WHITE PAPER
for the
Guidelines for Energy-Efficient Commercial Unitary HVAC Systems

Revised 1/19/01

Prepared for:
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1.1 EXECUTIVE SUMMARY

This White Paper details the processes undertaken in developing the Specification of Energy-Efficient Installation Practices for Commercial HVAC Systems (hereafter referred to as the Commercial Specification or Specification). It describes the project team, methods, issues, discussions and information basis used to support the resulting content, scope, and depth of the Specification. The purpose of this White Paper is to provide background information that is useful for program managers, educators, code officials, builders and others seeking to evaluate and implement the Commercial Specification.

The Commercial Specification is a compilation of energy-efficient best practices for the sizing, selection, installation and commissioning of unitary air-source air conditioner and heat pump systems up to 30 tons, both packaged and split systems. It covers new and retrofit commercial projects, and includes air distribution and controls. A copy is attached in Appendix 10.1.

1.2 PROJECT SCOPE

The goal of the project is to impact the energy efficiency of the large sector of small to mid-sized air conditioner and heat pump systems that are commonly installed by contractors using hasty installation practices and without the benefit of proper design. A number of Project Subcommittee members identified 5-ton new and replacement rooftop units as one of the groups in their jurisdiction that could most benefit from improved installation practices.

The targeted users of the Specification are the installing contractors – mechanical contractors in the light commercial sector. These contractors often use rule-of-thumb sizing and plan installations during construction projects. In reality, a specification strictly requiring rigorous engineering and expensive installations would be of little use. The Commercial Specification is intended as a helpful guide to energy-efficient best practices that can be used fully or in part, as applicable or as budget dictates. Benefits associated with each element – such as energy savings, cost savings, improved operation, and reduced maintenance – were highlighted to provide incentives for implementation.

1.3 BACKGROUND ON THE AUTHORS

Consortium for Energy Efficiency, Inc.(CEE)

The Consortium for Energy Efficiency served to facilitate the compilation of the specification, administer the research effort, manage the project and assist in obtaining industry/stakeholder input throughout the development process. The project was managed by Denise Rouleau with assistance from Mahri Lowinger.

CEE, a non-profit, public benefits corporation located in Boston, Massachusetts, expands national markets for super-efficient technologies using market transformation strategies. Members include electric and gas utilities, public interest groups, research and development organizations, and state energy offices. By working through CEE, these members leverage their individual efforts to affect national markets, achieving higher levels of energy efficiency and greater environmental benefits than possible through those individual efforts alone. More information on CEE is available at www.ceeformt.org.

Davis Energy Group, Inc. (DEG)
The principal author of the Commercial Specification and White Paper is Christina Manansala, Vice President and Senior Engineer of the Davis Energy Group (DEG), located in Davis, California. Barbara Okihiro provided research assistance. The Commercial Specification was reviewed by DEG cofounders Richard Bourne and David Springer.

Incorporated in 1981, Davis Energy Group is a team of consulting engineers whose primary focus is efficient cooling, heating and building systems. As leaders in the field of sustainable design, DEG has participated in the analysis, design, and commissioning of hundreds of energy-efficient commercial, institutional, and residential projects. To help further the industry, DEG is committed to leading research and development projects for energy-efficient products and systems. DEG has also authored numerous HVAC industry handbooks, installation guides and specifications, and conducted associated seminars and workshops. More information on the Davis Energy Group is available at www.davisenergy.com.

1.4 ACKNOWLEDGEMENTS

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National Grid USA
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2 SPECIFICATION DEVELOPMENT PROCESS

2.1 DEVELOPMENT OF SPECIFICATION ELEMENTS

2.1.1 Selection of Specification Elements

Specification elements refer to the various components and tasks that make up the installation of unitary systems, from start to finish. A preliminary list of Specification elements was generated by Davis Energy Group as a part of the project proposal. After the kickoff meeting, the list of elements was further developed with respect to the project goals, targeted audience and level of detail discussed with the project Subcommittee. The criteria used in the selection included:

A. Impact on energy use
B. Application to normal contractor design-build installations
C. Within standard industry practices
D. Well documented by industry research or standards
E. Influence of contractor selection or practice on results

The selected specification elements make up Sections 2-5 of the Commercial Specification, under the general headings Unitary Air Conditioners and Heat Pumps, Air Distribution, Controls, and HVAC Commissioning.

The following elements were eliminated or grouped with other elements:

A. System operation – too general
B. Factors affecting energy efficiency – covered in individual sections
C. Codes and standards – referenced where applicable
D. Unconditioned spaces – not substantially applicable

E. Clearances – covered in Unit Configuration and Location section
F. Shading/screening – covered in Unit Configuration and Location section
G. Duct leakage testing – not economically feasible for commercial systems
H. Monitoring – not commonly dealt with by design-build contractors of small commercial systems

2.1.2 Specification Format

For this phase of development, the Commercial Specification was produced in a simple, consecutive order using Microsoft Word without graphics or focus details. Each major element begins with a Benefits section in which the element is briefly described, and benefits such as energy savings are outlined. This is followed by a description of the best practices for energy-efficient installation of the associated element. Verification, functional testing, programming, adjustment, operation and maintenance for each element are grouped together in a separate section – HVAC Commissioning.

