AMERICAN SOCIETY OF HEATING, REFRIGERATING

AND AIR-CONDITIONING ENGINEERS, INC.

1791 Tullie Circle, NE Atlanta, GA 30329 404-636-8400

TC/TG/TRG MINUTES COVER SHEET

(Minutes of all meetings are to be distributed to all persons listed below

within 60 days following the meeting.)

TC/TG/TRG NO. TC4.11 DATE: January 1, 2001

TC/TG/TRG TITLE: Smart Building Systems

DATE OF MEETING: June 27, 2000 LOCATION: Minneapolis

Membership status as of 6/00

Members Present	Appt	Members Absent	Appt	Ex-Officio Members and Additional Attendance
Jim Braun	99-01	Arthur Dexter (int'l member)	96-00	Cliff Federspiel
Michael Kintner-Meyer	99-03	Todd Rossi	99-03	Jonathan West
John House	99-03	John Seem	99-03	Ian McIntosh

Steve Blanc	99-03	Patrick O'Neil (CM)	99-	Pornsok Songkakul
Mark Breuker	99-03	Mark Bailey (CM)	99-	Gene Strehlow
Barry Bridges	98-02	Tom Engbring (CM)	99-	Andy Suby
James Gartner	98-02	Ron Nelson (CM)	98-	John Scott
Philip Haves (int'l member)	96-00	Barry Reardon (CM)	99-	Damian Ljungquist
Rich Hackner	98-02	Meli Stylianou (CM)	99-	Srinivas Katipamula
John Mitchell	96-00			Paul Riemer
Les Norford	99-03			Mike Brambley
J. Carlos Haiad (CM)	96-			Robert Sonderegger
Curt Klaassen (CM)	99-			Bill Jones
George Kelly (CM)	99-			David Bornside
Carol Lomonaco (CM)	99-			Ryan Stroupe
David Kahn (CM)	96-			John Kettler
Brian Kammers (CM)	96-			David Branson
Jim Winston (CM)	96-			Geoff Levermore
Charles Culp (CM)	00-			Agami Reddy
Natascha Castro (CM)	99-			Osman Ahmed
Robert Old (CM)	00-			
Michael Brandemuehl (CM)	99-			

DISTRIBUTION:

ALL MEMBERS OF TC/TG/TRG

TAC CHAIMAN: Edward Gut

TAC SECTION HEAD: Byron Jones

ALL COMMITTEE LIASONS AS SHOWN ON TC/TG/TRG ROSTERS:

Program: Emil E. Friberg Manager Of Technical Services: Martin J. Weiland

Research: Sheila Hayter Manager Of Research: William W. Seaton

Standards: David Knebel Manager Of Standards: Claire B. Ramspeck

Journal: Chad Dorgan

TEGA: William Knight

Special Publications: Ramon Pons

ADDITIONAL DISTRIBUTION: Visitors listed above

ASHRAE TC ACTIVITIES SHEET

DATE: 1 Jan 2001

TC NO. TC4.11 TC TITLE: Smart Building Systems

CHAIR: J. Braun VICE CHAIR: J.W. Mitchell

TC Meeting Schedule

Location, past 12 mo.	Date	Location, next 12 mo.	Date
Dallas	2/8/00	Atlanta	1/30/01
Minneapolis	6/27/00	Cincinnati	6/26/01

TC Subcommittees

Subcommittee	Chair
Technology Development	T. Rossi
Communications and Integration	M. Kintner-Meyer
Testing and Evaluation	J. House
Research	G. Kelly
Program	C. Lomonaco
Standards	R. Hackner
Handbook	M. Bailey

Research Projects

1043-RP Fault Detection and Diagnostic Requirements and Evaluation Tools for Chillers

1139-RP Development and Comparison of On-Line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment

Long Range Research Plan (as approved by TC 4.11 at the Seattle Annual Meeting)

Rank	Title	W/S Written ?	TC Approved ?	To RAC ?
1	Evaluation and Assessment of Fault Detection and Diagnostic Methods for Centrifugal Chillers – Phase II	Yes	Yes	No
2	Integrated Control for Building Services	Yes (3rd draft)	Yes	Yes
3	Field Performance Assessment of Package Equipment to Quantify the Need for Monitoring, FDD, and Continuous Commissioning	Yes (1st draft)	No	No
4	Resolving Discrepancies Between Multiple, Hierarchically-Related, Fault Detection and Diagnostic Systems	Yes (1st draft)	No	No
5	Prototyping and Field Testing of Utility – Consumer Information Services	Yes	No	No
6	Benchmarking of FDD Tools for AHU's	No[1]	No	No
7	Development of Fault Detection and Diagnostics for Sensor Failures	No[1]	No	No

1. One-page project descriptions have been written.

Handbook Responsibilities - none

Standards Activities - none

Technical Papers from Sponsored Research - none

TC Sponsored Symposia (past 3 years, present, planned)

Title	Date (Given or Planned)
HVAC System Fault Detection And Diagnosis (Kelly)	Philadelphia, 1/97
Controlling Outdoor Air Ventilation for 62-1989 (Atkinson; TC 1.4 lead with TC4.11 as co-sponsor)	Toronto, 6/98
Fault Detection and Diagnostics - Learning from Building Operations (Ahmed; TC4.6 lead with TC4.11 as co-sponsor)	Chicago, 1/99
FDD Methods and Evaluation Techniques (Castro)	Chicago, 1/99
Recent Results from Fault Detection and Diagnostic Research (Norford)	Atlanta, 1/01
Recent Results from Fault Detection and Diagnostic Research II (House)	Cincinnati, 6/01

TC Sponsored Seminars (past 3 years, present, planned)

Title	Date (Given or Planned)
The Utility/Building Interface: Redefining an Old Relationship (Blanc)	Boston, 6/97
BACnet in the Real World (Bushby; TC 1.4 lead with SSPC 135 BACnet and TG4.SBS as co-sponsors)	Boston, 6/97
Automated Response To Real Time Pricing (Kammerud)	San Francisco, 1/98
The Delivery of New Energy Services under Electric Industry Deregulation (Nordham; TC4.11 lead with TC 1.4 as co-sponsor)	San Francisco, 1/98
Benefits of Integrating HVAC with Non-HVAC Systems (Newman; TC 1.4 lead with SSPC 135 BACnet and TC4.11 as co-sponsors)	San Francisco, 1/98
Impact of Electromagnetic Interference on Control Systems and Global Standards (Coogan; TC 1.4 lead with TC4.11 and TC 1.9 as co-sponsors)	San Francisco, 1/98
New Platforms and Gateways for Connecting into Building Management Systems (Phelan)	Toronto, 6/98
The Latest Control Communications Technologies (Gartner; TC 1.4 lead with TC4.11 as co-sponsor)	Toronto, 6/98
Customer Experience with Real-Time Pricing Electric Rates (Kintner-Meyer)	Chicago, 1/99

A Peek at a Real BACnet Building… GSA 450 Golden Gate BACnet Pilot Project (Blanc; TC4.11 lead, with TC1.4 co-sponsor)	Seattle, 6/99
State-of-the-Art Control Devices, Sensors, Motors and Intelligent Actuators (Atkinson; TC1.4 lead with TC1.2, SSPC 135 BACnet, and TC4.11 as co-sponsors)	Seattle, 6/99
Practical Experience Using DDC Systems for HVAC Commissioning and Continuing Evaluation (Bridges; TC1.4 lead with TC1.7, TC4.11 and TC9.9 as co-sponsors	Dallas, 2/00
Deregulation for Dummies (Haiad)	Dallas, 2/00
Evaluating the Benefits of Fault Detection and Diagnostics	Dallas, 2/00
Providing for the Most Important Part of a Smart Building Control System: People (Bridges)	Minneapolis, 6/00
Control Systems Integration, What's Happening with Practical Open-Architecture Solutions (TC 4.11 co-sponsor)	Minneapolis, 6/00
Deregulation and Energy Efficiency in the State of California (Haiad)	Minneapolis, 6/00
Diagnostics from an Operations Perspective, Needs and Experiences (Rossi)	Atlanta, 1/01
Adding New Life to Old System-Control Retrofit Case Studies (TC 1.4 lead)	Atlanta, 1/01
Maximizing Facility Performance with Computerization and Controls	Cincinnati, 6/01
FDD for Operations People, A Perspective on Using FDD Tools (Rossi)	Cincinnati, 6/01
Intelligent Agents What They Can Do For Your Building (Ahmed)	Cincinnati, 6/01
IFC’s for Building Operations (Kintner-Meyer)	Cincinnati, 6/01
Wireless DDC Systems (TC 1.4, Bridges lead)	Cincinnati, 6/01

