

**AMERICAN SOCIETY OF HEATING, REFRIGERATING AND
AIR CONDITIONING ENGINEERS, INC.**
1791 Tullie Circle, NE | Atlanta, GA 30329
(404) 636-8400

TC MINUTES COVER SHEET

T.C. NO. **9.9**

DATE OF MEETING: **June 29, 2003**

T.C. TITLE: **Commissioning**

LOCATION: **Kansas City, MO**

VOTING MEMBERS				EX-OFFICIO MEMBERS and ADDITIONAL ATTENDANCE
PRESENT	APPTD	ABSENT	APPTD	PRESENT
Janice Peterson	02	Jean Visier	01	Costas Balaras
Jerry Kettler	02	David Shipley	99	Michael Dolim
Kristin Heinemeier	01	Karl Stum	99	Mingsheng Liu
Richard Rose	00	Richard Casault	99	Tom Logan
Elia Sterling	99	Eli Howard	99	P. Elizabeth Jones
J R Anderson	00	Michael King	99	Zach Obert
Thomas Cappellin	00			Richard Kelso
Tim Corbett	02			Chad Dorgan
Charles Culp	01			Bill Koran
Larry Fisher	02			
Walter Grondzik	99			
Kenneth Peet	99			
Jeff Traylor	02			

NONVOTING MEMBERS					
PRESENT	APPTD	ABSENT	APPTD	ABSENT	APPTD
David Bevirt	01	Hollace Bailey	99	Daniel Henon	01
Rodney Lewis	99	David Boenside	01	Edward Iczkowski	02
Harvey Brickman	96	Barry Bridges	98	Eric Jenison	00
Wayne Dunn	01	David Butler	99	Charles Kiefer	99
J. Harry Enck	01	John Castelveccchi	99	Michael Kuk	00
Carl Lawson	02	Natascha Castro	02	Kathleen Radke	01
William McCartney	02	Daniel Frasier	02	Fred Schroeder	00
Andy Nolfo	02	Kenneth Fulk	00	Christopher Smith	99
John Rieke	99	Ken Gillespie	02	Cedric Trumen	00
Robert Towell	99	Stephen Hanser	98	Dennis Tuttle	94
		James Harrison	99	Henry Vance	01
		Philip Haves	98	Brandt Williams	02
		Charles Henck	02		

DISTRIBUTION

ALL VOTING MEMBERS AND LIAISONS:

<i>TAC Chairman</i>	Arthur McIvor	<i>TEGA</i>	Melvin Glass	<i>Staff Standards</i>	Claire Ramspeck
<i>TAC Section Head</i>	Birol Kilgis	<i>Special Pubs</i>	Marilyn Listvan	<i>Staff Res/ Tech</i>	Michael Vaughn
<i>Research</i>	Drury Crawley	<i>Standards</i>	Merle McBride	<i>ALI Liaison</i>	William Buck
<i>Journal/ Insights</i>	Ismena Deacon	<i>Program</i>	Jim Willson		

ASHRAE T.C. 9.9 ACTIVITIES SHEET

CHAIR: Janice Peterson
 VICE CHAIR: Jerry Kettler
 SECRETARY: Kristin Heinemeier

TC MEETING SCHEDULE

<i>Location - Past 12 months</i>	<i>Date</i>	<i>Location - Next 12 months</i>	<i>Date</i>
Chicago	1/03	Anaheim	1/04
Kansas City	6/03	Nashville	6/04

TC SUBCOMMITTEES

<u>Function</u>	<u>Chairman</u>
Handbook	Karl Stum
Program	Richard Rose
Membership	Elia Sterling
Research	Dave Shipley
Long Range Planning	Jerry Kettler
International Member/Journal	???
Standards	Rodney Lewis
Commissioning Guideline(s)	Carl Lawson
Web Master	Dave Shipley
Journal/Insights	

RESEARCH PROJECTS – Current

<u>Number</u>	<u>Title</u>
RP1137	Field performance Assessment of VAV Control Systems Before and After Commissioning

LONG RANGE RESEARCH PLAN

Priority	Title	W.S. Written	Approved By R&T
1)	Field Performance Assessment of Package Equipment to Quantify the Need for Monitoring, FDD, and Continuous Commissioning	Yes	No
2)	The Impact of Commissioning on Comfort	RTAR	No
3)	Effectiveness of Statistical Random Sampling of newly constructed HVAC Systems for Building Commissioning	No	No
4)	Performance Test Methods for existing rooftop units	No	No
5)	Field-Based Evaluation of Functional Performance Tests	No	No
6)	Methods of Improving Persistence of Commissioning Savings in Control Systems	No	No
7)	One Time vs Short-Term vs Seasonal Testing of Air-Handling Units	No	No

STANDARDS ACTIVITIES

Guideline 0 submitted for public review, comments responded to, final review before or at Kansas City

TECHNICAL PAPERS

From sponsored research - none
From other sources - unknown

PROGRAMS**TC SPONSORED SYMPOSIA** (Past 2 years, **present** and *planned*);

Cx Starts with Design Intent	Walt Grondzik	06/02
Cx Specialty Facilities	Carl Lawson	01/03

TC SPONSORED SEMINARS (Past 2 years, **present** and *planned*)

Impact of Cx on Commercial Markets	Andy Nolfo	01/03
Cx Specialty Facilities	Carl Lawson	01/03
Cx Life Safety Systems	Carl Lawson	06/03
<i>Impact of Total Building Cx</i>	<i>Carl Lawson</i>	<i>01/04</i>
<i>Cx is More than FPT</i>	<i>Rich Rose</i>	<i>01/04</i>
<i>Training Cx Agents</i>	<i>Jerry Kettler</i>	<i>06/04</i>
<i>Retrocommissioning</i>	<i>Andy Nolfo</i>	<i>06/04</i>
<i>Cx of DDC</i>	<i>Rodney Lewis</i>	<i>02/05</i>

TC SPONSORED FORUMS (Past 2 years, **present** and *planned*)

Results of One Pass RE-Commissioning	Charles Culp	06/01
Persistence of Savings for Central Systems	Ken Peet	06/03

PROGRAM PLAN: (See Above and attached)

JOURNAL PUBLICATIONS (Past 3 years, present and planned) - unknown

MEETING MINUTES – Sunday, June 29, 2003

**ASHRAE T.C. 9.9 - Commissioning
Kansas City, MO**

1. The meeting was called to order at 3:00 pm by Chairman Peterson
2. Self introductions were conducted.
3. Attendance sheets were distributed, and roll was taken: 13 Voting members in attendance.
4. Vice Chairman Comments: none.
5. Agenda was reviewed and no additions were made. (Lawson/Culp, 13/0/0).
6. Motion was made and seconded to approve minutes from Chicago. (Culp/Rose, 13/0/0).
7. Administrative matters: None addressed
8. Correspondence: Chairman Peterson reminded members that she is authorized to send a letter of appreciation from ASHRAE for attendance and participation in committee activities.
9. Society Liaisons: Brickman reported that TC9.9's chapter was published in 2003, and that the next revision is for the 2007 version. Karl Stum is still handbook committee chair, and along with committee members Culp, Peet, and Fisher, revisions for the next version are underway. ASHRAE has not yet decided whether to have the CD versions of the Handbooks as primary or secondary. ASHRAE is continually reviewing whether or not the Handbooks are relevant and meeting members' needs.

