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Restoring the Cleanliness of HVAC Systems

Residential and Commercial Heating, Ventilating, and Air Conditioning (HVAC) Applications

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FOREWORD

[This Foreword is not part of the Standard. It is merely informative and does not contain requirements necessary for conformance to the Standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ACCA or ANSI.]

Heating, ventilation, and air conditioning (HVAC) systems – recognized as being comprised of HVAC equipment, components, subassemblies, and associated ducts and piping – are only one of many inter-related systems in buildings responsible for providing comfortable and healthy indoor environments for human occupants. Changes in one building system can affect the others, impacting the overall building conditions and possibly affecting occupants' acceptability of the indoor environment. All building systems should therefore be properly maintained, both individually and in relation to the others.

As part of their normal operation, HVAC systems can accumulate considerable amounts of dirt, debris, allergens, and other particulates over a period of time. The HVAC system operation often involves moisture which can support the growth and colonization of bacterial and fungal microorganisms. These microorganisms can accumulate or amplify throughout the HVAC system over time depending on a variety of factors, including quality and location of air filters and other peripherals, maintenance schedules, and the indoor/outdoor environmental conditions. HVAC equipment and systems containing excessive debris, whether inert particles or microorganisms, have been shown to use more energy, distribute poorly conditioned air, and accelerate degradation of system components.

This Standard is intended for restoring the cleanliness of HVAC systems. Although the procedures are also designed to reduce an adverse effect on the indoor environment and other building systems, it is not intended to be recognized as the sole remedy for resolving all indoor air quality concerns.

The need for cleaning may arise when the HVAC system operation has resulted in the buildup of particulate and debris which may adversely impact the indoor environment and performance of the system. In such cases, the HVAC system will require cleaning activities beyond those performed in normal HVAC mechanical maintenance and servicing. This standard has been created to:

- Significantly improve the cleanliness of an HVAC system and return it to a reasonable serviceable condition, although not necessarily to return the system to an "as new" condition.
- Allow the contractor and/or owner to determine if replacing certain components of the HVAC system, or possibly replacing all of the HVAC system, is a more feasible approach versus undertaking associated cleaning activities.

This Standard asserts that when any portion of an HVAC system is cleaned, the entire HVAC system also must be considered for cleaning or replacement as well. The procedures within this document are designed to be initiated in their entirety, in the sequence described herein, to achieve satisfactory system cleanliness. It is recognized that a cleaned individual component can provide an improvement. However, cleaning single components or subassemblies without considering the complete HVAC system could result in a degradation of the indoor air quality. For example, the increased airflow from a newly-cleaned blower assembly can disturb previously adhered particulates within both the supply duct and the return duct, resulting in the release and subsequent distribution of undesired contaminants into the indoor environment.

This Standard acknowledges that HVAC systems could require considerable dismantling for proper cleaning (e.g., removal of coil from the refrigerant circuit). The HVAC system restorer will need a level of training and experience in order to perform the required procedures in accordance with this Standard, applicable industry standards, good practices, and federal / state / local requirements. In many states, such HVAC professionals and contractors may need to be licensed for these activities.

INTRODUCTION

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This standard has been created using a procedural format to assure that restoring HVAC system cleanliness yields maximum benefit with minimal impact on indoor air quality, building occupants, or the building structure during the cleaning process. This Standard describes cleaning methods and procedures that focus on improving the overall indoor air quality, existing equipment life, and safeguarding the building through comprehensive restoration practices. This Standard also provides direction to assess the economic viability of replacing HVAC components or systems versus cleaning them.

It is important to understand that the procedures within this document are not designed to be performed as individual tasks (i.e., cleaning the ductwork alone or the HVAC unit alone), but should be initiated in their entirety to assure the maximum benefit to indoor air quality and energy efficiency.

In order to address some procedures within this document, the HVAC system restorer may need to hold an EPA refrigerant certification, be experienced in brazing and heat exchanger coil removal, understand wiring schematics, and have a working knowledge of HVAC systems. HVAC units can be complex to dismantle and reassemble, limiting the number of qualified individuals who can appropriately access the internal components such as coils, drain pans, and secondary heat exchangers that collect and harbor significant amounts of particulate. The process of cleaning ductwork without properly addressing other system components may have little or no impact on improving the overall HVAC efficiency. Studies have illustrated that a relatively small amount of collected particulate on cooling coils will dramatically reduce efficiency. Collected particulate within the coil surfaces may also lead to possible microbial growth.

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1.0 PURPOSE

This Standard establishes minimum requirements to restore the cleanliness of residential and commercial HVAC systems in accordance with manufacturer- or customer-specified criteria.

The Standard defines minimum procedures and practices to:

a) Determine when airside surfaces should be cleaned, and when they require repair or replacement.
b) Clean the airside surfaces within HVAC systems.
c) Control the spread of contaminants which may be released as a result of the HVAC cleaning process.
d) Verify the cleanliness of HVAC systems.

2.0 SCOPE

2.1 The methodologies used in this Standard address the designed HVAC air pathways and associated airside HVAC components such as evaporator fan sections, air ducts, and components contained within HVAC systems.

2.2 Excluded from this Standard are the following:

a) Components or surfaces outside the design air pathway (e.g., condenser coils, compressors, condenser fan motors, exterior duct and/or equipment surfaces, etc.). These items should be maintained and serviced as required in accordance with the ACCA 4 QM Standard (residential) and ACCA/ASHRAE 180 Standard (commercial).
b) Non-ducted, free air return- or supply-plenums (i.e., wall cavities, joisted floors, floor or ceiling plenums, sub slabs, etc.).
c) The disturbance, cleaning, removal, abatement, or handling of any material regulated by federal, state or local law, or considered by these agencies to be hazardous.

3.0 ESTABLISHING CRITERIA FOR HVAC SYSTEM CLEANING

Prior to initiating any cleaning activities, an HVAC contractor or an independent Indoor Air Quality Consultant should determine the system cleaning needs and economic practicality of undertaking restorative cleaning activities. This determination shall include a site survey of the building, a visual assessment of the HVAC system's components, the age of the components under consideration, and an economic assessment of HVAC system cleaning versus equipment/component replacement. This Standard requires the involvement of a third-party indoor environmental consultant when correlations, or assertions, of HVAC system cleanliness are linked to occupant health.

