

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Home Improvement Catalyst: Advancing High Performance HVAC

September 2017



Optimizing HVAC System Performance



3 million HVAC replacements annually



\$14 billion HVAC service/repair expenditures annually



Research indicates 50% to 70% of systems are improperly designed, installed, or maintained



Improper installations are estimated to be 10% to 50% less efficient than they should be

Our Opportunity:

Improve field performance of HVAC system installation with **selection guidance for verification tools**

Review of Current State of Practice



Conducted **systematic literature review** gathering reports and results on the impacts to performance from improper HVAC installation

- Reviewed 35+ reports, outreach to industry experts, utilities, and REEOs
- Primary focus: existing homes HVAC replacement market



Creating a Snapshot

- Our Approach
 - Conducted a market scan
 - Categorized "tools" by core function and type
 - Focused on commercial software tools and products for collecting and analyzing data on HVAC system performance
- Visual Resources Available
 - High level visual guide to understand the variety of tools available and their primary functions
 - Selection and Comparison Matrix to assist in identifying verification tools for use in specific applications



HVAC Installation Verification Tools

Defining Core Functions:

- **Design:** Load calculation, sizing, equipment selection, and system design
 - ACCA Manual Software
 - OEM and third-party Sizing Apps
- Commissioning and Verification: Smart service tools, extended analysis, and airflow direct measurement
 - System Analysis Software
 - Refrigeration: Digital Gauges and Manifolds
 - Airflow Tools
 - System Analysis Hardware



- Performance Monitoring: OEM installed or after market sensors and software for capacity and system performance monitoring
 - 24/7: Hardware/Sensors or Software as a System (SAAS)
 - Wi-Fi Thermostats
 - Smart Thermostats
 - Indoor Air Quality Monitors



* Companies and logos presented in this Market Snapshot are illustrative examples of products available in their category (as of August 31, 2017). Their presentation in this Market Snapshot is for identification purposes only and does not indicate any product endorsement by the US Department of Energy or association with its trademark owner.

