/Rep Email	xxx@yyy.com
Owner's Representative		Customer Address	999 Deer Trl
		City	Whitefish
		State	MT
		Zip Code	59900

## EQUIPMENT DATA

Outdoor/Package Equipment Make	Rheem	Air Handler/Furnace Make <i>if split system</i>	Day and Night
Model	RA1348	Model	N8MSL070171GA
Serial	2568-F0984 1024	Serial	A142415999
Nominal Cooling Tonnage	4	Nominal Rated Cooling Airflow cfm	1500
Rated Gross Cooling Capacity Btu/h $q_{c, rated}$	47500	Rated Heating Output Capacity Btu/h <i>if furnace</i>	56000
Rated Cooling EER/EER2*	11.5	AHRI Certified Reference Number <i>if applicable</i>	
Reference Efficiency EER or EER2*	EER	Cooling Coil Make	Rheem
Economizer Make <i>if present</i>	NA	Model	RCF4821STA
Model	NA	Serial	M14-00004780

\*EER as defined in AHRI 210/240-2017 or AHRI 340/360-2022. EER2 as defined in AHRI 210/240-2023  
List Options and Accessories (e.g. 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)  
NA

## SYSTEM DATA

System Name/Area Served	Entire Home	System New or Existing	Existing
Total System Supply Registers	12	Filter(s) Clean or As-Found	As-Found
Total System Return Grilles	1	Coil(s) Clean or As-Found	As-Found
Project Plans Obtained or Drawn	Obtained		

## TEST RESULTS

Cooling System Performance Ratio  $CSP-r$  **92%**

Installed Cooling System EER  $ICS-eer$  **9.27**

## SUPPORTING CALCULATED VALUES

Total Supply Airflow cfm $Q_s$	1183	Capacity Adjustment Factor $C_c$	1.02	Measured System Btu/hr $q_{c, system}$	44636
Average Supply Enthalpy Btu/lb $h_s$	18.62	Adjusted Capacity Btu/h $q_{c, spec}$	48450	Compressor+Cond. Power $W_{P_{oc}}$	3011
Average Return Enthalpy Btu/lb $h_R$	26.41	Efficiency Adjustment Factor $C_E$	0.79		
Calculated Coil Entering Wet-bulb $^{\circ}F T_{wb, coil}$	60.6				

# Calculator Tool

<https://nciutilityservices.com/ashrae-221/>

## Field Test and Measurement Data

### INSTRUMENTATION

Instrument Type	Instrument Make	Model	Serial	Calibration Date
Air Capture Hood	Alnor	ABT-701	PPO-5917-A	9/9/2021
Multi-Sensor Psychrometer	Fieldpiece	JL3RH	THKW-94885-59A	9/9/2021
Watt Meter	Extech	382100	ECT-18011 1J	9/9/2021

### COOLING MODE SYSTEM STARTUP

All must be TRUE or NA

Outdoor air temperature 63°F to 105°F	TRUE	Separate exhaust system(s) off	TRUE
Occupied Space Temperature 70°F to 80°F	TRUE	Controls calling for all stages of cooling	TRUE
Coil entering wet-bulb 57°F to 73°F	TRUE	Economizer in minimum ventilation pos.	NA
System Operating Requirements met	TRUE	Windows closed, doors in normal occupied pos.	TRUE
		Intermittent auxiliary fan(s) off	NA

### MEASUREMENT DATA

Required for all cooling system tests	Required for systems with outdoor air ventilation	Required for ICS-eer			
Outdoor Temperature $^{\circ}F T_{out}$	74.0	Outdoor Airflow $Q_{out}$	249	Total Equipment Power $W_{P_{equip}}$	4016
Equipment Entering Wet-bulb $^{\circ}F T_{wb, ent}$	59.4	Outdoor Enthalpy Btu/lb $h_{out}$	31.81	Supply Fan Power $W_{P_{fan}}$	1005
		Outdoor Wet-bulb $^{\circ}F T_{wb, out}$	65		
		Equipment Entering Enthalpy Btu/lb $h_{ent}$	29		

