Specification of Energy-Efficient Installation and Maintenance Practices for Residential HVAC Systems

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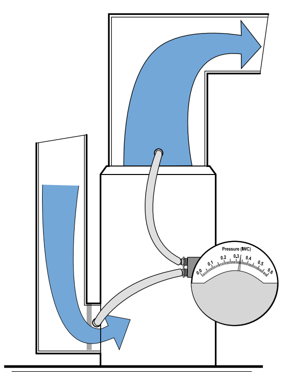

Acknowledgements

The Consortium for Energy Efficiency thanks the authors of this document, Rick Karg of R.J. Karg Associates and John Krigger of Saturn Resource Management.

The Consortium for Energy Efficiency and the authors thank the following individuals for answering questions, offering suggestions, and reviewing earlier drafts of this publication.

Michael Blasnick, Consultant
Terry Chapp, Modine Manufacturing Company
Bob Davis, Ecotope Inc.
Tom Downey, Proctor Engineering
Rob Faulke, National Balancing Institute
Andrew Fisk, New York State Energy Research and Development Authority
Doug Garrett, Building Performance and Comfort
Eli P Howard III, SMACNA
Marshall Hunt, Pacific Gas and Electric
John Jennings, Northwest Energy Efficiency Alliance
Jeff Johnson, New Buildings Institute
Tom Johnson, Lennox Industries
Joel Kinsch, North American Technician Excellence
Dave Lewis, Lennox Industries
Bruce Manclark, Delta-T Inc.
Gary Mazade, Energetechs
Steve Nadel, American Council for an Energy-Efficient Economy
Leon Neal, Advanced Energy Corporation
Gary Nelson, The Energy Conservatory
Chris Neme, Vermont Energy Investment Corporation
Colin O'Dell, Northeast Utilities
Jack Orum, HVAC Contractor
Danny Parker, Florida Solar Energy Center
Bill Pennington, California Energy Commission
John Proctor, Proctor Engineering
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Hank Rutkowski, Air Conditioning Contractors of America
Ron Rothman, The Energy Conservatory
Charles Segerstrom, Pacific Gas and Electric
Dick Shaw, Air Conditioning Contractors of America
Craig Sherman, Sacramento Municipal Utility District
Mia South, Environmental Protection Agency
John Tooley, Advance Energy Corporation
Jeff Warther, Carrier Corporation
Craig Wray, Larence Berkeley National Laboratory

Foreword

Proper sizing, installation and maintenance of HVAC equipment are major factors in operating efficiency. In fact, the potential energy savings from a quality installation are greater than those gained from the installation of high-efficiency equipment.

The *Specification of Energy-Efficient Installation and Maintenance Practices for Residential HVAC Systems* is a tool that can be of great help in achieving these energy savings. This manual is also a resource that serves many different groups, including electric and gas utilities, energy-efficiency program managers and industry groups as well as HVAC contractors and technicians. The specification describes, in great detail, the proper way to select, install and maintain HVAC equipment.

Proper sizing and installation can result in energy savings of up to 35 percent for air conditioners and 16 percent or more for furnaces. Moreover, energy-efficient installation and proper maintenance practices also provide substantial non-energy benefits, such as greater comfort, lower maintenance cost and longer equipment life.

The development of the *Specification* grew out of a need for a clear, accepted definition of an energy-efficient installation. This specification is a compendium of the best practices and test procedures that can significantly affect HVAC energy usage.

This document has many applications, including:

- Installation field guide
- Aid in curriculum development and contractor training
- Energy-efficiency program development
- Guide to develop consumer information pieces

In developing the *Specification*, the Consortium for Energy Efficiency (CEE) received input and guidance from a wide variety of HVAC industry stakeholders, including manufacturers, certification organizations, contractor associations, energy-efficiency organizations and experts in the field. We would like to thank those who took the time to make this specification a comprehensive and well researched document. CEE gratefully acknowledges Pacific Gas & Electric, Sacramento Municipal Utility District, and The New York State Energy Research & Development Authority for sponsoring the development of the specification.

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Chapter 1 – Abbreviations, Acronyms and Definitions

Abbreviations and Acronyms

ACCA – Air Conditioning Contractors of America.

AFUE – Annual fuel utilization efficiency.

ARI – Air-Conditioning and Refrigeration Institute.

ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Btu – British thermal unit.

COP – Coefficient of performance.

CFM – Cubic feet per minute.

CFM_{25} – Cubic feet per minute of air flow at 25 Pascals of pressure difference.

EER – Energy efficiency ratio.

EPA – Environmental Protection Agency.

^{O}F – Degrees Fahrenheit.

GAMA – Gas Appliance Manufacturers Association

HSPF – Heating seasonal performance factor (heat pumps).

HVAC – Heating, ventilating and air conditioning.

Manual D – *Residential Duct Systems* by ACCA.

Manual J – *Residential Load Calculation* by ACCA.

Manual S – *Residential Equipment Selection* by ACCA.

SEER – Seasonal energy-efficiency ratio.

SMACNA – Sheet Metal and Air Conditioning Contractors' National Association.

Definitions

Accumulator. In refrigeration systems, a storage tank at the evaporator exit or suction line used to prevent flood-back to the compressor.

Aerosol-Applied Duct Sealant. A sealant delivered to and deposited at duct leaks in the form of aerosol particles, carried by an air stream that pressurizes the duct system under controlled pressure, flow, and particle-injection conditions.

Annual Fuel Utilization Efficiency (AFUE). An efficiency rating measuring the percentage of the heat from the combustion of gas or oil transferred to the heated space during a heating season. Based on a test protocol and meant to estimate the seasonal efficiency.

Anticipator. A small electric, variable-resistance heater element in most heating thermostats that causes false indications of temperature in the thermostat for the purpose of minimizing the natural tendency of the thermostat control to overshoot the set temperature. Setting the anticipator control properly can save energy and reduce too frequent cycling of the heating unit.

Balance Point Temperature. For air-source heat pumps, the outdoor temperature at which the heat pump output, without supplemental heat, equals the heat loss of the building. A balance point temperature of less than 30°F is considered ideal.

British thermal unit (Btu). The energy required to raise or lower the temperature of a pound of water by one Fahrenheit degree.

Btuh. The number of Btus (British thermal units) transferred during a period of one hour.

Coefficient of Performance (COP), Heating. Ratio of the rate of net heat output to the rate of total energy input, calculated under designated operating conditions and expressed in consistent units.

Conditioned Space. Space in a building that is either directly or indirectly conditioned by a space-conditioning system, usually occupied spaces in a dwelling. Examples include conditioned kitchens and bedrooms. Basements are usually considered conditioned spaces if they are not thermally insulated from the occupied spaces of the dwelling.

Cooling Equipment. Equipment used to provide mechanical cooling for a room or rooms in a building.

Crawl Space. A space between the ground and the first floor of the building. Typically, crawl spaces are unconditioned.

Design Conditions. The parameters and conditions used to determine the performance requirements of space-conditioning systems.

Drop. For cooled air, the vertical distance between the bottom of a supply air outlet and the bottom of the air stream where it reaches its rated velocity, usually 50 feet per minute.

Duct Run out or Branch. A duct running from a trunk to a terminal unit (register or grille).

Electric Resistance Heating. Heating by electrical resistance coils.

Emergency Heat, Heat Pump. The backup heat required by some code jurisdictions in case of heat pump operation failure. Requires that the emergency heat be sufficient to maintain some minimum room temperature when the heat pump compressor is out of operation.

Energy-Efficiency Ratio (EER). The ratio of net cooling capacity (in Btuh) to total electrical energy use (in Watts) of a cooling system under designated operating conditions.

Gas Heating System. A natural gas or liquefied petroleum gas heating system.

Heat Pump. A space-conditioning device capable of heating and cooling by way of a refrigeration system.

Heating Seasonal Performance Factor (HSPF). For heat pumps, the total heating output of a heat pump under established test conditions, in Btu, divided by the total electric energy input during the test, in watt-hours.

Packaged Air Conditioning Equipment. All the cooling components are included in one cabinet, installed outdoors. Sometimes referred to as self-contained equipment.

Pascal. A metric system unit of pressure, the units for which are Newtons per square meter. There are 248 Pascals per inch of water gauge.

Pick-up Time. The period of time during which the space heating system is increasing the temperature in a conditioned space after a manual or automatic temperature setback.

Plenum. An air compartment or chamber to which one or more ducts are connected and that forms part of either the supply or return system.

Pull-down Time. For space cooling, the time required to reduce dwelling temperature to a comfortable level after a manual or automatic temperature setup.

Refrigerant Charge. The amount or weight of refrigerant in a compressor-based cooling system.

Refrigerant Metering Device. This device controls the flow of liquid refrigerant to the system evaporator coil(s).

Saturation Temperature. Boiling point or temperature of vaporization of a liquid.

Seasonal Efficiency. The efficiency of a space heater averaged over the entire heating season. Annual Fuel Utilization Efficiency (AFUE) is an estimate of seasonal efficiency. Contrast this with the steady-state efficiency, the efficiency during burner operation.

Seasonal Energy-Efficiency Ratio (SEER). The total cooling output of a central air conditioner in Btus under established test conditions, divided by the total electrical energy input in Watt-hours during the test.

Space-Conditioning System. A system that provides, either collectively or individually, heating, ventilating or cooling to the building's conditioned spaces.

Split-System Air-Conditioning Equipment. An air conditioning (heat pump) system that has the condenser (outdoor coil) remote from the evaporator (indoor coil).

Spread. The divergence of an air stream after it leaves an outlet, usually expressed in degrees of arc from the outlet centerline.

Steady-State Efficiency. The efficiency of a furnace during burner operation.

Subcooling. The temperature of a liquid when it is cooled below its condensing temperature.

Superheat. The temperature of a vapor refrigerant above its saturation change-of-state temperature.

Supplemental Heat, Heat Pump. Also referred to as auxiliary heat. The additional heat required to heat a building when the outdoor temperature is below the balance-point temperature. As the outdoor temperature drops, more supplemental heat is needed. Typically provided by electric resistance heating elements.

Thermostatic Expansion Valve (TXV), Cooling System. A cooling system using the TXV for regulating the flow of refrigerant into the cooling unit, actuated by the changes in evaporator pressure and superheat of the refrigerant leaving the cooling unit.

Throw. The vertical or horizontal distance air travels from the face of an air outlet to its rated velocity, usually 50 feet per minute.

UL 181. UL Standard for Factory-Made Air Ducts and Connectors.

UL 181A. UL standard for pressure-sensitive aluminum tapes, heat-activated aluminum tapes, and mastic closure systems for use with rigid fiberglass air ducts.

UL 181B. UL standard for pressure sensitive tapes and mastic closure systems for use with flexible air ducts.

Unconditioned Space. An enclosed space within a building, not directly or indirectly conditioned by a space-conditioning system. Examples include unconditioned attics, crawlspaces, and garages. Unconditioned spaces are usually thermally insulated from the occupied spaces in new dwellings but may not be in existing dwellings.

Chapter 2 – Introduction

2.1 Introduction.

A growing body of evidence suggests that most heating, ventilating, and air conditioning (HVAC) equipment – both standard and high efficiency – is improperly installed, with significant adverse consequences on residential equipment efficiency. Recent studies demonstrate that the manner of equipment installation may have a greater impact on actual equipment operation than its efficiency rating. Improved installation practices not only significantly increase system efficiency, they can also enhance occupant comfort, increase occupant health and safety, reduce equipment and maintenance costs, allow equipment downsizing, increase the installer's profit margin, and increase equipment life.[1]

2.2 Applicability.

This specification addresses the installation of residential space cooling, space heating and air-distribution systems. The focus is on the energy efficiency of newly installed systems and existing systems, and the long-term maintenance of the efficiency of systems. It also addresses the interaction of the components within systems.

2.2.1 **Air Conditioners and Heat Pumps.** Space-cooling equipment is addressed, including packaged systems, split-system cooling-only and heat pumps. The major elements addressed are equipment location, sizing, coil airflow, refrigerant charge, controls and maintenance of efficiency.

