AMERICAN SOCIETY OF HEATING, REFRIGERATION 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 person listed below within 60 days following the meeting.)

TC/TG/TRG No. TC 4.7 DATE: Feb. 8, 1997

TC/TG/TRG TITLE: Energy Calculations

DATE OF MEETING: Jan 28, 1997 LOCATION: Philadelphia

MEMBERS PRESENT	YEAR APPTD	MEMBERS ABSENT	YEAR APPTD	EX-OFFICIO MEMBERS & ADDIT'L ATTENDANCE
Chip Barnaby	1995	George Reeves	1993	
Bill Bahnfleth	1996			
Michael Brandemuehl	1993			
Drury Crawley	1993			
Dan Fisher	1994			
Jeff Haberl	1996			
Philip Haves	1994			
Jean Lebrun	1996			
David E. Knebel	1994			
Les Norford	1994			
Per Sahlin	1996			
Robert Sonderegger	1994			
Ed Sowell	1994			
Jeff Spitler	1995			
George Walton	1996			
Fred Winkelmann	1996			
Michael Witte	1994			

DISTRIBUTION

ALL MEMBERS OF THE TC/TG/TRG

TAC CHAIRMAN: James Porter

TAC SECTION HEAD: Terry Townsend

LIAISONS:

Program: Larry Degelman Journal: none

Handbook: George Reeves

TECHNICAL SERVICES: Claire Ramspeck

MANAGER OF RESEARCH: William A. Seaton

ADDITIONAL DISTRIBUTION:

ASHRAE TC/TG/TRG ACTIVITIES SHEET

DATE: Feb. 3, 1997

TC/TG/TRG NO.: **TC 4.7** **TC/TG/TRG TITLE:** **Energy Calculations**

CHAIRMAN **Charles Barnaby** **VICE CHAIRMAN** **Robert Sonderegger** **SECRETARY** **Jeff Spitler**

TC/TG/TRG MEETING SCHEDULE

LOCATION - past 12 months	**DATE**	**LOCATION** - planned next 12 months	**DATE**
San Antonio, TX	6/25/96	Boston, MA	7/1/97
Philadelphia, PA	1/28/97	San Francisco	1/20/98

TC/TG/TRG SUBCOMMITTEES

Function	**Chairman**
Component Models	Dan Fisher
Simulation	Phil Haves
Applications and Inverse Methods	Jeff Haberl

RESEARCH PROJECTS - Current		**Monitoring**	**Report Mode**
Project Title	**Contractor**	**Comm.Chm.**	**At Meeting**
Appendix 1			

LONG RANGE RESEARCH PLAN

Rank	Title	W/S Written	Approv	To R & T
1.	See attachment 9			
2.				
3.				
4.				

HANDBOOK RESPONSIBILITIES

Year & Volume	Chapter Title	**No.**	Deadline	**Handbook Subcom. Liaison**
1997	28 Energy Estimating Methods			NONE

STANDARDS ACTIVITIES - List and Describe Subjects

SPC 140P Standard Method of Test for Building Energy Software - Ron Judkoff

TECHNICAL PAPERS from Sponsored Research - Title, when presented (past 3 yrs. present & planned)

Appendix 2

TC/TC/TRG Sponsored Symposia - Title, when presented (past 3 yrs. present & planned)

Appendix 3

TC/TG/TRG Sponsored Seminars - Title, when presented (past 3 yrs. present & planned)

Appendix 4

TC/TG/TRG Sponsored Forums - Title, when presented (past 3 yrs. present & planned)

Priorities for Near-Term Developments in Building Simulation Programs (San Antonio),
Fast Multizone Models for System Optimization (San Antonio)

JOURNAL PUBLICATIONS - Title, when published (past 3 yrs. present & planned)

Additional Attendance*

Present this meeting?	Present last meeting?	Last Name	First Name	E-Mail
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		Amistadi	Henry	amistadi@maine.com
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	X	Ayres	J. Marx	
X	X	Bahnfleth	Bill	wpb5@psu.edu
X	X	Barnaby	Chip	cbarnaby@wrightsoft.com
		Bauman	Fred	bauman@popper.ced.berkeley.edu
X	X	Black	Al	mcclureeng@aol.com
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		Hansen	Jerry	
	X	Haves	Philip	p.haves@lboro.ac.uk
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	X	Herrlin	Magnus	magnus@vixen.bellcore.edu
	X	Hittle	Doug	hittle@lance.colostate.edu
X	X	Huang	Joe	YJHuang@lbl.gov
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		Judkoff	R.	ron_judkoff@nrel.gov
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		Kelso	Dick	rkelso@utk.edu
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		Lorsch	Harold	
		McClellan	Todd	mcclella@iblast.me.uiuc.edu
X	X	Mitchell	John	mitchell@engr.wisc.edu
X		Neymark	Joel	neymarkj@csn.net

Present this meeting?	Present last meeting?	Last Name	First Name	E-Mail
	X	Meyer	Jeff	jmeyer@p04.mn10.honeywell.com
X	X	Norford	Les	lnorford@mit.edu
		Ober	David	
X	X	Pegues	Jim	james.f.pegues@carrier.wltk.com
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X	X	Pedersen	Curt	cpederse@uiuc.edu
	X	Reddy	T. Agami	areddy@loanstar.tamu.edu
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		Rock	Brian	barock@ukans.edu
X		Sahlin	Per	plurre@engserve.kth.se
X	X	Smith	Vernon	vsmith@archenergy.com
X	X	Sonderegger	Robert	rcs@oak.synergic.com
X		Sowell	Ed	sowell@fullerton.edu
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		Taylor	Russ	taylor@dilbert.me.uiuc.edu
	X	Thomaston	Bill	
		Todorovic	Bravko	
X	X	Walton	George	gwalton@nist.gov
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	X	Yavuzturk	Cenk	cenk@okstate.edu
X	X	Yuill	Gren	gkyarc@engr.psu.edu

*** In order to preserve the e-mail addresses for all attendees, this is actually a complete list of attendees and recent attendees. It includes the voting members of the committee listed on page 1. An X in the "Present?" column indicates presence at this meeting.**

Appendix 1

RESEARCH PROJECTS -- CURRENT

Project Title	Contractor	Comm.Chm.	At Meeting
RP-665 Preparation of a Toolkit for Primary HVAC System Energy Calculations - Editing portion	Yuill & Bahnfleth	Mitchell	Yes
RP-669 Ice-On-Pipe Brine Thermal Storage System (??)		Knebel	?
RP-717 Attic Energy Calculation Model	Holometrix, Inc.	Jarnagin	?
865-RP Development of Accuracy Tests for Mechanical System Simulation	Penn State/Texas A&M	Walton	Yes

Appendix 2

TECHNICAL PAPERS FROM SPONSORED RESEARCH

January 1997

787-RP Rock, B., D. Wolfe. 1997. A Sensitivity Study of Floor and Ceiling Plenum Energy Model Parameters. ASHRAE Transactions v 103 n 1 1997.

June 1995

741-RP Spitler, J.D., J.D. Ferguson. 1995. Overview of the ASHRAE Annotated Guide to Load Calculation Models and Algorithms ASHRAE Transactions v 101 n 2 1995.

June 1994

665-RP Bourdouxhe, Jean-Pascal H.; Lebrun, Jean; Grodent, Marc; Saavedra, Claudio. Toolkit for primary HVAC system energy calculation - part 1: boiler model. ASHRAE Transactions v 100 n 2 1994. p 759-773

665-RP Bourdouxhe, Jean-Pascal H.; Saavedra, Claudio; Grodent, Marc; Silva, Katia L.; Lebrun, Jean J.Toolkit for primary HVAC system energy calculation - part 2: reciprocating chiller models ASHRAE Transactions v 100 n 2 1994. ASHRAE, Atlanta, GA, USA. p 774-786

756-RP Reilly, Susan M.; Ward, Gregory J.; Dunne, Christopher P.; Winkelmann, Frederick C. Modeling the solar heat gain reflected from neighboring structures ASHRAE Transactions v 100 n 2 1994. p 835-842

666-RP Krarti, Moncef; Claridge, David E.; Kreider, Jan F., Foundation heat transfer algorithm for detailed building energy programs. ASHRAE Transactions v 100 n 2 1994. p 843-850

Appendix 3

TC/TG/TRG SPONSORED SYMPOSIA

Title, When Presented

FUTURE:

San Francisco - January 1998

Symposium: *Accuracy Tests for Simulation Programs*
Chair - *Mike Witte*.
Potential speakers Haberl, Yuill

PAST:

Philadelphia - January 1997

TC 4.7/9.6 Symposium--"*Energy Inverse Analysis for Field Monitoring*"
Chair: Agami Reddy (409/862-2189, areddy@loanstar.tamu.edu).

San Antonio - June 1996:

Symposium: *External Environmental Impacts*
Chair - S. Reilly.

Symposium: *The Great Energy Predictor Shootout II*
Chair - Haberl

Atlanta - February 1996:

Symposium: *User Tools for Building Energy Simulation*
Chair - C. Gardner; three papers promised

Chicago - January 1995:

Symposium: *More New Algorithms for Computer Energy Analysis*

Orlando - June 1994:

Symposium: *New Algorithms for Building Energy Calculations*

Symposium: *The Great Energy Predictor Shootout*
Chair - Jeff Haberl; one paper from Kreider and Haberl and 4 top winners from Denver.

Symposium: *Differences between Calculated and Measured Loss Coefficients*
Chair - David Claridge; have 4 papers in to ASHRAE --being reviewed.