SUBCOMMITTEE REPORTS

10. Membership committee: The new roster will go into effect later in this week. One international member has dropped off the list.
11. Program Committee: See attached report. It was noted that symposia have been removed from the rating system: they are almost guaranteed to be accepted. There was discussion of a time for the program committee. There is really no better time than the current slot (coincident with Research and Long-Range Planning committees), so the Subcommittee chair was encouraged to get as much input as possible by email before the meeting, to minimize the length of discussion during the TC meeting.
12. Research Committee: See attached report.

13. Handbook Committee: No report.
14. Long Range Planning Committee: Report deferred to Old Business
15. Standards Committee: No report.
16. Commissioning Guidelines Committee: See GPC-1 and GPC-0 Liaison Reports.
17. Website: No report.
18. Journal and Insights/International: Bevirt reported that Special Publications is starting a committee to oversee Electronic media. Journal Insights committee is being combined with Special Publications. Larry Fisher is new liaison to Journal/Insights. A change has been made to expedite revision processes: Reference manuals are encouraged, rather than “MOPs and BARs” (Manuals of Procedures and Board Approved Rules).

LIAISON REPORTS

19. GPC-1 ‘HVAC Commissioning Process’ Liaison Report – Walter Grondzik: Guideline 0: Expect to vote for publication in one month: currently handling 5 public comments and editorial comments. August 8 is their deadline. Guideline 1: committee meets four times per year, and is about 2 years away from a final version.
20. GPC-4 ‘O&M Documentation Liaison Report’ –Jerry Kettler – Approved in Chicago to go for public review, tho it hasn’t gone out yet. They will put it out as it stands now, and issue a systems manual later.
21. SSPC 62 ‘Ventilation for Acceptable IAQ’ Liaison Report –Elia Sterling – Tied up business, approved addenda (N – calculations for ventilation, G: separate smoking spaces) were voted on by Standards. Committee is now being restructured to focus on a guideline for use of the standard—9.9 member Howard is chair of this committee.
22. SPC-90.1 ‘Energy Efficient Design of New Buildings’ - No report
23. SPC 111 Test, Adjust and Balance” Liaison Report – Jerry Kettler – Currently getting it into the right format, and resubmitting for public review.
24. GPC 11P MOT for Control Components – Jerry Kettler. They are trying to get this out for first public review. They desired to include pictures, but this was discouraged. Currently a Method of Test, but there is interest in making it a part of the Commissioning Guideline series (see Old Business).
25. TC1.4 –Control Theory and Application Liaison Report—Larry Fisher—A publication on reference applications is in the works. It will include on the order of one hundred published Sequences of Operations...possibly published as a special publication. Currently 6 have been submitted.

26. TC1.8 – Owning and Operating Costs - No report.
27. TC9.7 – Test and Balance - No report.
28. TG 9 – Moisture Management in Buildings – Should know by tomorrow whether or not this was approved.
29. Building Commissioning Association Liaison – BCA is developing a program for certification of Cx agents. Examination questions are currently being developed.

BUSINESS

30. Old Business:
 - a. Proposed Guidelines. Jerry Kettler circulated a description of a proposed Commissioning Guidelines system, which would include a series of commissioning-related guidelines. Several were of immediate interest, and he circulated a Title/Purpose/Scope for three new guidelines:
 - Commissioning Process for Existing Building HVAC&R Systems
 - Preparation of Owner’s Project Requirements and Basis of Design for the HVAC&R Commissioning Process
 - Training in Building Operation and Maintenance for the HVAC&R Commissioning Process.These three guideline proposals were approved by the TC (Traylor/Grondzik, 13/0/0).
 - b. The committee also took action to approach TC 1.7 about cosponsoring Guideline on “Training for Building Operation and Maintenance for the HVAC&R Commissioning Process” (Grondzik/Rose, 13/0/0).
31. New Business:
 - a. Several members of the committee expressed concern that Ron Wilkenson, who is an ASHRAE Distinguished Lecturer, gives lectures on Commissioning without representing contents of ASHRAE Guidelines. Chairman Peterson will write a letter to the Chapter Programs Committee, and individual members were also encouraged to express their concerns to this committee.
 - b. There was a discussion of the interaction between ASHRAE and USGBC relating to the commissioning requirements of the LEED rating system. Chairman Peterson reported that a Memorandum of Understanding was being discussed with the head of TAC. It was noted that regarding commissioning, LEED requires a guideline that can be simply referenced. Although ASHRAE’s GL 0 is not perfectly applicable, it would be appropriate for LEED to refer to it for compliance. ASHRAE should provide guidance to the application of this Guideline for LEED. The TC decided to establish a LEED Subcommittee, to serve as a “Quick Response Team” for clarification from USGBC. Chairman Peterson will serve as chair of this committee (and as *de facto* liaison with USGBC), and Anderson, Enck, Sterling, Peet and Heinemeier volunteered to participate in the committee.

32. The next TC9.9 Committee meeting will be on January 25, 2004 at 3 PM in Anaheim, CA.
33. Motion to adjourn was made at 16:55 and passed by acclimation.