3.1 *Minimum qualifications of HVAC inspector*: In order to effectively undertake the assessment requirements of this Standard, the HVAC inspection needs to be undertaken by professionals that:

- Have a working understanding of an HVAC system's internal components; especially components that restrict air flow, such as evaporator coils, secondary high efficiency heat exchangers, electric resistant heaters, and zoning dampers.
- Can disassemble and reassemble various systems/subsystems so that required access to the HVAC system can be affected during the assessment.
- Can recognize basic HVAC system design flaws (e.g., grossly undersized filtration, obvious air distribution problems, and improper/incomplete original installation).
- Understand duct leakage impacts, and particle bypass and infiltration issues.

3.2 *Building survey*: Prior to any scheduled cleaning processes, a building survey shall be undertaken to determine whether the building history indicates any of the following:

- The HVAC system has been affected by the accumulation of particulate;
- The HVAC system has been damaged or affected by fire, smoke, or water damage;
- The HVAC system is emitting odors;
- The HVAC system has been infested with birds, rodents, insects, etc.

NOTE: It is not the intent of this survey to assess the system for code compliance.

3.3 *Visual cleanliness assessment*: Observations shall be made as part of the building survey to assess the HVAC system's overall condition; both the cleanliness of the HVAC system and the material integrity of various components. Observations shall address:

3.3.1 *Internal condition*: Check the HVAC system components' internal condition for rust, corrosion, obstructions, biofilm, air leakage, particulate buildup, material integrity, moisture condition and drainage. This inspection includes, but is not limited to: the duct system, filter cabinets, ducted supply and return plenums, dehumidifiers, humidifiers, Energy Recovery Ventilators (ERVs), fresh air ducts, air handlers, furnaces, coils, and condensate drains.

3.3.2 *External condition*: The HVAC components' external condition for corrosion, biofilm, air leakage, materials integrity, location and condition, including but not limited to: the duct system, filter cabinets, supply and return plenums, dehumidifiers, humidifiers, ERVs, fresh air ducts, air handlers, furnaces, coils, and condensate drains.

3.3.3 *Condensate drains*: The functionality and proper operation of the condensate drains.

3.3.4 *Mechanical room*: When applicable, the condition of the HVAC unit's mechanical room should be considered in the survey process and evaluated for its impact on system cleanliness, air quality, and the cleaning approach.

3.4 *System assessment:* Information collected during the building survey and visual inspection of the HVAC system shall be documented and evaluated to assess the condition of the HVAC system. This assessment shall include recommendations on the following:

- Need for cleaning and/or replacement of components;
- A scope of work for the proposed project;
- Cleaning techniques.

4.0 HVAC SYSTEM RESTORATION PROTOCOL

4.1 *Worker protection*: The contractor shall use proper administrative controls, engineering controls, and provide personal protection equipment (PPE) required to safely perform any and all tasks associated with this Standard. Any and all PPE shall be used by properly trained and knowledgeable personnel in accordance with applicable OSHA requirements.

4.2 *General principles*: The four (4) guiding principles for particulate removal from HVAC systems:

4.2.1 *Containment*: The HVAC system's components shall be contained (isolated) from the environment they serve before undertaking activities to physically dislodge particulates. The isolation process shall employ negative de-pressurization techniques. Appropriate pressure differentials (i.e., 0.01 – 0.02 in. wg.) shall be maintained at all times to prevent undesirable release of particles, gases, or vapors into occupied spaces. All air cleaning equipment that discharges exhaust air within the indoor environment shall be HEPA-filtered and free of objectionable gases and vapors. Exhausts that terminate outside the building shall be at locations that preclude re-introduction through the outside air intakes or other entrances into the building.

NOTE: Establishing a negative pressure condition can in some cases adversely impact the indoor environment. For example, gas-fired equipment could back draft, introducing flue gases indoors, or possibly cause a hazardous flame roll out condition. In other cases, pressure differentials that are used for infection control (i.e., operating rooms or isolation rooms) could be adversely affected. In any event, establishing a negative pressure condition as part of the HVAC cleaning work shall NOT adversely affect the indoor environment, or result in a hazardous condition.

4.2.2 *Physical dislodgment*: Accumulated debris (particles) shall be properly dislodged in preparation for removal using the most effective and efficient method available that will not result in damage to the component(s) being cleaned.

4.2.3 *Particle transport*: Once particles are dislodged, they shall be removed in the safest, most effective and efficient manner that minimizes the impact upon the physical integrity of the HVAC system components. As the dislodged particulate matter increases in mass, or changes in state from dry to wet or oily, removal requirements and tools and cleaning methods shall change accordingly.

4.2.4 *Contaminant removal*: Physical removal of contaminants shall be the method for HVAC remediation. The use of any resurfacing products or antimicrobial approaches (e.g., sanitizers, ozone, or ultraviolet light) as a substitute for particulate removal and detailed cleaning shall NOT be used.

4.3 *Cleaning equipment*: All cleaning equipment shall be operated in accordance with the cleaning equipment manufacturer's guidelines and be appropriate for the cleaning operation being undertaken. Tools shall be visibly clean before being brought into a worksite.

4.3.1 *Particulate collectors*: No particulate collectors should be opened or accessed in occupied areas or conditioned buildings once debris has been collected. All high volume particulate collection machines shall provide sufficient airflow velocity within the ventilation system to transport airborne particulate to the collection chamber.

4.3.2 *Pressurized air supply*: Air compressors shall be properly sized to enable pneumatic tools to achieve manufacturer recommended pressures in accordance with this Standard. Air compressors shall be configured to reduce moisture, oil, unacceptable vapors (including fuel-fired exhaust fumes), and other contaminants prior to being discharged from pneumatic cleaning tools.

4.3.3 *HEPA-filtered canister vacuums*: All canister vacuums (wet or dry) used or located within the indoor environment shall use a HEPA filter.

4.3.4 *Duct surface brushing systems*: All cable, rod, and pneumatic-driven brushing systems shall be sized per the cleaning equipment manufacturer's instructions for the ductwork (i.e., size and material type) being cleaned.

4.3.5 *Power washers*: Power washers shall use appropriate combined pressure and water flow to penetrate the inner rows of heat exchangers without causing fin damage.

4.4 *Building isolation*: If the building remains occupied, the HVAC contractor shall protect and isolate the occupied areas from the cleaning areas by using HEPA-filtered, ambient air particulate collectors, temporary plastic polyethylene walls, plastic sheeting, or other critical barriers. The contractor shall maintain contaminated work environments continually under negative pressure relative to adjacent non-work areas as noted in §4.5.1.

4.5 *Cleaning processes and procedures*:

4.5.1 *Continuous pressure differential*: HVAC components being cleaned within an indoor conditioned environment area shall be maintained at a continuous pressure differential to prevent cross contamination of previously cleaned HVAC components, or contamination release into occupied spaces.