### SUPPLY REGISTER DATA

Minimum Supply Enthalpy Values Required: 3

Supply Register #	Room/Register Name	Airflow scfm $Q_{Sn}$	Enthalpy Btu/lb $h_{Sn, R3}$
1	Dining	214	
2	Living 1	120	
3	Living 2	85	18.59
4	Living 3	72	
5	Kitchen	33	18.89
6	Master Bath	72	
7	Master Bed	202	
8	Bed 1	31	
9	Bed 2	96	18.37
10	Bed 3	160	
11	Upstairs Bath	27	
12	Guest Bath	71	

### RETURN GRILLE DATA

Minimum Return Enthalpy Values Required: 1

Return Grille #	Room/Grille Name	Enthalpy Btu/lb $h_{Rn, R3}$
1	Dining Room	26.41

# NCI ComfortMaxx Web App

**ComfortMaxx** Find a Customer

**Split System Verify Test - Cooling Mode (w/Fixed Outside Air)**

**Ben Lipscomb** NCI  
 Ben's House Residential  
 Main: (503) 522-7140  
 Mobile: (503) 522-7140  
 Split AC No Heat w OA  
 Split Air Conditioner with No Heat with Fixed Outside Air

Lighting Mode

**Fan**

Method: Automatically Plot with NCI Fan Tables

**Fixed Outside Air Inlet**

Required Airflow: 500 CFM  
 Measured Airflow: 500 CFM

**Registers and Grilles**

Living Room		Return Grilles	
Supply Registers		Name	Airflow
Supply Register 1	945 CFM	Return Grille 1	445 CFM

Navigation:

Actions:

**ComfortMaxx** VERIFY

**Cooling System Verify Test Visual Report (Test Out)**

**Customer Details**  
 Ben Lipscomb  
 375 deer trail  
 whitefish, MT 59937  
 503-522-7140

**Contractor Details**  
 National Comfort Institute, Inc.  
 PO Box 147  
 Avon Lake, OH 44012  
 800-833-7058

**Location**: "Ben's House" (Residential)  
**Address**: 375 deer trail whitefish, MT 59937  
**Main Contact**:  
**System**: Split AC No Heat w OA 2  
 Split Air Conditioner with No Heat with...  
**Area Served**: Sq. Ft.

**Tested by**: Ben Lipscomb on Mar 20, 2022 11:04 PM  
**Test ID**: T:8518:10997

**Performance Results**

**Cooling Equipment Performance Score**  
 100% Efficiency  
 Your cooling equipment is designed by the manufacturer to deliver a specific amount of cool air into your home. The Cooling Equipment Performance Score is the percentage of the measured cooling capacity delivered into your home compared to the equipment rated cooling capacity. The ideal score is 100%, but a score of 90% or better is excellent compared to most installed equipment.

**Cooling System Performance Score**  
 88% Efficiency  
 A cooling system is made up of the cooling equipment in and a duct system that delivers cool air from the equipment into your home. The ideal Cooling System Performance Score is 100%. A lower score reveals unseen problems in your cooling system that increase utility bills and reduce your comfort. A System Performance Score of 80% or better is excellent compared to most installed systems.

https://www.comfortmaxx.net



Real World Application of ANSI/ASHRAE Standard 221





# HVAC Contractor Use: Proving Performance to Customers

- NCI's core use – teaching contractors to use measured performance in their business
- Test In – Assess existing system performance, diagnose issues, evidence-based sales
- Test Out – Verify performance of a new install, retrofit, or renovation
- Maintain – Periodically re-test to ensure continued performance
- See this month's issue of High Performance HVAC Today for an article explaining how this works