The format was kept simple to facilitate the next phase of work, during which the Specification will be developed into one or more documents intended for distribution. The documents will include illustrations and graphics to explain procedures and highlight important items. Potential formats include a field manual, an educational workbook and a set of abbreviated handouts or reference cards.

2.1.3 Energy Efficiency and Savings Claims

The benefits section outlines potential energy savings, installation cost savings, operational improvements, and/or maintenance impacts. Each benefit claim is referenced and based upon research published by established institutes. A list of the referenced documents, contact information and a brief description of each study is included in Section 7 of the Commercial Specification. The energy savings claims are based upon field studies of varying sample size and/or computer simulations.

2.1.4 Best Practices for Energy Efficiency

The best practices for energy-efficient installations were derived from existing standards, industry references, manufacturer's information and research publications. Additional information was contributed by industry experts serving on the Project Subcommittee and Industry Advisors panel.

One of the goals of the Commercial Specification is to address only elements, practices and factors that influence energy efficiency. The Specification is intended as a supplement to applicable codes, health and safety requirements and manufacturer's instructions, all of which take precedence.

Some of the installation practices direct the user to an industry standard such as ASHRAE, ACCA or SMACNA handbooks. This occurs only with standards that are well established and commonly used in the industry, when the standard was determined to contain the best practices available, and when importing the data into the Specification was impractical.

2.2 RESEARCH METHODS AND INFORMATION SOURCES

A research assistant gathered and screened all documents for applicability to energy-efficient HVAC installation practices within the scope of this project. Each document was cataloged and associated with key words indicating content. The documents were then reviewed, highlighted and further screened by the author to provide a bibliography (see Section 8) tailored to this project. Most information published before the mid-1990s was not included.

The following methods were used to identify publications:

A. **Internet** – Search engines were used to investigate key words associated with HVAC systems. This led to many documents that were computer downloaded.
B. **Libraries** – The general and physical sciences libraries at the University of California in Davis were searched for related documents and textbooks. The Davis Energy Group office library yielded many current publications. Proceedings from recent energy-efficiency forums were reviewed for applicable papers.
C. **Standards** – Current industry standards such as applicable ASHRAE, ARI, ADC, AABC, ACCA, SMACNA and E Source manuals were obtained and reviewed.
D. **Codes** – A summary of state energy codes was obtained. Uniform codes were reviewed.
E. **Manufacturer's Literature** – Unitary equipment specifications, performance data, installation and service manuals were reviewed.
F. **Subcommittee and Industry Advisors** contributed related papers.

2.3 COLLABORATION AND REVIEW

Preliminary matrices and drafts of the specification were circulated to the Project Subcommittee and Industry Advisors via e-mail for review (See Section 1.4 for a list of members). Review comments were summarized and circulated to the Subcommittee prior to each meeting. The Subcommittee, located nationwide, met via conference call to discuss the development of the Specification at the following key points:

A. Project Start
B. Review of Preliminary List of Specification Elements
C. Review of Specification Matrix outlining practices, savings and issues of each element
D. Review of Specification Draft

Based upon Subcommittee discussions and comments, the documents were revised and re-circulated to the Subcommittee and Industry Advisors for further review.

Although not all Subcommittee and Industry Advisor members were able to participate in each task, most organizations submitted review comments on one or more of the drafts.

2.4 SUGGESTED GRAPHICS FOR FUTURE DEVELOPMENT

Graphics will be added during the next phase of Specification development. The graphics are intended to assist program managers and trainers, as well as installers in the field.

Illustrations are recommended to clarify the following practices:

A. Schematic of typical rooftop and split-system unitary equipment with cut-away view of interior components.
B. Diagram pointing out common leak sites at rooftop unit and connection/sealing details between unit and ductwork.
C. Simple examples of constant volume (CV) and variable volume (VAV) duct systems, illustrating proper zoning.
D. Typical examples of high pressure drop duct fittings (to avoid) compared with energy-efficient alternatives.
E. Chase/plenum sealing details.
F. Duct connection sealing details – metal, flexible and metal-to-flexible.
G. Supply outlet to duct sealing detail.
H. Details of support, insulation, jacketing and reflective coating on ducts installed outdoors.
I. Testing static pressure and airflow testing at blower.
J. Measuring outside air intake for minimum ventilation and economizer operation.
K. Flow hood testing at air outlets.

Text boxes or other means of highlighting should be provided for these key issues:

A. Benefits of energy-efficient installation practices
B. Importance of proper load and ventilation calculations
C. Unit oversizing
D. Equipment efficiency ratings
E. Replacing older units
F. Tight duct construction
G. Common economizer problems
H. Programmable thermostats
I. Importance of commissioning

3 SPECIFICATION ELEMENT – UNITARY EQUIPMENT

3.1 GENERAL ISSUES WITH COMMON INDUSTRY PRACTICES

The Subcommittee and supporting research found the following problems with common industry practices:

A. Contractors use rule-of-thumb sizing for unitary equipment, generally providing a ton of cooling capacity for every 300-500 square feet. During retrofits dysfunctional units are often replaced with same-size units, without considering changes in the building, equipment or conditions.