4.5.2 *Particulate collectors*: All particulate collectors placed within an occupied or conditioned environment shall utilize HEPA filtration. Particle collectors shall be properly sized to avoid particle migration/release from within the HVAC system into the indoor environment. Contractors shall use appropriate testing methods applicable for project requirements to determine particulate retention capability of each cleaning device prior to using the device(s) on the job site. Cleaning equipment performance shall be monitored as part of an overall quality control/quality assurance plan.

4.5.3 *Fibrous glass duct insulation cleaning method*: The primary process for cleaning all fibrous glass ductwork or fibrous glass components internal surfaces shall be direct vacuuming of the duct surface using a canister vacuum equipped with HEPA filtration.

4.5.4 *Uniformity in cleaning*: Pneumatic or HVAC tools used to dislodge particulates and debris from a duct's interior surface shall uniformly clean all internal surfaces. Special attention shall be applied to the corners of non-round ductwork and component cabinetry.

4.5.5 *Fine particulate extraction*: After physical dislodgement, transport, and removal of attached particulates, airside surfaces of HVAC systems shall be washed with pressurized air to transport remaining dislodged particulate and/or debris to the high volume particulate collector.

4.5.6 *Electric heating and electric reheat coils*: Electric elements, or electric reheat coils, shall not come in contact with water or cleaning products unless they have been removed for cleaning. In cases where electric heating elements have been removed for cleaning, the electrical components must be protected before the elements are wet-washed with detergent.

SAFETY NOTE: Electric heating elements are often wired into separate circuitry other that the main HVAC systems electrical circuitry. Electrical deactivation must be verified per lock out / tag out procedures.

4.5.7 *Removal of contaminated materials from HVAC systems*: Contaminated materials, including fiberglass or flex ducts identified for replacement, shall not be disturbed until appropriate containment measures have been established and verified operational. Removal of contaminated items shall be done while using high volume particulate collection (HVPC) machines, or air filtration devices equipped with HEPA filtration, to preclude the release of particulate into occupied spaces. Materials to be removed from the contained area must be properly bagged and cleaned before transport outside the work area.

4.6 *Work sequence*: Cleaning work should follow the pathway of the HVAC systems designed airflow, beginning at the system's return air intakes. Cleaning should then proceed from return air intakes to the air handling unit, and then out through the supply trunk line, branch runs and discharge points. This work sequence, when properly performed, is designed to reduce the likelihood of cleaned portions of the ventilation system becoming re-contaminated.

4.7 *Protecting cleaned surfaces*: Precautions shall be used to protect cleaned surfaces of the HVAC system from becoming re-contaminated due to air flowing across unclean portions of the HVAC components. These precautions may include: a) the installation of temporary duct barriers or zoning devices to isolate cleaned sections, b) installation of temporary air filters within the duct system, and c) isolating and locking out the electrical circuitry of the system.

4.8 *Disposal of existing HVAC filters*: Once removed, all existing air filters should be placed in plastic bags and sealed with duct tape, prior to being transported through occupied spaces, and discarded in accordance with applicable Federal, State, and local regulations.

4.9 *Cleaning of HVAC system components and subsystems*:

4.9.1 *Cooling / heating coils*: Cooling and/or heating coils shall be wet-cleaned with detergent cleaners, and then rinsed using a pressurized water stream in a manner that will not damage the cooling coil. Pressurized chemical and water cleaning methods, such as pressure washers and chemical injection systems, shall be utilized for coils with a depth of 4 rows and greater. When heat exchanger coils cannot be removed, surfaces surrounding the coil, such as internal insulation or electronic devices, should be temporarily isolated and protected from water/detergent overspray.[1]

4.9.1.a *Coil access*: The upstream and downstream faces of the coil must be accessed for cleaning. Coils should be removed for cleaning whenever both faces of the coil cannot be completely accessed. Cooling coil removal for fluorochemical refrigerant systems must be performed in

[1] Refer to informative Appendix A-2.6 for an example of an isolation procedure to prevent overspray.

accordance with §4.9.1.b. As a cooling coil's depth increases beyond 4 rows, or when the fin spacing impedes the cleaning efforts, then the rinse water pressure must be increased to achieve a deeper penetration. However, in no event shall the pressure exerted upon the coil be such that it may result in damage to the fins or coil.

4.9.1.b *Coil removal*: Cooling coil removal requires a qualified technician to pump down the refrigerant for temporary storage into the air conditioning system's condenser unit, or into a separate secondary recovery tank. Federal, state, and local requirements must be observed for the capturing of refrigerants. Once the coil is removed using proper pump down procedures, both ends of the coil and the interconnecting copper piping must be properly sealed to prevent moisture or other contaminants from entering into the coil.

4.9.2 *Fan blades and fan housing*: Fan blades and fan housings shall be wet-cleaned with detergent, physically scrubbed, and then rinsed using a focused water stream. Water shall be contained and captured, as it can lead to damage.

4.9.3 *Motors*: The exterior housing of fan motors and their exterior wiring shall be carefully HEPA-vacuumed, and then damp wiped, as required to effectively remove debris. As applicable, wipe the motor shell, housing, and brackets with a rag dampened with a light solution of detergent-type cleaner, provided that the detergent is not corrosive and will not affect the motor windings, bearings, or mounts. When insulated wiring is openly exposed to the airstreams (e.g., motors in air handling units), each insulated wire shall be individually hand cleaned.[2] Pressurized air may gently be used to remove built-up debris inside the motor and the motor stator windings, if permissible by the motor manufacturer. If pressurized air is used, the motor housing must be properly cleaned (as above) after the air pressure is applied.

4.9.4 *Air handling units and interior heat exchanger cabinet surfaces*: All airside surfaces within air handling units shall be physically cleaned to remove accumulated particulate. Fibrous glass, or other materials used to insulate the interior of air handler cabinets, shall be inspected for fraying, tearing, and delaminating, as part of the cleaning process. The contractor shall repair or replace damaged fibrous glass (or other type) insulation during the cleaning and prior to energizing the HVAC system. Insulation that is wet, or has visible growth on it, shall be properly removed and replaced.

4.9.5 *Drain pans and drain line*: Rusted or deteriorated drain pans shall be assessed for replacement. All surfaces of the drain pan shall be wet-cleaned with proper detergent cleaners designed for this purpose, and physically scrubbed inside and out to dislodge contaminants. Contaminants in the drain pan shall be removed with a HEPA-filtered, wet vacuum during this process to prevent particulate and other biological matter from entering the drain line. During the remediation process, the drain line shall be cleared, as required, with pressurized water, or vacuumed out, with a HEPA vacuum to ensure continuous, free drainage.

