Residential Heating, Ventilation and Air Conditioning Standards

Volume 1

Home Builders Institute

An Overview of HBI Framework for Skill Standards

We are pleased to present the third in a series of National Skill standards for the residential construction industry. The goal of this project is to establish national standards for the residential construction industry that reflect industry skill requirements. The standards will provide trainers and educators with a basis for the certification and training of workers as well as will provide employers with objective benchmarks for employee selection and evaluating training needs. In addition, educators will find the standards useful for designing curriculum and evaluating individual training outcomes.

These standards in and by themselves do not represent a model-training program. These standards are designed to be a source in developing curricula and evaluating the outcomes of residential HVAC training programs.

Residential HVAC (Heating, Ventilation and Air Conditioning) standards are designed for installers of HVAC equipment and HVAC service technicians. Standards are developed and validated for the following eight HVAC specialties: *Air Conditioning, Gas Heat, Oil Heat, Hydronic Heat, Electric Heat, Geothermal Heat and Air Distribution*. Nineteen (19) critical work functions or duty areas are identified.

Critical work functions describe the major tasks and content areas of work within a specialty.

Key activities, the major tasks and knowledge involved in completing critical work functions, are also provided.

Performance Indicators, or skill standards, which help determine when critical work functions and key

activities are being performed competently and meet standards, are linked to critical work functions.

In addition, applied academic skills required to perform key activities are provided. These include mathematics, communications, and applied science skills.

Safety requirements are also linked to key activities.

How the Standards Were Developed

Committees of subject matter experts (SMEs) representing HVAC service technicians, small and medium size HVAC companies, as well as instructors and other experts in the field from different parts of the nation assisted in establishing and validating the standards. The final list of 19 critical work functions cutting across eight HVAC specialties reflect and accommodate regional differences.

The project called for the formation of a committee of National Association of Home Builders (NAHB) leaders in the field of HVAC. In addition, the author and editor of Delmar's HVAC text (Thompson Learning Company) were included in this committee.

These leaders represented the Northeast, Southwest, Southeast, Northwest, Mid-Atlantic and Gulf Coast regions of the U.S. The Chief Operating Officer of the Educational Foundation for Plumbing-Heating-Cooling Contractors National Association and staff from the Air Conditioning Refrigeration Institute (ARI) also participated on the committee.

- A preliminary list of critical work functions and activities organized into duty areas performed by HVAC installers and service technicians was developed through examination of industry texts, curriculum, association reference materials and other sources of information about the organization and array of tasks

performed and knowledge required in residential HVAC.

- An initial committee of nine SMEs reviewed and rated critical work functions, key activities and applied academic skills. The committee also reviewed academic skills, safety requirements and essential tools for each of these functions and activities.

- A second group of nine SMEs cross-validated the original list, then reviewed and approved performance standards for critical work functions and key activities.

Residential HVAC Specialties

The committees of SMEs divided the broad HVAC occupational category into eight specialties. This reflects the trend towards specialization in the residential home building industry.

The table below shows the percent of all HVAC activities performed by each specialty. A total 89 activities were identified and rated by the SME committees.

Table 1. What percent of HVAC activities are performed by each specialty?

Heat Pump	62%
Geothermal Heat	58%
Hydronic Heat	56%
Air Conditioning	48%
Gas Heat	46%
Oil Heat	45%
Electric Heat	45%
Air Distribution	39%

Table 1 illustrates a core of occupational activities that are common to many HVAC specialties.

For example, through training in Heat Pumps, trainees should acquire the foundation to work in other specialties as well.

How Standards are Organized

HVAC standards are organized into the follow broad categories: Applied Academic Skills; Basic Occupational Skills; and HVAC-Specific Occupational Skills. Performance indicators have been developed for each key activity required for completing critical work functions.

Applied Academic Skills include Heat Theory, Mathematics, Communications and Science Skills that are fundamental to HVAC Installers and Service Technicians.

Basic Occupational Skills include Safety and Tools and Equipment as well as HVAC Basic Automatic Controls, Electric Motors, and the Refrigeration Process.

HVAC Occupational Skills are organized into the following HVAC specialties: Electric Heat, Gas Heat, Oil Heat, Hydronic Heat, Air Conditioning, Geothermal Heat and Air Distribution.

The percentage of all HVAC installers and service technicians who perform the key activities identified in each skills category, and rated importance of these activities are displayed for HVAC specialties in Appendix A.

Applied Academic Skills

Residential HVAC installers and service technicians must master a broad array of applied academic skills in order to work and communicate effectively on the job site.

Theory of Heat

- Understand and apply the theory of heat and heat transfer.

- Understand and apply principles of matter and energy.
- Understand and apply refrigeration cycle and refrigerants used in residential and light commercial installations.

Mathematics

- Perform simple arithmetic functions including addition, subtraction, multiplication, and division of whole numbers, decimals, fractions and mixed numbers both with and without calculators.
- Measure and calculate linear distances, circles, angles, and radii in English and metric measurement systems.
- Identify common geometric shapes and compute area and volume using basic geometry.
- Measure temperature, weight, volume, and pressure in English and metric measurement systems.
- Understand and interpret job specification and manufacturers' tables, graphs and charts.
- Take accurate readings from and interpret different types of scales including volume and pressure gauges, airflow measurements and electrical meters.
- Solve multi-step problems using basic formulas.

Communication Skills

- Follow verbal directions.
- Follow written directions including reading and understanding technical manuals, schematics, tables, graphs, and charts.
- Give one- or two-step directions to associates and clients.
- Give multiple-step directions to associates and clients using diagnostic and technical data and information.

Science

- Understand and apply basic principles of temperature, pressure and temperature conversion.
- Understand and apply basic principles of alternating and direct current, series, parallel, and series parallel circuits, circuit overload protection, single- and three-phase voltage systems, transformers, grounding and bonding principles and electrical measurement.
- Understand and apply basic principles of heat transfer and combustion.
- Understand and apply basic principles of matter, mass and weight.
- Understand and apply basic principles of energy.
- Understand and apply basic principles of gas laws including the physical and chemical properties of refrigerants and hydrocarbons and their effects on the environment.
- Understand and apply the basic principles of airflow, velocity and pressure measurements.
- Understand and apply the basic principles of temperature and humidity.

