Title

A study of occupant comfort and workstation performance in PG&E's advanced office systems testbed

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A STUDY OF OCCUPANT COMFORT AND WORKSTATION PERFORMANCE IN PG&E'S ADVANCED OFFICE SYSTEMS TESTBED

Final Report

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ABSTRACT

This final report presents the results of research completed since June 1991 on PG&E's Advanced Office Systems Testbed (AOST) Project. The initial advanced office system selected for evaluation in the AOST office was the Personal Environmental Module (PEM), manufactured by Johnson Controls. The PEM represents one example of an emerging technology known as task conditioning, or localized thermal distribution (LTD). Workstation-based LTD systems that allow individuals a degree of control over their local environment have the potential to improve the energy efficiency of the building's air distribution system by enabling only the local workstation environments to be tightly controlled while relaxing the energy and comfort requirements in the less critical surrounding spaces.

Work was performed by UC Berkeley in the following task areas: (1) detailed field measurements of thermal comfort of the PG&E employees participating in the study, both before and after moving into the AOST office; (2) installation of a permanent data acquisition and information display system capable of recording and displaying the status of a selected number of performance parameters from the AOST office, including occupant use patterns from each of the eight workstations, supply and return conditions from the air distribution system serving the office, and average room air conditions; (3) analysis of the collected data; and (4) evaluation of the applied measurement methods.

INTRODUCTION

In the summer of 1991, Pacific Gas and Electric Company initiated a project to develop a prototype office to demonstrate and test the performance and energy use of advanced office furniture/environment systems, advanced lighting systems, and other innovative environmental control technologies. The project, originally entitled Office 2000, is now called the Advanced Office Systems Testbed (AOST). Listed below are the initial overall project objectives, including a summary of their current status.

1. **Develop a prototype office in which ergonomic, energy-efficient, and environmentally enhancing technologies can be installed, tested, and demonstrated.**

   The development of the prototype office was completed in early 1992. PG&E renovated an existing office space by modifying the existing air distribution duct system, installing new partitions and workstation furniture, subdividing the office with a glass partition wall and access door, and installing an efficient ambient lighting system. Due to the relatively small size of the office, the facility is less suitable as a general large-scale demonstration site and more appropriate as a testbed for learning how to monitor office environments and to what extent meaningful performance data can be obtained. In this regard, based on an analysis of measurements taken during the past year in the AOST office, additional modifications are now being considered to improve the usefulness and applicability of future tests and demonstrations. These proposed changes and future directions for the project are discussed at the end of this report.

The initial advanced office system selected for evaluation in the AOST office was the Personal Environmental Module (PEM), manufactured by Johnson Controls. The PEM represents one example of an emerging technology known as task conditioning, or localized thermal distribution (LTD). Workstation-based task conditioning systems that allow individuals a degree of control over their local environment have the potential to improve the energy efficiency of the building's air distribution system by enabling only the local workstation environments to be tightly controlled while relaxing the energy and comfort requirements in the less critical surrounding spaces. In comparison to conventional air distribution design, LTD systems have demonstrated significant improvements in thermal comfort, ventilation performance, and environmental satisfaction among office workers. As a result, increased levels of worker productivity are also likely to emerge as more LTD systems are introduced. Because LTD systems offer unique capabilities to condition offices with widely diversified energy loads and to respond to the thermal wishes of individual workers, there is a high probability that this technology will play an increasingly more important role in future and retrofitted office installations.

2. **Develop a data acquisition system (DAS) and measurement protocols for monitoring the energy and thermal performance of the office and for assessing the thermal comfort and satisfaction of the PG&E employees occupying the AOST office.**

The development and installation of two permanent DAS's addressing the above objective was successfully completed by two contractors: Endecon of San Ramon, CA, and the Center for Environmental Design Research (CEDR) at the University of California, Berkeley. Endecon's DAS focuses on the measurement of electrical energy use and is described elsewhere. UC Berkeley's DAS records and displays performance data from individual workstations, including detailed occupant use patterns of the individually-controllable PEM units, supply and return conditions from the heating, ventilating, and air-conditioning (HVAC) system serving the office, and average room air conditions. UC Berkeley researchers have also utilized an in-house portable measurement system to assess the thermal comfort of ten PG&E employees participating in this study.

The installed data acquisition systems have both been operating since April 1992. A period of testing and troubleshooting has followed, during which a number of issues have been addressed and satisfactorily resolved/completed, including: (1) data collection reliability, (2) scan rate capabilities, (3) coordination of two separate systems, including timing and merging of data files, (4) calibration of all measurement sensors, and (5) training of PG&E personnel to operate the systems and manage the large amount of collected data.

3. **Measure the effects of the installed advanced office systems on energy use, and worker thermal comfort, satisfaction, and productivity.**

As stated above, measurements have been made for about one year, producing an over-abundance of data, and drawing attention to the need for a well-conceived testing and analysis plan. Ron Kammerud, a consultant for PG&E, has been leading the effort towards this goal [Kammerud 1991]. Endecon has set up a data management system to allow the merging and analysis of the two sets of data from Endecon's and UC Berkeley's permanent DAS's. UC Berkeley has completed three thermal comfort field tests as part of this project: (1) Baseline Test - 16, 17 October 1991, (2) First Post-Occupancy Test (Test 1) - 30 April, 1 May 1992, and (3) Second Post-Occupancy Test (Test 2) - 16, 17 September 1992.

Due to the small number of workstations and office workers participating in this study, the measurement database is not large enough to establish statistically significant conclusions, although obvious trends and examples can be noted. The analysis of measurement results presented here has focused on (1) identifying what general office performance characteristics (e.g., thermal comfort, energy use, occupant use patterns, and overall HVAC system operation) can be measured in an office environment, (2) identifying what are the distinguishing features of the PEM in this AOST office setting that falls somewhere between a realistic large-scale office and a controlled laboratory environment, and (3) evaluating how appropriate the applied measurement and analysis methods are for these purposes. The lessons learned from the AOST project have provided guidance for modifying the AOST office facility to improve its capabilities in future planned experiments, and, if funding becomes available, for setting up and conducting a scaled-up field study of PEM performance in a PG&E facility or elsewhere.

4. **Plan for the future by identifying one or more sites suitable for larger-scale field tests of advanced office technology using methods developed in the AOST project, and by identifying additional manufacturers to provide other office environmental technologies to be installed and tested in the AOST office.**

   PG&E has acquired from Johnson Controls a total of 20 PEMs, four of which are installed in the AOST office. Funding constraints have delayed plans to install the remaining PEM units in a renovated PG&E office building in San Francisco to allow the demonstration and testing of a more representative sample of advanced office technology. A scaled-back effort is now proposed to focus attention on how to improve the capabilities of the AOST office, and, in particular, how to most effectively use the facility and the data it produces to demonstrate potential energy savings from advanced office technologies. PG&E personnel are currently heading up efforts to identify new advanced office systems to be installed in the AOST office after testing of the PEM units has been satisfactorily completed.

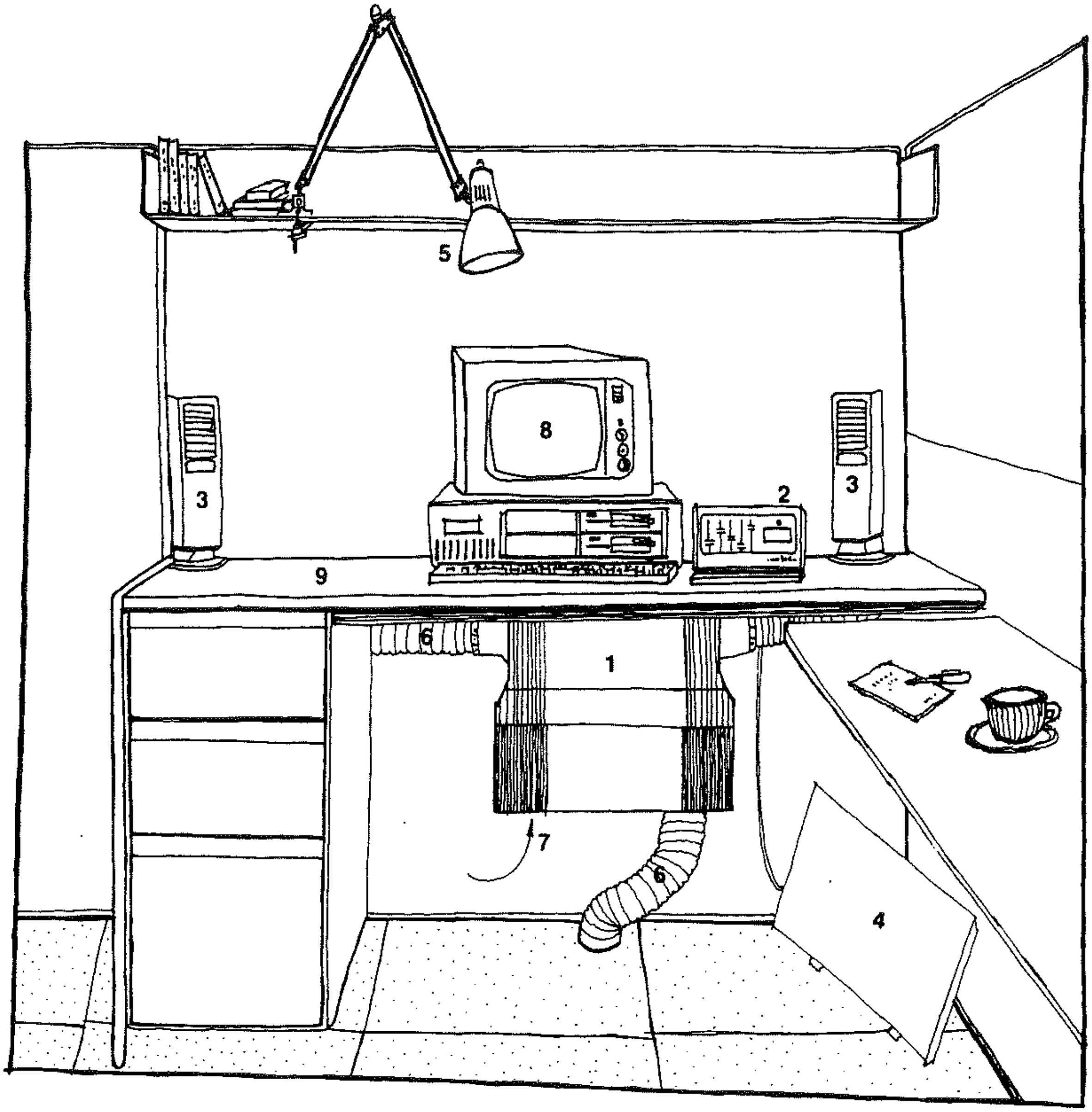
In this final report, we describe the work completed by CEDR at UC Berkeley. Most of the work has addressed the second and third objectives described above: developing and installing a monitoring network to measure and display the PEM and office performance characteristics, using the installed network to collect data, and performing thermal comfort measurements using our in-house portable measurement system. The hardware and software installations associated with the PEM/thermal monitoring and display network are described in detail, including network configuration, monitoring display screens, software operating instructions, sensor calibration, and system troubleshooting. The portable thermal comfort measurement system is also described in detail, including physical measurement system, subjective surveys, and measurement protocol. Measurement data have been analyzed to coincide with the three thermal comfort field tests. Results are presented and discussed for thermal comfort, PEM occupant use and energy use patterns, and HVAC performance. The results include data spreadsheets from all three thermal comfort tests. The report concludes with a discussion of the lessons learned from the AOST project and recommendations for future project directions. Based on the results of this project and our other ongoing research, some general recommendations to improve the performance of localized thermal distribution systems are presented in the Appendix.

PERSONAL ENVIRONMENTAL MODULE (PEM) DESCRIPTION

The Personal Environmental Module (PEM) manufactured by Johnson Controls, Milwaukee, Wisconsin, is the first advanced office system to be installed for evaluation in the AOST office. A sketch of a typical PEM installation is shown in Figure 1. The PEM is a desk-mounted unit supplying conditioned air at desktop level. It uses a self-powered mixing box that is hung in the back or corner of the knee space of the desk, and connected by flexible duct to two supply nozzles on the top of the desk. The supply vents may be rotated 360° in the horizontal plane and contain outlet vanes that are adjustable ±30° in the vertical plane. The mixing box uses a small variable-speed fan to pull supply air from a zero or very low pressure plenum either under the floor (as indicated) or from flexible ducts in the office partitions supplied from the ceiling (this is the duct configuration used in the AOST office). A second fan pulls air from the knee space through a mechanical prefilter. Both supply air and recirculated room air are drawn through an electrostatic air filter. The relative fractions of supply air and recirculated air are controlled by dampers on each of these two lines. The main supply line damper is never allowed to close completely, thus ensuring the delivery of fresh ventilation air at all times.

The unit has a desktop control panel containing adjustable sliders controlling the speed of the air emerging from the vents, its temperature (produced by adjusting the ratio of supply to recirculated air), the temperature of a 175 W radiant heating panel located in the knee space, the dimming of the occupant's task light, and a white noise generator in the unit that issues a rushing sound through the supply vents. The control panel also contains a motion-detector-based occupancy sensor that shuts the unit off when the workstation has been unoccupied for a few minutes. The control panel is connected to a microprocessor-based programmable controller contained inside the main PEM unit located under the desk. The controller receives the incoming setpoint information from the control panel and provides the necessary output signals to control the operation of all PEM components. The controller utilizes an RS-485 communication link allowing multiple controllers to be networked together and to be connected to a central system controller. As described below, this communication capability was used to set up a PEM monitoring network in the AOST office.

Each PEM unit is capable of providing approximately 40-150 cfm (20-70 L/s) of air. Even when its internal fans are turned off, the system is designed to deliver 40 cfm (20 L/s) to satisfy minimum ventilation requirements. In our laboratory at UC Berkeley, the maximum outlet velocity measured at the face of the 2.3 x 4 in. (58 x 100 mm) supply vent varied between 6.5 and 24.5 fps (2 and 7.5 m/s) over the same range of airflows described above. In operation, 55°F (13°C) is provided by a variable air volume HVAC system, with desk-level outlet temperatures in the range of 65°F (18°C).



1 PEM supply module
2 PEM control panel
3 PEM supply nozzle
4 radiant heating panel
5 task light
6 flexible supply duct
7 recirculated room air
8 personal computer
9 desk

Figure 1. Personal Environmental Module (PEM)

UC Berkeley and Lawrence Berkeley Laboratory have been studying PEM performance for the past three years as part of an ongoing research project sponsored by the California Institute for Energy Efficiency (CIEE). Laboratory experiments have been completed in UCB's Controlled Environment Chamber to investigate the thermal and ventilation performance of PEMs. Results indicate that the PEMs are capable of controlling over a wide range of thermal conditions, allowing office workers the opportunity to fine-tune the local workstation environment to their individual comfort preferences [Arens et al. 1991, Bauman et al. 1991, Bauman et al. 1993]. Under optimal operating conditions, the PEMs were able to provide true task ventilation (i.e., increased ventilation at the location of the occupant), with significantly lower ages of air at the breathing level in the workstation compared to that of the air leaving the room through the return grill [Faulkner et al. 1993]. Preliminary modeling studies of PEM energy use have concluded that PEM installations may use more or less energy compared to a conventional air distribution system depending primarily on operating strategies [Heinemeier et al. 1991, Seem and Braun 1992]. A recent research report describes the results of a survey of industry perspective on task conditioning systems, and also presents recommendations to improve task conditioning system performance [Bauman et al. 1992].

The first large installation (370 units) of PEMs was recently completed in a newly designed office building occupied by the West Bend Mutual (WBM) Insurance Company in West Bend, Wisconsin. The building was fully occupied in July 1991. The WBM building has provided a rare field research opportunity to study the impact of an advanced office technology (the PEM task conditioning system) on productivity. It was discovered that WBM had an established computer-based method for measuring the productivity of its employees. Researchers from Rensselaer's Center for Architectural Research, and Center for Services Research and Education, Troy, NY, carried out a study in which they used this existing WBM measure to track the productivity of over 100 employees for 27 weeks before, and for 24 weeks after they moved into the new building containing PEMs. The project investigators are claiming that the PEMs do increase worker productivity by up to 2%, although the validity of analysis methods used to extract productivity gains due to the PEM from gains resulting from the move to a new building and other factors is difficult to determine [Kroner et al. 1992].

OFFICE DESCRIPTION

The AOST office is located on the first floor of a two-story office building (Sunset Building) in San Ramon, California. It is part of a large area within the Sunset Building leased by PG&E's Research and Development Department. Figure 2 shows the floor plan of the AOST office. The 1,600 ft^2 office space has been subdivided by full-height glass walls into a 1,200 ft^2 main office and a 400 ft^2 side office. The main space accommodates eleven employees in an open plan office, including the eight participants in the AOST thermal comfort study. Entrance to the main office is from a central corridor adjacent to the south wall. The side office, bordering the north side of the building, contains one employee and the home base for the AOST data acquisition system. A conference room located to the north of the main office space is not a part of this study.

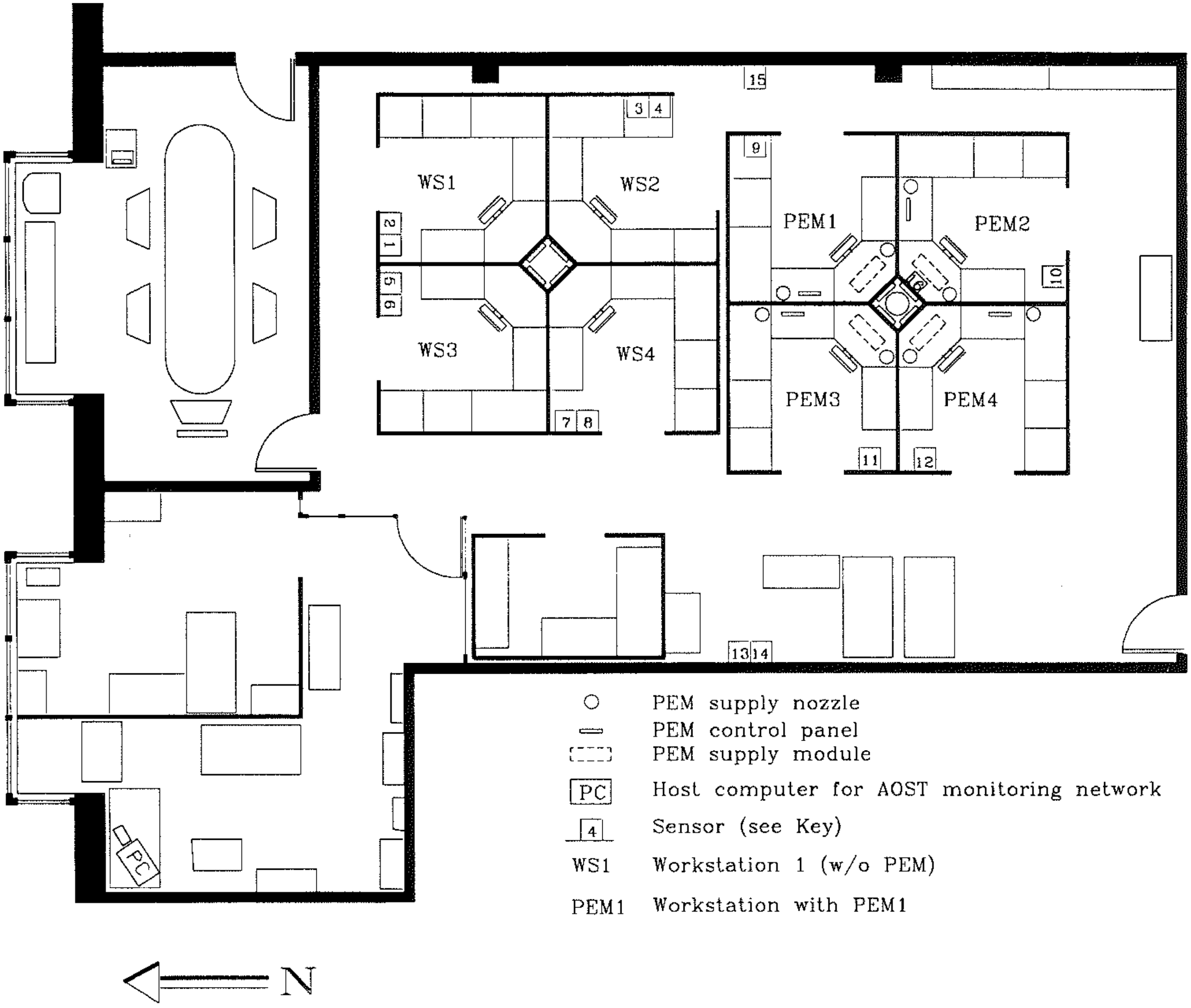


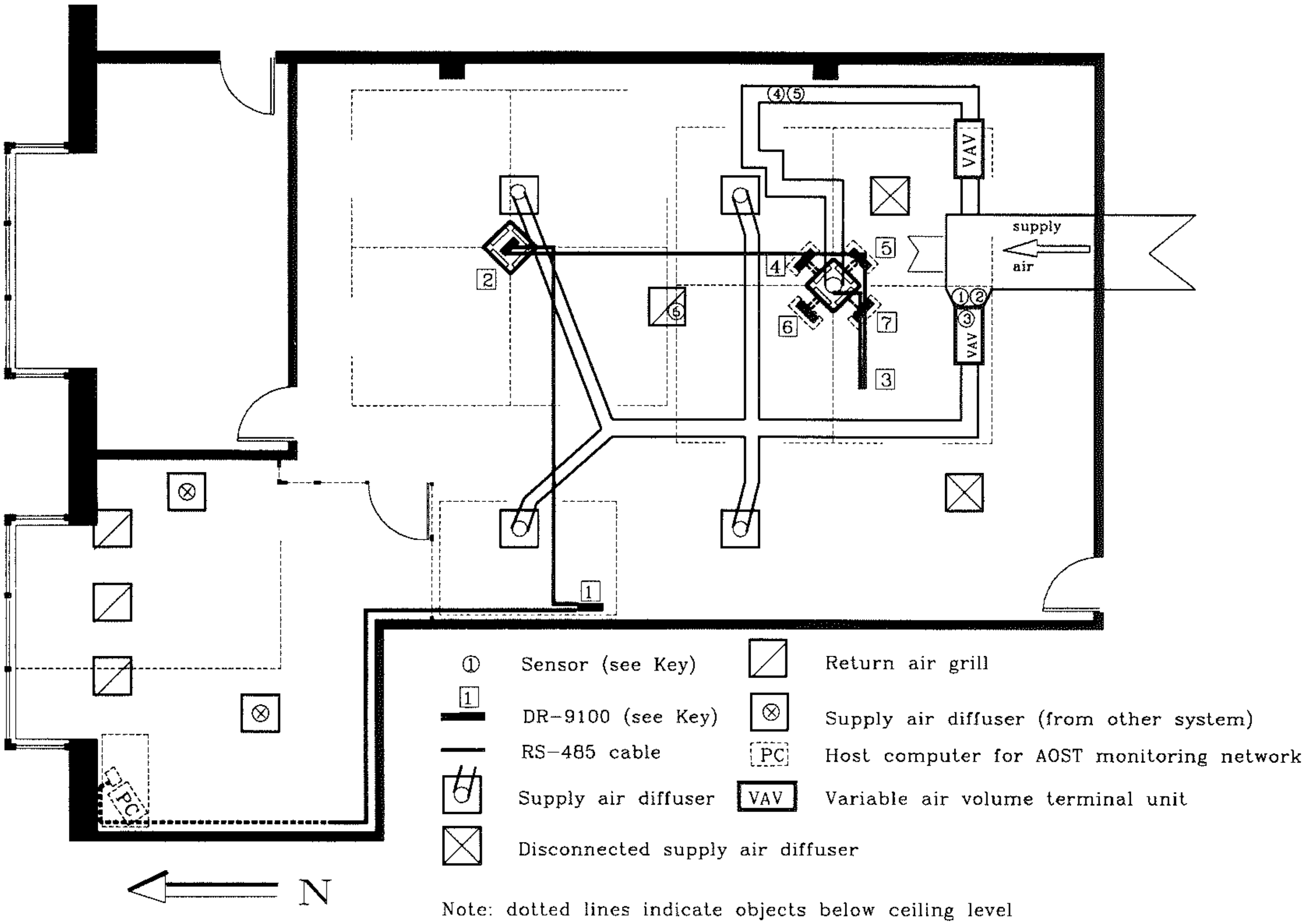
Figure 2. Advanced Office Systems Testbed: Floor Plan

Key for Figure 2

Sensor No.	UCB Label	Database Label	Description
1	T-WS1	TRM$W1	Air Temperature - Workstation 1
2	OCC-WS1	OCC$W1	Occupancy - Workstation 1
3	T-WS2	TRM$W2	Air Temperature - Workstation 2
4	OCC-WS2	OCC$W2	Occupancy - Workstation 2
5	T-WS3	TRM$W3	Air Temperature - Workstation 3
6	OCC-WS3	OCC$W3	Occupancy - Workstation 3
7	T-WS4	TRM$W4	Air Temperature - Workstation 4
8	OCC-WS4	OCC$W4	Occupancy - Workstation 4
9	T-P1	TRM$P1	Air Temperature - PEM1 Workstation
10	T-P2	TRM$P2	Air Temperature - PEM2 Workstation
11	T-P3	TRM$P3	Air Temperature - PEM3 Workstation
12	T-P4	TRM$P4	Air Temperature - PEM4 Workstation
13	T-TS/ TSP-TS	TRMTS/ TSPTS	Room Air Temperature at Thermostat/ Thermostat Setpoint
14	RH-RM	HRM$ZZ	Room Relative Humidity
15	T-RM	TRM$ZZ	Room Air Temperature
16	T-CEIL	TRM$CL	Near-Ceiling Air Temperature

As shown in Figure 2, the major features of the office configuration are two very similar workstation clusters, each containing four workstations. A Personal Environmental Module (PEM) was installed in each workstation in the cluster closest to the entrance (PEM1 - PEM4). The other cluster contains conventional workstations without PEMs, serving as a control group for comparison with the PEM workstations. The workstations are divided by 65-in. high Center Core partitions. The Center Core cluster design provides a central access area that proved to be convenient for installing the PEM air supply duct and the workstation monitoring networks. This central core was extended to the ceiling, forming a hollow column through which the air supply duct was run down from the ceiling to serve the four PEM units. The central column above the conventional workstation cluster looked identical, but contained no ductwork.

Figure 3 shows a diagram of the ceiling plenum plan, containing the air distribution system serving the AOST office. Conditioned air is provided to the office through two supply lines which split off from the large incoming trunk line from the rooftop air handling unit. Airflow through each supply line is controlled by a variable air volume (VAV) terminal box. The duct system dedicated to the PEM air supply was newly installed for this study. The VAV box on this PEM line is designed to maintain less than 0.1 in. WG static pressure, according to PEM installation guidelines. Under design conditions, even with its fan turned off, each PEM will provide approximately 40 cfm of supply air to satisfy minimum ventilation requirements to the local workstation. The remainder of the office space is conditioned by an existing ceiling-based air



Note: dotted lines indicate objects below ceiling level

Figure 3. Advanced Office Systems Testbed: Ceiling Plenum Plan

Key for Figure 3

No.	UCB Label	Database Label	Description
Sensor			
1	SAT-1	TSA$RM	Supply Air Temperature 1 (Room)
2	SARH	HSA$RM	Supply Air Relative Humidity
3	SAV-1	FDA$RM	Supply Air Volume 1 (Room)
4	SAT-2	TSA$PM	Supply Air Temperature 2 (PEM)
5	SAV-2	FDA$PM	Supply Air Volume 2 (PEM)
6	RAT	TRA$RM	Return Air Temperature
DR-9100			
1	Room	N/A	Monitors room air and humidity sensors
2	WS	N/A	Monitors air temperatures and occupancy in WS1 - WS4
3	HVAC	N/A	Monitors HVAC supply and return conditions
4	PEM1	N/A	Monitors PEM1 conditions and workstation temperature
5	PEM2	N/A	Monitors PEM2 conditions and workstation temperature
6	PEM3	N/A	Monitors PEM3 conditions and workstation temperature
7	PEM4	N/A	Monitors PEM4 conditions and workstation temperature

distribution system, that was modified for this study. This VAV box and duct system originally served six perforated diffusers, however, two diffusers located above the PEM workstation cluster were disconnected and their associated supply ducts capped (see Figure 3). Airflow control by this VAV box is tied to the operational room thermostat, located on the south wall. The air distribution system utilizes a ceiling plenum return with one centrally located return grill in the main office area and three return grills in the side office. The ceiling plenum is open and connected above the main and side offices, as well as above parts of the adjacent office spaces in the Sunset Building.

MONITORING NETWORK DESCRIPTION

The centerpiece in the development of the AOST office was the installation of two permanent data acquisition systems capable of monitoring in detail the energy and thermal performance of the office. As mentioned previously, Endecon was responsible for the energy use monitoring system that measures the voltage, current, and power factor of all electrical circuits in the office. This system is described elsewhere. UC Berkeley was responsible for setting up a monitoring network capable of recording and displaying PEM and workstation performance data, supply and return conditions from the HVAC system serving the office, and average room conditions. The UCB monitoring network is described below.

With the selection of the PEM as the initial advanced technology to be evaluated in the AOST office, we were presented with a unique opportunity to directly monitor the occupant use patterns and performance characteristics of individually-controlled PEM units by utilizing a network communication capability provided by the PEMs. We modeled our AOST monitoring network after the Personal Environmental Module Monitoring and Control System previously developed by Johnson Controls (described in proprietary internal reports by Johnson Controls). Johnson Controls used this system in their 1988 Advanced Office Design Demonstration, in which 24 PEMs were installed in a demonstration office in their Milwaukee headquarters building. In their installation, Johnson Controls implemented an object-oriented programming language for purposes of creating color graphic displays to demonstrate the PEM performance and allow visual analysis of the collected data. These display capabilities are also well suited to the objectives of the AOST project. We are extremely grateful to Johnson Controls for agreeing to provide us with the necessary technical support to configure the monitoring network hardware and to adapt the network software to serve the specific needs of our installation.

Network Hardware Description

The key hardware component of the AOST monitoring network is the DR-9100 Digital Room Controller contained within each PEM unit. The DR-9100 can accept six analog and six digital inputs and can provide up to seven outputs of various types, including analog, incremental, on/off pulse width modulating, and phase cut [Johnson Controls 1988, 1990]. These controllers can be networked together using an RS-485 communication link, providing a convenient configuration for monitoring PEM performance from a single host personal computer. Additional DR-9100 controllers and monitoring points can be easily added to expand the network. All monitoring software is executed from the host computer. The software enables data from connected DR-9100 controllers to be collected and stored in ASCII data files, and collected data from the files to be displayed on the computer monitor using attractive color graphic images.

Figure 4 presents a schematic diagram of the AOST monitoring network used to measure PEM and office thermal performance. A Dell System Model 325P (Intel 386 microprocessor) serves as the host computer. The monitoring software is written using three computer languages: Digitalk's Smalltalk/V 286, Spectra Publishing's PowerBasic 2.0, and Microsoft's Assembler. The software operation is described in greater detail below. A total of seven DR-9100 controllers are networked together using an RS-485 link. As shown in the figure, four of the controllers are contained within the four PEM units (PEM1 - PEM4) installed in the AOST office. For purposes of monitoring additional sensors, three more DR-9100s were added to the network. The host computer uses one of its serial (RS-232) ports to communicate with the RS-485 network via a Black Box RS-232 <--> RS-485 Interface Converter.

Within each PEM unit, the DR-9100 allows the status of several PEM control parameters to be monitored. In the PEM's original factory-shipped configuration, we were able to read over the network the following parameters: (1) discharge air temperature (a built-in sensor measures the temperature of the air leaving the main under-desk PEM unit), (2) discharge air temperature setpoint (from control panel), (3) radiant panel setpoint (from control panel), and (4) occupancy sensor status (from control panel). In addition, by making some wiring modifications to the

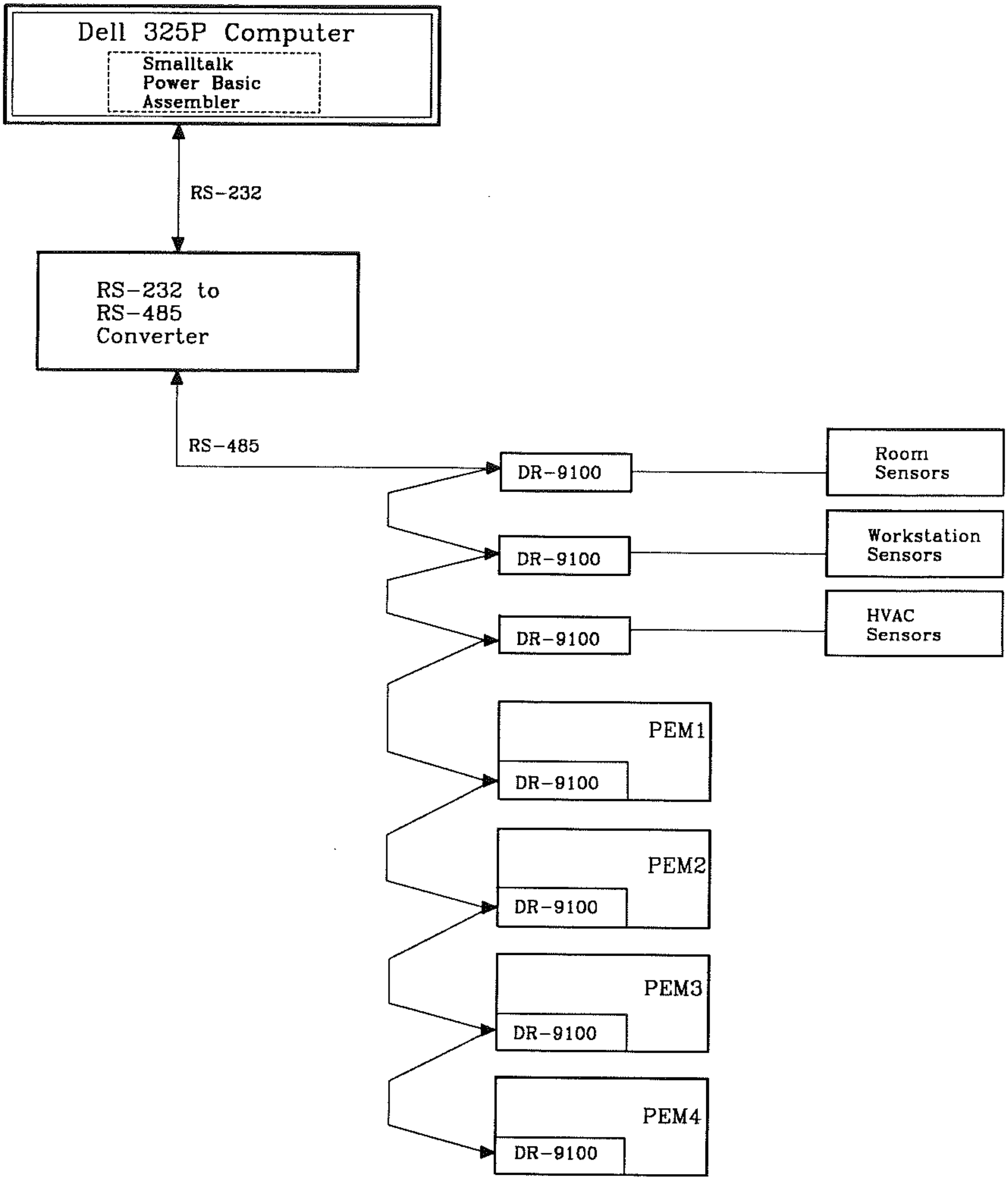


Figure 4. AOST Monitoring Network Schematic Diagram

auxiliary circuit board, we were able to utilize the three remaining unused analog input channels on the PEM's DR-9100 to monitor: (5) fan speed setpoint (from control panel), (6) task light setpoint (from control panel), and (7) workstation air temperature (a compatible temperature sensor [RS-9100] was mounted on the partition in the workstation and connected to the DR-9100 inside the PEM unit).