Symposium: *Energy Calculations for Measured Building Data*
Chair - David Claridge; has 1 paper in to ASHRAE --being reviewed.

Symposium: *Fast Energy Calculations*
Chair - Robert Sonderegger; has 2-3 abstracts may slip to Chicago.

Appendix 4

TC/TG/TRG SPONSORED SEMINARS

FUTURE:

Boston - June 1997

"Practical Experiences with Energy Calculations" to be chaired by Barnaby; potential speakers Hittle, Yuill, and Lebrun.

San Francisco - January 1998

"What can Modular Simulation Environments Do Today" to be chaired by Sowell; potential speakers: Sahlin, Sowell, and ????

PAST:

Philadelphia - January 1997
TC 4.7/9.6 Seminar--"Calibration of Computer Simulation for Building Energy Analysis" Taghi Alereza

Atlanta - February 1996:

Measurement of Energy and Demand Savings-ASHRAE Guideline 14P
Chair: George Reeves (co-sponsored with TC 9.6, Systems Energy Utilization)

San Diego - June 1995:

Innovative Uses of Building Energy Simulations Programs - C. Barnaby

Jan. 1995 - Innovative Uses of Computer Simulation - C. Gardner
Jan. 1995 - Predictor Shootout II: Measuring Results for Energy Conservation Retrofits - J. Haberl
Jan. 1995 - Energy Calculations for Measure Analysis - ?

Jan. 1994 - User Tools for Computer Energy Analysis - C. Gardner
Jan. 1994 - User Tools for Building Energy Simulation - C. Gardner
Jan. 1994 - Standardizing Formats for HVAC Component Models - How to Avoid Reinventing the Wheel - P. Sahlin

TC 4.7 Energy Calculations
6:00 - 8:30 PM, Tuesday, January 28, 1997
Marriott 411/412 Philadelphia, PA

AGENDA

1. Roll Call and Introductions	Spitler
2. Accept Agenda and Approve Minutes of San Antonio Meeting	Barnaby
3. Announcements	Barnaby
4. Membership	Sonderegger
5. Subcommittee Reports	
5.1 Component Models	Fisher
987-TRP Loads Toolkit contractor selection	Crawley
5.2 Simulation	Haves
717-RP Attic Model/Radiant Barrier Systems	Jarnagin
5.3 Applications and Inverse Methods	Haberl
865-RP Dev. of Accuracy Tests for Mech. System Simulations	Walton
5.4 Ad Hoc Neutral Model Format (NMF)	Sowell
5.5 Research	Crawley
5.6 Handbook	Norford
5.7 Program	Gardner
Philadelphia / Boston / San Francisco	
5.8 Standards: SPC-140, SMOT for Energy Software	Judkoff
5.9 90.1 Envelope Technical Assistance	Sonderegger
6.0 Old Business	
Educational outreach	Brandemuehl
IBPSA Liaison	Crawley
GPC 14P	Sonderegger
SPC 152 Liaison	Amistadi
7.0 New Business	
8.0 Adjourn	

TC 4.7 Minutes

Jan. 28, 1997

1. The meeting was called to order at 6:05 p.m. Roll was called with 17 out of 18 members present.

2. Ed Sowell moved to accept agenda Jeff Haberl seconded Unanimously approved.

3. Introductions were made.

4. Les Norford moved; Jeff Haberl seconded to approve minutes as presented. Unanimously approved.

5. Announcements were made:

   Upcoming conferences: IBPSA in Prague September 8-10 1997. http://sun1.fsid.cvut.cz/bs97/, Clima 2000 August 30- September 2 Brussels Contact Jean Lebrun (thermoap@ulg.ac.be). Thermal VII Dec. 7-11, 1997 (web address http://www.ornl.gov/ORNL/Energy_Eff/tectrans.html)

   Program deadlines: Feb. 14 Boston, August 15 San Francisco. TC 4.7 has a mail-server (see attachment 6, p. 49) **You should sign up**.

   R&T re-organization goes into effect July 1. A separate research committee will be formed.

   New membership details after next meeting: Carol Gardner, assisted by Joe Huang, will head Program subcommittee, Bill Bahnfleth will become Standards subcommittee chair. Kathleen Fraser to be added as Corresponding Member

6. Component models was reported by Dan Fisher. Minutes are Attachment 1. A "one pager" on Compilation of Diversity Factors and Schedules for Energy and Cooling Load Calculations was distributed. (Attachment 1)

7. Dru Crawley presented the report of the 987-TRP PMSC / technical evaluation committee. Dru Crawley moved, Dave Knebel seconded that the 987-TRP be awarded to the University of Illinois at Urbana-Champaign. Some discussion of the relative merits of the proposals ensued. Motion passed, 13-0-2, Chair Not Voting. (2 members out of the room as bidders.)

8. PMSC for 987-RP appointed by chair: Barnaby, Walton, Knebel, Crawley (chair) Tom Romine from was previously appointed by the TC4.1 chair to represent TC4.1

9. Phil Haves opened the Simulation subcommittee report by asking Ron Jarnagin to give the 717-RP PMSC report.

10. Ron Jarnagin reported on 717-RP. The PMSC recommended approval of the project pending receipt of all copies of the final report. Witte moved, Knebel seconded to approve project pending receipt of all copies of the final report. Motion passed, 15-0-1, Chair Not Voting.

11. Phil Haves continued to give the Simulation subcommittee report (Attachment 2). A work statement on "Imperfectly Mixed Single Room Air Flow Models for Practical Building Environmental and Energy Simulation", developed by 4.10 primarily was distributed. There is some relationship between this work statement and 927-TRP, bidder selected at this meeting (MIT). A consensus was reached that we ought to revise the work statement before Boston to make it "complementary" to 927-TRP. Draft work statements on "Goal Oriented Model Synthesis for Simulation" and "Modular Simulation of Building Envelope Performance" are being worked on. If interested, contact Phil

Haves P.Haves@lboro.ac.uk.

12. Jeff Haberl reported on the Application and Inverse Methods Subcommittee report. (Minutes are attached as attachment 3) A work statement "Development of Inverse Procedures for Building Energy Analysis Using Linear, Change-point, Linear and Multiple-linear Models" was distributed for consideration. The work statement had been revised based on discussion at the San Antonio meeting. Further discussion ensued. Some minor wordsmithing was done; also the "Justification of Need" should be strengthened. Jeff Haberl agreed to revise with an ad hoc subcommittee Robert Sonderegger, Bill Bahnfleth, Jean Lebrun, Les Norford.

    Moncef Krarti distributed a work statement 930-WS "Development of a Toolkit for Predicting Building Thermal and Electricity Use from Measured Data Using Neural Networks". This was a revised version of a work statement turned down by R&T a year ago. The revisions specifically addressed R&T criticisms. Jeff Haberl moved, Mike Brandemuehl seconded that we approve the work statement. 2-10-4, CNV. Moncef agreed to revise the work statement with help from Mike Brandemuehl.

    George Walton reported on 856-RP. The project should be complete by the next meeting. George Walton moved that we make a no-cost extension to the end of August '97; Les Norford seconded. Motion approved unaminously, except Jeff Haberl abstained. The chair appointed Robert Sonderegger to also serve on the PMSC.

13. Ed Sowell reported on the Ad Hoc NMF subcommittee. The only work was the review of 839-RP. The only remaining work is the technical paper. Ed Sowell suggested that "TC 4.7 request that the software product of 839-RP be made freely available to individuals and public organizations for the usage and integration with other software." Chip Barnaby agreed to write the appropriate letter.

    More information on 839-RP is available from the contractor, Per Sahlin plurre@engserve.kth.se. A self-extracting archive containing documentation and a Windows beta test version of the translator is available at ftp://urd.ce.kth.se/pub/rp839/nmfwin.exe

14. Dru Crawley handed out the Long Range Research Plan (Attachment 4) set in San Antonio. We received no stars and will need to revise the list in Boston.

15. Jan Kreider reported that the problems earlier reported with material being removed by ASHRAE staff have been resolved and 90% of the material will be put back into the chapter.

16. A brief discussion of programs was held. Carol Gardner, assisted by Joe Huang. The following program items were agreed to by consensus:

    A seminar for Boston , "Practical Experiences with Energy Calculations" to be chaired by Barnaby; potential speakers Hittle, Yuill, and Lebrun.

    A symposium for San Francisco, chaired by Mike Witte, "Accuracy Tests for Simulation Programs" will be held. Potential speakers Haberl, Yuill

    A seminar for San Francisco "What can Modular Simulation Environments Do Today" to be chaired by Sowell; potential speakers: Sahlin, Sowell, and ????

17. Mike Witte reported on SPC-140, Minutes are Attachment 5. A first draft of a standard has been distributed. A second, improved draft should be available in Boston.

18. Chip Barnaby reported that he had been approached by the Envelope subcommittee of SPC 90.1 regarding some potentially anomalous results with DoE 2 and BLAST. Subsequently, he appointed an ad hoc subcommittee consisting of Sonderegger, Pedersen and Winkelmann. Robert Sonderegger reported on the subcommittee's findings. Different buildings were modeled with different programs. However, the ad hoc subcommittee is still working on it.

19. Old business - educational outreach. Doug Hittle reported that a short course that included covering EES would not fly. He was directed to continue looking into a short course which just covered a public domain program. Gren Yuill handed out a proposed outline (Attachment 6) for a PDS program. Robert Sonderegger moved, Les Norford seconded that we recommend to the PDS committee that a building energy analysis PDS course using the attached outline be created. Motion carried unanimously.