B. Unit oversizing is very common and results in gross inefficiency. This is partly due to rule-of-thumb sizing and partly to avoid liabilities due to undersizing.
C. Economizers often malfunction and require careful commissioning and maintenance.

3.2 TARGETED PRACTICES FOR ENERGY EFFICIENCY

3.2.1 Load Calculations

A. **Benefits** – Since oversizing has such a large energy impact, load calculations are justifiably necessary. Improved computer software makes load calculations increasingly manageable. The energy savings claims for load calculations in the Specification were taken from the publications of three well established institutes:

Transforming Northeast Markets to Increase Energy Efficiency – Installation Practices of C&I Unitary HVAC Equipment, prepared by E-Cube, Inc., J. Wolpert, and D. Houghton for the Northeast Energy Efficiency Partnership, Inc., January 1998. Summary of research on cost-effective energy efficiency practices for commercial packaged 3 – 20 ton units, including interviews with contractors and industry experts, a literature search, and reviews of 4 existing projects covering over 100 sites.

Commercial Space Cooling and Air Handling Technology Atlas, 1995, E Source. Resource summarizing available and emerging commercial space cooling and air handling technologies and related research.

Field Investigation of Duct System System Performance in California Light Commercial Buildings, W.W. Delp, Ph.D., M.P. Modera, Ph.D., P.E., N. E. Matson, P.E., R.C. Diamond, Ph.D., Eric Tschudy, TO-98-8-2, ASHRAE Transactions Symposia. Duct performance study of 15 systems in eight northern California buildings.

B. **Methodology** – The Specification lists *ASHRAE Fundamentals – Load and Energy Calculations*[2c] and *ACCA Manual N*[5a] as approved and established hand-calculation methods. *DOE-2* and *ASEAM* were listed as non-commercial computer programs based upon ASHRAE or ACCA methods. Since the some of the available software is from commercial sources, the Subcommittee elected to omit those programs from the specification section. Commercial loads software is available from Wrightsoft Company (Manual N), Trane Company and Carrier Company. Manual N is the only commercial loads software not affiliated with an air conditioner manufacturer. All three programs are ASHRAE-based and use hourly calculations.

C. **Peak Load Reduction** – Although peak load reduction can play a major role in energy reduction, it is not commonly in the realm of the installing contractor. A brief section highlights major points, including a recommendation for applying ASHRAE 90.1 – Energy Standard for Buildings Except Low-Rise Residential[2a] or IECC-2000 International Energy Conservation Code.[17]

3.2.2 Equipment Sizing

There was much discussion among the Subcommittee on whether to recommend sizing the equipment to meet 100 percent of the calculated peak load, or to include a safety factor. Most members felt that a safety factor is unnecessary since it contributes to oversizing and peak conditions are infrequent. The 1989 version of *ASHRAE 90.1 Energy Standard for Buildings Except Low-Rise Residential*[2g] called for selecting units with capacities up to 110 percent of the sensible cooling load, but this was deleted from the 1999 version. In most cases the calculated load will fall between standard unit sizes, so selecting the closest size which provides at least 100 percent of the sensible load will usually result in a margin of extra capacity. It was decided to provide a brief discussion of the above.

3.2.3 Equipment Selection

A. **Benefits** – The energy savings claims for selecting high-efficiency equipment were taken from two sources:

Commercial Space Cooling and Air Handling Technology Atlas, 1995, E Source. Resource summarizing available and emerging commercial space cooling and air handling technologies and related research.

High-Efficiency Unitary HVAC Equipment: Commercial Cooling Update: Issue 14, August 1996. Electric Power Research Institute (EPRI).Initiative to bring together trade allies, utilities and users in New England and New Jersey in a strategic market intervention to increase availability and demand for energy-efficient equipment and installation practices.

B. **Efficiency Standards for New Equipment**

Three standards for air conditioner efficiency were evaluated: the U.S. Federal minimum efficiencies mandated by the U.S. National Appliance Energy Conservation Act (NAECA) and the Federal Energy Policy Act of 1992 (EPAct), ASHRAE 90.1-1999, and CEE's High Efficiency Commercial Air Conditioning (HECAC) Initiative.

With the implementation ASHRAE 90.1-1999 efficiency levels in October 2001, the U.S. Federal minimums, which cannot be lower than the ASHRAE standard, will probably be revised. The efficiency levels for both of these documents should be the same as HECAC Tier I for all but equipment under 65,000 Btu/h. The HECAC Initiative was chosen as the specified standard for the Commercial Specification in order to provide two levels of ratings. Recommending Tier I, which exceeds U.S. Federal and ASHRAE efficiency levels for equipment under 65,000 Btu/h, will impact a large portion of the targeted audience of this specification (5-ton units). Promoting Tier II will prepare the industry for the gradual shift to higher efficiency levels.