TC Sponsored Forums (past 3 years, present, planned)

Title	**Date** **(Given or Planned)**
What Are The Priorities For On-Line HVAC Fault Detection And Diagnosis? (Haves)	Philadelphia, 1/97
Exactly What Do Smart Buildings and Control Systems Mean Today? (Newman and Kelly; TC 1.4 lead with TG4.SBS and TCs 1.5 and 4.6 as co-sponsors)	Boston, 6/97

Occupant Driven Interactive Building Control (Bridges; TG4.SBS lead with TC 1.4 as co-sponsor)	San Francisco, 1/98
Now That We Have the BACnet Standard Protocol, are DDC Programming Language and Application Standards Next? (Nesler; TC 1.4 lead with SPC 135 BACnet and TG4.SBS as co-sponsors)	San Francisco, 1/98
CAB and BACnet Similarities and Dissimilarities (Newman; TC 1.4 lead with SPC 135 BACnet and TC4.11 as co-sponsors)	Toronto, 6/98
How Can We Accomplish Multi-Vendor Interoperability in Existing Facilities? (Coogan; TC1.4 lead with SPC 135 BACnet and TC4.11 as co-sponsors)	Chicago, 1/99
What's ASHRAE's Role in Deregulation? (Blanc)	Seattle, 6/99
Measuring the Benefit of Fault Detection and Diagnostics (Breuker; TC4.11 lead with TC1.4 as co-sponsor)	Seattle, 6/99
Should ASHRAE be involved in IFC and XML (Brambley)	Cincinnati, 6/01
New Sensor Technology, Other New Technologies (Kintner-Meyer)	Cincinnati, 6/01

TC Sponsored Public Sessions (past 3 years, present, planned)

Title	**Date** **(Given or Planned)**
Designing, Installing or Operating Engineers - Who Will Most Impact New Millenium Facilities? (Gartner; TC1.4 lead, with TC9.9 and TC4.11 as co-sponsors)	Chicago, 1/99

Journal Publications (past 3 years, present, planned)

Title	**When published**
None	

Minutes summary and activities sheet submitted by: Mark Breuker, TC4.11 Secretary

TC4.11 Minutes

Minneapolis: Tuesday, January 27, 2000

Roll Call, Introductions, Announcements, Minutes

Chairman Braun called the meeting to order at 3:30 p.m. A roll call showed that a quorum was present. In attendance at the meeting were Braun, Kintner-Meyer, House, Blanc, Breuker, Bridges, Gartner, Haves, Hackner, and Mitchell, for a total of 11 of 13 voting members. Braun distributed the minutes from the Dallas meeting, the agenda (the call-to-meeting letter and the agenda are in Appendix A), and the revised scope and organization of the committee. He then asked for introductions.

Carl Speich, the outgoing research liason for TC 4.11 introduced Sheila Hayter, the new research liason.

Braun requested comments for minutes submitted from Dallas meeting. It was noted that the minutes showed the incorrect roster for the Dallas and Minneapolis meeting, with new voting members Klaassen and Haiad officially beginning in July 2000. It was moved (House) and seconded (Blanc) to accept the minutes from the January 2000 meeting. The motion was approved unanimously.

Braun mentioned:

- Work statement must be submitted with a cover letter from the chair in the future.
- With the handbook going electronic, it will now be updated every year. Blanc noted that the paper copies will continue to be printed and distributed every 4 years.

- Program packets are due on August 4. They must be signed by the TC chair and prefer to mail them.
- There are a number of student receiving ASHRAE grant-in-aid awards for TC-related work. The amount is $7500 and an extra $1500 if the student publishes a paper.

Braun then asked for updates from the subcommittee chairs.

Technology Development Subcommittee (Rossi)

Rossi was unable to attend the committee meeting so Braun gave the update in his place.

Fault Detection and Diagnostic Requirements and Evaluation Tools for Chillers (1043-RP).

House reported that the majority of the work for this project has been completed including the literature and manufacturer's survey, the steady-state model, and experimental data collection. The dynamic model and documented MATLAB code must still be completed before the project is approved. They are planning a meeting in September to review the dynamic model. It was moved (House) and seconded (Hackner) to grant no-cost extension to Purdue University as follows: "TC 4.11 recommends that ASHRAE extend a no-cost extension to Purdue University for completion of 1043-RP until 2/15/2001". Vote was passed 10 in favor, none opposed, 1 abstain.

Development and Comparison of On-Line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment (1139-RP). Breuker gave an update on the progress by Drexel University on this project. Drexel reported that they had started data collection but would have only one season of chiller data to use rather than two, as stated in the original proposal. The Drexel team presented significant progress on the types of models being studied as well as some initial results obtained by testing these models with existing steady-state data.

Evaluation and Assessment of Fault Detection and Diagnostic Methods for Centrifugal Chillers – Phase II. This work statement describes a second-phase project intended to follow 1043-RP. John House made significant progress in updating the work statement to show how it fit into the overall research plan. Phase I includes the work being completed in RP-1043. The work in Phase II would focus on existing FDD methods and

assess them using the tools that were developed in Phase I. It would include:

Task 1: Literature review on assessing the effectiveness

Task 2: Develop procedures for evaluating and comparing

Task 3: Select FDD Methods for Evaluation

Task 4: Adapt and implement

Task 5: Assess performance

Task 6: Recommend FDD Methods for Real-time implementation.

Phase III would implement the methods via field testing.

Based on comments from the Dallas meeting, the level of effort was increased to $120,000.

Norford moved (Bridges 2nd) to approve the work statement for Phase II of the FDD Methods for Centrifugal Chillers and to add a cover letter to RAC which requested that it be held until 1043 is approved. Vote was 10 in favor, 0 opposed, chair abstain.

Volunteers for the PES included, Phil Haves (chair), Norford, Katipamula, and Klassen. Kelly noted that there must be a representative from RAC on the PES.

Development of FDD for Sensor Failures. Braun reported that Haves is working to revise the work statement for sensor failures and expects to have something ready for Atlanta.

Kintner-Meyer suggested a work statement on intelligent sensors and embedded technology issues. DOE is funding projects for industrial applications. Braun encouraged anyone interested in this topic to assist Kintner-Meyer draft a work statement for Atlanta.

The minutes of the subcommittee meeting are in Appendix C.

Communications and Integration Subcommittee (Kintner-Meyer)

There is one current work statement being developed by this committee. It was developed two years ago and addresses the problem of prototyping and testing of utility/customer communication services. A data model which described load monitoring, RTP, weather, energy efficiency, demand bidding was developed under previous work (RP-1011). The current work statement proposes to extend the work

- Phase 1: Simulation of the communication
- Phase 2: Field trial

The committee believed that this would be an extension of the BACnet standard. To gain support Kintner-Meyer gave a presentation to the BACnet committee on Sunday and is working with SteveBushby to shepherd through the committee. Once some acceptance by the BACnet committee has been received, the committee agreed to vote on the work statement. Steve Blanc agreed to work with Kintner-Meyer on this work statement to have it ready for Atlanta.

The minutes of the subcommittee meeting are in Appendix D.

Testing and Evaluation Subcommittee (House)

Integrated Control for Building Services

House presented a revised version of the work statement on integrated controls for building services. The work statement would produce a survey of stakeholders in the buildings to see what is being done in terms of integration and then a more detailed assessment of targeted buildings. Blanc would encourage bidders to partner with professional organizations. Others noted that it might want to include UL 864 – Fire and Security as well as local

codes and how they would affect the integration process.

The committee considered including international buildings and the problem of building diversity and how this could affect the sample size. Srinivas agreed to forward to ARI for possible interest. Osman and Brambley agreed to help rework the work statement for Atlanta.

Field Performance Assessment of Package Equipment to Quantify the Need for Monitoring, FDD, and Continuous Commissioning. Rossi did a significant amount of work revising this work statement to be ready for submission for consideration by the committee. The work statement focuses on the idea of performing a large-scale field study on how rooftop equipment is really performing and then a smaller number where the units are fixed and results are quantified. TC 9.9, TC 1.4, and TC 1.7 are also very interested in this work. The committee was very supportive of moving this work statement forward ASAP. Charles Culp volunteered to help prepare if for a vote in Atlanta.