Basic Occupational Skills

HVAC installers and service technicians are also required to be proficient in a variety of basic occupational skills many of which cut across all of the HVAC specialties.

General Safety Procedures

- Understand and apply proper general safety procedures when working with pressurized systems, electrical energy, heat, cold, and chemicals, rotating machinery, moving heavy objects.

Safety Rules

- Understand and apply Occupational Safety and Health Administration (OSHA) regulations that cover HVAC practices.
- Understand and apply Department of Transportation (DOT) regulations that cover the transportation and handling of hazardous materials, including refrigerants.
- Understand and apply Environmental Protection Agency (EPA) regulations that cover air quality as well as venting, recovery, reclaiming, and recycling of refrigerants.
- Apply basic fall protection safety procedures.
- Apply all OSHA, EPA and DOT hazardous materials safety requirements.
- Apply electrical safety procedures in NEC and local codes and regulations.
- Apply safety and maintenance procedures for power tools and cords.
- Apply OSHA rigging safety procedures.
- Apply OSHA ladder and scaffold safety and maintenance procedures.
- Use personal protective equipment (PPE) such as safety glasses, electrical protection, shoes, and hardhat.
- Use safe methods and tools for lifting and moving materials and equipment to prevent personal injury and property damage.
- Use proper procedures to prevent and respond to fire and other hazardous risks.
- Use proper procedures for reporting fire and safety incidents.
- Apply brazing and soldering safety procedures to prevent fires and personal injury.
- Apply OSHA, EPA, DOT and local safety procedures and codes for safe handling and storage of refrigerant containers.
- Apply proper safety precautions to prevent dangerous chemical reactions, fires and other hazards.

Tools and Equipment

Basic Safety of Tools and Equipment

- Describe the safe use of tools, including power tools used by heating and air conditioning technician.
- Describe the safe use of specialized service and installation equipment used to install and service air conditioning, heating and air conditioning systems.

Fasteners and Adhesives

- Describe, select and install the proper fasteners, adhesives and solvents used with wood, sheet metal, fiberglass, plastics and insulation.
- Describe, select and install the proper machine screw and masonry anchors and fasteners.
- Describe, select and install hanging devices and supports.
- Describe, select and install solderless terminals and screw-on wire connectors.

Tubing and Piping

- Identify, select, measure and install the proper type of pipe and tubing used in heating, air conditioning applications.
- Describe and apply proper procedures for measuring and fabricating copper pipe, including brazing, soldering, cutting, cleaning reaming, bending, flaring and swaging.
- Fabricate and install plastic piping including cutting, cleaning, solvent welding, connecting, and hanging, so that pipe does not leak.
- Describe and apply the proper procedures for measuring, cutting, cleaning, reaming and threading steel pipe joined with thread sealant properly applied so that it does not contaminate interior of piping and piping does not leak.
- Understand and install piping design for proper oil return in AC systems.

- Understand and install proper long-line refrigerant piping design.
- Explain the various factors that affect the selection of proper fittings or valves for specific installations including globe valves, gate valves, ball valves, check valves, elbows, and tees union.
- Explain the various factors that affect the selection of flanges, hangers, supports, and insulation.

Condensate Piping

- Identify, select, measure and install the proper condensate piping used in heating and air conditioning applications.
- Identify, select, locate and install drain lines to provide for proper discharge of condensate.
- Identify, select, locate and install proper traps and vents for condensate piping.
- Identify, select, locate and install proper auxiliary drain pans and secondary drains.

System Evacuation

- Understand and apply vacuum and evacuation procedures.
- Describe and apply the proper selection of a vacuum pump and the measurement of vacuum pressure.
- Describe and apply single and multiple vacuum evacuation procedures.
- List and apply proper safety procedures used in evacuation.

Refrigerant & Oil Management

- Understand the relationship between potential for ozone depletion and global warming.
- Describe how to recover, reclaim and recycle refrigerants.
- Differentiate between blended and azeotropic refrigerants.
- Differentiate among CFCs, HCFs, HFCs, and HCs.

- Understand and apply EPA regulations that apply to refrigerants and oils.
- Identify DOT-approved recovery cylinders.

System Charging

- Describe and apply the proper procedures for system charging.
- Describe how and when refrigerant is charged into the system in liquid or vapor states.
- Read, understand and interpret manufacturers' charging charts properly.

Checking Instruments

- Test and verify calibration of thermometers at low and high-temperature ranges.
- Test and verify ohmmeters and voltmeters for accuracy.
- Verify settings on multimeter before use.
- Describe and apply proper procedures for checking pressure and airflow instruments.
- Check operation of flue gas instruments.

Basic Automatic Controls

Basic Electricity & Magnetism

- Understand the principles of electron flow and parts of the atom.
- Understand the difference between alternating current and direct current.
- Explain the basic measurement principles of amperage, voltage, wattage and ohms.
- Apply Ohms' and Watts' Laws to calculate electrical values.
- Understand the principles of magnetism and electromagnetic induction.
- Explain the basic principles for series, parallel and series-parallel circuits.
- Determine voltage and current values for 120/240-volt single-phase service, wye-

connected (high-leg) three-phase service and delta-connected three-phase service.

- Determine voltage drop in a circuit.
- Read, interpret and properly apply manufacturers' electrical specifications.
- Understand the relationship between resistance, inductive reactance, and capacitive reactance.
- Read and interpret volt-ohm-milliamp meter (VOM).
- Understand and apply the principles of electrical circuit protection including fuses, circuit breakers, and ground fault interrupters (GFCI).
- Understand the principles of sine waves.
- Describe and apply NEC and local codes.