To monitor selected HVAC and room air conditions, we utilized the analog and digital input capabilities of three additional DR-9100s that were connected to the network. These DR-9100s served as remote signal conditioners for a group of sensors, providing power to each connected sensor requiring 15 VDC, and receiving the sensor's output signal (typically 0-10 VDC). An itemized list describing the AOST monitoring network configuration in detail is presented in Appendix A. For each monitored parameter, the list specifies the DR-9100 connection, the variable name, the sensor name, location, and output characteristics, and the sensor power requirements. The manufacturer's specifications for the sensors and equipment used in the monitoring network were previously described by Bauman (1992). A total of 47 parameters were monitored. Two sensors (SAV-1 and SAV-2) required a separate 24 VDC power supply that was shared with Endecon. The output from these two sensors was also shared with the Endecon monitoring system. All other sensors were powered by the DR-9100 units, except the occupancy sensors installed in the four conventional workstations, which used their own 24 VDC power packs.

Referring back to Figures 2 and 3, the actual locations of the host computer, main RS-485 cable, measurement sensors, and DR-9100s are shown. The host computer is located in the side office, at the northwest corner of the AOST facility. In this same area, several large electrical boxes housing all monitored energy use circuits, a multi-channel datalogger, and a second host computer for the energy use monitoring network have been installed by Endecon (described elsewhere). DR-9100 #1 is located above the ceiling along the west wall and monitors room temperature and humidity sensors. DR-9100 #2 is located at the bottom of the central column serving the conventional workstation cluster and monitors temperatures and occupancy in these four workstations. DR-9100 #3 is located above the ceiling as shown and monitors supply and return conditions in the HVAC system. DR-9100s #4-#7 are contained in the four PEMs and monitor PEM conditions and air temperature in each PEM workstation.

Network Software Description

The network monitoring and display software was written using a combination of three computer languages: Digitalk's Smalltalk/V 286, Spectra Publishing's PowerBasic 2.0, and Microsoft's Assembler. Smalltalk, an object-oriented programming system (OOPS), is the user-friendly interface and master controller for all functions of the AOST monitoring network. The Smalltalk program controls the AOST data acquisition, and runs the data display including mouse-driven menus, facility map displays, and trend data displays. As the master controller, Smalltalk can initiate the polling process over the network. At a scanning interval specified by the user, Smalltalk calls an executable PowerBasic program that accesses the connected DR-9100 controllers with Assembler routines. Scan rates as quick as 6 seconds (10 scans per minute) can be specified. After receiving the measurement data over the network, the PowerBasic program applies a unique calibration equation to each sensor's data, converting the reading to engineering units, and writes the result to ASCII data files before returning control to the Smalltalk program. These data files can then be used by Smalltalk to produce graphical data displays or imported into spreadsheets or other analysis programs for subsequent data management and analysis.

Table 1 shows the format used to write a block of data after each scan to the files. The first line contains the time in seconds since midnight and the status of the serial port (1 = connected, 0 = disconnected). For the network to be working, the status will always equal one. Each of the next seven lines contain an identification number and data from one DR-9100. The first of these data lines shows temperatures and occupancy status of the four conventional workstations (WS), the second shows temperatures and relative humidity from the AOST office (ROOM), and the third shows temperatures, airflows, and relative humidity from the HVAC supply and return lines (HVAC). Each of the next four lines contain PEM performance data and temperatures from the four workstations with PEMs (PEM1 - PEM4). Refer to Appendix A for the complete definition and specification of each variable listed in Table 1.

Each time the network is scanned, the PowerBasic code writes a block of data to two files. The file named "mm-dd-yy.DAT" (mm = month, dd = day, 19yy = year) contains all data collected on that particular date. After each scan, the block of data is appended sequentially to the end of the previously written file. At the same time, a second file named "NEW.DAT" is overwritten with the latest data from the network. NEW.DAT is only one data block long and always contains data from the most recent scan of the network.

The size of the daily data file (mm-dd-yy.DAT) is dependent on the scan rate and the time period during which data is actually recorded. For example, using a 30-second scan rate, a 12-hour data file (recorded between 7 am and 7 pm) takes up 540 KB. The source code for the PowerBasic program can be modified to set the start-time and end-time to any desired period for writing data to disk. The code can also be modified to include a timing loop of a user-specified length, allowing data collection and recording to take place in a stand-alone mode without the supervisorial control of Smalltalk.

Smalltalk Display Screens

In this section we describe and show examples of several Smalltalk display screens used to present selected measurement data in attractive color graphical displays. Smalltalk accesses the data files described above to produce these displays. Through the "Select Data to Analyze" menu item, Smalltalk calls one of the data files (for example, NEW.DAT is called if the most recent data is desired) and loads it for display. Mouse-driven pop-up menus enable the user to display selected data in two ways. (1) A "Facility Map" background shows a plan view of the AOST office, including outlines of the eight monitored workstations. Data from the PEMs and workstations are displayed inside each workstation on this map, providing a visual link between the collected data and the particular space from which the data were collected. The facility map display also allows comparisons of temperature, PEM parameters, and occupancy status between individual workstations. (2) A "Trend Data" display shows a series of graphs plotting PEM control parameters versus time for a typical working day, 7 am to 5 pm . To use the trend data display,

TABLE 1: DATA FILE FORMAT FOR AOST PROJECT

Personal Environmental Module (PEM) Monitoring Network

HEADER (row 1)	Seconds since midnight	Adapter Status (1=con; 0=discon)

DR-9100 LABEL	ID No.	**SENSOR LABEL (units)**							
WS (row 2)	1	T-WS1 (°C)	T-WS2 (°C)	T-WS3 (°C)	T-WS4 (°C)	OCC-WS1 (0,1)	OCC-WS2 (0,1)	OCC-WS3 (0,1)	OCC-WS4 (0,1)
ROOM (row 3)	2	T-TS (°C)	TSP-TS (°C)	T-CEIL (°C)	T-RM (°C)	RH-RM (%)			
HVAC (row 4)	3	SAV-1 (cfm)	SAV-2 (cfm)	SAT-1 (°C)	SAT-2 (°C)	RAT (°C)	SARH (%)		
PEM1 (row 5)	1	SAT-P1 (°C)	TSP-P1 (%)	RAD-P1 (%)	FAN-P1 (%)	LITE-P1 (%)	T-P1 (°C)	OCC-P1 (0,1)	
PEM2 (row 6)	2	SAT-P2 (°C)	TSP-P2 (%)	RAD-P2 (%)	FAN-P2 (%)	LITE-P2 (%)	T-P2 (°C)	OCC-P2 (0,1)	
PEM3 (row 7)	3	SAT-P3 (°C)	TSP-P3 (%)	RAD-P3 (%)	FAN-P3 (%)	LITE-P3 (%)	T-P3 (°C)	OCC-P3 (0,1)	
PEM4 (row 8)	4	SAT-P4 (°C)	TSP-P4 (%)	RAD-P4 (%)	FAN-P4 (%)	LITE-P4 (%)	T-P4 (°C)	OCC-P4 (0,1)	
	col 1	col 2	col 3	col 4	col 5	col 6	col 7	col 8	col 9

the user selects one of the four PEM workstations and the day to be analyzed. The display then shows a daily cycle of temperatures and PEM settings for the selected workstation. Refer to Appendix B for "Basic Instructions" for using the Smalltalk facility map and pop-up menus, and "General Information" for using Smalltalk in general and as it applies to the AOST facility map.

Figure 5 shows the Smalltalk display menu flow chart, indicating the range of display screens accessible through mouse-driven pop-up menus. In the following screen examples, data have been used from 30 April 1992, during the second thermal comfort field study.

- TURN TIMER ON
- TIMER RESET
- MANUAL AHU RESET
- FACILITY MAP
    - Select Data to Analyze [prompts for date and time]
    - Restore Map
    - Request Map
    - Occupancy Conditions
        - Occupancy
        - Gender
        - Age
    - Room Air Conditions
        - Room Temperatures and Humidity
        - Workstation Temperatures
    - PEM Parameters
        - Air Temperatures
            - PEM Workstation Temperatures
            - Set Point Temperature
            - Discharge Temperature
        - Fan
            - Fan Speed Set Point
        - Radiant Panel
            - Radiant Panel Set Point
        - Task Lighting
            - Task Lighting Set Point
    - HVAC Parameters
        - Supply Volumes
        - Supply Temperatures
        - Supply Relative Humidity
        - Return Temperature
- TREND DATA [prompts for date and workstation]
- EXIT DEMO

Figure 5. Smalltalk Display Menu Flow Chart

Figure 6 shows workstation temperatures (°C) at 1:38 pm for all eight workstations. This screen is generated by selecting "Workstation Temps" under the "Room Air Conditions" menu to display the four non-PEM workstations, and then selecting "PEM Workstation Temp" under the "Air Temps" sub menu of the "PEM Parameters" menu to display the four PEM workstations simultaneously.

Figure 7 shows the status of the four PEM fan speed setpoints (%) at 1:38 pm. This is generated by selecting "Fan" under the "PEM Parameters" menu. Other PEM parameters that can be displayed in this same manner include temperature setpoint (%), discharge temperature (°C), radiant panel setpoint (%), and task lighting setpoint (%).

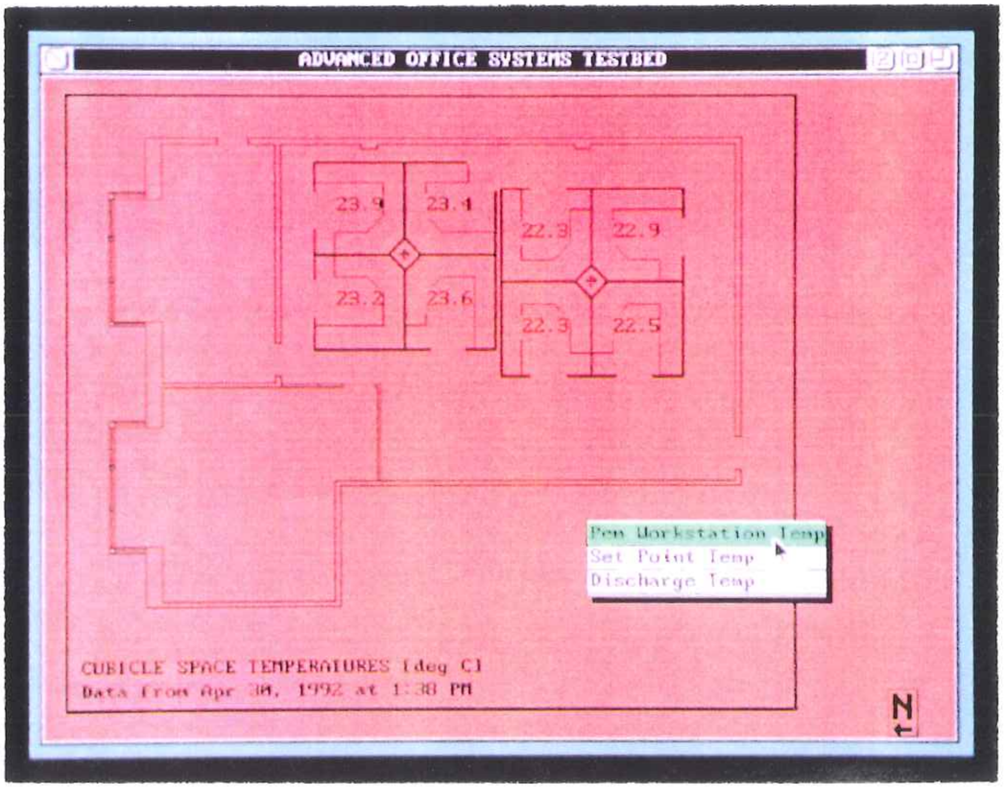
The user can also choose to display the occupancy status of the eight workstations by selecting "Occupancy" under the "Occupancy Conditions" menu. Figure 8 shows the occupancy status (IN, OUT) at 1:38 pm. The user can access a complete workstation pop-up display by clicking with the mouse within the desired workstation outline on the facility map to list data particular to that workstation. The workstation-specific data include limited occupant information (name, gender, age, etc.), date and time, occupancy status, and workstation temperature. If the selected workstation contains a PEM, as in the example shown in Figure 9, the additional PEM parameters are also displayed.

Figure 10 lists room air conditions, including temperatures (°C) and relative humidity (%), at 1:38 pm. This is generated by selecting "Room Temp and Humidity" under the "Room Air Conditions" menu. Various performance parameters from the HVAC system can also be displayed, including supply air volumes, supply air temperatures, supply air relative humidity, and return air temperature. Figure 11 lists supply air temperatures (°C) for the overhead (ROOM) air distribution system and the PEM air distribution system at 1:38 pm. This is generated by selecting "Supply Temps" under the "HVAC parameters" menu.

A "Trend Data" display can be accessed to show a series of graphs plotting PEM control parameters versus time for a selected date. The trend data graphs are plotted for a time interval of 7 am to 5 pm, a typical office working day. Figure 12 shows an example of such a display for one of the PEM workstations on 30 April 1992. The trend data display shows PEM discharge temperature, workstation temperature, occupancy status, and PEM setpoints for fan speed, task lighting, and radiant panel use.

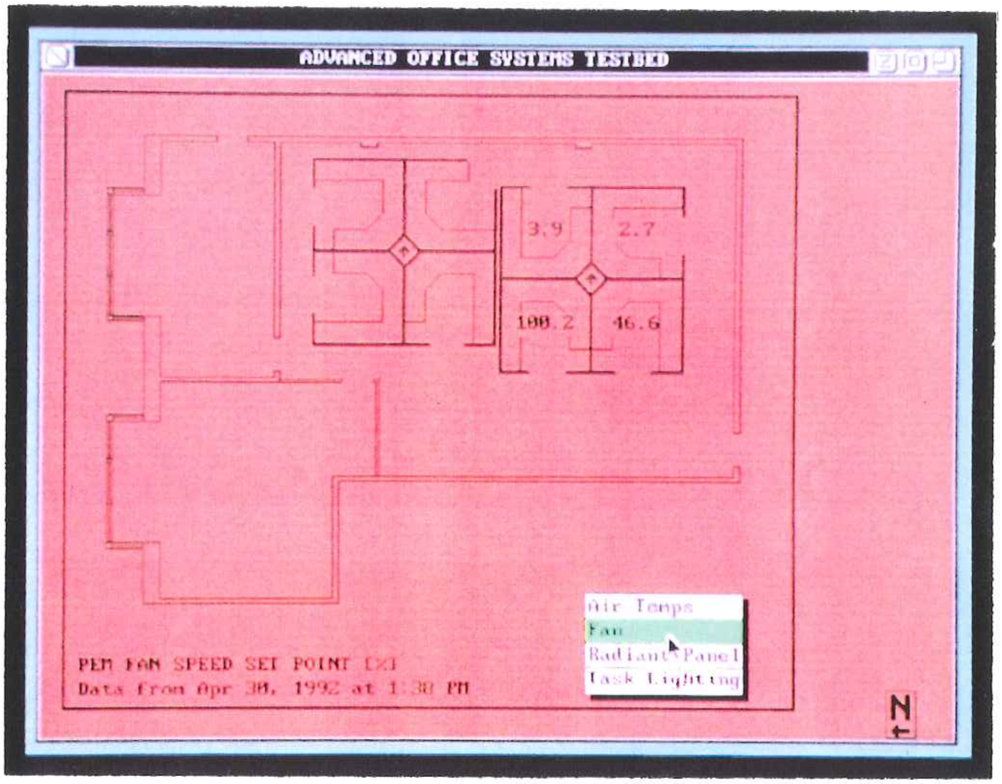
System Installation, Troubleshooting, and Calibration

Prior to installing the monitoring network in the AOST office, we obtained all the hardware (PEMs, DR-9100s, sensors, host computer, etc.) and assembled the entire network for testing and troubleshooting in our laboratory at UC Berkeley. Since we were adapting someone else's hardware and software for our own application, this was an important step to become familiar with the system. Johnson Controls and several affiliated consultants provided valuable assistance to us during this phase of the project.



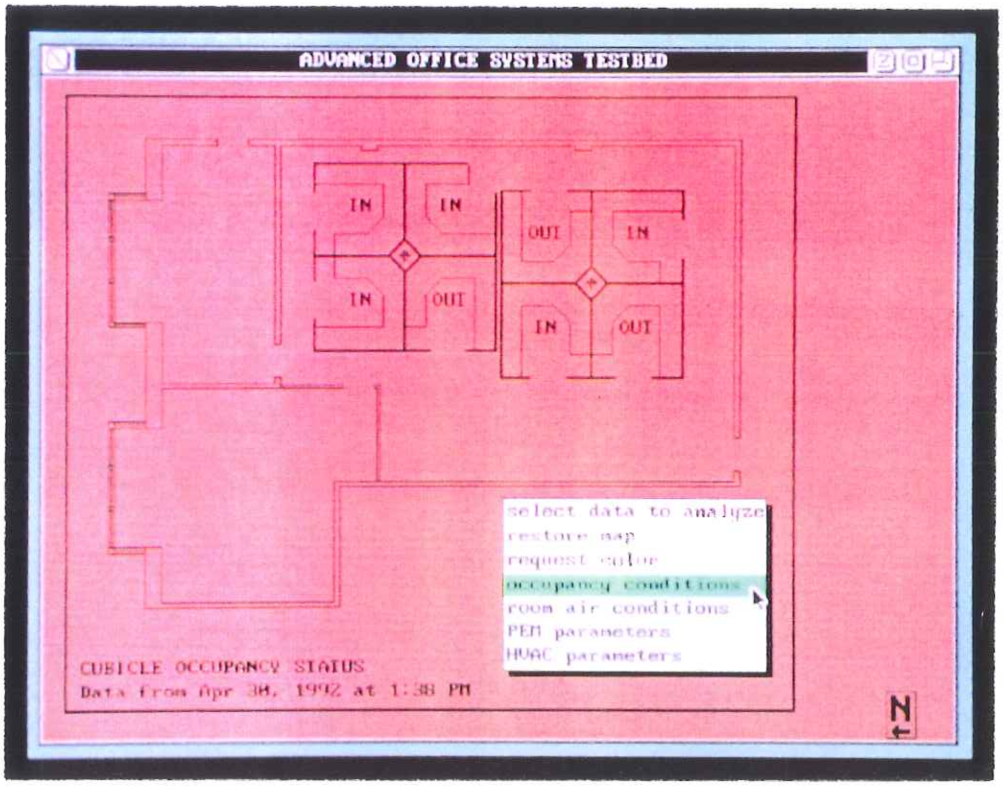
CUBICLE SPACE TEMPERATURES [deg C]
Data from Apr 30, 1992 at 1:38 PM

Figure 6. Smalltalk Display Screen: Workstation Temperatures



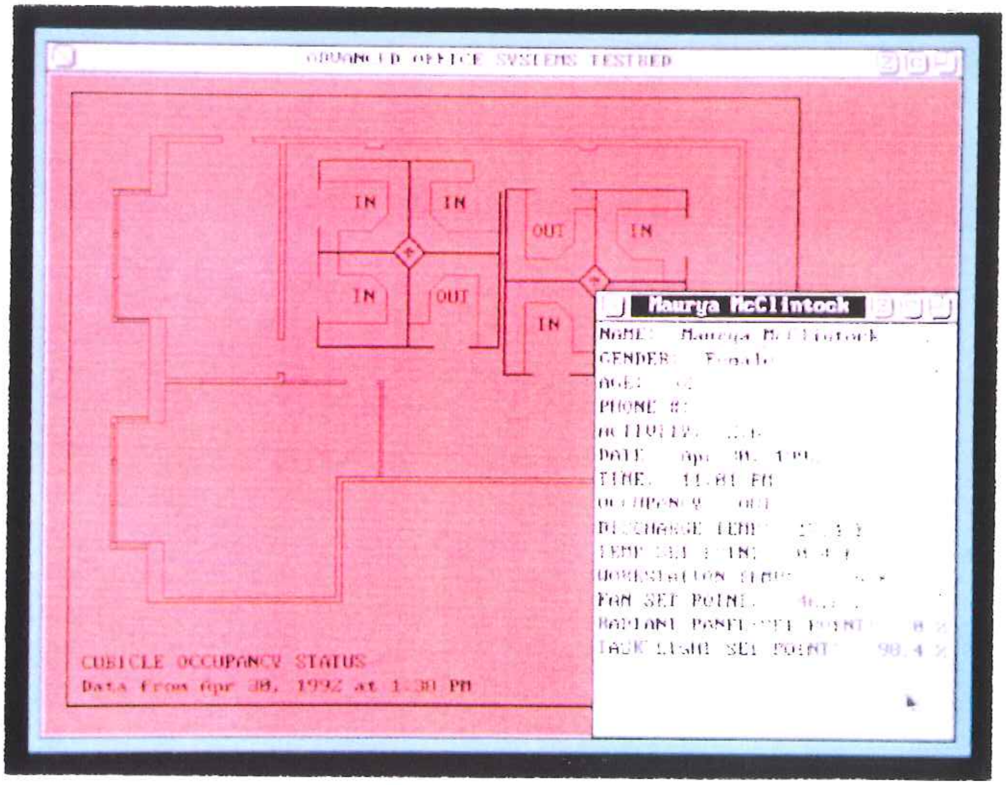
PEM FAN SPEED SET POINT [%]
Data from Apr 30, 1992 at 1:38 PM

Figure 7. Smalltalk Display Screen: PEM Fan Speed Setpoint



CUBICLE OCCUPANCY STATUS
Data from Apr 30, 1992 at 1:30 PM

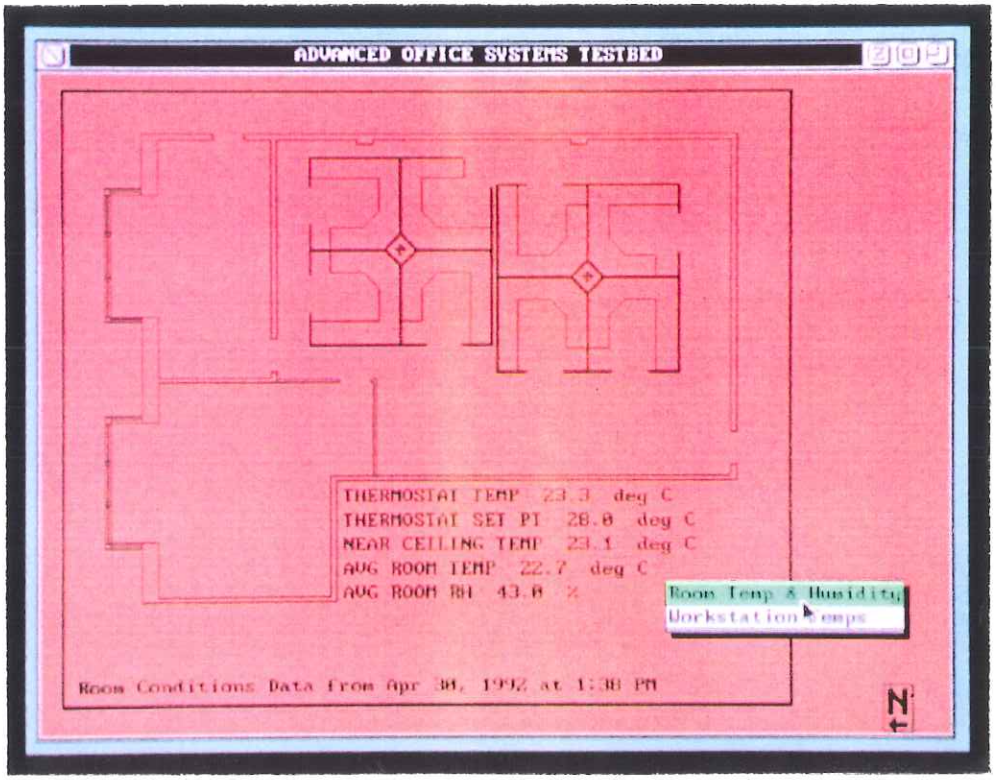
Figure 8. Smalltalk Display Screen: Occupancy Status



NAME: Maurya McClintock
GENDER: Female
AGE: [illegible]
PHONE #:
ACTIVITY: [illegible]
DATE: Apr 30, 1992
TIME: 11:01 PM
OCCUPANCY: OUT
DISCHARGE TEMP: [illegible]
TEMP SET POINT: [illegible]
WORKSTATION TEMP: [illegible]
FAN SET POINT: [illegible]
RADIANT PANEL SET POINT: 0 %
TASK LIGHT SET POINT: 98.4 %

CUBICLE OCCUPANCY STATUS
Data from Apr 30, 1992 at 1:30 PM

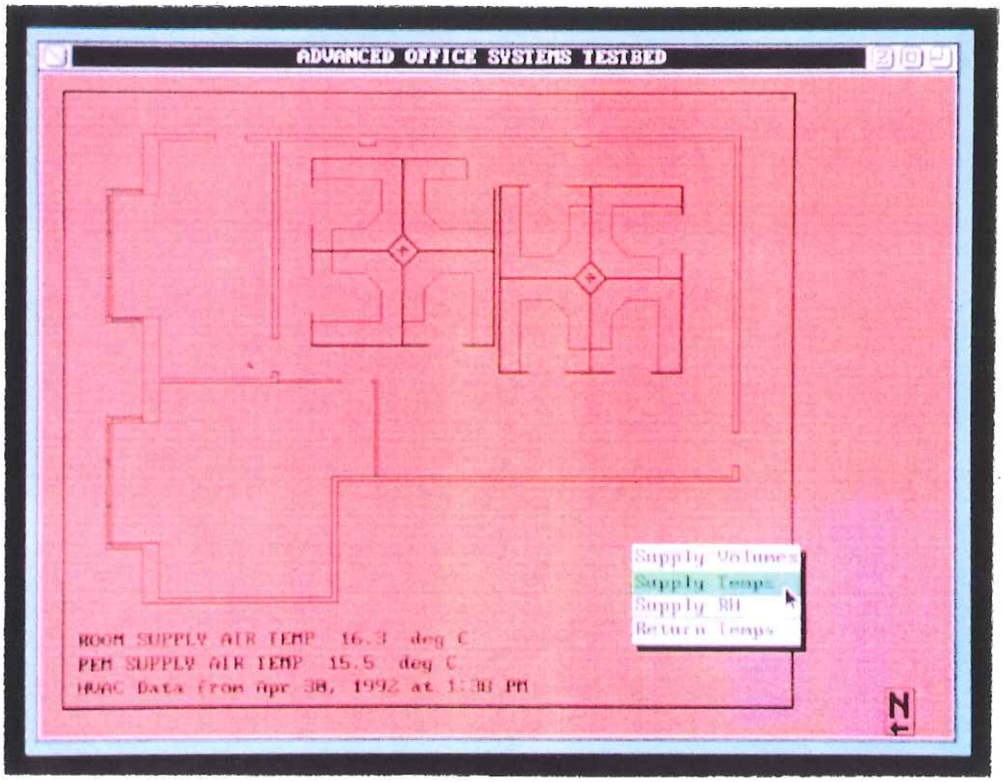
Figure 9. Smalltalk Display Screen: Complete Workstation Pop-up Display



THERMOSTAT TEMP 23.3 deg C
THERMOSTAT SET PT 28.0 deg C
NEAR CEILING TEMP 23.1 deg C
AVG ROOM TEMP 22.7 deg C
AVG ROOM RH 43.0 %

Room Conditions Data from Apr 30, 1992 at 1:38 PM

Figure 10. Smalltalk Display Screen: Room Air Temperatures and Humidity



ROOM SUPPLY AIR TEMP 16.3 deg C
PEM SUPPLY AIR TEMP 15.5 deg C
HVAC Data from Apr 30, 1992 at 1:38 PM

Figure 11. Smalltalk Display Screen: Supply Air Temperatures

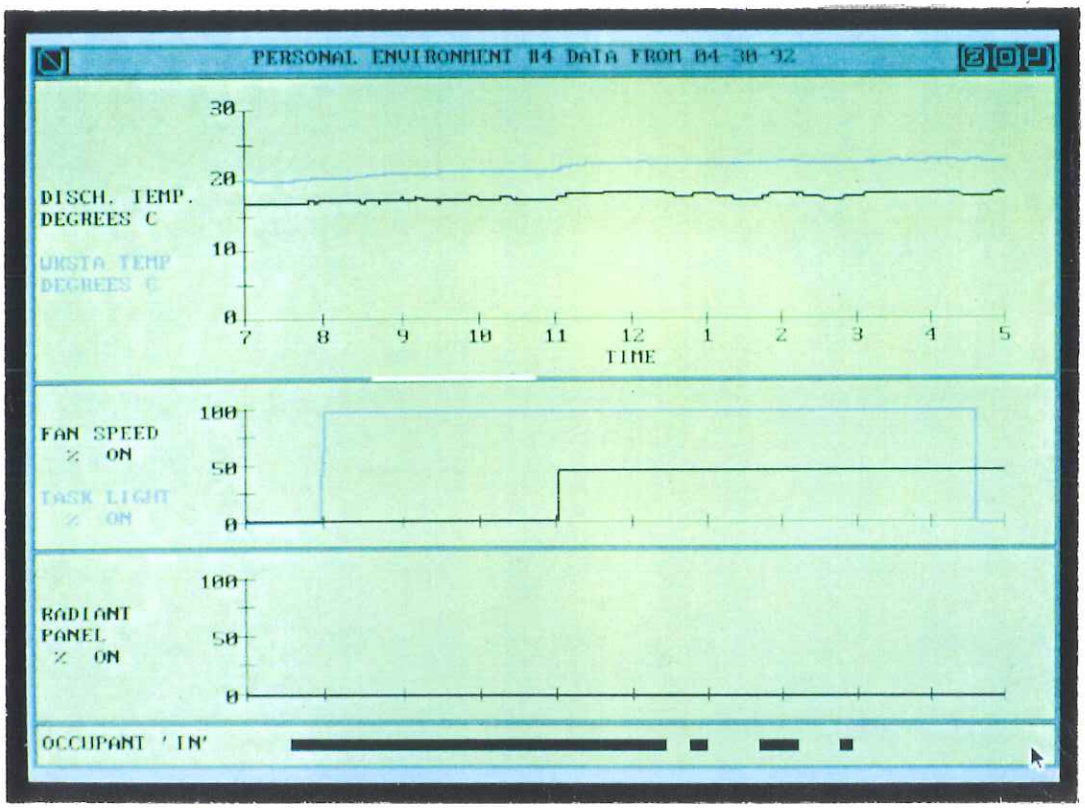


Figure 12. Smalltalk Display Screen: Trend Data

Using the assembled network, we performed preliminary calibration checks of all sensors using side-by-side comparisons with high-quality in-house reference sensors. These checks confirmed the correct connection and operation of the network hardware. Since installing the monitoring network in the AOST office in San Ramon, the accuracy of all sensors has been checked and the sensor calibration equations (contained in the PowerBasic program) have been modified, if necessary. The work performed to carry out the network calibration is described further below.

The measurement accuracy's discussed below refer to total system accuracy (sensor plus DAS). All workstation and room air sensors (RS-9100) appear to be reading to within ±1°C of the expected value. These sensors were checked by side-by-side comparison with two high quality laboratory reference temperature sensors whose accuracy was rated at ±0.2°C. The duct-mounted supply air temperature sensors (TS-9100) were initially found to have slightly larger errors because the lower temperatures being measured were below the range previously checked in our laboratory. New calibration coefficients were installed for these sensors and agreement is now also to within ±1°C of the expected value. Both the wall-mounted (RH-RM) and duct-mounted (SARH) relative humidity sensors have been checked with a sling psychrometer and agree to within ±3% of the expected value, matching the manufacturer's specifications. The discharge air temperature sensors contained in the PEM units are relatively inaccurate and only agree to within (±2-3°C) of the reference sensor. All occupancy sensors are operating correctly. The response time (time delay until the sensor status switches to 'unoccupied') of the sensors after the workstation is vacated is approximately three minutes for the PEM sensors and six minutes for the WS sensors.

Measurement of supply air volume to the ceiling-based diffusers (SAV-1), utilizes the existing variable-volume terminal unit serving that duct line. The terminal unit (Titus Model ESV-3000) features a multi-point center-averaging pressure sensor located at the inlet. Monitoring the pressure difference between the high and low pressure leads from the inlet sensor allows the total flow through the unit to be measured. During the first calibration check of this supply line (August 1992), two 8-point traverses were performed in the duct immediately upstream of the terminal unit with a hand-held anemometer. The flow measured by the traverses was found to agree to within about 10-20% of the flow measured by the inlet pressure sensor. The disagreement between these results was accounted for by two factors: (1) the incoming flow was quite nonuniform due to the upstream duct configuration; and (2) during the measurements, the flow was observed to fluctuate repeatedly (cycle) over a 45-second period with an amplitude of ±10%, making accurate measurements more difficult. At the same time, a flowhood was used to measure the air being supplied by the four diffusers served by this line. The total flow from the diffusers was found to be significantly less than that measured at the terminal unit. An inspection of the duct system in the ceiling plenum found that the flexible duct that had previously been disconnected and capped from the diffuser above the PEM2 workstation (see Figures 2 and 3) had reopened, allowing supply air to flow freely into the plenum area. The duct has since been resealed. A second calibration check of this supply line (March 1993) found the flow reported by the monitoring network agreeing to within 10-15% of the total flow measured with a flowhood at the four supply diffusers. Considering the time (1-2 minutes) required to complete the flowhood measurements, this is an acceptable comparison, indicating that no major leaks exist in the supply ducts.