Resolving Discrepancies Between Multiple, Hierarchically-Related, FDD Systems.

Mike Brambley agreed to scale back the work statement and present in Atlanta.

There is an RTAR on Benchmarking of FDD tools for air handling units. Les Norford and Mike Brambley volunteered to help move this along.

The minutes of the subcommittee meeting are in Appendix E.

Research Subcommittee (Kelly)

Kelly presented the research plan for the coming year, included in Appendix G and summarized as follows:

Priority	Project	Contributors	Status
1.	Evaluation and Assessment of Fault Detection and Diagnostic Methods for Centrifugal Chillers – Phase II	John House Srinivas Katipamula	Approved in Minneapolis 10-0-0 (CNV). Submit to RAC AFTER Phase I is completed.
2.	Integrated Control for Building Services	Mike Brambley John House Ron Kammerud John Mitchell	Original TRP Rejected by Tech. Council. Decided in Minneapolis to rework and reconsider in Atlanta. Explore possible ARTI funding. (Needs cover letter to RAC saying this is "second attempt".)
3.	Field Performance Assessment of Package Equipment to Quantify the Need for Monitoring, FDD, and Continuous Commissioning	Todd Rossi Mark Breuker Jim Braun	Draft WS exists. Todd Rossi will revise and complete BEFORE Atlanta meeting. Possible TC vote in Atlanta.
4.	Resolving Discrepancies Between Multiple, Hierarchically-Related, Fault Detection and Diagnostic Systems	Mike Brambley Todd Rossi	Mike Brambley will scale back scope and have revised WS by Atlanta.
5.	Prototyping and Field Testing of Utility – Consumer Information Services	Michael Kintner-Meyer Marty Burns Chuck McParland	In the hands of an "Action Committee" set up by SSPC 135. Reconsider in Atlanta.
6.	Benchmarking of FDD Tools for AHU's	John House Les Norford	An RTAR exists.
7.	Development of Fault Detection and Diagnostics for Sensor Failures	Phil Haves Arthur Dexter	One page description exists. Two page Issues Paper handed out by Phil

	Haves in Minneapolis.

Blanc moved (House 2nd) to accept the research plan as presented by Kelly. Vote was 10 in favor, 0 opposed, chair abstain.

Program Subcommittee (Lomonaco)

Lomonaco reviewed the program for the Atlanta meeting. The committee decided to move forward with one symposium due the timing. Norford accepted volunteers to help with paper reviews. Osman reported to have three speakers for the intelligent building agent seminar. The TC1.5 chair attended the meeting (David Branson, djbranson@csg.net) asking for co-sponsors for few different data modeling topics

o IFC – Industry foundation classes – data models

o XML – extendable markup language – extension of HTML

They are looking to do a seminar on the broad benefits of these data modeling activities. Brambley and Kintner-Meyer agreed to help out.

It was moved (House) and seconded (Bridges) to approve the program for Atlanta as presented by Lomonaco. The motion passed by unanimous voice vote. Programs as subsequently approved by ASHRAE are tabulated at the beginning of these minutes.

The

Old Business

ASHRAE reported that they would not be providing web-hosting services for the TCs. They are continually reassessing this and we are welcome to

make a proposal to change the policy. Jim mentioned that the minutes and agenda can be on ASHRAE site. Rich mentioned that the work statements are also on the web already.

Braun has drafted a vision statement for 4.11 handbook chapter and will share this with the TC in Atlanta. Braun to email a copy to the entire TC with the minutes.

Kelly and Bridges suggested that we have a brainstorming session to help establish some new areas of focus for the TC.

New business

Mike Brandemuehl presented a work statement from TC 1.4 on the Dymanic Modeling of Chilled Water Cooling Coils. Haves moved (Bridges 2nd) to co-sponsor the work statement. Vote was 10 in favor, 0 opposed.

Adjournment

It was moved (House), seconded (Bridges), and unanimously voted to adjourn at 6 p.m.

Appendices

1. Call to Meeting and Agenda

2. Scope and Organization
3. Technology Development Subcommittee Report
4. Communications and Integration Subcommittee Report (not available yet)
5. Testing and Evaluation Subcommittee Report
6. Research Plan and Activities
7. List of Subcommittee Attendees
8. Program Subcommittee Report – not provided by subcommittee chair

Appendix A.

Call to Meeting and Agenda

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

1791 Tullie Circle, NE, Atlanta, Georgia 30329-2305 404-636-8400 | Fax 404-321-5478

Reply to: Jim Braun

Ray W. Herrick Labs

Purdue University

W. Lafayette, IN 47907

(jbraun@ecn.purdue.edu)

June 19, 2000

Dear TC 4.11 Member, International Member, or Corresponding Member,

The **TC** on Smart Building Systems and its subcommittees will meet in Minneapolis according to the following schedule:

TC 4.11 Tech. Development Sunday (6/25) 3:00-4:00p Hyatt/Lake Superior A (5)

TC 4.11 Comm. & Integration Sunday (6/25) 4:00-5:00p Lake Superior A

TC 4.11 Testing & Evaluation Sunday (6/25) 5:00-6:00p Lake Superior A

TC 4.11 Smart Building Systems Tuesday (6/27**) 3:30-6:00p Hyatt/Lake Calhoun (5)**

TC 4.11 PMS 1139-RP (OVH) Sunday (6/25) 6:00-8:00p Lake Superior A

TC 4.11 PMS 1043 RP (OVH) Monday (6/26) 2:00-3:00p MCC/101E (1)

The TC is the sponsor or co-sponsor for the following sessions in Minneapolis:

Seminar 20: Control Systems Integration, What's Happening with Practical Open-Architecture Solutions, Monday, 6/26/2000 - 10:15 AM, Room: 101 GH, Gaylen V. Atkinson

Seminar 32: Deregulation and Energy Efficiency in the State of California, Tuesday, 6/27/2000 - 10:15 AM, Room: 101 GH, Chair: J. Carlos Haiad

Seminar 40: Providing for the Most Important Part of a Smart Building Control System: People, Wednesday, 6/28/2000 - 10:15 AM, Room: 101 GH, Chair: Barry Bridges

(See the ASHRAE Program Booklet to confirm session locations and times.)

Attached is a draft agenda for the full TC 4.11 committee meeting in Minneapolis. I hope to see you all there.

Jim Braun

Chairman, TC 4.11

ASHRAE TC 4.11, Smart Building Systems

2000 Annual Meeting, Minneapolis

AGENDA

Location: Hyatt/Lake Calhoun (5)

Date: Tuesday, June 27, 2000

Time: 3:30 - 6:00 p.m.

1. Roll call and introductions

2. Approval of Minutes from Dallas

3. Announcements

4. Technology Development Subcommittee Report (Todd Rossi)

1043-RP, Fault Detection and Diagnostic (FDD) Requirements and Evaluation Tools

for Chillers (John Seem)

1139-RP, Development and Comparison of On-Line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment (Mark Breuker)

Draft Work Statements

Program plans

Other activities

6. Communications and Integration Subcommittee Report (Michael Kintner-Meyer)

Draft Work Statements

Program plans

Other activities

7. Testing and Evaluation Subcommittee Report (John House)

Draft Work Statements

Program plans

Other activities

8. Research Subcommittee Report (George Kelly)

New Work Statements

Research Plan

9. Program Subcommittee Report (Carol Lomonaco)

Plans for Atlanta (1/2001)

Plans for Cincinnati (6/2001)

Plans for future meetings

10. TC 4.11 Website (Rich Hackner)

11. Old business

12. New business

13. Adjournment

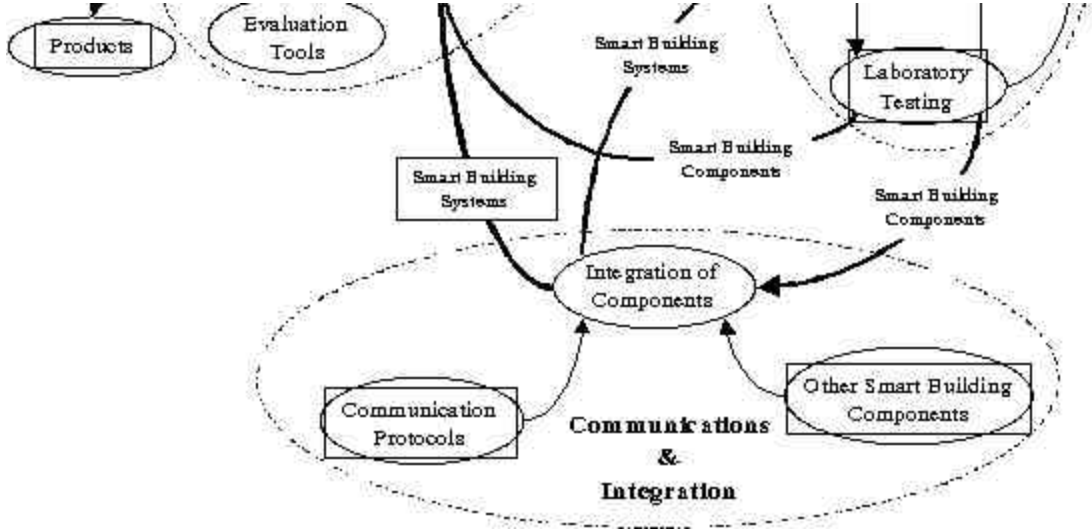
Appendix B.