Installation Verification Tool Selection Guide

				24/7 Hardware and Ser	isors	201 - S202	
	-	Target Audience	Type	Features	Benefits	Capability	Examples
	After Market Onboard Sensors and Monitoring	Consumers, Contractors	Monitoring system (10 add-on sensors) installed by a qualified HVAC technician and tracked via Cloud.	Sensors send data when HVAC system is turned on and can remotely monitor component problems and enable contractors to proactively address issues (when an alert is generated) before the issue results in a system fault or falure.	System performance monitoring provides a path for a proactive approach to addressing system faults and failures and can help optimize system performance. Fault data sent directly to contractor in real time improves response time and reduces transaction cost of	HVAC System Analysis, Long Term Monitoring	Comfort Guard
	OEM Onboard Sensors and Monitoring	Consumers, Contractors	Monitoring system built into equipment.		repairs.	Long Term Monitoring	York Affinity, Trane Nex
				28/7 SAAS Data Analytics and	Growarz	AL D	
	Software as a Service	Utilities, Energy	Software platform that monitors	Software solution that aggregates data to determine if there is a	Integrates HVAC performance monitoring and smart thermostat	Smart Controls	Eco Factor
Monitoring	(SAAS)	Retailers, Home Service Providers	HVAC systems for optimization and demand response.	fault with an HVAC system. It also connects with smart thermostats (to minimize energy consumption) and can provide demand response integration.	control for enhanced demand response capabilities.		
Performance	Smart Thermostats	Utilities, Energy Retailers, Home Service Providers, Consumers	An intelligent Wi-Fi enabled thermostat that automatically adjusts heating and cooling temperature settings for optimal performance.	Common features include: learning occupant habits and preferences to automate schedule, providing HVAC energy use data and denied insights/feedback to occupants; and remote control access through Wi-FI and smart devices.	Leverage analytical algorithms and pattern recognition (and connect with many emerging for devices) to provide convenience, comfort, insight, control, as well as opportunities to manage the reliability and efficiency of a home's heating and cooling remotely through a smartphone.	Smart Controls	Nest, Cor, Ecobee
	Wi-Fi Thermostats	Utilities, Energy Retailers, Home Service Providers, Consumers	A Wi-Fi enabled thermostat that gives users remote access to control their heating and cooling (and fan) settings	Programmable thermostat with remote access capabilities through Wi-Fi and smart devices. Limited capability to send automated notifications via a phone app when conditions migrate outside of normal cancers.	Ability to remotely monitor and adjust a home's heating and cooling temperature. May provide opportunities for optimizing the energy efficiency of a home's HVAC system.	Smart Controls	Sensi
	Indoor Air Quality (IAQ) Monitors	Consumers, Contractors	Stand-alone monitoring device to continually monitor and measure aspects of IAQ, and data log those measurements over a period of time.	The range of measurements varies, but typically include measuring PM10, PM2.5, total VOCs, C02, temperature, and humidity (none yet measure CO). Some models are IoT and thermostar ready (that is, can be configured to turn on the fan of an HVAC system to filter air when the device measures poor IAQ).	Monitoring tool that provides insight into a home's IAQ. Some models connect with emerging IoT devices and may provide a path to a proactive and streamlined approach to improving IAQ.	Indoor Air Quality Monitoring	Foobot, Awair
	Funtana Anatharia	Target Audience	Type	Hand Tools & System An Features	alysis Benefits	Capability	Example Products
rification	Hordware	Utilities	manifold, gauges, or probes that perform extended system analysis and integrate with smart phones.	whereas measurement out that reveage mode prioric aparatics to measure data points in real-line for fault analysis and offer improvement solutions on system performance.	whereas measurements (or temperature sing pressure) so teamine the process for gathering system diagnostics. System performance calculations and analytics streamline and enhance in-field improvement solutions. And, smart phone integration (through an app) further leverages wireless capabilities to streamline data reporting for the user.	Uniter Service room	initianitido, mas
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ommissioning & Verif	Refrigeration: Digital Gauges & Manifolds	Contractors	Digital manifold.	Leverages digital technology to determine superheat and sub- cooling and record measurements over time. There are many models on the market, with more continually being developed.	Streamlined and more accurate approach to charging a refrigeration system directly by superheat or sub-cooling. With built-in temperature and pressure charst, eliminates the need to manually read a dial and then calculate superheat or sub-cooling, which can reduce refrigerant charging errors and cause system performance issues.	Smart Service Tool	Testo, Fieldpiece
Commissioning & Verif	Refrigeration: Digital Gauges & Manifolds Airflow Tools	Contractors Contractors	Digital manifold.	Leverage digital technology to determine superheat and sub- cooling and record measurements over time. There are many model: on the market, with more continually being developed. There are various tools in the market, each with different features and technical capabilities, but the purpose of each is to measure airfow.	Streaming and more accurate approach to charging a refrigeration system directly systemater or sub-colling. With built- temportance and pressure charts, eliminates the need to manually read a dual and the calculate superhear to all-cooling, which can reduce refrigerant charging errors and cause system performance and the system ainflow in a single measurement.	Smart Service Tool Airflow Direct Measurement	Testo, Fieldpiece True FlowPlate