Measurement of supply air volume in the duct line serving the four PEM units (SAV-2) is accomplished with an Eldridge Products Series EP-8831 thermal mass flowmeter. As shown in Figure 3, the duct was configured to accommodate a straight length of duct (approximate ten duct diameters) upstream of the measurement location. This produced a well-developed velocity profile within the 12-in. round duct, allowing reliable flow measurement at a single point. A ten-point traverse with the EP-8831 at this measurement location (March 1992) confirmed the effectiveness of the straight duct configuration. Table 2 presents the results of the traverse performed under minimum flow conditions (all PEM fan setpoints set at minimum); the measurement positions are determined to represent the centers of equal concentric areas. The total flow is simply the average of the ten readings. The results demonstrate the flat, well-developed velocity profile in the duct. The EP-8831 sensor was permanently installed at the center of the duct and read 135 cfm, equal to the average result from the traverse. Also shown in the table for comparison are the results of flow measurements at each of the eight PEM supply nozzles made with a hand-held anemometer. The disagreement between the two results for total PEM supply volume is less than 10%, a good result for this type of measurement.

In general, the measurement accuracy's described above are quite adequate for the intended use of the collected data: to observe overall trends in the performance of the HVAC system and to identify any significant thermal events in the AOST office that may account for unexpected PEM and thermal comfort results.

Troubleshooting the operation of the system software that controls the data collection process also proved to be challenging for a number of reasons.

Table 2. Calibration Results of PEM Supply Air Volume

Supply Duct			PEM Supply Nozzles		
Point	Position (R = radius)	Airflow (cfm)	Wrkstn.	Nozzle	Airflow (cfm)
1	0.051R	140	PEM1	left	13
2	0.163R	130	PEM1	right	20
3	0.293R	135	PEM2	left	23
4	0.452R	140	PEM2	right	17
5	0.684R	135	PEM3	left	20
6	1.316R	135	PEM3	right	18
7	1.548R	140	PEM4	left	20
8	1.707R	135	PEM4	right	14
9	1.837R	120			
10	1.949R	120			
Total		**135**			**145**

1. The assembly language code written to access the DR-9100 had timing loops and other time-based statements that were dependent on the speed of the computer. These machine-dependent statements interfered with the proper handshaking required for smooth data transmission between the DR-9100s and the computer through its serial port. Several modified versions of the assembler code were tested before achieving reliable communication over the monitoring network. However, at the time of writing this report, we have only communicated consistently at the slower 8-MHz clock speed of the host Dell computer. While this is not a problem for data collection, Smalltalk would operate more effectively at the faster 25-MHz clock speed.

2. Despite the improvements described above, evidence still persisted that a timing problem was resident in the data collection software. Over the course of a day, the host computer's clock was losing time. The amount of time lost was directly proportional to the monitoring network scan rate. A 30-second scan rate produced an 8-second loss of time for every one hour of operation, making it difficult to accurately merge the two separate data files generated by UC Berkeley's and Endecon's monitoring systems. In this case, the offending statement was in the PowerBasic code within the write-to-file routine (repeated every scan). The code was corrected and now operates correctly without any timing problems.

3. Work on the problems described above was complicated by the fact that the original assembler code was written by an Italian affiliate of Johnson Controls and was not well documented. We acquired the services of Chuck Rohrer, a consultant from Technisoft Corp., Milwaukee, WI, who worked on the original PEM project, to address these programming difficulties.

During the troubleshooting and calibration period described above, we spent some time studying and evaluating the performance of the HVAC system serving the AOST office. We identified several HVAC issues requiring further attention. These issues are described briefly below.

1. As mentioned above, an uncapped duct line allowed cool primary air to be supplied directly to the ceiling plenum. Although the line has since been recapped, we do not know how long this line was open. It may have been open during the first comfort field test in the AOST office (30 April - 1 May 1992). Under these circumstances, it is difficult to make an accurate assessment of HVAC performance. There is a high probability of short-circuiting with an unknown amount of supply air being delivered directly to the return plenum.

2. Also mentioned above, the airflow through the VAV box serving the ceiling diffusers fluctuated rather significantly over a 45-second cycle. This would seem to indicate a flow control problem at the VAV box or at the main air handling unit.

3. The Titus VAV box serving the ceiling diffusers was originally sized and installed to handle the load from a larger office space. After the renovation of the AOST office and the addition of a second supply line serving the four PEM workstations, the required flow through this VAV box was significantly reduced. VAV boxes are known to have difficulty throttling down below about 20% of maximum flow. The correct operation of the VAV box should be checked, as it may account for the fluctuating flow described above in (2). Future plans to test the AOST office under elevated thermostat setpoint conditions (reduced airflow) also make it desirable that a properly sized VAV box be installed.

4. During the renovation of the HVAC system for the AOST office, it was planned to separate, to the extent possible, the operation of the supply lines serving the two workstation clusters in the office. This was done by disconnecting two ceiling diffusers that were located above the PEM workstations, and leaving the other four to condition the remaining areas of the office. However, as shown in Figure 3, one of the remaining diffusers is directly above the PEM1 workstation, providing little chance (if one ever existed) that the operation of two supply systems can be distinguished. This configuration may also tend to overcondition the PEM workstation area, reducing the need to use the PEM air supply. If additional improvements are made to the AOST office, we recommend that the operation of the two supply lines be completely separated. By allowing one or the other supply line to be closed off, the effect of the PEM air supply (or the overhead supply) on the thermal performance of the office can be more clearly investigated.

THERMAL COMFORT FIELD MEASUREMENTS

A second major component of the work performed by CEDR researchers has been the measurement and detailed evaluation of thermal comfort both before and after the installation of the AOST office. Eight PG&E employees were originally selected to be participants in the thermal comfort study. Using an in-house portable measurement system, we have applied previously developed thermal comfort assessment methods to complete three field tests of the study participants, as described below.

1. At the work locations in the Sunset Building occupied by the eight participants prior to moving into the AOST office to establish a baseline profile of thermal comfort conditions. This test was completed on 16, 17 October 1991.
2. Soon after moving into the AOST office to assess their immediate reactions to the new work environment. This test was completed on 30 April - 1 May 1992.
3. Several months after moving into the AOST office to assess occupant comfort and satisfaction after a period of acclimatization. This test was completed on 16, 17 September 1992.

Results from these three field tests have been analyzed within the context of existing thermal comfort standards. This process includes the calculation of standard comfort indices, comparison of AOST data to similar data from a ten building sample of Bay Area office buildings, and comparison to existing ASHRAE and ISO standards [ASHRAE 1981; ISO 1984, 1985]. Described below are our physical instrumentation package, field measurement protocols, and subjective survey.

Physical Measurement System

In 1991 CEDR developed a second-generation physical measurement system for use on PG&E's ACT^2 thermal comfort field study. This portable measurement cart has been used for the AOST office comfort study reported here. The system design was based on an earlier version that was developed and used for an ASHRAE-funded field study carried out by CEDR in the San Francisco Bay area in 1987 [Schiller et al. 1988; Benton et al. 1990]. The new thermal measurement cart takes advantage of recent technological developments in data acquisition hardware and transducers by packaging these in a frame smaller and more maneuverable than the original cart design. The new cart, like its predecessor, collects a complete set of detailed measurements characterizing the local thermal environment using an automated approach. We collected data for air temperature, relative humidity, air velocity, globe temperature, and radiant asymmetry to satisfy the requirements of ASHRAE and ISO.

The new cart design meets the following specifications:

- The system is capable of collecting concurrent physical data (air temperature, dew-point temperature, globe temperature, radiant asymmetry, air velocity, and illuminance) from an array of transducers placed to represent the immediate environment of our seated subjects.

- The physical measurement transducers and their interrogation meets the ASHRAE 55-81 (1981) and ISO 7726 (1985) standards for accuracy and response time.

- Physical measurements are made as close as possible to the exact physical position of the subject completing the subjective questionnaire, and as soon as possible after completion of the questionnaire.

- The survey process, including subjective responses and physical measurements, is completed in approximately 10 minutes per workstation visit.

- All physical and subjective data are collected in machine-readable form. Compiling data in digital files during the collection process eliminates keypunch errors and expedites daily summary sheets for error checking.

- The instrumentation package is mobile and portable, its battery power capable of a full day's operation without recharge.

- The data acquisition system provides a real-time display of measured values for error-checking purposes. These values are hidden from the sight of test subjects to avoid bias in their answers to subjective questions.

- The field equipment is automated to the extent that student assistants with modest training could contribute to the daily data collection effort.

To meet these specifications, we assembled an array of transducers, constructed an integrated signal processing and data acquisition system, and programmed two laptop computers for data reduction and display in real-time. All equipment is mounted on a two-wheeled chassis of 3 inch by 1 inch aluminum tubing with a wooden "chair" attached to the front (see Figure 13). In addition to battery storage, the "seat" of the chair shields the sensors and carries the laptop computer that issues the subjective survey questionnaire at each workstation visit. We had several signal processing devices custom-built to our specifications for this application and they are mounted under the seat and in the seat back. Behind the seat back is a second laptop computer that provides the cart operator with a real-time view of the transducer values and presents a stripchart-format time history of the previous ten minute's data.

The cart's transducer specifications and the heights of each from the floor are listed in Table 3. These sensors were chosen to meet the response time and accuracy requirements of ASHRAE Standard 55-81 and ISO Standard 7726 for thermal assessment. In general, the temperature sensors are accurate to within 0.2°C and have a time-constant of several seconds. The sensors we used are YSI Series 700 probes having a vinyl-coated tip on a flexible signal wire. Where globe temperature was measured, we mounted a table tennis ball on the cart with one of the YSI temperature sensors in the center of the "globe". The globe is painted gray for the proper emissivity and responds to the balance between radiation and convection in the physical environment. In an office environment where the differences between workstations are relatively small, the globe should reach equilibrium well within the 5 minute measurement period. A short

a	transducers at 1.1 m (air temperature, globe temperature, air velocity)
b	transducers at 0.6 m (air temperature, globe temperature, air velocity)
c	transducers at 0.1 m (air temperature, globe temperature, air velocity)
d	radiant asymmetry transducer
e	illuminance sensor
f	inlet, dew point sensor
g	laptop computer
h	data acquisition and signal conditioning compartment
i	battery compartment
j	pseudo chair (storage compartment for subjective survey laptop computer)

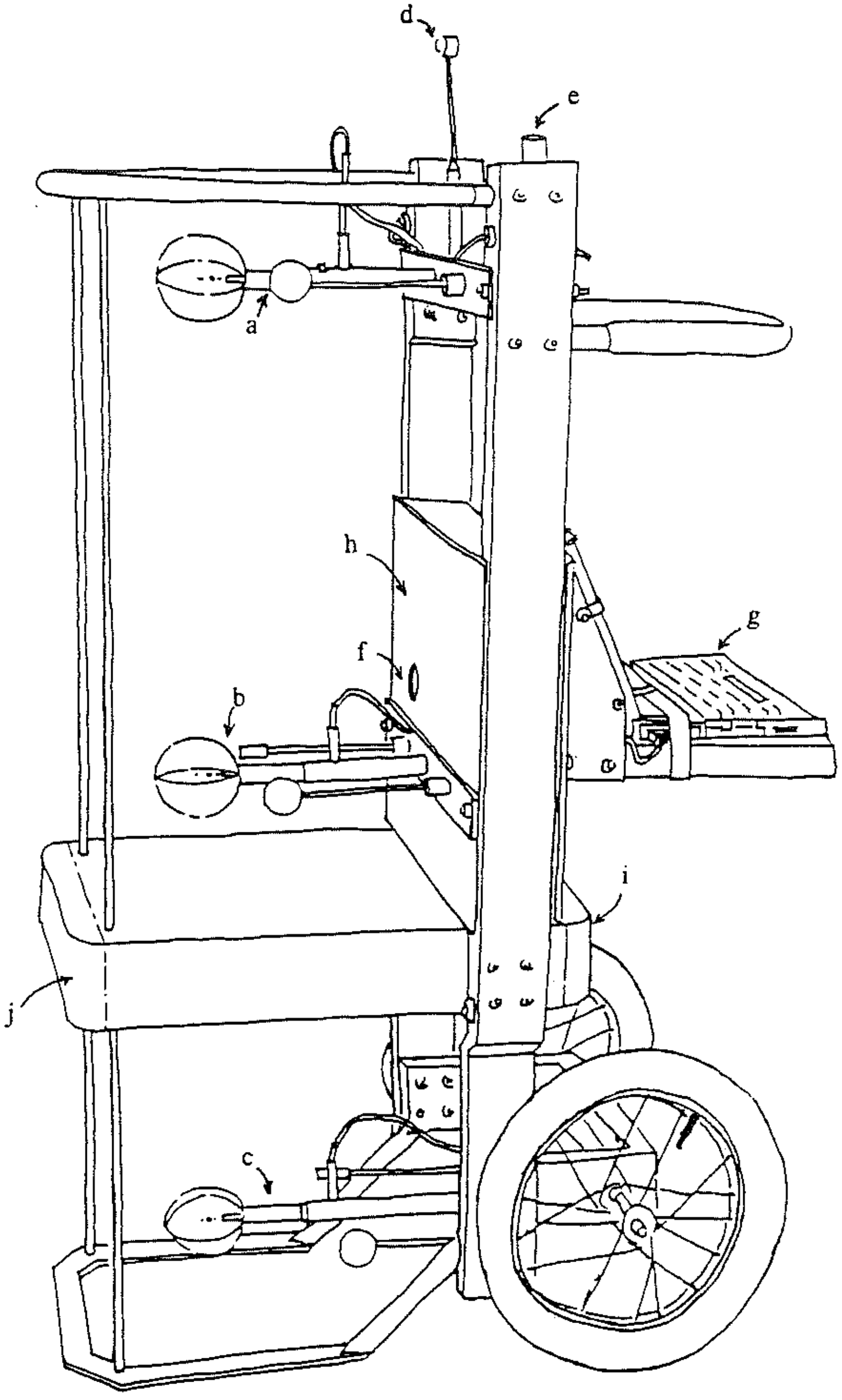


Figure 13. Sketch of Measurement Cart

TABLE 3
Transducer Specifications

QUANTITY	SENSOR DESCRIPTION	SENSOR LOCATION	MEASUREMENT ACCURACY				RESPONSE TIME
			ASHRAE 55-81	ISO-7726	MANUFACTURER	CALIBRATION	
Air Temperature	shielded composite thermistor	0.1, 0.6, 1.1 m	± 0.2°C	Required: ± 0.5°C Desired: ± 0.2°C	± 0.1°C over range 0 to 40°C	± 0.2°C over range 20.7 to 28.5°C	5 sec (90%)
Globe Temperature	composite thermistor inside 38 mm diameter table tennis ball (painted grey)	0.1, 0.6, 1.1 m;	Desired: ± 0.2°C (for MRT)	Required: ± 2.0°C Desired: ± 0.2°C (for MRT)	± 0.1°C over range 0 to 40°C (for thermistor)	± 0.1°C over range 18.7 to 25.1°C (for thermistor); ± 1°C (for operative temp.)	2.5 min (63.2%); 5.8 min (90%)
Air Velocity	spherical omnidirectional temp. compensated anemometer	0.1, 0.6, 1.1 m	± 0.05 m/s over range 0.05 to 0.5 m/s	Required: ± 5% ± 0.05 m/s Desired: ± 2% ± 0.07 m/s over range 0.05 to 1.0 m/s	± 0.01 m/s over range 0.05 to 1.0 m/s	factory calibration checked by intercomparison	< 0.1 sec (63%);
Humidity	chilled-mirror dew point sensor	0.6 m	± 0.6°C (for dew point temp.)	± 0.15 kPa (for water vapor partial press)	± 0.5°C (for dew point temp. over range: -18°C to 38°C)	factory calibration checked with sling psychrometer	10 sec
Radiant Temperature Asymmetry	opposing plane radiant temperature sensors	1.1 m	± 1.0°C	Required: ± 1.0°C Desired: ± 0.5°C	± 0.5°C for $\lvert T_{pr} - T_{air} \rvert \leq 15$°C	± 0.4°C over range 18.7 to 25.1°C (for plane radiant temp.)	60 sec (90%)
Illumination	silicon photovoltaic photometer	1.1 m	N/A	N/A	± 5%	factory calibration checked by intercomparison	instantaneous

discussion of globe temperature and it's measurement is provided in Benton, Bauman and Fountain (1990).

Air velocity was measured at three heights by Dantec 54R10 anemometers. The 54R10 is an omni-directional fully temperature-compensated sensor with a time constant of 0.1 second. A fast response time is essential for accurate measurement of turbulence in the airflow. Each sensor has two nickel-plated quartz spheres supplied with a small electrical current. The current heats the spheres which in turn are cooled by passing airflow. Velocity is measured by regulating the electrical current to maintain the spheres at a constant temperature.

Dewpoint temperature is measured by a General Eastern DEW-10 chilled mirror dewpoint transducer. In this transducer, a heated chimney draws a small sample of room air into a measuring chamber where a small mirror is continuously cooled. A nearby LED shines a beam of light at the mirror where it is reflected to a photosensor. When the mirror reaches the dewpoint temperature of the air sample, water condenses on the mirror scattering the light beam so the signal to the photosensor is interrupted. Then the temperature of the mirror is measured and sent to the central datalogger.

Radiant asymmetry is measured by a Bruel and Kjaer Plane Radiant Asymmetry sensor. Plane radiant temperature is defined as the uniform surface temperature of a hemisphere that produces the same incident radiation on a black surface as the actual environment. Radiant asymmetry is the difference between the plane radiant temperatures of small planes facing opposite directions. The radiant asymmetry probe consists of two pairs of gold-plated and black-painted elements connected to thermopiles. Each side of the probe has a gold and a black element. The measurement is based on the fact that the gold element exchanges heat primarily by convection while the black element exchanges heat by both convection and radiation. Thus any voltage generated across the thermopiles results from heat transfer by radiation between the black element and the environment.

Illuminance is an ancillary parameter that may be useful in later analysis. A cosine-corrected silicon photometer manufactured by Li-Cor measured illuminance in the horizontal plane.

The cart's data acquisition system consisted of several signal processors feeding a central datalogger programmed to poll the sensors and relay the data to a laptop computer for display and storage. Since both the air velocity and air temperature sensors are inherently non-linear transducers, signal processing is required to convert these measurements to engineering units. In the case of the temperature sensors, a linearization bridge on the signal side is required while more extensive circuitry is necessary for controlling the current supplied to the anemometers and providing temperature compensation. The signals from all transducers and signal conditioning are sent continuously to the heart of the system, a Campbell Scientific 21X Micrologger. The datalogger measures the sensor signals and converts each to engineering units using polynomial curve fits or linear conversions as appropriate. The 21X is connected to a lightweight laptop computer that serves as data display, operator interface, and data storage device.

The Campbell Scientific datalogger also controls the timing and sequence of measurements. A data-collection sequence is initiated by the operator flipping a switch mounted on the top of the cart. This instructs the datalogger to begin storing data from the sensors and is indicated by an LED glowing solid green near the cart switch. The laptop computer continuously displays data in a stripchart fashion with an indicator showing whether the data is being stored or not. After one minute of monitoring the transducers as they come into equilibrium with the physical environment at the workstation, the datalogger shifts into "burst" mode. Burst mode is the only state in which the datalogger can sample the anemometers quickly enough to measure turbulence intensity. During the next three minutes, the datalogger is completely occupied with the air velocity measurement, collecting 60 data points per second while the LED blinks green. After the burst measurement is complete, the 21X collects data from the other sensors at the rate of one sample per second for the remaining one minute. During the last minute of data collection, the LED glows solid red and turns off when the measurement sequence is complete and the cart can be safely moved. The total number of air velocity readings taken during the three minute measurement burst is 7,200, too much data to process in real-time. So, as the cart is being moved to the next workstation, a post-measurement processing sequence reduces the 7,200 readings to engineering units, calculates turbulence intensity, and stores the final values on the hard disk with data from the other transducers.

Subjective Survey System

As in our previous thermal comfort fieldwork, the subjective survey system is divided into two parts, background and online. The background survey is a 10 page paper survey with questions relating to demographics, job satisfaction, work area satisfaction, health, and characteristic emotions. It is issued to and collected from the subjects before any workstation visits. The online survey is given before each workstation visit and has questions relating to current thermal sensation, environmental satisfaction, emotions, clothing, and activity level. The new subjective survey laptop is carried in the cart seat, has a adjustable back-lit screen, a 80286 processor, and battery power for a full day.

To reduce the online survey completion time, several changes were recently made to the content of the survey instruments. The most notable is that a section on coping strategies was added to both the background and online surveys. Coping strategies represent ways in which the subject can make changes to the local thermal environment. In the background survey, available coping strategies were listed by the subject and those available to him/her were presented during each online visit and their status was recorded, e.g. fan on, blinds half open, etc. Coping strategies are particularly applicable to the four participants in the AOST office who have PEM units in their workstations. Copies of the background survey and the online survey computer screens are presented in Appendixes C and D.

Field Measurement Protocol

Eight PG&E employees were originally selected to participate in the study, including three females and five males. During the baseline field test, one male subject was unavailable to be measured. Although this particular subject participated in the second field test (first post-occupancy survey) he subsequently vacated the AOST office and was not involved in the third and final field test. He was replaced in the last test with another male subject. In addition, one female subject participated only in the baseline survey and was replaced with another female subject who participated in both post-occupancy surveys. This pattern of changing occupancy represents one of the problems associated with obtaining reliable trend data over a relatively long period of time (approximately one year). In the case of the small sample size in the AOST comfort study, only six subjects participated in all three field tests. During the first two field tests, 39 online visits were made, and during the last field test, 38 visits were completed. Each visit lasted approximately 10 minutes for the combined subjective and physical measurements.

The field measurement protocol closely followed that developed in our previous thermal comfort field work. While a physical measurement is collected at a particular workstation, the field worker looks for potentially available subjects to take the subjective survey. Having found the next subject, the field worker enters the subject's identification number into the laptop computer and places it on the subject's desk. While the subject takes the survey, the field worker retrieves the cart from the previous workstation and moves it to the vicinity of the subject taking the survey. When the survey is completed, the field worker removes both the laptop computer from the subjects' desk and the subjects' chair from in front of the desk. The cart is then placed in the location and orientation of the subjects' chair and the measurement period is initiated by flipping a switch on the cart. During the next five minutes, the cart collects physical data at the workstation.

RESULTS

In this section we present and discuss the measurement results, including: (1) thermal comfort assessment based on the three field surveys, and (2) PEM and HVAC performance from the installed monitoring network. Since the baseline thermal comfort test predates the installation of the AOST monitoring network, we begin by describing the findings of the thermal comfort studies.

Thermal Comfort

The complete data sets from the three thermal comfort studies (baseline survey, first post-occupancy survey, and second post-occupancy survey) are presented in spreadsheet form in Appendixes E, F, and G. Each data set includes, for each workstation visit, values for each of the major physical comfort parameters, variables characterizing the subject's subjective assessment of the thermal environment, and calculated values for the major thermal comfort indices. To complete the data sets, we calculated the standard comfort indices (PMV, PMV*, DISC, TSENS, ET*, SET*, and HSI) for each workstation visit using the Fobelets and Gagge (1988) two-node comfort model. The model accounts for the combined effects of air temperature, air velocity, mean radiant temperature, relative humidity, clothing level, and activity level.

The measured and calculated values from all studies are summarized in Tables 4 - 7. Table 4 shows a comparison of the AOST Baseline, first Post-Occupancy (Test 1), and second Post-

Occupancy (Test 2) tests to selected buildings studied in ASHRAE RP-462, a field study of ten office buildings in the San Francisco Bay area [Schiller et al. 1988]. Since we found a significant seasonal variation in conditions during the ASHRAE study and the first two AOST tests occurred during what could be considered swing seasons, Table 4 is shown in two parts. Table 4a shows a comparison to our previous winter measurements and Table 4b shows a comparison to our previous summer measurements. Table 5 shows a comparison of the three AOST tests and the ASHRAE RP-462 buildings to the ASHRAE 55-81 comfort standard. The results are discussed below.

Our measurements to establish baseline conditions for the AOST comfort study indicated that the major physical variables affecting comfort were substantially within normal ranges. Air temperature averaged 22.2°C through our workstation visits, a value only slightly lower than the winter and summer averages of the ASHRAE RP-462 field study. Indoor air velocities, averaging 0.10 meters per second for the Baseline test, were equal to the summer averages measured in our previous ten-building field study, falling within the zone considered to be "still-air". Radiant effects in the Sunset Building were insignificant. Dewpoint temperatures, which had been found to be low during a previous ACT^2 baseline test, were all within the limits specified by the ASHRAE 55-81 comfort standard, presumably due to corrective action during ACT^2 renovation work. The clothing insulation values reported by the AOST study participants were in the normal range and fell between the winter and summer averages of the ASHRAE RP-462 field study.

Baseline results for effective temperature (ET*) and operative temperature (both indices that combine other physical parameters into a "temperature" index) were slightly below the winter averages and more than 1°C lower than the summer averages calculated for the ASHRAE RP-462 field study. Values for effective temperature index fell within ASHRAE 55-81 specifications for 100% of our workstation visits compared to 83.9% of the winter workstation visits in the ASHRAE RP-462 field study (see Table 5). For summer conditions, however, this percentage dropped to only 23.1% due to the lower temperatures being maintained in the Sunset Building. This value was substantially lower than the 68.3% of acceptable ET* values achieved during the summer measurements of the ASHRAE RP-462 field study. Table 5 indicates that, except for a small percentage of air velocity results, the AOST baseline data were substantially within the ASHRAE winter comfort zone.

Physical measurement results from the two post-occupancy comfort studies (AOST Tests 1 and 2 in Tables 4 and 5) are very similar and indicate that the average air temperature in the AOST office is nearly 1°C higher than the baseline result (23.0°C and 22.9°C versus 22.2°C). Calculated temperature indices such as ET* and operative temperature are also higher than the baseline, primarily due to the higher air temperature. This improves the agreement with ASHRAE 55-81 specifications for summer conditions, as 69.2% for Test 1 and 78.9% for Test 2 of the calculated ET* values fall within the acceptable range compared to 23.1% for baseline results (see Table 5). In fact, Table 5 indicates that the results for dew point temperature, ET*, and air velocity from both AOST Tests 1 and 2 demonstrate generally equal or improved agreement with ASHRAE 55-81 compared to the average results from both the winter and summer data from the ASHRAE RP-462 field study. Clothing level in the AOST office is slightly lower than baseline conditions (0.47 and 0.50 versus 0.55).

TABLE 4a

Distribution of Physical Data: Comparison of AOST Baseline - Oct. 1991 (A-B), Test 1 - May 1992 (A-1), and Test 2 - Sept. 1992 (A-2) to selected ASHRAE RP-462 winter measurements

Building	Pilot	A	B	C	D	E	F	G	H	I	All	A-B	A-1	A-2
Sample Size	121	123	101	134	132	136	122	148	145	146	1308	39	39	38
Clothing (clo)														
mean	0.57	0.55	0.70	0.59	0.61	0.61	0.54	0.57	0.56	0.55	0.58	0.55	0.47	0.50
std. dev.	0.13	0.12	0.14	0.13	0.14	0.12	0.11	0.13	0.15	0.13	0.14	0.13	0.10	0.10
minimum	0.30	0.30	0.39	0.33	0.24	0.38	0.24	0.26	0.26	0.31	0.24	0.36	0.26	0.36
maximum	0.90	0.90	1.13	1.07	1.00	1.14	0.83	0.93	0.99	1.14	1.14	0.92	0.62	0.69
Air Temperature (°C) (mean of 3 heights)														
mean	23.1	23.1	21.3	22.7	22.2	23.4	22.9	23.0	22.4	23.2	22.8	22.2	23.0	22.9
std. dev.	1.0	0.9	1.7	0.6	1.2	1.1	0.8	0.9	1.4	0.6	1.2	0.6	0.3	0.3
minimum	20.4	21.2	17.4	20.8	19.2	20.6	20.9	20.7	20.0	21.5	17.5	20.5	22.4	22.2
maximum	25.4	25.7	24.9	24.1	24.8	25.6	25.0	25.0	29.8	24.5	29.8	23.3	23.6	23.5
Vapor Pressure (torr)														
mean	7.4	6.4	6.2	8.9	8.9	10.6	6.2	8.8	6.6	7.6	7.8	9.6	9.3	9.8
std. dev.	1.3	0.7	1.0	0.6	0.8	0.6	1.3	1.4	1.0	1.0	1.7	0.5	0.1	0.3
minimum	5.4	4.8	4.6	8.0	6.9	8.9	4.6	6.4	5.1	4.6	4.6	8.4	9.1	9.3
maximum	9.0	7.8	11.2	10.3	10.9	11.8	9.2	11.4	8.8	9.3	11.8	10.4	9.6	10.3
Dew Point Temperature (°C)														
mean	6.6	4.6	4.0	9.5	9.5	12.1	4.1	9.2	4.9	7.1	7.3	10.5	10.2	10.9
std. dev.	2.7	1.6	2.2	0.9	1.3	0.9	2.7	2.3	2.2	1.9	3.3	0.8	0.2	0.4
minimum	2.3	0.6	0.1	7.9	5.8	9.5	0.1	4.7	1.4	0.0	0.0	8.6	9.8	10.1
maximum	9.6	7.5	13.0	11.6	12.5	13.7	10.0	13.3	9.4	12.1	13.7	11.8	10.6	11.7
Air Velocity (m/s) (mean of 3 heights)														
mean	0.10	0.06	0.06	0.04	0.04	0.06	0.05	0.08	0.05	0.05	0.06	0.10	0.10	0.10
std. dev.	0.07	0.04	0.06	0.06	0.04	0.05	0.02	0.05	0.03	0.03	0.05	0.04	0.03	0.04
minimum	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.04	0.05	0.05
maximum	0.39	0.26	0.37	0.56	0.20	0.27	0.11	0.30	0.19	0.17	0.56	0.21	0.18	0.31
Operative Temperature (°C) (mean of 3 heights)														
mean	23.3	23.3	21.4	22.9	22.3	23.6	23.1	22.2	22.6	23.3	22.9	22.3	23.1	23.1
std. dev.	1.0	1.0	1.7	0.6	1.1	1.0	0.8	0.9	1.3	0.5	1.2	0.6	0.3	0.4
minimum	20.7	20.8	17.8	21.1	19.5	21.0	21.1	21.0	20.4	21.8	17.8	21.0	22.6	22.2
maximum	25.7	26.4	25.5	24.2	24.3	25.6	25.3	25.1	28.5	24.6	28.5	23.4	23.5	23.6
ET* (°C) (mean of 3 heights)														
mean	22.8	22.7	21.0	22.6	22.0	23.4	22.6	22.8	22.1	22.9	22.5	22.3	23.0	23.0
std. dev.	0.9	0.8	1.6	0.7	1.1	1.0	0.7	0.9	1.3	0.6	1.1	0.6	0.3	0.3
minimum	20.4	20.9	17.4	20.8	19.3	20.6	20.8	20.6	19.8	21.0	17.4	20.9	22.5	22.2
maximum	24.9	24.8	24.3	24.0	24.4	25.5	24.3	24.9	28.3	24.2	28.3	23.3	23.4	23.5

TABLE 4b

Distribution of Physical Data: Comparison of AOST Baseline - Oct. 1991 (A-B), Test 1 - May 1992 (A-1), and Test 2 - Sept. 1992 (AC) to selected ASHRAE RP-462 summer measurements

Building	Pilot	A	B	C	D	E	F	G	H	I	All	A-B	A-1	A-2
Sample Size	**123**	**119**	**92**	**108**	**115**	**123**	**107**	**117**	**23**	**107**	**1034**	**39**	**39**	**38**
Clothing (clo)														
mean	0.47	0.50	0.47	0.54	0.53	0.54	0.55	0.55	0.50	0.53	0.52	0.55	0.47	0.50
std. dev.	0.12	0.13	0.10	0.16	0.11	0.10	0.13	0.12	0.14	0.11	0.12	0.13	0.10	0.10
minimum	0.16	0.23	0.25	0.20	0.26	0.27	0.24	0.28	0.22	0.34	0.16	0.36	0.26	0.36
maximum	0.71	0.92	0.64	1.44	0.97	0.98	0.87	0.99	0.74	0.81	1.44	0.92	0.62	0.69
Air Temperature (°C) (mean of 3 heights)														
mean	24.6	22.6	23.4	22.6	22.4	24.3	24.4	22.7	22.4	22.8	23.3	22.2	23.0	22.9
std. dev.	1.6	0.5	0.5	1.0	0.8	1.0	1.2	0.6	0.8	0.6	1.3	0.6	0.3	0.3
minimum	21.8	21.1	22.4	20.1	20.5	21.7	21.0	21.0	21.3	21.4	20.7	20.5	22.4	22.2
maximum	29.5	23.6	25.0	24.5	24.6	26.3	27.6	24.2	24.1	25.4	29.5	23.3	23.6	23.5
Vapor Pressure (torr)														
mean	11.2	12.0	13.2	11.6	13.2	13.6	15.0	13.8	13.3	12.9	12.9	9.6	9.3	9.8
std. dev.	0.7	0.5	0.8	0.5	0.8	0.8	0.6	0.9	0.4	0.6	1.3	0.5	0.1	0.3
minimum	8.6	11.2	11.3	10.7	11.8	10.6	13.2	12.2	12.5	12.0	8.6	8.4	9.1	9.3
maximum	12.7	13.0	16.6	12.9	15.8	15.2	16.7	16.9	14.6	17.7	17.7	10.4	9.6	10.3
Dew Point Temperature (°C)														
mean	13.0	14.0	15.5	13.5	15.5	16.0	17.5	16.2	15.6	15.1	15.1	10.5	10.2	10.9
std. dev.	0.9	0.6	0.9	0.6	0.9	0.9	0.6	1.0	0.5	0.7	1.6	0.8	0.2	0.4
minimum	9.0	12.9	13.1	12.3	13.7	12.1	15.5	14.3	14.7	14.0	9.0	8.6	9.8	10.1
maximum	14.9	15.2	19.1	15.1	18.3	17.7	19.2	19.4	17.0	20.2	20.2	11.8	10.6	11.7
Air Velocity (m/s) (mean of 3 heights)														
mean	0.20	0.11	0.11	0.10	0.11	0.12	0.11	0.16	0.11	0.11	0.10	0.10	0.10	0.10
std. dev.	0.19	0.02	0.03	0.01	0.03	0.03	0.02	0.09	0.02	0.02	0.09	0.04	0.03	0.04
minimum	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.05	0.02	0.01	0.00	0.04	0.05	0.05
maximum	1.24	0.20	0.24	0.18	0.25	0.30	0.22	0.67	0.19	0.23	1.24	0.21	0.18	0.31
Operative Temperature (°C) (mean of 3 heights)														
mean	24.7	22.8	23.6	22.8	22.6	24.5	24.5	23.0	22.6	22.8	23.5	22.3	23.1	23.1
std. dev.	1.6	0.5	0.5	1.0	0.8	1.0	1.1	0.6	0.7	0.6	1.2	0.6	0.3	0.4
minimum	22.1	21.6	22.6	20.3	20.8	22.1	21.3	21.3	21.5	21.4	20.3	21.0	22.6	22.2
maximum	29.5	23.7	25.2	24.6	24.6	26.4	27.6	24.5	24.1	25.4	29.5	23.4	23.5	23.6
ET* (°C) (mean of 3 heights)														
mean	24.5	22.7	23.7	22.7	22.7	24.6	24.8	23.1	22.7	23.0	23.5	22.3	23.0	23.0
std. dev.	1.4	0.5	0.5	1.0	0.8	1.0	1.2	0.6	0.7	0.7	1.3	0.6	0.3	0.3
minimum	22.0	21.3	22.7	20.2	20.9	21.8	21.3	21.4	21.7	21.6	20.2	20.9	22.5	22.2
maximum	29.0	23.7	25.0	24.6	24.9	26.5	28.0	24.5	24.4	25.8	29.0	23.3	23.4	23.5

TABLE 5

Comparison to ASHRAE Standard 55-81 Comfort Zones
Selected ASHRAE RP-462 buildings, AOST Baseline - Oct. 1991 (A-B), Test 1 - May 1992 (A-1), and Test 2 - Sept. 1992 (A-2)

	Building	Pilot	A	B	C	D	E	F	G	All	A-B	A-1	A-2
WINTER	Sample Size	121	123	101	134	132	136	122	148	1308	39	39	38
Dew Point Temperature (°C)													
	% < 1.7°C	0.0	2.4	7.9	0.0	0.0	0.0	16.4	0.0	2.9	0.0	0.0	0.0
	1.7°C ≤ % ≤ 16.7°C	**100.0**	**97.6**	**92.1**	**100.0**	**100.0**	**100.0**	**83.6**	**100.0**	**97.1**	**100.0**	**100.0**	**100.0**
	% > 16.7°C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ET* (°C) (average of 3 heights)													
	% < 20.0°C	0.0	0.0	29.7	0.0	3.8	0.0	0.0	0.0	2.8	0.0	0.0	0.0
	20.0°C ≤ % ≤ 23.6°C	**84.3**	**86.2**	**65.3**	**96.3**	**94.7**	**58.8**	**91.8**	**82.4**	**83.9**	**100.0**	**100.0**	**100.0**
	% > 23.6°C	15.7	13.8	5.0	3.7	1.5	41.2	8.2	17.6	13.2	0.0	0.0	0.0
Air Velocity (m/s) (average of 3 heights)													
	% ≤ 0.15 m/sec	**81.8**	**95.9**	**97.0**	**97.8**	**97.0**	**94.1**	**100.0**	**91.9**	**95.3**	**89.7**	**92.3**	**92.1**
	% > 0.15 m/sec	18.2	4.1	3.1	2.2	3.1	5.9	0.0	8.1	4.7	10.3	7.7	7.9
SUMMER	Sample Size	123	119	92	108	115	123	107	117	1034	39	39	38
Dew Point Temperature (°C)													
	% < 1.7°C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1.7°C ≤ % ≤ 16.7°C	**100.0**	**100.0**	**95.7**	**100.0**	**93.0**	**86.2**	**11.2**	**61.5**	**83.5**	**100.0**	**100.0**	**100.0**
	% > 16.7°C	0.0	0.0	4.3	0.0	7.0	13.8	88.8	38.5	16.5	0.0	0.0	0.0
ET* (°C) (average of 3 heights)													
	% < 22.8°C	7.3	51.3	4.3	52.8	50.4	8.9	2.8	29.9	27.7	76.9	30.8	21.1
	22.8°C ≤ % ≤ 26.1°C	**72.4**	**48.7**	**95.7**	**47.2**	**49.6**	**88.6**	**84.1**	**70.1**	**68.3**	**23.1**	**69.2**	**78.9**
	% > 26.1°C	20.3	0.0	0.0	0.0	0.0	2.4	13.1	0.0	4.1	0.0	0.0	0.0
Air Velocity (m/s) (average of 3 heights)													
	% ≤ Vmax*	**88.6**	**100.0**	**100.0**	**100.0**	**100.0**	**99.2**	**100.0**	**91.5**	**97.6**	**100.0**	**100.0**	**97.4**
	% > Vmax*	11.4	0.0	0.0	0.0	0.0	0.8	0.0	8.5	2.4	0.0	0.0	2.6

* Summer maximum limit for air velocity is extended for air temperatures between 26-28°C.
For $T_a < 26°C$, $V_{max} = 0.25$ m/sec. V_{max} then increases 0.275 m/sec for each degree C of T_a above 26°C, up to a maximum of 0.8 m/sec at $T_a = 28°C$.