TC 4.11, Smart Building Systems Scope and Organization

July 1, 1999

Overall Committee Scope

The Technical Committee on Smart Building Systems (SBS), TC 4.11, is concerned with the development and evaluation of technologies that could enable the widespread application of smart building systems. “Smart” buildings should take advantage of automation, communications, and data analysis technologies in order to operate in the most cost-effective manner. This implies integration of building services such as HVAC, fire, security, and transportation; the automation of many of the operation and maintenance functions traditionally performed by humans; and the interaction with outside service providers such as utilities, energy providers, and aggregators. Currently, three subcommittees form the backbone of the TC’s activities: technology development, communications and integration, and testing and evaluation. The scope and activities of these subcommittees loosely follow the product development process as depicted in following flow chart and as defined in the following sections.



Technology Development Subcommittee

The Technology Development Subcommittee is concerned with research issues associated with the development of emerging smart building technologies such as (but not restricted to) automated commissioning, performance monitoring, fault detection and diagnosis, optimal maintenance scheduling, and optimal control. The primary outcome of research endorsed by this subcommittee is expected to data and models that enable development of the technologies and comprehensive methods that are the basis of the technologies. An integral part of the development process is simulation and laboratory testing. Proposed designs must be tested and modified prior to field evaluation. Specific research topics that are ongoing or planned under this subcommittee are:

- 1043-RP Fault Detection and Diagnostic (FDD) Requirements and Evaluation Tools for Chillers
- 1139-RP Development and Comparison of On-Line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment
- Fault Detection and Diagnostic Methods for Chillers
- Development of Fault Detection and Diagnostics for Sensor Failures

Communications and Integration Subcommittee

The Communications and Integration Subcommittee is concerned with research issues associated with enabling the seamless interaction of smart building components and services. An important aspect of this work is to identify the information that is necessary to support smart building technologies, and to identify the requirements of communication protocols to support the exchange of this information between different building services, between buildings and utilities, between multiple buildings, with outside service providers, etc. Specific research topics that are ongoing or planned under this subcommittee are:

- 1011-RP Utility/EMCS Communication Protocol Requirements (Completed: 6/99)
- Resolving Discrepancies Between Multiple, Hierarchically-Related, Fault Detection and Diagnostic (FDD) Systems
- Prototyping and Field Testing of ASHRAE's Utility Consumer Interface Models (UCIM)

Testing and Evaluation Subcommittee

The Testing and Evaluation Subcommittee is concerned with research issues associated with assessing the benefits (market potential) and performance of smart building technologies. 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. Specific research topics that are ongoing or planned under this subcommittee are:

- 1020-RP Demonstration of Fault Detection and Diagnostic Methods in a Real Building
- Integrated Control for Building Services
- Quantifying the Benefits of HVAC Equipment Monitoring and Fault Detection
- Multi-Application Comparison of Fault Detection and Diagnostic Methods

Appendix C.

TC4.11 Technology Development Subcommittee Meeting

Minutes
Minneapolis: June 25, 2000 3:00-4:00 p.m.

1. Srinivas Katipamula and John House provided an overview of a work statement entitled Evaluation and Assessment of Fault Detection and Diagnostic Methods for Centrifugal Chillers – Phase II. The work statement was considered at length at the Dallas meeting and the comments led to the following changes:

· A roadmap outlining how the three phases (Phase I is 1043-RP) of the project fit together and how they relate to 1139-RP.

· Although this project seeks to use existing FDD technologies, the wording was changed to recognize that some effort would be necessary to adapt and implement FDD methods found in the literature.

· The bidder/contractor should be given more flexibility regarding the methods implemented. A minimum number (four) of methods was specified and the wording also requires the bidder to address the breadth of methods in the literature; however, the specific classes of methods are not dictated.

· Evaluation criteria was added to the Other Information for Bidders section to assist bidders and proposal evaluators.

There was some discussion of the timing of this work statement because the Phase I work (1043-RP) is ongoing. A no-cost extension will likely be needed for 1043-RP, so it is uncertain when the final report will be available. The plan is to suggest approval of the work statement at this meeting, but not submit it to RAC until the 1043-RP final report is approved. George Kelly will discuss this with Carl Speich to see how we should proceed.

Technical comments regarding the work statement included the following:

Jim Braun

· WS should reference literature review of FDD methods in Phase I because several of these studies attempted to assess the performance of their FDD methods.

· Should the WS specify an implementation platform for the FDD methods such as the NIST FDD Test Shell, Matlab, etc.

The ensuing discussion led to the conclusion that the wording should be changed in the Other Information for Bidders to require bidders to explain the implementation platform and documentation procedures for the FDD methods.

John Mitchell

· The wording should be changed in Task 3 to require contractors to investigate “all” the faults identified and studied in Phase I.

ACTIONS: John House will make minor revisions to the WS prior to the full committee meeting. George Kelly will determine how to proceed with the WS with regard to 1043-RP.

2. Mike Brandemuehl discussed a WS entitled Dynamic Modeling of Chilled Water Cooling Coils. The WS was submitted by TC 4.6 and rejected by RAS. RAS did not appear to understand why this work was needed and who would use it. The justification is being revised to address this lack of understanding. Discussion indicated that dynamic models do not exist (particularly in the open literature) and are needed by controls manufacturers, FDD researchers, etc. Representatives of the controls manufacturers indicated they could probably get letters of support for the WS.

ACTION: Subcommittee will recommend the full committee vote to co-sponsor the WS.

3. Review of Ongoing Projects

· 1043-RP: Development and Evaluation of FDD Methods for Chillers – Phase I

Jim Braun gave a short review of the project. The transient models are not yet complete, but it is anticipated that they will be completed in the next two to three months.

· 1139-RP: Development and Comparison of On-Line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment

Mark Breuker gave a short summary of the project status. The project appears to be progressing according to schedule.

4. Phil Haves discussed an outline for a WS on sensor FDD. The basic approach that Phil envisioned is to use conservation equations to diagnose sensor faults. Phil was looking for comments regarding whether this was the right approach to describe in the WS. Comments from the subcommittee included the following:

· Rich Hackner mentioned that some protocols have been developed for metered data that might be helpful.

· Osman Ahmed noted that fault detection of sensor problems is easier than diagnosing the problems. Osman also noted that we need to be careful about the location of the sensor.

· Phil Haves asked if inappropriate sensor type is in the scope of this work.

Other general comments included:

· Should we validate existing methods or try to develop new methods?

· We might want to look at commissioning information to see if there are existing techniques to adapt.

ACTION: Phil Haves and Arthur Dexter will expand the outline for the Atlanta meeting.

Submitted by:

John House

Appendix D.

TC4.11 Communications and Integration Subcommittee Meeting

Minutes
Minneapolis: June 25, 2000 4:00-5:00 p.m.