2.2.2 **Gas Furnaces.** Ducted central gas furnaces are covered. The primary items addressed are equipment location, sizing, heat exchanger airflow, controls and maintenance of efficiency.

2.2.3 **Ducts and Air Handlers.** Forced-air ducted distribution systems for both space cooling and heating are addressed. The major items covered are location, sizing, duct and plenum tightness, duct insulation values and maintenance of distribution efficiency.

For each of the specification elements, a verification method is provided. A number of the elements only require visual verification. Others, such as furnace heat rise, require verification with the use of inexpensive equipment and a simple test.

Finally, in some cases (such as duct leakage) more complicated test procedures are necessary for proper verification. When selecting these more complex test procedures, the most practical and accurate procedures were chosen for this specification, without losing sight of the cost of test equipment and the relative complexity of the methods.

2.3 ENERGY STAR® Specification for Existing Ductwork.

This *Specification of Energy-Efficient Installation and MaintenancePractices for Residential HVAC Systems*, where appropriate, complies with ENERGY STAR *Specification for Existing Ductwork*. For information about this ENERGY STAR Specification, call 888-STAR-YES or visit the ENERGY STAR web site at www.energystar.gov.

Please Note: Because the primary focus of this specification is installation practices affecting system energy efficiency, the specification does not directly address the elements of installation that can impact occupant health and safety. In the field, occupant health and safety should always be the primary concern of the installing and servicing technician. It is strongly recommended that appropriate health and safety testing be done as part of a technician's routine procedures.

2.4 Relation of this *Specification* to Other Codes and Standards.

This *Standard* is intended to meet or exceed existing codes and regulations and to conform to accepted building practices. It is not intended to replace existing codes and standards. The contractor should comply with all relevant codes, standards, and manufactures' specifications.

2.5 Quick Reference Tables.

The following quick reference tables list the elements of this specification. The Quick Reference elements are keyed to the numbers of the Specification text.

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[1] C. Neme, J. Proctor, and S. Nadel, National Energy Savings Potential from Addressing Residential HVAC Installation Problems (U.S. Environmental Protection Agency ENERGY STAR Program, 1999), pp. 1-2.

Quick Reference for HVAC Installation Specification
Air Conditioners and Heat Pumps: Split and Packaged Systems

Section/Specification Element	Specification Element	Potential Benefits	Verification Test or Method
3. Air Conditioners and Heat Pumps: Split and Package Systems			
3.1 Selection and Sizing	- Comply with ENERGY STAR® efficiency guidelines. - Select for adequate and efficient sensible and latent cooling. - Use *Residential Load Calculation, Manual J*. - Use *Residential Equipment Selection*, *Manual S*.	- Proper selection can increase thermal comfort and save energy. - 2—10% savings per year are possible for sizing correctly rather than over sizing. - Also, possible reduced duct size, surface area, and leakage.	- *Residential Load Calculation,* Manual J by ACCA. - *Residential Equipment Selection*, Manual S by ACCA.
3.2 Placement of Equipment	- Follow manufacturer s recommendations - Minimize ductwork length. - Allow sufficient access to all equipment. - Don t restrict airflow to outdoor coil. - Avoid outdoor coil locations that might be adversely affected by rain, snow, seasonal flooding, or vegetation.	- Not confirmed by research, but could be substantial.	- Visual inspection.
3.3 Indoor Coil Airflow	- 400 CFM for wet coil, ± 50 CFM. - 425 — 450 CFM for dry coil, + 50 CFM.	- 6-10% energy savings per year for non-TXV or fixed orifice device. - 2% energy savings per year for TXV.	- Duct Blower test — 3.13.1. - Supplementary Heat Test for heat pumps (temperature rise) — 3.13.2. - Flow Hood test — 3.13.3. - Pressure Drop test — 3.13.4 (See Text for limitations of test)
3.4 Refrigerant Charge	- Manufacturer s specification	- Improper refrigerant charge is probably the most significant cause of loss of efficiency. - Fixed orifice type: 10—20 % energy savings per year are possible. - TXV type: 5% energy savings per year are possible.	- Superheat method for fixed orifice devices — 3.14.1. - Subcooling for thermal expansion valve (TXV) devices — 3.14.2. - Weigh-in refrigerant test — 3.14.4.
3.5 Refrigerant Lines for Split System	- Insulate suction lines, not liquid lines. - Size lines and line length to manufacturer s specifications. - Limit line length.	Increased energy efficiency due to slowed heat transfer.	- Visual inspection.
3.6 Fan Delay Relay	- Should be installed to continue the operation of the air handler blower for a minimum of one minute after the compressor cycles off. Not required in hot, humid climates.	- Increases efficiency by purging ductwork of conditioned air and extracting maximum cooling capacity from the evaporator coil.	- Visual inspection.
3.7 Cooling/Heating Programmable Thermostat	- Programmable thermostats should be ENERGY STAR® labeled.	- Savings from automatic temperature change can result in significant energy savings, depending on operation and climate.	- Visual inspection.

Quick Reference for HVAC Installation Specification
Air Conditioners and Heat Pumps: Split and Packaged Systems (continued)

Section/Specification Element	Specification Element	Potential Benefits	Verification Test or Method
3. Air Conditioners and Heat Pumps: Split and Package Systems (continued)			
3.8 Indoor Heat Pump Thermostat, Heating Operation	- Should be intelligent recovery, staging, or ramping types. - Changeover from heating to cooling must be manual, not automatic. - Thermostat must maintain a 3 degree temperature differential before supplemental heat is activated. - Thermostat must have an emergency heat switch.	- If the heat pump thermostat is not working properly in heating mode, the expensive supplementary heat can be unnecessarily activated, resulting in wasted energy.	- Visual inspection.
3.9 Air-Source Heat Pump Outdoor Lockout Thermostat	- When a non-intelligent or non-ramping heating thermostat is used, an outdoor lockout thermostat is required. (Note: Emergency heat should not be subject to lockout).	- Without an outdoor lockout thermostat, the expensive supplementary heat can be unnecessarily activated.	- Visual inspection.
3.10 Heat Pump Defrost Control, Heating Operation	- Select model with microprocessor defrost that learns. - If defrost is a time/temperature type, set the time interval to provide the highest operating efficiency.	- Optimized defrost control increases energy efficiency of the equipment.	- Visual inspection and manufacturer s specifications.
3.11 Access for Maintenance	- Provide adequate clearance for all necessary servicing and maintenance.	- Allows proper service and maintenance, thereby ensuring the maximum efficiency of the equipment.	- Visual inspection.
3.12 Maintenance Items	- Follow the manufacturer s regularly scheduled maintenance program guidelines. - Inspect the following items at servicing: - Filters, - Indoor and outdoor coils, - Indoor coil airflow, - Refrigerant change, - Refrigerant lines, - Air handler blower parts, and - Controls.	- Proper maintenance of equipment and controls will retain system efficiency and extend equipment life.	- Visual inspection or appropriate instrumented diagnostics procedure.

Quick Reference for HVAC Installation Specification
Gas Furnaces

Section/Specification Element	Specification Element	Potential Benefits	Verification Test or Method
4. Gas Furnaces			
4.1 Selection and Sizing	- Comply with ENERGY STAR® efficiency guidelines. - Select for adequate heating capacity and blower performance. - Use *Residential Load Calculation,* Manual J. - Use *Residential Equipment Selection*, Manual S.	- Proper selection can increase thermal comfort and save energy. - Over sizing a furnace by more than 1.4 times can lead to loss in seasonal efficiency, higher equipment cost, comfort sacrifices due to short cycling, and premature degradation of the furnace and/or vent system.	- *Residential Load Calculation,* Manual J. - *Residential Equipment Selection*, Manual S.
4.2 Heat Exchanger Temperature Rise/Airflow	- Temperature rise across the heat exchanger should be within the manufacturer s specifications. - If manufacturer s specifications are not available, use at temperature rise between 40 and 70 degrees.	- Can save as much as 2% per year in energy costs.	- Temperature rise test. - Duct Blower test — 4.9.1. - Flow Hood test — 4.9.2.
4.3 Blower Thermostat Control	- Set the blower-on and blower-off temperatures according to the manufacturer s specifications.	- Increases efficiency by purging ductwork of conditioned air.	- Visual inspection and test with use of a thermometer.
4.4 Fan Delay Relay	- Should be installed to continue the operation of the air handler blower for a minimum of one minute after the burner cycles off.	- Increases efficiency by purging ductwork of conditioned air.	- Visual inspection.
4.5 Programmable Thermostat	- Programmable thermostats should be used and should be ENERGY STAR® labeled.	- 1-3% energy savings per 8-hour setback, depending on climate.	- Visual inspection.
4.6 Thermostat Anticipator Control	- Space heating thermostats should have anticipators as a feature. - If anticipator is adjustable, make sure it is set correctly.	- Proper adjustment of the anticipator can save as much as 2% annual energy use.	- Visual inspection.
4.7 Access for Maintenance	- Provide adequate clearance for all necessary servicing and maintenance.	- Allows proper service and maintenance, thereby ensuring the maximum efficiency of the equipment.	- Visual inspection.
4.8 Maintenance Items	- Follow the manufacturer s regularly scheduled maintenance program guidelines. - Inspect the following items at servicing: - Steady-state efficiency test, - Filters, - Gas manifold pressure, - Orifices sizing, - Heat exchanger temperature rise, - Cooling evaporator coil, - Blower thermostat control, - Air handler blower parts, and - Controls.	- Proper maintenance of equipment and controls will retain system efficiency and extend equipment life.	- As necessary.

Quick Reference for HVAC Installation Specification
Ducts and Air Handlers

Section/Specification Element	Specification Element	Potential Benefits	Verification Test or Method
5. Ducts and Air Handlers			
5.1 Duct Location	- All ducts should be located within the conditioned spaces whenever possible. - No ducts in exterior wall cavities. - Always install ducts, don t use building cavities. - No panned floor joists. - Don t use crawl spaces as plenums.	- Reduces conduction and air-leakage losses.	- Visual inspection.
5.2 Duct System Design	- Use *Residential Duct System, Manual D*, 1995 edition or later.	- If ducts are not sized large enough to permit adequate airflow, system efficiency can be adversely affected.	- *Residential Duct System, Manual D*, 1995 edition or later.
5.3 Allowable Duct Leakage, New Air Distribution Systems	- 25 CFM of leakage for every 400 CFM of measured airflow, or - The sum of supply and return leakage divided by air handler fan flow shall be a maximum of 6%.	- Can save 15% in energy costs per year for new systems.	- Tests for Ensuring Proper Air Handler Airflow — 3.13 and 4.9. - Total Duct Leakage and Percentage Duct Leakage Test — 5.13.1.
5.3 Allowable Duct Leakage, Existing Air Distribution Systems	- 40 CFM of leakage for every 400 CFM of measured airflow, or - The sum of supply and return leakage divided by air handler fan flow shall be a maximum of 10%.	- Can save 10% in energy costs per year for existing systems.	- Tests for Ensuring Proper Air Handler Airflow — 3.13 and 4.9. - Total Duct Leakage and Percentage Duct Leakage Test — 5.13.1.
5.4 Duct Sealing Materials and Methods	- Refer *to Duct Installation and Sealing Specification.*	- Use of the proper materials and methods extends the life of the ducted system, retaining duct efficiency.	- Visual inspection.
5.5 Insulation, New and Existing Installations	- Follow insulation manufacturer s recommendations. - Refer *to Duct Installation and Sealing Specification*	- Duct insulation slows heat transfer, making the ducted distribution network more efficient.	- Visual inspection.
5.5.2 Insulation, New Installations	- No insulation required for ducts in conditioned spaces, except to prevent condensation. - In unconditioned spaces a minimum R-value of 6 is required. - Ducts located on the exterior of building require a minimum R-value of 8.	- Duct insulation slows heat transfer, making the ducted distribution network more efficient.	- Visual inspection.
5.5.3 Insulation, Existing Installations	- No insulation required for ducts in conditioned spaces, except to prevent condensation. - In unconditioned spaces a minimum R-value of 6 is required. - Parts of ductwork that are not accessible do not require insulation. - If ducts are already insulated to R-4 or greater, no additional insulation is needed. - Ducts located on the exterior of building require a minimum R-value of 8.	- Duct insulation slows heat transfer, making the ducted distribution network more efficient.	- Visual inspection.