Table 6 shows a comparison of overall average values of landmark variables of subjective response and comfort. Results are presented for the AOST Baseline, Test 1, and Test 2. Thermal sensation vote is a subjective declaration of thermal sensation on a -3 (cold) to +3 (hot) scale. On this scale, the central value of 0 represents thermal neutrality and ASHRAE considers the central three values of -1 (slightly cool), 0 (neutral), and 1 (slightly warm) to be thermally acceptable. Average thermal sensation vote was -0.04 for the Baseline test, representing a result that was very near the neutral point. The average thermal sensation vote for Test 1 was 0.22, a slightly higher value, perhaps reflecting the increased air temperatures in the AOST office. However, for Test 2, the average thermal sensation was 0.04, again very near the neutral reading of zero.

The McIntyre thermal preference scale is a three-point scale in which subjects are asked if they would prefer to be warmer (-1), have no change (0), or be cooler (+1). As shown in Table 6, average results from the thermal preference vote found only a very slight preference to be cooler for the Baseline and Test 1, but no desire to change (0.00) for Test 2, implying that on average all subjects were satisfied with their thermal environment. The calculated comfort indices of SET* (Standard Effective Temperature), DISC (Discomfort), and PMV (Predicted Mean Vote) from all three tests were very similar and well within reasonable bounds.

Table 7 presents a comparison of most of the same variables contained in Table 6, but in this case broken down into groups of subjects with and without PEMs in their AOST office workstation. Although subjects did not have PEMs during the Baseline test, results for these groups of PEM and non-PEM subjects are shown for all three tests to identify any trends or obvious differences. Average thermal sensation is slightly warmer for PEM subjects (0.14) compared to non-PEM subjects (-0.19) during the baseline. This trend is reversed during Test 1 (0.02 vs. 0.44), a result that may be attributable to the local air supply characteristics of the PEMs. However, in Test 2, the trend of thermal sensation vote again resembles that of the baseline data with PEM subjects claiming to be slightly warmer (0.18) than the non-PEM subjects (-0.11). The difficulty in establishing a clear pattern over the three tests is not unexpected due to the small number of subjects involved in the study.

Nevertheless, a few more obvious observations are worth mentioning. The general comfort scale is a six-point scale ranging from very uncomfortable (1) to very comfortable (6). During Test 1, shortly after the subjects occupied the AOST office, those with PEMs voted a noticeable increase in general comfort compared to the Baseline (5.30 vs. 4.93). However, the non-PEM subjects voted a significant drop in general comfort compared to the Baseline (4.58 vs. 5.33). The higher general comfort exhibited by PEM subjects over non-PEM subjects in Test 1, was no longer evident in Test 2, perhaps indicating that an initial highly positive response to the PEM was somewhat reduced over time.

Ventilative comfort is a six-point scale in which the subjects describe their ventilative environment as being stuffy (1) to breezy (6). During the Baseline, when no PEMs were available, both groups had very similar ventilative comfort votes. After occupying the AOST office, as expected, the PEM subjects have a higher average ventilative comfort rating than the non-PEM subjects do in both Tests 1 and 2.

TABLE 6

Landmark Variables of Subject Response and Comfort Averages for AOST Baseline, Test 1, and Test 2

	AOST Baseline (Oct. 1991)	AOST Test 1 (May 1992)	AOST Test 2 (Sept. 1992)
Thermal Sensation	-0.04	0.22	0.04
Thermal Preference	0.06	0.08	0.00
General Comfort	5.16	4.95	4.76
Ventilative Comfort	3.81	3.67	3.84
Lighting Comfort	4.25	4.23	4.42
Estimated Temperature (°C)	21.96	21.08	21.93
Metabolic Rate (met)	1.1	1.1	1.1
Clothing Level (clo)	0.55	0.47	0.50
Effective Temperature* (°C)	22.26	22.95	23.02
DISC	-0.01	-0.02	-0.03
SET* (°C)	21.42	21.84	22.21
PMV	-0.26	-0.22	-0.19

TABLE 7

Comparison of Landmark Variables of Subject Response, Comfort Averages, and Air Velocities for AOST Baseline, Test 1, and Test 2

	Baseline		Test 1		Test 2	
Variable	PEM (3)	Non-PEM (4)	PEM (4)	Non-PEM (4)	PEM (4)	Non-PEM (4)
Thermal Sensation	0.14	-0.19	0.02	0.44	0.18	-0.11
Thermal Preference	0.21	-0.06	0.10	0.05	-0.16	0.16
General Comfort	4.93	5.33	5.30	4.58	4.79	4.74
Ventilative Comfort	3.79	3.83	3.95	3.37	3.95	3.74
Lighting Comfort	4.00	4.44	3.90	4.58	4.21	4.63
Metabolic Rate	1.1	1.1	1.1	1.1	1.2	1.1
Clothing Level	0.51	0.59	0.50	0.44	0.51	0.49
ET* (°C)	22.5	22.1	22.9	23.0	23.0	23.1
DISC	-0.05	0.01	-0.02	-0.03	-0.02	-0.03
SET* (°C)	21.6	21.3	21.9	21.7	22.3	22.1
PMV	-0.24	-0.27	-0.21	-0.23	-0.20	-0.18
Velocity at 1.1 m (m/s)	0.11	0.09	0.18	0.10	0.19	0.11
Velocity at 0.6 m (m/s)	0.12	0.11	0.12	0.08	0.10	0.09
Velocity at 0.1 m (m/s)	0.08	0.09	0.06	0.07	0.07	0.07

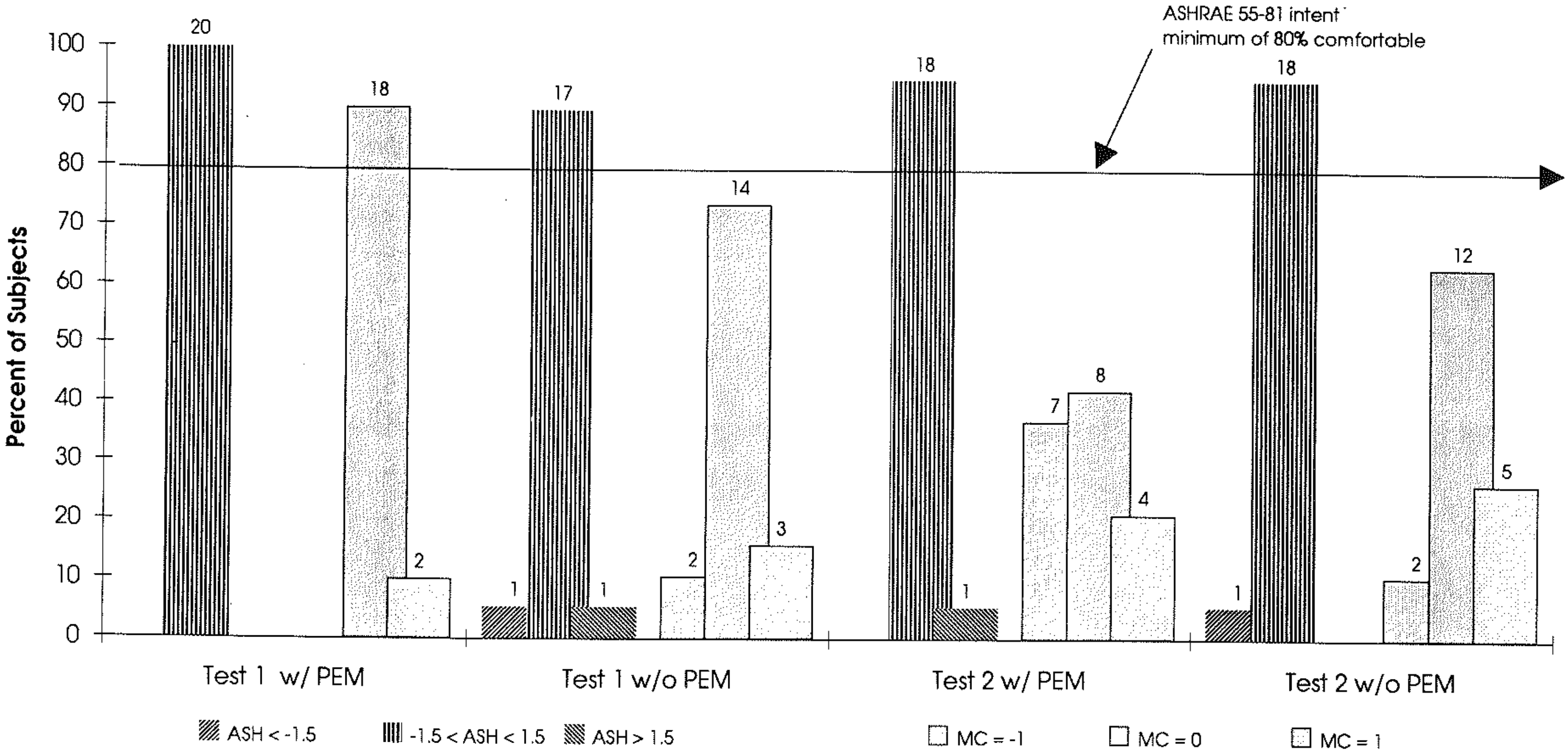
Also included in Table 7 are average air velocities at each of three measurement heights (0.1, 0.6, and 1.1 m). While all velocity results were very similar between PEM and non-PEM subjects during the Baseline, the average velocity for PEM subjects compared to non-PEM subjects in the AOST office was noticeably higher at the 1.1 m height for both Test 1 (0.18 m/s vs. 0.10 m/s) and Test 2 (0.19 m/s vs. 0.11 m/s). This demonstrates that the desk-mounted PEM supply nozzles have a significant impact on air movement at heights near the desk level.

Averaging the subjective votes together, as in the tables described above, can tend to mask some of the underlying patterns inherent in the data. Figure 14 compares occupant assessment of thermal comfort on the ASHRAE thermal sensation and the McIntyre thermal preference scales. Results are shown for Tests 1 and 2, and are subdivided into groups of subjects with and without PEMs. As described above, convention holds that the middle three categories of the thermal sensation scale ($-1.5 < ASH < 1.5$) are considered thermally acceptable, and, according to ASHRAE Standard 55-81 [ASHRAE 1981], 80% of the building occupants should fall within this range. Figure 14 shows that each of the four groups of subjects meet this criteria, with only a few votes falling outside of the central "thermally acceptable" categories.

Also shown in Figure 14 are the results from the McIntyre scale, which illustrates comfort on the basis of thermal preference. During Test 1, 90% (18 out of 20) of the subjects with PEMs preferred to have no change in their thermal environment, while 74% (14 out of 19) of the subjects without PEMs were in the same category. In Test 2, however, the distribution of thermal preference votes has changed considerably, particularly for the PEM subjects. Despite the high percentage of subjects voting to be thermally acceptable on the thermal sensation scale, only 42% (8 out of 19) of the subjects with PEMs voted for no change on the McIntyre scale. Almost as many subjects, 37% (7 out of 19), preferred to be warmer, and 21% (4 out 19) preferred to be cooler. Recall that the average thermal preference vote for all subjects in Test 2 was 0.00 (Table 6). The large percentage of subjects with PEMs desiring to be warmer was consistent with measurements and observations indicating that the overall AOST office temperature tended to be on the cool side, causing the PEM air supply to overcool the local workstation environment in several cases. For subjects without PEMs in Test 2, 63% (12 out 19) preferred to have no change, a result that is fairly similar to that of Test 1.

Since the PEMs allow the occupants to dynamically control their local environment, it is also of interest to observe temporal patterns in the thermal comfort data. Figure 15 presents average, maximum, and minimum air velocities measured at the 1.1 m height during Test 2 (16, 17 September 1992). Results are binned by hour of day and are shown for workstations with PEMs in Figure 15a, and without PEMs in Figure 15b. The data clearly indicate a pattern in which occupants tended to use the increased air movement provided by the PEMs to cool themselves after returning from lunch. This is consistent with the fact that two of the four occupants with PEMs were known to play basketball over lunch time. The maximum velocity recorded between 1:00 and 2:00 pm was 0.81 m/s. In comparison, all velocities recorded in workstations without PEMs were quite low (≤ 0.2 m/s), as expected.

Figure 14. Comfort Votes on the ASHRAE Thermal Sensation (ASH) and McIntyre (MC) Scales



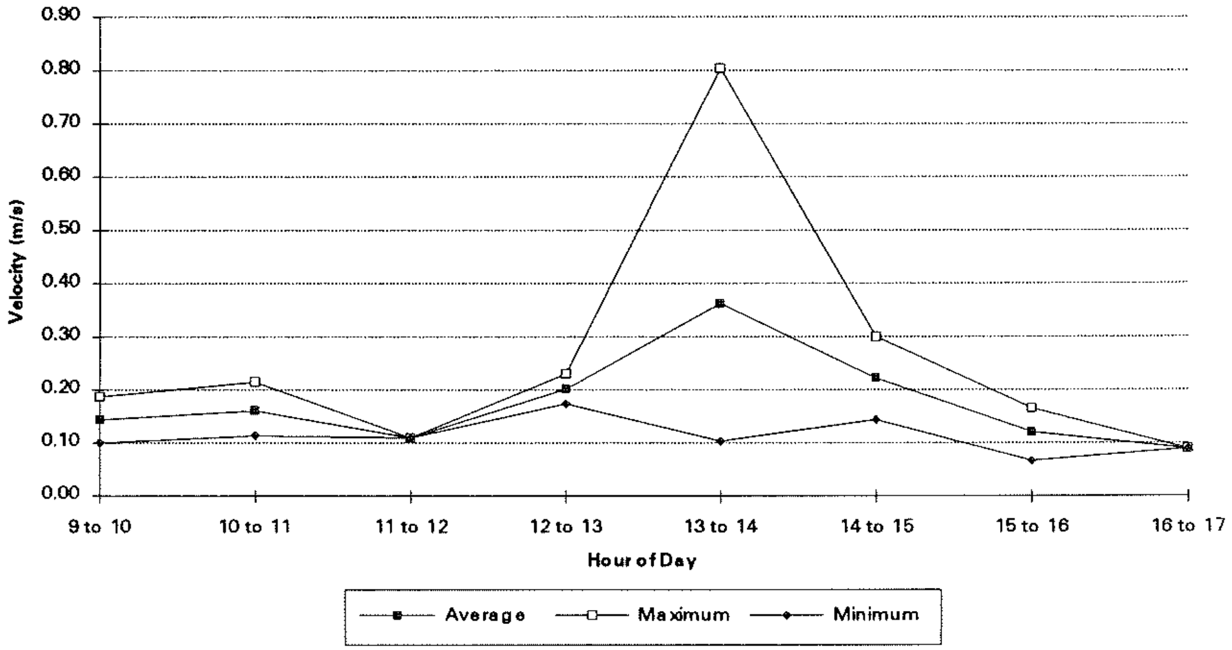


Figure 15a. Velocity at 1.1 m Height in Workstations with PEMs: 16, 17 September 1992

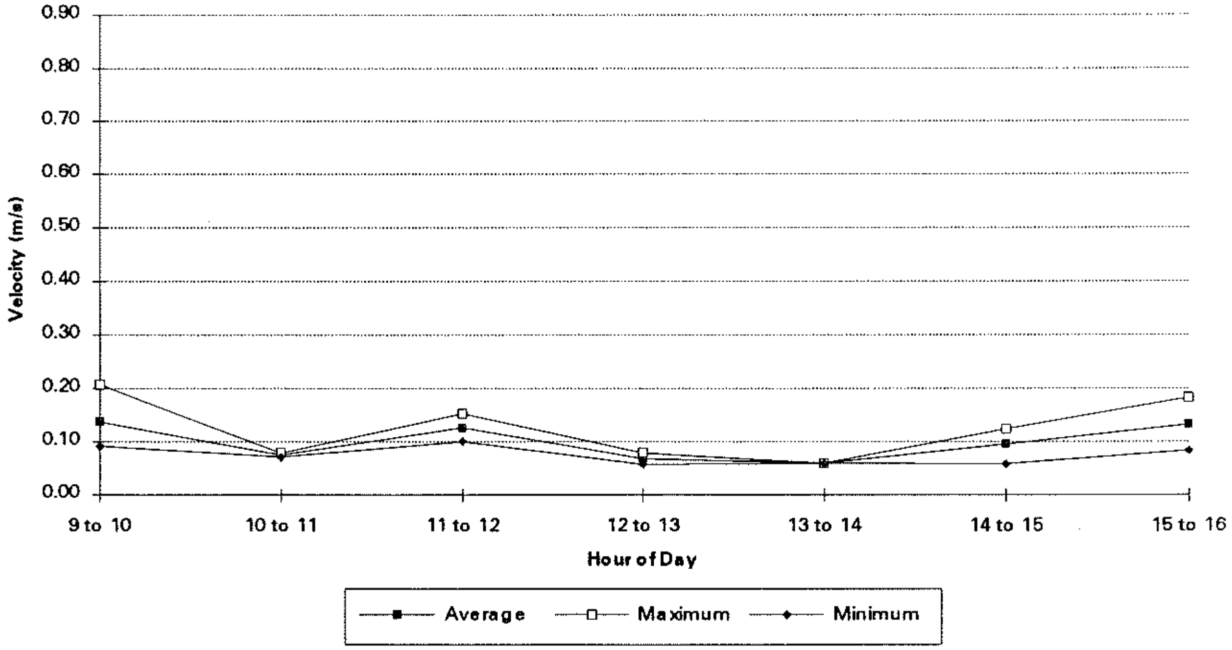


Figure 15b. Velocity at 1.1 m Height in Workstations without PEMs: 16, 17 September 1992

PEM Performance

Data have been collected on a daily basis since April 1992 from both the UC Berkeley and Endecon permanent monitoring networks. We have analyzed the network measurement results to coincide with the first and second post-occupancy comfort tests (Tests 1 and 2) in the AOST office. In this section, we present and discuss findings regarding the performance of the PEMs, including occupant use patterns, power quality, and power consumption.

As described earlier, the PEM monitoring network records a set of data that describes in detail for each PEM workstation the occupant's use of the desktop control panel. The monitored PEM control parameters include: (1) discharge air temperature setpoint, (2) fan speed setpoint, (3) radiant panel setpoint, (4) task light setpoint, and (5) occupancy sensor status. Figures 16a and 16b show examples of the occupant use patterns from two PEM workstations between the hours of 7 am and 7 pm on 30 April 1992. In both figures setpoint position (0-100%) for the task light, fan, radiant panel, and temperature are shown on the left axis, while occupancy (0-1) is shown on the right axis. Ten-minute average data are shown. In Figure 16a, the light is turned on 100% all day long. The fan setpoint stays at 20% during the morning and jumps to 100% when the occupant returns from lunch (playing basketball). After another hour, the fan is turned down to 60% until the end of the day. Radiant panel and temperature controls are unused all day long. The short occupancy peaks during the later morning and noontime hours may in fact be due to visits to the workstation by office workers other than the occupant. In Figure 16b the only evidence of setpoint adjustment is with the task light. All other control setpoints are unused all day long.

To investigate the energy performance of the PEM units on a component basis, we performed detailed energy measurements using the Endecon monitoring network in March 1993. Since the current Endecon network monitors the total plug load from all four PEMs, we unplugged all but one PEM at a time, and then recorded current, voltage, and power readings in response to different PEM control settings. This allowed us to develop empirical relationships between power and control setting for the three major energy-consuming components, the fan, task light, and radiant panel. The other two available PEM control parameters (discharge air temperature and white noise) had a negligible impact on energy use. The empirical power relationships could then be applied to the recorded occupant use patterns (from UC Berkeley's monitoring network) to produce a time-based image of PEM energy performance broken down by PEM components and individual workstations. The energy measurement data are presented in Figures 17 to 19 and discussed briefly below.

The results of the detailed energy tests indicated that the minimum power consumption of the PEM is about 5 W/unit, when the occupancy sensor is off (PEM deactivated). This minimum value increases to about 20 W/unit, when the workstation is occupied, even with all other control settings at their minimum levels. Figure 17 presents the measured power vs. PEM fan control settings (all other controls are at minimum). Figure 17a shows real power (W), Figure 17b shows apparent power (VA), and Figure 17c shows power factor (real power/apparent power). The PEM fan uses 90 W of real power at its maximum setting (including the PEM base power of 20 W) and is quite linear in nature, with a power factor approaching 95% at its maximum speed. The

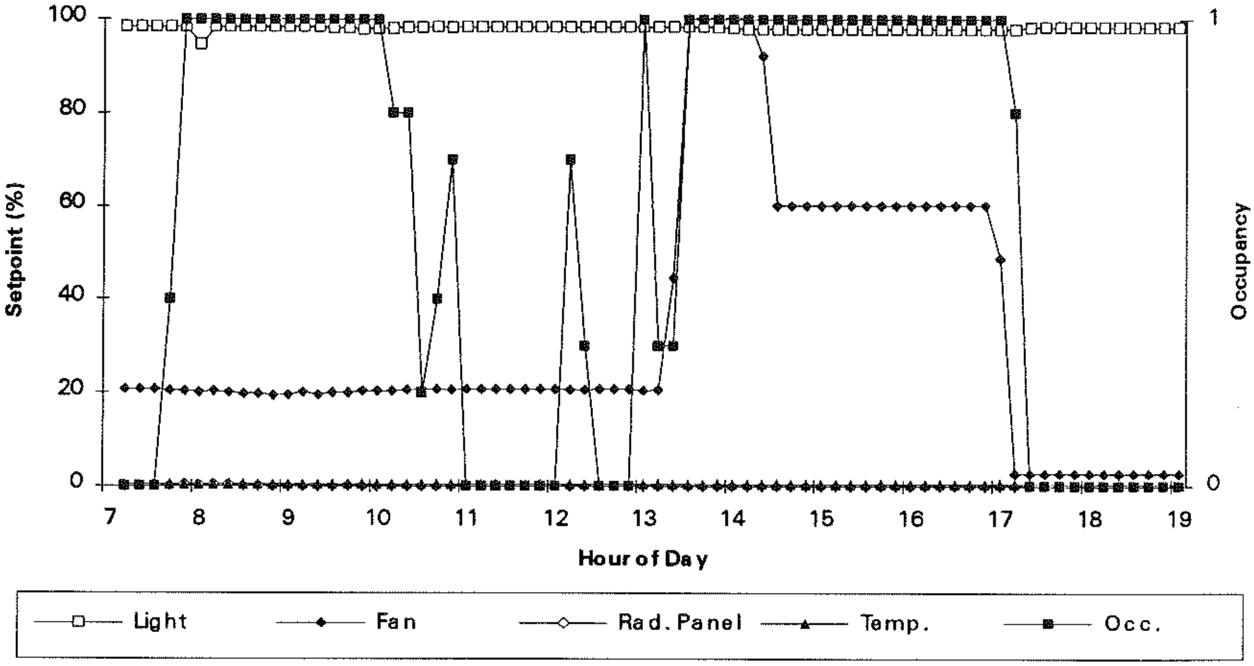


Figure 16a. PEM Setpoints and Occupancy: 30 April 1992

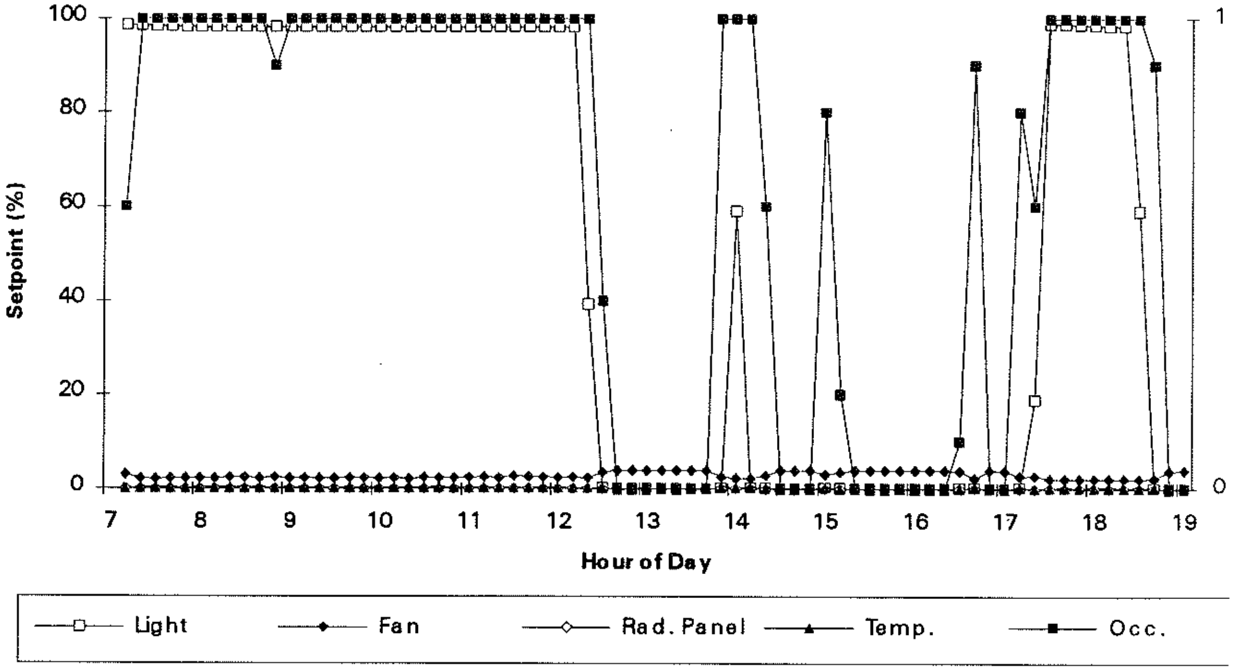


Figure 16b. PEM Setpoints and Occupancy: 30 April 1992

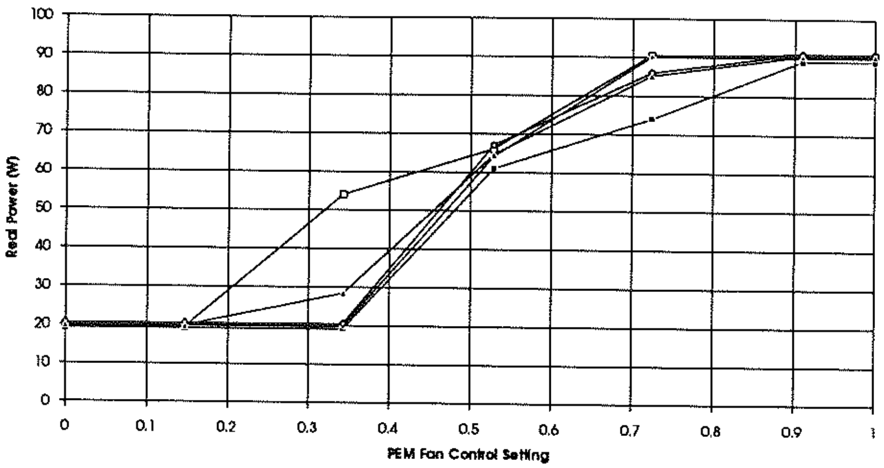


Figure 17a. Real Power (W) vs. PEM Fan Control Setting

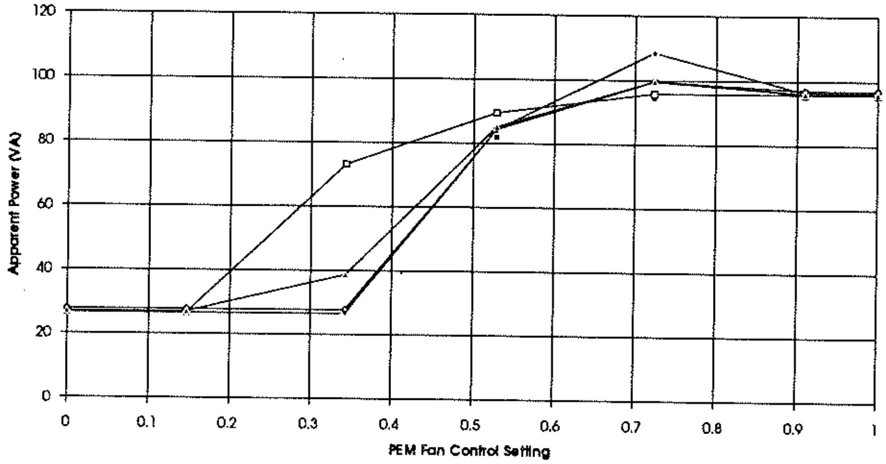


Figure 17b. Apparent Power (VA) vs. PEM Fan Control Setting

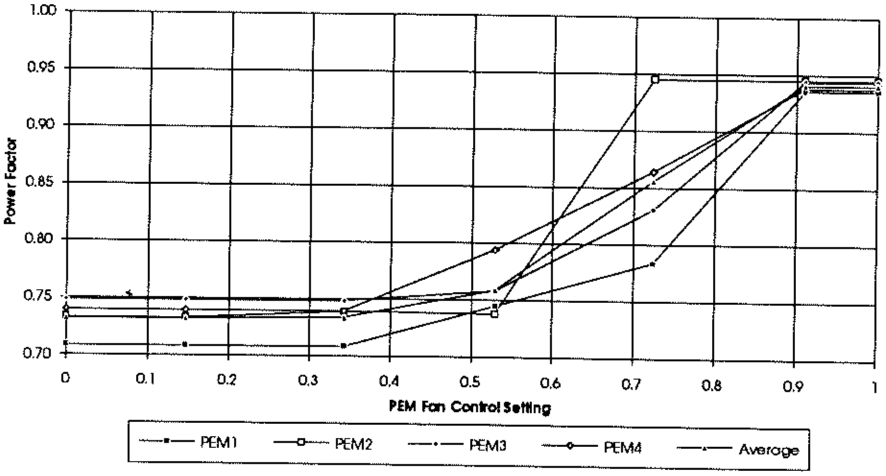


Figure 17c. Power Factor vs. PEM Fan Control Setting

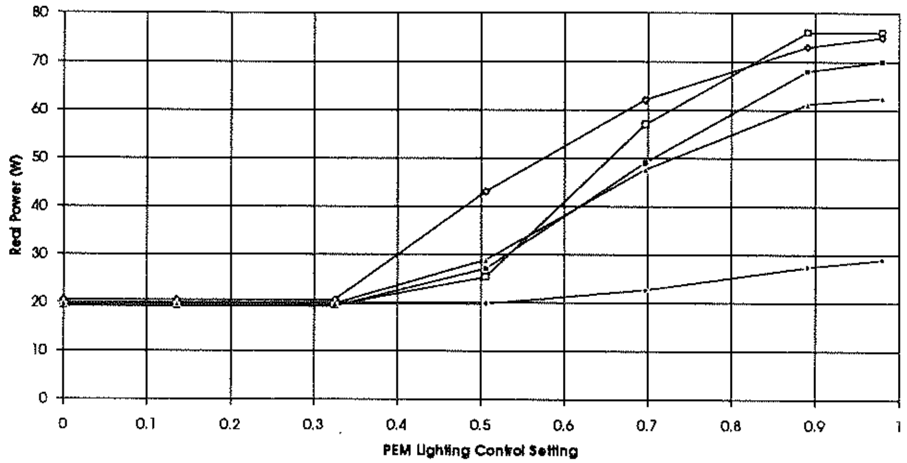


Figure 18a. Real Power (W) vs. PEM Task Light Control Setting

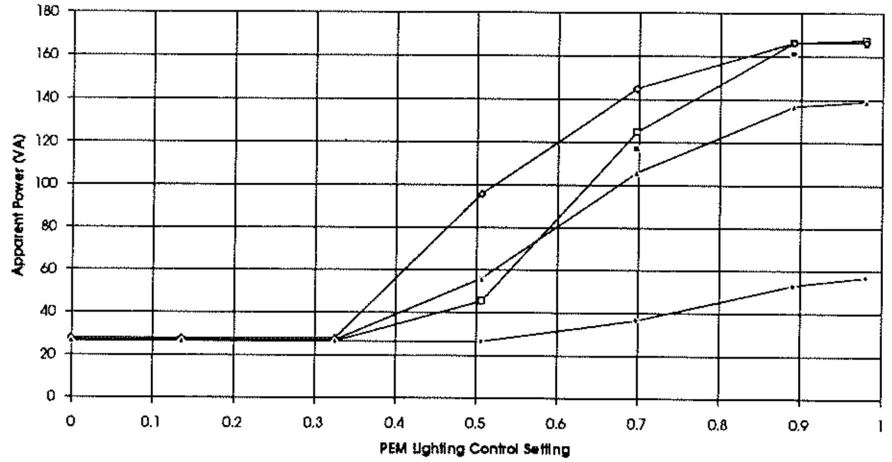


Figure 18b. Apparent Power (VA) vs. PEM Task Light Control Setting

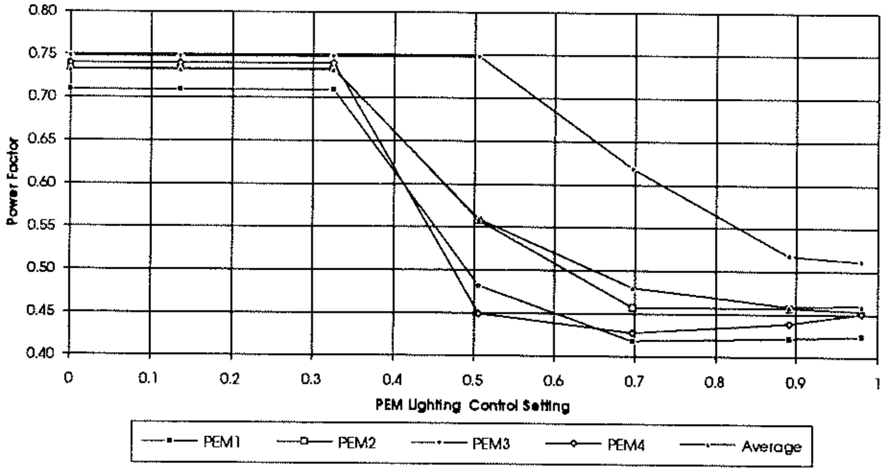


Figure 18c. Power Factor vs. PEM Task Light Control Setting

data also indicate, that most of the actual control operation of the fan is confined to the middle third of the control setting span. In most cases, there is little variation in power usage over the bottom and top ranges of the control setting.