- Michael Kintner-Meyer reviewed work statement "Prototyping and Testing of Utility/Customer Information Services"
- Michael presented work statement to BACnet committee. They now have an action item to review 4.11 report.
- They will review work statement and vote to support. Michael would like a letter of support.
- Barry reviewed the discussion in the BACnet subcommittee. There was interest. There were comments on the feedback of rate structure.
- BACnet extention is necessary to adopt this technology. Also issue about integration to automated meter reading.
- Time scale… BACNet meeting coming up this summer and fall… then discuss more in Atlanta.
- Michael asked for contributors. Bob Old (Siemans) offered.
- Michael asked about new work statement ideas
- Michael suggested wireless controls and sensors. Is there interest? Are they cost effective
- Breuker wondered how this would lead to a work statement
- Blanc suggested a seminar. He expressed concerns about reliability inside metal buildings.
- Kelly offered IFC for HVAC equipment related to XML. Is this appropriate for ASHRAE? IFC describes the components in the buildings for used in different phases in the building life cycle (e.g. cooling coils, fins per inch).

- Osman discussed new TC 4.12. Major stumbling block for FDD and related technology is the configuration information. Need to get an automated way for the architects to input data directly into a build that can be used during the operational phase.
- George: Need this product to move forward in smart operations of buildings.
- Blanc + others: Need program, seminar or forum or both, providing background information. (Osman,Osman can get people from STEP, Dave Robin automated logic, Osman has a contributor from architect community, Hitchcock). George: can get contributors to talk about needs. George: Forum should be "Should ASHRAE be involved?". Would like a seminar followed by a forum in Atlanta. Blanc: have seminar and forum with same title calling it part I and part II. Michael offered to chair the seminar. Michael will ask Steve Bushby to chair the forum, otherwise he will find someone else in time for Carol's deadline.
- TC 1.5 is also working on this topic. Also… simulation and controls TCs.
- House: Facility Dynamics has product (COMIT) for commissioning that is not full data model, but moves toward this area.
- Michael: industry news, brown out in CA is leading to efforts to control loads. He described a pilot program for load shedding. Carlos: there is a new tariff for voluntary load shedding for bidding over the web.
- There is another seminar in Atlanta that Osman is chairing. "Intelligent agents: What they can do for your building". Helps make decisions for you by finding synergistic relationships. Three papers: PNNL, a CA company, plus another. There was a title change. Osman is looking other contributors. Need building applications.

Appendix E.

TC4.11 Testing and Evaluation Subcommittee Meeting

Minutes
Minneapolis, June 25, 2000 5:00-6:00 p.m.

Discussion on workstatement titled "Integrated Control for Buildings Services".

John House discussed the workstatement and indicated the main changes from the last version, which are:

- The cost of the workstatement was increased to $200,000
- Utility companies and BOMA (Building Owner and Management Association have expressed interest in assisting with the survey.

This workstatement had previously been successfully bid and TC 4.11 selected a bidder. The recommendation by TC 4.11 was eventually rejected by Tech. Council. This current version of the workstatement is a revised version of the previously bid workstatement.

Steve Blanc provided his assessment of the previous workstatement, indicating it was too open-ended and should have been more market-oriented. It is premature at this stage of the analysis of integrated controls for buildings services to involve scientist/researchers. Providing a market overview is the primary focus of the workstatement. Furthermore, Steve mentioned that the effectiveness analysis should not be in the workstatement. Suggestion was to eliminate the effectiveness issue altogether.

John House mentioned that PECI suggested that the cost of the workstatement of 150k-200k is appropriate for this survey. ARTI expressed interest in cost sharing. Srinivas indicated the ARTI is still interested to cost share. John promised to integrate all comments for the vote at the full TC meeting.

Discussion on "Field Performance Assessment of Package Equipment of Quantify the Need for Monitoring, FDD, and Continuous Commissioning Technology".

Todd Rossi discussed the workstatement titled: "Field Performance Assessment of Package Equipment of Quantify the Need for Monitoring, FDD, and Continuous Commissioning Technology."

TC 9.9 is co-sponsoring this workstatement. There are two approaches for assessment.

1. Perform research and get as much information with little regard to cost
2. Perform assessment with cost considerations, i.e. target the most cost-effective analysis that promises the biggest return on investment.

The feedback from TC 9.9 is to suggest the 1st approach at this stage of the science and technology.

Todd requested input by TC 4.11 members to finalize this workstatement for voting at the full TC 4.11 meeting.

Rick Hackner suggested to review the previous work by others. Steve Blanc suggested the workstatement be more specific on the size of the rooftop equipment. Suggested was to specify that the equipment to be investigated be more than 10-ton packaged units with two or more stages. Also discussed was the significance of climate, as it has an effect on equipment runtime and exposure to harsh environments such as salty sea-air.

Srinivas suggested to add to the list of benefits of the workstatment that the results of this project could be be used by the industry to prioritize their maintenance and diagnostics efforts.

Discussion on workstatement titled: "Multiple Hierarchical Diagnostics for HVAC systems".

Mike Brambley felt that there was not sufficient support in the TC at this point to move this workstatement forward. George Kelly entertained the idea to scale down the workstatement and to articulate what the value of this project would be. Mike will down-scale this workstatement for discussion at the next ASHRAE meeting.

Discussion on a Research Topic Acceptance Request) for a workstatement titled: "Benchmarking of FDD Tools for AHUs."

John House reported on an RTAR he has written as a follow-up to 1020-RP "Demonstration of Fault Detection and Diagnostics Methods in a Real Building". The objective is to perform a larger scale comparison of numerous AHU FDD methods. The study would be performed by a contractor who was not involved in the development of the methods.

Submitted by

Michael Kintner-Meyer

Appendix F.

TC 4.11 Smart Building Systems

Research Plan and Activities

July 2000

Research Objectives: The long-term goal of TC 4.11 is to conduct research on topics that will lead to the development and application of "smart" building systems. "Smart" buildings of the future will take advantage of automation, communications, and data analysis technologies in order to operate in the most cost-effective manner. A smart building would most likely have fully integrated control of building services such as HVAC, fire, security, and transportation. Integrated systems would reduce initial costs and could be "supervised" so as to meet the primary objectives of comfort, safety, and performance at minimum operating cost. In addition, the integration of the hardware and software for operation and monitoring of equipment would lead to reductions in support staff needs and improved equipment reliability. Further cost reductions and reliability improvements would be possible through the integration of automated techniques for detection and diagnosis of equipment faults. Ultimately, "smart" building systems could facilitate the use of "remote" support staff that operates, monitors, and maintains a number of different buildings from a centralized location. At this higher level, a smart building might communicate and inter-operate with other smart buildings for the purpose of load aggregation and centralized control and with outside service providers, such as utilities, energy providers, aggregators, and newly developing companies providing fault detection, automated commissioning, optimization, and other innovative services. In addition to the savings in operating costs associated with "smart" buildings, other benefits include energy conservation and enhanced occupant safety and comfort.

Three subcommittees form the backbone of the TC's activities: Technology Development, Communications and Integration, and Testing and Evaluation. The Technology Development Subcommittee is concerned with research issues associated with the development of emerging smart building technologies such as automated commissioning, performance monitoring, fault detection and diagnosis, optimal maintenance scheduling, and optimal control. The primary outcome of research endorsed by this subcommittee is expected to be data and models that enable development of the technologies and comprehensive methods that are the basis of the technologies. The Communications and Integration Subcommittee is concerned with research issues associated with enabling the seamless interaction of smart building components and services. An important aspect of this work is to identify the information that is necessary to support smart building technologies, and to identify the requirements of communication protocols to support the exchange of this information between different building services, between buildings and utilities, between multiple buildings, with outside service providers, etc. The Testing and Evaluation Subcommittee is concerned with research issues associated with assessing the benefits (market

potential) and performance of smart building technologies. 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.

Current TC 4.11 research includes projects in many of these areas. The evaluation of communication protocol requirements between utilities and energy management systems was addressed in the recently completed research project 1011-RP. Fault detection and diagnostics (FDD) is being considered for a number of different HVAC applications. Demonstration of the performance and benefits of current FDD approaches for air handling systems was performed as part of the recently completed research project 1020-RP. Tools for enabling the assessment of FDD methods for chillers are being developed in 1043-RP, while the development of on-line training techniques for model-based FDD methods is being carried out in 1139-RP for vapor compression equipment.