Commissioning & Verif	Refrigeration: Digital Gauges & Manifolds Airflow Tools System Analysis Software	Contractors Contractors Utilities, Contractors	Digital manifold. Tools to measure airflow directly or indirectly. Software platform that verifles pixtem performance.	Leverage digital technology to determine superheat nat sub- cooling and record measurements our time. There are many models on the market, with more contrausly being developed. There are various tools in the market, each with different features and technola capabilities, but the purpose of each is to messure arfox. Woot set as repository for capturing field data liquid by the user land than calculates par performance.	Steamine and more accurate approach to charging a refigurerision spream directly by potential or sub-cooling. With built in remperature and pressure charging eliminates the needs to manually reads and and then could appropriate or accounting, which can reads and and then charging energy and cause system particular strates. Accurately quantifies total system airflow in a single measurement. Typically these serve as a quality assumed documentation system to capater disports and system particular.	Smart Service Tool Airflow Direct Measurement Extended Analysis	Testo, Fieldpiece True FlowPlate HVAC Save, CheckMel
Commissioning & Verif	Retrigeration: Digital Gauges & Manifolds Airflow Tools System Analysis Software	Contractors Contractors Utilities, Contractors	Digital manifold. Tools to measure airflow directly or indirectly. Software platform that verifies system performance.	Leverage digital formiong to determine significant and sub- dising and recold memory to determine significant and sub- fications and the marker, with more community large developed. There are version to bits the marker, such with different failures and sources to bits the marker, and with different failures and the calculates uption purposed of each to the sear- and bits of as as a responsion for organizing field data shaped to the use and then calculates uptions purformed.	Streaming and more accurate approximation to sharping a refregerious streaming and provide the stream of the stre	Smart Service Tool Airflow Direct Measurement Extended Analysis	Testo, Fieldpiece True FlowPlate HVAC Save, CheckMel
Commissioning & Verif	Retrigeration: Digital Gauges & Manifolds Airflow Tools System Analysis Software	Contractors Contractors Utilities, Contractors	Digital manifold. Tools to measure airflow directly or indirectly. Software platform that verifies system performance.	Leverage Sight forthology to determine sporther and sub- ologing and scalar laverance to use fram. Frame a many models on the market, with more community tang developed. There are various tools in the market, each with different features and school capabilities, but the purpose of each to measure affect. Work as as reporting for capturing feed data liped by the user and the calculates lipitine performance. <u>Capacity Loss 4.5 Dreign Calor</u>	Streamine and more socures approximation to simplify a reference of present endership societates or tac-onicity. While the in- temportunities and pressure chainst, determined the need to measure induce reflected chaining errors and cause system performance transes. Accurately quantifies total system airflow in a single measurement. Typically these serve as a quality assumance documentation system to captore disponsition and space performance. Earlier Table Borefast	Smart Service Tool Airflow Direct Measurement Extended Analysis Capability	Testo, Fieldpiece True FiowPlate HVAC Save, CheckIMel Example Products
Delign Commissioning & Verif	Refrigeration: Digital Gauges & Manifolds Airflow Tools System Analysis Software ACCA Manual Software	Contractors Contractors Utilities, Contractors Target Audience Contractors (HVAC Designers)	Digital manifold. Tools to measure airflow directly or indirectly. Software pathom that verifies inystem performance. Type Software, oug, and web based load calculators for WMZ designers to generate Manaul servors.	Leverage digital forthology to determine significant and Lad- dong and recoid manners to write film. First are analy models on the matter, with more community there developed there are various tools in the manner, such with different features and all outsides. Not the purpose of exhibits to messare and the calculates tools the optimum of exhibits to messare and their calculates instrem participants. The purpose features are also also all the provide the such as and their calculates instrem participants. The developed calcula- tion of the calculates instrem participants. The developed calcula- formers are supported to ACC and the developed calcula- centerion in using halve coupled with Minuel 3) and selecting approprints MUC expertent.	Streamine and more accurate apports to sharped a reference internet method spacetare to successive approximate methods and the stream of the stream of the stream methods end them coloures usedness of sub-coloure, which can be appreciated to starp screen and cause system performance issues. Accurately appreciate storage schema approximate to capture degroots and system performance. Internet tools the provide storage schema performance.	Smart Service Tool Airflow Direct Measurement Extended Analysis Capability Load Calculation	Testo, Fieldpiece True FlowPlate HVAC Save, CheckMel Example Products Wrightsoft
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Design Commissioning & Verif	Rethigenation: Dighail Gauges & Manifolds Airflow Tools System Analysis Software ACCA Manual Software Sizing Apps	Contractors Contractors Unlittes, Contractors Target Audience Contractors Contractors Contractors	Digital manifold. Digital manifold. Tools to measure airflow directly or indirectly. Software parlom toxic vertiles system performance. Type: Constraints of work descriptions of the performance of the pe	Leverage digital forthology to determine sporther and Lad- dong and stroot memore the own fram. For the many- models on the matter, with more community tang developed. There are various tools in the manter, each with different features and technical capabilities, both the purpose of each is to messare with the calculates by the optimum of the data of the so- and then calculates system performance. Restarts and spotiation of the so- restarts and spotiation of the so- programmers. All spotiations and solid professions are solid professional of the solid and capacity sting calculations in sing MACA sports and acid spotiations appointed in the solid and capacity sting calculations in sing MACA spotiations.	Streamine and more accurate apports to sharped a reference streamine and provide the sharped stream of the sharped interface and provide the sharped stream of the sharped mode and provide the sharped stream of the sharped resolution of the sharped resolution of the sharped resolution of the sharped resoluti	Smart Service Tool AntToo Direct Measurement Extended Analyse Capability Load Catculation Load Catculation Load Catculation and Soing Analyse	Testo, Fieldpiece True FlowPlate HVAC Save, CheckMel Example Products Wrightsoft HVAC Buddy, HVAC Dail Load