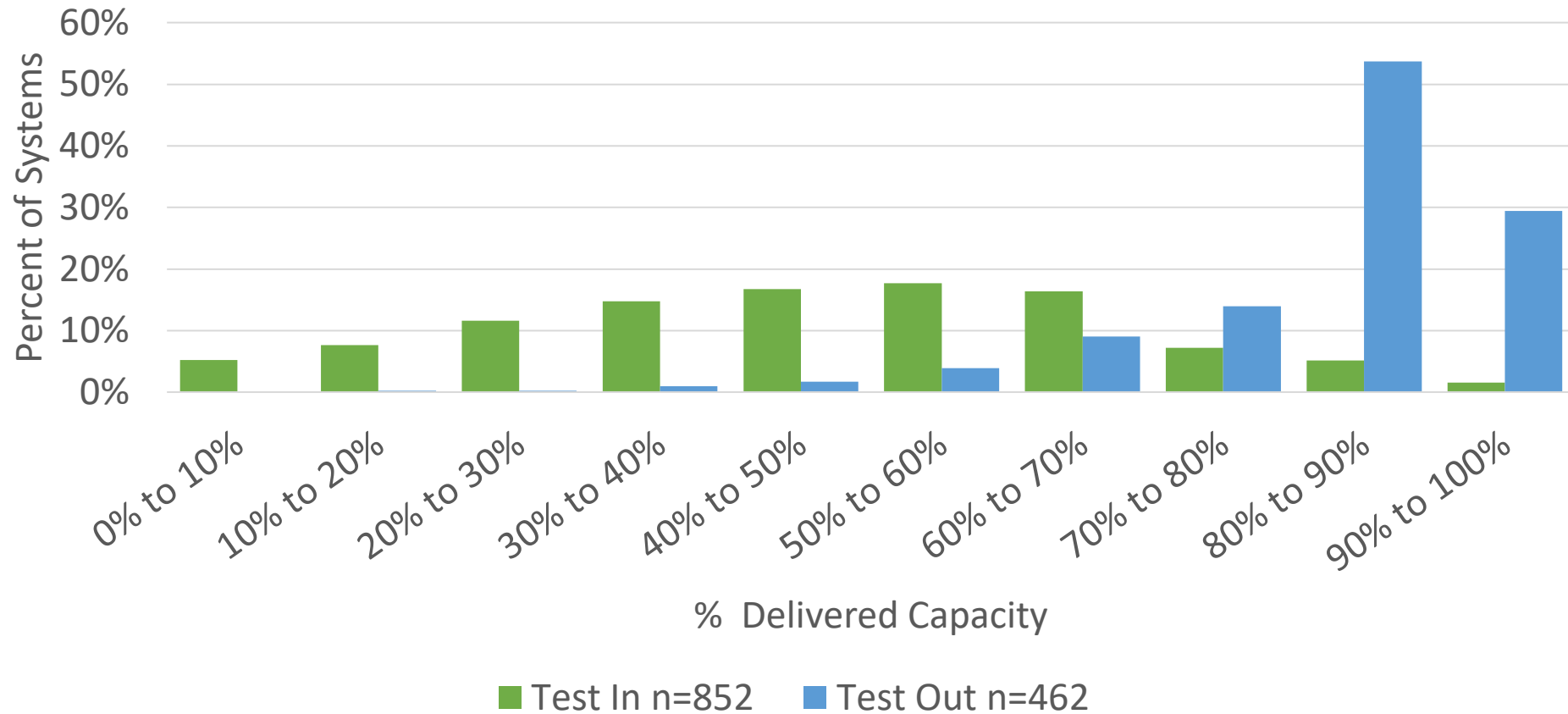
[HVACToday.com](https://www.hvactoday.com)