—END OF REPORT—

ATTACHMENTS

- Program Committee Report p. 5
Research Committee Report p. 6

Program Committee Report – June 28, 2003 – Kansas City

TC 9.9 PROGRAM SCHEDULE

Status

City	Type	Title	Chairman	Speakers	Abstract Complete	Paper Complete	Paper Approved
Anaheim 1/24/04 to 1/28/04	Seminar	Impact of Total Building Cx	Carl Lawson	Charles Culp			
				Chad Dorgan			
Anaheim 1/24/04 to 1/28/04	Seminar	CX is more than FPT	Rich Rose	Tim Corbett			
				Jeff Traylor Bill McCartney Jerry Kettler			
Nashville 6/26/04 to 6/30/04	Seminar	Training Cx Agents	Gerry Kettler	Jeff Traylor			
				Charlie Culp Andy Hoiro Rick Casault			
Nashville 6/26/04 to 6/30/04	Seminar	Retro-Commissioning	Andy Nolfo	Janice Peterson			
				Tim Corbett Charlie Culp Carl Lawson			
Orlando 2/05/05 to 2/09/05	Seminar	Cx of DDC Systems	Rodney Lewis	Ken Gillespie			
				Larry Fisher Jim Cogan Steve Doty			

TC 9.9 Research Subcommittee Report

2003 Summer Meeting

Saturday, June 28, 2003, 1:00-3:00pm

Hyatt Regency Crown Center – Van Horn B

1. Call to Order

Ken Peet (Substituting for Dave Shipley) called the meeting to order. Attendees included Ken Peet, Maria Corsi, Costas Balaras, Daniel Choiniere, Ken Gillespie, and David Bornside. Anyone who wants to be added to the distribution list for this subcommittee should get their contact information to Dave Shipley.

2. Funded Projects

<i>Priority</i>	<i>Title</i>	<i>Status</i>	<i>Contractor</i>	<i>Notes</i>
	RP 1137 – Field Performance Assessment of VAV Control systems Before and After Commissioning	In-Progress	Patrick Fleming/ Stantech Consulting	<i>There will be a verbal report given on this project at the full committee meeting</i>

3. Projects in the Pipeline

(Note: A new research plan is not due at this time. The priority order shown below has not been formally voted on by the subcommittee and should be considered approximate. It will be finalized in Kansas City.)

<i>Priority</i>	<i>Title</i>	<i>Status</i>	<i>Author</i>	<i>Notes</i>
1	Field Performance Assessment of Package Equipment to Quantify the Need for Monitoring, FDD, and Continuous Commissioning	Work Stmt	Todd Rossi	Sponsored by 4.11; Prioritized RTAR. Todd reports the work statement is on track. RAC conditionally approved it with two remaining issues, one a spelling error (!) and the other more substantive. We need to make sure our research liaison is informed and consulted.
2	The Impact of Commissioning on Comfort	RTAR	Dave Shipley	RTAR written. TC 2.1 did not consider it in Hawaii, but did distribute it for comment afterwards. Dave has revised it to reflect their comments. New version is included here. Dave will provide 2.1 with copies and consult their research chair before their meeting (3 pm Sunday).
3	Effectiveness of Statistical Random	Title	This Title has no	This is a new title

<i>Priority</i>	<i>Title</i>	<i>Status</i>	<i>Author</i>	<i>Notes</i>
	Sampling of newly constructed HVAC Systems for Building Commissioning		Champion yet	
4	Performance Test Methods for existing rooftop units	Title	Needs Champion	Dovetail with TC4.11 project on Field Performance Assessment. No action at this time.
5	Field-Based Evaluation of Functional Performance Tests	Title	Needs Champion – maybe Phil Haves?	Select subset of FPT Library and evaluate the technical and practical aspects of the proposed methods.
6	Methods of Improving Persistence of Commissioning Savings in Control Systems	Title	Ken Peet, David Underwood	Looking to do a Forum or Seminar
7	One Time vs Short-Term vs Seasonal Testing of Air-Handling Units	Title	Mingsheng Liu	Awaiting outcome of WS-1092

4. Overall Discussion of TC 9.9 Research

The following is the strategic plan of the subcommittee:

- Our proposed projects must have a tie-in to market transformation activities, in order to ensure that they have useful application, but they should not be focused on market transformation.
- Projects should address hard engineering problems, and should not answer questions that could be answered simply with focused effort by TC members.
- Projects should focus on topics where ASHRAE sponsorship would add necessary credibility to findings.
- Pursue co-funding opportunities to pursue problems that are both technical and marketing in nature (can ASHRAE contribute to another institution's project?)

The subcommittee sees two major thrusts to its work:

- *Projects that try to measure the benefits of commissioning* – the long-term objective being to build up solid evidence measuring each of several terms in the benefit equation (e.g. improved compliance with comfort criteria, improved compliance with ventilation for IAQ, reduced change orders, and other quantifiable measures) so that we can ultimately add it all up and be able to state the technical benefits of doing commissioning. That will enable a financial analyst to conduct a cost-benefit calculation by assigning an economic value to each of the costs and benefits.
- *Projects that try to assess the relative success of different approaches to commissioning* – the objective here being to make specific comparisons between different techniques, to compare their effectiveness and costs. This would provide commissioning practitioners with new tools and advice on which of the existing techniques and tools work the best.

Research Subcommittee Membership

TC 9.9 Building Commissioning

Attend?	Name	Organization	E-mail	Phone	Fax
	J. R. Anderson	Anderson Engineering	Jrhazel@bellsouth.net	901-754-5420	901-753-2585
	Bryan Alcorn	California Energy Commission	Balcorn@energy.state.ca.us	916-654-4222	
	David Branson	Compliance Services Group, Inc.	Djbranson@csg.net	806/748-0040	806/748-0030
	Harvey Brickman	Tishman	brickman@tishman.com	212-399-3651	212-739-6088
	Barry Bridges	Sebesta Blomberg	bbridges@sebesta.com	651-634-0775	651-634-7400
	Charlie Culp	Texas A&M University	Cculp@tamu.edu	979/458-2654	979/862-3336
	Wayne Dunn	Sunbelt Solutions	waynedunn@aol.com	904-737-5700	904-737-0932
	H. Jay Enck	CH2Mhill	Jenck@CH2M.com	770/604-9095	770/604-9183
	Glenn Friedman	Taylor Engineering	gfriedman@taylor-engineering.com	510-749-9135	510-749-9136
	James Gartner	Roberts Gordon	jimg@rg-inc.org	513-759-4327	513-759-4328
X	Ken Gillespie	Pacific Gas & Electric	KLG2@pge.com	925-866-5329	
	Kristin Heinemeier	Brooks Energy & Sustainability Lab	kristin-h@tamu.edu	210-534-7227 x23	210-534-7238
	Daniel Henon	Sewanee – The University of the South	dhenon@sewanee.edu	931-598-1913	931-598-1745