Quick Reference for HVAC Installation Specification

Ducts and Air Handlers (continued)

Section/Specification Element	Specification Element	Potential Benefits	Verification Test or Method
5. Ducts and Air Handlers (continued)			
5.6 Room Pressure Imbalances	- While air handler is operating and house is closed up, pressure differences between 1) closed room and the outdoors and 2) the main body of the house with all the interior doors closed should be no more than 0.01 inches water gauge (3 Pascals), positive or negative.	- High-pressure differences between spaces in a house and the outdoors can increase air leakage to and from the outdoors. Decreasing these pressures can save energy. - Room depressurization may cause hazardous back drafting of combustion gases.	- Room Pressure Imbalances Test — 5.14.1.
5.7 Selection and Location of Supply Registers	- At least one supply-air register should be installed in each conditioned room. - Each register should be able to handle the required heating and cooling CFM and air velocity. - Maximum velocity of 700 feet per minute. - Select for proper throw, drop, and spread.	- Proper selection and placement of supply-air registers can increase occupant comfort.	- Visual inspection.
5.8 Selection and Location of Return Grilles	- Return-air grilles should be located to provide pressure-balanced air circulation during air handler operation. - Max. velocity of 500 feet per minute.	- The proper placement of return-air grilles minimized indoor pressure imbalances during air handler operation, thereby conserving energy lost due to forces air leakage.	- Visual inspection.
5.9 Duct Support	- Ducts should be supported so as to prevent dislocation or damage. - Refer *to Duct Installation and Sealing Specification.*	- Supporting ducts in a proper and durable fashion helps maintain duct system efficiency.	- Visual inspection.
5.10 Volume Dampers	- Supply branch ducts should be equipped with volume dampers to allow for manual balancing of distribution airflow. - After installation, the ducted system should be properly balanced.	- A properly balanced duct system increases occupant comfort and reduces occupant complaints.	- Visual inspection.
5.11 Access for Installation and Maintenance	- Adequate clearance should be provided on all sides of the equipment to allow for easy access for periodic maintenance. - All doors leading from the mechanical room to the outdoors should be large enough to allow easy passage of equipment.	- Adequate clearance for the maintenance of important equipment components allows the equipment to be serviced properly and regularly, thereby ensuring the maintenance of maximum equipment efficiency.	- Visual inspection.
5.12 Maintenance Items	- Inspect the following items at servicing: - Filters, - Duct obstructions and debris, - Duct leaks and disconnections, - Volume dampers, - Duct balancing, - Duct insulation, and - Room pressure imbalances.	- Proper maintenance of the forced-air distribution system will help retain system efficiency.	- Visual inspection.

Chapter 3 – Air Conditioners and Heat Pumps: Split and Packaged Systems

3.1 Selection and Sizing of Space-Cooling Equipment: Specification.

3.1.1 **Equipment Efficiency Ratings.**

(a) Air conditioners and heat pumps should comply with the required efficiency of local or utility energy codes or, as a minimum, meet ENERGY STAR efficiency levels.

(1) Central air conditioners and air-source heat pumps: minimum 12 SEER.

(2) Air-source heat pumps: minimum 7.6 HSPF.

(3) Gas-fired heat pump: COP of 1.26 for heating and 1.32 for cooling.

(4) Air conditioners and heat pumps should be equipped with thermostatic expansion valves, which compensate for variations in airflow and refrigerant charge better than fixed orifice valves.

(b) **Verification of Efficiency for Split Systems.**

(1) The efficiency of split systems must be verified by the latest edition of *Directory of Certified Unitary Equipment Standards* by ARI.

(2) An evaporator coil should be installed which is verified to be a rated match with the condenser coil, as listed in the current *Directory of Certified Unitary Equipment Standards* by ARI.

(3) All equipment should be properly tagged (nameplate) and easily identified by make and model number.

(c) **Verification of Efficiency for Packaged Systems.**

(1) The efficiency of packaged systems must be verified by the latest edition of *Directory of Certified Unitary Equipment Standards* by ARI.

Common sizing mistakes

- Miscalculation of the square footage and orientation of glazing
- Using winter Air Changes per Hour (ACH) rather than summer ACH
- Miscalculation of summer ACH
- Exaggeration of outdoor design temperature (too warm for cooling equipment sizing)
- Sizing by capacity of existing equipment
- Sizing by rules of thumb.

3.1.2 **Equipment Selection.** Equipment should be selected in accordance with the most recent edition of *Residential Equipment Selection* (Manual S) by ACCA, or a comparable industry-accepted method.

3.1.3 **Load Calculation.** An accurate load calculation must be performed before equipment is selected.

This load should be calculated with the most recent edition of *Residential Load Calculation* (Manual J) by ACCA, or a comparable industry-accepted method. Computer software programs based on the most recent edition of Manual J are acceptable.

(a) For the purpose of load calculation, the interior design temperature used should be 75°F for cooling and 70°F for heating.

Oversizing can lead to:

- Higher equipment cost
- Excessive loading/unloading
- Frequent cycling
- High conditioned-space humidity
- Large conditioned-space temperature swings
- Low efficiency and high operating costs
- Short equipment life
- Occupant discomfort
- Nuisance service calls

Advantages of proper sizing as opposed to oversizing are:

- Less expensive equipment
- Ease of obtaining proper airflow
- Can lead to greater occupant comfort
- Can lead to longer equipment life
- Quieter equipment operation
- Leads to greater operating efficiency
- Lower operating costs
- Can lead to lower maintenance cost
- Might lead to increased profit margin for installer

(b) For cooling-only equipment (not heat pumps) cooling capacity should be no more than 1.15 times the calculated total cooling load.

Exception: If certified equipment is not manufactured that meets the above requirement, selected equipment may be as much as one-half ton larger than the calculated total Btuh cooling load.

(c) Air conditioners and heat pumps with multi-speed/variable-speed compressors should be sized within the cooling capacity range of the equipment as specified by the manufacturer.

(d) The latent cooling capacity of air conditioners and heat pumps must equal or exceed the calculated latent load, with no specific excess limit on latent capacity.

(e) Select cooling airflow based on desired sensible load ratio. Sensible load ratio = sensible load ÷ (sensible load + latent load). This will vary according to the characteristics of the building and the local climate. (See Manual S by ACCA, Section 1-5, Estimating the Cooling CFM.)

(f) For heat pumps:

(1) In warm or moderate climates, heat pumps should be selected so that total capacity is no greater than 115 percent of the total calculated load.

(2) In cold climates, heat pumps should be selected so that total capacity is no greater than 125 percent of the total calculated load.

(3) Select a heating balance point temperature appropriate for outdoor design conditions without significantly over-sizing for comfort cooling. Generally, low-range balance points are associated with climates that are predominately hot because the heating load is small relative to the cooling load. Conversely, high-range balance points are associated with climates that are predominately cold because the heating load is larger.

(4) The most appropriately selected manufacturer's supplemental heat package should be installed so that the combined operation of the heat pump compressor and the supplemental heaters satisfies the design heat load. Supplemental heaters assist the heat pump compressor in heating the house when the outdoor temperature is below the design balance point temperature.

3.1.4 **Verification.** Before installation, check sizing of the air conditioner or heat pump by comparing Manual J load calculation with the rated capacities (total, sensible and latent) at design conditions.

3.1.5 **Benefits.** Oversizing comfort-cooling equipment can lead to efficiency losses of from 2 -10 percent, higher equipment cost, poor dehumidification performance caused by short cycles, and premature equipment degradation, according to reports by the U.S. EPA ENERGY STAR program.[1] On the positive side, correctly sized equipment can lead to reduction in the size of air distribution ducts, resulting in increased efficiency of the ducted distribution system.

3.1.6 **Discussion.** Using a mathematical sizing procedure, such as Manual J, requires know-how and time. If a designer performs many load calculations each week, he or she will become proficient quickly and will become skilled from experience.

Improper sizing leads to customer complaints, system inefficiencies, and premature equipment degradation. Because it is difficult to properly adjust for improper sizing once the equipment has been installed, sizing "by the book" (Manual J or a comparable method) is strongly encouraged.

Many suppliers offer a free load-calculation service to their installers. If such a service is used, it is vitally important that the installer make sure the method being used is based on Manual J. It is also important that the installer provide accurate job information – such as house dimensions, insulation values, and window U-values and solar transmittance – to the person calculating the load.

3.2 Placement of Equipment: Specification.

3.2.1 Follow manufacturer's recommendations for placement of indoor equipment (some equipment is approved only for installation in conditioned space).

3.2.2 Placement of split and packaged systems should minimize ductwork length.

3.2.3 Allow sufficient space around indoor and outdoor units for proper operation and servicing. Minimum clearances between equipment and adjacent structures, walls, or other objects shall be:

(a) On the side containing the service panel, 36 inches,

(b) On all other sides, 12 inches,

(c) Above vertical discharge unit, at least 48 inches,

(d) As specified by manufacturer and local codes.

3.2.4 If visual inspection indicates that airflow to the outdoor coil might be restricted, verify with this test:

(a) Run the unit for 15 minutes. Measure the temperature of the ambient air to determine if the air entering the unit is significantly warmer than the ambient air temperature. If it is, recirculated exhaust air is being pulled into the entering air stream.

3.2.5 Avoid placement of outdoor equipment under building eaves where collected rainwater, snow or ice can fall on the unit or airflow to the outdoor coil may be restricted. Also avoid areas where snow drifts.

3.2.6 For heat pumps, protect the outdoor unit from strong prevailing winds. If possible, locate the outdoor unit on the downwind side of the building in a sunny spot.

3.2.7 For outdoor units, allow clearance for water to drain away. Check the outdoor unit cabinet condensation and defrost drain hole locations and be sure they are not blocked by the mounting pad or rack.

3.2.8 Inform building occupants to keep the area within 3 feet of the outdoor unit free of any vegetation or structures that will obstruct airflow into or out of the equipment.

3.2.9 Where snowfall is:

(a) Below 20 inches annually, the outdoor unit may be placed on a ground-level concrete pad constructed at least 3 inches above the surrounding grade level,

(b) From 20 to 40 inches annually, the outdoor unit should be mounted on a rack that elevates the equipment at least 12 inches above the ground-level pad,

More tons at the register, more money in installers' pockets

If cooling systems are installed with the proper airflow at the coil, the correct refrigerant charge and with tighter duct systems, the effective installed cooling capacity per ton significantly increases. This allows installers to put in smaller systems and become more competitive in the marketplace. Improved installation practices also improve occupant comfort and reduce callbacks.

(c) More than 40 inches, the outdoor unit should be mounted on a rack that elevates the equipment at least 16 to 24 inches above the ground-level pad.

3.2.10 **Benefits.**

(a) Proper clearances from permanent and temporary obstructions, like snow, helps ensure maximum operating efficiency of the cooling equipment.

3.3 Indoor Coil Airflow: Specification.

3.3.1 Measured airflow over the indoor coil should be the equivalent of 400 CFM per ton for a wet coil (condensation on coil) and 425 CFM per ton for a dry coil (no condensation on coil), plus or minus 50 CFM (for low sensible-load-ratio areas, the airflow will be on the low side of this CFM range, for higher sensible-load-ratio areas, the airflow will be on the high side of the range).

3.3.2 Indoor coil airflow always should be measured after any duct and plenum sealing has been completed, if practical. If this is not practical, do a visual inspection for big leaks and leaky building cavity returns before measuring airflow. If large leaks are found, temporarily block the return side of the system. At that point, measuring airflow with a duct blower is probably the only way to get a reasonable accurate CFM.

3.3.3 **Verification.** Check airflow at installation start-up and servicing.

(a) **Most Accurate Method.** The preferred verification method for airflow measurement is a calibrated duct blower. Refer to Duct Blower Test for Ensuring Proper Airflow, Section 3.13.1.

(b) **Alternate Method 1**. Supplementary Heat Test (temperature rise) for Ensuring Proper Air-Handler Fan Flow. Refer to Section 3.13.2.