TC 4.11, Smart Building Systems

Research Plan and Activities
June 2000

Current Research Projects

1043-RP - Fault Detection & Diagnostic Requirements & Evaluation Tools for Chillers

1139-RP - Development and Comparison of On-line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment

2000-2001 Research Plan

Priority	Project	Contributors	Status
1.	Evaluation and Assessment of Fault Detection and Diagnostic Methods for Centrifugal Chillers – Phase II	John House Srinivas Katipamula	Approved in Minneapolis 10-0-0 (CNV). Submit to RAC AFTER Phase I is completed.
2.	Integrated Control for Building Services	Mike Brambley John House Ron Kammerud John Mitchell	Original TRP Rejected by Tech. Council. Decided in Minneapolis to rework and reconsider in Atlanta. Explore possible ARTI funding. (Needs cover letter to RAC saying this is “second attempt”.)
3.	Field Performance Assessment of Package Equipment to Quantify the Need for Monitoring, FDD, and Continuous Commissioning	Todd Rossi Mark Breuker Jim Braun	Draft WS exists. Todd Rossi will revise and complete BEFORE Atlanta meeting. Possible TC vote in Atlanta.

4.	Resolving Discrepancies Between Multiple, Hierarchically-Related, Fault Detection and Diagnostic Systems	Mike Brambley Todd Rossi	Mike Brambley will scale back scope and have revised WS by Atlanta.
5.	Prototyping and Field Testing of Utility – Consumer Information Services	Michael Kintner-Meyer Marty Burns Chuck McParland	In the hands of an "Action Committee" set up by SSPC 135. Reconsider in Atlanta.
6.	Benchmarking of FDD Tools for AHU's	John House Les Norford	An RTAR exists.
7.	Development of Fault Detection and Diagnostics for Sensor Failures	Phil Haves Arthur Dexter	One page description exists. Two page Issues Paper handed out by Phil Haves in Minneapolis.

RESEARCH TOPIC ACCEPTANCE REQUEST

Title: Evaluation and Assessment of Fault Detection and Diagnostic Methods for Centrifugal Chillers – Phase II

TC/TG: TC 4.11 Smart Building Systems

Research Category: Operation and Maintenance Tools

Research Classification: Basic and Applied Research

TC/TG Priority: 1

Other Interested TC/TGs:

Possible Co-funding Organizations:

State-of-the Art (Background):

Recent research and development efforts have made significant progress toward enabling FDD for vapor-compression equipment; however, given their impact on comfort and energy use, there have been relatively few studies aimed at chillers. To address the need for a comprehensive study of automated diagnostics for chillers, a three-phase research project was initiated in 1998. Phase I was aimed at identifying the important faults for chillers and the sensors needed to detect and diagnose the faults, and developing some of the tools (laboratory chiller data and a simulation model capable of producing

representative chiller data) for testing various chiller FDD methods. A more detailed description of the scope and findings of Phase I is provided in the ensuing paragraph. Phase II will focus on adapting and implementing existing FDD methods for application to a chiller, developing additional tools for assessing the performance of FDD methods, and using the Phase I and II tools to identify the most appropriate FDD method(s) for laboratory and field testing. The third phase of the study will be aimed at performing real-time laboratory and field testing of the FDD method(s) recommended in Phase II in order to ascertain the performance of the tools under non-ideal conditions. It is envisioned that the outcome of Phase III will be a chiller FDD algorithm for incorporation within commercial products.

Phase I (1043-RP) identified important chiller faults and the sensors necessary for detecting and diagnosing these faults. Literature reviews performed as part of Phase I summarized studies of FDD methods applied to HVAC equipment and systems, and chiller modeling. The chiller modeling literature review established that dynamic models capable of capturing the main dynamic characteristics of chillers do not exist. A dynamic model is needed for simulating fault-free and faulty chiller performance under real (steady-state and dynamic) operating conditions so that in Phase II, the output of the model can be used to evaluate thoroughly the effectiveness and robustness of various methods that might be utilized for chiller FDD. The dynamic chiller model is another deliverable of the Phase I project. In addition, laboratory data for normal operation and a number of fault conditions (at various levels of severity) were collected at various load conditions (27 different operating states were considered) for a 90-ton centrifugal chiller. The data collected included both transient and steady state conditions for the following faults: reduced water flow in the condenser, reduced water flow in evaporator, refrigerant leakage, refrigerant overcharge, presence of excess oil, condenser fouling, presence of non-condensables in the refrigerant, and faulty expansion valve.

Advancement to the State-of-the-Art (Justification):

A significant portion of the energy and maintenance costs for operating commercial HVAC systems is associated with chillers. Although current control systems typically monitor many variables, this information is not used for diagnosing faults. At best, these systems incorporate automatic shutdown procedures that guard against catastrophic failures. Although there is a large body of literature on FDD techniques for applications in critical processes and the body of literature for HVAC systems is growing, very little has been published for chillers. Due to the large scope of the problem, studies related to FDD of chillers have typically focused on the development and evaluation of a particular FDD method and have not attempted to perform a rigorous comparison of a variety of FDD techniques. Research is needed to evaluate existing on-line methods for detecting and diagnosing common faults in centrifugal chillers. Furthermore, a side-by-side comparison of FDD methods by a single researcher using a common set of tools will help establish the most promising on-line FDD method(s) for chillers. Identification of reliable FDD methods for chillers will not only improve the operational performance but also reduce both energy and maintenance costs of chillers. This study will provide a major contribution to the field of FDD for chillers by:

- developing methods for evaluating FDD methods for chillers,
- identifying, adapting and implementing in software FDD methods appropriate for chillers, and
- evaluating the FDD methods using tools from Phase I (data and simulation model) and Phase II (FDD assessment tool).

The result of this study (Phase II) will be the identification of an FDD method (or methods) that is recommended for laboratory and field testing in Phase III. The overall impact of the three-phase study will be to advance the FDD technology closer to widespread commercialization. The main benefit to the ASHRAE membership will be a major step in the development of methods that, when implemented in new and existing chillers, will detect and diagnose operating faults before they become problems, thereby reducing maintenance costs, energy costs and occupant discomfort associated with the operation of cooling systems.

Objective:

The objectives of this study are:

1. To develop procedures for evaluating and comparing FDD methods for centrifugal chillers;
2. To assess the performance of FDD methods for chillers using data generated from a dynamic chiller model and data collected from laboratory tests;
3. To recommend cost effective chiller FDD method(s) for real-time laboratory and field testing in Phase III.

RESEARCH TOPIC ACCEPTANCE REQUEST

Title: Integrated Control for Building Services

TC/TG: TC 4.11 Smart Building Systems

Research Category: Operation and Maintenance Tools

Research Classification: Basic and Applied Research

TC/TG Priority: 2

Other Interested TC/TGs:

Possible Co-funding Organizations: ARTI

Background / State-of-the Art:

Integration of the control of multiple building services such as HVAC, fire, security, and transportation may offer many benefits to building owners and operators. First-cost benefits can accrue if individual systems can serve multiple functions: for example, an EMCS can control both the HVAC and lighting systems. Operating cost benefits can also be achieved: for example, operating schedules for HVAC and vertical transport can be better coordinated if there is a single supervisory control node. Finally, operational efficiencies can be achieved through integration of systems by reducing the number of different systems in a facility, thereby reducing demands on the building operators. Integrating the control of multiple building services is not an innovative concept. The benefits cited above have motivated efforts to integrate the control of building services for many years, with many

different approaches having been taken and different levels of success having been achieved. An objective study documenting what systems have been integrated in the past and why, what has been successful and what has failed, and what are possibilities for the future is needed to help decision makers understand the potential and limitations of various integration approaches they might consider.

In the context of this project, integration is the product of a design that is proactive in exploiting opportunities to reduce redundancies in the operations and control capabilities for the different building systems. The result of integration is a building where the systems work effectively together to maximize cost effectiveness, energy efficiency, reliability, and occupant satisfaction. Hardware and communications technologies are major ingredients in achieving this end, but they do not ensure success. The fundamental issue is not how communication between systems is achieved, but rather, what information is communicated, and what is done with that information. In this project, levels of integration associated with building services will be examined in order to (1) improve understanding of what is being integrated and why, (2) understand the benefits and costs of different approaches to integration, and (3) identify meaningful indicators of success.

Advancement to the State-of-the-Art (Justification):

Building owners and operators are responsible for operation and maintenance of many of the services provided in their building, including, but not limited to, HVAC, illumination, fire, security, and transportation. These building services are increasingly coming under the control of both distributed and centralized control systems. Vendors also offer a number of different approaches for collecting and displaying information on the operation and performance of these systems. BACnet and other communications protocols are now available to facilitate integration of control and/or information content services. However, several obstacles to achieving successful integration of building services remain:

- General guidelines are not available to help an owner or operator decide on those services that should be included in an integrated approach and those that should not.
- Advantages and disadvantages of including individual services in an integrated system have not been established.
- Indicators of effective (or ineffective) integration have not been identified.
- Objective information and tools produced by an impartial source that provide a basis for integrating services are not available to the design community.

