**Building Science Education Solution Center – Commissioning**PNNL-SA-200645

Proficiency Level 1: Remember

**Learning Objective 1.1:**

* List three common HVAC installation faults and their impact on energy use, occupant comfort, equipment reliability, and utility bills.

**Lecture Notes 1.1:**

Effective heating, ventilation, and air conditioning (HVAC) installation is pivotal for the performance, efficiency, and longevity of HVAC systems. Understanding common faults in HVAC installation is crucial for addressing issues that could have significant short- and long-term consequences.

**1. Common HVAC Installation Faults**

Common HVAC installation faults include improper refrigerant charge, insufficient airflow, and duct leakage. The widespread prevalence of these faults raises significant concerns, as evidenced by various research findings. For instance, a comprehensive review of research findings on residential installation practices[[1]](#footnote-1) indicates that 70-90% of air conditioner and heat pump systems exhibit at least one performance-compromising fault due to improper installation or inadequate maintenance. When factoring in duct leakage, these rates escalate to an alarming 90-100%.

The prevalence of HVAC installation faults highlights the need to encourage better installation practices. The common faults in these systems not only affect individual households but also cause environmental issues and economic problems on a broader scale. Industry-wide efforts aimed at improving installation practices, adherence to standards, and ongoing education are crucial in mitigating the widespread issue of improper HVAC installation.

**2. Impact of Improper Installation**

The impacts of improper HVAC installation extend broadly, affecting both energy efficiency and occupant utility costs. According to a model developed by the National Renewable Energy Laboratory (NREL)[[2]](#footnote-2), improper HVAC installation is not only an energy efficiency concern but also has substantial financial implications. The NREL model estimates that approximately 9% of the energy used in HVAC systems nationwide is attributed to installation-related faults. Nationally, this energy waste results in an increase of approximately $2.5 billion in utility bills annually.

Furthermore, common installation faults can lead to a reduction of cooling or heating as illustrated in Figure 1. The chart depicts that 4% of energy losses are due to improper refrigerant levels, 3% due to improper airflow, and 15% attributed to duct leakage.



**Figure 1**. Most residential heat pumps are installed incorrectly and with energy-wasting faults. (Source: ENERGY STAR)

Premature equipment failure is also a risk, as strain from improper installation can cause components to fail early, necessitating expensive repairs or replacements. Air distribution issues from poorly installed ductwork can result in uneven heating or cooling and occupant discomfort. For example, insufficient airflow can lead to hot or cold spots, making it uncomfortable for occupants and causing the HVAC system to work harder, increasing energy consumption. Noise complaints are another potential consequence, as faulty installation can lead to noisy operation, disrupting occupants' peace and comfort. Lastly, safety hazards, such as electrical fires or mold and moisture problems, may arise from improper installation posing risks to the well-being of occupants.

**3. Value Proposition of Quality HVAC Installations**

Understanding common faults and how to fix them is crucial for HVAC professionals. Quality installations not only benefit homeowners by improving energy efficiency, comfort, reliability, and cost-effectiveness but also enhance the reputation and trust of HVAC businesses. A history of successful installations builds trust with clients and leads to more business opportunities through recommendations. In addition, finding and fixing faults at the time of installation can reduce callbacks which can be costly to HVAC businesses due to additional truck rolls, gas, and technician/installer time that can be spent on another job.

Relevant Resources:

* Barriers to Broader Utilization of Fault Detection Technologies for Improving Residential HVAC Equipment Efficiency. <https://www.nrel.gov/docs/fy22osti/82024.pdf>
* Residential HVAC Installation Practices: A Review of Research Findings

<https://www.energy.gov/sites/prod/files/2018/06/f53/bto-ResidentialHVACLitReview-06-2018.pdf>

* Impact of Installation Faults in Air Conditioners and Heat Pumps in Single-family Homes on U.S. Energy Usage <https://www.sciencedirect.com/science/article/pii/S030626192031045X?via%3Dihub>
* NIST Technical Note 1848: Sensitivity Analysis of Installation Faults on Heat Pump Performance <https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1848.pdf>

**Problem Set 1.1:**

1. According to the NREL model, what percentage of the energy used in HVAC systems is estimated to be attributed to installation-related faults, leading to a substantial financial burden on utility bill payers?

2. Identify one symptom of insufficient airflow in an HVAC system and explain its potential impact on occupant comfort.

3. List some potential consequences of incorrect refrigerant charge in an HVAC system.

**Learning Objective 1.2:**

* Define residential HVAC commissioning

**Lecture Notes 1.2:**

Commissioning is an essential step in ensuring the efficient and reliable operation of HVAC systems; however, most HVAC businesses do not test and commission their systems. In this lecture, we explore the definition of residential HVAC commissioning, highlighting its crucial importance and impact in ensuring expected system performance and addressing installation-related faults.