20. Dru Crawley reported on IBPSA-USA.

21. Robert Sonderegger reported on GPC 14P, ASHRAE proposed guideline "Measurement of Energy and Demand Savings" and waved a draft document in front of the committee.

22. John Leber reported that SPC 152 is hoping to have a public review draft in a couple months. (Residential Distribution Efficiency) Contact John Leber for more information.)

23. Chip Barnaby started a discussion of subcommittee rescheduling and possible merger of the Components and Simulation subcommittees. Consensus: App. Inv. Methods 6:00-7:30 Monday nights; the new merged components and simulation subcommittees 7:30-9:30 p.m. Monday nights.

24. Robert Sonderegger moved to adjourn, Phil Haves seconded. Unanimously approved. Meeting adjourned at 8: 35 p.m.

TC 4.7 Component Models Subcommittee Minutes

January 27, 1997

1. The meeting was called to order at 6:05 p.m. A list of attendees is attached below
2. Chip Barnaby reported on the editing of the primary toolkit. It's done and turned in. The schedule for publication is not known yet.
3. Chip Barnaby reported that the 987-RP evaluation committee has met and will make a recommendation at the full committee meeting.
4. Dan Fisher reported on a "one-pager" entitled "Compilation of Diversity Factors and Schedules for Energy and Cooling Load Calculations". There was a considerable amount of interest and a consensus that the research is needed. An ad hoc subcommittee was appointed to develop a work statement: Les Norford (absent but volunteered!), Robert Sonderegger, and Vernon Smith.
5. Jan Kosny reported on a work statement being developed by Joe Huang. The work statement is now under revision.
6. Chip Barnaby queried the committee as to whether or not anything had come of Dave Claridge's work on the effects of infiltration into a wall on its U value. George Walton agreed to look into this.
7. Dan Fisher raised a query from TC6.5, requesting help to develop some component models for radiative heating/cooling devices. Some discussion.. Dan Fisher will develop a one-pager by Boston.
8. Chip Barnaby encouraged all to sign up on the TC 4.7 list server. Instructions were passed out.
9. Chip proposed a change in meeting times to reduce the Monday-night marathon. One possibility is to combine Components and Simulation into a "Forward-modeling" group and then have it meet simultaneously with the "Backwards-modeling" (Applications and Inverse Modeling) group.
10. In the last minutes of the meeting, Dan Fisher announced that we need to pay more attention the program. He then also drew our attention to the need to have a procedure for maintaining the toolkits.
11. The meeting was adjourned at 6:59:59.

Name	Affiliation	E-mail address
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George Walton	NIST	gwalton@nist.gov
Carol Gardner	GEMS/Glumac	cmg@glumac.com
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Dru Crawley	DOE	drury.crawley@hq.doe.gov

"One Pager"

From
TC 4.7, Energy Calculations
Component Models Subcommittee

Compilation of Diversity Factors and Schedules for Energy and Cooling Load Calculations

January 20, 1997

Background
In most buildings, internal heat sources such as office equipment, lights and people account for a large percentage of the calculated cooling load. Indeed, building energy calculations are often dominated by the magnitude of the hourly internal loads. In spite of this fact, until recently very little attention has been given to this aspect of energy calculations. The ASHRAE HOF currently provides no guidance in this area. Although the indoor work environment has undergone a complete transformation in the last 15 years—with a computer, printer or copier on every desk; the ASHRAE literature has not been updated.

RP___" " sponsored by TC 4.1 clearly addresses a large part of the problem. This experimental research project analyzed various types of office equipment to determine the steady state rate of convective and radiative heat transfer from the equipment. Steady state operation of the equipment, however, tells only half of the story. People enter and leave the building, lights and monitors are turned on and off and computers cycle down to "energy saving" mode. This diversity in the operating schedule is usually accounted for by means of a "diversity factor" or an hourly schedule. To provide all of the tools necessary to estimate the impact of internal heat sources on the cooling load, both steady state operating conditions and the diversity that is expected in the steady state operation must be accounted for.

Justification of Need
Hourly energy calculations require the specification of both the maximum expected energy transferred to the space by equipment, people and lights, and the diversity or schedule that is expected to modify the peak energy. The uncertainity attached to these numbers is very high. Recent studies indicate that energy engineers routinely "guess" high by a factor of two to five! (Wilkins, USACERL Report) There is a marked disparity between the level of detail and accuracy that is expected from other aspects of the energy calculation, such as the calculation of conduction heat transfer through the envelope and the level of accuracy that is possible in the estimation of internal loads. The seriousness of the problem is highlighted by the fact that the magnitude of the internal loads routinely dominate the energy calculation. The most significant contribution to the cooling load is estimated without any assistance from the ASHRAE literature. As a result, in spite of tremendous advances in computing power and the availability of detailed and accurate methods for other aspects of the procedure , the uncertainty attached to the estimation of cooling loads is still unnecessarily high. To remedy the neglect of this area two steps must be taken. First, the steady state heat transfer rates from modern office equipment must be measured. Second, deviation of this equipment from steady state operating conditions in various office environments must be assessed. The first area has already been addressed. The research proposed in this workstatement will begin to address the second area.

Objective
The first objective of this project is to determine the availability in the American and European literature of diversity factors and schedules for the calculation of internal loads. The second objective is to compile available diversity factors and schedules with appropriate use guidelines in a format that is conducive to publication in the ASHRAE Handbook of Fundamentals and the ASHRAE Heating and Cooling Load Manual.

Scope

1. Perform a thorough review of the literature related to the scheduling of office equipment, lights and people.
2. Compile diversity factors and schedules from all available sources, including the European literature.
3. Provide clear guidance on the application of diversity factors and schedules to various types of buildings and office environments. These guidelines should account for differences in both use and business culture.

Level of effort
6 man months, $30,000

Contributors
Dan Fisher, Klaus Sommer

TC 4.7 Simulation Subcommittee

January 27, 1997

Minutes

1. The meeting was called to order at 8:35 p.m. A list of attendees is attached below
2. The chair called for a report on 717-RP, but no one could report on it.
3. Kevin Knapmiller reported on 856-WS. As it turns out, TC 6.4 has a project out for bid - TRP-927 which would substantially duplicate what we proposed to do under 856-WS. More information will be available by the full committee.
4. Phil Haves distributed a draft work statement "Goal Oriented Model Synthesis for Simulation" and orally presented Zulfi Cumali's comments on same. A lengthy, vigorous discussion ensued. Barrett Flake, Phil Haves and Les Norford agreed to proceed with development
5. Phil Haves distributed a draft work statement "Modular Simulation of Building Envelope Performance". Yet another lengthy, vigorous discussion ensued. Fred Winkelmann, Per Sahlin, and George Walton volunteered to expand and revise the work statement.
6. A five minute discussion of "other potential research" was held. No conclusions were reached.
7. The discussion segued into a discussion of programs. One idea was a seminar on state-of-the-art seminars and the other was related to "how to use simulation programs" and the sensitivity of simulation programs to their inputs.
8. The meeting was adjourned at 10:03 p.m..

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Work Statement From TC 4.7

Title

Modular Simulation Of Building Envelope Performance

Background

Component-based simulation programs such as TRNSYS [1] and HVACSIM+ [2] allow models of mechanical system components such as fans and coils to be connected easily in a variety of different configurations. Component models with differing levels of detail or with differing capabilities may be substituted without affecting the rest of the system model and without the need for computer programming. Different system configurations may be constructed easily, again without the need for programming. The same techniques cannot be used as easily or as effectively with the model elements used in building loads simulation (e.g. radiant exchange, solar distribution), mainly because of the richer connectivity between the building elements involved. Existing building simulation programs, such as BLAST [3] and DOE-2 [4], have 'hard-wired' calculation procedures for calculating instantaneous heating and cooling loads and it is extremely difficult to extend or modify these calculation procedures. The room models in the libraries of the component-based simulation programs are either self-contained within a single component model or consist of elements (wall conduction, radiant exchange) that are connected in a prescribed way. There appears to be little previous work on this particular problem. One project that did address this problem (among others) was the "Energy Kernel System" project carried out in the UK in the late 1980's [5]; however, the project does not appear to have produced any immediately usable results in this area.

Justification of Need

A simulation method that allowed the different elements used in building envelope simulation to be connected more easily would give designers and researchers the possibility of a tool that would have the flexibility to allow novel elements and different calculation procedures to be incorporated more easily.

Objectives

Develop and test an efficient method of coupling the different algorithms required for building load calculations that permits flexible reconfiguration.

Scope

1. Review different approaches to connecting component models to form system models, including those used in TRNSYS and HVACSIM+, SPARK [6], IDA [7] and the UK

Energy Kernel System, and assess their advantages and disadvantages for application to this work. Assess the relevance of the Neutral Model Format (NMF) [8] and of product modeling, including the work of the European Community's COMBINE project and the approach being adopted by the Interoperability Alliance International.

2. Identify and characterize the model elements used in building envelope simulation, in particular those included in the Building Loads Toolkit (???-RP). Address the range of physical phenomena modeled, the alternative methods of modeling each of the phenomena and the different numerical methods employed.

3. Categorize the inputs and outputs for each model element, identifying possible methods of structuring/grouping. {The question of "input/output-free" modeling should be addressed in the WS}

4. Define several linking schemes in which mutually compatible sets of inputs and outputs from all the element types can connect together to form a problem in which each variable is neither over- or under-determined. Assess the schemes in terms of their use of hierarchical groupings to produce higher level, simpler, ways of connecting elements.

5. Implement a prototype embodying one or more of the most promising linking schemes.

Deliverables

Progress and Financial Reports shall be made to the Society through it Manager of Research at quarterly intervals.