Commercial air conditioners and heat pumps that meet Tier I efficiency levels of HECAC currently represent 40 percent of the available equipment market, indicating that the demand and sales of high-efficiency products are increasing. The availability of Tier II (superior ratings) equipment has also steadily risen, from 9 percent in 1997 to 13 percent in 1999.[1] Increasing numbers of utilities and energy organizations are beginning to promote Tier II through incentive programs.

3.2.4 Unit Configuration, Location and Installation

Energy savings data related to unit configuration, location and installation was not available. The best practices were developed from discussions with the Subcommittee and Industry Advisors, and from reviewing installation manuals for unitary equipment.

3.2.5 Economizers

A. **Benefits** due to economizers are somewhat controversial. Malfunctioning economizers can be large energy drains. Substantial energy savings are possible, but only with conscientious commissioning and maintenance. The energy savings and malfunction claims for economizers were taken from three publications:

Commercial Space Cooling and Air Handling Technology Atlas, 1995, E Source. Resource summarizing available and emerging commercial space cooling and air handling technologies and related research.

Transforming Northeast Markets to Increase Energy Efficiency – Installation Practices of C&I Unitary HVAC Equipment, prepared by E-Cube, Inc., J. Wolpert, and D. Houghton for the Northeast Energy Efficiency Partnership, Inc., January 1998. Summary of research on cost-effective energy-efficiency practices for commercial packaged 3-20 ton units, including interviews with contractors and industry experts, a literature search, and reviews of 4 existing projects covering over 100 sites.

When Good Economizers Go Bad, T. Lunneberg, P.E., September 1999, ER-99-14, E Source. Comprehensive and current evaluation of economizers based upon nationwide surveys, available research, and industry interviews.

B. **Best practices** were derived from the three publications listed above, ASHRAE 90.1-1999 and from discussions with the Industry Advisors and Subcommittee. Some in the industry feel that since proper function is rare, economizers should not be installed. Many energy codes, however, require economizers. Since savings due to economizers can be large, they are recommended in the Commercial Specification when required by code or ASHRAE 90.1-1999, which bases the requirement upon climate conditions and unit size.

Emphasis was placed on correct installation of high quality components and careful commissioning. Particularly with new unitary equipment, economizer components are selected by the manufacturer, not the installer, making it difficult to ensure quality systems. The need to improve manufacturer's standard and optional economizer packages, as well as installation and maintenance improvements, is indicated by the literature. As older equipment is replaced with more reliable equipment, economizers should become a more effective energy-saving measure.

Recent research from the New Buildings Institute shows that most economizers malfunction.

3.2.6 Energy-Efficient Ventilation

As energy savings due to ventilation vary greatly, there was no available data. Eliminating cooling and heating energy used to condition excessive quantities of outside air can save large amounts of energy. The most effective way to ensure this is to perform accurate ventilation calculations. The Specification calls for calculations based upon ASHRAE 62-1999 or local code requirements. Several methods of reducing ventilation air were included, based upon discussions with the Subcommittee and Industry Advisors.

3.2.7 Additional Options and Accessories

This section lists options and accessories available from unitary equipment manufacturers that contribute to energy efficiency. The list was derived from reviewing manufacturer's literature and the E Source Commercial Space Cooling and Air Handling Technology Atlas.

4 SPECIFICATION ELEMENT – AIR DISTRIBUTION

4.1 GENERAL ISSUES WITH COMMON INDUSTRY PRACTICES

The Subcommittee and supporting research found the following problems with common industry practices:

A. Poor comfort and inefficient operation due to unfavorable zoning.
B. Leaky ductwork due to poor installation practices.
C. High pressure drop in ductwork systems due to inefficient duct layout and low-budget practices such as undersizing ductwork, extensive use of flexible ducts and lack of proper fittings.
D. Temperature rise due to poor duct location and insulation.
E. No outdoor air intake is present on many smaller systems.

4.2 TARGETED PRACTICES FOR ENERGY EFFICIENCY

4.2.1 Zoning

Best practices for zoning and constant/variable volume air delivery systems were derived from the E Source Commercial Space Cooling and Air Handling Technology Atlas and discussions with the Subcommittee.

4.2.2 Distribution Types

A brief section defining air distribution system types was included.

4.2.3 Duct System Parameters

A. **Benefits** throughout this section were derived from the E Source Commercial Space Cooling and Air Handling Technology Atlas.

B. **Best practices** – The Duct System Parameters section of the Specification includes duct location, ductwork and accessory selection, duct system design and layout. The Specification recommends round, galvanized steel ductwork as most efficient and encourages its use by providing substantial energy savings information. It is recognized, however, that due to construction budgets, flexible ductwork is often used. Design guidelines and installation practices for substantially improving flexible duct systems are included.

C. **Information sources** – Due to the large volume of information associated with numerous duct and fitting types, the Specification refers to ASHRAE, ACCA and SMACNA manuals for duct design and ductwork and component sizing. These industry standard manuals are commonly used by HVAC installers. The best practices for duct system parameter were derived from:

Commercial Space Cooling and Air Handling Technology Atlas, 1995, E Source. Resource summarizing available and emerging commercial space cooling and air handling technologies and related research.