(c) **Alternate Method 2**. Flow hood Test for Ensuring Proper Airflow. Refer to Section 3.13.3.

(d) **Alternative Method 3.** Static Pressure Test for Estimating Airflow. Refer to Section 3.13.4.

3.3.4 **Benefits.** Field studies suggest that about 70 percent of installed residential cooling systems have inadequate airflow at the indoor coil.[2] One study showed that the inadequate airflow of 320 CFM per ton, rather than 400 CFM, for fixed orifice (capillary tube) air conditioners results in a loss of 6-15 percent efficiency.[3] Thermal expansion valve (TXV) units do not suffer as large a loss in efficiency for low airflow.

3.4 Refrigerant Charge: Specification.

Manufacturer's recommendations must be followed for refrigerant charge. Coil airflow should be adjusted and verified before refrigerant charge checked. Refrigerant charge-checking is particularly important with split-system air conditioners and heat pumps.

3.4.1 **Verification.**

(a) **Superheat Method.** For systems with fixed metering devices (capillary tube or fixed

If airflow is too high . . .

If airflow and static pressure are too high, duct leakage increases, register temperatures are too low in heat pump heating mode, latent cooling capacity decreases and air handler blower energy use increases.

If airflow is too low . . .

If airflow is too low, distribution efficiency drops (especially for heat pumps) and accelerated compressor wear can lead to failure, often resulting from slugging. Units must have at least 350 CFM per ton at the coil to ensure that only gas refrigerant is leaving the evaporator coil and that liquid refrigerant is not evaporating in the line. Additional problems can result from low airflow, including coil freezing, too much latent cooling and lower capacity.

When to connect your gauges

When servicing residential cooling systems, a gauge manifold should not be connected every time the system is serviced. This is because a small amount of refrigerant escapes each time the gauge is connected. Because many small systems have a critical refrigerant charge, this can adversely affect the system. Check the refrigerant charge unless you know the unit was recently charged using superheat or subcooling and there are no indications of low capacity.

The problem of releasing refrigerant when checking the charge can be minimized by using a short gauge line connector for the high side or by using a small hand valve to keep the refrigerant in the system when disconnecting the gauges.

Indications of low refrigerant charge include:

- Inadequate cooling capacity
- An overheated compressor motor resulting from low suction pressure
- If the system has a sight glass, bubbles *might* indicate a low charge (a clamp-on "sight glass" may be used to electronically "listen" for bubbles)

Indications of refrigerant overcharge include:

- Excessive condensation on compressor housing as a result of refrigerant flood back
- In severe cases, compressor failure

orifice), the evaporator superheat method should be used along with manufacturer's recommendations. Refer to Section 3.14.1.

(b) **Subcooling Method.** For systems with thermostatic expansion valves (TXV), the subcooling method should be used along with manufacturer's recommendations. Refer to Section 3.14.2.

(c) When the outdoor temperature is below 80°F use Simulating Design Temperatures for Superheat and Subcooling Tests. Refer to Section 3.14.3.

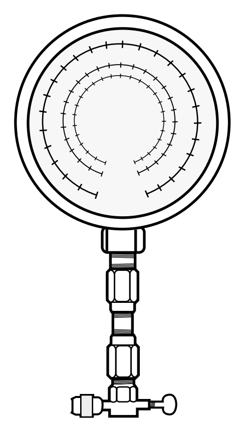
(d) Weighing the refrigerant may be used along with manufacturer's recommendations. Refer to Section 3.14.4.

3.4.2 **Benefits.** Improper charge is probably the most significant contributor to loss of efficiency for space cooling equipment. Overcharging can cause flood back, slugging, and premature compressor failure. Undercharging prevents adequate cooling of the air passing over the coils, and can cause continuous operation, compressor overheating and failure. Both of these conditions lower cooling efficiency. Field studies conducted over the last eight years found that about 75 percent of installed cooling equipment was improperly charged. These studies show that fixed-orifice equipment suffers an efficiency loss of 10-20 percent for overcharging and a 20 percent loss in efficiency for a 20 percent undercharge of refrigerant. Thermal expansion valve (TXV) equipment is less sensitive of refrigerant levels. A 20 percent overcharge or undercharge for typical TXV equipment demonstrated about a 5 percent loss in efficiency.[4]

3.4.3 **Discussion.** As demonstrated by field tests, installing and servicing technicians frequently overlook or do not know the proper procedure for refrigerant charging. The efficiency losses resulting from improper charging are significant enough to warrant verification at installation and servicing.

3.5 Refrigerant Lines, Split Systems,

Short gauge connection



Accidentally removing refrigerant from systems is a problem when measuring discharge pressure. A short gauge connection with a shutoff gives the saturated vapor less volume in which to condense.

Insulation and Protection: Specification.

3.5.1 Suction lines for split systems should be insulated with a minimum of 3/8-inch thick closed-cell elastomeric pipe insulation to prevent condensation and to slow heat transfer.

3.5.2 Refrigerant line insulation exposed to weather should have a waterproof covering providing protection from ultraviolet light and weather damage.

3.5.3 Refrigerant line length.

(a) The maximum horizontal length is 50 feet. Check with equipment manufacturer whenever horizontal length is greater than 50 feet.

(b) The maximum vertical length is 20 feet. Check with the manufacturer whenever the vertical length is greater than 20 feet.

(c) Use long-radius bends, long-radius elbows and a minimum of fittings to minimize line friction losses.

3.5.4 Use long-radius bends and a minimum of fittings to minimize line friction loses.

3.5.5 **Verification.** Visual inspection for integrity of suction-line insulation. Visual inspection and refrigerant charge testing for integrity of line seal.

3.5.6 **Benefits.** Suction refrigerant line insulation increases the operating efficiency of the equipment. Liquid lines should not be insulated because the heat loss to the outdoor air during cooling season increases the efficiency of the unit.

Refrigerant line leaks adversely affect operating efficiency and can result in equipment breakdown.

3.6 Fan-Delay Relay: Specification.

If not already included in the cooling equipment, heat pump or thermostat, a fan-delay relay should be installed to continue the operation of the air handler blower for a minimum of one minute, or a manufacturer's present time delay, after the compressor cycles off.

Exception: In hot, humid climates a fan-delay relay is not required. In such a climate, it has been found that in delayed shutdown of the air handler fan can reintroduce significant amounts of water vapor back into the house due to the evaporation of water on the evaporator coil.

3.6.1 **Verification.** Time the operation of the blower after the compressor shuts down.

3.6.2 **Benefits.** The fan-delay relay increases efficiency by 1) purging the ducted distribution system of conditioned air and 2) extracting the maximum cooling capacity from the evaporator coil.

3.7 Cooling/Heating Programmable Thermostats: Specification.

3.7.1 Programmable thermostats should be installed for interior temperature control and should have the following features:

(a) Thermostats should be ENERGY STAR labeled.

(b) Separate weekday and weekend programs, each with up to four customized temperature settings – two for occupied periods and two for energy-saving periods when the house is unoccupied or when the occupants are sleeping.

(c) Thermostat must have ability to maintain room temperature plus or minus 2°F of setpoint temperature.

(d) Thermostat must have a hold feature that allows users to temporarily override the

Thermostat education

Because programming is often complicated, help the occupants understand how to operate the programmable thermostat. This is especially important during the initial installation and programming.

programmed settings without deleting them.

(e) The maximum recommended setpoint increase for cooling is 8°F. The maximum recommended setpoint decrease for heating is 10°F.

(f) **Verification.** Check for proper operation at installation.

(g) **Benefits.** Savings for temperature offset (automatically turning the thermostat setting up, not off) vary depending on climate, equipment, and house envelope characteristics. Studies have demonstrated savings from 1-3 percent per 1°F of eight-hour offset for heating (for temperature offsets within a range of 5-10°F). Two eight-hour setback periods per 24-hour period double savings. For cooling, computer modeling and measured savings show a 2-5 percent savings per 1°F of eight-hour offset.[5] Customers will complain about the amount of time required to achieve a cooling setpoint during a heat wave, unless the extra time is factored into the time settings of the thermostat.

3.7.2 Thermostat should be mounted on an interior wall in an area of average temperature and away from direct sunlight, distribution supply airflow, stairwells, water pipes, appliances and sources of electrical interference.

3.8 Indoor Heat Pump Thermostat, Heating Operation: Specification.

3.8.1 Thermostats should be "intelligent-recovery, staging," or "ramping" types that do not allow supplemental heat to activate a) during temperature pick-up at the end of an automatically programmed temperature setback or b) when an occupant increases the thermostat offset.

3.8.2 Change-over from heating to cooling and back must be manually activated; it may not be automatic. (Exception: A full-featured comfort management zoning system, which maintains a dead band between the cooling and heating setpoints.)

3.8.3 Thermostats that are not "intelligent-recovery" or "ramping" are not acceptable unless an outdoor lockout thermostat is used as a component of the control system (see Section 3.9).

3.8.4 Indoor thermostat must have an emergency heat switch that will:

(a) Permit all supplemental heaters to be energized under control of the indoor thermostat – with the compressor and outdoor thermostat bypassed – when the compressor or refrigerant system is inoperative; and

(b) Activate an indoor indicator light whenever the system is operating on emergency heat.

3.8.5 **Verification.** Verify proper operation at installation.

3.8.6 **Benefits.** If a heat pump thermostat is not working properly, the expensive supplementary heat can be unnecessarily activated by an increase in thermostat temperature setting or during pick-up time after a programmed temperature offset. This can lead to higher energy costs for temperature setback.

3.8.7 **Discussion.** Because occupants adjust comfort thermostats, and programming is often complicated, make certain the occupants under-

> ***Heat pump defrost cycle***
>
> The outdoor coil refrigerant of a heat pump operates at a temperature below freezing when the outdoor temperature is below 45°F (the outdoor coil operates at a temperature 20-25°F lower than the outdoor air temperature). The need for defrost varies with the outdoor air conditions and the running time of the heat pump.
>
> Defrost is accomplished by reversing the heat pump system to the cooling mode and stopping the outdoor fan. This temporarily makes the outdoor coil the condensing coil without a fan, so the coil gets quite warm quickly, even in the coldest weather.

stand how to operate the programmable thermostat. This is especially important at the initial installation of the device.

3.9 Air-Source Heat Pump Outdoor-Lockout Thermostat, Heating Operation: Specification.

3.9.1 An outdoor-lockout thermostat is required regardless of the type of indoor thermostat installed.
3.9.2 The outdoor thermostat must lock out the supplemental heat when the outdoor temperature is greater than the heat pump balance point (usually 25-40°F, depending on the climate). **Caution:** Emergency heat should not be subject to lockout under any circumstances.
3.9.3 Wire the outdoor-lockout thermostat so the supplemental heater is not subject to lockout during the outdoor coil-defrost cycle.
3.9.4 Locate the outdoor-lockout thermostat in a location that will allow the sensing bulb to determine the true outdoor temperature, not the supply or outdoor air-stream temperatures.
3.9.5 **Verification.** Verify proper operation at installation.
3.9.6 **Benefits.** If a non-intelligent or non-ramping comfort thermostat is installed, expensive supplementary heat can be unnecessarily activated by an increase in thermostat temperature setting or during pick-up time after a programmed setback. This can lead to higher energy costs for temperature setback. An outdoor-lockout thermostat prevents this from occurring, but allows supplementary heat to be activated during the outdoor-coil defrost cycle.

3.10 Heat Pump Defrost Control, Heating Operation: Specification.

If installing a new heat pump, select a model with microprocessor defrost control (this control "learns" to defrost only when needed). For an existing system, if the defrost control is an electronic combination time/temperature device where defrosting the outdoor coil is initiated at a pre-selected time interval (provided the outdoor coil is below the present initiation temperature), set the time interval to provide the highest defrost efficiency for local weather conditions.
3.10.1 **Verification.** Follow manufacturer's verification procedures.
3.10.2 **Benefits.** Excessive defrosting of the outdoor coil during cold weather reduces the efficiency of heat pump operation. Of course, an iced outdoor coil also reduces efficiency. The control for defrosting of the outdoor coil must be adjusted to optimize efficiency – just enough to keep the coil free of ice without any unnecessary operation.