Automatic Control Circuits

- Read and draw a simple schematic of an electrical control circuit, properly interpreting and using proper NEMA control symbols.
- Understand basic principles of semiconductors including diodes, rectifiers, transistors, thermistors, diacs, triacs and heat sinks.
- Describe different types of automatic controls and explain principles of operation.
- Understand the operation of devices that use bimetal sensors to detect thermal change.
- Understand the principles of fluid expansion to detect thermal change.
- Understand the principles of thermocouples and thermistors and how they react to thermal change.

Automatic Control Components

- Explain the differences and application of low- and high-voltage controls.
- Explain how electrical motors are protected from high temperature and over-loading.

- Describe the uses of pressure-sensing devices, including low- and high-pressure controls and pressure relief valves.
- Describe the functions of mechanical and electromechanical controls.
- Explain the function of solid-state relays in circuits.
- Explain the basic principles of control transformers.
- Explain the basic principles of operation for variable-speed motor controls.
- Explain the basic principles of operation for defrost systems.
- Explain the basic principles of operation for flow switches.
- Explain the basic principles of operation for humidistats and dehumidistats.
- Explain the basic principles of operation for fan-limit switches.
- Explain the basic principles of operation for oil-pressure failure switches.
- Explain the basic principles of operation for solenoid valves.
- Explain the basic principles of the operation for short-cycle timers.
- Understand the application of electronic controls.
- Understand functions and operation of programmable and non-programmable thermostats.
- Describe the differences between electronic and electromechanical controls.
- Describe the operation of electronic control boards for use in air conditioning, heat pump, oil burner and gas furnace circuits.
- Identify and troubleshoot a basic electronic control circuit board.

Troubleshoot Automatic Controls

- Troubleshoot mechanical, electromechanical, and electronic control devices.
- Recognize the control components in a heat-cool circuit.
- Troubleshoot control devices using pictorial and line-type electrical wiring diagrams.
- Conduct systematic and comprehensive diagnostic practices consistent with manufacturer specifications.
- Follow all safety electrical safety practices.
- Record electrical voltage and other electrical readings.
- Prepare repair plan that meets applicable manufacturer and job specifications.

Integrated Circuit Control Boards

- Understand the principles of the operation of integrated circuit control boards.
- Identify and troubleshoot integrated circuit control boards.

Electric Motors

Types and Characteristics of Electric Motors

- Understand and explain the characteristics of single-phase, three-phase and split-phase motors.
- Understand the principle of torque and applications for low- and high-torque motors.
- Identify different types of motors and motor specifications including variable speed and multi-speed fan motors.
- Describe the use of motors in hermetic compressors.
- Describe electric motor protection devices, including low- and high-voltage, heat and single-phasing.

- Describe the principles of operation of different types of motors.

Application of Motors

- Understand the design features that influence the selection of motors: power supply, work requirements, motor insulation, bearing types, mounting characteristics/frame size, and cooling requirements.
- Describe the applications of three-phase and single-phase motors.

Motor Controls

- Understand the principles and differences among a relay, contactor, and magnetic starter.
- Understand different types of external motor overload protection.
- Describe the proper procedures when resetting safety devices to start electric motors.

Troubleshoot Electric Motors

- Identify and describe the various types of electric motor problems.
- Distinguish the difference between mechanical or electrical malfunctions.
- Describe a capacitor checkout procedure.
- Describe troubleshooting an electric motor.

Refrigeration

Principles of Evaporators & Refrigerant Systems

- Understand the differences between air conditioning and refrigeration systems.
- Describe different types of evaporators.
- Understand the principles of multiple- and single-circuit evaporators.

Refrigerant Metering Devices (Expansion Devices)

- Understand and apply the operating principles and selection of appropriate refrigerant metering devices.
- Understand the operating characteristics of expansion devices and how they respond to load changes.

Condensers

- Understand the principles of heat exchange as applied to condensers.
- Describe the operating characteristics and differences between water-cooled and air-cooled condensers.
- Explain the operation of and differences between open-loop and closed-loop water condenser systems.
- Explain the differences among a tube and fin condenser coil, a coaxial tube condenser, a tube and shell condenser, and a serviceable-tube condenser.
- Understand the relationship between condensing refrigerant and condensing medium.

Compressors

- Understand the function of a refrigerant compressor.
- Explain the differences between hermetic and semi-hermetic compressor.
- Identify and describe the various components and parts of compressors.

Accessories and Minor Components

- Understand the principles of refrigeration system components, including mechanical, electrical and electromechanical controls, as well as accessories such as receivers, accumulators, filter-driers, and high- and low-pressure switches, time delays, reversing valves and solenoid valves.

Troubleshoot Refrigeration Systems

- Understand the operating conditions for air-cooled, open-loop and closed-loop water-cooled systems.
- Describe and diagnosis problems in a refrigeration system such as low or excessive refrigerant charge, low or high-pressures, unsatisfactory compressor performance, and restrictions in refrigerant systems.

Skill Levels and Training

HVAC installer skill standards can typically be met in training programs of six months to one-year, depending upon the student's prior educational background (especially in mathematics and science), work experience, interests and mechanical aptitude, as well as breadth, scope and sequence of the training program. Installers usually perform work under the direction of service technicians or highly experienced and/or skilled installers.

Installer skills are typically learned in high school vocational programs, apprenticeship programs, informal or formal HVAC-based training programs, on-the-job-training, or some combination of these programs.

HVAC service technicians work independently and most likely have experience as installers. Service technicians typically require two years of training as well as two or more years of work experience mastering skills learned in training. Incumbent workers with extensive experience in HVAC may be able to demonstrate competence on standards with little or no additional structured training.