Attend?	Name	Organization	E-mail	Phone	Fax
	John House	Iowa Energy Center	jhouse@energy.iastate.edu	515-965-7345	515-965-7056
	Daniel Choiniere	Natural Resources Canada	Daniel.choiniere@nrcan.gr.ca	703-803-2980	703-803-3732
	Mingsheng Liu	University of Nebraska	mliu2@unl.edu	402-554-2173	
	Andy Nolfo	National Environmental Balancing Bureau	anolfo@prodigy.net	636-227-4326	636-227-0425
	Tim O'Connor	Glaxo Wellcome Inc.	TJO9480@GlaxoWellcome.com	919-483-2085	919-483-0403
X	Ken Peet	LSE Engineering Inc.	Kpeet@lse-engineering.com	502-584-8930	502-584-8934
Non Member	David Bornside	Siemens	David.bornside@siemens.com	847-941-5422	847-215-9519
	Mary Ann Piette	Lawrence Berkeley National Lab	MAPiette@LBL.gov	510-486-6286	510-486-4673
	Dave Shipley	Marbek Resource Consultants	Shipley@marbek.ca	613/523-0784 x232	613/523-0717
	Elia Sterling	Theodor D. Sterling and Assoc.	Elia@sterlingiaq.com	604-681-2701	604-681-2702
	Karl Stum	Ch2Mhill	kstum@CH2M.com	503/235-5022	
	Cedric Trueman	Trueman Engineering Services	ctrueman@ampsc.com	250-472-3521	250-472-3524
	Dave Underwood	U.S. Army Corps of Engineers	d-underwood@cecer.army.mil	217-373-6780	217-373-6740
	David Venters	BuileFile	dgventers@buildfile.com	904-703-0861	904-737-0932

Attend?	Name	Organization	E-mail	Phone	Fax
	Jean Christophe Visier	CSTB	vizier@cstb.fr	+33 164688294	+33 164688350
	Craig Wray	Lawrence Berkeley National Labs	cpwray@lbl.gov	510-486-4021	510-486-6658
Non Member	Costas Balaras	National Observatory of Athens	costas@meteo.noa.gr		
Non-member	Maria Corsi	Iowa Energy Center	mcorsi@energy.iastate.edu	515-965-7343	
	Janice Peterson	Portland General Electric	Janice_Peterson@pgn.com		

RESEARCH TOPIC ACCEPTANCE REQUEST

Title: Field Performance Assessment of Packaged Equipment to Quantify the Benefits of Proper Service and Assessing the Long Term Need for Monitoring, FDD, and Continuous Commissioning Technology

TC/TG: TC 4.11 Smart Building Systems (Todd Rossi: rossi@acr.com)

Research Category: Operation and Maintenance Tools

Research Classification: Basic and Applied

TC/TG Priority: 1 (TC 4.11)

Estimated Cost and Duration: \$150,000 (\$125,000 ASHRAE + \$25,000 DOE) and 24 months.

Other Interested TC/TGs: TC 9.9 (priority #2)

Expected Co-funding: \$25,000 co-funding for this project promised by the U.S. Dept. of Energy.

Handbook Chapters Affected by Project Results:

State of the Art (Background):

Packaged HVAC equipment is the most common source of heating, air conditioning, and ventilation in small- and medium-size commercial buildings, including popular suburban retail shopping malls, supermarkets, and restaurants. Compared to large built up systems, packaged equipment are generally smaller and more numerous. Therefore, technicians spend less time servicing individual packaged units and the resultant field performance of this equipment may be much worse than that of their counterpart in built up systems.

Field studies performed to date to assess the field performance of packaged equipment have been limited in scope and somewhat inconclusive. In 1992 and 1993, an HVAC/Refrigeration tune-up pilot program was implemented in Wisconsin to evaluate the effectiveness of HVAC and refrigeration tune-ups in saving energy and reducing peak demand in nine commercial buildings¹. The results varied widely, but energy savings of up to 15% were achieved in most buildings. Four major limitations to the study were cited including; (1) the number of sample points was small; (2) other factors affected building energy consumption; (3) HVAC performance enhancements improved comfort but did not always save energy; and (4) it was difficult to quantify the effect of particular maintenance activities without better controlled conditions or more sample points. A two-year study by the Electric Research Power Institute that was concluded in 1997 investigated the energy and demand impacts of maintenance on rooftop packaged heating and cooling equipment². Six long-term and 24 short-term sites were monitored. The short-term sites established the immediate impact of maintenance on savings and the long-term sites determined its persistence. The most prevalent problem was low refrigerant charge. No significant change in unit performance due to low charge, filter maintenance, or coil cleaning was observed. The study concluded that the cost of annual maintenance programs are unlikely to be offset by utility cost savings alone.

¹ Kasmar J., Valerie N., "Energy Impacts from Commercial Air Conditioning Maintenance – A WDSO Evaluation Report", Wisconsin Demand-side Demonstrations, 2901 W. Beltline Drive Suite 307, Madison WI 53713, (608) 275-7180, (608) 275-7199 (FAX), May 1995

² Krill W. (EPRI Project Manager, Customer Systems Group), "The Impact of Maintenance on Package Unitary Equipment", TR-107273 3831, Electric Power Research Institute, 3412 Hillview Ave, Palo Alto CA 94304, Feb. 1997

Other than these studies it is generally unknown how packaged equipment performs in the field. Laboratory studies of rooftop units show that performance is sensitive to typical faults observed in the field³, yet these studies provide mixed results. An open and unbiased ASHRAE sponsored research project provides opportunity for our engineering community to participate in a study to observe these effects in the field.

Advancement to the State of the Art (Justification):

This project would take additional steps toward quantifying the benefits of proper service in packaged equipment by assessing current performance of a statistically significant number of units in the field and documenting how the performance improves when a subset of these units are properly serviced. This approach will establish a more rigorous baseline than previous studies for the maximum possible benefits of proper servicing.

Packaged equipment performance has a direct impact on occupant comfort, indoor air quality and facility energy use in a large fraction of commercial buildings in the US. A recent DOE report indicates that rooftop and unitary A/C equipment consumes 1.03 out of a total of 1.66 quads (62%) of total energy consumed for cooling the current building stock of commercial buildings in the US. This research project will assess the level of improvement in energy efficiency that can be expected from proper servicing of packaged equipment, thereby establishing the need for diagnostic technology that can facilitate improved servicing of this type of equipment.