> ***Access for technicians***
>
> If technicians do not have easy access to equipment components that require periodic inspection and cleaning, these components will go without service and equipment efficiency will suffer. Unfortunately, technicians frequently are provided with too little space to install the equipment with adequate clearance for maintenance.
>
> If possible, it is best if the installing technician is part of the design team so that he can ensure there is ample space for the equipment and ductwork.

3.11 Access for Maintenance: Specification.

3.11.1 When installing comfort cooling equipment, an open space shall be provided around electrical panels and equipment sections requiring servicing. These spaces shall be a minimum of 30 inches wide by 36 inches deep, or as specified by local code. Items requiring maintenance include filters, air handler blowers, refrigeration coils and controls.
3.11.2 Minimum clearances between equipment and adjacent structures, walls or other objects shall be:

(a) On the side containing the service panel, 36 inches;

(b) On all other sides, 12 inches, or

(c) As specified by manufacturer and local codes.

3.11.3 All doors leading from the mechanical room to the outdoors should be large enough to allow easy passage of equipment.

3.11.4 **Verification.** Visual inspection at installation.

3.11.5 **Benefits.** Adequate clearance for the maintenance of important equipment components allows the equipment to be serviced properly and regularly, thereby ensuring the maintenance of maximum equipment efficiency.

3.12 Maintenance Items: Specification.

3.12.1 Follow manufacturer's regularly scheduled maintenance program guidelines.

3.12.2 All equipment literature, including installation instructions and maintenance records, should be affixed to the equipment by means of a plastic storage pocket or other appropriate means.

3.12.3 The following items should be inspected and properly maintained at annual servicing for the purpose of maintaining system efficiency.

(a) **Filters.** Verify with visual inspection whether filter requires cleaning or replacement

(1) Clean or replace filter(s) as required. Do not attempt to clean a filter that is designed to be thrown away.

(2) Make sure the filter compartment(s) are tight fitting. Make tight fitting or seal as necessary.

(3) If appropriate, educate occupants about recommended filter cleaning or changing.

(b) **Indoor and outdoor coils.** Check for debris, cleanliness and any obstruction to free airflow through the coils. Clear debris and clean, if necessary.

(1) To clean outdoor coil:

[i] Turn off power to condensing unit.

[ii] To avoid damaging the coil fins, clean the condenser coil using a bristle brush, or vacuum using a soft bush attachment, or lightly spray water or other cleaner.

[iii] Turn power to condensing unit back on.

(2) To clean indoor coil:

[i] Turn power off to air handler and compressor.

[ii] If no access panel exists, create a resealable access panel in a workmanlike manner.

[iii] The indoor coil cleaning shall be done using a brush, vacuum, or air pressure. If a cleanser is used, rinse the coil with water from a spray bottle before proceeding with the next step.

[iv] Check condensate drain line for clogging, rust, etc. Clean as needed.

[v] Access panel shall be closed and sealed with approved tape or mastic. Identify access panel with permanent label or marker.

[vi] Turn power back on to air handler and compressor.

(c) **Indoor coil airflow.** Measure the coil airflow to verify it is within the recommended range. Use procedures in Section 3.3. Clean coil if required.

(d) **Refrigerant charge.** Refrigerant charge should match the manufacturer's recommendations. Verify refrigerant charge at servicing unless you know the unit was recently charged using superheat or subcooling and there are no indications of low capacity. See Section 3.4.

(e) **Refrigerant lines.** Check for damage to lines and fittings. Inspect for damage to line insulation.

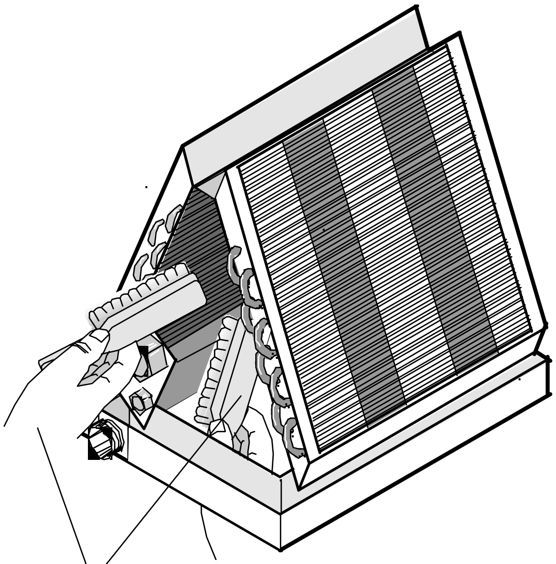
(f) **Air handler blower belts.**

(1) Check for wear, slippage and proper alignment.

(2) Adjust belt tension or replace belt if required.

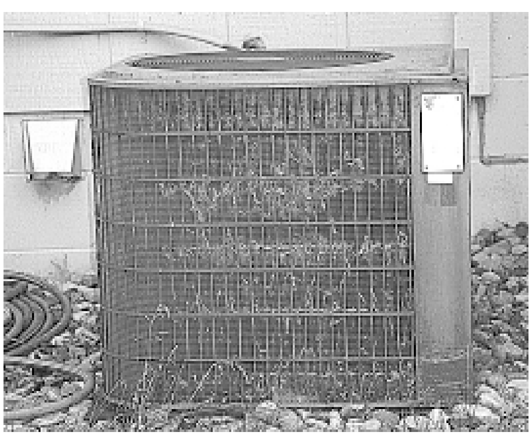
(g) **Air handler blower motor.**

Cleaning indoor and outdoor coils



Clean coil from side or underneath for upflow furnaces.

Removing a metal panel at the end, or accessing the a-coil from underneath, are two common ways of cleaning its underside.



Condenser coils can get loaded with dirt, grass, and lint. This debris can be easily removed with a brush and gentle spray of water from the inside of the coil. This condenser should be 3 inches above the surrounding ground on a concrete pad but is not.

(1) Lubricate according to manufacturer's recommendations.

(2) Check the blower motor and blower bearings, whether belt-driven or direct-drive with the power off.

[i] Hold the motor casing with one hand and grab the shaft with the other hand. Move the shaft up and down and side to side. The shaft will, under normal conditions, slide in and out of the motor case a slight amount. However, if there is excessive "play" or movement (side to side), or if there is a "sticky" spot as you spin the shaft, the bearings are bad. If this is the case, it is recommended that the motor be replaced.

[ii] Belt-driven blower bearings can be checked by turning off the power to the blower, disconnecting the belt and spinning the blower with your hand; the blower wheel should rotate several times on its own. If the bearings are bad, they should be replaced.

(h) **Air handler blower vanes.**

(1) Check for proper rotation of blower. Adjust if necessary.

(2) Check for buildup of dust, dirt and debris. Any dirt buildup on the blower vanes will greatly reduce airflow.

(3) Clean if necessary.

[i] Turn off power to blower.

[ii] Clean blower vanes using a brush, vacuum or hot water. If water or cleansers are used, rinse the blower components and allow them to dry before proceeding. Protect the blower motor from water and chemicals.

[iii] When the blower is extremely dirty, the blower assembly should be removed, separated from the blower motor and power washed. Allow the blower components to dry before proceeding. Reinstall the blower assembly and motor.

[iv] Turn power to the blower unit back

on.

[v] Check and adjust airflow across the coil if necessary.

[vi] Controls. Verify the proper operation of all controls, including high-limit switches, comfort thermostats, defrost controls and outdoor-lockout thermostats. See Sections 3.6, 3.7, 3.8, 3.9, and 3.10.

3.12.4 **Benefits.** Proper maintenance of equipment and controls will retain system efficiency, extend the life of the equipment and ensure occupant comfort.

3.12.5 **Discussion.** The maintenance items listed here can impact system efficiency. Not all maintenance items are included here, especially those that do not directly influence system efficiency.

Verification Tests

3.13 Tests for Ensuring Proper Air-Handler Airflow.

3.13.1 **Duct-Blower Test for Ensuring Proper Airflow.**

(a) **Objective of test.** The measurement of air-handler airflow. The most accurate test of the air handler airflow is done with a duct blower in conjunction with the air handler's blower. Airflow is measured after duct-leakage testing and duct sealing because measuring airflow in leaky ducts is inaccurate. During the test, the return is blocked so all return air comes through the duct blower where the airflow can be measured.

(b) **Required equipment.**

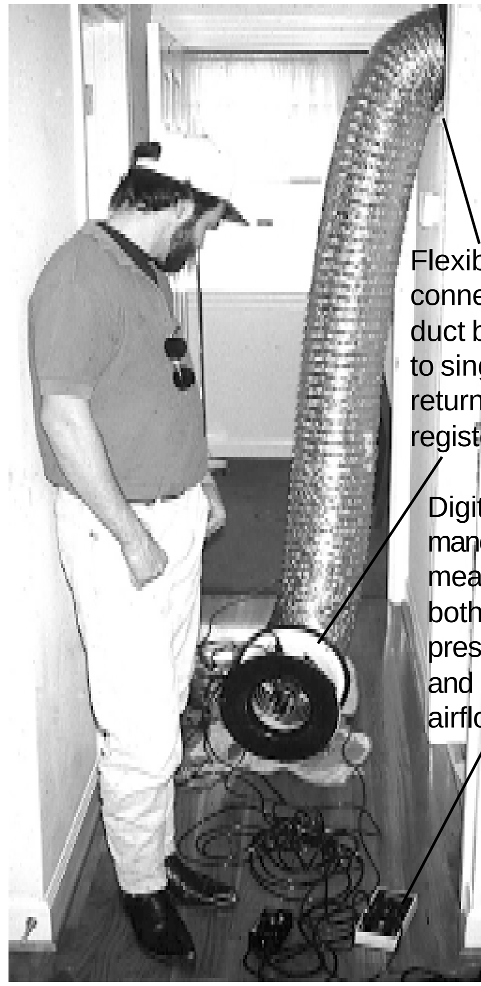
(1) Duct blower, a fan-powered flow-measuring device.

(2) A digital or analog manometer and tables for translating pressures to flows. The tables for the specific duct blower being used.

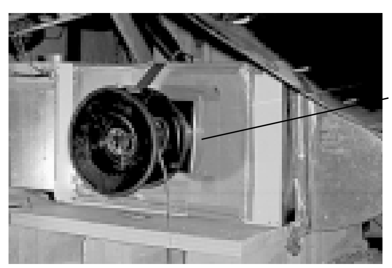
(3) A contractor using an Aeroseal Incorporated, aerosol-applied duct-sealant system or an equivalent product.

(c) **Setup.**

Connecting the duct blower



Connecting the duct blower to a single central return gives an accurate airflow reading as long as the ducts have been sealed to specifications listed in Chapter 5.



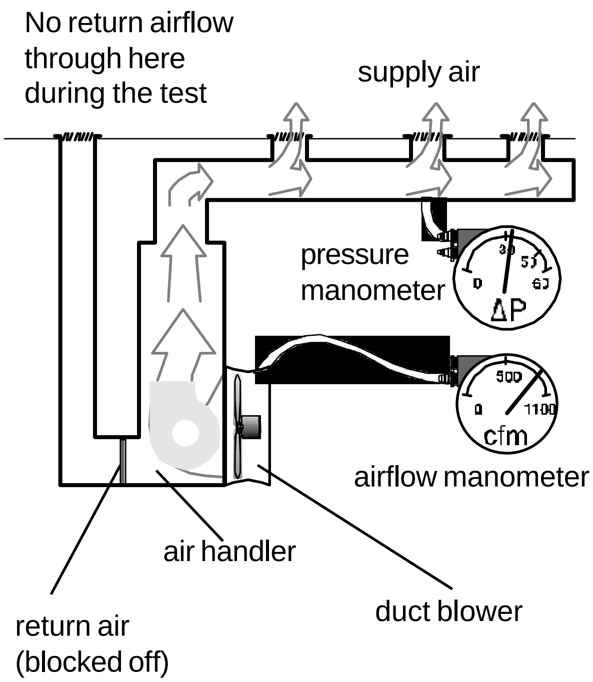
Blocking the return plenum and connecting the duct blower directly to the air-handler cabinet works well for systems with more than one return register.