Figure 18 presents the measured power vs. PEM task light control settings (all other controls are at minimum). Figure 18a shows real power, Figure 18b shows apparent power, and Figure 18c shows power factor. All except one of the task lights consume about 70 W of real power at their maximum setting (including the PEM base power of 20 W). The power factors were quite poor for the task lighting control, with most units falling below 50% at their maximum setpoint. This was consistent with the rather unsatisfactory performance of the PEM dimming control (e.g., flickering, buzzing, premature failure of lamps), indicating that the PEM dimmer was incompatible with the installed task lights in the workstations.

Figure 19 presents real and apparent power versus PEM radiant panel control settings (all other controls are at minimum). At its maximum setting, the radiant panel consumes by far the most energy of any PEM component, using about 225 W/unit of real power (including the PEM base power of 20 W). The radiant panel is evidently quite linear with power factors approaching 100%. There is no variation in power factor over the span of control settings because the panel operates in an on/off mode with the percentage of on-time being proportional to the control setting.

Figure 20 presents the real power use pattern for the four monitored PEMs between the hours of 7 am and 8 pm on 16 September 1992, during Test 2. The ten-minute-average data are broken down by the amount of power used by each PEM component: base, fan, task light, and radiant panel. The pattern of use takes into account the status of the occupancy sensor in each

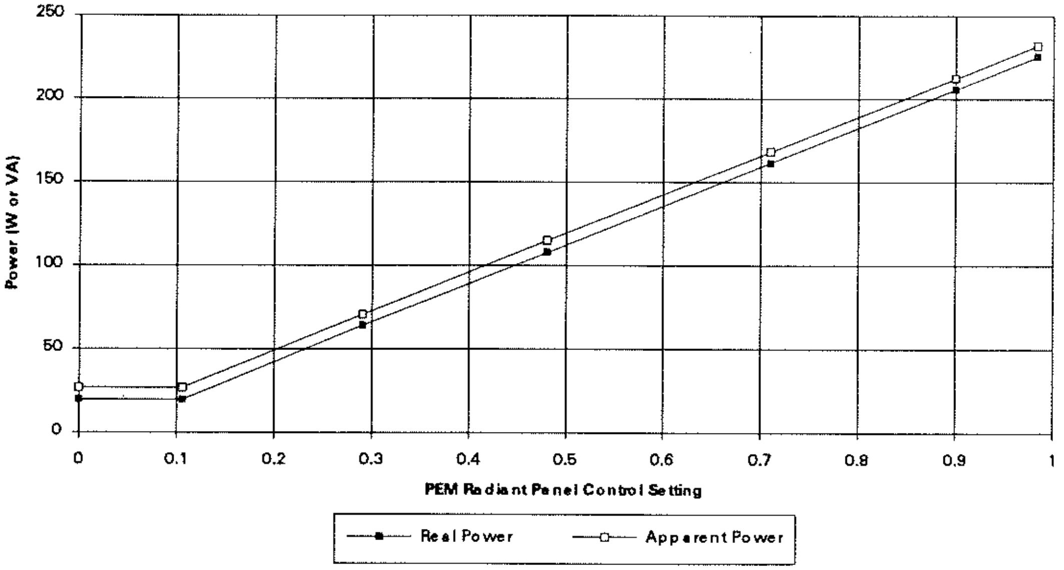
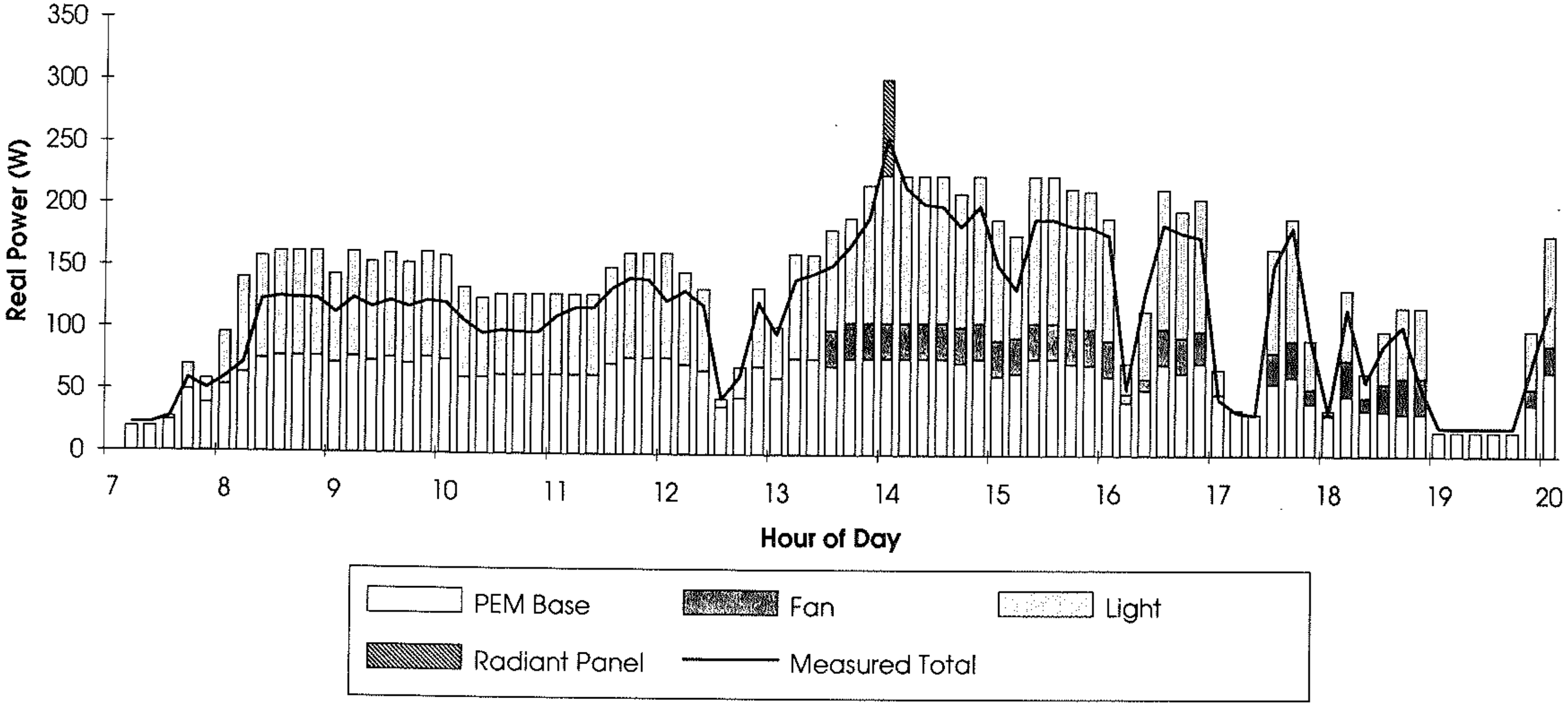


Figure 19. Real (W) and Apparent (VA) Power vs. PEM Radiant Panel Control Setting

Figure 20. Real Power Based on Measurement and PEM Components
16 September 1992



workstation. Also shown for comparison is the total real power as measured by the Endecon data acquisition system on that date. The agreement in total power is acceptable considering that the empirical power data were obtained from short-term readings of a variable signal. The fact that the component-based results consistently exceed the real time Endecon measurements (averaged over a ten-minute period) suggests a bias in the short-term readings that could be corrected. Nevertheless, the accuracy with which the component-based calculations track the highly variable time history of power consumption is remarkable.

Figure 20 demonstrates how the base power consumption for the four PEMs varies between a minimum of 20 W when all PEM workstations are unoccupied at the beginning and near the end of the day, and its maximum value of about 80 W. On average, lights tend to use the largest amount of energy, despite the fact that one of the four task lights was disconnected on this day and did not contribute to the measured total. The total fan load is fairly low and shows up only after lunch and throughout the afternoon. The radiant panel was used only during one ten-minute period near 2 pm (perhaps only as a test?) and contributes to the days maximum total power measurement of 304 W.

Figure 21 presents the same data shown in Figure 20, except in this case the results are broken down by individual PEM units. In this example, PEM2 usually uses at least half of the total measured power, due to the fact that the occupant was in the workstation with his light on for most of the day, and also used the fan during the afternoon. In comparison, PEM4 uses no more than 20 W during the entire day, because the task light was disconnected, and no other controls were used.

Figure 22 presents the energy use pattern for the four monitored PEMs between the hours of 7 am and 7 pm on 30 April 1992, during Test 1. On this day, only lights and fans were used. The lighting load is higher than that shown in Figures 20 and 21 due in part to the fact that all four task lights were in use. The majority of the fan use occurs after lunch and during the afternoon, although a small amount of fan energy is used during the hour before lunch time. The peak power consumption reaches 388 W around 2 pm, coinciding with the peak fan energy usage.

If one assumes that task lights would be present in a typical office environment, the additional localized heat load imposed by the PEM units is generated only by the base PEM energy usage (5-20 W/unit) and the fans. As observed by our measurements, radiant panel usage would be expected to be absent or minimal for most interior office zones in which cooling is the dominant space conditioning energy requirement. In this example, the additional load imposed by the PEM units averages between 20 to 50 W per workstation, when occupied, representing a heat load density of 0.3 to 0.7 W/ft^2 for a typical 72 ft^2 (8.5 ft by 8.5 ft) workstation in the AOST office.

The energy-saving capability of the occupancy sensor is demonstrated in Figure 23. Two energy use patterns are shown for the four monitored PEMs on 30 April 1992. One takes into account the effect of the occupancy sensor ("with occupancy sensor") and shows the same pattern of use displayed in Figure 22. The second higher energy use pattern ("without occupancy sensor") is produced by applying an occupancy weighting factor of one to all control settings after the workstations are first occupied at the beginning of the day. This is equivalent to having the lights

Figure 21. Real Power Based on Measurement and PEM Units
16 September 1992

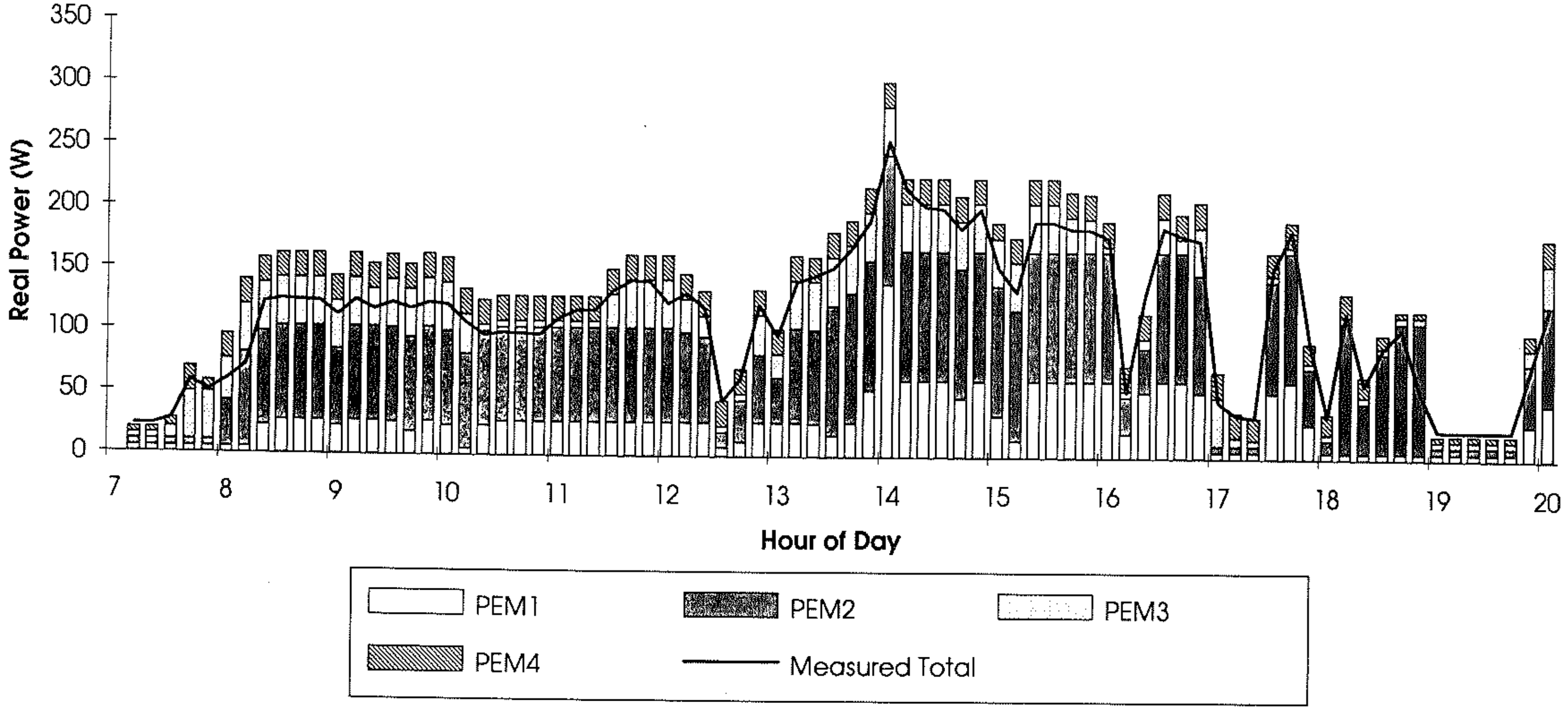


Figure 22. PEM Energy Use Pattern: 30 April 1992

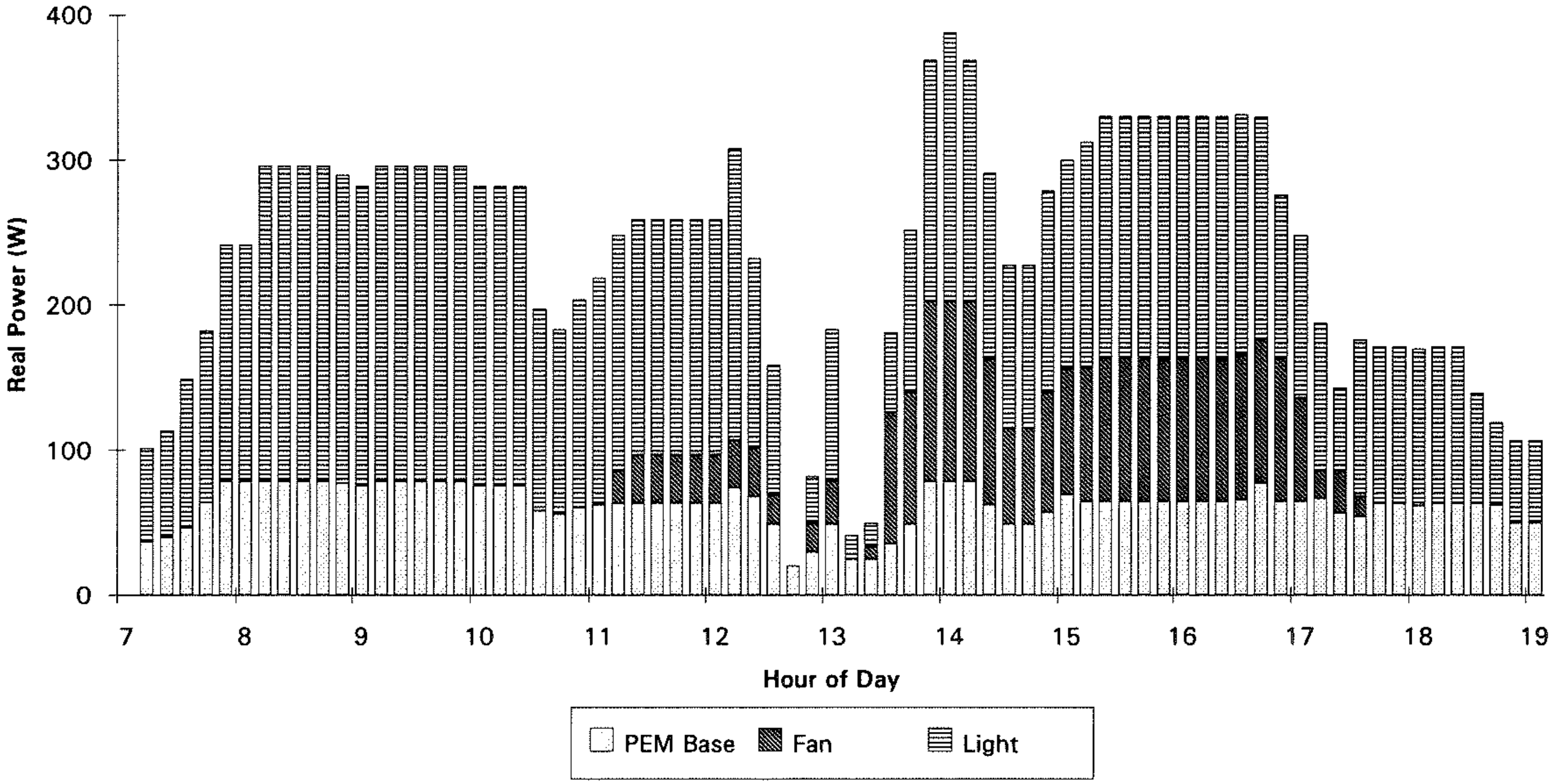
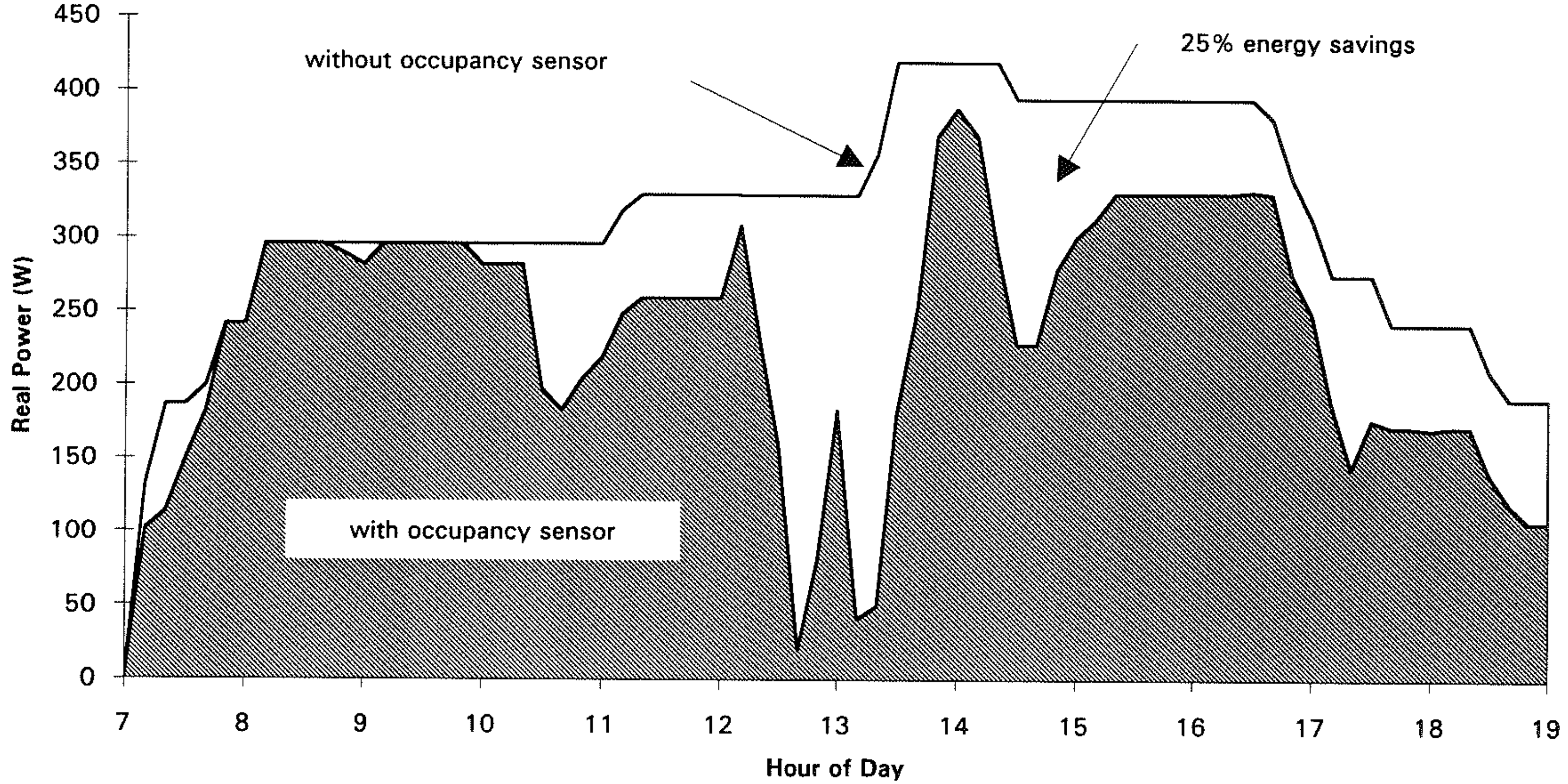


Figure 23. PEM Energy Savings due to Occupancy Sensor: 30 April 1992



and fans continue to operate at the same level, even when the workstations are vacant during the day. In this example, 25% of the PEM energy use is saved by the capability of the occupancy sensors to turn off the PEM units when the workstations are unoccupied.

HVAC Performance

In this section we present and discuss findings regarding the performance of the HVAC system serving the AOST office, including supply air temperature and volume, and room temperatures and humidity.

In Figure 24, the total PEM supply air volume (measured in the duct serving the four PEM units) is compared to the total PEM fan setpoints for 30 April 1992. The total occupancy-weighted fan setpoints are calculated by summing up the result for each workstation based on a value between zero and one, corresponding to the minimum to maximum setpoint on the control panel, and multiplied by one when the workstation is occupied and zero when it is unoccupied. For example, if all four fan setpoints were at their maximum setting, but only two workstations were occupied, the total weighted fan setpoint would equal two. The setpoint and supply volume profiles follow similar patterns. As described previously, even when its internal fans are turned off (minimum setpoint) a flow of approximately 40 cfm is maintained through each PEM unit for ventilation purposes. Figure 24 indicates a flow of between 130 and 140 cfm when the total PEM fan setpoints are at or near their minimum, in agreement with design conditions. PEM fan usage reaches its peak shortly after lunch when two of the PEM subjects return from playing basketball and turn up their fans to cool off. They maintain a higher fan usage for most of the afternoon. The PEM supply air volume also increases during the afternoon, indicating that the VAV box controlling the flow to the PEMs is operating properly.

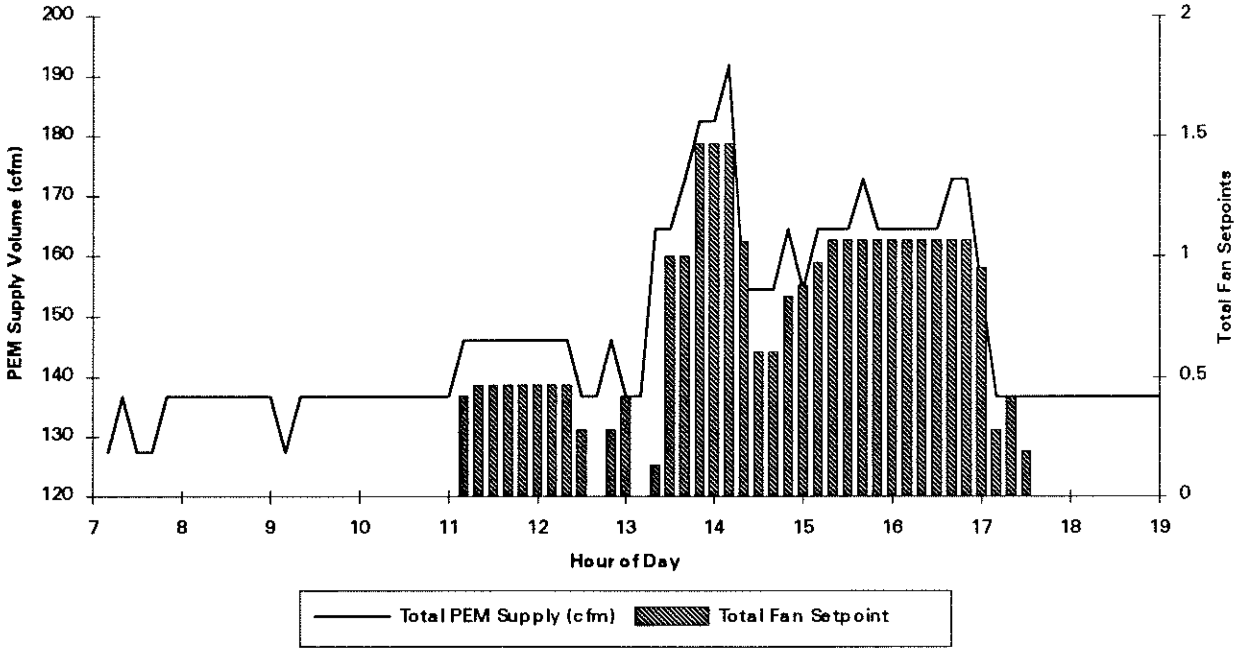


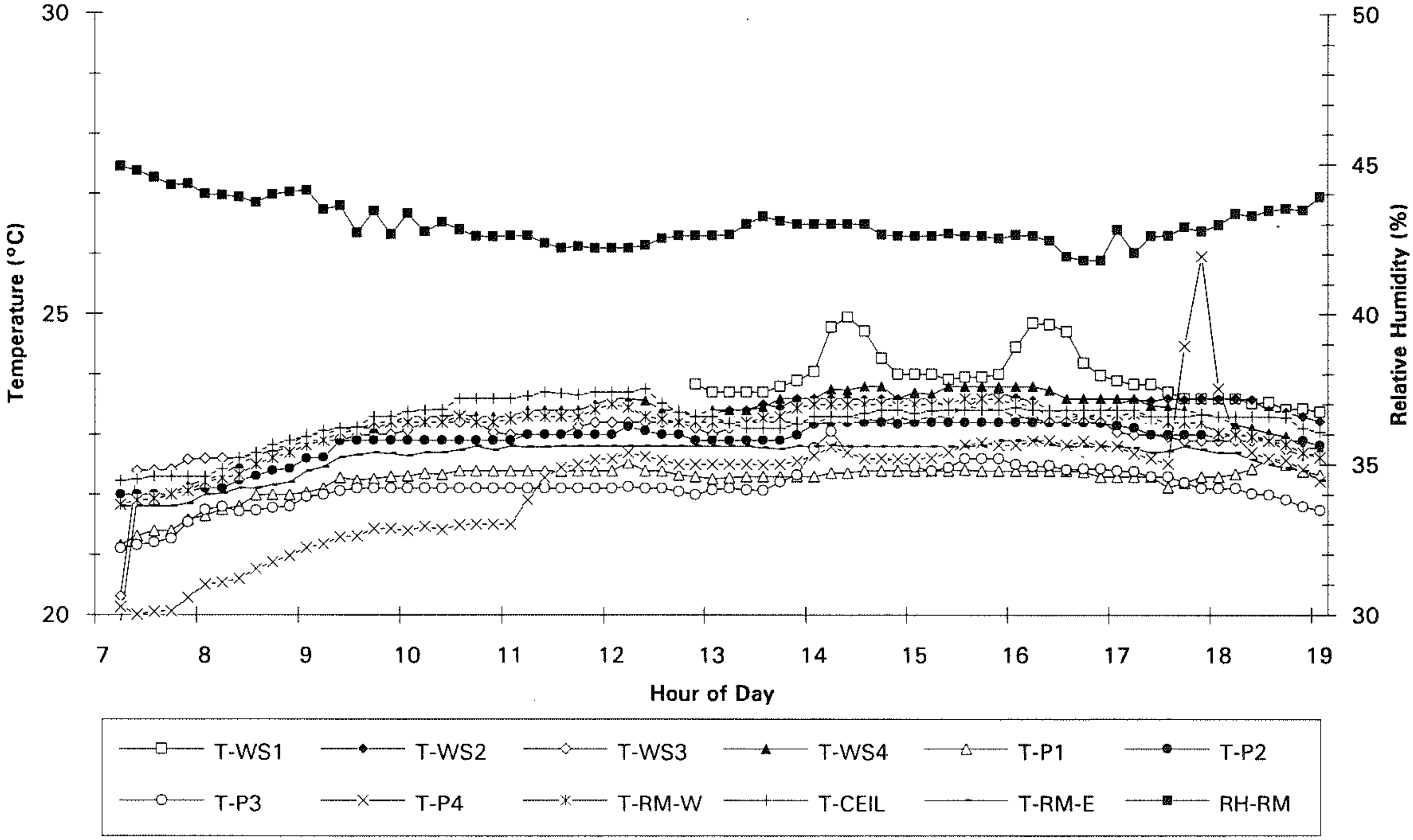
Figure 24. PEM Supply Air Volume and Occupancy-Weighted Fan Setpoints

Figure 25 shows ten-minute average trend data for workstation and room air temperatures, as well as average room relative humidity, for 30 April 1992. Temperatures are displayed for the four conventional workstations (T-WS1 to T-WS4), the four PEM workstations (T-P1 to T-P4), and room temperature on the west wall (T-RM-W), east wall (T-RM-E), and near the ceiling (T-CEIL). Under most circumstances, all eleven air temperature sensors agree to within 2°C. Air temperatures in the fourth PEM workstation (T-P4) are lower during much of the morning. Notes from the comfort survey indicate that the PEM supply nozzle closest to the temperature sensor was pointed toward the sensor, possibly accounting for this result. After 11 am, the nozzle was turned away from the sensor and toward the occupant, allowing the measured workstation air temperature to increase. The small but noticeable peaks occurring in the afternoon do not correspond to visits from the portable comfort measurement system. It seems likely that some heat source (e.g., a person) close to the temperature sensors caused these increases. Room relative humidity falls between about 42 and 45% during the entire monitoring period.

Measured supply volumes and room temperatures are shown together for 30 April 1992 during Test 1 (Figure 26a) and for 16 September 1992 during Test 2 (Figure 26b). Of note is the fact that the ceiling-based air supply volume is on the order of six times that of the PEM air supply. This imbalance emphasizes the difficulty in distinguishing the performance characteristics of the two air distribution systems. As previously discussed, the overhead air supply tends to dominate the control of overall thermal conditions throughout the office, reducing the need for localized conditioning within the PEM workstations. The overhead air supply volume in Figure 26a shows little variation during the course of the day, despite the higher recorded room temperatures during the middle of the day. This is perhaps indicative of the uncapped flexible supply duct described earlier in *System Installation, Troubleshooting, and Calibration*. In Figure 26b, the leaking overhead supply duct was known to have been capped and the ceiling-based supply volume is somewhat reduced compared to Figure 26a, although still at least three to four times higher than the PEM air supply. The VAV box controlling the overhead air supply does not appear to be operating correctly as it throttles back to its lowest volume during the middle of the day, when room temperatures are highest, and reaches its maximum volume at 8 pm, when the office is unoccupied.