Justification and Value to ASHRAE:

Industry (i.e., building owners and facility managers) will benefit from this research by utilizing the results of the project to prioritize their maintenance and diagnostic efforts. The results will also help guide future efforts at ASHRAE, government and industry to develop technology and document its costs and benefits to help achieve widespread acceptance in the marketplace. Furthermore, the development of packaged equipment performance indices and experience with measuring, documenting, and reporting them will help researchers and product developers establish a unified approach to quantifying performance.

Objective:

The objectives of this research project are to study and document:

1. The actual field performances of 375 packaged HVAC units and compare them to industry norms or manufacturer's specifications for new equipment.
2. The implementation of diagnostic and proper service procedures and the resulting performance enhancement for at least 75 of the 375 units.
3. The need for monitoring, FDD, and continuous commissioning technology to address the long-term service needs of packaged equipment in the field.

To preserve generality and anonymity and to prevent competition between unit manufacturers, units are to be classified generically into categories including age, nominal capacity, refrigerant, type of expansion device, compressor technology, design EER, electrical specifications. No make or model names or any other similar characteristics will be used to identify the units used in this study.

Bidders will be expected to collaborate with maintenance organizations such that this project will fund only the incremental costs of collecting and analyzing the data, not the cost of servicing.

³ Breuker, M.S. and J.E. Braun. 1998b. Evaluating the Performance of a Fault Detection and Diagnostic System for Vapor Compression Equipment, *IJHVAC&R Research* 4(4).

ASHRAE RESEARCH WORK STATEMENT

**SPONSORED BY TC 4.11 (SMART BUILDING SYSTEMS) (Priority 1)
CO-SPONSERED BY TC 9.9 (BUILDING COMMISSIONING) (Priority 2)**

PROJECT TITLE

Field Performance Assessment of Package Equipment to Quantify the Benefits of Proper Service and Assessing the Long Term Need for Monitoring, FDD, and Continuous Commissioning Technology

BACKGROUND

HVAC equipment monitoring, FDD, and continuous commissioning tools provide increased reliability and lower operating costs to the owner. Increased reliability would improve the productivity in conditioned spaces (e.g. higher sales in retail stores, higher production yields in manufacturing facilities and higher productivity in offices). Lower operating costs are derived from reduced energy consumption and less emergency service.

Packaged HVAC equipment is the most common source of heating, air conditioning, and ventilation in small and medium size commercial buildings, including popular suburban retail shopping malls, supermarkets, and restaurants. A recent DOE report indicates that rooftop and unitary A/C equipment consumes 1.03 out of a total of 1.66 quads (62%) of total energy consumed for cooling the current building stock of commercial buildings in the US⁴. Compared to large built up systems, packaged equipment are generally smaller and more numerous. Therefore, service technicians do not spend nearly as much time on each unit. As a result, their actual field performance may diverge from design intent more severely than their counterparts in built up systems.

In 1992 and 1993, an HVAC/Refrigeration tune-up pilot program was implemented in Wisconsin to evaluate the effectiveness of HVAC and refrigeration tune-ups in saving energy and reducing peak demand in commercial buildings⁵. Nine sites were studied including retail and grocery stores, restaurants and an office building. The results varied widely, but energy savings of up to 15% were achieved in most buildings. Four major limitations to the study were sited including:

1. The number of sample points was small.
2. Other factors effected building energy consumption.
3. HVAC performance enhancements improved comfort but did not always save energy.
4. It was difficult to quantify the effect of particular maintenance activities without better controlled conditions or more sample points.

⁴ Energy Information Administration (EIA/DOE). *Annual Energy Outlook 1999*. U.S. Department of Energy. DOE/EIA - 0383(99). December 1998.

⁵ Kasmar J., Valerie N., "Energy Impacts from Commercial Air Conditioning Maintenance – A WDSO Evaluation Report", Wisconsin Demand-side Demonstrations, 2901 W. Beltline Drive Suite 307, Madison WI 53713, (608) 275-7180, (608) 275-7199 (FAX), May 1995

A two-year study by the Electric Research Power Institute that was concluded in 1997 investigated the energy and demand impacts of maintenance on rooftop packaged heating and cooling equipment⁶. Six long-term and twenty four short-term sites were monitored. The short-term sites established the immediate impact of savings and the long-term sites determined its persistence. The most consistent problem noticed was low refrigerant charge. No significant change in unit performance due to low charge, filter maintenance, or coil cleaning was observed. The study concluded that the cost of annual maintenance programs are unlikely to be offset by utility cost savings alone.

Other than these two studies, it is generally unknown how packaged equipment actually performs in the field. Laboratory studies of rooftop units show that performance is sensitive to typical faults observed in the field⁷, yet these studies provide mixed results. An open and unbiased ASHRAE sponsored research project provides the first opportunity for our community of engineers to participate in a study to observe these effects in the field.

This work statement takes additional steps toward quantifying the benefits of proper service in packaged equipment by assessing the equipment's current performance level in the field and documenting how the performance improves when the equipment is properly serviced. This establishes a baseline for the maximum possible benefits. Future work statements may investigate more detailed issues including:

1. the cost of using various tools and technology,
2. overall system efficiency including duct leakage and the dynamic aspects of heating and cooling distribution systems,
3. isolating the benefits associated with specific technologies, and
4. measuring more bottom line benefits such as improvement in energy efficiency, worker productivity, indoor air quality and occupant comfort.

Quantifying the benefits of HVAC monitoring, FDD, and commissioning tools is challenging and this difficulty is the most significant barrier to market acceptance of these tools. Operating costs are the easiest to quantify monetarily. Increased reliability is more difficult to quantify, but may, for example, be measured as the percent of occupied time at set point. Quantifying the benefits of increase reliability is even more difficult.

Issues concerning the quantifying benefits include:

1. Increased up time may result from detecting hard faults faster and anticipating performance degradations as they develop.
2. First costs will increase by the introduction of monitoring equipment.
3. Energy and service costs can either increase or decrease because more up time and increased awareness of service needs may offset expected efficiency improvements.
4. Short-term costs may also increase soon after monitoring and FDD is implemented and then decrease as expected after pent up demand for more and better service is satisfied.

⁶ Krill W. (EPRI Project Manager, Customer Systems Group), "The Impact of Maintenance on Package Unitary Equipment", TR-107273 3831, Electric Power Research Institute, 3412 Hillview Ave, Palo Alto CA 94304, Feb. 1997

⁷ Breuker, M.S. and J.E. Braun. 1998b. Evaluating the Performance of a Fault Detection and Diagnostic System for Vapor Compression Equipment, *IJHVAC&R Research* 4(4).