HVAC Occupational Skills

HVAC specialties require different skill sets, standards or performance indicators. The following is a breakdown of critical work functions, activities and

standards for the following HVAC specialties: *Air Conditioning, Gas Heat, Oil Heat, Hydronic Heat, Electric Heat, Geothermal Heat and Air Distribution.*

Electric Heat

Principles of Electric Heat

- Understand and explain principles of electric heat elements installed in air handlers, electric furnaces and duct heaters.
- Understand and explain principles of electric heat elements installed in air handlers.
- Install proper electric heat elements in air handlers according to manufacturer specifications and applicable NEC and other local codes.
- Provide required voltage and safety controls for electrical and control circuits.
- Follow applicable safety procedures.

Install Electric Furnace

- Install electric furnaces according to manufacturer specifications.
- Comply with applicable NEC and local codes.
- Provide required voltage and safety controls as specified.
- Follow all applicable safety procedures.

Install Electric Duct Heaters

- Install duct heaters according to manufacturer specifications.
- Comply with applicable NEC and other local codes.
- Size duct heaters properly to the duct and airflow requirements.
- Install control circuits to provide required voltage and safety controls as specified.
- Follow all applicable safety procedures.

Troubleshoot Electric Heating System

- Follow systematic and comprehensive diagnostic practices consistent with manufacturer's specifications.
- Follow all appropriate safety regulations and procedures.
- Record electrical measurements and temperatures not meeting specified operating parameters.

Gas Heat

Principles of Gas Heat

- Understand and explain principles of gas-fired forced-air heating systems, such as combustion and operation of heat exchangers.
- Describe the major components of gas-fired furnaces and types of fuel.
- Explain the basic principles of operation for gas burner controls.
- Describe the procedures for taking flue-gas carbon dioxide readings and temperatures.

Install Gas Furnaces

- Install gas-fired forced-air heating systems according to manufacturer's specifications.
- Comply with applicable AGA standards, local codes and regulations, including combustion air and venting.
- Install furnace with all electrical and control circuits as specified.
- Ensure that system operates within manufacturer specifications.

Install Gas Piping

- Install gas-fired forced-air heating system piping according to applicable local codes, AGA standards and manufacturer's specifications.
- Perform tests to determine that piping and joints do not leak.

Install Gas Venting

- Install vents according to manufacturer specifications and applicable local codes.
- Perform tests to determine that all seams and joints do not leak.

Provide Combustion Air for Gas-Fired System

- Provide combustion air to meet local code and manufacturer specifications.

Gas Safety Tests and Start-Up

- Perform all applicable safety tests to meet manufacturer specifications and applicable codes at start-up.
- Follow all applicable safety procedures.

Troubleshoot Gas Heat Systems

- Follow systematic and comprehensive diagnostic practices consistent with manufacturer's recommendations.
- Record electrical measurements, pressures and temperatures not meeting specified operating parameters, including measurements of gas valves, pilot lights, blower fans, and other system components and safety devices operating outside manufacturer specifications.
- Prepare repair plan that meets applicable manufacturer's specifications and local codes.

Oil Heat

Principles of Oil Heat

- Understand and apply the principles of oil-fired forced air-heating systems.
- Describe the major components of oil heating systems.
- Explain the basic principles of operation for oil burner controls.
- Describe basic service and preventive maintenance procedures.

- Describe basic diagnostic procedures to determine burner efficiency, basic malfunctions, and corrective procedures.

Install Oil Furnaces

- Install oil-fired forced-air heating system according to manufacturer's specifications.
- Comply with applicable NEC, National Fuel Gas Code, and local codes.
- Install all electrical and control circuits, voltage and safety controls as specified.
- Follow all applicable safety procedures.

Install Oil Piping and Tanks

- Install steel piping according to manufacturer specifications and applicable codes.
- Measure, cut and install piping correctly with thread sealant properly applied at joints.
- Install joints without leaks.
- Properly support all piping using clamps and supports spaced with adjustments to ensure adequate flow of oil without sagging between supports.
- Follow all applicable safety procedures.
- Install oil tanks according to manufacturer specifications and applicable codes.
- Install below-ground tanks level and compacted with approved materials to prevent movement.
- Install above-ground tanks slightly pitched towards the outlet.
- Follow all applicable safety procedures.

Install Oil Venting

- Install vents according to manufacturer specifications and applicable codes.
- Perform tests to determine that all seams and joints do not leak.
- Follow all applicable safety procedures.

Provide Combustion Air Oil-Fired System

- Provide combustion air to meet all applicable local codes as well as heating system and manufacturer specifications.

Oil Safety Tests and Start-Up

- Perform all applicable safety tests at start-up to meet manufacturer specifications and applicable local codes at.
- Follow all applicable safety procedures.

Troubleshoot Oil Heat Systems

- Follow systematic and comprehensive diagnostic practices consistent with manufacturer specifications.
- Record draft and combustion efficiency measurements and stack temperatures.
- Record measures of other component parts not meeting specified operating parameters including pumps, burner motor, blower fan, nozzles and other system components and safety devices operating outside manufacturer specifications.
- Prepare repair plan that meets applicable manufacturer specifications and local codes.

Boilers

- Understand and apply principles of electric, gas and oil boilers.

Hydronic Heat

Principles of Hydronic Hat

- Understand and apply principles of gas-fired, electric or oil-fired hot water and radiant panel hydronic heating systems.
- Describe the major components of hydronic heating systems including pressure relief valve, zone control valve, balancing valve, limit controls, expansion tank, boiler, backflow prevention device and air elimination device.

- Understand and apply principles of centrifugal pumps.

Install Hydronic Heating Systems

- Install gas-fired, electric or oil-fired hot water and radiant panel hydronic heating systems according to manufacturer specifications.
- Comply with applicable NEC and other codes and regulations.
- Install boiler, pumps, piping, makeup water supply and other components properly for the correct water flow to meet building's heating and domestic hot-water requirements.
- Fill and bleed the system according to manufacturer specifications.
- Install all safety devices properly as required by local codes.
- Follow all applicable safety procedures.

Test Integrity of Hydronic Heating Water Circuits

- Test hydronic heating piping system, including heating and hot-water circuits for leaks and air entrapment.
- Make adjustments as required.
- Test that system does not leak.
- Follow all applicable safety procedures.