**1. What is Residential HVAC Commissioning?**

Residential HVAC commissioning is a step-by-step process where we carefully inspect, test, and adjust the HVAC system after installation. The main goal is to confirm that the system operates at its intended efficiency, matches design specifications, and functions reliably in-field. Table 1 lists a generic workflow used in the residential HVAC commissioning process.

Table 1. Generic Workflow for Residential HVAC Commissioning.

|  |  |  |
| --- | --- | --- |
| **Key Element** | **Purpose** | **Importance** |
| Visual Inspection | Identify proper installation of all components, enabling early detection of faults | Some construction-related installation faults can be identified through visual inspection  |
| Performance Verification | Confirm the system operates as designed | Ensures intended airflow, refrigerant charge level, and control requirements are met and that the system is delivering the intended capacity and efficiency |
| Fault Resolution | Address issues identified during commissioning | Immediate resolution improves system reliability, prevents breakdowns |
| Adjustments for Performance Improvement | Fine-tune settings and potential retrofit for improved performance | Ensures efficient operation and identifies retrofit opportunities for long-term high-performance efficiency and reliability |

**2. Why Does Residential HVAC Commissioning matter?**

Residential HVAC commissioning holds significant importance for several reasons:

* **Verification of System Performance:** Commissioning ensures the system meets specified performance criteria, accounting for equipment differences and installation complexities.
* **Addressing Installation Faults:** Commissioning identifies and rectifies common installation faults, ensuring optimal system operation.
* **Enhanced Reliability:** Commissioning mitigates short- and long-term reliability issues by promptly addressing any identified faults, reducing the likelihood of unexpected breakdowns.
* **Energy Efficiency:** A well-commissioned HVAC system operates efficiently, leading to lower utility bills and reduced environmental footprint.

**3. Impact of Residential HVAC Commissioning**

Residential HVAC commissioning is a comprehensive process that goes beyond the initial installation, focusing on system inspection, performance verification, fault resolution, and adjustments for performance improvement. It is a proactive approach to ensure that residential HVAC systems operate efficiently, reliably, and in accordance with industry standards. While the primary beneficiaries are homeowners, who will experience enhanced energy efficiency, sustained comfort, and prolonged system reliability, the positive impacts of commissioning extend to contractors and technicians.

For contractors and technicians, residential HVAC commissioning presents a valuable opportunity to showcase their expertise and dedication to delivering high-quality installations. By adhering to standard commissioning processes, these professionals can establish a positive reputation for reliability and competence within the industry. A track record of successful commissioning contributes to the trust clients place in contractors, fostering long-term relationships and potential repeat business.

Moreover, residential HVAC commissioning directly benefits technicians by reducing the likelihood of post-installation callbacks. The inspection and fault resolution during commissioning minimize the chances of system malfunctions or breakdowns, ultimately lowering the need for additional service calls. This reduction in callbacks not only saves time and resources but also enhances the overall efficiency and profitability of the technician's work.

In essence, residential HVAC commissioning emerges as a win-win strategy, providing tangible advantages to homeowners in terms of comfort, energy savings, and system reliability, while simultaneously elevating the professional standing of contractors and technicians within the HVAC industry.

Relevant Resources:

* Residential HVAC Installation Practices: A Review of Research Findings

<https://www.energy.gov/sites/prod/files/2018/06/f53/bto-ResidentialHVACLitReview-06-2018.pdf>

* Impact of Installation Faults in Air Conditioners and Heat Pumps in Single-family Homes on U.S. Energy Usage <https://www.sciencedirect.com/science/article/pii/S030626192031045X>
* Sensitivity Analysis of Installation Faults on Heat Pump Performance <https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1848.pdf>
* Barriers to Broader Utilization of Fault Detection Technologies for Improving Residential HVAC Equipment Efficiency. <https://www.nrel.gov/docs/fy22osti/82024.pdf>

**Problem Set 1.2:**

1. What is the main goal of residential HVAC commissioning?

**Learning Objective 1.3:**

* List the key industry standards and documents that describe residential HVAC commissioning.

**Lecture Notes 1.3:**

Successful commissioning of residential HVAC systems involves adhering to established industry standards and guidelines. This lecture presents key industry standards and documents governing residential HVAC system commissioning. This isn't an exhaustive guide to quality installation but rather a compilation of key best practices and commonly overlooked aspects.

**Standards and Industry Guidance:**

The industry has developed several guidelines and standards that define residential HVAC system commissioning as described below. Although these standards exist, there is a great need to increase the adoption of these standards and other best practices among residential HVAC professionals.