Measured supply air temperatures (SAT) are shown for 30 April 1992 during Test 1 (Figure 27a) and for 16 September 1992 during Test 2 (Figure 27b). Data are presented for temperatures measured in the overhead ducts serving the ceiling-based diffusers and PEM units, as well as the discharge air temperatures measured at the outlet of each PEM fan box under the desk. The duct temperature measurements differ because they are measured at significantly different locations. In general, the temperatures at each measurement location follow the same pattern during the day, reflecting the cycling of the central chiller serving these supply lines. An exception to this pattern occurs when the PEM fan units are turned on. On 30 April 1992, the fan in PEM3 was set to its maximum speed at about 1:30 pm (see Figure 16a), and at the same time, the PEM3 supply temperature shown in Figure 27a increased by 2°C. This is caused by the PEM fans drawing a larger amount of warmer recirculated room air into PEM fan box, where it mixes with the cool ducted primary air. This is understandable because the PEM box and recirculation damper are not tightly sealed and the overhead VAV box serving the PEMs can not respond as quickly as the individual

Figure 25. Workstation and Room Air Temperatures and Relative Humidity: 30 April 1992



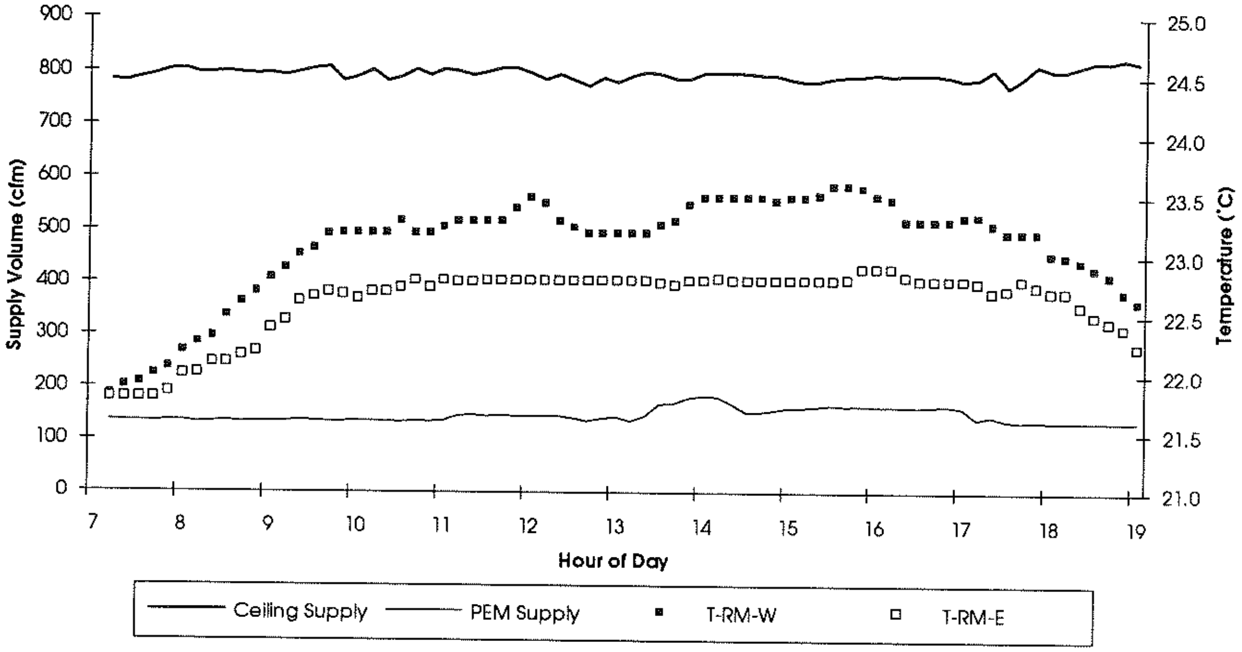


Figure 26a. Supply Volumes and Room Temperatures: 30 April 1992

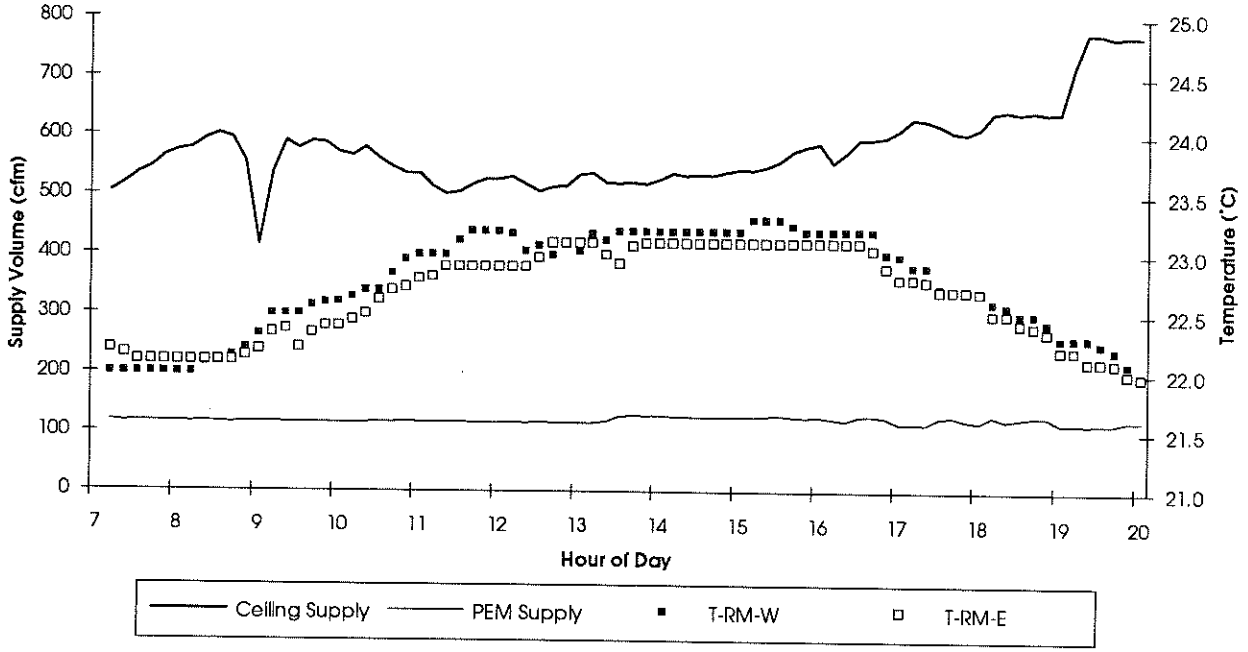


Figure 26b. Supply Volumes and Room Temperatures: 16 September 1992

Figure 27a. Supply Air Temperatures: 30 April 1992

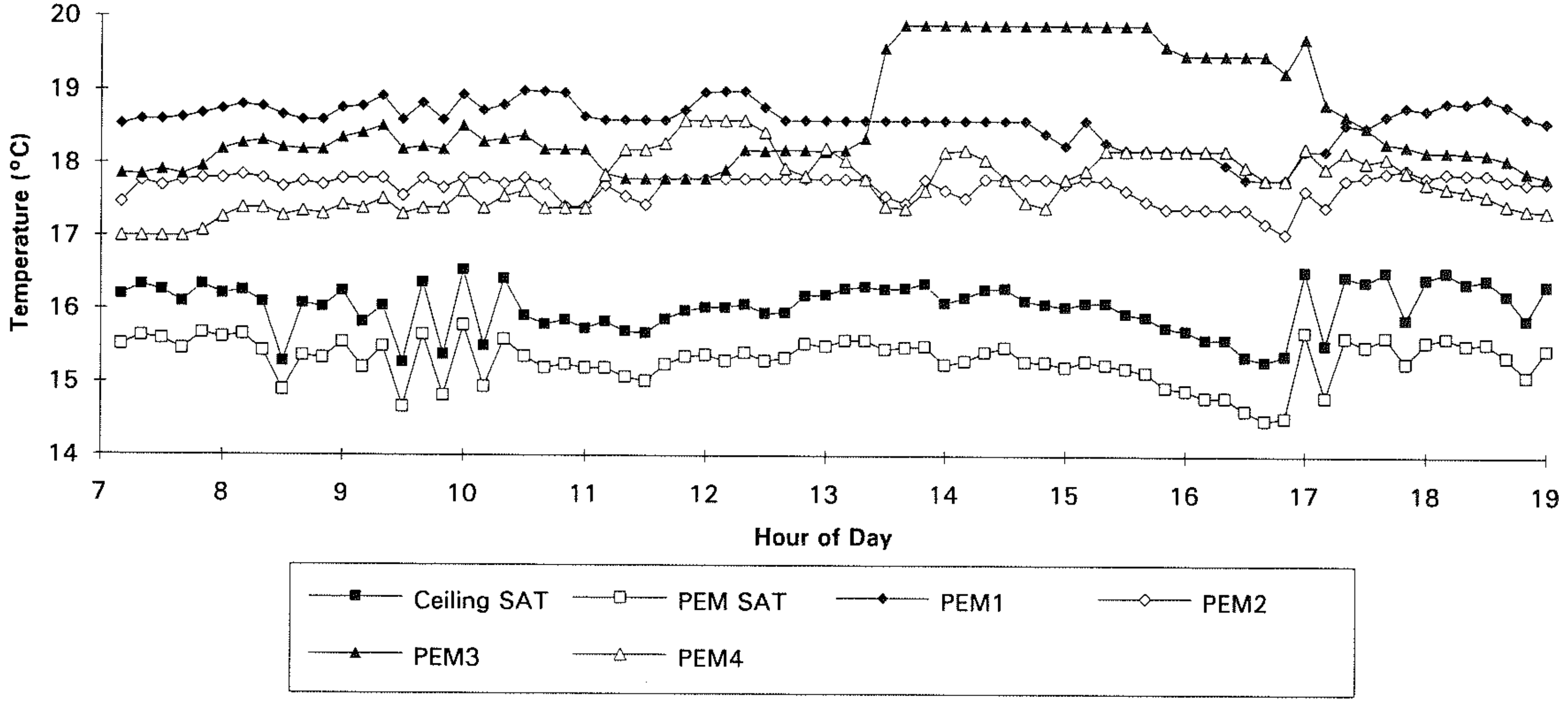
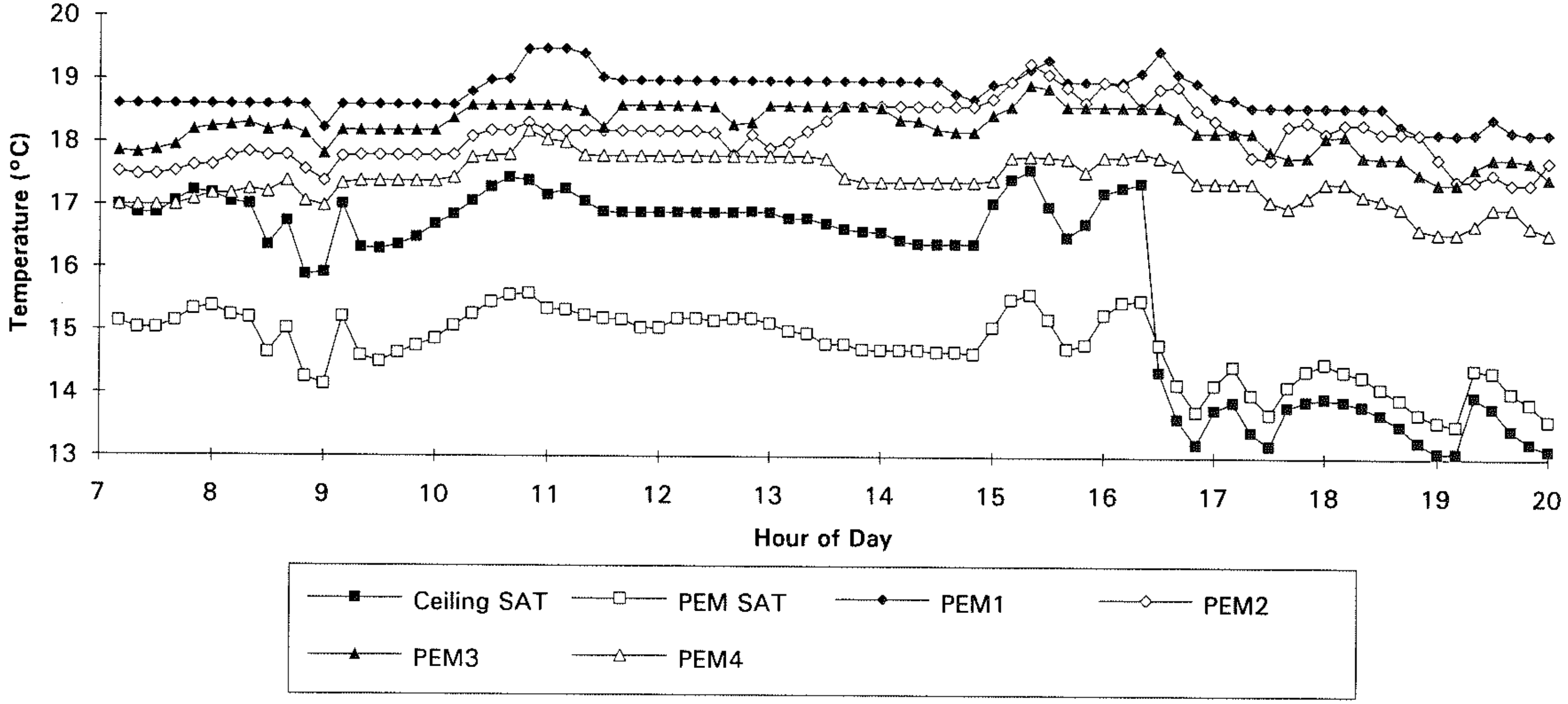


Figure 27b. Supply Air Temperatures: 16 September 1992



PEM controls. A similar pattern of increased PEM supply temperature corresponding to PEM fan operation is also shown for PEM4 during the afternoon in Figure 27a, and for PEM2 during the afternoon in Figure 27b. On average, PEM supply temperatures range from 2°C to nearly 4°C higher than the PEM SAT (measured upstream in the overhead duct), demonstrating the magnitude of the temperature rise through the long supply ducts serving the PEMs.

CONCLUSIONS

The Advanced Office Systems Testbed Project has successfully developed a facility in which advanced office technologies can be installed, tested, and demonstrated in a realistic office space. State-of-the-art data acquisition systems have been installed, providing detailed measurements of the performance of these advanced office systems, as well as a means for evaluating the suitability of the applied measurement and analysis methods. The measurement protocols and data acquisition systems are capable of collecting a large amount of data addressing energy use, thermal performance, environmental control, occupant use patterns, and thermal comfort. The manageable size of the AOST office has permitted project personnel to experience and learn from all aspects of developing and operating an office monitoring system. The lessons learned from the project have provided guidance for modifying the AOST office facility to improve its capabilities in future planned experiments, and for preparing for future scaled-up field studies of office technology.

The first advanced office system to be installed and tested in the AOST office was the Personal Environmental Module (PEM), manufactured by Johnson Controls. The PEM represents one example of an emerging technology known as task conditioning, or localized thermal distribution (LTD). Based on the results of this project and our other ongoing research, some general recommendations to improve the performance of localized thermal distribution systems are presented in Appendix H.

By utilizing a network communication capability provided by the PEMs, we were able to directly monitor the occupant use patterns and performance characteristics of individually-controlled PEM units. With the assistance of Johnson Controls, who had previously developed a PEM monitoring network at their headquarters building in Milwaukee, WI, we adapted their hardware and software to the configuration of the AOST office. The monitoring network software allows data to be collected and displayed on attractive color-graphic screens, to visually demonstrate the PEM performance characteristics to visitors of PG&E's AOST facility.

In addition to the issues described above, several important lessons have been learned through our work on the AOST Project. These are described briefly below.

1. The PEM monitoring network provides a good example of what an increasing number of environmental control technologies may look like in the future. Advances in microcomputer and communication technologies allow distributed (as opposed to centralized) intelligent control networks to be utilized to manage an increasing number of complex building environmental control and system integration issues. The effective performance of future

installations of PEMs and other task conditioning technologies will require the application of similar computer-based networks. Future monitoring efforts should take advantage to the extent possible of network compatibility to record the pattern of control and operation on a detailed basis, as was done with the PEM monitoring network.

2. Valuable experience was gained through the instrumentation and monitoring of the HVAC performance in the AOST office. As described in the troubleshooting section, several performance problems (e.g., uncapped supply line, oversized VAV box, etc.) were identified that impacted the interpretation of previously collected data as well as limiting the range of possible operating conditions during tests planned for the future. These kinds of HVAC problems represent conditions typically encountered in real buildings, underscoring the importance of carefully considering the HVAC configuration in a building selected for field evaluation.

3. One of the major objectives in developing the AOST facility was to identify advanced office systems and technologies that can lead to important reductions in electrical energy use while maintaining or improving the comfort and quality of the indoor environment. Based on the experiments completed to date, we know that the use of occupancy sensors is very effective at limiting excessive energy use associated with the PEM units and other workstation-based equipment that can be turned off when the workstation is unoccupied. However, the PEM system, as it is currently configured and operated in the AOST office, does not represent an energy saving technology in comparison to conventional HVAC systems. As discussed by Bauman et al. (1992), the energy performance of a building containing a task conditioning system, such as the PEM, will be strongly dependent on the sophistication with which the task conditioning system is integrated with the building's central HVAC system. In the AOST office, this system integration was less than optimal, as described further below.

4. While the PEM installation in the AOST office provided an opportunity to collect PEM performance data, the integration of the PEMs with the operation of the centralized HVAC system did not represent an optimized configuration or control strategy. The existence of two separate air distribution systems (ceiling-based and PEM-based) simultaneously providing cooling to the AOST office precludes the ability to adequately distinguish the thermal and ventilation performance characteristics of the two systems. For example, there is no feedback mechanism to allow airflow to the ceiling-based diffusers (serving the conventional workstations in the office) to be adjusted in response to changes in the PEM supply airflow. This will tend to increase the energy consumption of PEM workstations in comparison to conventional workstations. Since it is extremely important to obtain reliable information on the system integration issue, we highly recommend that future modifications and tests in the AOST office correct these operational limitations, as discussed further below.

   The potential for improved local comfort and ventilation under individual control within the PEM workstations should allow conditioning requirements in parts of the surrounding office to be relaxed. These effects should be investigated. We know from the data collected to date that the PEM control panels are used rather sparingly. We assume that this under utilization of the control capabilities of the PEM is due to the fact that thermal conditions in the entire

AOST office are maintained within the ASHRAE-specified comfort zone. There is little need to fine-tune the environment, except under extreme conditions (e.g., returning to work after playing basketball during lunch). In the future, tests could be defined to investigate the use of the PEM controls in situations when the demand for local control may be increased (e.g., raise room thermostat setpoint, disconnect primary (cool) air supply to PEMs, etc.).

5. The adaptation of the original PEM monitoring network to the AOST office, while certainly benefiting from the earlier developmental work and technical assistance by Johnson Controls, proved to be troublesome and time-consuming. As described previously, a lack of documentation and familiarity with the assembler code used to access the DR-9100 network has made it more difficult to solve several timing and computer-dependent problems. In future installations of this kind, it is recommended that alternate software approaches be investigated, in an effort to make the system operation more robust and understandable.

6. Due to the small number (ten) of AOST office workers participating in the study, the measurement database is not large enough to establish statistically significant PEM performance results. In addition, there are no reliable methods available to directly measure worker productivity in the AOST office. To date, the analysis of measurement results from the testbed has focused on identifying what effects can be measured in an office environment with PEMs, providing guidance for a scaled-up field study of PEM performance if funding and a suitable test site can be identified.

   On the other hand, the AOST office represents a unique facility for carefully defined studies of advanced office technology. Although smaller than a typical office building, the AOST office is considerably larger than a single-room controlled environment chamber, such as the one at UC Berkeley. It therefore falls somewhere in-between a rigidly controlled laboratory setting and an uncontrolled but larger and more realistic office space. Field studies in office buildings are always limited by any number of the following factors, including limited time to complete the study, limited access, limited data acquisition capabilities, potential for uncooperative building occupants (both individuals and company-wide), and usually no control over the HVAC operation of the building. The AOST office provides a practical alternative to field studies of this type due to its detailed data acquisition systems, cooperative tenant (PG&E), potential to improve the integration of the advanced (PEM) system with the central HVAC system, and the possibility of having some control over the thermal and occupancy conditions within the AOST office during future tests.

FUTURE DIRECTIONS

Described briefly below are our recommendations and suggestions for future work related to the AOST Project.

1. It is highly recommended that the existing overhead air distribution system and PEM installation be modified to allow improved system integration and operation. The most effective approach in this regard would be to (1) isolate to the extent possible the operation

of the air distribution system serving the AOST office from the HVAC system operation in the Sunset Building, (2) install four more PEMs in the other four workstations in the AOST office, and (3) replace the existing oversized VAV box controlling the overhead air distribution system. The isolation of the AOST air distribution system would require the installation of a damper in the main supply duct feeding the AOST office, and perhaps a secondary fan and reheat coil (downstream of the damper) to improve control of air volume and temperature. Adding four PEM units to the office would entail the installation of a new, resized variable-air-volume (VAV) terminal unit and overhead supply duct to be brought down the vertical column serving the other workstation cluster. A shut-off damper or some other means should be installed in each of the two air distribution systems (overhead and PEM), allowing one or the other to be completing closed down during future tests.

By eliminating the air supply from the overhead diffusers, future tests of the PEMs in the AOST office will not be complicated by the interaction of the PEM air supply with the overhead air supply. Also, by sizing the terminal units (in both the overhead and PEM systems) to match the ventilation requirements of the space more closely, improved system operation and control will also be achieved. This should increase the likelihood that well-planned tests could produce more substantial conclusions regarding the thermal and energy performance of PEMs. With this configuration, it should be possible to provide all the necessary conditioned air to the space (even if 2-3 additional workers are located along the west wall) through the eight PEM units. Although we would no longer have the side-by-side comparison of PEM vs. non-PEM workstations, due to the small total number of workstations, the AOST office is really not suited to generate meaningful results of this nature. By retaining the overhead duct system and supply diffusers, future installations of other advanced office systems could make use of overhead air supply if desired, increasing the versatility of the testing capabilities of the AOST office.

2. Using the existing data collection capabilities in the upgraded AOST office, additional tests should be defined and carried out to demonstrate more effectively the energy performance and occupant use patterns of PEM units. If tests can be carried out to show more clearly that PEM units have the potential to save energy and/or improve worker comfort and satisfaction, this information will be very valuable in planning and promoting future larger-scale field tests and other work in this area.

   With the upgraded air distribution system in place, tests could be conducted to investigate occupant response and PEM performance under different space temperature control strategies, diversified heat load distributions, and with partially-disabled PEM units. For example, by maintaining a higher average room temperature in the AOST office (raise thermostat setpoint), workers can be made to more effectively use the cooling capability of the PEM air flow to maintain their desired comfort level while allowing some overall cooling energy savings to be realized. Additional energy savings may result by allowing greater temperature variations (slow drifts) to occur in response to the outside daily temperature cycle. Office configurations can be set up in which heat loads vary significantly from workstation to workstation to test the localized comfort control capability of the PEM.

Other tests in which the PEM units are temporarily modified or disabled (e.g., disconnect primary (cool) air supply to PEMs) can provide more data on occupant use patterns.

3. Although the PEM monitoring network is fully functional, development of additional capabilities could improve its effectiveness, particularly as a visual tool to demonstrate the office performance to visitors. New Smalltalk graphic display screens that could be developed include: (1) PEM control panels showing the relative position of the control levers, (2) plan view of the ceiling air distribution ducts, showing the location and current status of sensors monitoring HVAC performance, and (3) an automated software-driven demonstration tool that steps through a series of screens to show the full range of display options provided by Smalltalk. Additional development work could respond to suggestions from users of the system to improve the overall performance of Smalltalk.

4. It is recommended that future measurement plans, both in the AOST office and other field test sites, include some amount of ventilation efficiency testing. These measurements are typically carried out using tracer gas techniques and can provide valuable multipoint data to demonstrate the task ventilation performance characteristics of the PEM units in comparison to the surrounding office space. Tracer gas tests in the AOST office could help determine the effectiveness of different ventilation system designs and operating strategies.

5. An important objective of the AOST project is to develop and test the monitoring methods that could be applied to future scaled-up field studies of PEM performance in selected buildings. We know from the experiences of the AOST project that the overall effectiveness of any future field study will be greatly enhanced by specifying plans for the office configuration and selecting the study participants as soon as possible. Studies of occupant response and satisfaction, thermal comfort, and productivity (if a suitable measure can be identified) will benefit from this early planning by allowing baseline measurements to be taken of the study participants before they occupy the new or renovated office. Baseline measurements will be more meaningful if they can be taken well in advance of the move into the office. If possible, it is advisable to select two distinct groups of subjects to participate in the study: (1) a group who will eventually occupy workstations having PEM units, and (2) a control group of equal number who will occupy conventional workstations in the new/renovated office. Analysis and comparison of measurement data from these two groups will provide the best opportunity to extract significant PEM performance results.

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APPENDIXES

A. AOST Monitoring Network Configuration

B. Smalltalk Basic Instructions and General Information

C. Background Survey

D. Online Subjective Survey

E. Complete Baseline Data Spreadsheet: 16, 17 October 1991

F. Complete Test 1 Data Spreadsheet: 30 April - 1 May 1992

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APPENDIX A

AOST Monitoring Network Configuration

ADVANCED OFFICE SYSTEMS TESTBED MONITORING NETWORK CONFIGURATION
Center For Environmental Design Research, UC Berkeley

DR-9100			Variable		Sensor					Power	
Label	Item Label	Item Addr.	Description	Label	Name	Location	Output	Eng. Units	Range	Input	Source
WS	AI1	J4/2	Air Temperature - Workstation 1	T-WS1	JC RS-9100	39 in.	0-10 V	°C	0-40	15 VDC	DR-9100
WS	AI2	J4/3	Air Temperature - Workstation 2	T-WS2	JC RS-9100	39 in.	0-10 V	°C	0-40	15 VDC	DR-9100
WS	AI3	J9/2	Air Temperature - Workstation 3	T-WS3	JC RS-9100	38 in.	0-10 V	°C	0-40	15 VDC	DR-9100
WS	AI4	J9/3	Air Temperature - Workstation 4	T-WS4	JC RS-9100	40 in.	0-10 V	°C	0-40	15 VDC	DR-9100
WS	DI1	J1/1	Occupancy - Workstation 1	OCC-WS1	Unenco PIR-1000	39 in.		-	0,1	24 VDC	211 power pack
WS	DI2	J1/2	Occupancy - Workstation 2	OCC-WS2	Unenco PIR-1000	39 in.		-	0,1	24 VDC	211 power pack
WS	AI5	J6/3	Occupancy - Workstation 3	OCC-WS3	Unenco PIR-1000	38 in.		-	0,1	24 VDC	211 power pack
WS	DI5	J3/1	Occupancy - Workstation 4	OCC-WS4	Unenco PIR-1000	40 in.		-	0,1	24 VDC	211 power pack
ROOM	AI1	J4/2	Thermostat Temperature	T-TS	JC RS-9100-8108	60 in.	0-10 V	°C	0-40	15 VDC	DR-9100
ROOM	AI2	J4/3	Thermostat Temperature Setpoint	TSP-TS	JC RS-9100-8108	60 in.	0-10 V	°C	0-40	15 VDC	DR-9100
ROOM	AI3	J9/2	Near-Ceiling Air Temperature	T-CEIL	JC RS-9100	101 in.	0-10 V	°C	0-40	15 VDC	DR-9100
ROOM	AI4	J9/3	Average Room Air Temperature	T-RM	JC RS-9100	60 in.	0-10 V	°C	0-40	15 VDC	DR-9100
ROOM	AI5	J6/3	Average Room Relative Humidity	RH-RM	JC HE-6300	60 in.	0-10 V	%	0-100	15 VDC	DR-9100
HVAC	AI1	J4/2	Supply Air Temperature 1 (Room)	SAT-1	JC TS-9100	duct	0-10 V	°C	0-40	15 VDC	DR-9100
HVAC	AI2	J4/3	Supply Air Temperature 2 (PEM)	SAT-2	JC TS-9100	duct	0-10 V	°C	0-40	15 VDC	DR-9100

DR-9100			Variable		Sensor					Power	
Label	Item Label	Item Addr.	Description	Label	Name	Location	Output	Eng. Units	Range	Input	Source
HVAC	AI3	J9/2	Supply Air Volume 1 (Room)	SAV-1	Veltron 1000C	duct	0-5 V	cfm	0-1630	24 VDC	ASTRAN LS-3A
HVAC	AI4	J9/3	Return Air Temperature	RAT	JC RS-9100	plenum	0-10 V	°C	0-40	15 VDC	DR-9100
HVAC	AI5	J6/3	Supply Air Volume 2 (PEM)	SAV-2	EP-8831	duct	4-20 ma	cfm	0-860	24 VDC	ASTRAN LS-3A
HVAC	AI6	J6/2	Supply Air Relative Humidity	SARH	JC HE-6310	duct	0-10 V	%	0-100	15 VDC	DR-9100
PEM1	AI1	J4/2	Air Temperature - PEM1	T-P1	JC RS-9100	39 in.	0-10 V	°C	0-40	15 VDC	DR-9100
PEM1	AI2	J4/3	Discharge Temp. Setpt. - PEM1	TSP-P1	existing in PEM	control panel		%	0-100		DR-9100
PEM1	AI3	J9/2	Fan Speed Setpoint - PEM1	FAN-P1	existing in PEM	control panel	4.5-7 V	%	0-100		DR-9100
PEM1	AI4	J9/3	Radiant Panel Setpoint - PEM1	RAD-P1	existing in PEM	control panel	0-10 V	%	0-100		DR-9100
PEM1	AI5	J6/3	Discharge Temperature - PEM1	SAT-P1	existing in PEM	flex duct		°C	0-40		DR-9100
PEM1	AI6	J6/2	Task Light Setpoint - PEM1	LITE-P1	existing in PEM	control panel	0-8 V	%	0-100		DR-9100
PEM1	DI2	J1/2	Occupancy - PEM1	OCC-P1	existing in PEM	control panel		-	0,1		DR-9100
PEM2	AI1	J4/2	Air Temperature - PEM2	T-P2	JC RS-9100	38 in.	0-10 V	°C	0-40	15 VDC	DR-9100
PEM2	AI2	J4/3	Discharge Temp. Setpt. - PEM2	TSP-P2	existing in PEM	control panel		%	0-100		DR-9100
PEM2	AI3	J9/2	Fan Speed Setpoint - PEM2	FAN-P2	existing in PEM	control panel	4.5-7 V	%	0-100		DR-9100
PEM2	AI4	J9/3	Radiant Panel Setpoint - PEM2	RAD-P2	existing in PEM	control panel	0-10 V	%	0-100		DR-9100
PEM2	AI5	J6/3	Discharge Temperature - PEM2	SAT-P2	existing in PEM	flex duct		°C	0-40		DR-9100

DR-9100			Variable		Sensor					Power	
Label	Item Label	Item Addr.	Description	Label	Name	Location	Output	Eng. Units	Range	Input	Source
PEM2	AI6	J6/2	Task Light Setpoint - PEM2	LITE-P2	existing in PEM	control panel	0-8 V	%	0-100		DR-9100
PEM2	DI2	J1/2	Occupancy - PEM2	OCC-P2	existing in PEM	control panel		-	0,1		DR-9100
PEM3	AI1	J4/2	Air Temperature - PEM3	T-P3	JC RS-9100	36 in.	0-10 V	°C	0-40	15 VDC	DR-9100
PEM3	AI2	J4/3	Discharge Temp. Setpt. - PEM3	TSP-P3	existing in PEM	control panel		%	0-100		DR-9100
PEM3	AI3	J9/2	Fan Speed Setpoint - PEM3	FAN-P3	existing in PEM	control panel	4.5-7 V	%	0-100		DR-9100
PEM3	AI4	J9/3	Radiant Panel Setpoint - PEM3	RAD-P3	existing in PEM	control panel	0-10 V	%	0-100		DR-9100
PEM3	AI5	J6/3	Discharge Temperature - PEM3	SAT-P3	existing in PEM	flex duct		°C	0-40		DR-9100
PEM3	AI6	J6/2	Task Light Setpoint - PEM3	LITE-P3	existing in PEM	control panel	0-8 V	%	0-100		DR-9100
PEM3	DI2	J1/2	Occupancy - PEM3	OCC-P3	existing in PEM	control panel		-	0,1		DR-9100
PEM4	AI1	J4/2	Air Temperature - PEM4	T-P4	JC RS-9100	33 in.	0-10 V	°C	0-40	15 VDC	DR-9100
PEM4	AI2	J4/3	Discharge Temp. Setpt. - PEM4	TSP-P4	existing in PEM	control panel		%	0-100		DR-9100
PEM4	AI3	J9/2	Fan Speed Setpoint - PEM4	FAN-P4	existing in PEM	control panel	4.5-7 V	%	0-100		DR-9100
PEM4	AI4	J9/3	Radiant Panel Setpoint - PEM4	RAD-P4	existing in PEM	control panel	0-10 V	%	0-100		DR-9100
PEM4	AI5	J6/3	Discharge Temperature - PEM4	SAT-P4	existing in PEM	flex duct		°C	0-40		DR-9100
PEM4	AI6	J6/2	Task Light Setpoint - PEM4	LITE-P4	existing in PEM	control panel	0-8 V	%	0-100		DR-9100
PEM4	DI2	J1/2	Occupancy - PEM4	OCC-P4	existing in PEM	control panel		-	0,1		DR-9100

APPENDIX B

Smalltalk Basic Instructions
and
General Information

BASIC INSTRUCTIONS

instruct.doc

Basic Instructions for the use of the Menus, and the Facility Map and Trend Data displays for the Advances Office Systems Testbed Project.

QUICK AND DIRTY STARTUP AND EXIT

To Enter Smalltalk:

- First you must get to the directory that houses the smalltalk program - to do this, type in:
  CD \STV286 <enter> (<enter> is the enter key)
- To start up the smalltalk program, type in:
  V /D:100 <enter> (note the space between V /)
  This starts the program leaving some of the computer's memory open for use by the basic and assembly code to gather data.

  Note: To use the mouse in smalltalk, "clicking" the right button will bring up menus and "clicking" the left button will "pick" (select) whatever the cursor on the screen is pointing to.
- In the main screen (anywhere in the pink screen except in the window labeled TRANSCRIPT at the top) "click right" to bring up the main menu.
- Move the cursor (the arrow on the screen) to highlight (in yellow) FACILITY MAP in the menu and "click left" to pick it.
- A ghost image of a rectangle will appear with the cursor as the upper left corner - position the corner where you want it and "click left" to fix it in position (the upper left corner of the screen is best.)
- The cursor will now be the lower right corner of the ghost rectangle - position the corner where you want it and "click left" to fix the size of the Facility Map on the screen (the larger the ghost rectangle the better - it makes things easier to read.)
- There will be a delay (the screen will show a blank white window) while the image of the Facility Map is being drawn.

To Display Data on the Facility Map Underlay:

- In the Facility Map window (the blue screen with a floor plan) "click right" to bring up the main Facility Map menu.
- To choose to display any of the choices in the main Facility Map menu - move the cursor to highlight your choice and "click left" to choose it.
- Either a sub-menu will appear with some more choices, or a purple window will appear asking for an entry to be typed in, or data will be displayed on the screen.

  for example:

  Highlight and "click left" on PEM PERAMETERS

A sub menu will appear - highlight and "click left" on AIR TEMPS

A sub menu will appear - highlight and "click left" on DISCHARGE TEMP Detailed explanations of the different menu items and what they will display are described below.