The Principal Investigator shall report in person to the TC at the annual and winter meeting and answer such questions regarding the research as may arise. A Final Report shall be prepared and submitted to the Society by the end of the contract period covering complete details of all research carried out on the project. Unless otherwise specified, six draft copies of the final report shall be furnished for review by the PMS. Following approval by the PMS and TC 4.7, the following will be delivered:

- Four bound copies.
- One unbound copy, printed on one side only, suitable for reproduction.
- Two copies on 3 1/2” diskette(s); one in ASCII format and one in Rich Text Format (RTF).

A Technical or Symposium Paper on this research shall be prepared in a form suitable for presentation at a Society meeting. The Paper shall conform to Section 5 of the Society’s Author’s Manual for Technical and Symposium Papers.

Level of Effort

It is estimated that the project will require ?? person months of effort with the total project to be completed within an ?? month time period based on an estimate of ? person-months of the Principal Investigator and ?? person months of a research assistant.

References

1. Klein, S. A., Beckman, W. A. and Duffie, J. A., "TRNSYS - a transient simulation program", ASHRAE Trans, 82, Pt 2, 1976.

2. Park, C., Clarke, D. R. and Kelly, G. E., An overview of HVACSIM+, a dynamic building/HVAC/control systems simulation program", Proceedings 1st. Annual Building Energy Simulation Conference, Seattle, WA, 1985.

3. "BLAST (Building Loads and System Thermodynamics) User's Manual", BLAST Support Office, University of Illinois at Urbana-Champaign, 1986

4. "DOE-2 User Manual", Lawrence Berkeley National Laboratory, Berkeley, CA

5. Clarke, J. A. et al,"The Energy Kernel System: The Way Ahead?", Proceedings of Building Environmental Performance '91", BEPAC, Canterbury, UK, 1991

6. Sowell, E. F. and Buhl, W. F. and Erdem, A. E. and Winkelmann, F. C., "A Prototype Object-based System for HVAC Simulation", Proceedings of System Simulation in Buildings '86, Li\`{e}ge, Belgium, 1986

7. Sahlin, P. and Bring, A., "IDA Solver - A Tool for Building and Energy Systems Simulation", Proceedings of Building Simulation '91, Nice, France, 1991

8. Sahlin, P. and Sowell, E. F., "A Neutral Model Format for Building Simulation Models", Proceedings of Building Simulation '89, IBPSA, Vancouver, 1989

Work Statement From TC 4.7 (High Risk Category)

TITLE
Goal Oriented Model Synthesis for Simulation

BACKGROUND
Traditional building simulation methodologies allow building systems to be modeled either as prescribed systems, as in BLAST, DOE-2 etc., or as user-described systems, as in HVACSIM+, TRNSYS etc. In each case, the configuration of the system is determined before the simulation is run and cannot be changed 'on the fly' during the run. The user can optimize a particular system design by varying particular parameters and re-running the simulation, and can then choose between designs involving different system configurations by comparing the results of runs with different (optimized) system configurations. In programs such as BLAST and DOE-2, the user is restricted to the configurations that have been implemented by the developer, which naturally tended to be conventional systems for conventional buildings. In those programs, such as HVACSIM+ and TRNSYS, that have the flexibility to allow the user, rather than the developer, to specify the system configuration, the process of actually specifying the configuration is time consuming and error-prone and is also limited by the ability of the user to generate alternative, feasible, configurations. A highly desirable advance would be for alternative configurations to be generated automatically. Some programs, e.g. TRNSYS, can perform parametric variations automatically. Automatic configuration generation and variation, together with automatic parameter variation, could then be combined with a suitable search technique to perform automatic optimal design. The resulting optimization problem is a mixed discrete/continuous problem, since the various possible configurations form a discrete set and most component sizing parameters are discrete whereas most of the operational parameters will be continuously variable, albeit constrained to a fairly well-defined range. One search technique that is particularly suited to mixed optimization problems is the genetic algorithm [1]. The principle of natural selection is used to evolve a set of solutions of progressively increasing fitness. Genetic algorithms can cope with local minima and can be adaptd to deal with constraints, two significant difficulties associated with the optimization problem defined by HVAC system design. Another possible optimization method is simulated annealing .The application area for the 'proof of concept' prototype goal oriented simulation program to be developed in this project is secondary HVAC systems. This application area has been selected because there is a wide variety of methods of conditioning the air supplied to spaces by HVAC systems and because several comprehensive libraries of models of secondary system components have already been developed [2,3,4,5].

JUSTIFICATION OF NEED
Current simulation programs are mainly used to confirm performance and optimize sizing and operational parameters once the basic design decisions have been made. Simulation would be able to play a much more significant role in design if simulation programs were set up also to help designers in the early stages of design. . In particular, the ability to generate and investigate a wide range of system configurations would allow novel and

innovative system configurations to be generated and assessed much more easily and efficiently, leading to system configurations that are better matched to the particular requirements of each design.

OBJECTIVES

Develop a working demonstration program that implements a goal-oriented model synthesis scheme applied to the problem of the design and simulation of HVAC secondary systems.

SCOPE

The main elements of a goal oriented simulation program are:

i) A configuration generator. A configuration consists of a set of components (fans, coils etc.) and a set of connections between the components. The possible connections are limited by the need for compatibility of type (e.g. connect air to air, not air to water) and compatibility of direction (i.e. connect inlets to outlet not inlets to outlets).

ii) An automatic editor for the selected simulation program(s) that will generate input files corresponding to the different designs produced by the configuration generator.

iii) A component-based simulation program, together with a set of models that predict the quantities necessary to evaluate the cost functions of interest (e.g. first cost, life cycle cost). Currently available component libraries contain models that will predict energy and environmental performance. Meaningful design optimization also requires a prediction of first cost (i.e. purchase cost plus installation cost). For each class of component (e.g. coils, fans) the first cost can be expected to be a fairly simple function of size and it should be possible to extend current models to predict approximate first cost without significant difficulty.

iv) A run-time supervisor that can use one or more search techniques in order to optimize the design. The search techniques will require repeated simulation runs with different system configurations and/or parameter values.

The tasks involved in developing a prototype goal oriented simulation program for HVAC secondary systems are:

1. Produce an inventory of existing design alternatives for secondary systems, itemizing the components used and the ways in which they can be connected to each other and to components and sources/sinks outside the boundaries of the system. Define a set of pseudo-components (e.g. sources of ambient air, chilled water) that will be used to impose boundary conditions on the simulation. Select a set of configurations to be used in testing the configuration generator, as discussed below.

2. Review component-based simulation programs and select suitable program(s) and component models for target application.

3. Extend component models to include an approximate estimate of first cost. A simple cost model is sufficient for the 'proof of concept' goal-oriented simulation to be developed here, but the implementation should allow for more accurate and realistic cost models to be added in later versions.

4. Develop configuration generator: group component model inputs and outputs into 'links' of pre-defined type (e.g. moist air, water refrigerant) consisting of pre-defined variables (e.g. a moist air stream can be defined by its temperature, humidity ratio, mass flow rate and, if relevant to the calculations, pressure). Develop a method that allows all physically realizable HVAC secondary system configurations to be generated automatically. Consider possible ways in which the number of configurations can be limited, e.g. elimination of redundant components, setting a (user-defined) threshold on system complexity. Present viable alternative approaches, together with a recommendation, to the PMS. Implement the configuration generator in such a way that the criteria for eliminating particular configurations can be changed easily by the user.

5. Test the configuration generator by verifying (a) that it can generate all of the test set of configurations referred to in (1) above, and (b) that all (or at least a random sample) of the configurations generated are physically realisable.

6. Develop an editor or editors that will generate input files for the simulation program(s). The components and their connections will be defined by the configuration generator. The boundary conditions will be determined by the design brief and the initial values and feasible ranges of the parameters will be determined from expert knowledge, e.g. rules of thumb. A topic that will require special investigation is the generation of initial values and feasible ranges for the parameters. One possibility that should be investigated is the automation of the psychrometric analysis methods used in conventional system sizing. A more major challenge is the automatic generation of a control strategy for each configuration. One possibility would be to perform an on-line optimization at each timestep to generate the optimal operating point, since a system model is necessarily available. If this proves too difficult, the more restricted objective of optimizing for design conditions could still be addressed a limited proof of concept.

7. Review optimization methods and select one or more methods for implementation. The selection criteria should reflect the nature of the design problem and should include the ability to deal with local minima, constraints and a combination of discrete and continuous variables. (Various parameters relating to system sizing are discrete, e.g. available coil size, in addition to the discrete nature of alternative system configurations.)

8. Implement the selected optimization method(s) in a software environment that allows the simulation program(s), together with the appropriate input files, to be called in order to evaluate the value of the selected cost function for different parameter values.

9. Develop a set of design briefs for use as test problems for the goal-oriented simulation. These should differ in complexity and include cases where the optimal design can be established analytically and others where there are several design configurations that are close to the optimum.

10. Test the prototype goal-oriented simulation using the test problems developed in (8) and, where possible, modify the approach and the software to improve its performance.

11. Assess the overall performance of the prototype and the technical viability of the approach. If appropriate, make recommendations for further work:
    i) how the approach could be further developed generically
    ii) how the prototype implementation could be made more robust
    iii) how the approach could be implemented in other application areas (e.g. primary systems)
    iv) how the practical utility of the approach could be assessed, e.g. by trials involving practising designers.