Delign Commissioning & Verif	Retrigeration: Dighai Gauges & Manifolds Airflow Tools System Analysis Software ACCA Manual Software Sizing Apps	Contractors Contractors Utilities, Contractors Target Audience (PNAC Designers) Contractors Torsea Audio	Digital manifold. Toda's measure airflow directly or indirectly. Software platform that verifies instrements of the software performance. Type Type Software, Ouer, and web based load calculators for MVX. designers to generate Manail arcont. Generate Manail arcont. Software	Leverage digital forchoopy to determine significant and sub- dising and intradi memoremic low differs. There are many models on the marker, with more community long developed: There are various babls the marker, stack with different futures and the strends and subditional to the marker, stack with different futures and the calculates system performance. Capacity (Stack Stack Strends Strends Stack Stack Stack Strends Informa supported hy ACC Stack Strends Stack Stack Stack Informa supported hy ACC Stack Strends Stack Stack Stack Stack Informa supported hy ACC Stack Strends Stack Stack Stack Stack Informa supported hy ACC Stack Stack Stack Stack Stack Stack Informa supported hy ACC Stack Stack Stack Stack Stack Stack Information Stack Stack	Streamine and more accurate approxis to sharple a reflection streamine and more accurate approxis to sharple approximate present develop spacetime to sub-color approximate read a plan of their accurate spacehold or sub-colore, which can be approximate and the streamine approximate and approximate tasks. Accurately approximate to approximate accurate proformance and the streamine approximate accurate the streamine and the stream test approximate accurate the stream test hash Expension approximate and expension accurate the stream conformability and endogramme sub-colors. The provide accurate approximate accurate the stream conformability and endogramme sub-colors. The provide accurate accurate the streamine accurate the provide accurate accurate accurate the streamine reporting the streamine accurate accurate the streamine accurate accurate the streamine accurate accurate the streamine accurate accu	Smart Service Tool Airflow Direct Measurement Extended Analysis Capability Load Calculation Load Calculation and Soing Analysis Consolition	Testo, Fieldpiece True FlowPlate HVAC Save, CheckMel Example Products Wrighton HVAC Buddy, HVAC Dai Load
Distribution Design Commissioning & Verif	Retrigeration: Digital Gauges & Manifolds Airflow Tools System Analysis System Analysis Sizing Apps System Analysis System Analysis	Contractors Contractors Utilities, Contractors Target Audience Contractors Target Audience Utilities, Contractors	Digital manifold. Digital manifold. Todal to measure airflow directly or indirectly. Software plantform that verifies instreme performance. <u>Type</u> <u>Typp</u> <u>Type</u> <u>Type</u> <u>Type</u>	Leverage digits forchoopy to determine significant and sub- dising and incolinements one time. There are many models on the matter, with more community integrations(). The matter are varied to be the market and a significant failures and the strends bable in the market and a significant failures and the calculates system performance. Caseable, state 4 as recommon the significant failures in the calculates system performance. Caseable, state 4 as recommon the significant failures in the calculates system performance. Caseable, state 4 as recommon the significant failures in the calculates system performance. Caseable, state 4 as recommon the significant failures in the calculates of the caseable with Marked 3 and selecting appropring the VAC caperations Marked 5 and selecting appropring the VAC caperations Marked 5 and selecting the size from the size of the caped with Marked 5 and selecting appropring the VAC caperations in the size of the size of solved for the calculates as a region for caperating field data input by level and the calculates system performance meets.	Streamine and more accurate approxis to sharple a reflexition (Streamine and you accurate a sub-coloris, With Nu-tho mean a sub-coloris, With Nu-tho mean a sub-coloris, With Nu-tho Nu-thouse reflexitient coloris accurate to use-coloring, which can device reflexitient coloris accurate to use-coloring, which can colorize the sub-coloris accurate to use-coloring, which can colorize the sub-colorise accurate to use-coloring, which can colorize the sub-colorise accurate the sub-colorized transmission and system performance. Transmission and system performance the most conformabia and energy efficient equipment sub-coloris. Theramined approach to using (FAX equipment and is more granges) the most off-thom specialized. States States Transmission accurate the most consolidation of the sub- period with the sub-specialized. States St	Smart Service Tool Antion Direct Measurement Extended Analysis Capability Load Calculation Load Calculation Load Calculation Capability Distribution System Analysis	Testo, Pieldpiece True PiowPlate HVAC Save, CheckMel Example Products Wrightsoft HVAC Budy, HVAC Dai Load Example Products HVAC Save, CheckMel, ConfortMass

Selection Guide available here: https://rpsc.energy.gov/tech-solutions/hvac

Matrix documents installation verification tools by:

- Target audience, system type, capability, features and benefits and example products
- Designed as summary guidance to help contractors, programs, utilities and others in selecting the appropriate installation verification tools

Next steps...

Understanding Key Performance Indicators (KPIs)

- Summarize performance measurements (e.g., refrigerant charge, airflow, static pressure, etc.) used when installing HVAC systems
 - Follows industry standards (ACCA 5) and OEM specs
- Are NOT intended to be used as an installation checklist or process
- Recommend: industry and OEM standards

KPIs provide the basis for establishing performance criteria for field verification tools

Field Verification Tool Performance Criteria:

Provides the key measurement capabilities, tolerances, analytical capacity, etc. for diagnostic and monitoring tools

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