To Display Data on the Trend Data Graph Underlay:

- In the main screen (anywhere in the pink screen except in the window labeled TRANSCRIPT at the top) "click right" to bring up the main menu.
- Move the cursor (the arrow on the screen) to highlight (in yellow) TREND DATA in the menu and "click left" to pick it.
- The program will prompt for the date of the collected data to be displayed - typing in the date (in the form mm/dd/yy) and <enter> will load the data collected for that day.
- A ghost image of a rectangle will appear with the cursor as the upper left corner - position the corner where you want it and "click left" to fix it in position (the upper left corner of the screen is best.)
- The cursor will now be the lower right corner of the ghost rectangle - position the corner where you want it and "click left" to fix the size of the Facility Map on the screen (the larger the ghost rectangle the better - it makes things easier to read.)
- There will be a delay (the screen will show a blank white window) while the image of the Facility Map is being drawn.

To Exit Smalltalk:

- To exit the Facility Map move the cursor to the little white box with a slash through it located in the upper left corner of the Facility Map screen - "click left" and the Facility Map display will be erased.
- In the main window (the pink screen) "click right" to bring up the main menu.
- Move the cursor to highlight EXIT DEMO in the menu and "click left" to pick it.
- A sub menu will appear - highlight EXIT SMALLTALK and "click left".
- Another sub menu will appear - highlight FORGET IMAGE and "click left".

POP-UP MENU OVERVIEW

MAIN MENU

Turn Timer On/Off

"Picking" (with the mouse cursor) turns on/off the timer. This timer polls the PEMs for data (using the Turbo Basic code "off2000.exe") at a specified interval. The data is written to the data files in the data directory (see "Select Data to Analyze" below).

Turning ON displays a window asking for a time interval (in seconds) to collect data. "On" will be written in the Transcript window and the PEMs will be polled for data at the specified interval until the timer is turned off.

Turning OFF the timer, turns off the polling and data will no longer be collected. "Off" will be written in the Transcript window. (The Transcript window is the small window in the upper left corner of the screen that is titled SMALLTALK/V TRANSCRIPT.)

Manual AHU Reset

"Picking" displays a series of windows asking for desired set points for the AHUs (Air Handling Units.)

Facility Map

"Picking" allows the placement of a Facility Map underlay on the computer screen.

To place the Map on the screen: Position the upper left corner of the ghost image somewhere on the screen and click to lock it in place - drag the lower right corner of the ghost image until the desired size is obtained and click to lock it in place.

Exit Demo

Exits to the main Smalltalk menu.

FACILITY MAP MAIN MENU

Select Data to Analyze

"Picking" displays a sub menu:

Enter "new" to evaluate data

"New" comes up in the window as the default, so just hitting the <enter> key will load the most recently created (single time period) block of data into the facility map. The data can then be viewed using menu items described below.

Enter date (mm/dd/yy) to evaluate data

Typing in: a date (in the format above but without the parentheses) and the <enter> key, will load the data collected for that day. You will then be prompted for a specific time that data was collected during that day.

Select a Time to Evaluate Data

Typing in: a time (in 24-hour format: ie. 13:30 = 1:30 pm) and the <enter> key, loads the block of data for that time, on the date specified above, into the facility map. The data can then be viewed using menu items described below.

Restore Map

"Picking" (with the mouse cursor) erases the data displayed on the facility map so that a new set of data can be displayed without becoming confusing to read. This command doesn't need to be used every time as most re-displays clear the screen before they redraw.

Request Color

"Picking" allows you to reset the background color for data display on the Facility Map.

Occupancy Conditions

"Picking" displays a sub-menu:

Occupancy

"Picking" displays the occupancy (whether the occupant was IN/OUT) of the cubicle during the time of the data being displayed.

Gender

"Picking" displays the gender (MALE/FEMALE) of the occupant of the cubicle.

Age

"Picking" displays the age of the occupant of the cubicle.

Room Air Conditions

"Picking" displays a sub-menu:

Room Temp and Humidity

"Picking" displays room temperatures (the average room temperature and near-ceiling temperature), thermostat temperature and set point, and average relative humidity for the room.

Workstation Temps

"Picking" displays the air temperature in the four non-PEM cubicles during the time of the data being displayed.

PEM Parameters

"Picking displays a sub-menu:

Discharge Air Temps

"Picking" displays a sub-menu:

PEM Workstation Temp

"Picking" displays the air temperature in the four PEM cubicles during the time of the data being displayed.

Set Point Temp

"Picking" displays the relative position (0 - 100%) of the set point temperature control lever located on the control panel for the PEMs in the four PEM cubicles during the time of the data being displayed.

Discharge Temp

"Picking" displays the air discharge temperature for the PEMs in the four PEM cubicles during the time of the data being displayed.

Fan

"Picking" displays a sub-menu:

Air Flow Set Point

"Picking" displays the relative position (0 - 100%) of the fan speed set point control lever located on the control panel for the PEMs in the four PEM cubicles during the time of the data being displayed.

Radiant Panel

"Picking" displays a sub-menu:

Radiant Panel Set Point

"Picking" displays the relative position (0 - 100%) of the radiant panel set point control lever located on the control panel for the PEMs in the four PEM cubicles during the time of the data being displayed.

Task Lighting

"Picking" displays a sub-menu:

Task Lighting Set Point

"Picking" displays the relative position (0 - 100%) of the task lighting set point control lever located on the control panel for the PEMs in the four PEM cubicles during the time of the data being displayed.

HVAC Parameters

"Picking" displays a sub-menu:

Supply Volumes

Picking" displays the HVAC supply volume to the room ceiling diffusers and to the PEMs during the time of the data being displayed.

Supply Temps

"Picking" displays the HVAC supply temperature to the room ceiling diffusers and to the PEMs during the time of the data being displayed.

Supply RH

"Picking" displays the HVAC supply relative humidity during the time of the data being displayed.

Return Temps

"Picking" displays the HVAC return temperature (plenum temperature) during the time of the data being displayed.

GENERAL INFORMATION geninfo.doc

Convenient information for using Smalltalk in general and as it applies to the Advanced Office Systems Testbed Facility Map

DIRECTORIES AND FILES USED:

The STV286 directory is the home of the Smalltalk program. Smalltalk is the user friendly interface and master controller for all functions of the Advanced Office Systems Testbed control chamber data aquisition system. The Smalltalk program runs the Advanced Office Systems Testbed facility map, menus, and data display. Smalltalk also initiates the polling process of the PEMs to gather data.

To start up the Smalltalk program:
type in: cd stv286
this will change the directory to stv286
type in: v /d:100
this will start the Smalltalk program (more detailed instructions on start-up and shut-down are in the instruct.doc file)

The C:\PB directory is the home of the 'Power Basic' files that are responsible for actually polling the PEMs for data. The basic programs used to gather data are called through the 'Timer On/Off' menu item in Smalltalk (see instruct.doc for information on how to use menu items.)

The C:\DATA directory is the home of all of the data files that are created when the PEMs are polled. A data file is called for display through the 'Select Data to Analyze' menu item in Smalltalk (see instruct.doc for information on how to use menu items.)

GLOBAL VARIABLES THAT ARE DEFINED:

The following global variables are defined in the initVariables instance method (under Representation Applications - Facility Map methods). They should be changed in this method for new controll chambers with different cubicle and data collecting configurations.

NumCubes - is defined as the total number of cubicles in the controll chamber - in the Advanced Office Systems Testbed control chamber this is 8.

NumPems - is defined as the number of cubicles that are serviced by PEMs and will have data collected from the PEMs attributed to them - in the Advanced Office Systems Testbed control chamber this is 4.

NumWksta - is defined as the number of cubicles that are serviced by the AHUs and will have data collected from AHU#1 attributed to them - in the Advanced Office Systems Testbed control chamber this is 4.

NumAhus - is defined as the number of AHU's that will have data attributed to them - in the Advanced Office Systems Testbed control chamber this is 3.

To change these global variables:

- Use the class hierarchy browser to get into the Representation Applications method (scroll the upper left pane of the window down until this method appears, highlight this option and click twice to display sub-methods)
- Get into the Facility Map method (highlight this option in the upper left pane and click to display its instance methods in the upper right pane of the window)
- Get into the initVariables instance method (scroll the upper right pane down until this method appears, highlight it and click on it to display the code of this method in the bottom pane of the window)
- Type in the new values for the global variables and save the changes (to save: with the cursor in the bottom pane of the window, click right on the mouse to pull up the menu - highlight the option SAVE and click left on it)
- Also be sure to save the image after making changes (click right somewhere in the pink screen to bring up the main menu - highlight and click on EXIT DEMO - then highlight and click on SAVE IMAGE in the nest menu the pops up)

CHANGING CUBICLE ATTRIBUTES:

Each cubicle will have data assigned to it (for example:

```
aCubicle := Cubicle new.
aCubicle addrCUBE: 1.
aCubicle name: 'Gail Brager'
        age: '31'
        gender: 'Female'
        activity: '3.0'
        color: 12
        height: (17/8)
        width:  (17/8)
        xCoord: (23/4)
        yCoord: (3/2).
Cubicles add: aCubicle. )
```

The data that may need to be changed are: name, age, gender, and activity. All other attributes should not need to change. If more cubicles need to be added to the control chamber, copy an entire cubicle section and edit it as explained above. In addition change the addrCUBE attribute number to coorispond to the new cubicle number.

To change initial attributes of the cubicles:

- Use the class hierarchy browser to get into the Representation Applications method (scroll the upper left pane of the window down until this method appears, highlight this option and click left twice to display its sub-methods.)

- Get into the Facility Map sub-method (highlight this option in the upper left pane and click left to display its instance methods in the upper right pane of the window.)

- Get into the createCubicles class method (highlight class in the lower right box of the upper right pane of the window - then scroll the upper right pane down until the createCubicles method appears - highlight it and click left on it to display the code of this method in the bottom pane of the window.)

- Type in the appropriate new data as it pertains to the new control chamber's cubicle occupants and save the changes. (To save: with the cursor in the bottom pane of the window, click right on the mouse to pull up the main window pane menu - highlight the option SAVE and click left on it.)

- Reinitialize the cubicles (highlight the line below by draging the cursor accross it until the line is displayed as white letters on a black background - in the lower pane of the window, click right to pull up the main window pane menu - highlight the option DO IT and click left.) This will put the new information into the cubicles and the new Facility Map.

```
FacilityMap createCubicles
```

- Also be sure to save the image after making changes. (Click right somewhere in the pink screen to bring up the main menu - highlight and click left on EXIT DEMO - a sub menu will pop up - highlight and click left on SAVE IMAGE.)

APPENDIX C

Background Survey

UNIVERSITY OF CALIFORNIA, BERKELEY

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO
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COLLEGE OF ENVIRONMENTAL DESIGN
DEPARTMENT OF ARCHITECTURE
BERKELEY, CALIFORNIA 94720

A STUDY OF INDOOR CLIMATE AND COMFORT

Office 2000 Demonstration Project

As part of PG&E's Office 2000 Demonstration project, the Building Science Group in the Dept. of Architecture is investigating how building occupants respond to the thermal environments in your building. The results will serve the larger agenda of PG&E's investigation of buildings' energy efficiency and environmental quality, while also furthering our understanding of your working conditions before and after you move into the Office 2000 Demonstration Office. The project involves collecting physical measurements along with occupants' subjective ratings of the thermal conditions in their workspace.

As a participant, you will initially be asked to fill out a background information form requiring approximately 20 minutes to complete. This form addresses basic demographic data as well as your overall impressions of and satisfaction with a range of attributes of the workplace. It is important that these forms are completed and returned before our field study begins.

The remainder of the survey consists of approximately 5 visits to your workstation by a project member over the course of 2-3 days. At each visit you will be asked to answer a short (2-8 minutes) series of questions addressing your immediate comfort, clothing and activity levels. The questions are administered on a laptop personal computer. We will then ask you to step away from your desk for 5 minutes while an instrumented cart is placed in your normal working position to gather data on the physical environment.

It is important that we have an opportunity to visit you 5 times during the 2-3 day measurement period. However, our objective is to be as unobtrusive as possible. If the researcher approaches you at an inconvenient time, please let him or her know when would be a more convenient time during that day.

Please be assured that your identity will remain anonymous and your responses will be kept confidential. All data will be associated with an ID number only.

The success of this project hinges on the role of volunteers. Volunteers in past projects have found the experience educational as well as enjoyable. We are sincerely grateful for your interest and cooperation.

Advanced Office Systems Testbed

Comfort Study -- Background Survey

Please note: All survey responses will remain confidential.
Participants will remain anonymous and will only be identified by an assigned ID code.

Background Characteristics

1. Name: ____________________ 2. Date: ____________________

3. Department or group: ____________________

4. Occupation: ____________________

5. Job title: ____________________

6. Work phone number: ____________________ 7. Cubicle: ____________________

8. Home zip code: ____________________

9. On the average, how many <u>hours per week</u> do you work at this job?	_____ Hours at work
10. On the average, how many <u>hours per day</u> do you sit at your work area?	_____ Hours at desk
11. What is your approximate height?	_____ Feet, _____Inches
12. What is your approximate weight?	_____ Pounds
13. What is your age?	_____ Years

Please check the following:

14. Your gender? 1 ☐ Male 2 ☐ Female

15. Your ethnic background?

1 ☐ Asian American
2 ☐ Black
3 ☐ Caucasian
4 ☐ Hispanic
5 ☐ Other (please specify:____________________)

16. Is English your primary language? 1 ☐ Yes 2 ☐ No

17. What is the highest grade of school you completed?

1 ☐ 8th grade or less
2 ☐ between 9th and 11th
3 ☐ high school graduate
4 ☐ some college
5 ☐ college graduate (B.A., B.S.)
6 ☐ some graduate school
7 ☐ M.A. or equivalent
8 ☐ Ph.D., M.D., or LL.B.

Office Description

We would like to know your general impressions of your office work area, as influenced by room temperature, humidity, air movement and illumination. Next to each word, please write the number from the scale below which best reflects HOW OFTEN YOUR WORK AREA SEEMS THAT WAY.

5 always
4 often
3 sometimes
2 rarely
1 never

_____ adjustable
_____air-conditioned
_____ airless
_____ airy
_____ blinding
_____ bright
_____ chilly
_____ close
_____ cold
_____ comfortable
_____ controllable
_____ cool
_____ cozy
_____ damp
_____ dark
_____ dim
_____ drafty
_____ dry
_____ dusty
_____ flickering
_____ fresh
_____ gloomy
_____ heated
_____ hot
_____ humid
_____ illuminated
_____ inadjustable
_____ misty
_____ over-heated
_____ shadowy
_____ shiny
_____ smoky
_____ snug
_____ stale
_____ stifling
_____ stuffy
_____ sunny
_____ uncomfortable
_____ uncontrollable
_____ under-heated
_____ unventilated
_____ ventilated
_____ warm
_____ well-lit
_____ window-less

In terms of comfort, how acceptable is your office work area overall? (check one below)

6 ☐ **very acceptable**
5 ☐ **moderately acceptable**
4 ☐ **slightly acceptable**
3 ☐ **slightly unacceptable**
2 ☐ **moderately unacceptable**
1 ☐ **very unacceptable**

Do you have any additional comments about the comfort of your office work area?

Work Area Satisfaction

We are interested in knowing how satisfied you are with different characteristics of your work area. Using the scale below, please indicate how SATISFYING YOUR WORK AREA IS with respect to each characteristic by circling the number that reflects how you feel.

6 very satisfied
5 moderately satisfied
4 slightly satisfied
3 slightly dissatisfied
2 moderately dissatisfied
1 very dissatisfied

(circle one number for each item)

How satisfied are you with:

1. The type and levels of sounds?	1	2	3	4	5	6
2. The lighting?	1	2	3	4	5	6
3. The temperature?	1	2	3	4	5	6
4. The air quality?	1	2	3	4	5	6
5. The ventilation and air circulation?	1	2	3	4	5	6
6. The colors of walls or partitions?	1	2	3	4	5	6
7. The furniture and equipment?	1	2	3	4	5	6
8. The amount of space available to you?	1	2	3	4	5	6
9. The level of privacy?	1	2	3	4	5	6
10. The comfort of your chair?	1	2	3	4	5	6
11. Provision of non-smoking work areas?	1	2	3	4	5	6

Personal Comfort

Now that you've told us how frequently you experience different attributes of your work area environment, and indicated your level of satisfaction with a number of characteristics, we are interested in your perception of the quality of specific aspects of the thermal and luminous environments. Please complete each of the following statements by checking the box that best expresses your personal feelings or preferences.

1. On average, I perceive my work area to be: (check one)

6 ☐ very comfortable
5 ☐ moderately comfortable
4 ☐ slightly comfortable
3 ☐ slightly uncomfortable
2 ☐ moderately uncomfortable
1 ☐ very uncomfortable

2. On average, I perceive the TEMPERATURE of my work area to be: (disregarding the effects of air movement, lighting and humidity)

6 ☐ very warm
5 ☐ moderately warm
4 ☐ slightly warm
3 ☐ slightly cool
2 ☐ moderately cool
1 ☐ very cool

3. On average, I perceive the AIR MOVEMENT of my work area to be: (disregarding the effects of temperature, lighting and humidity)

6 ☐ very drafty
5 ☐ moderately drafty
4 ☐ slightly drafty
3 ☐ slightly stuffy
2 ☐ moderately stuffy
1 ☐ very stuffy

4. On average, I perceive the LIGHTING of my work area to be: (disregarding the effects of temperature, air movement and humidity)

6 ☐ very bright
5 ☐ moderately bright
4 ☐ slightly bright
3 ☐ slightly dim
2 ☐ moderately dim
1 ☐ very dim

5. On average, I perceive the HUMIDITY of my work area to be: (disregarding the effects of temperature, air movement, and lighting)?

6 ☐ very humid
5 ☐ moderately humid
4 ☐ slightly humid
3 ☐ slightly dry
2 ☐ moderately dry
1 ☐ very dry

Personal Control

To what extent are you able to control the environment of the office space you are in right now? For each question below make a check mark next to the statement which best expresses your personal feelings or behavior patterns.

1. HOW MUCH CONTROL do you feel you have over the thermal conditions of your workplace? (check one)

5 ☐ complete control
4 ☐ high desgree of control
3 ☐ moderate control
2 ☐ slight control
1 ☐ no control

2. HOW SATISFIED ARE YOU with this level of control? (check one)

6 ☐ very satisfied
5 ☐ moderately satisfied
4 ☐ slightly satisfied
3 ☐ slightly dissatisfied
2 ☐ moderately dissatisfied
1 ☐ very dissatisfied

3. CAN YOU EXERCISE ANY OF THE FOLLOWING OPTIONS to adjust the thermal environment at your workplace? (check Y-*yes* or N-*no* for each item)

1 Y ☐ N ☐ open or close a window
2 Y ☐ N ☐ open or close a door to the outside
3 Y ☐ N ☐ open or close a door to an interior space
4 Y ☐ N ☐ adjust a thermostat
5 Y ☐ N ☐ adjust the drapes or blinds
6 Y ☐ N ☐ turn a local space heater on or off
7 Y ☐ N ☐ turn a local fan on or off

4. In general, how often DO YOU EXERCISE ANY OF THE FOLLOWING OPTIONS to adjust the thermal environment at your workplace?

5 always
4 often
3 sometimes
2 rarely
1 never
0 not available

(circle one number for each item)

1 open or close a window 0 1 2 3 4 5
2 open or close a door to the outside 0 1 2 3 4 5
3 open or close a door to an interior space 0 1 2 3 4 5
4 adjust a thermostat 0 1 2 3 4 5
5 adjust the drapes or blinds 0 1 2 3 4 5
6 turn a local space heater on or off 0 1 2 3 4 5
7 turn a local fan on or off 0 1 2 3 4 5

››

Please note: All survey responses will remain confidential.
Only statistical summaries of this, and most other questions, will be provided.

››

Job Satisfaction

The questions below ask about different characteristics of your job. Please indicate how SATISFYING YOUR JOB IS with respect to each characteristic by circling the number that reflects how you feel.

6 very satisfied
5 moderately satisfied
4 slightly satisfied
3 slightly dissatisfied
2 moderately dissatisfied
1 very dissatisfied

(circle one number for each item)

How generally satisfied are you with:

1. Your job overall? 1 2 3 4 5 6
2. Your company's policies? 1 2 3 4 5 6
3. The degree of access to other people you work with? 1 2 3 4 5 6
4. The opportunity to develop your skills? 1 2 3 4 5 6
5. Your job security? 1 2 3 4 5 6
6. Your relations with your co-workers? 1 2 3 4 5 6
7. Your relations with your supervisors? 1 2 3 4 5 6
8. Your pay? 1 2 3 4 5 6
9. Your chances for advancement? 1 2 3 4 5 6
10. Your level of responsibility? 1 2 3 4 5 6
11. Your independence or autonomy? 1 2 3 4 5 6
12. The degree of recognition for good work? 1 2 3 4 5 6
13. Your interest in the work itself? 1 2 3 4 5 6
14. The quality of equipment you work with? 1 2 3 4 5 6
15. The time pressures of your job? 1 2 3 4 5 6

››

Please note: The following sections contain questions about you. They are not concerned with your building, your office work area, or any other aspect of the environment. The focus is on the kind of person you are.

››

Health Characteristics

Below are some symptoms that people experience at different times. Please indicate how often YOU HAVE EXPERIENCED EACH SYMPTOM IN THE PAST MONTH by circling the appropriate number from the scale below.

5 very often
4 often
3 sometimes
2 rarely
1 never

(circle one number for each symptom)

1. Headache	1	2	3	4	5	6
2. Dizziness	1	2	3	4	5	6
3. Sleepiness	1	2	3	4	5	6
4. Sore or irritated throat	1	2	3	4	5	6
5. Nose irritation (itch or running)	1	2	3	4	5	6
6. Eye irritation	1	2	3	4	5	6
7. Trouble focusing eyes	1	2	3	4	5	6
8. Difficulty concentrating	1	2	3	4	5	6
9. Skin dryness, rash or itch	1	2	3	4	5	6
10. Fatigue	1	2	3	4	5	6

11. Do you take over-the-counter or prescription drugs that might influence your comfort while at work? (check one) 1 ☐ Yes 2 ☐ No

On the average:

12. How many cigarettes do you smoke per day? _____ Cigarettes

13. How many cups of caffeinated beverages do you drink per day? _____ Cups per day

14. How many hours do you exercise per week? _____ Hours

Your Characteristic Emotions

A number of words which people have used to describe their characteristic emotions are given below. Please read each word and rate HOW OFTEN YOU FEEL THAT WAY using the scale below. In each case simply write the number in the blank which best reflects how often you feel that way.

5 very often
4 often
3 sometimes
2 rarely
1 never

_____ Frustrated

_____ Uncomfortable

_____ Happy

_____ Energetic

_____ Sad

_____ Fatigued

_____ Comfortable

_____ Burdened

_____ Relaxed

_____ Restless

Your Environmental Sensitivity

A number of questions related to YOUR TYPICAL RESPONSE TO ENVIRONMENTAL CONDITIONS are given below. To indicate your answer to a question circle the number from the following scale which best expresses how you TYPICALLY feel.

6 very sensitive
5 moderately sensitive
4 slightly sensitive
3 slightly insensitive
2 moderately insensitive
1 very insensitive

(circle one number for each question)

1. Do you tend to be SENSITIVE to environments which are TOO NOISY? 1 2 3 4 5 6
2. Do you tend to be SENSITIVE to environments which are TOO HOT? 1 2 3 4 5 6
3. Do you tend to be SENSITIVE to environments which are TOO COLD? 1 2 3 4 5 6
4. Do you tend to be SENSITIVE to environments which have TOO LITTLE AIR MOVEMENT ? 1 2 3 4 5 6
5. Do you tend to be SENSITIVE to environments which have TOO MUCH AIR MOVEMENT ? 1 2 3 4 5 6
6. Do you tend to be SENSITIVE to environments which are TOO DIMLY LIT? 1 2 3 4 5 6
7. Do you tend to be SENSITIVE to environments which are TOO BRIGHT? 1 2 3 4 5 6
8. Do you tend to be SENSITIVE to environments which have POOR AIR QUALITY? 1 2 3 4 5 6

*****

Do you have any other comments about your sensitivity to environmental conditions?

____

____

____

Summary Comments

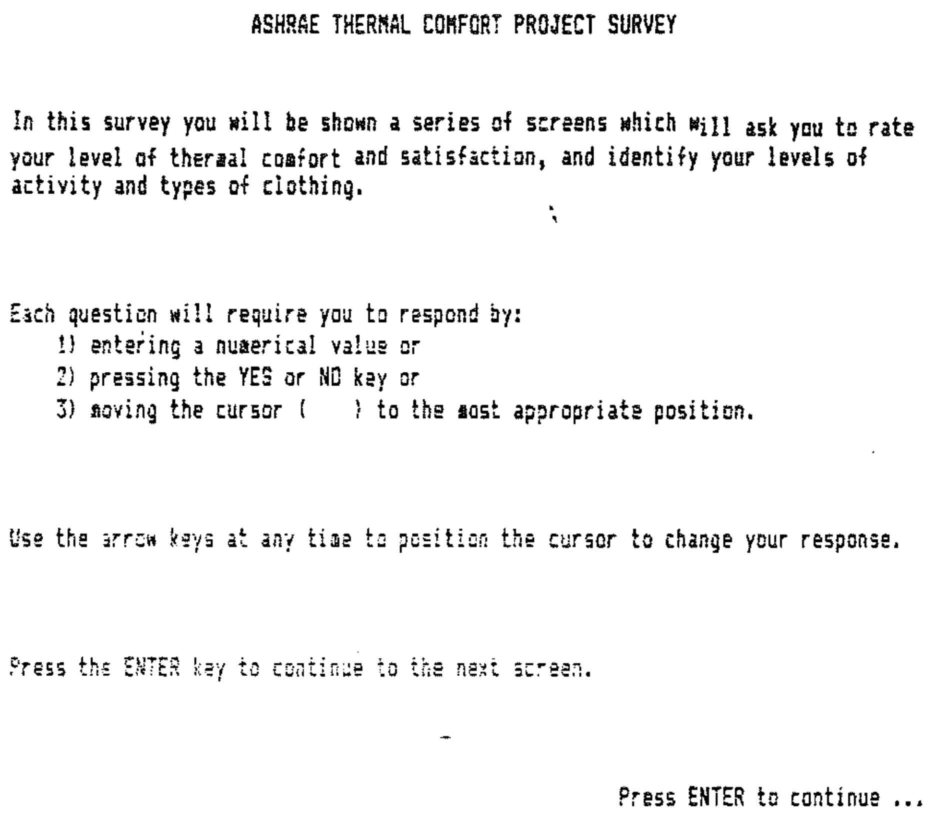
Please list any additional comments you have about the comfort of your office work area.

Thank you very much for your help.

APPENDIX D

Online Subjective Survey

ONLINE SUBJECTIVE SURVEY SCREENS



ASHRAE THERMAL COMFORT PROJECT SURVEY

In this survey you will be shown a series of screens which will ask you to rate your level of thermal comfort and satisfaction, and identify your levels of activity and types of clothing.

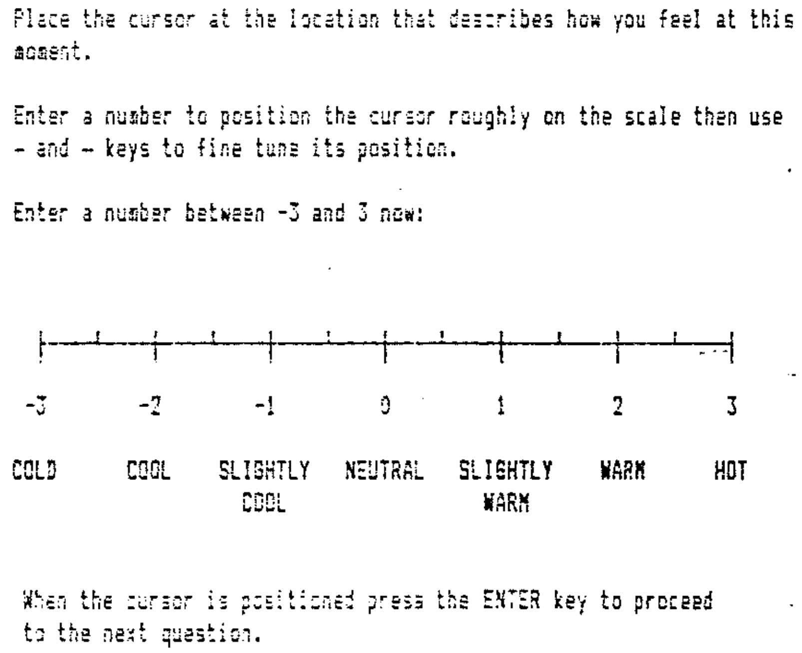
Each question will require you to respond by:

1) entering a numerical value or
2) pressing the YES or NO key or
3) moving the cursor (   ) to the most appropriate position.

Use the arrow keys at any time to position the cursor to change your response.

Press the ENTER key to continue to the next screen.

Press ENTER to continue ...



Place the cursor at the location that describes how you feel at this moment.

Enter a number to position the cursor roughly on the scale then use - and - keys to fine tune its position.

Enter a number between -3 and 3 now:

-3	-2	-1	0	1	2	3
COLD	COOL	SLIGHTLY COOL	NEUTRAL	SLIGHTLY WARM	WARM	HOT

When the cursor is positioned press the ENTER key to proceed to the next question.

I would like to be:

WARMER

NO CHANGE

COOLER

Use the - and - keys to select a word then press the ENTER key to proceed to the next screen.

Please answer the following questions in terms of how comfortable you are RIGHT NOW. In response to each question enter a single number from the scale provided. Use the arrow keys for correcting mistakes.

1. How comfortable is your office work area RIGHT NOW (enter one of the following numbers) ?

6 = very comfortable
5 = moderately comfortable
4 = slightly comfortable
3 = slightly uncomfortable
2 = moderately uncomfortable
1 = very uncomfortable

2. What would you estimate the temperature to be RIGHT NOW ?

press ENTER to continue ...

```
3. How comfortable is your office work area RIGHT NOW in terms of air flow
   (enter one of the following numbers) ?

                        6 = very drafty
                        5 = moderately drafty
                        4 = slightly drafty
                        3 = slightly stuffy
                        2 = moderately stuffy
                        1 = very stuffy


4. How comfortable is your office work area RIGHT NOW in terms of lighting
   (enter one of the following numbers) ?

                        6 = very bright
                        5 = moderately bright
                        4 = slightly bright
                        3 = slightly dim
                        2 = moderately dim
                        1 = very dim


                                              press ENTER to continue ...
```

```
 To indicate how you feel RIGHT NOW, enter the appropriate number from
 the scale below beside each word in the list. You may use the - and -
 keys to move through the words for corrections.

            6 = very appropriate for describing my mood
            5 = moderately appropriate for describing my mood
            4 = slightly appropriate for describing my mood
            3 = slightly inappropriate for describing my mood
            2 = moderately inappropriate for describing my mood
            1 = very inappropriate for describing my mood

                  Frustrated          Relaxed
                  Comfortable         Sad
                  Happy               Energetic
                  Fatigued            Burdened
                  Uncomfortable       Restless

                       press ENTER to continue to the next screen
```

During the last hour, have you made any of the following changes in your environment or behavior to improve thermal comfort? Use the YES or NO key to answer:

Opened or closed a window
Opened or closed a door to an interior space
Adjusted the drapes or blinds
Turned a local fan on or off
Adjusted my clothes
Drank a hot or cold drink
Took a break by leaving my workplace
Talked to others about the thermal conditions
Talked to staff responsible for thermal conditions
Ignored thermal conditions, concentrated on my work

If you made other significant changes to improve the thermal environment, please tell the survey person when they return to collect this computer.

Press ENTER to continue

This screen lists the changes you made during the last hour. Enter a number from the scale below to rate the effectiveness of each change in improving your comfort:

1 = No effect
2 = Slight effect
3 = Moderate effect
4 = Major effect

Opened or closed a window
Opened or closed a door to an interior space
Adjusted the drapes or blinds
Turned a local fan on or off
Adjusted my clothes
Drank a hot or cold drink
Took a break by leaving my workplace
Talked to others about the thermal conditions
Talked to staff responsible for thermal conditions
Ignored thermal conditions, concentrated on my work

Press ENTER to continue

```
Within the last 15 MINUTES ...........


   Have you been  1. SITTING most of the time,
                  2. WALKING around most of the time
                  3. Both SITTING and WALKING around ?  (PRESS 1, 2, or 3) ?


   Have you eaten a SNACK or MEAL (YES/NO) ?



   Have you drunk anything    a. Hot (YES/NO) ?
                              b. Cold (YES/NO) ?
                              c. Caffeinated (YES/NO) ?



   Have you smoked a cigarette (YES/NO) ?



                                                   Press ENTER to continue ...


                            CURRENT CLOTHING CHECKLIST

For each item of clothing which you are wearing RIGHT NOW enter one of the
numbers from the scale below to indicate its relative weight. You may skip all
items which are correct.

                          0  Not Wearing the item AT THIS TIME
                          1  Light weight
                          2  Medium weight
                          3  Heavy Weight

UNDERLAYER:                          OUTERLAYERS:
  0  top: 1= sleeveless                 0  Sweater
          2= Tshirt                     0  Vest
          3= long underwear             0  Jacket

  0  bottom: 1= briefs               FOOTWEAR:
             3= long underwear          0  Socks
                                        0  Shoes: 1= sandals
MIDLAYER:                                         2= shoes or sneakers
  0  short sleeve shirt                           3= boots
  0  long sleeve shirt
  0  Pants
  0  Shorts
                                                  Press ENTER to continue ...
```

CURRENT CLOTHING CHECKLIST

For each item of clothing which you are wearing RIGHT NOW enter one of the numbers from the scale below to indicate its relative weight. You may skip all items which are correct.

0 Not Wearing the item AT THIS TIME
1 Light weight
2 Medium weight
3 Heavy Weight

UNDERLAYER:
0 top (1= bra or camisoile,
2= Tshirt, 3=long underwear)
0 bottom (1= briefs, 3=long
underwear)
0 slip (1= half slip, 2=full slip)

FOOTWEAR:
0 socks
0 pantyhose
0 shoes (1=sandals, 2=shoes or
sneakers, 3=boots)

MIDLAYER:
0 short sleeve shirt
0 long sleeve shirt
0 Dress
0 Skirt
0 Pants or slacks
0 Shorts

OUTERLAYERS:
0 Sweater
0 Vest
0 Jacket

Press ENTER to continue ...

ARE YOU REALLY DONE WITH THE CLOTHING SCREEN (YES/NO) ?

THANK YOU

for your time in responding to this survey.

Please notify a project worker that you are finished.

OK ?