Quantifying the benefits of HVAC equipment monitoring and FDD is a relatively difficult and broad topic area that will be addressed in a series of several work statements.

CONTRIBUTION TO ASHRAE'S BROADER GOALS

The Testing and Evaluation Subcommittee in TC 4.11 is concerned with research issues associated with assessing the benefits (market potential) and performance of smart building technologies such as fault detection and diagnostics, automated commissioning, self-configuring systems, etc. Research endorsed by this subcommittee is expected to result in data, metrics, methods, and tools/standards/guidelines for quantifying smart building system benefits and performance in a standardized manner, as well as findings from the actual application of these metrics, methods and tools.

Research related to assessing the benefits of smart building technology can help define and justify research on such technology by establishing how (and by how much) the performance of existing technology can be improved. Successful studies of this nature can lay the groundwork for acceptance of new technology by end-users. To be successful and to gain support from ASHRAE, studies should be targeted at existing technology that is known to have performance problems. Furthermore, proposed studies should have a clear procedure and set of metrics (or at least such procedures and metrics should be perceivable at the start of the research) that will enable performance to be quantified in an objective manner (e.g., energy savings, time savings, etc.). In some cases a study may include demonstrations of prototype tools that can improve performance, while in other cases the study may be limited to measuring the performance of an existing technology, as new technology does not yet exist.

This study deals with field performance assessments of HVAC equipment. Its outcome should help establish the need for automated FDD and continuous commissioning tools. Studies aimed at field performance assessments of other equipment (e.g., chillers, fan coil units) may also be merited.

JUSTIFICATION

The motivation for this research arises from recent ASHRAE-sponsored research projects in TC 4.11 and TC 9.9 to study commissioning and fault detection and diagnostic technology for HVAC equipment including 1020-RP, 1043-RP, and 1139-RP. These research projects primarily focus on air handling units and large chiller plants used in larger facilities.

Packaged equipment performance has a direct impact on occupant comfort, indoor air quality and facility energy use in a large fraction of commercial buildings in the US. This research project will assess the need for similar diagnostic technology more tightly focused on this type of equipment.

Industry (i.e., building owners and facility managers) will benefit from research by utilizing the results of the project to prioritize their maintenance and diagnostic efforts. The results will also help guide future efforts at ASHRAE, government and industry to develop technology and document its costs and benefits to help achieve wide acceptance in the marketplace. Furthermore, the development of packaged equipment performance indices and experience with measuring, documenting, and reporting them will help researchers and product developers after this work is complete.

OBJECTIVE

The objectives of this research project are to study and document:

- (1) The actual field performances of 375 packaged HVAC units and compare them to industry norms or manufacturer's specifications for new equipment.
- (2) The implementation of diagnostic and proper service procedures and their resulting performance enhancement for at least 75 of the 375 units.
- (3) The need for monitoring, FDD, and continuous commissioning technology to address the long term service needs of packaged equipment in the field.
- (4) The nature and frequency of any deficiencies found.

Refrigeration cycle efficiency and capacity and indoor air quality as measured by the ventilation rate (CFM/sq.ft.) will be the primary performance indices. Other performance criteria may include:

- (1) compressor inlet superheat and power quality to assess adequate compressor protection against premature failure
- (2) occurrences of mechanical failures such as worn belts and contactors, refrigerant leaks, and condensate problems
- (3) economizer problems
- (4) heating system problems

Unlike the previous studies referenced in the background section, the sample sizes selected in this study (375 and 75 units) is expected to provide statistically significant inputs:⁸

1. 5% difference in performance would be regarded as significant
2. 12% estimate of the actual sample standard deviation⁹
3. 95% probability that the experiment will identify a difference in performance of at least 5%
4. 95% confidence in the results
5. In the first experiment, where 375 units are sampled the performance of a unit can be better or worse compared to another unit (bi-directional change expected). In the second experiment, where the units are serviced, its performance can only improve after it is repaired (uni-directional change expected).
6. In the first experiment, samples are not paired, but in the second experiment they are paired. Pairing helps reduce sample size because the control case is expected to be similar (i.e., same unit under similar operating conditions) to the test case except for the effect being tested (i.e., unit was serviced).

This statistical analysis resulted in a sample size of 151 units for the first experiment where 375 units were selected and 34 units for the second experiment where 75 units were selected. Approximately three times as many units were selected for the study than this analysis requires insuring there is enough data to accommodate input errors and unforeseen events in the experiment.

⁸ Private email communications, January 7, 2002, David F. Shipley, P.Eng. Shipley@marbek.ca, 613/523-0784 ext. 232.

⁹ Based on efficiency estimates on 1450 samples obtained in a proprietary study performed by Field Diagnostics Services, Inc., Contact: Todd M. Rossi, Ph.D., rossi@fielddiagnostics.com 215/741-4959 ext. 15.

QUALIFICATION OF BIDDERS

Bidders are expected to demonstrate a familiarity with published work related to this study. Bidders should also be able to demonstrate expertise in test plan development and field performance measurements. Refer to ASHRAE Guideline 14B for valuable reference material.

SCOPE

Task #1 – Literature Review

The contractor shall research other work done to assess the field performance of packaged HVAC equipment. Look into work that has been recently performed/funded by EPRI and PG&E.

Note that this literature review should not be focused on specific tools, such as fault detection and diagnostics. The contractor should identify published material on performance tests of packaged HVAC equipment. Although field performance is preferred, laboratory studies should also be included.

Task #2 - Identification of suitable field installations

The contractor shall identify at least 375 packaged units located at least 35 different sites. The equipment must be owned and operated by a variety of different organizations so that the results are not overly biased to the way specific organizations operate. Units operating in different climates, providing a variety of different average runtime hours, humidity, etc., and a larger variety of different equipment makes, models, and ages helps provide a more typical sampling of the installed base of packaged equipment in the US. The contractor shall document these aspects of the selected units (excluding specific references to equipment and location brand names) and describe how this selection achieves a typical sampling of equipment in the US. The contractor shall also document the maintenance program for the selected units and as much of their recent service history as possible.

At least half of the units should be large enough to have multiple refrigeration cycles and have at least 10 tons of capacity. The units should not have had any special attention leading up to the study for the past 2 years if they are at least that old.

In order to preserve generality and anonymity and to prevent competition between unit manufacturers, units are to be classified generically into categories including:

1. Age
2. Nominal capacity
3. Refrigerant
4. Type of expansion device
5. Compressor technology
6. Design EER
7. Electrical specifications

No make or model names or any other similar characteristics may be used to identify the units used in this study.