Building Cavities Used as Ducts: Air Leakage Characteristics and Impacts in Light Commercial Buildings, J.B. Cummings and C.R. Withers, Jr., TO-98-8-4, ASHRAE Transactions Symposia. Study of building cavities used as ducts based upon Florida Solar Energy Center study of 70 commercial buildings (see reference no. 10) and field testing.

ASHRAE Handbook, 1997 Fundamentals American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc. (ASHRAE).

Manual Q – Commercial Low Pressure, Low Velocity Duct System Design, Air Conditioning Contractors of America (ACCA).

Manual T – Air Distribution Basics for Residential & Small Commercial Buildings, ACCA.

HVAC Duct Construction Standards – Metal & Flexible, 1995, with Addendum 1, 11/97, Sheet Metal and Air Conditioning Contractors' National Association (SMACNA).

HVAC Systems – Duct Design, 1990, (SMACNA).

Installation/Operation/Maintenance, Rooftop Lt. Comm. 5D, August 1998, American Standard Inc., The Trane Co.

Flexible Duct Performance & Installation Standards, 1996, Air Diffusion Council (ADC).

4.2.4 Duct Installation

A. **Benefits** – A number of studies claim widely varying duct leakage rates and energy savings due to duct leakage reduction. The data included in the Specification, from field studies and computer simulations conducted by the Lawrence Berkeley National Labs, was judged to be reasonably conservative by the Subcommittee. That study found an average supply duct leakage of 26 percent of fan flow in light commercial buildings. Simulations showed a 60-70 percent fan power increase resulting from 20 percent leakage. Recent research from the New Buildings

Institute shows that duct leakage can cause up to a 30 percent increase in annual energy use. The benefit data in this section was taken from:

Commercial Thermal Distribution Systems, Mark Modera, Lawrence Berkeley National Laboratory, February 1999. Summary of LBNL research studies based upon field study and computer simulations using the TRANSYS simulation engine.

Exterior Exposed Ductwork: Delivery Effectiveness and Efficiency, W.W. Delp, Ph.D., N.E. Matson, P.E., M.P. Modera, Ph.D., P.E., TO-98-8-1, ASHRAE Symposia. Case study exterior exposed ductwork on a one-story community college building in California.

Commercial Space Cooling and Air Handling Technology Atlas, 1995, E Source. Resource summarizing available and emerging commercial space cooling and air handling technologies and related research.

B. **Best practices** call for duct construction in accordance with SMACNA HVAC Duct Construction Standards – Metal and Flexible, 1995.[12a] This is probably the most widely used industry standard for duct construction. Duct insulation and sealing is recommended to be in accordance with ASHRAE 90.1-1999, which is slightly more comprehensive than SMACNA in that it covers ductwork under 2" w.c., prohibits pressure-sensitive tape as the primary sealant in some cases, and gives requirements for ducts located outdoors, in unconditioned spaces and in conditioned spaces. Additional practices were derived from the following publications:

HVAC Air Duct Leakage Test Manual, 1985, Sheet Metal and Air Conditioning Contractors' National Association (SMACNA).

Commercial Space Cooling and Air Handling Technology Atlas, 1995, E Source. Resource summarizing available and emerging commercial space cooling and air handling technologies and related research.

Transforming Northeast Markets to Increase Energy Efficiency –- Installation Practices of C&I Unitary HVAC Equipment, prepared by E-Cube, Inc., J. Wolpert, and D. Houghton for the Northeast Energy Efficiency Partnership, Inc., January 1998. Summary of research on cost-effective energy efficiency practices for commercial packaged 3-20 ton units, including interviews with contractors and industry experts, a literature search, and reviews of four existing projects covering over 100 sites.

Flexible Duct Performance & Installation Standards, 1996, Air Diffusion Council (ADC).

Exterior Exposed Ductwork: Delivery Effectiveness and Efficiency, W.W. Delp, Ph.D., N.E. Matson, P.E., M.P. Modera, Ph.D., P.E., TO-98-8-1, ASHRAE Symposia. Case study exterior exposed ductwork on a one-story community college building in California.

Manual Q – Commercial Low Pressure, Low Velocity Duct System Design, Air Conditioning Contractors of America (ACCA).

4.2.5 Evaluation of Existing Ductwork Systems for Retrofit

This section briefly covers evaluating the condition, sizing, layout, and quality of existing ductwork systems.

4.2.6 Reconditioning of Existing Ductwork Systems

A. **Benefits** were quoted from a Florida study of 70 small commercial buildings by the Florida Solar Energy Center[10] and from information from W.W. Delp, PhD., Lawrence Berkeley National Labs, who has participated in a number of studies involving repair of duct leakage.

B. **Best practices** were based upon the same publications listed above for Duct Installations, with the addition of Commercial Thermal Distribution Systems, Mark Modera, Lawrence Berkeley National Laboratory, February 1999, a summary of LBNL research studies based upon field study and computer simulations using the TRANSYS simulation engine.