Hydronic Heating Systems Start-Up

- Perform all applicable safety tests that meet manufacturer specifications and applicable codes at start-up.
- Follow all applicable safety procedures.

Troubleshoot Hydronic Heating Systems

- Follow systematic and comprehensive diagnostic practices consistent with manufacturer specifications.

- Record electrical measurements, pressures and temperatures and other system parameters not meeting specified operating parameters.
- Prepare repair plan that meets applicable manufacturer and job specifications.

Alternative Heating

- Understand and apply principles of alternative stoves, fireplace inserts and solar heating systems.
- Explain proper venting for gas and wood stoves.
- Explain the safety hazards of wood stoves.
- Understand and apply the basic principles of active and passive solar heating.

Packaged Electrical Air Conditioning and Gas Heating Units

- Explain the basic principles of operation for air conditioning systems that operate in conjunction with gas heating systems.
- Properly read and interpret schematic diagrams for an air conditioning system that operates in conjunction with a gas heating system.

Install Air Treatment Devices

- Understand indoor air treatment devices and carbon monoxide safety standards.
- Understand and apply principles of air treatment devices.
- Install indoor air treatment devices according to manufacturer specifications, job requirements and local codes.
- Comply with applicable NEC and local codes.
- Follow all applicable safety procedures.
- Understand and apply principles of fresh air ventilation and air exchange.

- Understand and apply principles of dehumidification and humidification.
- Properly connect a dehumidistat and humidistat in a circuit.

Troubleshoot Air Treatment Devices

- Follow systematic and comprehensive diagnostic practices consistent with manufacturer specifications.
- Record measurements not meeting specified operating parameters.
- Prepare repair plan that meets applicable manufacturers, job specifications and local codes.

Air Distribution Systems

Principles of Air Distribution Systems

- Understand and apply principles of air distribution systems.
- Describe proper components of air distribution systems.
- Describe appropriate uses of propeller and centrifugal blowers.
- Describe the different types of air-measuring devices and their uses in measuring air quantities and air flow.
- Understand and use a duct calculator.

Install Air Distribution Systems

- Install air distribution systems with materials and practices that conform to all applicable standards and local codes.
- Provide airflow to rooms that match heat loss/heat gain calculations.
- Fabricate, install and insulate metal square and rectangle, flexible, fiberboard, round metal and combination duct systems according to manufacturer specifications.

- Support trunk ducts and branch ducts with necessary brackets and hangers as specified in standards and local codes.
- Connect branch ducts to trunk ducts.
- Seal all seams to ensure no leakage.
- Test air distribution systems for balance, system airflow, pressure and leaks to meet job and manufacturer specifications.

Troubleshoot Air Distribution Systems

- Conduct systematic and comprehensive diagnostic practices consistent with job and manufacturer specifications and ACCA Manual D or equivalent.
- Identify air distribution parameters not meeting required operating specifications.
- Prepare repair plan that meets applicable performance requirements.

Air Conditioning

Principles of Air Conditioning

- Understand and apply the basic principles of air conditioning related to heat transfer, temperature, humidity, and air movement.
- Describe and explain the function of air conditioning components including evaporator, condenser, compressor, metering devices, fans, air distribution systems, and air filtration systems.
- Describe and explain the function of condensate drains.
- Understand and apply the basic principles and effects of dew-point temperature, wet- and dry-bulb temperature, room temperature, ambient temperature and relative humidity.
- Explain the relationship of air properties to comfort of humans.

- Understand air conditioning design standards set by the Air Conditioning and Refrigeration Institute (ARI).

Install Air Conditioning Systems

- Install air-conditioning package or split system to manufacturer specifications.
- Comply with applicable NEC and local codes and regulations.
- Provide the airflow required by job specifications.
- Securely fasten the air conditioning unit as specified.
- Locate and install the air handler on a solid base or suspend it from a strong support according to manufacturer specifications and local code.
- Locate and install the air handler, condenser and evaporator coil in serviceable positions.
- Install the condensate drain system according to job and manufacturer specifications and local codes.
- Properly connect all electrical and control circuits to provide voltage and safety controls as specified.
- Install air filtration system according to manufacturer and job specifications.
- Install evaporative cooling system according to manufacturer specifications.
- Test condensate drain to verify that it meets job and manufacturer specifications.

Air Conditioning Control Systems

- Understand and describe basic components of air conditioning control systems.
- Understand the differences between operating controls and safety controls.
- Describe the functions of system components such as operating and safety controls,

thermistors, internal relief valves, overload protectors and thermostats.

Air Conditioning Evacuation and Charging

- Understand the purpose of evacuating systems before charging.
- Perform evacuation and charging according to manufacturer specifications.

Recover, Reclaim and Recycle Refrigerants

- Perform recovery, reclamation and recycling of refrigerants in compliance with EPA regulations based on Section 608 of the Clean Air Act.

Air Conditioning Start-up and Performance Testing

- Check all electrical and refrigerant connections and drains at start-up as specified by local codes.
- Understand and evaluate ambient operating conditions of air conditioning equipment according to manufacturer specifications, including system pressures and temperatures.
- Compare operating performance of air conditioning systems with manufacturer specifications.

Troubleshoot Air Conditioning Systems

- Perform systematic and comprehensive diagnostic practices consistent with manufacturer specifications.
- Compare suction, discharge pressures and refrigerant temperatures to manufacturer specifications at current ambient conditions.
- Check and record Delta T (temperature difference) of air across the evaporator.
- Check and record line and low-voltage power measurements not meeting specified operating parameters.
- Prepare repair plan that meets applicable manufacturer and job specifications.

Air-to-Air Heat Pumps (Air Source Heat Pumps)

Principles of Air-to-Air Heat Pumps

- Understand and apply the basic principles of air-to-air heat pumps including heat sources, types of heat pumps, balance points and heat transfer.
- Understand the coefficient of performance (COP) and heating seasonal performance factor (HSPF).
- Describe the functions of various air-to-air heat pump components including reversing valve, metering devices, thermostatic expansion valves, condensate drains and controls.
- Use the manufacturer performance data with calculations of heat loss and equipment capacity to determine the balance point.