Task #3 - Development of a test plan

The contractor shall develop a test plan that includes:

- (1) A detailed description of the selected performance indices with selection justification. Refrigeration cycle efficiency and capacity estimates and indoor air quality as measured by the ventilation rate (CFM/sq.ft.) are required performance indices. They can be measured as a steady-state snap shot in one site visit without prolonged monitoring. The contractor should describe in detail how all performance indices are estimated including a discussion on required measurements, their accuracy, and the estimation errors of the performance indices. The unit's driving conditions including outdoor temperature and return air temperature and humidity must be measured and documented.
- (2) A detailed description of the measuring tool to be used. Describe measurement accuracy/sensitivity, calibration procedure, and what limits the estimates of the performance indices (e.g. one or more sensor accuracy, non-uniform air temperature and humidity distributions, and surface refrigerant temperature measurements).
- (3) A procedure for making measurements and estimating the performance indices. Include a budget for the time and costs associated with initial service technician training and per unit costs and time after the initial period is over. This work statement does not require monitoring. Snap shots of steady-state performance under the test conditions are acceptable.
- (4) A procedure for compiling and documenting the results of the initial assessment with a discussion of how conclusions will be drawn. Describe how the reference performance indices will be obtained.
- (5) A detailed description of how the units to be serviced will be selected and a justification for why this selection procedure best achieves the project goals. The contractor will service at least 75 units. At least half of them will be more that 10 tons with two refrigeration cycles.
- (6) A procedure for servicing the units and documenting the process as well as its impact on the performance indices.
- (7) A procedure for compiling and documenting the results of the measure/service/re-measure phase of the project with a discussion of how conclusions will be drawn.

The selected installations and test plan should be reviewed and approved by the Project Monitoring Subcommittee before continuing to task #3. A preliminary test plan should be included with the proposal anticipating as much detail as possible.

Task #4 - Performance Assessment

The contractor shall follow the approved test plan by:

1. acquiring and calibrating the test equipment,
2. measuring and documenting the performance of the units with the help of the owner's service provider,
3. selecting units to be repaired, and
4. following through with the service technician to document the repair procedure and resulting performance improvements.

Cooling tests must be performed under normal load conditions where the outdoor temperature is above 75°F and there is enough load so that the return air temperature is above 68°F during the test.

The initial assessment of each site will be completed and evaluated before going back to service selected units. Timing the servicing phase shall be no slower than the service provider's normal schedule for making repairs so the initial assessment is still valid at servicing time.

Task #5 – Preliminary reports

At predetermined times during the assessment/servicing of the units, the contractor will provide preliminary letter reports to the PMS describing how the tests are proceeding relative to the plan and recommending any changes needed to improve the results.

Task #6 - Documentation of Findings

The contractor shall provide a comprehensive final report that includes all measurements and documented service procedures and conclusions summarizing the performance improvements possible by properly servicing packaged units. The report should also relate the system performance and improvements to the particular type of package system and draw any conclusions that are supportable from the analysis.

DELIVERABLES

Progress and financial reports shall be made to the society through the Manager of Research (MOR) at quarterly intervals on, or before, the first day of January, April, June and October throughout the duration of the contract. The principal investigator shall report in person to the sponsoring TC at the annual and winter meetings. A preliminary report shall be prepared and submitted to the Manager of Research (MOR) and Project Monitoring Subcommittee (PMS) at the completion of tasks 1 and 2. A final report shall be prepared and submitted to the Manager of Research (MOR) and Project Monitoring Subcommittee (PMS) at the completion of all remaining tasks that covers all details of the research carried out as part of this project.

Following approval of the PMS and TC, the contractor will furnish copies of the final report as follows:

1. an executive summary suitable for wide distribution to the industry and public at large,
2. six bound copies of the final report,
3. one unbound copy of the report printed on one side only suitable for reproduction and
4. two copies on diskette or CD-ROM in ASCII and Microsoft Word format.

One or more technical papers shall be submitted in a form suitable for presentation at a society meeting. All papers shall be submitted through the MOR and not the publication editor. Additionally, a technical article suitable for publication in the ASHRAE RESEARCH JOURNAL may be requested and provided by the contractor on a voluntary basis.

LEVEL OF EFFORT

It is expected that this project will require twenty-four (24) months to complete at a cost of \$150,000 (\$125,000 ASHRAE + \$25,000 DOE). This estimate includes:

1. Three (3) person-months for the principal investigator and a total of twenty four (24) person-months for one or more supporting project staff.
 2. \$100 per unit for service contractors to document equipment performance during normally scheduled inspections on at least 375 packaged units at approximately 35 different sites.
 3. \$300 per unit for service contractors to work with the research staff to document the service process and the resulting performance improvements on at least 75 of the 375 units.
- \$25,000 co-funding by the U.S. Department of Energy is anticipated for this research project.

OTHER INFORMATION FOR BIDDERS

1. Bidders providing units operating in different climates, providing a variety of different average runtime hours, humidity, etc. will have an advantage. A larger variety of different equipment types and ages will also be favored. The bidder should discuss these aspects of the selected units and describe how this selection helps provide a typical sampling of the installed base of packaged equipment in the US. Including letters of support from the equipment owners and their service providers with the proposals is encouraged.
2. Bidders are expected to collaborate with maintenance organizations such that this project only funds the incremental costs of collecting and analyzing the data.
3. Funding is envisioned to occur under two contracts, one with ASHRAE for approximately \$125K and one with Brook Haven National Laboratory (BNL) for approximately \$25K. BNL provide a good faith intention to co-fund this research, but is not bound in any way until the details are worked out in the contracting process. The BNL contact is John Andrews (jandrews@bnl.gov). John may activity participate in the PMS as well as supervise the contract for BNL.