(1) Set up a static pressure gauge to measure the duct pressure at the supply plenum, or a few feet away from the supply plenum, in a main supply trunk with reference to the house. Once the measurement probe is located properly (select a location that gives the highest pressure), tape the static pressure probe to hold it in place. The openings in the probe must be perpendicular to the airflow in the plenum or duct.

(2) Make sure all supply registers and return grilles are open and not taped. Leave filters installed. If filters are dirty, replace or clean.

(3) Perform required duct sealing to conform to standards explained in Section 5.13.1 before measuring airflow.

System airflow test using the duct blower



The duct static pressure achieved during normal operation is reproduced, using the duct blower. The return is blocked when it isn't used to connect the duct blower, so that all the system's air must travel through the duct blower where it is measured by the airflow manometer.

(d) **Conducting the test.**

(1) Turn on the system air handler by setting the thermostat fan switch to the "on" position. Systems without a fan "on" switch will need to run in cooling mode to operate at the higher of two speeds (heating usually uses a lower speed), or in heating mode for heating-only systems. If the air handler provides both heating and cooling, make sure you activate the fan speed for the appropriate application – heating or cooling. A useful verification check is to clamp an ammeter around the color wire you think corresponds to heating or cooling to determine if the wire is energized. Proceed with the test.

(2) Make sure the system air handler is on higher speed (for cooling). Measure and record the normal operating duct static pressure with reference to the house. This is the reference pressure, Psp, to be used later. Do not remove the static-pressure probe after this measurement.

(3) Shut off power to the air handler. Connect the duct blower to blow into the single return register or into the air handler at the blower compartment. All the return air should now come through the duct blower. Use the following procedures to connect the duct blower.

[i] For single-return systems: Remove the grille at the single return register. Connect the duct blower through its flexible tube or directly to the register.

[ii] For multiple-return systems: Block the return plenum's main return entry to the air handler. Filters are often located in a good location for this temporary blockage. Alternatively, the main return can be disconnected and supported temporarily, while this large duct is moved slightly to block its opening into the air handler. If the duct blower is connected to an air

handler, located outside the conditioned space, the door or access panel between the conditioned space and the air handler location must be opened.

(4) Turn on the air-handler fan. Make sure the air-handler fan is running on its normally higher speed – at the speed corresponding to your desired airflow test – heating or cooling.

(5) Turn on the duct blower to blow into the air handler, increasing airflow until the manometer measuring supply-plenum static pressure reads the same as in Section 3.13.1 (d)(2), Psp, with reference to the house.

(6) Measure and record the airflow through the duct blower. Refer to the duct-blower instruction book, if necessary. This is total system airflow in cubic feet per minute (CFM).

[i] If supply-duct pressure cannot be achieved with the duct-blower fan and the air-handler fan turned on, remove the flexible duct extension – if you have used it – from the duct blower, and connect the duct blower directly to the air-handler compartment. If high enough pressure still cannot be reached, proceed to the next step, Section 3.13.1 (d) (6) [ii].

[ii] With the duct-blower and the air-handler fans turned on, measure and record the following: a) the maximum pressure (Pmax) with reference to the house, and b) the maximum duct blower-fan flow in CFM (Bmax) at the maximum pressure, Pmax. Then use the equation in the sidebar (left) to estimate total air-handler airflow, Q.

(e) **Interpreting the results.** This airflow measurement should yield an accuracy of ±5 percent or better.

If duct blower cannot supply the airflow needed, use this equation:

$$Q = \frac{B_{max}}{\sqrt{\dfrac{P_{max}}{P_{sp}}}}$$

Where: Q = Total estimated air handler airflow, in CFM;

B_{max} = maximum duct blower fan flow in CFM at maximum duct blower pressure with duct blower fan and air handler fan on as in Section 5.1.1 (d)(6)

P_{max} = maximum pressure, duct with reference to the house, attainable with duct blower and air handler fan on as in Section 5.1.1 (d)(6)

P_{sp} = normal operating duct pressure with reference to the house, with the air handler on high speed as in Section 5.1.1 (d)(2).

3.13.2 **Supplementary Heat Test (temperature rise) for Ensuring Proper Air Handler Fan Flow.**

(a) **Objective of test.** This test measures air-handler airflow for 1) heat pumps with electric supplementary heat and 2) electric resistance furnaces with cooling coils.

A simple method for determining system airflow for this equipment is measuring the temperature rise across electric-resistance heating coils. These electric-resistance coils share the same air stream as the heat pump's indoor coil, or the external evaporator coil of the air conditioner. The measured temperature rise, together with the wattage of the resistance heat, is used to calculate airflow.

(b) **Limitations of test.** This test is valid only for 1) heat pumps with electric supplementary heat and 2) electric resistance furnaces with cooling coils.

(c) **Required equipment.**

(1) Volt-ohmmeter
(2) Ammeter
(3) Accurate thermometer

(d) **Conducting the test.**

(1) Engage electric resistance heating coils and the blower, making sure that the heat pump's compressor is off.

(2) Measure amperes of current, feeding both wires to the electric-resistance heat strips and add these ampere measurements together.

(3) Measure voltage between the two hot-wires feeding the strips.

(4) With a radiation-shielded thermometer, measure the temperature rise (delta T) of the air across the heat strip, after at least 5 minutes of operation. Keep the thermometer out of the line-of-sight of the hot coils. Move the thermometer around, looking for a stable average supply temperature.

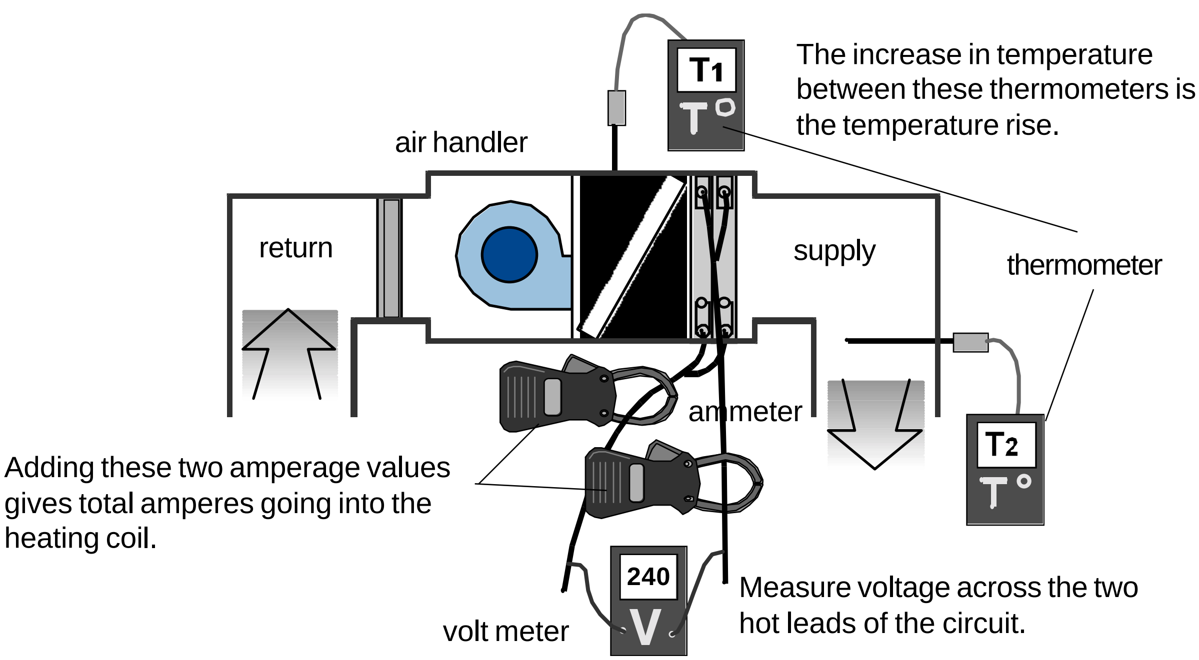
(5) Apply this formula to calculate airflow in CFM: CFM = 3.16(volts x amps)/delta T.

(e) **Interpreting the results.** This airflow measurement should match system-design airflow and manufacturer's specifications. The accuracy of this test depends on the averaging of the measured temperatures, which can vary widely. Measuring a temperature profile across both the length and width of the duct with an accurate thermometer, and averaging the temperature profiles with a calculator, will usually produce accuracy of around ±25 percent.

3.13.3 **Flow Hood Test for Ensuring Proper Airflow.**

(a) **Objectives of test.** This test measures the fairly laminar airflow at return registers. Measuring supply-register airflow isn't as accurate because supply air is more turbulent and because supply registers along walls don't allow the flow hood to be centered over them.

Supplemental heat test or temperature-rise test



When measuring the temperature rise across the resistance heat, keep the probes out of a direct line-of-sight with the coils to prevent a false reading from infrared radiation. Taking several temperature readings in a grid at each location makes this test more accurate.

The flow-hood inlet must be larger than the return registers, although 10 percent of the register may be blocked with tape to allow the flow hood to cover the entire opening.

(b) **Limitations of test.** This test works best on systems with one to four return registers located in areas where a flow hood can cover the registers and be centered over them. Return airflows should be well within the range of the flow hood's accuracy.

(c) **Setup.** Perform required duct sealing to conform to standards explained in Section 5.13.1 before measuring airflow.

(d) Conducting the test.

(1) Turn on the air handler to run at the higher fan speed, normally used for cooling.

(2) Center the flow hood over the return register, covering it completely. If the register is larger that the flow hood, seal up to 10 percent of the register with tape before covering it.

(3) Read and record the airflow. Add together the airflows of the return to get the total system airflow.

3.13.4 **Static Pressure Test for Estimating Airflow.**

(a) **Objective of Test.** This test can roughly estimate airflow if the manufacturer's table for static pressure versus airflow is available. It is often used to judge the cleanliness of an evaporator coil.

(b) **Limitations of the test.** Static pressure can vary widely from point to point within the measurement area, especially when ducts take an abrupt change of direction near the air handler. Access to both sides of the coil for testing static pressure can be difficult and requires great care and planning to avoid damaging the coil.

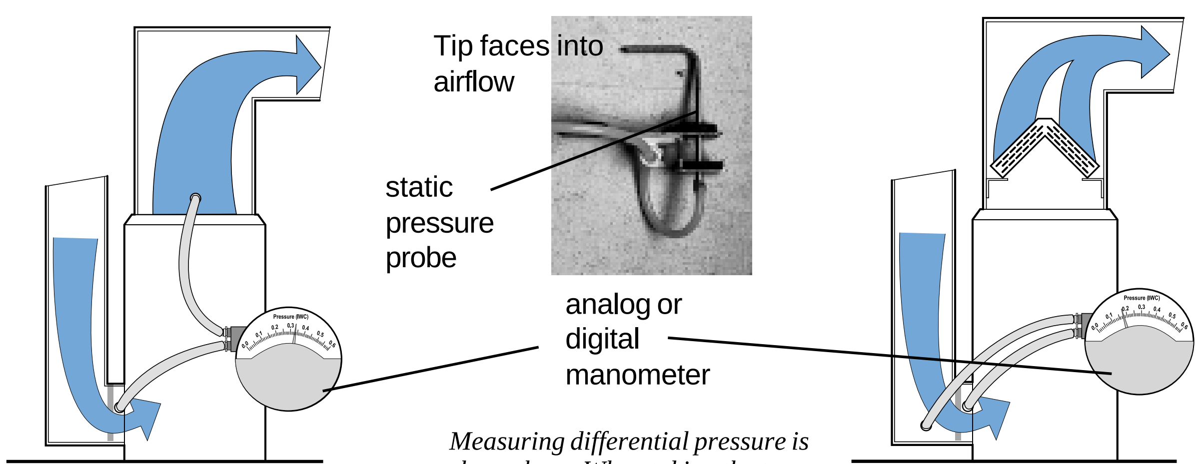
(c) **Required equipment.**

(1) Digital or analog manometer
(2) Static pressure probe or pitot tube
(3) Drill and bits
(4) Screw or nut drivers

(d) **Conducting the test.**

(1) Use a drill with a drill-stop to establish a hole or use existing openings to gain access to both sides of the coil or air handler.