DELIVERABLES

Progress and Financial Reports shall be made to the Society through its Manager of Research at quarterly intervals. The Principal Investigator shall report in person to the TC at the annual and winter meetings and answer such questions regarding the research as may arise. A Final Report shall be prepared and submitted to the Society by the end of the contract period covering complete details of all research carried out on the project. Unless otherwise specified, six draft copies of the final report shall be furnished for review by the PMS. Following approval by the PMS and TC 4.7, the following will be delivered:

1. Four bound copies.
2. One unbound copy, printed on one side only, suitable for reproduction.
3. Two copies on 3 1/2" diskette(s); one in ASCII format and one in Rich Text Format (RTF).
4. A Technical or Symposium Paper on this research shall be prepared in a form suitable for presentation at a Society meeting. The Paper shall conform to Section 5 of the Society's Author's Manual for Technical and Symposium Papers.

LEVEL OF EFFORT

It is estimated that the project will require 42 person months of effort with the total project to be completed within an 36 month time period based on an estimate of 6 person-months of the Principal Investigator and 36 person months of a research assistant. The expected cost is ~$150-200,000 (?).

REFERENCES

1. Wright, J. A., "HVAC Optimisation Studies: Sizing by Genetic Algorithm", Building Services Engineering Research and Technology, 17(1), 1996
2. ASHRAE 629-RP, "Preparation of a Toolkit for Secondary HVAC System Energy

Calculations", Final Report.
3. Klein, S. A., Beckman, W. A. and Duffie, J. A., "TRNSYS - a transient simulation program", ASHRAE Trans, 82, Pt 2, 1976.
4. Park, C., Clarke, D. R. and Kelly, G. E., An overview of HVACSIM+, a dynamic building/HVAC/control systems simulation program", Proceedings 1st. Annual Building Energy Simulation Conference, Seattle, WA, 1985.
5. ASHRAE 825-RP, "A Standard Simulation Testbed for the Evaluation of Control Algorithms and Strategies", Final Report, 1997.

MINUTES

TC 4.7 Subcommittee on Applications and Inverse Methods
Monday, January 27th, 1997, 7:00 - 8:30 p.m.
Marriott Room #305
Chair: Jeff Haberl

AGENDA

1. Introductions (all)
2. Discussion of the minutes from June 1996 (all)
3. Brief Review of the Long Range Research Plan (all)
4. Status report on Work Statements (all)
   - WS "Procedures for Inverse Building Energy Analysis Methods..." (Krarti/Haberl)
   - WS "Calibrated Computer Models"...rejected by TC 4.7 (Haberl).
   - WS 930 "Toolkit for ANNs..."..reject by R&T, rewrite (Krarti)
   - *New* WS "Methodology Development for Lighting/HVAC Interact..." (all)
5. Old Business (all)
6. New Business (all)
7. Adjourn

ATTENDING THE MEETING:

Joe Huang, LBNL	yjhuang@lbl.gov
Samir Moujaes, UNLV	samir@me.unlv.edu
Jan Kosny, Univ. Tenn	kyo@ornl.gov
Vernon Smith, AEC	vsmith@archenergy.com
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Kathleen Fraser, Fraser & Assc	kfraser@canuck.com

GENERAL DISCUSSION

Haberl opened the meeting at 7:07 p.m. followed by introductions of all persons present. The minutes from the June 1996 meeting were then discussed.

MOTION: To approve the minutes from the June 1996 meeting (Sonderegger, 2nd by Krarti). Approved.

Haberl then reviewed the agenda for the San Antonio meeting and suggested the Long Range Research Plan be reviewed briefly and that discussion of the individual WS would then follow with a goal of having one or two ready for 4.7, Old Business, New Business, etc. All agreed.

DISCUSSION OF LONG RANGE RESEARCH PLAN (LRRP).

A brief discussion was then held concerning the LRRP. The ordering of the LRRP remains unchanged from the San Antonio meeting with the exception of one new WS. One pagers of the WS are attached. Haberl noted that authors were prepared to discuss #1, #4, and WS 930 tonight.

DISCUSSION OF INDIVIDUAL WS.

WS #1 "Development of Procedures for Inverse Method Building Energy Analysis Using Linear and Change-point Linear Models (Single Variable)."

Haberl began the discussion by explaining the history of this WS and mentioning that he had revised the WS as per the comments from the San Antonio meeting, which included: limiting the WS to linear and change-point linear regression with one independent parameter (i.e., temperature). Also, that ANNs had been specifically excluded.

Krarti asked for an explanation about why this WS had been limited in scope to linear and change-point linear models, and why ANNs had been eliminated.

Haberl mentioned that at the full 4.7 meeting it had been suggested that the scope was too broad and would produce a RP that might not be biddable. 4.7 had recommended researching only those methods in the NEMVP and GPC14P for starters and then expanding into dynamic methods and/or ANNs in future WS.

Comments included:

- That the WS be expanded to include multiple linear regression of independent variables.
- That the WS be expanded to include a discussion of uncertainty.
- That a task be added to include real examples.
- Make a list of deliverables that explain what the final product will include, for example, a discussion of how a change-point model is calculated, and why it is not easily done with a spreadsheet and/or SAS, what's missing with current packages, etc.
- Move the description to the "Additional Information..."
- Modify Page 7, #1.
- Use FORTRAN 90.
- Renumber #3, and 4 on page 7.

MOTION: To forward the WS as amended to full committee for vote (Sonderegger, Huang 2nd). Approved.

ACTION: Haberl agreed to make these changes and bring the WS to vote for full committee.

Discussion then moved to #4 *"Development of procedures for assessing how well hourly whole-building energy simulation programs are calibrated to measured energy and internal environmental data." (Haberl).*

Comments included:

- What is the intended use of this WS. Is this to be a toolkit? Tool?
- Is a toolkit the right thing to develop?
- Should tool handle large amounts of data or monthly data?
- Does tool become guideline?
- WS should be rewritten to become an evaluation of methods: How to calibrate to LOADS, SYSTEMS, PLANT, etc. and include an real example with data from a well documented case study.

It was then decided to table the discussion of the WS until Boston.

ACTION: Haberl agreed to redo the WS with the comments from the committee in mind. The new WS would become an evaluation of the methods for calibrating a simulation program to LOADS, SYSTEMS, PLANT, etc. with an emphasis on producing an annotated bibliography and a working example.

Discussion the moved to WS #930 *Development of a procedures for predicting building thermal and electricity use from measured data with artificial neural networks* (Krarti/Kreider).

Krarti explained that the WS had been received back from R&T and that R&T had asked for more justification as to why ASHRAE needed to spend money on this when there were commercial ANN tools already developed.

Krarti read the new sentences that he had added and mentioned that the emphasis was on the fact that *there were no commercially available tools for creating ANNs for predicting building energy use and/or environmental conditions.*

Several other comments were made as well:
- This is really needed by service companies for predicting loads from thermal storage.
- WS needed to specifically require FORTRAN 90 deliverable.

MOTION: To forward the WS to 4.7 for a vote (Haberl, Huang 2nd). Approved.

ACTION: Krarti agreed to edit the WS and bring copies to 4.7 for a vote.

Haberl then briefly discussed the WS that had been given to 4.7 A&IM by TC 9.6 entitled: *Methodology Development to Determine Impacts of Interior Lighting and Plug Load Efficiency Improvements in Conditioned Buildings (Huang/Haberl)*

What needed to be done with the proposal was to recast it to become a series of simulations of the most common building/system types to assess thermal interaction between lighting and plug loads. Work needed to specifically address short-comings of previous EPRI and other work. Deliverable would be a nomograph and/or empirical set of equations that would allow the user to quickly assess the thermal interaction of a retrofit to lighting and/or plug loads without simulating an entire building.

ACTION: Huang agreed to rewrite the WS for Boston. Haberl will help Huang.

MOTION: To adjourn the meeting (Barnaby, Haberl 2nd). Meeting adjourned.

LONG RANGE RESEARCH PLAN FOR TC 4.7 APPLICATIONS & INVERSE METHODS: JUNE 1996 (IN ORDER OF A&IM PRIORITY)

A&IM RANK	TC 4.7 RANK	TITLE AND STATUS AS OF SAN ANTONIO WITH ACTION TO BE TAKEN.
#1	#1	Development of procedures for inverse method building energy analysis (Krarti). *STATUS: WS by Krarti discussed in Atlanta. Krarti revised. Needs to be revised and brought to Philadelphia.* *1/97 Haberl has updated and circulated via email.*
#2	#3	Development of an Analytical Validation Test Suite for Whole-building Energy Simulation Programs -- Building Fabric (Judkoff) *STATUS: New WS by Judkoff...will have WS in Philadelphia.*
#3	#7	Development of an Empirical Validation Test Suite for Whole-building Energy Simulation Programs -- Building Fabric (Judkoff, Huang) *STATUS: New WS by Judkoff...will have WS in Philadelphia.*
#4	#2	Development of procedures for assessing how well hourly whole-building energy simulation programs are calibrated to measured energy and internal environmental data. (Haberl). *STATUS: WS rejected by 4.7. Haberl Revised. WS needs to be discussed in Philadelphia.*
#5 WS 930	#8	Development of a procedures for predicting building thermal and electricity use from measured data with artificial neural networks (Krarti/Kreider). *STATUS: WS Rejected by R&T. Krarti revised. WS discussed in Atlanta. Krarti revised. WS discussed in San Antonio. WS to be revised and discussed in Philadelphia.*
#6	NONE	Development of procedures for baselining energy use at large central plants (Haberl). *STATUS: One Pager. WS needs to be written.*
#7	NONE	Development of a reference set of validated semi-empirical tests for primary and secondary HVAC equipment simulations. (Haberl, Judkoff) *STATUS: New one pager. WS needs to be written.*
#8	NONE	Development of a procedures for preparing weather data for use with building energy analysis programs (Haberl). *STATUS: Draft WS delivered at San Antonio. Needs discussion. Haberl will forward WS to TC 4.2 for joint consideration.*
#9	NONE	Development of procedures for analyzing energy savings from HVAC and Lighting Retrofits using an inverse bin method and main meter, before/after data (Haberl). *STATUS: One Pager only. WS needs to be written.*
#10	NONE	Develop self-describing information exchange methods for computer programs used in HVAC industry for analysis, design and evaluation (Cumali). *STATUS: One pager.*
NEW	NONE	Methodology Development to Determine Impacts of Interior Lighting and Plug Load Efficiency Improvements in Conditioned Buildings (Huang/Haberl) *STATUS: New WS from TC 9.6, had received ** from R&T.*

ASHRAE ONE PAGE WORK STATEMENT
FROM TC 4.7 APPLICATIONS AND INVERSE METHODS SUBCOMMITTEE

TITLE: A&IM RANK: #1
Development of procedures for inverse method building energy analysis.