*Real World Application of ANSI/ASHRAE Standard 221*

# CSP-r Data

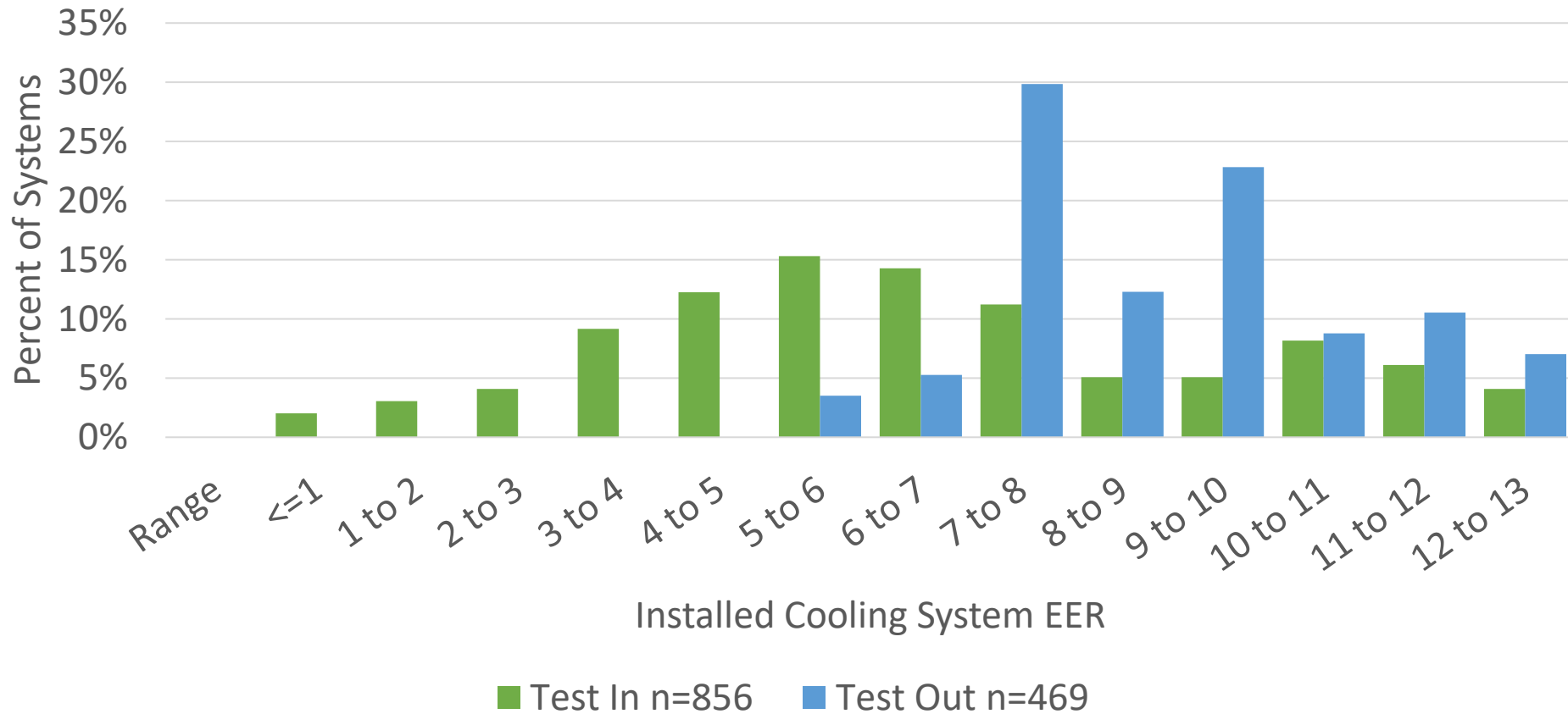
## System Performance Score Distribution



Average Field Measured Performance	Test In	Test Out	Improvement
<b>Cooling System Performance Ratio</b>	<b>48%</b>	<b>83%</b>	<b>73%</b>

# ICS-eer Data

## Installed System Efficiency Distribution



Average Field Measured Performance	Test In	Test Out	Improvement
<b>Installed Cooling System EER</b>	<b>6.7 (61%)</b>	<b>9.0 (82%)</b>	<b>34%</b>

# Certifying System Performance

Contractors: [ncicertified.com](https://ncicertified.com)

Homeowners: [ncicertified.net](https://ncicertified.net)

- 3<sup>rd</sup> Party Certification of system performance offered to contractors by NCI
- “Silver” or “Gold” levels based on key performance metrics
  - Airflow
  - Static Pressure
  - Equipment Performance
  - System Performance



# Ongoing Maintenance

- Once a system is certified, high level performance can be tracked with just 3 easy to gather data points
- Deviations indicate a change or deterioration in system performance, diagnostic starting points

**NCI CERTIFIED**  
SYSTEM PERFORMANCE™

**Certification #:**

**Servicing Company:**

**Call for Service:**

 Click QR code or visit the URL below to locate your certificate and performance report  
[NCICertified.com/Lookup](https://www.ncicertified.com/lookup)