Install Heat Pump

- Install air source heat pump (package or split systems) according to manufacturer specifications.
- Comply with applicable NEC and local codes.
- Securely fasten the heat pump unit.
- Properly install all electrical and control circuits to provide voltage and safety controls as specified.
- Test the condensate drain to verify that it meets manufacturer specifications and local codes.

Supplementary, Auxiliary or Emergency Heat

- Understand and apply the principles of supplemental, auxiliary or emergency heat including electric, oil and gas sources.

Charging and Evacuating Heat Pumps

- Charge and evacuate heat pumps according to manufacturer specifications.

Performance and Start-up Testing

- Check all electrical and refrigerant connections and drains at start-up as specified by local codes.
- Verify that all safety devices function properly.
- Understand and evaluate ambient operating conditions of heat pump equipment according to manufacturer specifications, including system pressures and temperatures.
- Test that the system has proper airflow per specifications.
- Compare operating performance of heat pump systems with manufacturer specifications.

Troubleshoot Heat Pumps

- Perform systematic and comprehensive diagnostic practices consistent with manufacturer specifications.
- Compare suction, discharge pressures and refrigerant temperatures to manufacturer specifications at current ambient conditions.
- Check and record delta T (temperature difference) of air across the indoor coil.
- Check operation of reversing valve and defrost system.
- Check and record line and low-voltage power measurements not meeting specified operating parameters.
- Prepare repair plan that meets applicable manufacturer and job specifications and local codes.

Geothermal or Water-Source Heat Pumps

Principles of Geothermal Heat Pumps

- Understand and apply the principles of open-loop and closed-loop heat pumps.

- Describe different ground-loop configurations for closed-loop geothermal systems.
- Explain the advantages and disadvantages of series- and parallel-flow configurations in geothermal pump systems.
- Describe the different types and water sources for geothermal or water-source heat pumps.

Install Geothermal or Water-Source Heat Pumps

- Install geothermal or water-source heat pump according to manufacturer specifications.
- Comply with applicable NEC and local codes.
- Securely fasten the heat pump unit.
- Properly install all electrical and control circuits to provide voltage and safety control as specified.
- Properly size and assemble heat pump transfer piping system without leaks to meet manufacturer~~'s~~ and job specifications.
- Test system for air and water leaks.

Supplementary, Auxiliary or Emergency Heat

- Understand and apply the principles of supplemental, auxiliary or emergency heat including electric, oil and gas sources.

Charging and Evacuating Heat Pumps

- Charge and evacuate heat pumps according to manufacturer specifications.

Performance and Start-up Testing

- Check all electrical and refrigerant connections and drains at start-up as specified by local codes.
- Verify that all safety devices function properly.
- Understand and evaluate ambient operating conditions of heat pump equipment according to manufacturer specifications, including system pressures and temperatures.

- Test that the system has proper airflow per specifications.
- Test that the system has proper waterflow pressure and temperature per specifications.
- Compare operating performance of heat pump systems with manufacturer specifications.

Troubleshoot Geothermal or Water-Source Heat Pumps

- Perform systematic and comprehensive diagnostic practices consistent with manufacturer specifications.
- Compare suction, discharge pressures and refrigerant temperatures to manufacturer specifications at current ambient conditions.
- Check and record delta T (temperature difference) of air across the indoor coil.
- Check operation of reversing valve.
- Check waterflow, GPM, and inlet and outlet temperatures.
- Check and record line and low-voltage power measurements not meeting specified operating parameters.
- Prepare repair plan that meets applicable manufacturer and job specifications and local codes.

Evaporative Coolers

Principles of Evaporative Coolers

- Understand and apply principle of evaporative coolers.

Install Evaporative Coolers

- Install evaporator coolers according to manufacturer specifications.
- Comply with applicable NEC and local codes.
- Provide airflow as required by specifications.

- Securely fasten the cooling unit and all electrical and control circuits to provide voltage and safety controls as specified.
- Test system for air and water leaks.
- Install piping system and drains with no leakage.

Performance and Start-up Testing

- Check all electrical and water connections and drains at start-up as specified by local codes.
- Verify that all safety devices function properly.
- Understand and evaluate ambient operating conditions of equipment according to manufacturer specifications, including system pressures and temperatures.
- Test system for proper airflow per specifications.
- Test that the system has proper water flow over evaporator pads per specifications.
- Compare operating performance of system with manufacturer specifications.

Troubleshoot Evaporative Coolers

- Conduct systematic and comprehensive diagnostic practices consistent with manufacturer specifications.
- Record electrical voltage, airflow, temperature and relative humidity measurements.
- Prepare repair plan that meets applicable manufacturer and job specifications.

Critical Work Functions and Key Activity Ratings

Importance ratings and percent of installers and service technicians who perform critical work functions and key activities for the eight HVAC specialties are found in Appendix A.

Importance

The importance of key activities, tasks and topical content areas reported in Appendix A is the product of the proficiency or skill required to perform each task and the impact or risk to the employer, job incumbent, and/or homeowner if the task is preformed improperly. Impact or risk includes possible injury to the job incumbent, financial exposure or litigation to the employer, health risk to the home owner, to name but a few.

Proficiency was rated by the SMEs using a four-point scale with 1 indicating Minimally Skilled and 4 indicating Highly Skilled.

Risk was rated using a four-point scale with a 1 indicating Minimal Risk and 4 indicating Catastrophic Risk.

The *percent of installers and all service technicians who perform activities* was rated by SMEs.

Appendix B lists tools and equipment required for HVAC installers and service technicians.