4.9.5.a *System drainage verification*: Proper drainage of the drain pan and drain line shall be verified. Drains pans that do not drain properly, or pans that

[2] When wiping down the wires of the motor, care must be exercised to avoid pulling on unsupported electrical wires and wiring harnesses.

continually hold water after the HVAC unit cycles off, shall be noted to the client or the client's representative.

4.9.5.b *Secondary drains open to outdoors under negative pressure*: Secondary drains shall be fitted with a device that prevents air intrusion, assures condensate drainage, or stops system operation in the event condensate fails to properly drain.

4.9.6 *HVAC airflow control components*: Airflow control components such as Variable Air Volume (VAV) boxes, mixing boxes, automated dampers, turning vanes, sound attenuators, and air duct components, shall be cleaned through access openings large enough to completely remove accumulated particulate, or by dismantling the component. All internal airside surfaces of these components shall be cleaned. Original fixed damper positions shall be marked and reset after cleaning.

4.9.7 *Registers, diffusers and grilles*: All registers, diffusers or grilles shall be removed from the system for wet-cleaning. The cleaning process shall include applying a detergent type cleaner, physically brush scrubbing all surfaces of the diffusers, and rinsing with clear water using a focused water stream in a manner that does not damage the product. Any fiberglass or other insulation on the inside of a diffuser (e.g., lay in type diffusers) shall be properly replaced if wetted during the cleaning process. Original damper positions of diffusers should be marked and reset after cleaning. Removal of registers should not take place until the HVAC system has an established continuous negative pressure differential in accordance with §4.5.1.

4.9.8 *Ductwork system*: Ductwork indicating signs of prolonged wetting, resulting in compromised duct, shall be considered for removal and replacement. Moisture accumulation areas in ductwork shall be identified for cause and correction. Ductwork requiring replacement shall adhere to basic containment procedures when being removed in an occupied or conditioned space. Any replaced ductwork shall meet all Federal / state / local code requirements and recognized industry practices.

4.9.8.a *Rigid ducts*: Interior surfaces of non-porous rigid ducts (i.e., metal or PVC) shall be cleaned using proper techniques designed to dislodge accumulated debris on the interior surfaces without damaging the surfaces being cleaned. Tools and equipment used to clean surfaces shall also be capable of suspending and moving dislodged fine particulates, allowing the particulates to be transported back to the high volume particulate collectors. This processes shall be accomplished through the use of cable, rod, or pneumatic driven brushing tools, pneumatically powered air whipping devices, and/or direct contact brushing with either a HEPA filter, canister vacuum, or hand brushing while the duct is maintained at a pressure differential lower than the occupied or conditioned space. All internal surfaces of the duct must be physically cleaned to a visually uniform condition.

4.9.8.b *Fiberglass lined or duct board ductwork*: Porous ductwork surfaces such as fiberglass duct board, and internally lined sheet metal surfaces with fiberglass duct liners, shall be cleaned using HEPA-filtered, canister vacuums in conjunction with attached soft-bristled brush heads without damaging the surfaces being cleaned. Fiberglass insulated duct liner, or duct board that has been wet for more than 48 hours, or is contaminated

with the presence of visual biological growth, shall be removed and replaced.

4.9.8.c *Flexible non-metallic ducts*: Flexible type ducts containing particulates and debris shall be cleaned using tools that will not damage the interior surface of the duct. Flexible ductwork with visible biological growth shall be replaced. Replacement flexible ductwork shall meet Federal / state / local code requirements and manufacturers' installation instructions upon reinstallation.

4.10 *Duct service openings and closures*

4.10.1 *Metal ducts*: Service openings for metal ducts with internal insulation shall be resealed with an insulated and gasketed door, or an insulated and gasketed metal patch. Service openings should not cut through duct seams or joints, and shall comply with all SMACNA requirements. Fibrous glass insulation on the replacement patch shall be new and be of equal R value and type to the liner it is replacing. The system's original duct insulation shall not be reused. Closures must incorporate HVAC fasteners, such as screws, bend tabs, or other HVAC methods, to permanently attach the closure to the duct surface; tape alone is not acceptable. All access openings created for inspection and/or cleaning shall be re-closed in a manner that does not alter the airflow, or adversely impact the building's indoor air quality. All openings made in the duct system shall be sealed in accordance with industry standards and Federal / state / local code requirements, using materials acceptable under those standards and codes.

4.10.2 *Service openings and closure fiberglass duct board ducts*: Duct board ducts are listed with Underwriters Laboratories as UL 181 Class 1 Rigid Air Ducts. Fiberglass duct systems should use UL 181A listed closure systems to assure an acceptable air-tight performance, so that air is delivered at design temperatures with maximum efficiency. These ducts shall be accessed with the installation of access doors or can be opened using an intersecting 45 degree incision. Ducts and access openings in ducts constructed from fiberglass duct board shall be fastened together using clinching staples on approximately 2-inch centers and approved pressure-sensitive tape. Where staples cannot be used, joints shall be held together using appropriate pressure-sensitive tapes (as noted in §6.2.2), provided surface adhesion is satisfactory and will not fail during the expected life of the duct system.

4.10.3 *Flexible ducts*: Flexible ducts shall not be penetrated (i.e., cut through the mylar surface) for cleaning. Flexible ductwork shall be accessed from either end's connection point if such accessing can be effected in a manner that does not compromise the integrity of the duct.

4.10.4 *Use of mastic*: Mastic shall be applied liberally over the entire joint between and over mated surfaces. When using over holes or gaps that are larger than 1/8 to 1/4 inch, mastic shall be followed by at least one layer of fiberglass mesh tape, topped by a layer of mastic that fills the serim pattern completely and covers the mesh.

5.0 POST CLEANING VERIFICATION

5.1 *Post cleaning acceptance*: HVAC system cleanliness shall be assessed after cleaning, but before the application of any surface treatments if used, or the introduction of any appropriate treatment-related substance to the ventilation system. HVAC components shall be evaluated by the owner's representative for visible cleanliness via direct visual inspection, or with a visual inspection system (i.e., mirrors, boroscope and cameras). The owner's representative may direct the firm conducting the cleaning services to provide additional access openings into the ventilation system as deemed necessary to thoroughly verify cleanliness.

5.2 *Post cleaning verification*: Contractors performing cleaning services shall perform quality control/quality assurance efforts throughout the cleaning process for strict conformance to this standard on all work performed by their firm, or by other subcontractors performing work under their direction.