Although integrated control of multiple building services has been performed at different levels for years, there is a general lack of understanding of what should be integrated, why it should be integrated and how it should be integrated. This research project will provide valuable information on the benefits associated with the effective integration of building services. The results should significantly improve the design decision-making process for engineers, owners, and operators, and is expected to identify tools and information needed to support and facilitate integration during design. This research is needed by the sponsoring committee to assess the needs for possible ASHRAE standards and/or guidelines on evaluating and choosing the best approach to integrating building services in different applications. In addition, the project may identify needs for communications protocols or other technology that can make integration a more practical and achievable option.

Objective:

The objectives of this project are:

1. To provide a succinct description and assessment of the state of the art of integrated control through survey of stakeholders and field analysis of buildings representing examples of effective integration of systems;

2. To define the benefits of integration by identifying the interactions (type of interaction, information exchanged, command and control decisions, assumptions made by one system about another system, etc.) between different building services necessary for normal operational situations and those necessary for other situations such as in response to a fire alarm;

3. To quantify the economic impact of effective integration;

4. To identify the technical and economic characteristics indicative of effective integration;

5. To identify opportunities for research directed at advancing the capabilities of the design community to specify and achieve integrated control designs.

RESEARCH TOPIC ACCEPTANCE REQUEST

Title: Field Performance Assessment of Package Equipment to Quantify the Need for Monitoring, FDD, and Continuous Commissioning

TC/TG: TC 4.11 Smart Building Systems

Research Category: Operation and Maintenance Tools

Research Classification: Basic and Applied

TC/TG Priority: 3

Other Interested TC/TGs: TC 9.9

Possible Co-funding Organizations: BOMA

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. 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. 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 be much worst than their counterpart in built up systems. It is not known how this equipment is actually performing in the field. If there is great potential, new measurement and information technology tools as well as new service procedures need to be developed and applied to package HVAC equipment in order to improve long term performance.

Advancement to the State-of-the-Art (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. This research project will assess the need for similar technology for packaged HVAC equipment. If the need is there, the results or this work should help guide future efforts in ASHRAE, government, and industry to develop diagnostic and service procedures and to document their costs and benefit. The focus of the work will be on roof top unit performance, since these systems have a direct impact on occupant comfort, indoor air quality, and facility energy use in a large fraction of commercial buildings in the US.

Objective:

The objectives of this research project are to:

1. Study and document the actual field performance of a large number of packaged roof top units and compare the results to industry norms or manufacturer's specifications,

1. iImplement diagnostic and service procedures on a subset of these units and measure and document the resulting performance improvement, and

1. Recommend additional research on the development of appropriate measurement and information technology tools and new service procedures that will significantly improve the long-term performance of package roof top HVAC systems.

RESEARCH TOPIC ACCEPTANCE REQUEST

Title: Resolving Discrepancies Between Multiple, Hierarchically-Related, Fault Detection, and Diagnostic (FDD) Systems

TC/TG: TC 4.11 Smart Building Systems

Research Category: Operation and Maintenance Tools

Research Classification: Basic and Applied

TC/TG Priority: 4

Other Interested TC/TGs: TC 4.6

Possible Co-funding Organizations:

State-of-the-Art (Background):

Large systems, including buildings, can be represented in a hierarchical structure where the entire system is divided into sub-systems, which are in turn divided into sub-sub-systems. Fault detection and diagnostic (FDD) methods or software modules can operate on one or more levels or at different levels throughout this hierarchical structure. Such systems promise to provide the greatest benefits for large systems (e.g., all the HVAC equipment in a 40 story building) that need the hierarchical structure to divide the system into manageable components, but the hierarchical structure could be applied to smaller buildings and may be of value in implementing the diagnostic processes themselves.

When FDD methods operate on hierarchically-related entities, they may produce results that contradict one another. Subsystems have interactions (consider, for example, the chilled water temperature that is produced by the chiller and used by cooling coils). This, along with uncertainty in measured conditions, creates the potential for overlapping and conflicting results when FDD methods are applied to different individual entities at different levels or subsystems in the hierarchy. For example, the chiller FDD might call for a warmer chilled water temperature while some of the cooling coils it serves call for a lower chilled water temperature. For a building operator to use advice from these distributed, independent FDD systems, some coordination of their results or resolution of conflicts is needed. Conflict resolution might be done manually by the FDD user (e.g., building operator), automatically at a supervisory level (e.g., on the operator workstation), or automatically at distributed points in the FDD system.

This work statement focuses on resolving conflicts between FDD solutions that are likely

to utilize distributed computing (i.e.. processing takes place at multiple locations distributed through out the building and/or control system), but it also applies to FDD methods implemented as separate processes or software modules run on the same computer.

Advancement to the State-of-the-Art (Justification):

Fault detection and diagnostic (FDD) techniques are emerging from research and are beginning to be tested in real buildings. Many of these techniques focus on specific HVAC subsystems or components of them; others operate at the whole-building level to identify performance anomalies and identify subsystems causing the anomalies. At the same time, control functions are becoming more distributed with much control processing (computing) taking place at the device or subsystem level, rather than at a central (building-level) location. This provides opportunities for the use of distributed FDD in conjunction with distributed control, yet creates the need to coordinate and resolve conflicts between diagnostic results produced by different FDD systems. This research project responds to that need by providing information that will be needed by the HVAC professions to

successfully apply distributed FDD in buildings by developing and evaluating methods for resolving conflicts between FDD systems.

Objective:

The objective of this research is to investigate how results from FDD methods applied separately to distributed and hierarchically-related HVAC subsystems and equipment can overlap and potentially conflict with one another. Then, based on this investigation, identify or develop, test and evaluation methods for resolving these conflicts. The final results of this research will be a well-documented evaluation of methods for overcoming conflicts generated by FDD methods or software along with guidance regarding circumstances under which to use each adequately-performing method. The final document shall include detailed examples of method applications.

RESEARCH TOPIC ACCEPTANCE REQUEST

Title: Prototyping and Testing of Utility/Customer Information Services

TC/TG: TC 4.11 Smart Building Systems

Research Category: Operation and Maintenance Tools

Research Classification: Advanced Concepts

TC/TG Priority: 5

Other Interested TC/TGs: TC 1.4, TC 1.5

Possible Co-funding Organizations:

State-of-the-Art (Background):

Utilities and telecom companies have been experimenting with energy and non-energy information services for several years. Most of the experimentation has been performed in small-scale pilot programs with a relatively small number of participants. The majority of the technology

implementations are centered around providing services such as automatic meter reading, outage detection, and real-time-pricing (RTP) transmission. Only recently, spurred by the restructuring efforts in the electric power industry and the Telecommunication Act of 1996, has the industry has made bolder steps in marketing and implementation of information services.

On-site power generation from emergency generators has only recently been offered by technology companies and generator manufacturers. Web-based applications have emerged that provide gateway capabilities to interface commonly used EMCS. These systems can be bundled with other asset management services to provide full solutions to property management companies and ESCOs for load management, energy efficiency monitoring, alarm response, and diagnostics, as well as providing facility management functions such as asset inventory, facility maintenance scheduling and automated processing of work orders and procurement.

Direct load management applications are predominant in residential homes, where appliances such as air conditioners, pool pumps, and water heaters were cycled during peak times to reduce load. Most of the residential information services offered are Internet and cable TV services. However, given that a communication infrastructure is being developed by means of these applications, the same communication device transmitting entertainment information can be used to transmit energy information service in future applications.

By and large, utility trials have focussed on implementing some targeted applications. Most of these were not concerned with the development of underlying communication infrastructures that would provide interoperability across network and communication technologies. Now the industry needs to complete the development of standards necessary to enable these services to a broad customer base including commercial, industrial and residential customers. Significant steps toward that end have already been done. The Electric Power Institute (EPRI) with its Utility Communication Architecture standardization efforts and, recently, ASHRAE with its support of research project 1011-RP are providing a systematic approach toward defining communication standards targeted at utility-customer communications.