Static pressure test for estimating airflow



Static pressure difference across the air handler can estimate airflow using tables in manufacturer's literature.

Measuring differential pressure is shown here. When taking the two individual readings with one hose and probe, subtract absolute values of the two pressure measurements.

Static pressure difference across the filter detects dirt and gives a rough estimate of airflow using manufacturer's information.

(2) Attach two static pressure probes to tubes leading to the ports of the manometer. For analog manometers, attach the high-side port to the probe inserted downstream of the coil or air handler.

(2) Optional. If only one static pressure probe or pitot tube is available, take the readings on each side of the coil and subtract their values. Disregard positive or negative signs given by a digital manometer.

(3) Consult manufacturer's literature for a table, relating static pressure difference to airflow. Find airflow for the static pressure measured above.

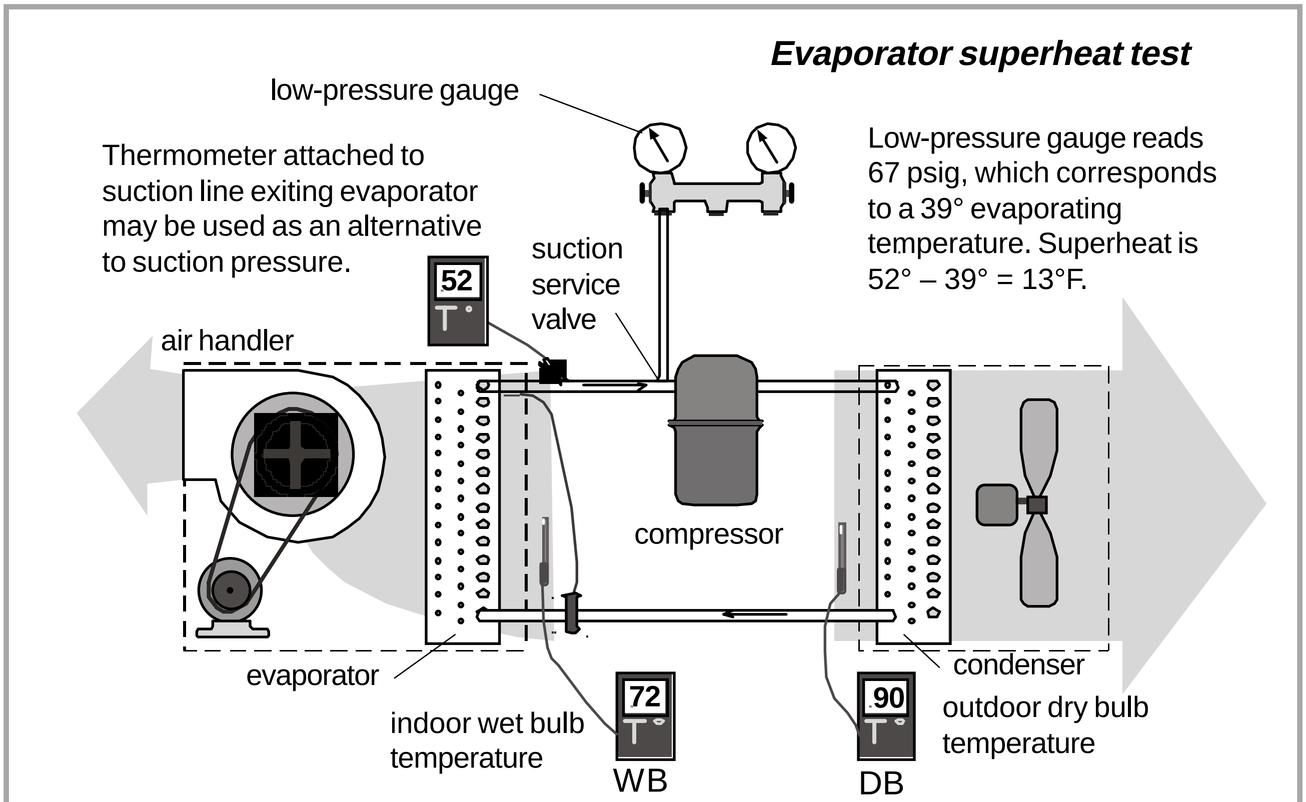
(e) **Interpreting the results.** Coils and air handlers have static pressure ranging from 0.20 IWC (50 Pascals) and 0.80 IWC (200 Pascals) as found in the field. This variation results from the air-handler and duct design, duct size and obstructions to airflow.

3.14 Tests for Ensuring Proper Refrigerant Charge.

3.14.1 Evaporator Superheat Test for Refrigerant Charge.

(a) **Objective of test.** Determine proper refrigerant charge for the efficient and safe operation of the equipment. Adjusting the charge to produce the ideal superheat temperature for the current indoor and outdoor temperatures optimizes system performance and efficiency. Superheat is an excellent indicator of correct system performance for all types of air conditioners and heat pumps with capillary or fixed-orifice expansion devices, operating in the cooling mode.

(b) **Limitations of test.** Follow manufacturer's recommendations for the



The correct evaporator superheat is obtained from a superheat table that lists superheat values, depending on outdoor dry bulb and indoor wet bulb air temperatures. The correct superheat value is then compared to the measured superheat value as determined above.

evaporator-superheat test. If manufacturer's recommendations are not available, abide by these limitations:

(1) This test is only to be used for fixed orifice/capillary systems and not for thermostatic expansion value (TVX) systems.

(2) This test should only be done when the outdoor temperature is at least 80°F. Indoor temperature should be higher than 70°F.

(c) **Required equipment.**

(1) Refrigeration gauge set.

(2) Accurate, contact digital thermometer or infrared thermometer with auxiliary devices (as needed) to accomplish good contact for the thermometer probe.

(3) Sling psychrometer.

(d) **Conducting the test with outdoor temperature greater than 80°F.**

(1) Determine the recommended superheat temperature from the permanent sticker inside the condenser unit, from manufacturer's literature, or from a manufacturer's slide rule.

(2) Measure the compressor-suction pressure at the suction-service valve. Add 2 pounds per square inch of gauge pressure (psig) for line losses between the evaporator and compressor. Then convert this pressure to a boiling-point temperature using temperature-pressure tables for the system's refrigerant.

(3) Measure the suction-line temperature at the evaporator's outlet.

(4) Subtract the boiling-point temperature determined in Section 3.14.1 (d)(1) from the measured temperature in Section 3.14.1 (d)(2). This is the superheat temperature.

(5) Measure the dry bulb temperature of the air entering the outdoor coil.

(6) Measure the wet bulb temperature of the return air.

(7) Find the ideal superheat value from the table or slide rule provided by the manufacturer.

(8) If the actual superheat is greater than the ideal superheat obtained from the table, add refrigerant, 2-4 ounces at a time.

(9) If the actual superheat is less than the theoretical, remove refrigerant, 2-4 ounces at a time. Refrigerant must be removed into an empty Department-of-Transportation-approved (DOT-approved) recovery cylinder or one containing the same refrigerant as the system.

(10) Allow the system to run for 10 minutes to adjust to the new operating conditions. Repeat the superheat procedure until the measured superheat temperature is within one degree of the ideal superheat temperature.

(e) **Interpreting the results.** Correcting the charge to produce the manufacturer's recommended superheat temperature ensures efficient operation of the heat pump or air conditioner.

3.14.2 **Subcooling Test for Ensuring Proper Refrigerant Charge.**

(a) **Objective of test.** Determine proper refrigerant charge for the efficient operation of the equipment.

(b) **Limitations of test.** Follow manufacturer's recommendations for the evaporator subcooling test. If manufacturer's recommendations are not available, abide by these limitations: This test is only to be used for thermal expansion valve (TXV) systems when the outdoor temperature is at least 80°F.

(c) **Required equipment.**

(1) Refrigeration gauge set.

(2) Accurate, contact digital thermometer or infrared thermometer with auxiliary devices as needed to accomplish good contact for the thermometer probe.

(d) **Setup.**

(1) Heat pump or air conditioner should be running in the cooling mode for 10 minutes prior to the test.

(e) **Conducting the test with outdoor**

temperature greater than 80°F.

(1) Measure the compressor discharge pressure. Convert this pressure to the condensing temperature, using temperature-pressure tables for the system's refrigerant. Or, simply measure the surface temperature of a protruding loop of tubing in the center of the condenser between that section's inlet and outlet.

(2) Measure the temperature of the liquid refrigerant leaving the condenser.

(3) Subtract the liquid-refrigerant temperature measured in Section 3.14.2 (e)(2) from the condensing temperature determined in Section 3.14.2 (e)(1). This is the subcooling temperature.

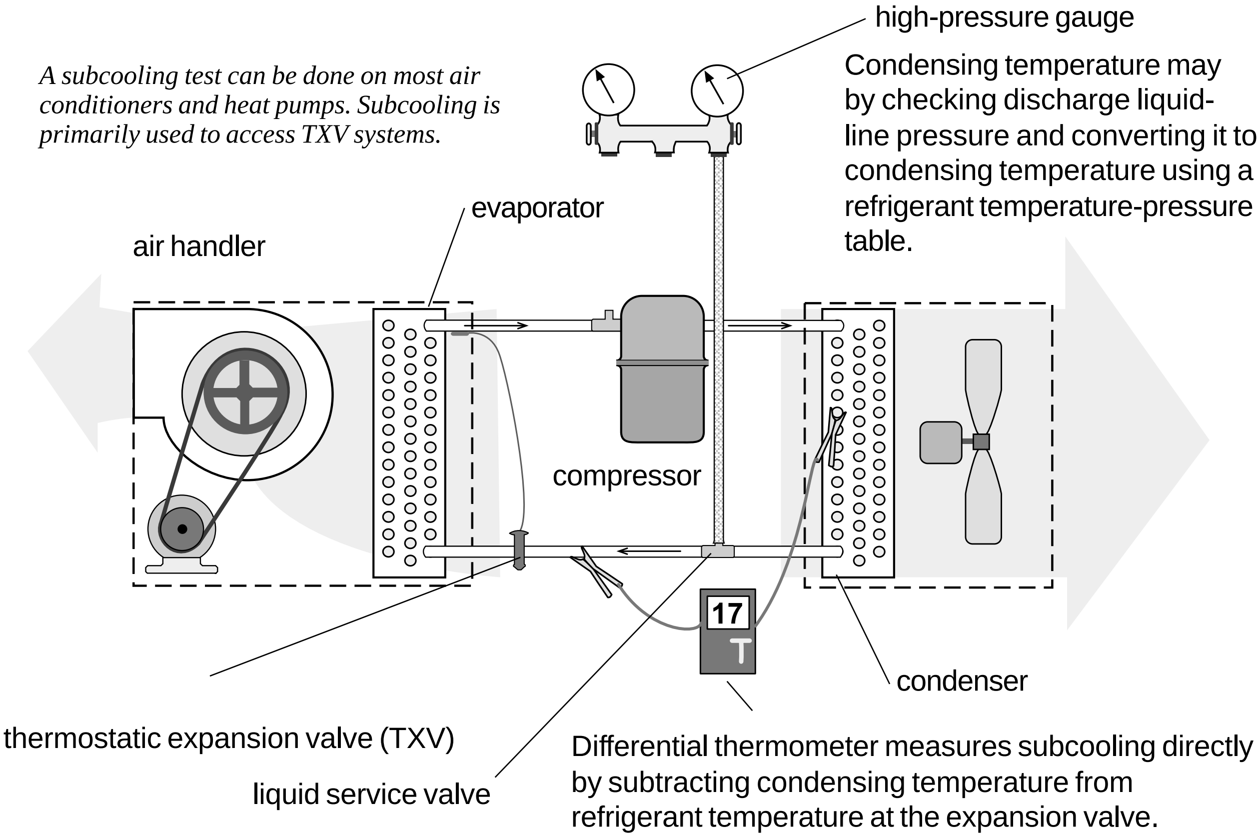
(4) Find the correct subcooling temperature from the permanent sticker inside the condenser unit, from manufacturer's literature or from a manufacturer's slide rule. Add refrigerant if the measured subcooling temperature is below the recommendation. Subtract refrigerant if the subcooling temperature is higher than recommended. Refrigerant must be removed into an empty DOT-approved recovery cylinder or one containing the same refrigerant as the system.