EVALUATION CRITERIA

The following weighting will be used in the selection of the Contractor:

1. **Contractor's understanding of the Work Statement, as revealed in the proposal: 20%**
2. **Quality of methodology proposed for conducting research: 20%**

The methodology should include a description and justification of the FDD methods that the bidder envisions evaluating. The degree to which the proposed methods represent the breadth of FDD methods that appear in the literature will be an important factor in this criterion. The methodology should also include a description of the evaluation procedure and criteria that the bidder anticipates using in the evaluation of the FDD methods.
3. **Contractor's capability in terms of facilities: 10%**
4. **Qualifications of personnel for this project: 20%**

Of special importance is the experience and qualifications of the personnel identified in the proposal related to FDD method development, particularly FDD applied to vapor-compression equipment.
5. **Student involvement: 5%**
6. **Probability of contractor's research plan meeting the objectives of the Work Statement: 20%**
7. **Performance of contractor on prior ASHRAE projects or other energy projects (No penalty for new contractors): 5%**

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RESEARCH TOPIC ACCEPTANCE REQUEST

Title: The Impact of Commissioning on Comfort

Research Category: Indoor Air Quality, Comfort and Health

Research Classification: Basic and Applied

TC/TG Priority: 4 (TC 9.9)

Estimated Cost:

Other Interested TC/TGs: 2.1

Possible Co-funding Organizations: Maybe BOMA? DOE?

Handbook Chapters to be Affected By Results of this Project: Fundamentals Ch. 8, Applications Ch. 41

State-of-the-Art (Background):

Standard 55 specifies the combinations of indoor space environment and personal factors that will produce thermal environmental conditions acceptable to 80% or more of the occupants within a space. Building codes do not typically require compliance with Standard 55, but it forms a component of the standard of care for HVAC system design.

ASHRAE's previous research includes RP #702, a field study on thermal comfort in hot humid climates (by MacQuarie University), RP #821, a field study on thermal comfort in a cold climate (by Concordia University), and RP#921, a field study on thermal comfort in hot arid climates (by Murdoch University). Richard deDear and Gail Brager compiled and analyzed numerous studies of thermal comfort in occupied buildings, mostly office buildings, in RP #884 "Developing An Adaptive Model Of Thermal Comfort And Preference." The data available from these studies may provide a baseline from current building populations for the variation in achievement of thermal comfort conditions.

Current ASHRAE research (1257-TRP) is aimed at quantifying the effects of temperature, humidity, air supply rate, and supply air quality on academic performance of school children. The proposed research fits in the context of this and other efforts to quantify the benefits of designing buildings to achieve thermal comfort conditions.

Advancement to the State-of-the-Art:

Advocates of building commissioning claim that one of the benefits of the approach is improved thermal comfort in the commissioned buildings. In effect, commissioning is expected to reduce the likelihood that the HVAC systems provided in a building will fail to achieve comfort conditions in a given space. If this effect is significant, the value of the comfort improvements associated with commissioning will likely exceed the value of most of its other claimed benefits.

Because there is a lack of hard statistical evidence on the benefits of commissioning, there is a need for ASHRAE-sponsored research to provide this information. A study targeted at comfort benefits will begin to address this need, but only if the sample size is large enough to identify a statistically significant difference between comfort in commissioned buildings and comfort in non-conditioned buildings.

Ideally, the study would define commissioning strictly in accordance with ASHRAE Guideline 1. In reality, commissioning practice is a continuum. For the purposes of this study, commissioning is an independent, binary variable. Researchers will have to agree on a threshold of practice above which a building will be

considered commissioned. This threshold will have to be set appropriately so that enough buildings meet it to permit statistical analysis. The dependent variable to be measured is the number of Standard 55 compliance errors measured during a site visit. This measurement would need to be normalized by number of zones measured.

The successful study will offer its key conclusion in the following form: "Commissioning a building to at least the described threshold of practice will reduce Standard 55 compliance errors by xx%."

Justification and Value to ASHRAE

Research that shows the connection between commissioning and comfort will enhance the value of both Guideline 1 and Standard 55. It will provide compelling evidence of the value of implementing commissioning, which will increase the number of practitioners who adopt Guideline 1. If the link between commissioning and comfort is real, this will in turn increase the number of buildings that successfully meet their comfort objectives. Furthermore, commissioning according to the Guideline requires documented design intent documents, which are likely to include an explicit comfort requirement—an opportunity for increased use of Standard 55.

Objective

The overall objective is to gather evidence on the connection between commissioning and thermal comfort.

The following tasks will be required:

- Agree on a level of commissioning practiced in enough buildings to permit statistical analysis.
- Identify a category of buildings from which both a sample of commissioned buildings and a control group of non-commissioned buildings can be drawn.
- Review data collected in previous studies (consult TC 2.1 for data), to calculate mean and standard deviation for the key research variable: number of Standard 55 compliance errors measured in a given building at a given time (normalized by number of zones measured in a given building).
- Use the standard deviation from previous studies to calculate a required sample size.
- Collect data on the key research variable for a sample of commissioned buildings and a control group of non-commissioned buildings
- Analyze the data and write a technical paper

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Revised: 21 January 2003

RESEARCH TOPIC ACCEPTANCE REQUEST (RTAR)

Title: Utilization of Random Sampling Technology in Performing Building Commissioning

Research Category: Operation and Maintenance Tools

Research Classification: Applied

TC/TG Priority: 3 (TC 9.9)

Estimated Cost: \$125,000.00

Other Interested TC/TGs: 1.5; 4.1; 4.7; 4.11

Possible Co-Funding Organizations: NIBS (National Institute of Building Sciences); BCA (Building Commissioning Association)

Handbook Chapters to be Affected By Results of this Project: HVAC Applications Chapter 42 "New Building Commissioning"

State-of-the-Art (Background):

The application of statistical techniques is well known in the manufacturing arena as well as many other areas. However, the application of this statistical approach to the application of Building Commissioning is new and misunderstood. Some organizations have had success in applying the technology, however, it has proved difficult to stimulate a larger segment of the profession to move toward this accepted principle: it is not necessary to test 100% of a population to determine the projected results, good or bad.

Advancement to the State-of-the-Art :

The advancement of the application would be beneficial from the ease and economical benefit to the commissioning practitioners and owners of buildings. This project would build on the lessons of statistical sampling in other industries, to document and test the technique as part of the building commissioning process.

Justification and Value to ASHRAE:

To provide adequate supported tested evidence the application of this statistical technique would benefit the practice of commissioning buildings and their components and systems. It is hoped that the research would lead to the development of a guide to using statistical sampling in commissioning. The guide would then become a special publication.

Objective :

The objective would be to test the statistical sampling approach in three commercial buildings: small, medium, and large. The project will:

1. Develop a documented understanding of how statistical sampling is used on actual projects, i.e., document the process itself;
2. Develop a documented understanding of how non-statistical sampling is used on actual projects, i.e., document the alternative process;
3. Compare the two options and give analysis of the benefits and disadvantages of each; and
4. Make recommendations as to when and how each should be applied.