* [**ACCA 5 QI-2015**](https://www.acca.org/viewdocument/hvac-quality-installation-specification-english): First introduced in 2007, this ANSI/ACCA HVAC Quality Installation Specification (ACCA 2015) establishes minimum criteria for proper installation of HVAC systems. It applies to unitary air conditioning and heat pump systems, furnaces, and boilers in both residential and commercial buildings. The specification is split into sections that verify aspects of design, equipment installation, distribution, system documentation, and owner education.
* [**ACCA 9 QlvP-2016**](https://www.acca.org/viewdocument/hvac-quality-installation-verification-protocols): The ACCA Quality Installation Verification Protocols (ACCA 2016) complement the guidelines outlined in ACCA 5 QI. ACCA QIvP provides evaluation protocols in two levels of system verification: Level 1 Installation Checklist Verification and Level 2 Field Verification. This standard also provides program administrators with minimum requirements for programmatic policies and procedures.
* [**RESNET/ACCA 310-2020**](https://www.resnet.us/wp-content/uploads/ANSIRESNETACCA_310-2020_v7.1.pdf): The RESNET/ACCA Standard for Grading the Installation of HVAC Systems (RESNET/ACCA 2020) establishes procedures, tolerances, and documentation practices associated with the evaluation and grading of an HVAC system’s design and installation. It consists of five evaluation tasks: 1) design review, 2) total duct leakage, 3) blower fan airflow, 4) blower fan watt draw, and 5) refrigerant charge. This standard is intended to support energy rating and labeling used by energy raters, energy auditors, or HVAC Contractors. The standard applies to unitary air conditioners and heat pumps up to 65 kBtuh and furnaces up to 125 kBtuh.
* [**ASHRAE Standard 221-2020**](https://webstore.ansi.org/standards/ashrae/ansiashraestandard2212020): The ANSI/ASHRAE Test Method to Field-Measure and Score the Cooling and Heating Performance of an Installed Unitary HVAC System (ASHRAE 2020) provides a field evaluation and test method to measure and score the performance of an installed unitary HVAC system. The score is based on delivered cooling or heating capacity or cooling efficiency. This standard applies to single-zone unitary split and packaged direct expansion cooling, air-source heat pump, and combustion furnace systems of any capacity and with forced-air distribution systems.

These standards share similar scopes, applicable equipment, and audiences, although some may focus on specific types of practitioners (e.g., RESNET/ACCA 310 focuses on home energy raters). Table 1 compares the intended applications, sectors, and audiences for each standard.

Table 1. Comparison of Industry Quality Installation Standards

| **Standard** | **Equipment Types** | **Sector** | **Audience** |
| --- | --- | --- | --- |
| ACCA 5 QI-2015 | Unitary air conditioners, air-source/water-source heat pumps, geothermal heat pumpsFurnaces (gas-fired, oil-fired, electric, other)Boilers (gas-fired, oil-fired, electric, other) | Commercial, Residential | HVAC Contractors,Equipment Manufacturers,HVAC Trainers,Utilities,Building Owners/Operators,Certification Bodies |
| ACCA 9 QlvP-2016 | Unitary air conditioners, air-source/water-source heat pumps, geothermal heat pumpsFurnaces (gas-fired, oil-fired, electric, other)Boilers (gas-fired, oil-fired, electric, other) | Commercial,Residential | Program Administrators,HVAC Contractors,Third-Party Verifiers |
| RESNET/ ACCA 310 | Unitary air conditioner, air-source heat pump up to 65 kBtuHFurnace up to 125 kBtuh | Residential | Home Energy Raters,Energy Auditors,HVAC Contractors |
| ASHRAE 221 | Single-zone unitary split and packaged direct expansion (DX) cooling, air-source heat pump, and combustion furnace HVAC system of any capacity with forced-air distribution systems. | Commercial, Residential | HVAC Contractors,Technicians,Design Engineers,Balancing and Energy, M&V Professionals,Manufacturers,Facility Personnel,Commissioning Agents |

In conclusion, understanding and implementing relevant standards and industry practice is paramount for successful HVAC commissioning. Professionals in the field should be well-versed in the guidelines provided by organizations such as ASHRAE, ACCA, and RESNET to ensure that residential HVAC systems are commissioned to these standards and industry guidance.

**Problem Set 1.3:**

1. Name one organization that establishes standards or guidance for residential HVAC commissioning.
1. DOE EERE. *Residential HVAC Installation Practices: A Review of Research Findings*, 2018. [↑](#footnote-ref-1)
2. Winkler, Jon, et al. Impact of installation faults in air conditioners and heat pumps in single-family homes on US energy usage. *Applied Energy* 278 (2020): 115533. [↑](#footnote-ref-2)