OBJECTIVE:
The objective of this research is to develop procedures for inverse method building energy analysis. Such procedures would result in a toolkit which would be similar to ASHRAE's HVAC-01 and HVAC-02 toolkits in format and would contain algorithms and documented computer code for performing inverse method calculations. These procedures would exclude artificial neural networks and calibrated simulation models, and would be applicable to hourly, daily and monthly building energy use data.

SCOPE:
This research includes: (1) Thorough literature search into the current methods that are used to empirically analyze building energy use, (2) development of computer code for that performs inverse method calculations, and (3) assembly of such code into an ASHRAE Toolkit including the appropriate documentation.

BENEFIT:
The project will benefit ASHRAE membership as well as the general public as follows:
1. ASHRAE to develop a standard toolkit of inverse methods software.
2. Software suppliers as an aid for incorporating standard inverse building energy analysis programs.
3. Text book publishers for documenting inverse methods.
4. ASHRAE for developing more effective training programs for teaching engineers how to apply inverse calculation software.
5. Improving indoor air quality by providing ASHRAE members with software for performing inverse calculation software for analyzing IAQ.
6. Improving energy efficiency by providing ASHRAE members with inverse calculation software for calculating energy conservation savings.

ESTIMATED COSTS: DURATION:
$95,000 18 calendar months

CONTRIBUTORS:
Moncef Krarti,
Jeff Haberl

ASHRAE ONE PAGE WORK STATEMENT
FROM TC 4.7 APPLICATIONS AND INVERSE METHODS SUBCOMMITTEE

TITLE: A&IM RANK: #2
Development of Analytical Validation Test Suite for Whole-building Energy Simulation Programs -- Building Fabric (Judkoff).

OBJECTIVE:

The objective of this research is to create a reference set of steady-state analytical solutions for verifying building fabric heat transfer simulation. Such procedures would result to the accuracy tests developed by RP865. These procedures would be useful for verifying simulations of building fabrics or envelopes. ASHRAE has established the Standard Method of Test for Building Energy Software (SPC 140P SMOT) for developing procedures for testing the accuracy of building energy software. SPC 140P SMOT is to be based on two validation methods: (1) analytical tests and (2) inter-model comparisons.

SCOPE:

This research includes: (1) performing a literature search to determine the different methods that have been used to calculate the heat transfer across the building fabric. (2) development of standard set of accuracy tests for selected fabrics, and (3) documenting the procedures.

BENEFIT:
The project will benefit ASHRAE membership as well as the general public as follows:
1. ASHRAE to develop standard procedures for assessing how well computer simulations calculate heat flow across fabrics or envelopes.
2. Software suppliers as an aid for incorporating ASHRAE's procedures into their building energy analysis programs.
3. Text book publishers for documenting fabric calculations.
4. ASHRAE for developing more effective training programs for teaching engineers how to use computer simulation programs.
5. Improving energy efficiency by providing ASHRAE members with improved procedures for calculating heat transfer.

ESTIMATED COSTS: DURATION:
$95,000 18 calendar months

CONTRIBUTORS:
Ron Judkoff

ASHRAE ONE PAGE WORK STATEMENT
FROM TC 4.7 APPLICATIONS AND INVERSE METHODS SUBCOMMITTEE

TITLE: A&IM RANK: #4
Development of computerized procedures for calibrating hourly building energy simulation programs to measured thermal electrical and environmental data.

OBJECTIVE:
The objective of this research is to develop procedures that will assist ASHRAE engineers in calibrating hourly simulation programs such as DOE-2 and BLAST to measured data from actual buildings. Such procedures could then eventually be developed into toolkits that are similar to ASHRAE's HVAC-01 and HVAC-02 toolkits in format and would contain algorithms and documented computer code for assessing how well computer simulations are calibrated to measured building energy data.

SCOPE:
This research includes: (1) performing a literature search to determine the different methods that are currently being used to calibrate hourly simulation programs, (2) development of standard procedures for performing the calibrations, and (3) documenting the procedures.

BENEFIT:
The project will benefit ASHRAE membership as well as the general public as follows:
1. ASHRAE to develop standard procedures for assessing how well computer simulations are calibrated to measured building energy data.
2. Software suppliers as an aid for incorporating ASHRAE's calibration assessment procedures into their building energy analysis programs.
3. Text book publishers for documenting calibration assessment procedures.
4. ASHRAE for developing more effective training programs for teaching engineers how to calibrate computer simulation programs.
5. Improving indoor air quality by providing ASHRAE members with improved procedures for calibrating building energy simulation programs.
6. Improving energy efficiency by providing ASHRAE members with improved procedures for calibrating building simulation programs.

ESTIMATED COSTS: DURATION:
$95,000 18 calendar months

CONTRIBUTORS:
Jeff Haberl

ASHRAE ONE PAGE WORK STATEMENT
FROM TC 4.7 APPLICATIONS AND INVERSE METHODS SUBCOMMITTEE

TITLE: A&IM RANK: #5
Development of procedures for predicting building thermal and electricity use from measured data using artificial neural networks.

OBJECTIVE:
The objective of this research is to develop and document procedures for predicting building thermal and electricity use which utilizes artificial neural networks, or connectionist methods. Such procedures would results in a toolkit would be similar to ASHRAE's HVAC-01 and HVAC-02 toolkits in format and would contain algorithms and documented computer code for performing artificial neural network predictions of building energy use.

SCOPE:
This research includes: (1) Development of computer code for that performing artificial neural network calculations, (2) assembly of such code into an ASHRAE Toolkit including the appropriate documentation.

BENEFIT:
The project will benefit ASHRAE membership as well as the general public as follows:
1. ASHRAE to develop a standard toolkit for artificial neural network calculations.
2. Software suppliers as an aid for incorporating artificial neural network calculations into building energy analysis programs.
3. Text book publishers for documenting artificial neural network methods.
4. ASHRAE for developing more effective training programs for teaching engineers how to apply artificial neural network calculations.
5. Improving indoor air quality by providing ASHRAE members with neural network software for analyzing IAQ.
6. Improving energy efficiency by providing ASHRAE members with neural network software for calculating energy conservation savings.

ESTIMATED COSTS: DURATION:
$95,000 18 calendar months

CONTRIBUTORS:
Moncef Krarti,
Jan Kreider

ASHRAE ONE PAGE WORK STATEMENT
FROM TC 4.7 APPLICATIONS AND INVERSE METHODS SUBCOMMITTEE

TITLE: A&IM RANK: #6

Development of a procedure for baselining energy use at large central plants.

OBJECTIVE:
The objective of this research is to develop and document a procedure that will baseline the energy use at large central plants. This would include the capability of developing a baseline at large central plants that serve many buildings and that contain multiple interconnected chillers, boilers, heat exchangers, electrical generation equipment, etc. This system would be capable for normalizing for different operational strategies, addition or subtraction of building stock, weather conditions and other variables such as equipment loading, etc. This type of baseline procedure is intended to be used to measure savings from retrofits to equipment in central plants. Such a procedure could then lead to a toolkit that would be similar to ASHRAE's HVAC-01 and HVAC-02 toolkits in format and would contain algorithms and documented computer code for preparing weather data for use by the most widely used building analysis programs.

SCOPE:
This research includes: (1) performing a literature search to determine the previous work that has been accomplished in this area, (2) developing an baseline calculation procedure, and (3) validating the procedure with measured data from an actual central plant, and (3) documenting the procedure in the appropriate ASHRAE report.

BENEFIT:
The project will benefit ASHRAE membership as well as the general public as follows:
1. ASHRAE to develop a standard procedure for baselining large central plants.
2. Software suppliers as an aid for incorporating ASHRAE's baseline procedure into their building energy analysis programs.
3. Text book publishers for documenting ASHRAE's baseline procedure.
4. ASHRAE for developing more effective training programs for teaching engineers how to baseline large central plants.
5. Improved energy efficiency by providing ASHRAE members with a procedure to baseline large central plants.

ESTIMATED COSTS:	DURATION:
$95,000	18 calendar months

CONTRIBUTORS:

Jeff Haberl

ASHRAE ONE PAGE WORK STATEMENT
FROM TC 4.7 APPLICATIONS AND INVERSE METHODS SUBCOMMITTEE

TITLE: A&IM RANK: #7

Development of a reference set of validated semi-empirical tests for primary and secondary HVAC equipment simulations.