C. **Aerosol duct sealing** – Although this relatively new technology is not widely available, it was recommended because it has good potential for overcoming some of the problems associated with repair of existing systems, such as effectiveness, access and business interruption. For commercial applications, it is currently limited to small duct systems.

5 SPECIFICATION ELEMENT – CONTROLS

5.1 GENERAL ISSUES WITH COMMON INDUSTRY PRACTICES

The Subcommittee and supporting research found the following problems with common industry practices:

A. Controls are often improperly commissioned. Unprogrammed thermostats, incorrect settings, uncalibrated equipment and untested control sequences can greatly impact energy usage. Economizers are particularly susceptible.
B. Components are commonly outdated, unreliable or corroded.
C. Sensors are often improperly located, resulting in incorrect system operation.
D. Residential-type thermostats are used in commercial facilities with the fan switch in “auto” position, causing low outdoor airflow rates.

5.2 TARGETED PRACTICES FOR ENERGY EFFICIENCY

5.2.1 General

A. **Benefits** – Controls strategies and system types vary greatly. Comprehensive energy savings data was not available. One study published in the ASHRAE Journal (see No. 9, Bibliography) claimed a 38 percent energy savings due to the installation of an energy management system. This claim was not included in the Commercial Specification however, because the study looked only at one building, the EMS system was not very well utilized and EMS systems are not commonly installed by the targeted audience.

B. **Best practices** – The Specification calls for energy-efficient controls and settings in accordance with ASHRAE 90.1-1999, which covers most items related to unitary equipment. Additional information was derived from:

Transforming Northeast Markets to Increase Energy Efficiency – Installation Practices of C&I Unitary HVAC Equipment, prepared by E-Cube, Inc., J. Wolpert, and D. Houghton for the Northeast Energy Efficiency Partnership, Inc., January 1998.

When Good Economizers Go Bad, T. Lunneberg, P.E., September 1999, ER-99-14, E Source.

Roach and C. Mangeng, "Selective Passive Cooling Strategies: A Generic Economic Analysis for Office Buildings, Passive Solar Journal, v.2, no. 2, 1983.

Commercial Space Cooling and Air Handling Technology Atlas, 1995, E Source.

5.2.2 Controls Retrofits

This section was included to address the common problem of inefficient and incorrect operation due to deteriorated and outdated controls.

5.2.3 Controls Strategies

Although most unitary equipment is controlled only by simple thermostats, sections on systemwide controls, fan controls and night ventilation were included due to the high potential for energy savings.

6 SPECIFICATION ELEMENT – HVAC COMMISSIONING

6.1 GENERAL ISSUES WITH COMMON INDUSTRY PRACTICES

The Subcommittee and supporting research found the following problems with common industry practices:

A. Many systems are not commissioned, but are simply turned on and adjusted just enough to get them running. Economizer systems, in particular, often operate incorrectly.
B. Construction verification for installation quality, methods and materials usually doesn't occur.
C. Components and systems are often incorrectly calibrated, set or adjusted.
D. Many systems are not well maintained and fall out of farther away from correct, efficient operation.
E. Poorly kept commissioning and maintenance records are common.

6.2 TARGETED PRACTICES FOR ENERGY EFFICIENCY

A. **Benefits** – Savings due to commissioning vary greatly. Energy savings information for the average new office building was taken from an article published in the ASHRAE Journal – The Price of Commissioning Equals Cost Savings, Carl N. Lawson, January 1996.

B. **Best practices** – A number of lengthy publications exist on the subject of commissioning that discuss reasons for commissioning and give vague information on protocol. However, very little or no specific information is available on procedures, such as checklists, forms, troubleshooting guides or documents covering specific systems. The commissioning section was derived from:

ASHRAE Standard Guideline 1-1996, The HVAC Commissioning Process.

Installation/Operation/Maintenance, Rooftop Lt. Comm. 5D, August 1998, American Standard Inc., The Trane Co.

Installation, Start-Up and Service Instructions, Single-Package Rooftop Heating/Cooling Units, 48HJ15SI, 1996, Carrier Corporation.

Transforming Northeast Markets to Increase Energy Efficiency – Installation Practices of C&I Unitary HVAC Equipment, prepared by E-Cube, Inc., J. Wolpert, and D. Houghton for the Northeast Energy Efficiency Partnerships, Inc., January 1998.

When Good Economizers Go Bad, T. Lunneberg, P.E., September 1999, ER-99-14, E Source.

Commercial Thermal Distribution Systems, Mark Modera, Lawrence Berkeley National Laboratory, February 1999.

HVAC Duct Systems Inspection Guide, 1989, Sheet Metal and Air Conditioning Contractors' National Association (SMACNA).

HVAC Air Duct Leakage Test Manual, 1985, SMACNA.

Testing and Balancing Procedures, 1997, Associated Air Balance Council (AABC).

ASHRAE Standard 90.1-1999, Energy Standard for Buildings Except Low-Rise Residential Buildings.

Smarter Energy – Packaged and Unitary AC Systems Guide, Pacific Gas & Electric Company, San Francisco CA.