Date	Technician	Mode: <input type="checkbox"/> Heat <input type="checkbox"/> Cool	Equipment Δ P	Equipment Δ T	OA Temp.
		<input type="checkbox"/> Heat <input type="checkbox"/> Cool			
		<input type="checkbox"/> Heat <input type="checkbox"/> Cool			
		<input type="checkbox"/> Heat <input type="checkbox"/> Cool			
		<input type="checkbox"/> Heat <input type="checkbox"/> Cool			
		<input type="checkbox"/> Heat <input type="checkbox"/> Cool			
		<input type="checkbox"/> Heat <input type="checkbox"/> Cool			
		<input type="checkbox"/> Heat <input type="checkbox"/> Cool			
		<input type="checkbox"/> Heat <input type="checkbox"/> Cool			
		<input type="checkbox"/> Heat <input type="checkbox"/> Cool			
		<input type="checkbox"/> Heat <input type="checkbox"/> Cool			
		<input type="checkbox"/> Heat <input type="checkbox"/> Cool			
		<input type="checkbox"/> Heat <input type="checkbox"/> Cool			
		<input type="checkbox"/> Heat <input type="checkbox"/> Cool			
		<input type="checkbox"/> Heat <input type="checkbox"/> Cool			
		<input type="checkbox"/> Heat <input type="checkbox"/> Cool			

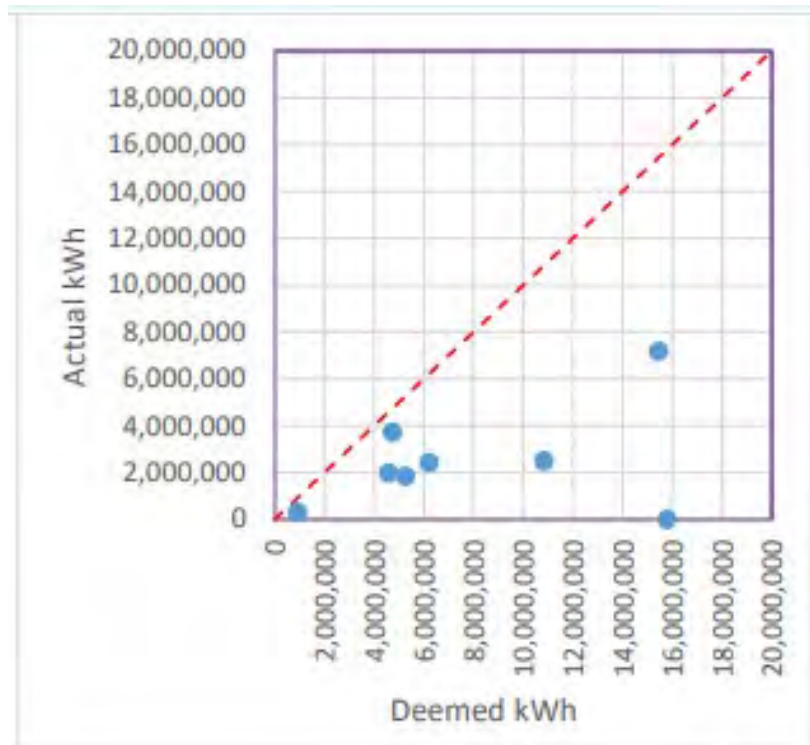
This system has received a certification. To maintain this level of peak performance, annual testing must be performed by an NCI-Certified contractor.

# Utility Program Use: Predicting HVAC Efficiency Program Savings

Download the whitepaper:

<https://nciutilityservices.com/whitepapers/>

## Deemed Savings



## Performance-Based Savings



# Alternative to Checklist-Based QA/QC

## Excerpt: ACCA Standard 5 HVAC Quality Installation Specification

DISTRIBUTION	10	Duct Conduction Losses/Gains	- For the installed system (at design conditions), the temperature difference between the temperature at each/any supply register and the temperature at the evaporator coil is less than 5°F and less than 15°F from the temperature of the heat exchanger or heating element
	11	External Static Pressure Capability	- The duct system should be sized to handle the required system design CFM at the rated static pressure capability of the equipment fan/blower
	12	Air Filtration	- Filters of correct size/selection for equipment application (per application requirement/OEM specifications) - Filter housing is tight with gasketed access panels/doors
	13	Duct Design	- Duct Supply and Duct Return are designed per ACCA Manual D <sub>g</sub> , ACCA Manual Q <sub>g</sub> , ASHRAE standards or per other acceptable engineering methods
	14	Duct Construction	- Duct material selection, construction, assembly and installation are per duct material manufacturer specifications, SMACNA standards, or the authority having jurisdiction - Flexible ducts and flexible duct connectors shall meet code requirements
	15	Registers, Grilles, Diffusers	- Selection (based on throw, volume, mixing, direction, location) is per ACCA Manual D <sub>g</sub> , ACCA Manual T <sub>g</sub> , SMACNA, grill / register / diffuser manufacturer specifications
	16	Rate of Airflow	- Velocity in the duct (FPM) per ACCA Manual D <sub>g</sub> or approved equal - Velocity at the grille (FPM) per recommended FPM for the selected grille
	17	Noise	- Decibel (dB) noise levels are compliant with recommendations from the Air Movement and Control Association (AMCA)
18	Sound Reduction	- Isolation for suspended equipment, air handlers, furnaces in attics - Isolation for roof-mounted or ground-mounted equipment	

- Long checklists add administrative burden, make things more likely to slip through the cracks, don't necessarily ensure high performance
- Standard 221 could be required producing between 1 and 3 performance metrics per install
- Sample of systems for each contractor verified by program

# Code Compliance Acceptance Testing

STATE OF CALIFORNIA  
**SPACE CONDITIONING SYSTEM AIRFLOW RATE**  
CEC-CF3R-MCH-23-H (Revised 1/19)

CALIFORNIA ENERGY COMMISSION  
CERTIFICATE OF VERIFICATION  
CF MCH-23-H  
Page 2 of 3

Space Conditioning System Airflow Rate

Project Name: \_\_\_\_\_ Enforcement Agency: \_\_\_\_\_  
Dwelling Address: \_\_\_\_\_ City: \_\_\_\_\_

**F. Additional Requirements**

01	Air filters that meet the applicable requirements of Standards Section 150.0(m)12 or 150.0(m)13 were used during system airflow rate measurement identified on this Certificate of Installation.
02	The airflow rate measurement apparatus used to perform the airflow rate measurement identified on this Certificate of Installation is calibrated in accordance with the apparatus manufacturer's specifications and conforms to the requirements of RA3.3.1.
03	All registers were fully open during the diagnostic test.
04	System fan was set at maximum speed during the diagnostic test.
05	If fresh air duct is part of the HVAC system it was not closed during the diagnostic test.
06	Airflow rate and fan watt draw shall be simultaneous measurements when used to calculate the Fan Efficacy test.
07	Verification Status: <input type="checkbox"/> Pass - all applicable requirements are met; or <input type="checkbox"/> Fail - one or more applicable requirements are not met. Enter reason for failure in comments field below; or <input type="checkbox"/> All N/A - This entire table is not applicable
08	Correction Notes: The responsible person's signature on this compliance document affirms that all applicable requirements in this table have been met unless otherwise noted in the Verification Status and the Corrections Notes in this table.

**G. Determination of HERS Verification Compliance**  
All applicable sections of this document shall indicate compliance with the specified verification protocol requirements in order for this Certificate of Verification as a whole to be determined to be in compliance.

01	
----	--

Prescriptive  
Acceptance

Performance-  
Based Acceptance

- CSP-r
- HSP-r
- ICS-eer



# Summary of Applications

## Current Applications

- HVAC Contractor
  - Diagnostics
  - Sales
  - Verification
  - Maintenance

## Potential Future Applications

- Performance-based savings estimation
- Energy Efficiency program verification
- Code compliance verification

# Resources

- Buy Standard 221: [https://www.techstreet.com/standards/ashrae-221-2020?product\\_id=2185614](https://www.techstreet.com/standards/ashrae-221-2020?product_id=2185614)
- Download the 221 Calculator: <https://nciutilityservices.com/ashrae-221/>
- Learn About ComfortMaxx: <https://nationalcomfortinstitute.com/pro/index.cfm?pid=1054>
- Read Articles on Measured System Performance: <https://hvactoday.com/>
- Read NCI's White Paper on Performance-Based Savings: <https://nciutilityservices.com/whitepapers/>
- Get Trained and Certified by NCI in Residential or Commercial System Performance: <https://nationalcomfortinstitute.com/pro/index.cfm?pid=940>

# Questions?

Contact me: [benl@ncihvac.com](mailto:benl@ncihvac.com)