5.2.1 *Verification methods*: The contractor shall assess the cleanliness of the system by visual inspection, surface comparison testing, or the NADCA vacuum test contained in the ACR Standard.

5.2.2 *HVAC activation*: The contractor performing cleaning services shall not activate the HVAC system unless it has achieved the cleanliness level as established in §3.0.

5.2.3 *Record keeping*: Records of the pre- and post-cleaning system operational measurements should be kept in the job file and be available to the owner, or owner representative, for review/acceptance.

6.0 POST CLEANING PRODUCTS AND USAGE

6.1 *Resurfacing products*: Resurfacing products shall be specifically designed for use on the HVAC component and applied per the manufacturer's instructions. All surfaces to be resurfaced shall be properly cleaned, and the surfaces shall achieve post-cleaning verification, before any resurfacing products are applied. The contractor shall assure that products requiring EPA registration be applied in strict accordance with label instructions. HVAC systems shall be well ventilated when resurfacing, or when coating products are applied to HVAC ductwork and other HVAC system components. If applying coating products to fibrous glass insulated duct liner or duct board, a visual inspection shall be made to determine if the fibrous glass integrity and adhesion is capable of supporting the weight of the applied coating product.

6.2 *Closure products*:

6.2.1 *Mastics*: When mastics are used to seal duct joints, the mastics shall be labeled to meet UL Standards 181A or 181B; UL 181A-M for fiberglass ducts, UL 181B-M for flexible ducts, and either for rigid metal ducts and components.[3] Mastic must not be diluted.

6.2.2 *Tapes for rigid fiberglass duct board ducts and other openings*: When heat-activated and pressure-sensitive tapes are used to seal duct board closures and access openings, the tapes shall be labeled to meet UL Standards 181A or 181B; UL 181A-H for rigid fiberglass ducts; pressure sensitive tapes labeled UL 181A-P for rigid fiberglass ducts; UL 181B-FX for flexible ducts; and either UL 181A-P or UL 181B-FX for rigid metal ducts and components.

6.3 *Sanitizers, disinfectants and other antimicrobial products*: A product must be registered by EPA for a specific use before it can be used for that purpose. EPA has assessed the safety of only some antimicrobial products for use specifically in HVAC systems. The product manufacturer's directions concerning information about cleaning the system before application, using the correct amount, proper application method, and the conditions under which the product can be used, shall be followed. All hazards and precautionary statements shall be read and the product is to be used strictly according to its label. As a precaution, all occupants and pets shall leave, or be removed from, the premises during applications, and not be permitted to return until after the minimum time duration specified within the product manufacturer's instructions.

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[3] Water-based mastics are preferable to petroleum-based mastics because they have shorter curing times, easier cleanup, and more "forgiving" application characteristics.

APPENDIX A – HVAC MAINTENANCE, PERIODIC INSPECTIONS, CLEANING, BENCHMARKING

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A-1 MAINTENANCE AWARENESS

Failure to maintain proper conditions of cleanliness in HVAC systems and carelessness in servicing or repair operations have been linked to an increased likelihood of HVAC system failure, reducing the life expectancy of the equipment, impacting the indoor air quality of the areas being service by the equipment, and impacting the energy efficiency of the HVAC systems. Practitioners are pointed to the ANSI/ACCA 4 QM Standard (residential) and ANSI/ACCA/ASHRAE 180 Standard (commercial) for maintenance requirements. See also Appendix D for a listing of other documents that provide maintenance guidelines.

A-2 INSPECTION AND CLEANING OF HVAC COMPONENTS

A-2.1 *Inspection frequency*: Inspections to determine the amount of dust and other material in the HVAC unit and associated ducts (both discharge and return), should be made yearly. However, if after several inspections such frequency is determined to be inappropriate, the interval between inspections can be adjusted to suit the conditions.

A-2.2 *Contaminants*: Cleaning should be undertaken whenever visual inspections indicate that there is substantial visible mold growth inside hard surface (i.e., sheet metal) ducts or on other components of the heating and cooling system. Ducts are infested with vermin, (e.g., rodents or insects); or ducts are clogged with excessive amounts of dust and debris and/or particles are actually released into the environment from your supply registers. The amount and kind of dust and dirt depends greatly on the occupancy and the HVAC systems configuration. Additional access doors or panels may be needed for a complete cleaning of duct systems and are often helpful for future inspections and maintenance.

A-2.3 *Plenums*: Ceiling cavities, raised floors, and duct distribution plenums should be inspected in a manner similar to that of ducts, beginning with bi-annual inspections and adjusting the frequency to suit dirt buildup conditions.

A-2.4 *Damp wiping*: During inspections, need to identify if any portions of the HVAC system needs to be cleaned using a damp wiping protocol. Damp wiping of specific components surfaces may be required in cases where dry cleaning methods such as HEPA-vacuuming, or HVAC brushing, cannot successfully remove particulate and/or deposits. This does not normally apply to ductwork components unless additionally specified within a scope of work. Damp wiping methods for cleaning components should be performed with disposable towels, or rags properly wetted with a mild solution of detergent and water. When component cleaning is taking place in an occupied or conditioned environment, the components to be cleaned should be removed whenever possible, contained or isolated for removal form the occupied environment, and cleaned outside of the occupied space.

A-2.5 *In-place coil cleaning*: Many contractors incorrectly surface-clean the airside of interior heating/cooling coils and leave internal contamination. The objective of the following protocol is to thoroughly clean the coils, surface as well as inner coil area. The first step in wet-cleaning a coil in-place requires lining, or protecting, the air handler with a

moisture barrier to prevent water and cleaning solution run-off from contacting the air handler's insulation or any porous surfaces. Next, inspect the coil for total blockage by placing a bright incandescent or fluorescent drop light behind it. Most coils will show consistent visible light through all portions of the coil when the coil is completely clean. This technique works on coils no deeper then 4 rows in depth. [Note: Most commercial coils are generally too thick for this technique.]

Several precautions must be taken to ensure that the large amounts of water used to rinse the coils is controlled. Alteration of this protocol may lead to problems of water leaking, either into the facility or where it is not intended. The first line of defense, or primary moisture control mechanism, is a clear drain line, allowing water to flow through its intended direction. The second line of defense is a secondary drain line that many systems are equipped with, in case the primary drain line clogs. The next, and perhaps most important prevention method, is to insert a HEPA-filtered, wet vacuum crevice tool into the drain pan during the entire cleaning operation. A flexible, plastic catch basin (such as a concrete mortar pan) is the fourth level of water control during an in-place coil cleaning and is mainly used on systems from 1 to 5 tons. The flexible pan is place under a coil pan to catch any overflowing. Many residential "A" coils can be partially pulled out of the plenum to place the flexible pan underneath the coil, thereby, catching water and any cleaning products that come off of the coil. Finally, the fifth level of precaution is to have the entire area protected with a water impermeable tarp. However, this step may be eliminated in installations that use an auxiliary drain pan (e.g., attic applications).