(5) Allow the system to run for 10 minutes to adjust to the new operating conditions. Repeat the subcooling procedure, until the measured subcooling temperature matches manufacturer's recommendations or is 10° to 15°F.

(f) **Interpreting the results.** The metering device must be supplied with subcooled

Subcooling test

A subcooling test can be done on most air conditioners and heat pumps. Subcooling is primarily used to access TXV systems.



liquid. This is one of the main design requirements of all refrigeration systems. A subcooling temperature between 10° and 15°F is common for a properly functioning residential air conditioner, but it is better to use manufacturer's specifications for subcooling if they are available.

3.14.3 **Simulating Design Temperatures for Superheat and Subcooling Tests.**

(a) **Objective of test.** Blocking a portion of the condenser's airflow makes it possible to perform a superheat or subcooling test when outdoor temperature is below 80°F because the reduced airflow simulates hot weather.

(b) **Required equipment.**

(1) Digital thermometer. (Note: A differential digital thermometer makes this test easier).

(2) Probes for measuring air temperature and refrigerant-tubing surface temperature.

(3) A tarp or piece of cardboard or plastic for blocking the condenser.

(c) **Conducting the test**

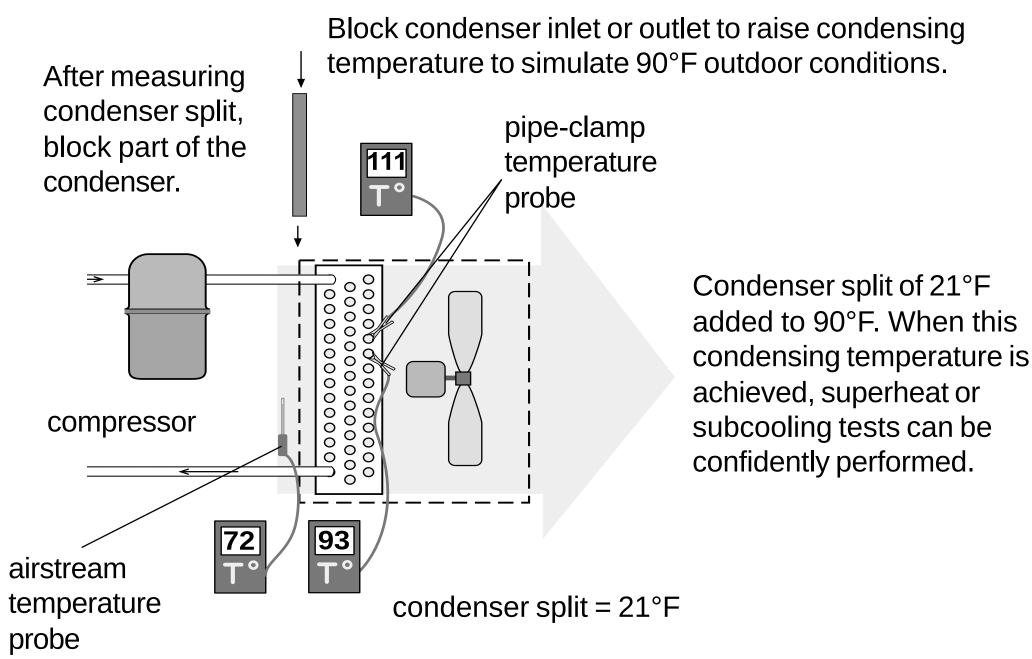
(1) Measure the condensing temperature by measuring the surface temperature of a condenser pipe loop near the vertical center of the condenser.

(2) Measure outdoor temperature and subtract from condensing temperature obtained in (1) to arrive at the "condenser split."

(3) To simulate 95°F outdoor temperature, add this condenser split to 95°F, the outdoor temperature being simulated (design temperature).

(4) Block condenser airflow until reaching the condensing temperature obtained in (3). Block equal areas of each condenser circuit. Or, block the fan outlet in such a way as to retard the airflow equally across the outlet of

Simulating hot outdoor temperatures for superheat and subcooling tests



Hot outdoor conditions are simulated by first measuring the condenser split during existing outdoor conditions. Then this temperature is added to 90°F and the condenser is blocked until that condensing temperature is reached – in this case, 111°F.

Simulating design temperatures with increased head pressure

Section 3.14.3 discusses blocking the airflow through the outdoor coil or fan in order to simulate a warmer outdoor temperature and then verifying the simulation with temperature readings. The verification of this simulation can also be determined by measuring head pressure, but only if you have the appropriate manufacturer's specifications. Of course, this procedure requires a gauge set. If you use this method, be careful not to release or contaminate refrigerant.

the condenser fan.

(5) Check superheat or subcooling as outlined previously.

(d) **Interpreting the results.** By making the condenser unit run at design conditions, the measured superheat and subcooling values better simulate design conditions under which the unit was tested.

3.14.4 **Weigh-In Refrigerant Test to Ensure Proper Refrigerant Charge.**

(a) **Objective of test.** This is the preferred method of achieving the correct charge: It can be used 1) for new installations, 2) for systems where the refrigerant has leaked out, 3) to correct refrigerant charge if found to be incorrect after checking superheat or subcooling or 4) to remove existing refrigerant in an EPA-approved manner and recharge the system by weighing in the correct amount of refrigerant whenever superheat or subcooling tests can't be employed.

(b) **Required equipment.**

(1) Approved DOT-approved refrigerant cylinder evacuated to recommended vacuum.

(2) Refrigerant recovery/recycle unit with clean filter-drier elements.

(3) Manufacturer's instructions for recovering and recycling refrigerant.

(4) Electronic scale or graduated cylinder for measuring refrigerant.

(5) Gauge set.

(6) Air-conditioner or heat-pump manufacturer's literature listing the weight of refrigerant needed by the system.

(c) **Setup.**

(1) Measure airflow and correct low airflow as described in Section 3.13.

(2) Check refrigerant charge by superheat or subcooling tests as described in 3.14.1 and 3.14.2, if possible.

(3) If superheat test or subcooling tests are inappropriate (as in winter), or if superheat or subcooling temperature is incorrect, or if a leaking system has only a partial charge, follow the procedure outlined in (d), below.

(d) **Conducting the test.**

(1) Follow the recovery/recycle unit's operating instructions for connecting hoses.

(2) Recover the refrigerant into a DOT-approved cylinder, noting the weight of refrigerant recovered and recycled.

(3) Connect the EPA-approved recovery cylinder or disposable cylinder to the gauge manifold. To prepare for liquid charging, connect the gauge manifold to the liquid valve of the recovery cylinder. If using a disposable cylinder, turn it upside down.

(4) With the compressor off, open the cylinder's valve and suction service valve, and let the liquid refrigerant flow in.

(5) If liquid stops flowing before the complete charge has entered, reconfigure the gauge manifold and cylinder to charge with vapor through the suction service valve.

(6) With the compressor running, add the remaining refrigerant as a vapor. Before opening path between the cylinder and the system, check the low-pressure gauge to make sure the cylinder pressure is higher than the system's suction pressure.

(7) Weigh in the remainder of the charge.

(8) Check performance after 10 minutes of

operation using superheat test, subcooling test, or a combination of other indicators including: temperature difference across evaporator and condenser, compressor suction and discharge pressures, evaporator- and condenser-saturation temperatures, and other indicators as provided by the manufacturer.

(e) **Interpreting the results.**

(1) The charge should be no more than one ounce greater or less than the manufacturer's specifications. Manufacturers provide a variety of charts and tables to assess heat-pump performance during the heating season. This information can be used to verify that the weighing-in procedure was successful. In the cooling mode, use procedures in Section 3.14.4 to simulate design conditions for checking the weighing-in procedure by superheat or subcooling.

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[1] C. Neme, J. Proctor, and S. Nadel, National Energy Savings Potential from Addressing Residential HVAC Installation Problems (U.S. Environmental Protection Agency ENERGY STAR Program, 1999), p. 3.

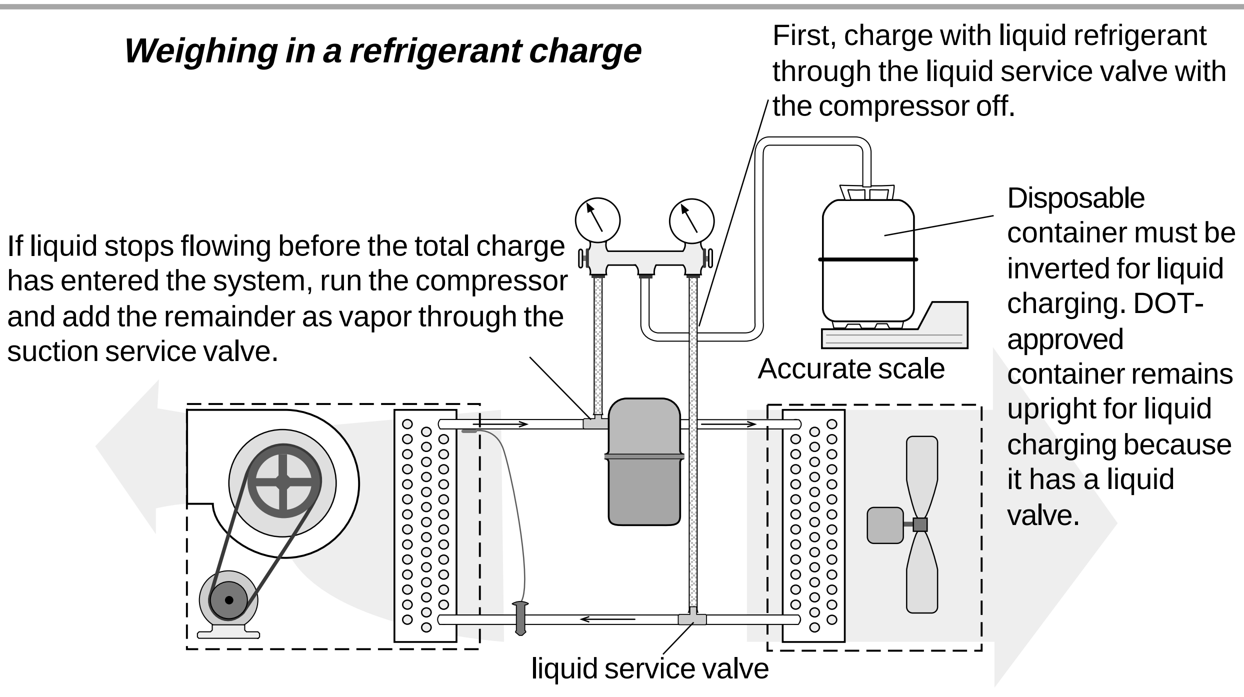
[2] C. Neme, J. Proctor, and S. Nadel, *National Energy Savings Potential from Addressing Residential HVAC Installation Problems* (U.S. Environmental Protection Agency ENERGY STAR Program, 1999), p. 5.

[3] D.S. Parker, J.R. Sherwin, and D.B. Shirey, *Impact of Evaporator Coil Air Flow in Residential Air Conditioning Systems* (Florida Solar Energy Center, 1997), Table 4.

[4] C. Neme, J. Proctor, and S. Nadel, *National Energy Savings Potential from Addressing Residential HVAC Installation Problems* (U.S. Environmental Protection Agency ENERGY STAR Program, 1999), p. 9.

[5] Honeywell Corporation, *Residential Controls for Heating and Cooling,* 1997.

Weighing in a refrigerant charge



Weighing in refrigerant corrects for low charge as determined by superheat or subcooling tests. If refrigerant must be withdrawn, a recovery/recycle unit must be used. For heat pumps or air conditioners charged during outdoor temperatures less than 70°F, the system must be evacuated in an EPA-approved manner and recharged by weight.