Operation and Maintenance in Office Buildings: Defining Baseline, L.M. Gordon, T. Haasl, Portland Energy Conservation, Inc., 1996 American Council for an Energy-Efficient Economy – Commercial Buildings: Program Design, Implementation, and Marketplace Issues.

6.3 COMMISSIONING AGENCY

A qualified third-party commissioning agency is recommended to best ensure compliance with the procedures. When the project budget does not allow this, commissioning can be completed by the installing contractor(s), if appropriately qualified.

6.4 DOCUMENTATION

The documentation section was well detailed to encourage inclusion of all key procedures and help ensure compliance with specifications. Well-detailed and updated commissioning documents provide a good basis for system diagnostics, operation, service and maintenance.

6.5 COMMISSIONING PROCEDURES

Initially, Davis Energy Group attempted to develop specific procedures for commissioning each component and system. However, after review by and discussion with the Industry Advisors and Subcommittee, it was decided that the commissioning procedures should be dramatically shortened to checklist-type summaries of important items for each system, with references to manufacturer's instructions. This is mainly to avoid deviation from manufacturer's instructions, which can differ for a variety of reasons that can affect performance. In addition, a cumbersome commissioning section might obscure key items and discourage installers from initiating commissioning.

6.6 TRAINING

Recommendations for training programs for Owner's representatives are included. This will help facilitate an understanding of the systems so the Owner's representatives can evaluate system operation and commissioning and provide ongoing maintenance.

6.7 OPERATION AND MAINTENANCE

A comprehensive checklist of periodic operation and maintenance tasks is included and tailored for unitary equipment. Manufacturer's representatives on the Subcommittee stressed the importance of O&M on system performance. Use of a qualified service contractor is recommended as an alternative to facility personnel.

7 INDUSTRY ACCEPTANCE

7.1 INTRODUCTION TO INDUSTRY

The methods used to introduce the Commercial Specification to the HVAC industry will influence how the program is received and accepted. The inclusion of industry organizations in the Industry Advisors panel is a good start in the process of preparing industry for the Commercial Specification.

Industry Groups to target:

A. Contractors
B. Architects
C. HVAC designers and consultants
D. Local and general building and code officials
E. Equipment manufacturers and their representatives
F. Utilities
G. Energy-efficiency organizations
H. Industry standards organizations

Recommendations to facilitate a positive reception:

A. Engage industry groups, including contractors, in a beta testing process to generate feedback. This will allow contractors to participate and take responsibility in the program. The feedback will also be helpful in development of the Specification and training programs.

B. Produce introductory packages tailored to each industry group.
C. Produce media announcements advertising the benefits, impacts and goals of the project.
D. Promote incentives programs to be implemented during the introductory phase to counteract market barriers.
E. Launch an educational outreach program.
F. Closely monitor and document program progress and respond appropriately.
G. Promote the Specification for use as an industry standard. Encourage reference or adoption by energy codes, local jurisdictions and industry standards.
H. Contact equipment manufacturers to encourage development of equipment to facilitate standards embodied by the Specification.

7.2 MARKET BARRIERS

The following are potential market barriers to implementation of the Commercial Specification. These items should be addressed in the educational phase of the program.

A. Deviation from current practices.
B. Perception of increased installation costs. This is not necessarily the case; sometimes installed costs are lower with downsized equipment or more efficiently laid out duct systems.
C. Training time.
D. Profit margins associated with larger, commonly sold equipment.
E. Access to technical support by manufacturers.

7.3 EDUCATION

Training programs are crucial to the acceptance and effective implementation of the Commercial Specification. Appropriate learning tools based upon the Commercial Specification should be developed for use in educating participating groups. Suggestions for developing a training program include:

A. Develop the current Specification into a portable field manual for contractors, including illustrations and a clear, simple format.
B. Produce a set of abbreviated quick reference cards of key points for field and training use.
C. Develop a Trainer's manual, demonstration exhibits and audio-visual aids for use by program managers in training contractors, building and code officials.
D. Provide a training course for Trainers.
E. Develop exhibit materials for conferences, trade shows, etc.
F. Develop an educational videotape for training, distribution and media coverage.
G. Develop several example projects, including conventional and energy-efficient design plans, costing worksheets and energy simulations.

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9 DEFINITIONS

AABC: Associated Air Balance Council.

ACCA: Air Conditioning Contractors of America.

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

ACH: Air changes per hour.

ADC: Air diffusion council.

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

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

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

ANSI: American National Standards Institute.

ARI: Air Conditioning and Refrigeration Institute.

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

ASTM: American Society for Testing and Materials.

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

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

Btu: See British thermal unit.

Btuh: The number of Btu's (British thermal units) transferred during a period of one hour.

cfm: Cubit feet per minute.

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

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

Crawl Space: A space immediately under the first floor of a building and above the ground. Typically crawl spaces are unconditioned.

DSM: Demand-side management

Design capacity: Output capacity of a system or piece of equipment at design conditions.

Design conditions: Specified environmental conditions, such as temperature, required to be produced and maintained by a system, and under which the system must operate.