Do not begin the cleaning process until the negative air machine is running, registers have been removed, all necessary equipment is in place, and the drain line is clear. Drain lines can be unclogged by using suction from the wet vacuum (insert the hose on the end of the drain line, or through a cut made near or inside the air handler), or by flushing with a water hose. The front and back of the coil is dry-brushed several times before applying cleaning detergent using a soft stainless steel, or brass bristle brush, to avoid damaging the coil's fins. Use the wet vacuum (HEPA-filtered when located indoor) and a soft bristle brush attachment to remove the loose coil surface particulate. Use tarps and flexible pans to catch water overflow. After the debris has been removed from the coil, begin applying cleaning agents to the side of the coil which the airflow hits first. Apply the cleaning solution from the top of the coil downward, allowing it to flow slowly.

Many coil cleaners react with the aluminum fins of the air handler and may begin foaming as applied. This foaming action allows penetration into the coil and helps to "boil" out the debris deep within the fin structure.[4] Both sides of the coil need to be treated in this manner, allowing the coil cleaner to emulsify the internal dirt and debris. This process generally takes 2 - 3 applications on a residential coil needing restoration. [Note: Stronger coil cleaner may be used for deeper commercial coils.] Not all coils can be restored completely due to the impacted nature of the contaminants between the fins.

Once the maximum penetration has been achieved, a thorough rinsing with fresh water must follow. In order to control the amount of water, wet vacuums are used to remove

[4] CAUTION: This 'foaming' and 'boiling' that removes soil from coils is a chemical reaction that may also remove some of the fin surface metal. More important, the reaction etches the surface and can impact the ability of the surface to shed water efficiently. This has latent capacity implications as the retained moisture can re-evaporate back into the air stream. In extreme cases, the excess water can be carried over into the supply plenum where it promotes microbial growth. Some preliminary analysis have indicated that ten minutes of fin surface exposure to a chemical cleaner with pHs below 3 or above 14 can remove more than 10% of the metal by weight. Resultantly, technicians should use cleaners with pHs between 3 and 12 and minimize the time that the chemical agent is in contact with the surfaces.

the water from the drain pan. All chemical residues must be rinsed off the coil fins before the system is put back into operation.

Check constantly to be sure no water or cleaning solution leaks onto external surfaces. Leakage can cause severe damage to ceilings, walls, floors and carpeting. When cleaning is complete, the coil must be meticulously inspected to ensure that it is entirely free of contaminates. Improperly cleaned or impacted coils may emit a foul, moldy odor when the air handler is in use.

Always ground drop lights with GFCI and use only rough service drop light bulbs to avoid the dangers of electrocution and exploding bulbs. Be very careful with cleaning solutions as they are can be extremely caustic and can cause severe chemical burns.

A-3 DUCTWORK CLEANING CONSIDERATIONS

A-3.1 *Rigid ducts*: Metal ductwork with no internal liner, or with an external insulating wrap can withstand very aggressive brushing techniques. The connection points or seams of metal ductwork commonly accumulate particulate and often need special attention during cleaning.

A-3.2 *Fiberglass lined or duct board ductwork*: Duct board ducts and plenums should be physically opened at strategic locations for cleaning. Two methods are generally combined to clean duct board components:

- The first method is to use a high volume particle collector, HVPC. The HVPC is attached to the duct board HVAC system and the machine energized to create a pressure differential between the zone being cleaned and the occupied or conditioned space. The HVPC allows dislodged fine particulate to move back through the ductwork to the machines primary collection area.
- The second method uses HEPA-filtered, canister vacuums to physically contact the duct surface with soft bristle brushes. The HVPC primary function is to prevent dislodged particulate from entering into the occupied or conditioned space.

Duct board must have accesses created by penetrating the duct surface using a cutting knife. Before an incision is made into any of the duct board, it is recommended each area of incision be thoroughly wet wiped with a damp rag in a band approximately twelve inches wide to remove all dirt and debris. If this is not done prior to cutting, it will be very difficult, if not impossible, to get any tape or glue to stick to the duct surface when closing the access opening. Specialty doors are also made for the closing of duct board ducts as well. When a duct board system displays fiberglass erosion, tearing, degradation, or is evidently incorrectly installed, it should be corrected.

A-3.3 *Flexible non-metallic ducts*: Flexible nonmetallic duct (or flex duct) consists of a duct inner liner, supported on the inside by a helix wire coil, and covered by blanket insulation with a flexible vapor-barrier jacket on the outside. Flexible duct is often used for run outs, with metal collars connecting the flexible duct to supply plenums, trunks, and branches constructed from sheet metal or duct board. Flexible duct can be torn, crushed, pinched, or damaged during cleaning. Common tools for cleaning are cable driven, or pneumatic brushing systems with soft bristle brushes, or pneumatic whipping techniques.

A-3.4 *Power-driven duct cleaning devices*: Power-driven HVAC or pneumatic brush systems are often used for ductwork cleaning. This equipment may only be used in ducts where appropriate pressure differentials have been established between the duct and the occupied space using air movement devices. The purpose of these tools is to physically contact and brush internal ductwork surfaces to dislodge particulate and/or debris from the interior surfaces of the duct. Following any HVAC brushing technique, all surfaces of

the cleaning zone shall be air washed using a pressurized, compressed air source to further assist transport of dislodged fine particulate and/or debris to the HVPC.

A-4 OUTSIDE AIR INTAKES

A-4.1 *Environmental conditions*: The general environmental conditions of all outside air intakes should be observed when the ducts are inspected. However, air intakes can become contaminated faster than other sections of the HVAC system. Items to be noted include the following:

- Accumulations of combustible material near the intake.
- The presence of buildings or structures that could present an exposure to the intake, allowing smoke and fire to be drawn in.
- The visible condition of any automatic damper designed to protect the opening against exposure to fire.
- Presence and condition of gratings or screens to prevent entry of pests and/or large particulate matter.

A-4.2 *Combustible material*: Where accumulations of combustible material are noted, they should be removed immediately and arrangements made to avoid/minimize future accumulations.

A-5 FANS AND FAN MOTORS

Fans and fan motors should be inspected at least yearly and possibly more often in hot and humid climates. Care should be exercised in lubricating fans to avoid allowing lubricant to run onto the fan blades. Fans also should be checked for alignment and checked to see that they are running freely.