BACKGROUND
ASHRAE research project RP865 is developing a reference set of analytical tests for air-side HVAC simulations. To complete the validation of a general purpose HVAC simulation program a reference set of test is now needed for the primary and secondary HVAC equipment simulations, including: pumps, coils, chillers, air-conditioners, boilers, furnaces, etc.

OBJECTIVE:
Using the previously developed work including the results from RP865, and the HVAC 01 and HVAC 02 toolkits as a guide develop a reference set of semi-empirical tests for primary and secondary HVAC equipment simulations.

SCOPE:
This research includes: (1) documenting relevant publications regarding semi-empirical models for primary and secondary HVAC systems (i.e., pumps, blowers, chillers, boilers, etc.), (2) locate a set of valid experimental data for validating the semi-empirical models and validate the models, (3) develop a set of procedures that can be used to use the semi-empirical models to perform an accuracy test on the commonly used primary and secondary HVAC systems.

BENEFIT:
The project will benefit ASHRAE membership as well as the general public as follows:
1. ASHRAE to develop a standard method of applying inverse bin method calculations that include latent cooling, thermal mass, and solar effects.
2. Software suppliers as an aid for developing inverse bin method calculations that are capable of measuring latent cooling, thermal mass and solar effects.
3. Text book publishers for developing more accurate inverse methods for evaluating actual building performance data.
4. ASHRAE for developing more effective training programs for teaching engineers how to apply inverse bin methods.

ESTIMATED COSTS: DURATION:
$75,000 18 calendar months

CONTRIBUTORS:
Jeff Haberl
Ron Judkoff

ASHRAE ONE PAGE WORK STATEMENT
FROM TC 4.7 APPLICATIONS AND INVERSE METHODS SUBCOMMITTEE

TITLE: A&IM RANK: #8
Development of procedures for preparing weather data for use with building energy analysis programs.

OBJECTIVE:
The objective of this research is to develop and document a toolkit that will prepare weather data from varying sources (i.e., NWS, local measured data, etc.) for use by building energy analysis programs such as DOE-2, BLAST, ASEAM, etc. Such a toolkit would be similar to ASHRAE's HVAC-01 and HVAC-02 toolkits in format and would contain algorithms and documented computer code for preparing weather data for use by the most widely used building analysis programs.

SCOPE:
This research includes: (1) performing a literature search to determine the different sources, format, methods of electronic transfer, and quality of weather information (e.g., NWS, solar, and other weather data bases), (2) performing a literature search to determine the different methods that are in use for preprocessing weather data for use by DOE-2, BLAST, ASEAM, PRISM and other programs and/or packing into TRY, TMY, WYEC-2, or BIN format, (2) development of computer codes for performing the weather data preprocessing, and (3) assembly of such code into an ASHRAE Toolkit including the appropriate documentation.

BENEFIT:
The project will benefit ASHRAE membership as well as the general public as follows:
1. ASHRAE to develop a standard toolkit for processing weather data into a format that is useful for building energy analysis programs.
2. Software suppliers as an aid for incorporating ASHRAE's processed weather data into their building energy analysis programs.
3. Text book publishers for documenting weather data processing routines.
4. ASHRAE for developing more effective training programs for teaching engineers how to preprocess weather data for building energy analysis programs.
5. Improved energy efficiency by providing ASHRAE members with improved weather data for analyzing existing buildings.

ESTIMATED COSTS:	DURATION:
$95,000	18 calendar months

POTENTIAL CO-SPONSORS	CONTRIBUTORS:
TC 4.2	Jeff Haberl

ASHRAE ONE PAGE WORK STATEMENT
FROM TC 4.7 APPLICATIONS AND INVERSE METHODS SUBCOMMITTEE

TITLE: A&IM RANK: #9
Development of procedures for analyzing energy savings from HVAC and Lighting Retrofits using an inverse bin method and main meter, before/after data.

OBJECTIVE:

The objective of this research is to develop and document procedures that will analyze measured data from HVAC and lighting retrofits using an inverse bin method. This method would accept hourly columnar data from on-site measurements of energy use and ambient conditions, and would calculate a bin model that captures weather dependent and non-weather dependent (i.e., schedule dependent loads). Such procedures could then be used to produce a toolkit that is similar to ASHRAE's HVAC-01 and HVAC-02 toolkits in format and would contain algorithms and documented computer code for preparing weather data for use by the most widely used building analysis programs.

SCOPE:
This research includes: (1) performing a literature search to determine the previous work that has been accomplished toward performing inverse bin method calculations on measured data (versus bin method design calculations), (2) develop an inverse bin method procedures that will calculate the average hourly weather-dependent energy use per bin, and (3) documenting the procedures in an ASHRAE report.

BENEFIT:
The project will benefit ASHRAE membership as well as the general public as follows:
1. ASHRAE to develop a standard procedure for analyzing retrofit energy savings using an inverse bin method.
2. Software suppliers as an aid for incorporating ASHRAE's inverse bin method into their building energy analysis programs.
3. Text book publishers for documenting the inverse bin method.
4. ASHRAE for developing more effective training programs for teaching engineers how to use an inverse bin method for analyzing building energy retrofits.
5. Improved energy efficiency by providing ASHRAE members with an inverse bin method toolkit for measuring retrofits savings.

ESTIMATED COSTS: DURATION:
$95,000 18 calendar months

CONTRIBUTORS:
Jeff Haberl

ASHRAE ONE PAGE WORK STATEMENT
FROM TC 4.7 APPLICATIONS AND INVERSE METHODS SUBCOMMITTEE

TITLE: A&IM RANK: #10
Develop self-describing information exchange methods for computer programs used in HVAC industry for analysis, design and evaluation.

OBJECTIVE:
The objective of this research is to develop methods of self description for input and output from computer programs to enable unhindered communication among them.

SCOPE:
The scope of this research will focus on two selected areas: a) Hydronic Systems.
b) Energy Analysis.

This research includes: 1) Classification of input and output data, 2) definition of data models, 3) development/selection of methods of self description, 4) test of the developed methodology, 5) code that permits the data exchange for the two selected areas, 6) description of the methodology and code so that it can be applied to computer programs of interest by ASHRAE members.

BENEFIT:
The project will benefit ASHRAE membership as well as the general public as follows:
1) Help solve the data incompatibility problem among computer programs.
2) Facilitate computer aided design work done by ASHRAE members.
3) Make translation of data from detailed to simple computer programs.
4) Permit use of a variety of programs from the same input/output.
5) Save significant amounts of time in design, analysis, and evaluation of projects requiring use of multiple programs,
6) Improve energy efficiency and cost by permitting use of many different programs in design work from different vendors,
7) Permit greater flexibility of data representation without imposing constraints of standards on data format or content.

ESTIMATED COSTS: DURATION:
$75,000 18 calendar months

CONTRIBUTORS:

Zulfi Cumali,
Jeff Haberl

ASHRAE ONE PAGE WORK STATEMENT
FROM TC 4.7 APPLICATIONS AND INVERSE METHODS SUBCOMMITTEE

TITLE: A&IM RANK: **NEW**
Methodology Development to Determine Impacts of Interior Lighting and Plug Load Efficiency Improvements in Conditioned Buildings

OBJECTIVE:
The objective of this research is to expand upon the previous work by EPRI and others to develop a methodology whereby the thermal interaction of plug loads and lighting loads can be empirically estimated for the most common building and systems types based upon parametric computer simulations. This work would be beneficial to energy service companies who could use it to more accurately assess the thermal interaction of retrofits to plug and light loads beyond the previously accomplished work.

SCOPE:
This research includes: (1) Thorough literature search into the current methods that are used to empirically determine the thermal interaction of retrofits to plug and lighting loads, (2) development of the necessary parametric computer simulations to determine a suite of test cases in representative cities of North America, and (3) assembly of the results into an easy to use nomograph and/or algorithm for use by engineers and architects to estimate the thermal interaction without using simulation.

BENEFIT:
The project will benefit ASHRAE membership as well as the general public as follows:
1. ASHRAE to develop a standard methods for assessing the thermal interaction.
2. Software suppliers as an aid for incorporating such standard methods into estimation programs.
3. Text book publishers for documenting such methods.
4. ASHRAE for developing more effective training programs for teaching engineers and architects how to apply such methods.
6. Improving energy efficiency by providing ASHRAE members with improved methods.

ESTIMATED COSTS: DURATION:
$95,000 18 calendar months

CONTRIBUTORS:
Joe Huang, Jeff Haberl

ASHRAE TC 4.7 1997-98 Long Range Research Plan

Approved by TC 4.7 in San Antonio

June 25, 1996

TC Priority	Title	Status	Subcommittee/ Principal Author
1.	Development of Procedures for Inverse Method Building Energy Analysis	WS in Phila.	A&IM/Krarti
2.	Development of Computerized Procedures for Calibrating Hourly Building Energy Simulation Programs to Measured Energy Use and Internal Environmental Data	WS in Phila.	A&IM/Haberl
3.	Development of Analytical Tests for Building Envelope Algorithms	Draft for Phila.	A&IM/Judkoff (SPC 140)
4.	Modeling Two-Dimensional Heat Transfer through Walls in Hourly Simulation Programs	Draft for Phila.	CM/Huang
5.	Modular Simulation of Building Loads	Draft for Phila.	Simulation/Haves
6.	Fast Multizone Models for System Optimization	Draft for Phila.	Simulation/Lebrun
7.	Development of an Empirical Validation Test Suite for Building Envelope Algorithms	Draft for Phila.	A&IM/Judkoff
8.	Development of Procedures for Predicting Building Thermal and Electricity Use Using Artificial Neural Networks	WS in Phila. 930-WS	A&IM/Krarti & Kreider
9. HR	Goal Oriented Model Synthesis for Simulations and Design	*HIGH RISK*	Simulation/Cumali & Haves

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MINUTES
SPC-140 SMOT FOR BUILDING ENERGY SOFTWARE
PHILADELPHIA 1/27/97
R. Judkoff

MEMBERSHIP

The following letter was sent by Ron Judkoff to Bill Richards (SPLS Liason) in early February 1997 concerning membership on SPC-140.