Appendix A
HBI/NAHB Heating, Ventilation and Air Conditioning Standards Importance Matrix

Rating Scale

Extremely Important Content/Tasks 13-16
Moderate Important Content/Tasks 9-12
Somewhat Important Content/Tasks 5-8
Low Importance Content/Tasks 0-4

Specialties

AC= Air Conditioning ELEC=Electric Heat,
GAS=Gas Heat PUMP=Heat Pump,
Oil=Oil Heat GEO=Geothermal
HYD=Hydronic Heat, AirD=Air Distribution

Critical Work Functions	Importance		% of all Installers who perform this task?	% of all Service Techs who perform this task?	*Which specialty performs this task?*							
	Installers	Service			AC	GAS	OIL	HYD	ELEC	PUMP	GEO	AirD
Heat												
Principles and Theory of Heat	1	6	0%	100%	●	●	●	●	●	●	●	●
Matter & Energy	1	6	0%	100%	●	●	●	●	●	●	●	●
Refrigeration & Refrigerants	1	16	0%	100%	●					●	●	
Average	1	9	0%	100%								
Safety												
General Safety Practices	16	16	100%	100%	●	●	●	●	●	●	●	●
Safety Rules (OSHA, EPA, DOT)	16	16	100%	100%	●	●	●	●	●	●	●	●
Average	16	16	100%	100%	●	●	●	●	●	●	●	●
Tools and Equipment												
Basic Safety of Tools and Equip.	16	16	100%	100%	●	●	●	●	●	●	●	●
Fasteners and Adhesives	12	12	100%	100%	●	●	●	●	●	●	●	●
Tubing and Piping	16	16	100%	100%	●	●	●	●	●	●	●	
Condensate Piping	16	16	100%	100%	●	●	●	●	●	●	●	
System Evacuation	1	12	0%	100%	●					●	●	
Refrigerant & Oil Management	1	12	0%	100%	●					●	●	
System Charging	1	16	0%	100%	●					●	●	
Checking Instruments	1	12	0%	100%	●	●	●	●	●	●	●	●
Average	8	14	50%	100%								

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Critical Work Functions	Importance: Installers	Importance: Service	% of all Installers who perform this task?	% of all Service Techs who perform this task?	*Which specialty performs this task?* AC	GAS	OIL	HYD	ELEC	PUMP	GEO	AirD
Basic Electricity & Magnetism	2	16	25%	100%	●	●	●	●	●	●	●	●
Automatic Control Circuits	2	16	25%	100%	●	●	●	●	●	●	●	●
Automatic Controls	1	8	25%	100%	●	●	●	●	●	●	●	●
Automatic Control Components	1	8	25%	100%	●	●	●	●	●	●	●	●
Troubleshoot Controls	1	12	0%	100%	●	●	●	●	●	●	●	●
Integrated Circuit Control Boards	2	8	0%	100%	●	●	●	●	●	●	●	●
Average	2	11	17%	100%								
Electric Motors												
Types of Electric Motors	1	6	0%	100%	●	●	●	●	●	●	●	●
Application of Motors	1	9	0%	100%	●	●	●	●	●	●	●	●
Motor Controls	1	12	0%	100%	●	●	●	●	●	●	●	●
Troubleshoot Electric Motors	1	12	0%	100%	●	●	●	●	●	●	●	●
Average	1	10	0%	100%								

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Critical Work Functions	Importance Installers	Importance Service	% of all Installers who perform this task?	% of all Service Techs who perform this task?	*Which specialty performs this task?* AC	GAS	OIL	HYD	ELEC	PUMP	GEO	AirD
Refrigeration Process												
Principles of Evaporators & Refrig.	1	12	0%	100%	●					●	●	
Expansion Devices	1	12	0%	100%	●					●	●	
Condensers	1	12	0%	100%	●					●	●	
Compressors	1	16	0%	100%	●					●	●	
Accessories & Minor Components	1	12	0%	100%	●					●	●	
Troubleshoot Refrigeration Systems	1	16	0%	100%	●					●	●	
Average	1	13	0%	100%								
Electric Heat												
Principles of Electric Heat	1	16	25%	75%					●	●	●	
Install Electric Elements in Air Handlers	9	12	75%	75%					●	●	●	
Install Electric Furnace	9	12	75%	75%					●	●		
Install Electric Duct Heaters	12	16	25%	75%					●	●		●
Install Related Wiring & Controls	12	16	75%	75%					●	●	●	●
Troubleshoot Electric Heating System	1	16	0%	75%					●	●	●	●
Average	7	15	46%	75%								

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Critical Work Functions	Importance		% of all Installers who perform this task?	% of all Service Techs who perform this task?	*Which specialty performs this task?*							
	Installers	Service			AC	GAS	OIL	HYD	ELEC	PUMP	GEO	AirD
Gas Heat												
Principles of Gas Heat	6	16	50%	50%		●		●				
Install Gas Furnaces	9	16	50%	50%		●		●				
Install Gas Piping	12	16	50%	50%		●		●				
Install Gas Venting	16	16	50%	50%		●		●				
Provide Ventilation and Combustion Air	16	16	50%	50%		●		●				
Gas Safety Tests and Start-Up	1	16	0%	50%		●		●				
Troubleshoot Gas Heating System	1	16	0%	50%		●		●				
Average	9	16	36%	50%								
Oil Heat												
Principles Oil Heat	1	16	25%	50%			●	●				
Install Oil Furnaces	9	16	25%	50%			●	●				
Install Oil Piping and Tanks	16	16	25%	50%			●	●				
Install Oil Venting	16	16	25%	50%			●	●				
Provide Combustion Air	16	16	25%	50%			●	●				
Oil Safety Tests and Start-up	1	16	0%	50%			●	●				
Troubleshoot Oil Heat System	1	16	0%	50%			●	●				
Average	9	16	18%	50%								