A-6 SYSTEM BENCHMARKING

HVAC system performance measurements can provide additional assurance that implemented cleaning activities were effective. These performance measurements assess the operational characteristics of the system prior to, and post-cleaning, and may include static pressure profile, refrigerant charge, temperature differentials, and airflow measurements. If this system benchmarking is undertaken, it is imperative that the proper engineering safety controls be implemented so as to avoid health and safety issues during measurement.

APPENDIX B – GENERAL TOOL RECOMMENDATIONS

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In restoring the cleanliness of HVAC systems and components, contractors need a varied set of tools depending on the procedures to be undertaken and on the type of system(s) to be cleaned. Contractors undertaking HVAC cleaning work need to maintain appropriate tools and equipment necessary for achieving the level of cleanliness required by this specification. Examples of such tools include:

B-1 *Duct cleaning equipment*

- HEPA-filtered HVPC
- HEPA filter air scrubbers
- HEPA filter canister vacuums
- Wet vacuums

B-2 *Coil cleaning equipment*

- Pressure washing equipment
- High pressure steam cleaners
- Coil cleaner injection pumps

B-3 *Verification tools (for determining airflow resistance over coils or filters)*

- Digital manometer
- Analog manometer
- Flow hood or bolometer
- Velometer

B-4 *General hand tools*

- Drills (cordless and corded)
- Hole cutting tools for both metallic and nonmetallic ducts
- Metal cutting shears (hand and or powered)
- Various hand brushes
- Panduit strapping tools
- Refrigerant gauges
- Thermometers, direct contact and probe
- Digital sling psychometers
- Multimeter (volts, amps, ohms)
- Hex drivers ¼”, 5/16”, 3/8”, ½”
- Screwdrivers

APPENDIX C – DEFINITIONS

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access: That which enables a device, appliance, or equipment to be reached by ready access, or by a means that first requires the removal or movement of a panel, door, or similar obstruction.

air filter: A device used to reduce the concentration of, or remove particles from, air moving through HVAC systems.

air-handling unit: A blower or fan used for the purpose of distributing supply air to a room space or area.

air terminal unit: An appliance receiving, conditioning, and delivering air supplied through an HVAC system.

ceiling plenum: An enclosed portion of the building structure, other than an occupied space being conditioned, that facilitates air movement and thereby serves as a part of the air distribution system.

coils: Heat exchangers inside an HVAC system that temper and/or dehumidify the air handled by the HVAC system. These include heat exchangers, with or without extended surfaces, through which water, ethylene glycol solution, brine, volatile refrigerant, or steam, is circulated for the purpose of total cooling (sensible cooling plus latent cooling), or sensible heating of a forced-circulation air stream.

containment: Practices used to minimize cross contamination from affected to unaffected areas caused by airflow, occupant movement, and material handling.

damper: A manually or automatically controlled device to regulate draft or the rate of flow of air or combustion gases.

detergent cleaner: A cleaning compound formulated with synthetic or natural detergents (e.g., soap), sequestrants, builders, and other ingredients so as to have a pH greater than 3 and less than 12.

duct: A designed conduit used for conveying air.

duct system: A continuous passageway for the transmission of air that, in addition to ducts, includes duct fittings, dampers, and plenums.

fan: An air moving device that creates a pressure difference causing airflow.

heat exchanger: A device that transfers heat from one medium to another.

HEPA filter: High efficiency particulate air filter that removes 99.97% of particles passing through it sized at 0.3 micrometers (i.e., microns).

high volume particulate collectors (HVPC): Equipment capable of moving air at a high rate (generally recognized as being greater than 800 CFM) and whose primary filtration cabinet is designed for volume collection (i.e., cubic footage) of debris and particulate.

HVAC system: In this standard, any designed system of ducts, plenums and air-handling equipment that circulates air within a space and includes systems made up of one or more air-handling units. Examples of equipment and components include: blower housings, cooling and heating coils, blower wheels, filter banks, air handling units, insulation, condensate pans, grilles / louvers / registers, acoustic sound devices, dampers, manifolds, ductwork interiors, mixing and distribution boxes, control boxes, humidifiers, dehumidifiers, ERVs, HRVs, VAV boxes, and turning vanes.

indoor environmental consultant: A qualified person who can perform an investigation of an indoor environment, including mechanical systems, for the purpose of assessing the overall quality of the environment, and who can perform pre- and post-inspections of HVAC systems for purposes of documenting system cleanliness and/or mechanical condition.

restoring: Restoring/restoration in this Standard implies cleaning efforts to significantly improve the cleanliness of an air conditioning system; not necessarily to return it to its "as new" condition, and does not include the mechanical repair, or repairs to the HVAC system.

resurfacing products: Coatings, usually polymers, which cover a surface for the repair, protection, or enhancement of the surface.

return air: Air removed from a conditioned space or location and re-circulated.

return air system: An assembly of connected ducts, plenums, fittings, registers and grilles through which air from a space, or spaces, to be heated or cooled is conducted back to the supply unit.

service: To repair, or to make fit for use, HVAC systems that are not functioning properly.

APPENDIX D – PERTINENT HVAC BIBLIOGRAPHY & RESOURCES

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The following documents are offered for informational purposes only and are not considered part of the requirements of this standard. The editions/versions/dates of the documents indicated here are current as of the date of this ACCA standard.

ACCA **Air Conditioning Contractors of America (2800 Shirlington Road, Suite 300, Arlington, VA, 22206; tel: 703/575-4477; www.acca.org)**

Standards

ACCA 4 QM - 2013	Quality Maintenance of Residential HVAC Systems, 2013
ACCA 5 QI – 2015	HVAC Quality Installation Specification, 2015
ACCA 9 QIvp - 2011	HVAC Quality Installation Verification Protocols, 2011
ACCA 12 QH - 2011	Home Evaluation and Performance Improvement, 2014
Standard 180-2012	Standard Practice for Inspection and Maintenance of Commercial HVAC Systems, 2012

Other Documents

- Residential Duct Diagnostics and Repair, 2003
- B. A. Penney, J. E. Woods, and G. C. Hourahan, Good HVAC Practices for Residential and Commercial Buildings: A Guide for Thermal, Moisture and Contaminant Control to Enhance System Performance and Customer Satisfaction, 2003
- Technicians Guide & Workbook for Quality Installations, 2015
- Technicians Guide & Workbook for Home Evaluation and Performance Improvement, 2015