Dear Mr Richards:

Here are my recommendations for changes to SPC-140. These changes are necessitated by several resignations and changes of job status among the committee members.

RECONSTITUTION OF SPC-140

- Kathleen Fraser — Change from "Producer" to "User."
- Charles Barnaby — voting to non-voting
- Bruce Wilcox — appoint as "Producer"
- Jeff Spitler — voting to non-voting
- Carol Gardner — resigned
- Mike Witte — Change from non-voting to voting "User"
- Dru Crawley — Change from "User" to "General Interest"
- George Walton — Change from "General Interest" to "Producer"
- Fred Winkelmann — Appoint as voting "Producer"

The current recommended constitution of the voting committee is:

GENERAL INTEREST	USER	PRODUCER
Judkoff	Fraser	Wilcox
Maeda	Haberl	Sondreggor
Crawley	Witte	Walton
		Winkelmann

For some reason our earlier request for these changes was never processed. We would appreciate it greatly if you would expedite this request for action here in Philadelphia if possible. Please advise me if additional action on this matter is required.

Sincerely,

R. Judkoff, Chair SPC-140

cc:
Pearl Silviar, Sara Deppen, Jim Heldenbrand, Mike Witte

CORRESPONDANCE SINCE LAST MEETING

Working Draft 96/1 distributed to SPC 140 participants. See "intermodel comparison based tests" below.

GENERAL

Nothing to report.

INTERMODEL COMPARISON BASED TESTS

NREL produced a working draft (96/1) of the SMOT. This draft incorporates a revised version of IEA BESTEST into Section 3 (Compliance Validation). Specific revisions to IEA BESTEST include:

- removal of sections containing country/code reports
- exclusion of results not used for range setting and removal of range setting bars
- adaptation of HERS BESTEST format for case by case descriptions with all tables and figures clearly called out as requested by Sara Deppen (ASHRAE).

The draft was distributed to the committee members in October 1996 along with a "List of Comments and Questions" which identified areas requiring input from the committee.

Committee Discussion

Judkoff began discussion by stating the goal of the meeting as:

- obtain committee agreement on any necessary content changes
- NREL will implement those changes
- a revised version will be submitted for letter ballot regarding distribution for public comment.

Judkoff described options for administering the test as:

#1 run all the tests you can and use given diagnostic flow logic to identify potential bugs
#2 run the qualification tests (600-650, 900-960) first, and follow them with diagnostic tests as indicated by the diagnostic flow logic
#3 user gets to choose #1 or #2.

Wilcox recommended user's choice (#3) not be allowed. Fraser stated that monthly bin programs would probably not be able to run many of the diagnostic cases. Witte was supportive of #3. Wilcox supported #2. Several committee members were concerned about how example results would fit in.

Haberl proposed TRP-865 (HVAC calcs) be included in the SMOT. Judkoff thought it would be better to wait to add it until that work is done and leave the section blank as a placeholder. Haberl and Judkoff agreed to delete the current rough draft that was included as a placeholder.

MOTION - Sonderegger/Walton
IEA BESTEST example results be included as an informative appendix.

Wilcox commented that if results aren't normative, users won't know what to do with them. Judkoff said that some of the results are already out of date as new versions of software are issued frequently; including results as an informative appendix allows others to generate more up-to-date example results. Witte suggested that the standard could have no results at all. Many committee members thought this would make the standard useless. Wilcox suggested that all example results be dated and include appropriate software version numbers.

Motion Passed: 7-0-0 (Maeda absent, chair not voting).

Judkoff raised the issue of including selected input files as an informative appendix. Crawley suggested these be on diskette and not as hard copy. Neymark noted that NREL does not have all the input decks because some of the IEA participants did not submit them. Crawley said we shouldn't give the results for any program we didn't have the input decks for.

MOTION - Fraser/Walton
Include input files used for generating results on diskette as an informative appendix for DOE2, BLAST and SERIRES/SUNCODE, and any other input decks that NREL can obtain.

Motion Passed: 5-1-1 (Crawley no, Maeda absent, chair not voting).

General discussion regarding test flow logic recommenced. The committee informally agreed that test designations of "preliminary" and "diagnostic" be changed to "base" (or synonym) and "in depth" respectively, and to adopt the following as section headings:

3.a Base case
3.b Low mass base tests
3.c High mass base tests
3.d Free float base tests
3.e In depth tests - series A
3.f In depth tests - series B

where 3.x.x level headings would designate separate cases (except the base case).

Witte suggested that the additional "compliance" flow charts (not originally part of IEA BESTEST) included with the "List of Comments and Questions" be ditched. The committee agreed.

Fraser wanted to more clearly define what is meant by "agree" and "disagree" when comparing user generated results to example results. Sonderegger suggested "agree" mean similar order of magnitude and sensitivity. Fraser also volunteered to develop better language regarding that the SMOT does not establish compliance criteria, but is just a method for evaluating software.

The committee established a general flavor for the SMOT as a catalog of available tests where users may run all the tests they think will be useful for analyzing their software. Users should note where their software could not model a case, or otherwise why they chose not to do a case. The SMOT should give guidance for the usefulness of each test. NREL will generate appropriate SMOT introductory language for further review by the committee. As part of this discussion the committee informally agreed to move the flow logic diagrams to an informative appendix.

Future Work

The goal for the June meeting (Boston) is to vote on a public review draft. Since we're not there yet, at least one conference call will be necesssary to complete discussion. The following topics remain open:

- better define the process of running tests
- ground coupling (this came up in informal discussion after the meeting)
- formalize that the diagnostic is an informative appendix (that would be consistent with having results as informative appendix which the committee already formally agreed to)
- discuss new language regarding the terms "agree" and "disagree".

NREL will organize mailings prior to conference call and set up the call itself. This should happen in March or April, hopefully sooner than later. Assuming the above issues are resolved in timely fashion, then it should be possible to incorporate changes to the draft during May in time for distribution before the meeting.

ANALYTICAL TESTS (865-TRP HVAC SYSTEMS)

The contractors (Pennsylvania State University, Gren Yuill; Texas A&M, Jeff Haberl) met with the Project Monitoring Subcommittee (Judkoff, Knebel, Walton (chair)) at 1:15p, monday 1/27/97 for further review. For details of the meeting contact George Walton.

EMPIRICAL DATA SETS (BUILDING FABRIC)

No progress was made on work statements since San Antonio. Haberl will send sample drafts to Judkoff for him to work from in order to generate complete work statements.

ANALYTICAL TESTS (BUILDING FABRIC)

No progress was made on work statements since San Antonio. Haberl will send sample drafts to Judkoff for him to work from in order to generate complete work statements.

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USING BUILDING ENERGY ANALYSIS PROGRAMS

COURSE OUTLINE

G. K. Yuill
Jan. 22, 1997

1. INTRODUCTION TO THE COURSE
1.1 Objectives
1.2 Content of the Course
1.3 A Brief History of the Development of Building Energy Analysis

2.0 BUILDING ENERGY
2.1 Introduction
2.2 The Energy Balance on a Building
2.2.1 Factors Influencing the Energy Load on a Building
2.2.2 Energy Calculations and Design Load Calculations
2.3 Building HVAC Systems and How They Work
2.4 Analyzing HVAC System Operation and Energy Consumption
2.5 Building Energy Standards

3.0 BUILDING ENERGY ANALYSIS COMPUTER PROGRAMS
3.1 How Building Energy Analysis Programs Work
- 3.1.1 Introduction
- 3.1.2 Hour-by-Hour Analysis Methods
- 3.1.3 Reduced Hour-by-Hour Analysis
- 3.1.4 The ASHRAE Simplified Method

3.2 What Building Energy Analysis Computer Programs Can and Can't Do
3.3 Verification

4.0 LIFE CYCLE COSTING
4.1 Introduction
4.2 Present Worth Calculations
4.3 Life Cycle Cost Parameter Evaluation
4.4 Performing Optimizations

5.0 PRACTICAL APPLICATION OF BUILDING ENERGY ANALYSIS TO NEW BUILDING DESIGN
5.1 Introduction
5.2 The Benefits
5.3 The Barriers to Success
5.4 Critical Success Factors
5.5 Doing the Job
- 5.5.1 What Factors to Analyze
- 5.5.2 Performing the Analysis

6.0 PRACTICAL APPLICATION OF BUILDING ENERGY ANALYSIS TO RETROFIT PROJECTS
6.1 Introduction
6.2 The Benefits
6.3 Using Energy Use Data in Model Development
6.4 Doing the Job
- 6.4.1 What Factors to Analyze
- 6.4.2 Performing the Analysis

6.5 Performance Contracting

TC 4.7 E-mail List Server

January 1997

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(If the chairman and others know that the mailing list is complete, it greatly simplifies the task of sending e-mail notices to the committee. Thanks!)

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901LTG@GARD.COM	90.1 Lighting Subcommittee
901ECB@GARD.COM	90.1 Energy Cost Budget Subcommittee
901OTHR@GARD.COM	90.1 Other/Adhoc Subcommittees
SSPC62-L@GARD.COM	Standard 62 Committee Mailing List

ASHRAE staff are not involved in the operation of these lists. Please do not ask them for help.

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