Differential dry bulb or enthalpy controls: In economizers, they measure both the outside air and return air conditions and select the cooler or drier airstream to minimize the use of mechanical cooling.

Direct digital control (DDC): A type of control where controlled and monitored analog or binary data (e.g., temperature, contact closures) are converted to digital format for manipulation and calculations by a digital computer or microprocessor, then converted back to analog or binary form to control physical devices.

Drop: For cooled air, the vertical distance between the bottom of a supply air outlet and the bottom of the airstream where it reaches its terminal velocity, often assumed to be 50 feet per minute.

Drybulb Temperature: Air temperature as measured by a standard thermometer, which does not take humidity into account.

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

ECM: electronically commutated motor, a brushless dc motor with built-in speed and torque controls. The ECM has the efficiency and speed control advantages of a dc motor without its disadvantages: i.e. carbon brush wear, short life and noise.

Economizer, air: A duct and damper arrangement and automatic control system that together allow a cooling system to supply outside air to reduce or eliminate the need for mechanical cooling during mild or cold weather.

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

Energy Efficiency Ratio (EER): The ratio of net cooling capacity (in units of Btu/hr) to total electrical energy use (in units of Watts) of a cooling system under designated operating conditions.

Energy factor (EF): A measure of water heater overall efficiency.

Enthalpy: A measure of the energy content of air that takes into account both drybulb temperature and humidity.

Expansion Valve Superheat: The difference between the temperature of the external bulb, and the corresponding system refrigerant saturation temperature at the bulb location.

fpm: Feet per minute, a measure of air velocity.

HVAC: Heating, ventilating and air conditioning.

Heating Seasonal Performance Factor (HSPF): The total heating output of a heat pump during its normal annual usage period for heating (in Btu) divided by the total electric energy input during the same period.

ICC: International Code Council.

IECC: International Energy Conservation Code.

NAECA: U.S. National Appliance Energy Conservation Act of 1987.

Pascal: A metric system unit of pressure, measured by Newtons per square meter. There are 249.0889 Pascals per inch of water column.

Peak Block Load: Simultaneous peak load for the entire building/system.

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

Plenum: An air compartment or chamber to which one or more ducts are connected, forming part of either the supply or return systems.

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

Refrigerant Charge: The actual amount of refrigerant in the closed cooling system or the weight of refrigerant required for proper functioning of the closed refrigerant system.

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

Reset: Automatic adjustment of the controller set point to a higher or lower value

R-value of insulation: The thermal resistance of the insulation alone as specified by the manufacturer in units of $h \cdot ft^2 \cdot {}^oF/Btu$ at a mean temperature of 75^o F. Rated R-value refers to the thermal resistance of the added insulation in framing cavities or insulated sheathing only and does not include the thermal resistance of other building materials or air films.

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

Seasonal Energy Efficiency Ratio (SEER): The total cooling output of a central air conditioner in Btu's during its normal usage period for cooling, divided by the total electrical energy input in Watt-hours during the same period.

Setback: Reduction of heating (by reducing the set point) or cooling (by increasing the set point) during hours when a building is unoccupied or during periods when lesser demand is acceptable.

Set point: Point at which the desired temperature (^{o}F) of the heated or water cooled space is set.

Single-zone system: An HVAC system serving a single HVAC zone.

SMACNA: Sheet Metal and Air Conditioning Contractors National Association.

Space Conditioning System: A system that provides – either collectively or individually – heating, ventilating, or cooling within or associated with conditioned spaces in a building.

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

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

Supplemental Heat, Air-Source Heat Pump: Also referred to as auxiliary heat. The additional heat required to heat a building when the outdoor temperature is below the balance point temperature. As the outdoor temperature drops, more supplemental heat is needed.

Thermostatic Expansion Valve (TXV) Cooling System: A cooling system uses the TXV for regulating the flow of refrigerant into the cooling unit, actuated by the changes in evaporator pressure and superheat of the refrigerant leaving the cooling unit. The basic response of the TXV is to superheat.

Throw: The vertical or horizontal distance air travels from the face of an air outlet to its terminal velocity, often assumed to be 50 feet per minute.

UL: Underwriter's Laboratory.

Unitary Cooling Equipment: One or more factory-made assemblies that normally include an evaporator or cooling coil, and a compressor and condenser combination. Units that perform a heating function are also included.

Unitary Heat Pump: One or more factory-made assemblies that normally include an indoor conditioning coil, compressor(s), and outdoor refrigerant-to-air coil or refrigerant-to-water heat exchanger. These units provide both heating and cooling functions.

Variable Air Volume (VAV) System: HVAC system that controls the drybulb temperature within a space by varying the volumetric flow of heated or cooled supply air to the space.

w.g.: Water gauge, denotes a measure of air pressure in inches of water, such as the static pressure rating of a fan or the pressure drop in ductwork.

Zone, HVAC: A space or group of spaces within a building with heating and cooling requirements that are sufficiently similar so that desired conditions (e.g., temperature) can be maintained throughout with input from a single sensor or averaged input from multiple sensors.