ASHRAE **American Society of Heating, Refrigerating and Air-Conditioning Engineers (1791 Tullie Circle, NE., Atlanta, GA; tel: 404/636-8400; www.ashrae.org)**

Standards and Guidelines

Standard 62.1-2013	Ventilation for Acceptable Indoor Air Quality, 2013
Standard 62.2-2013	Ventilation for Acceptable Indoor Air Quality in Low-Rise Residential Buildings, ANSI Approved, 2013
Standard 126-2008	Method of Testing HVAC Air Ducts, 2008
Guideline 0-2013	The Commissioning Process, 2013
Guideline 1-2007	The HVAC Commissioning Process, 2007
Guideline 4-2008	Preparation of Operating and Maintenance Documentation for Building Systems. 2008 (RA 2013)
Guideline 29-2009	Risk Management of Public Health and Safety in Buildings, 2009

Other Documents

- Handbook of Fundamentals 2013
- Handbook of HVAC Systems and Equipment, 2012
- L. Harriman, G. W. Brundrett, and R. Kittler, Humidity Control Design Guide for Commercial and Institutional Buildings, 2001

ASTM **American Society for Testing and Materials (100 Barr Harbor Drive, West Conshohocken, PA 19428-2959; tel: 610) 832-9585; www.astm.org)**

Standards

ASTM C 411	Standard Test Method for Hot-Surface Performance of High-Temperature Thermal Insulation, 2005
ASTM D 93	Standard Test Methods for Flashpoint by Pensky–Martens Closed Cup Tester, 2002
ASTM E 136	Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C, 2004

EPA **Environmental Protection Agency Office of Radiation and Indoor Air Indoor Environments Division (6609J; 1200 Pennsylvania Avenue, N.W. Washington, DC 20460 (202) 343-9370 www.epa.gov/iaq)**

"Should you have the air ducts in your home cleaned," EPA-402-K-97-002, October 1997

IAPMO **International Association of Plumbing and Mechanical Officials (5001 E. Philadelphia Street, Ontario, CA, 91761; tel: 909.472.4100; www.iapmo.org)**

- Uniform Mechanical Code, 2015
- Uniform Plumbing Code, 2015

ICC **International Code Council (500 New Jersey Avenue, NW 6th Floor, Washington, DC 20001; tel: 888/422-7233; www.iccsafe.org)**

- International Building Code, 2015
- International Energy Conservation Code, 2015
- International Fire Code, 2015
- International Residential Code, 2015
- International Mechanical Code, 2015
- International Fuel Gas Code, 2015

IICRC **Institute of Inspection, Cleaning and Restoration Certification (4043 S. Eastern Ave., Las Vegas, NV 89119; tel: 775/553-5458; www.iicrc.org)**

Standard S520 Standard and Reference Guide for Professional Mold Remediation, 2007

NATE **North American Technician Excellence (2111 Wilson Blvd., Suite 510, Arlington, VA, 22201; tel: 703/276-7247; www.natex.org)**

NATE offers certifications tests for service and installation technicians to highlight relevant applied knowledge. Separate 'service' and 'installation' tests are given in the following specialty categories: air conditioning, distribution, air-to-air heat pump, gas heating (air), oil heating (air), hydronics gas, hydronics oil.

NADCA **National Air Duct Cleaning Association (1120 Route 73, Suite 200, Mt. Laurel, NJ 08054; tel: 856/380-6810; www.nadca.com)**

- ACR Standard, 2013 edition: Assessment, Cleaning & Restoration of HVAC Systems
- HVAC Inspection Manual - Procedures for Assessing the Cleanliness of Commercial HVAC Systems

NAIMA **North American Insulation Manufacturers Association (44 Canal Center Plaza, Suite 310, Alexandria, VA 22314; tel 703/684-0084; www.naima.org)**

- Fibrous Glass Duct Construction Manual, 1st edition, 1989
- Fibrous Glass Duct Construction Standard, 2002
- Fibrous Glass Duct Liner Standard, 2002

NFPA **National Fire Protection Association (Batterymarch Park, Quincy, MA, 02169; tel: 617/770-300; www.nfpa.org)**

NFPA 54 National Fuel Gas Code, 2015
NFPA90a Standard for the Installation of HVAC Systems 1999 Edition
NFPA 90b Standard for the Installation of Warm Air Heating and Air-Conditioning Systems, 1999 edition

NIOSH **National Institute for Occupational Safety & Health (1600 Clifton Road, Atlanta, GA, 30333; Tel: 404/639-3534; www.cdc.gov/niosh/homepage.html)**

- Interim Recommendations for the Cleaning and Remediation of Flood-Contaminated HVAC Systems: A Guide for Building Owners and Managers; 2010

SMACNA **Sheet Metal and Air Conditioning Contractors' National Association (4201 Lafayette Center Drive, Chantilly, VA, 20151; tel: 703/803-2980; www.smacna.org)**

- Fibrous Glass Duct Construction Standards, 2003
- Fire, Smoke and Radiation Damper Installation Guide for HVAC Systems, 2002
- HVAC Air Duct Leakage Test Manual, 2012
- HVAC Duct Systems Inspection Guide. 2000
- HVAC Duct Construction Standards, Metal and Flexible, 2005
- HVAC Systems Commissioning Manual. 1994
- HVAC Systems – Duct Design, 1990
- HVAC Systems Testing, Adjusting & Balancing. 2002
- IAQ Guidelines for Occupied Buildings Under Construction, 1995
- Rectangular Industrial Duct Construction Standards, 2004
- Round Industrial Duct Construction Standards, 1999

UL **Underwriters Laboratories Inc., (333 Pfingsten Road, Northbrook, IL 60062; tel: 847/272-8800; www.ul.com)**

Standards

UL 181	Standard for Safety Factory-Made Air Ducts and Air Connectors, 2003
UL 181A	Standard for Safety Closure Systems for Use with Rigid Air Ducts and Air Connectors, 2005
UL 181B	Standard for Safety Closure Systems for Use with Flexible Air Ducts and Air Connectors, 2005
UL 555	Standard for Safety Fire Dampers, 1999
UL 555S	Standard for Safety Smoke Dampers, 1999

Other Documents

- Building Materials Directory, 1995
- Fire Resistance Directory, 1995
- Gas and Oil Equipment Directory, 1995

U.S. DOE **United Stated Department of Energy – Office of Energy Efficiency and Renewable Energy (EERE) (1000 Independence Ave SW, Washington, DC 20585; tel: 202-586-5000; www.energy.gov/eere/office-energy-efficiency-renewable-energy)**

- HVAC System Installation and Sealing Proper Duct Installation Increases Efficiency