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Critical Work Functions	Importance		% of all Installers who perform this task?	% of all Service Techs who perform this task?	*Which specialty performs this task?*							
	Installers	Service			AC	GAS	OIL	HYD	ELEC	PUMP	GEO	AirD
Boilers												
Principles of Boilers	9	16	25%	50%		●	●	●	●			
Electric Boilers	1	16	25%	50%				●	●			
Gas Boilers	4	16	25%	50%		●		●				
Oil Boilers	4	16	15%	35%			●	●				
Average	5	16	23%	46%								
Hydronic Heat												
Principles of Hydronic Heat	1	16	10%	50%		●	●	●	●			
Types of Hydronic Heating Systems	2	16	25%	50%		●	●	●	●			
Install Hydronic Heating Systems	9	16	25%	50%		●	●	●	●			
Test Integrity of Hydronic Heating Water Circuits	9	16	25%	50%		●	●	●	●			
Safety Tests and Start-Up	1	16	0%	50%		●	●	●	●			
Troubleshoot Heating Systems	1	16	0%	50%		●	●	●	●			
Average	4	16	14%	50%								

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Critical Work Functions	Importance Installers	Importance Service	% of all Installers who perform this task?	% of all Service Techs who perform this task?	*Which specialty performs this task?* AC	GAS	OIL	HYD	ELEC	PUMP	GEO	AirD
Alternative Heating	1	4	2%	5%								
Air Treatment Devices												
Install Air Quality Devices	9	12	100%	100%	●	●	●	●	●	●	●	●
Troubleshoot Air Treatment Devices	1	12	0%	100%	●	●	●	●	●	●	●	●
Average	5	12	50%	100%								
Packaged Units												
Electric, AC, Heat Pumps & Gas Units	1	9	0%	100%	●	●		●	●	●	●	
Air Distribution Systems												
Principles of Air Distribution Systems	6	12	100%	100%	●	●	●	●	●	●	●	●
Install Air Distribution Systems	9	12	100%	100%	●	●	●	●	●	●	●	●
Troubleshoot Air Distribution Systems	1	12	0%	100%	●	●	●	●	●	●	●	●
Average	5	12	67%	100%								

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Critical Work Functions	Importance		% of all Installers who perform this task?	% of all Service Techs who perform this task?	*Which specialty performs this task?*							
	Installers	Service			AC	GAS	OIL	HYD	ELEC	PUMP	GEO	AirD
Air Conditioning (Cooling)												
Principles of Air Conditioning	1	9	25%	100%	●					●	●	●
Install AC Systems	6	9	85%	100%	●					●	●	●
AC Control Systems	4	9	15%	100%	●					●	●	
AC Evacuation and Charging	1	16	0%	100%	●					●	●	
Recover, Reclaim & Recycle Refrigerants	1	16	0%	100%	●					●	●	
AC Safety Start-up & Performance Testing	1	9	0%	100%	●					●	●	●
Troubleshoot Air Conditioning Systems	1	16	0%	100%	●					●	●	
Average	2	12	18%	100%								
All-Weather Systems (Heat Pumps)												
Principles of Air-to-Air Heat Pumps	1	12	50%	100%						●		
Install Heat Pump	6	12	75%	100%						●		
Supplementary, Auxiliary, Emergency Heat	1	12	25%	100%						●		
Charging & Evacuating Heat Pumps	1	16	0%	100%						●		
Heat Pump Start-Up and Performance Testing	1	16	0%	100%						●		
Troubleshoot Heat Pumps	1	16	0%	100%						●		●
Average	2	14	25%	100%								

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Critical Work Functions	Importance Installers	Importance Service	% of all Installers who perform this task?	% of all Service Techs who perform this task?	*Which specialty performs this task?* AC	GAS	OIL	HYD	ELEC	PUMP	GEO	AirD
Geothermal or Water-Source Heat Pumps												
Principles of Geothermal Heat Pumps	1	12	5%	10%								
Install Geothermal Heat Transfer Piping System	6	12	5%	10%							●	
Supplementary, Auxiliary or Emergency Heat	2	12	5%	10%							●	
Charging & Evacuating Heat Pumps	1	16	0%	10%							●	
Heat Pump Start-Up and Performance Test	1	16	0%	10%							●	
Troubleshoot Heat Pumps	1	16	0%	10%							●	●
Average rage	2	14	3%	10%								
Evaporative Coolers												
Principles of Evaporator Coolers	1	6	10%	15%								●
Install Evaporative Coolers	4	6	10%	15%								●
Evaporator Coolers Start-Up and Perf. Test	4	6	10%	15%								●
Troubleshoot Evaporative Coolers	1	6	0%	15%								●
Average	3	6	8%	15%								

Appendix B
HBI / NAHB HVAC Standard Tools

Percent of Installers and Techs Using Specific HVAC Tools

	Installers	Techs		Installers	Techs
Standard Hand Tools					
Hammer, Tape Measure	100%	100%	Duct blaster/blower door	0%	15%
Tool belt, bag or box	100%	100%	Vacuum Pump	0%	100%
Duct Fabrication			Refrigerant Recovery Tools	0%	100%
Fiber Duct Board Tools	100%	100%	Charging Scale	0%	100%
Metal Duct Tools	100%	100%	Hoists	100%	50%
Flex Duct Tools	100%	100%	Gauge Manifold Set	75%	100%
Copper Tubing Tools	100%	100%	Pocket thermometer	0%	100%
Steel Pipe Operations Tools			Schraeder Core	75%	100%
Pipe Wrenches	100%	100%	Personal Protection Equipment		
Cutters and Threaders	50%	50%	Safety glasses	100%	100%
Brazing & Soldering	100%	100%	Steel Toe Safety Shoes	100%	100%
Leak Detection	0%	100%	Safety or Dust Filter Mask	100%	100%
Insulation Tools	100%	50%	Hard Hat	100%	100%
Squeegee	100%	100%	Gloves	100%	100%
Duct Sealing Tools	100%	100%	Individual Fall Arrest	100%	100%
Meters					
Electrical Meters	25%	100%			
Pressure Meters	25%	100%			
Hygrometers	0%	100%			
Temperature Gauges	25%	100%			