Advancement to the State-of-the-Art (Justification):

As a natural extension of ASHRAE research project 1011-RP, "Utility/Energy Management and Control System (EMCS) Communication Protocol Requirements", a two phase project for prototyping and field testing a set of selected information services defined in research project I011-RP is proposed. Phase I will focus on the prototyping and testing of information services under lab conditions in which the communicating parties are

simulated. In Phase II, field trials will be proposed to implement and test the prototyped information services at 3-5 customer sites under real-world conditions. This ATAR describes Phase I only. Phase II will be defined in a later, separate ATAR.

The primary objectives of research project 1011-RP were: 1) to identify potential new information services that utilities or electricity suppliers are likely to offer to their customers, 2) to determine the communication and data requirements to establish these services, and 3) to develop data object models that support interoperability for the implementation of the services. This project will build on this previous work. It will implement and test selected information services for commercial/industrial and residential applications in BACnet and CEBus environments. To expedite the prototyping and testing phase, the development is proposed to be performed in a simulated environment in which the communication between a utility/service provider and its customers is simulated in several networked computers under laboratory conditions. This work is specifically designed to verify the completeness, usability, of the set of data object models developed in 1011 - RP through a real implementation. By using the BACnet protocol for in-building communication it will build on and support the ASHRAE's standards work.

Objective:

The implementation of a prototype of selected energy/information services will target the

following objectives:

1. To verify the completeness of the data object and device models for selected energy and information services proposed under ASHRAE 1011-RP. The implementation will check the completeness and provide a basis for proposing enhancements/ modification to the object models.

2) To test the mapping of the data object models to BACnet and CEBus protocols, since the seamless bidirectional transport of information is imperative for robust communication.

3. To provide experience with real implementation and provide the credibility and the refinement necessary to establish communication standards for energy/information services.

3. To assist the development of communication software necessary for the preparation of energy/information services to be studied in field trials during Phase II.

RESEARCH TOPIC ACCEPTANCE REQUEST

Title: Benchmarking of FDD Tools for AHUs

TC/TG: TC 4.11 Smart Building Systems

Research Category: Operation and Maintenance Tools

Research Classification: Basic and Applied Research

TC/TG Priority: 6

Other Interested TC/TGs:

Possible Co-funding Organizations:

State-of-the Art (Background):

This RTAR proposes a follow-on study to ASHRAE 1020-RP, "Demonstration of Fault Detection and Diagnostic Methods in a Real Building". The objective of 1020-RP was to demonstrate FDD methods in a real building, to assess the strengths and weaknesses of the methods investigated, and to provide guidance for future research in this area that will accelerate the development of FDD technology. The comparison included data for seven different faults collected during multiple seasons of the year. Both abrupt and degradation faults were considered. The data was collected at the Iowa

Energy Center Energy Resource Station, a real building that serves as a test facility for energy-efficient technologies. The test procedure consisted of the following three steps:

1. preliminary commissioning tests,
2. one-week of control tests in which faults were implemented and the researchers were told what faults were implemented (including severity), at what time they were implemented, and for how long they were implemented, and
3. one-week blind tests in which the researchers knew only that the faults considered during the control tests would be implemented at some time during that week.

Step 1 was performed once, while steps 2 and 3 were performed once during summer conditions, again during winter conditions, and a final time during spring conditions. Both FDD methods proved capable of consistently detecting the faults, with a small number of exceptions. Fault diagnosis procedures were improved over the course of the tests and at the conclusion were also generally effective. However, diagnosis was made considerably easier than in what are likely to be typical conditions, due to the limited number of known faults, the known magnitude of the faults, and the excellent maintenance of building equipment and sensors.

The test procedure was then altered in order to evaluate the performance of the methods without the benefit of the control test data. The new test procedure was carried out on a different AHU and the researchers were not told what faults were implemented. The performance of the methods suffered with the removal of step 2. In particular, the ability to diagnose the implemented faults was poor.

Advancement to the State-of-the-Art (Justification):

Prototype FDD tools for AHUs have been in existence for approximately two years. It is estimated that there are at least eight to 10 AHU FDD tools at various stages of development. At least one of these tools is being sold to building owners and operators, although none are currently implemented directly in energy management and control systems. Controls manufacturers are moving toward implementing FDD capabilities in their controllers, but they are moving cautiously because the technology is still in its infancy. Further assessment of prototype FDD tools for AHUs would assist controls

manufacturers in their efforts to identify the most promising tools for evaluating the operation of AHUs. This will speed the commercialization of this technology, thereby benefiting building owners, operators, and occupants by helping ensure the buildings are comfortable and utilize energy efficiently.

ASHRAE 1020-RP pointed out how difficult it is to detect and diagnose faults in real buildings. Furthermore it pointed out how difficult it is to evaluate the tools. The proposed study would entail blind testing of FDD tools by an independent party using data produced in a real building. This would eliminate the expert knowledge of tool developers from the evaluation and would help establish how well the tools can be used by someone other than their developers. The data produced will include a number of common faults introduced in a controlled and repeatable manner. The data will be one of the deliverables of the project and will be useful for further developmental work related to FDD tools.

Objective:

The primary objective of this study is to perform an independent assessment of FDD tools for AHUs to establish their capabilities to detect and diagnose faults in a real building. A secondary objective of the study is to produce AHU data sets with embedded faults that can be used by developers to test their FDD tools.

TC 4.11, Smart Building Systems

Research Project Description

Priority 7

Project Title: Development of Fault Detection and Diagnostics for Sensor Failures

Summary: The purpose of this research is to develop Fault Detection Diagnostics (FDD) methods for detecting failed sensors of the type that are typically used in HVAC systems, including: temperature sensors, electricity sensors and flow sensors. Examples of known FDD sensors techniques include: high-low limit comparisons, model comparisons, sensor redundancy, and analytical redundancy. This work would be beneficial to implementing Fault Detection Diagnostics that are dependent on the accurate data from a suite of sensors.

Objectives: This objectives of this research include: (1) a thorough literature search into the current methods that are used to detect sensor failures of the type that typically used in HVAC systems, (2) the development of a suite of FDD procedures for HVAC sensors, and (3) the testing and verification of the developed FDD procedures on specially prepared data from sensors that contain known faults.

Benefits: The project will benefit ASHRAE membership as well as the general public as follows:

1. Assist ASHRAE to develop methods to detect fault diagnostics in sensors.
2. Help equipment suppliers as an aid for incorporating FDD techniques into equipment.
3. Encourage the documentation of such methods.
4. Allow ASHRAE to develop more effective training programs for teaching engineers and architects how to apply FDD methods to sensors.

5. Improving energy efficiency by providing ASHRAE members with improved methods for sensor FDD.

Estimated Cost: $75,000

Estimated Duration: 18 months

Methods of Publishing Research Results:

Detailed Reports

Technical Paper(s)

Appendix G.

List of Subcommittee Attendees

Minneapolis: January 1, 2001

		Tech Dev	Comm Integration	Test Eval
Voting Members				
Jim Braun	99-01	x	x	x
Michael Kintner-Meyer	99-03	x	x	x
John House	99-03	x	x	x
Steve Blanc	99-03	x	x	x
Mark Breuker	99-03	x	x	x
Barry Bridges	98-02		x	x
James Gartner	98-02			
Philip Haves (Intnl)	96-00			
Rich Hackner	98-02	x		x
John Mitchell	96-00	x	x	
Todd Rossi	99-03	x	x	x
John Seem	99-03			
Arthur Dexter (Intl)	96-00			
Les Norford	99-03	x	x	X
Non-Voting Members				
J. Carlos Haiad	96-	x	x	X
Curt Klaassen	99-	x	x	X

George Kelly (CM)	99-	x	x	x
Carol Lomonaco (CM)	00-	x	x	x
David Kahn (CM)	96-			
Brian Kammers (CM)	96-			
Jim Winston (CM)	96-			
Charles Culp (CM)	00-			
Natascha Castro (CM)	99-	x	x	x
Robert Old (CM)	00-	x	x	x
Michael Brandemuehl(CM)	99-			
Patrick O'Neill (CM)	99-			
Mark Bailey (CM)	98-			
Tom Engbring (CM)	99-			
Ron Nelson (CM)	98-			
Barry Reardon (CM)	99-			
Meli Sylianou (CM)	99-			
Srinivas Katipamula		x	x	x
Paul Reimer		x	x	
Tim Salsbury		x		
Osman Ahmed		x	x	
Darrell Massie		x		
Roy Crawford		x		
Agami Reddy		x	x	
Kristin Heinemeier			x	x
Peter Armstrong			x	x
Gene Strehlow				x
Yi Jiang				x