APPENDIX E

Complete Baseline Data Spreadsheet
16, 17 October 1991

THERMAL COMFORT ASSESSMENT

Baseline Survey DATA - Advanced Office Systems Testbed (AOST) Baseline - 16,17 October 1991

Building Science Group - Center for Environmental Design Research - UC Berkeley

SITE VISIT SPECIFICS

PHYSICAL DATA

Bldg. Code	MEA No.	Julian Date	Cart PSHR	Visit Code	Subject	Gender (1M) (2F)	Time	Air TEMP 1.1m degC	Air TEMP 0.6m degC	Air TEMP 0.1m degC	Est. TEMP degC	Globe TEMP 1.1m degC	Globe TEMP 0.6m degC	Globe TEMP 0.1m degC	DEW POINT 0.6m degC	PRT DELTA 1.1m degC	ILLUM illumn. 1.1m lux	VELOC Ave 1.1m m/s	VELOC Ave 0.6m m/s	VELOC Ave 0.1m m/s	VELOC Brst Ave 1.1m m/s
CO	NO	Date	PSHR	VST	SUB	GEN	TIME	TAH	TAM	TAL	Etmp	TGH	TGM	TGL	TD	PRTD	LUX	VELH	VELM	VELL	UBARH
O	1	289	2	1	3	1	944	22.6	22.4	22.1	23.9	22.7	22.3	22.1	11.2	-0.2	1101	0.14	0.12	0.17	0.16
O	2	289	2	1	7	2	959	21.8	21.6	21.3		21.9	21.6	21.3	11.2	0.1	721	0.08	0.08	0.06	0.08
O	3	289	2	1	1	1	1007	22.7	22.4	22.1	21.1	22.9	22.5	22.3	11.3	0.7	924	0.05	0.09	0.07	0.06
O	4	289	2	1	2	1	1018	22.6	22.7	22.4	20.0	22.6	22.7	22.4	10.9	-0.5	776	0.17	0.16	0.08	0.10
O	5	289	2	1	4	2	1027	23.0	22.7	22.4	22.2	23.2	22.8	22.5	11.3	0.6	780	0.06	0.06	0.06	0.11
O	6	289	2	1	6	1	1043	22.1	21.7	21.4	21.1	22.3	21.9	21.5	8.8	0.3	783	0.08	0.08	0.14	0.04
O	7	289	2	1	5	2	1055	20.3	20.5	20.7		20.9	20.8	20.9	8.6	-0.3	631	0.30	0.23	0.15	0.23
O	8	289	2	2	3	1	1125	22.8	22.6	22.5	23.9	23.0	22.6	22.4	11.2	-0.5	1093	0.16	0.14	0.15	0.16
O	9	289	2	2	1	1	1132	23.1	22.9	22.6	22.2	23.3	23.0	22.7	11.3	0.7	983	0.04	0.06	0.05	0.04
O	10	289	2	2	2	1	1140	22.5	22.6	22.5	20.0	22.6	22.7	22.5	10.7	-0.6	807	0.15	0.14	0.05	0.11
O	11	289	2	2	4	2	1155	22.6	22.7	22.4	21.1	22.9	22.9	22.5	10.6	-0.7	903	0.10	0.09	0.16	0.04
O	12	289	4	2	7	2	1354	22.1	21.9	21.5		22.3	21.8	21.5	10.0	-0.1	588	0.05	0.08	0.05	0.06
O	13	289	4	2	5	2	1410	21.3	21.4	21.5		21.7	21.6	21.7	9.0	-0.9	652	0.21	0.15	0.17	0.24
O	14	289	4	2	6	1	1418	22.3	21.9	21.7	23.9	22.6	22.1	21.8	9.2	-0.2	756	0.05	0.04	0.12	0.05
O	15	289	4	3	2	1	1444	22.4	22.8	22.2	20.0	22.4	23.0	22.2	9.8	-1.0	731	0.15	0.20	0.05	0.11
O	16	289	4	3	1	1	1500	23.0	22.8	22.5	23.3	23.2	22.9	22.6	10.4	-0.2	1047	0.06	0.09	0.04	0.04
O	17	289	4	3	4	2	1538	22.6	22.5	22.3	20.0	22.8	22.5	22.3	10.5	-0.6	825	0.06	0.07	0.08	0.02
O	18	289	4	3	3	1	1555	23.5	23.4	23.0	23.9	23.6	23.4	23.1	10.9	-0.5	1104	0.15	0.13	0.11	0.19
O	19	289	4	3	5	2	1618	22.8	22.8	22.8		23.1	22.9	22.8	10.5	-0.9	670	0.18	0.16	0.15	0.26
O	20	289	4	3	6	1	1626	23.2	23.1	22.9	23.9	23.6	23.2	23.0	10.3	-0.2	775	0.06	0.07	0.09	0.05
O	21	289	4	4	1	1	1637	23.4	23.3	23.1	21.1	23.6	23.4	23.1	10.9	-0.3	1042	0.08	0.11	0.05	0.08
O	22	290	5	3	7	2	935	21.6	21.3	21.0		21.8	21.3	21.1	10.9	-0.1	701	0.07	0.10	0.05	0.07
O	23	290	5	4	3	1	944	21.7	21.5	21.3		22.0	21.6	21.4	11.2	0.1	1077	0.16	0.12	0.07	0.14
O	24	290	5	4	2	1	955	23.2	23.1	22.2		23.2	23.3	22.2	11.8	-0.6	806	0.07	0.07	0.04	0.06

O	25	290	5	4	4	2	1012	23.1	22.8	22.5		23.1	22.7	22.4	11.7	0.1	843	0.08	0.10	0.11	0.06
O	26	290	5	4	6	1	1027	23.0	22.7	22.4		23.2	22.7	22.5	10.9	-0.2	748	0.06	0.05	0.04	0.04
O	27	290	5	4	5	2	1042	22.7	22.6	22.4		22.9	22.7	22.4	10.6	0.3	893	0.08	0.09	0.12	0.08
O	28	290	5	4	7	2	1115	22.3	22.0	21.7		22.3	22.1	21.6	11.4	0.2	608	0.06	0.07	0.07	0.06
O	29	290	4	5	7	2	1346	21.9	21.3	21.0		22.0	21.3	21.0	10.9	0.1	584	0.06	0.09	0.06	0.05
O	30	290	4	5	3	1	1354	22.4	22.1	21.8	23.9	22.6	22.2	21.9	10.7	-0.3	1116	0.16	0.15	0.17	0.08
O	31	290	4	5	4	2	1406	21.8	21.8	21.8	21.1	21.9	21.8	21.6	10.2	-0.5	918	0.11	0.12	0.21	0.05
O	32	290	4	5	2	1	1416	21.4	21.6	21.3	21.1	21.4	21.6	21.3	10.2	-1.2	730	0.12	0.15	0.06	0.10
O	33	290	4	5	5	2	1434	22.0	21.9	21.9		21.9	21.9	21.9	10.4	-0.5	677	0.19	0.14	0.11	0.14
O	34	290	4	5	6	1	1441	22.4	22.2	22.1	23.9	22.7	22.3	22.1	10.1	-0.1	804	0.08	0.09	0.13	0.06
O	35	290	4	6	2	1	1608	21.3	21.4	21.2	18.3	21.2	21.3	21.1	10.2	-1.2	725	0.12	0.16	0.08	0.15
O	36	290	4	6	4	2	1618	21.6	21.6	21.3	20.0	21.7	21.6	21.3	10.2	-0.3	825	0.07	0.09	0.09	0.13
O	37	290	4	6	5	2	1630	22.0	22.0	21.9		22.1	22.0	21.9	10.0	-0.4	661	0.21	0.15	0.14	0.18
O	38	290	4	6	6	1	1637	22.8	22.5	22.2	23.9	23.0	22.6	22.4	10.2	-0.1	768	0.06	0.10	0.10	0.06
O	39	290	4	6	3	1	1653	22.0	22.1	22.1	23.3	22.1	22.1	22.0	11.0	-0.4	1116	0.18	0.11	0.13	0.26

PHYSICAL DATA

	Air TEMP 1.1m degC	Air TEMP 0.6m degC	Air TEMP 0.1m degC	Est. TEMP degC	Globe TEMP 1.1m degC	Globe TEMP 0.6m degC	Globe TEMP 0.1m degC	DEW POINT 0.6m degC	PRT DELTA 1.1m degC	ILLUM illumn. 1.1m lux	VELOC Ave 1.1m m/s	VELOC Ave 0.6m m/s	VELOC Ave 0.1m m/s	VELOC Brst Ave 1.1m m/s
Average	22.34	22.24	22.00	21.96	22.51	22.30	22.03	10.54	-0.26	827.98	0.11	0.11	0.10	0.10
Std. Dev.	0.68	0.65	0.60	1.76	0.67	0.65	0.60	0.75	0.47	161.32	0.06	0.04	0.04	0.07
Maximum	23.46	23.36	23.10	23.90	23.63	23.40	23.14	11.82	0.74	1116.00	0.30	0.23	0.21	0.26
Minimum	20.31	20.52	20.71	18.30	20.86	20.81	20.86	8.58	-1.23	583.80	0.04	0.04	0.04	0.02

						COMFORT QUESTIONS					AFFECT QUESTIONS								
VELOC Brst Ave 0.6m m/s UBARM	VELOC Brst Ave 0.1m m/s UBARL	VELOC Brst TI 1.1m TIH	VELOC Brst TI 0.6m TIM	VELOC Brst TI 0.1m TIL	MAIN BATTERY VDC BAT	ASH Scale (-3,3) cold hot ASH	McINT Scale (-1,1) cooler warmer MC	GEN COMF (1,6) uncomf. comf. COMF	VENT COMF (1,6) stuffy drafty VENT	LIGHT COMF (1,6) dim bright LIGHT	Frustrated	Comfortable	Happy	Fatigued	Uncomfortable	Relaxed	Sad	Energetic	Burdenec
0.10	0.17	0.08	0.49	0.31	11.9	1	1	3	4	4	4	4	3	2	2	4	1	3	5
0.09	0.07	0.26	0.60	1.69	11.9	-0.4	0	6	4	5	1	1	1	1	1	1	1	1	1
0.11	0.08	0.65	0.61	1.53	11.9	-0.5	0	5	4	4	2	5	5	2	2	4	1	5	2
0.14	0.10	0.27	0.37	0.42	11.9	0	0	6	4	4	1	5	5	2	2	4	1	4	1
0.13	0.12	0.22	0.34	0.58	11.9	2	1	5	4	4	1	5	1	6	2	3	6	2	5
0.05	0.09	0.69	1.33	0.53	11.8	-1	0	5	4	3	2	5	4	1	1	4	1	4	2
0.21	0.14	0.34	0.32	0.33	11.8	0	0	6	4	5	1	6	6	1	1	6	1	6	1
0.15	0.12	0.36	0.54	0.47	11.7	0	0	4	4	4	1	5	4	2	2	4	1	3	5
0.04	0.05	1.49	2.38	3.03	11.7	0.5	1	4	3	4	2	4	4	2	3	4	1	4	3
0.11	0.05	0.54	0.53	1.77	11.8	0	0	6	4	4	1	5	5	2	1	4	1	4	2
0.11	0.16	2.77	0.30	0.18	11.8	0	0	6	4	6	1	5	2	5	1	3	5	4	2
0.06	0.04	0.16	0.31	0.59	11.6	-0.5	0	5	4	5	1	1	1	1	1	1	1	1	1
0.21	0.15	0.47	0.13	0.33	11.6	0	0	6	4	5	1	6	6	1	1	6	1	6	1
0.08	0.13	1.01	1.02	0.23	11.6	0	0	5	4	3	2	5	4	2	2	5	2	4	2
0.22	0.05	0.23	0.21	1.00	11.5	0	0	6	4	4	1	5	5	1	1	4	1	4	1
0.05	0.04	0.50	0.18	0.30	11.6	1	1	3	3	4	3	4	4	2	2	4	1	4	2
0.06	0.11	0.86	0.28	0.23	11.5	-1	-1	4	4	4	2	4	3	2	4	5	5	5	2
0.10	0.09	0.40	0.19	0.31	11.4	-1	0	5	4	4	2	5	4	4	2	2	1	3	4
0.24	0.13	0.86	0.49	0.22	11.5	0	0	6	3	5	1	6	6	1	1	6	1	5	1
0.05	0.04	1.12	0.50	0.91	11.4	0	0	5	5	3	2	1	4	3	2	5	2	4	2
0.08	0.05	0.28	0.26	2.91	11.4	0	0	6	3	4	2	5	5	2	2	5	1	4	2
0.12	0.04	0.21	0.10	0.48	12.3														
0.13	0.13	0.12	0.28	0.41	12.3														
0.12	0.04	0.26	0.32	0.17	12.2														

0.13	0.14	1.39	0.20	0.22	12.3														
0.06	0.05	0.33	0.40	0.15	12.3														
0.11	0.07	0.95	0.60	0.71	12.3														
0.07	0.06	0.47	0.85	2.36	12.1														
0.15	0.04	0.25	0.15	0.32	12.1	-0.5	0	5	4	5	1	5	5	1	1	1	1	5	1
0.15	0.15	0.36	0.29	0.44	12.0	0	0	5	4	4	1	5	4	1	1	4	1	4	4
0.14	0.07	0.93	0.26	1.01	12.0	-2	-1	4	4	5	3	4	4	2	2	6	3	5	2
0.14	0.07	0.33	0.20	0.34	10.1	0	0	6	4	4	2	5	5	1	2	5	1	5	1
0.08	0.08	0.43	0.42	1.29	12.4	0	0	6	3	5	1	6	6	1	1	6	1	6	1
0.09	0.06	0.37	0.37	0.20	12.4	0	0	5	4	3	2	5	4	2	2	5	2	4	1
0.18	0.06	0.51	0.26	0.46	12.3	0	0	6	4	4	2	5	5	1	1	5	1	5	2
0.07	0.10	0.14	0.37	0.20	12.4	0	0	6	3	6	4	4	3	2	3	5	4	5	4
0.11	0.12	0.17	0.27	0.17	12.4	0	0	6	3	5	1	6	6	1	1	6	1	5	1
0.05	0.07	0.41	0.24	0.86	12.3	0	0	5	4	3	2	5	4	2	2	5	2	4	2
0.19	0.10	0.44	0.19	0.51	12.3	1	0	4	4	4	1	4	4	3	1	4	1	3	4

						COMFORT QUESTIONS					**AFFECT QUESTIONS**								
VELOC Brst Ave 0.6m m/s	VELOC Brst Ave 0.1m m/s	VELOC Brst TI 1.1m	VELOC Brst TI 0.6m	VELOC Brst TI 0.1m	MAIN BATTERY VDC	ASH Scale (-3,3) cold hot	McINT Scale (-1,1) cooler warmer	GEN COMF (1,6) uncomf. comf.	VENT COMF (1,6) stuffy drafty	LIGHT COMF (1,6) dim bright	Frustrated	Comfortable	Happy	Fatigued	Uncomfortable	Relaxed	Sad	Energetic	Burdene
0.11	0.09	0.55	0.44	0.72	11.89	-0.04	0.06	5.16	3.81	4.25	1.69	4.56	4.13	1.94	1.66	4.25	1.69	4.09	2.19
0.05	0.04	0.50	0.40	0.73	0.44	0.70	0.44	0.92	0.47	0.80	0.86	1.32	1.41	1.19	0.75	1.44	1.38	1.23	1.33
0.24	0.17	2.77	2.38	3.03	12.44	2.00	1.00	6.00	5.00	6.00	4.00	6.00	6.00	6.00	4.00	6.00	6.00	6.00	5.00
0.04	0.04	0.08	0.10	0.15	10.08	-2.00	-1.00	3.00	3.00	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

	COPING MECHANISMS													**ACTIVITY FLAGS**					
d Restless	Opened/Closed window	Opened/Closed door to outside	Opened/Closed door to inside	Adjusted thermostat	Adjusted Drapes/Blinds	Space heater on/off	Local fan on/off	Adjust clothes	Hot or cold drink	Took a break	Talked to others	Talked to staff	Ignored	MET(estimated) MET	Eat food FOOD	Hot drink DHOT	Cold Drink DCLD	Caffeine DCAF	Smoke CIG
2	9	9	9	9	9	9	9	0	0	2	0	0	2	1.2	0	1	0	1	0
1	9	9	9	9	9	9	9	0	0	0	0	0	0	1	0	1	0	1	0
3	9	9	9	9	9	9	9	0	0	3	0	0	1	1	0	0	0	0	0
2	9	9	9	9	9	9	9	0	0	0	0	0	1	1.2	1	1	0	1	0
2	9	9	9	9	0	9	9	0	0	2	0	0	2	1.2	0	0	0	0	0
1	0	0	0	0	9	9	9	0	1	0	0	0	1	1	1	1	0	1	0
1	9	9	0	9	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
5	9	9	9	9	9	9	9	0	0	2	0	0	2	1.4	0	0	0	1	0
2	9	9	9	9	9	9	9	0	2	1	0	0	1	1	0	0	0	0	0
2	9	9	9	9	9	9	9	0	0	0	0	0	0	1	0	0	0	0	0
4	9	9	9	9	0	9	9	0	3	3	0	0	0	1.2	1	1	0	1	0
1	9	9	9	9	9	9	9	0	0	0	0	0	1	1.2	0	0	0	0	0
1	9	9	0	9	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
1	0	0	0	0	9	9	9	0	0	0	0	0	0	1	0	0	0	0	0
2	9	9	9	9	9	9	9	0	0	0	0	0	0	1	0	0	0	0	0
3	9	9	9	9	9	9	9	2	1	2	0	0	2	1	0	0	0	0	0
2	9	9	9	9	0	9	9	0	0	2	0	0	2	1.2	1	0	0	0	0
4	9	9	9	9	9	9	9	0	0	2	0	0	0	1	1	0	0	1	0
1	9	9	0	9	0	0	0	0	1	1	0	0	0	1.2	0	0	1	0	0
1	0	0	0	0	9	9	9	0	0	0	0	0	0	1	0	0	0	0	0
2	9	9	9	9	9	9	9	2	0	0	0	0	1	1	0	0	0	0	0

d

	COPING MECHANISMS													ACTIVITY FLAGS					
Restless	Opened/Closed window	Opened/Closed door to outside	Opened/Closed door to inside	Adjusted thermostat	Adjusted Drapes/Blinds	Space heater on/off	Local fan on/off	Adjust clothes	Hot or cold drink	Took a break	Talked to others	Talked to staff	Ignored	MET(estimated)	Eat food	Hot drink	Cold Drink	Caffeine	Smoke
1	9	9	9	9	9	9	9	0	0	0	0	0	1	1.2	0	0	0	0	0
4	9	9	9	9	9	9	9	0	0	0	0	0	0	1	1	0	0	0	0
5	9	9	9	9	0	9	9	4	0	3	0	0	3	1.2	1	0	0	0	0
2	9	9	9	9	9	9	9	0	0	0	0	0	0	1.2	0	1	0	1	0
1	9	9	0	9	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
1	0	0	0	0	9	9	9	0	0	0	0	0	0	1	0	0	0	0	0
1	9	9	9	9	9	9	9	0	0	0	0	0	0	1.2	0	0	0	0	0
3	9	9	9	9	0	9	9	0	1	2	0	0	1	1.2	0	0	0	0	0
1	9	9	0	9	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
1	0	0	0	0	9	9	9	0	0	0	0	0	0	1	0	0	0	0	0
4	9	9	9	9	9	9	9	0	0	0	0	0	2	1.2	0	0	0	1	0
2.09	7.59	7.59	6.19	7.59	6.19	7.59	7.59	0.25	0.28	0.78	0.00	0.00	0.72	1.09	0.22	0.19	0.03	0.28	0.00
1.28	3.32	3.32	4.24	3.32	4.24	3.32	3.32	0.84	0.68	1.10	0.00	0.00	0.89	0.11	0.42	0.40	0.18	0.46	0.00
5.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	4.00	3.00	3.00	0.00	0.00	3.00	1.40	1.00	1.00	1.00	1.00	0.00
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
NO	5	5	10	5	10	5	5	29	26	20	32	32	17						
1	0	0	0	0	0	0	0	0	4	2	0	0	8						
2	0	0	0	0	0	0	0	2	1	7	0	0	6						
3	0	0	0	0	0	0	0	0	1	3	0	0	1						
4	0	0	0	0	0	0	0	1	0	0	0	0	0						
N/A	27	27	22	27	22	27	27	0	0	0	0	0	0						

CLOTHING

QUESTIONS(header for women's clothing only)

SURVEY
COMPLETION TIMES(seconds)

Underlayer			Footware			Midlayer						Outerlayers							
top	bottom	slip	socks	pantyhose	shoes	ss shirt	ls shirt	dress	skirt	pants	shorts	sweater	vest	jacket		Comfort	Affect	Activity	Clothing
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	CLO				
CL1	CL2	CL3	CL4	CL5	CL6	CL7	CL8	CL9	CL10	CL11	CL12	CL13	CL14	CL15					
0	1	0	2	2	0	0	0	0	1	2	0	0	0	0	0.55	32	73	22	97
1	1	1	0	1	1	0	0	2	0	0	0	0	0	0	0.55	76	85	50	136
0	1	0	1	1	0	0	0	0	1	2	0	0	0	0	0.5	31	67	35	81
0	1	0	2	2	0	0	0	0	2	2	0	0	0	0	0.57	19	36	25	98
1	1	2	1	1	2	0	0	3	0	0	0	0	0	0	0.84	53	88	24	91
2	1	0	1	2	0	0	0	0	0	2	0	0	0	0	0.57	67	124	30	168
0	1	0	1	0	2	1	0	0	0	2	0	1	0	0	0.57	75	62	15	166
0	1	0	2	2	0	0	0	0	1	2	0	0	0	0	0.55	19	45	76	14
0	1	0	1	1	0	0	0	0	1	2	0	0	0	0	0.5	22	39	22	35
0	1	0	2	2	0	0	0	0	2	2	0	0	0	0	0.57	12	39	11	6
1	1	2	3	1	2	0	0	3	0	0	0	0	0	0	0.92	27	65	20	56
1	1	1	0	1	1	0	0	2	0	0	0	0	0	0	0.55	34	22	22	17
0	1	0	1	0	2	1	0	0	0	2	0	1	0	0	0.57	26	36	15	27
2	1	0	1	2	0	0	0	0	0	2	0	0	0	0	0.57	28	51	27	69
0	1	0	2	2	0	0	0	0	2	2	0	0	0	0	0.57	13	31	10	21
0	1	0	1	1	0	0	0	0	1	2	0	0	0	0	0.5	37	110	20	20
1	1	2	3	1	2	0	0	3	0	0	0	0	0	0	0.92	25	95	54	57
0	1	0	2	2	0	0	0	0	1	2	0	0	0	0	0.55	64	66	23	156
0	1	0	1	0	2	1	0	0	0	2	0	1	0	0	0.57	27	34	21	9
2	1	0	1	2	0	0	0	0	0	2	0	0	0	0	0.57	15	38	17	82
0	1	0	1	1	0	0	0	0	1	2	0	0	0	0	0.5	53	27	10	15

1	1	1	0	1	1	1	0	0	2	0	0	0	0	0	0.42	20	43	15	39
0	1	1	0	1	0	0	0	0	1	1	0	0	0	0	0.42	23	30	16	12
1	1	0	3	0	2	1	0	0	0	1	0	0	0	0	0.51	18	48	17	39
0	1	1	0	2	0	0	0	0	2	2	0	0	0	0	0.48	8	20	13	31
1	1	0	1	0	2	1	0	0	0	0	0	1	0	0	0.36	26	18	11	47
2	1	0	2	2	0	0	0	0	0	2	0	0	0	0	0.59	17	32	17	42
0	1	1	0	2	0	0	0	0	2	2	0	0	0	0	0.48	9	24	15	4
1	1	0	3	0	2	1	0	0	0	1	0	0	0	0	0.51	36	127	23	19
1	1	0	1	0	2	1	0	0	0	0	0	1	0	0	0.36	24	46	11	8
2	1	0	2	2	0	0	0	0	0	2	0	0	0	0	0.59	15	26	14	18
0	1	1	0	1	0	0	0	0	1	1	0	0	0	0	0.42	15	23	14	53

CLOTHING

QUESTIONS(header for women's clothing only)

SURVEY

COMPLETION TIMES(seconds)

Underlayer			Footware			Midlayer						Outerlayers							
top	bottom	slip	socks	pantyhose	shoes	ss shirt	ls shirt	dress	skirt	pants	shorts	sweater	vest	jacket		Comfort	Affect	Activity	Clothing
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	CLO				
0.63	1.00	0.41	1.28	1.19	0.72	0.25	0.00	0.41	0.66	1.38	0.00	0.16	0.00	0.00	0.55	30	52	22	54
0.75	0.00	0.67	0.96	0.78	0.92	0.44	0.00	0.98	0.79	0.87	0.00	0.37	0.00	0.00	0.13	19	30	14	48
2.00	1.00	2.00	3.00	2.00	2.00	1.00	0.00	3.00	2.00	2.00	0.00	1.00	0.00	0.00	0.92	76	127	76	168
0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	8	18	10	4

COMFORT MODEL

INPUT AND OUTPUT VARIABLES

TOTAL	TAAV	TRAV	PAAV	VELAV	TCR	TSK	PWET	ET*	SET*	DISC	TSENS	PMV	PMV*	HSI
224	22.37	22.36	9.96	0.14	36.83	33.29	6.00	22.35	22.11	-0.04	-0.04	-0.27	-0.28	8.46
347	21.57	21.63	9.96	0.10	36.81	32.21	6.00	21.61	20.86	0.00	-0.21	-0.29	-0.29	2.97
214	22.40	22.73	10.03	0.10	36.82	32.50	6.00	22.57	21.48	0.00	-0.16	-0.21	-0.22	4.74
178	22.57	22.56	9.77	0.11	36.83	33.50	6.25	22.54	22.46	-0.02	-0.02	-0.24	-0.25	8.88
256	22.70	22.98	10.03	0.12	36.84	33.95	13.60	22.80	24.90	0.32	0.24	0.27	0.36	19.48
389	21.73	22.07	8.48	0.10	36.80	30.67	6.00	21.84	17.58	0.00	-0.59	-0.80	-0.92	-3.60
318	20.50	21.41	8.37	0.19	36.81	31.65	6.00	20.93	19.69	0.00	-0.33	-0.48	-0.53	0.50
154	22.63	22.71	9.96	0.14	36.85	33.57	10.15	22.63	22.88	-0.01	-0.01	-0.12	-0.15	14.70
118	22.87	23.13	10.03	0.10	36.82	32.73	6.00	22.99	21.92	0.00	-0.13	-0.15	-0.17	5.77
68	22.53	22.67	9.64	0.10	36.82	32.78	6.00	22.57	22.01	0.00	-0.12	-0.15	-0.15	5.86
168	22.57	22.96	9.57	0.10	36.84	34.03	15.11	22.67	25.38	0.43	0.33	0.36	0.48	21.33
95	21.83	21.90	9.20	0.10	36.83	32.93	6.00	21.83	21.58	-0.07	-0.07	-0.31	-0.33	7.47
104	21.40	22.07	8.60	0.20	36.81	31.96	6.00	21.68	20.39	0.00	-0.26	-0.37	-0.43	2.62
175	21.97	22.36	8.71	0.10	36.81	30.80	6.00	22.11	17.91	0.00	-0.55	-0.74	-0.86	-2.69
75	22.47	22.61	9.07	0.13	36.82	32.73	6.00	22.48	21.92	0.00	-0.13	-0.16	-0.17	5.78
187	22.77	23.03	9.45	0.10	36.82	32.65	6.00	22.86	21.78	0.00	-0.14	-0.17	-0.20	5.48
231	22.47	22.60	9.51	0.10	36.84	33.99	14.46	22.44	25.17	0.38	0.29	0.32	0.43	20.42
309	23.30	23.44	9.77	0.13	36.82	33.13	6.00	23.33	22.63	0.00	-0.07	-0.07	-0.08	7.37
91	22.80	23.14	9.51	0.21	36.83	33.58	7.25	22.91	22.84	-0.01	-0.01	-0.15	-0.18	10.84
152	23.07	23.46	9.38	0.10	36.82	33.15	6.00	23.23	22.68	0.00	-0.07	-0.07	-0.08	7.26
105	23.27	23.46	9.77	0.10	36.82	32.91	6.00	23.32	22.26	0.00	-0.10	-0.11	-0.14	6.53
	21.30	21.50	9.77	0.10	36.83	31.95	6.00	21.41	19.99	-0.19	-0.19	-0.45	-0.49	4.89
	21.50	21.86	9.96	0.13	36.82	31.95	6.00	21.71	20.13	-0.22	-0.22	-0.40	-0.43	3.76
	22.83	22.97	10.37	0.10	36.83	33.25	6.00	22.90	22.06	-0.04	-0.04	-0.27	-0.30	8.19

	22.80	22.66	10.30	0.11	36.83	33.31	6.00	22.72	22.14	-0.04	-0.04	-0.27	-0.29	8.35
	22.70	22.90	9.77	0.10	36.82	32.98	6.00	22.78	22.37	0.00	-0.09	-0.10	-0.10	6.62
	22.57	22.76	9.57	0.10	36.81	31.94	6.00	22.63	20.42	0.00	-0.26	-0.35	-0.40	2.63
	22.00	22.00	10.10	0.10	36.83	32.31	6.00	22.00	20.61	-0.14	-0.14	-0.39	-0.43	6.07
117	21.40	21.47	9.77	0.10	36.83	31.96	6.00	21.44	20.02	-0.19	-0.19	-0.44	-0.49	4.96
81	22.10	22.39	9.64	0.13	36.81	31.99	6.00	22.24	20.49	0.00	-0.25	-0.34	-0.38	2.56
122	21.80	21.73	9.32	0.10	36.83	32.64	6.00	21.73	21.14	-0.10	-0.10	-0.34	-0.37	6.82
72	21.43	21.44	9.32	0.10	36.83	32.28	6.00	21.41	20.54	-0.15	-0.15	-0.40	-0.43	5.82
102	21.93	21.87	9.45	0.10	36.81	31.56	6.00	21.86	19.57	0.00	-0.34	-0.48	-0.52	0.30
108	22.23	22.50	9.26	0.10	36.82	32.73	6.00	22.33	21.91	0.00	-0.13	-0.16	-0.16	5.60
52	21.30	21.08	9.32	0.13	36.83	32.13	6.00	21.17	20.29	-0.17	-0.17	-0.42	-0.45	5.46
205	21.50	21.57	9.32	0.10	36.83	32.50	6.00	21.51	20.91	-0.12	-0.12	-0.36	-0.39	6.43
89	21.97	22.04	9.20	0.14	36.81	31.59	6.00	21.96	19.64	0.00	-0.34	-0.47	-0.53	0.62
73	22.50	22.83	9.32	0.10	36.82	32.90	6.00	22.63	22.22	0.00	-0.11	-0.12	-0.13	6.29
105	22.07	22.06	9.83	0.18	36.83	32.34	6.00	22.05	20.65	-0.14	-0.14	-0.38	-0.43	6.46

COMFORT MODEL
INPUT AND OUTPUT VARIABLES

TOTAL	TAAV	TRAV	PAAV	VELAV	TCR	TSK	PWET	ET*	SET*	DISC	TSENS	PMV	PMV*	HSI
159	22.20	22.38	9.55	0.12	36.82	32.59	6.79	22.26	21.42	-0.01	-0.13	-0.26	-0.28	6.46
88	0.63	0.63	0.47	0.03	0.01	0.80	2.33	0.62	1.66	0.13	0.18	0.24	0.28	5.28
389	23.30	23.46	10.37	0.21	36.85	34.03	15.11	23.33	25.38	0.43	0.33	0.36	0.48	21.33
52	20.50	21.08	8.37	0.10	36.80	30.67	6.00	20.93	17.58	-0.22	-0.59	-0.80	-0.92	-3.60

APPENDIX F

Complete Test 1 Data Spreadsheet
30 April - 1 May 1992

THERMAL COMFORT ASSESSMENT

Survey DATA - Advanced Office Systems Testbed (AOST) Test #1 - 30 April, 1 May 1992

Building Science Group - Center for Environmental Design Research - UC Berkeley

SITE VISIT SPECIFICS | **PHYSICAL DATA**

Bldg. Code	MEA No.	Julian Date	Cart PSHR	Visit Code	Subject	Gender (1M) (2F)	Time	Air TEMP 1.1m degC	Air TEMP 0.6m degC	Air TEMP 0.1m degC	Est. TEMP degC	Globe TEMP 1.1m degC	Globe TEMP 0.6m degC	Globe TEMP 0.1m degC	DEW POINT 0.6m degC	PRT DELTA 1.1m degC	ILLUM illumn. 1.1m lux	VELOC Ave 1.1m m/s	VELOC Ave 0.6m m/s	VELOC Ave 0.1m m/s	VELOC Brst Ave 1.1m m/s
CO	NO	Date	PSHR	VST	SUB	GEN	TIME	TAH	TAM	TAL	Etmp	TGH	TGM	TGL	TD	PRTD	LUX	VELH	VELM	VELL	UBARH
O	1	121	4	1	6	1	852	22.8	22.6	22.4	20.0	23.0	22.6	22.5	10.4	-0.2	1293	0.08	0.09	0.10	0.07
O	2	121	4	1	3	1	901	22.8	22.7	22.5	22.2	22.9	22.6	22.5	10.5	0.0	516	0.10	0.07	0.09	0.05
O	3	121	4	1	4	2	912	22.8	22.6	22.5	25.6	23.0	22.7	22.6	10.5	0.2	1248	0.13	0.10	0.07	0.08
O	4	121	4	1	8	1	919	22.5	22.5	22.3	20.6	22.7	22.6	22.3	10.6	-0.7	400	0.12	0.09	0.08	0.13
O	5	121	4	1	1	1	934	22.7	22.3	22.4	21.1	22.8	22.5	22.4	10.6	-0.3	644	0.16	0.08	0.07	0.07
O	6	121	4	1	7	2	1003	23.4	23.2	22.8		23.5	23.2	22.9	10.6	-0.1	1275	0.07	0.06	0.05	0.10
O	7	121	4	1	9	2	1013	23.1	23.0	22.9	15.6	23.2	23.0	22.9	10.5	-0.2	1271	0.14	0.06	0.07	0.14
O	8	121	4	2	3	1	1117	23.1	23.1	23.0	23.9	23.5	23.2	23.0	10.1	-0.7	530	0.12	0.30	0.10	0.17
O	9	121	4	2	4	2	1131	23.1	23.0	22.8	21.7	23.3	23.0	22.9	10.2	-0.2	1275	0.13	0.12	0.10	0.13
O	10	121	4	2	7	2	1149	23.3	23.2	23.0		23.6	23.4	23.1	10.3	-0.3	1271	0.09	0.12	0.06	0.11
O	11	121	4	2	6	1	1156	23.4	23.2	22.9	20.0	23.6	23.4	23.0	10.3	-0.3	1269	0.09	0.11	0.09	0.07
O	12	121	4	2	8	1	1204	22.9	22.9	22.7	20.0	23.1	23.0	22.7	10.4	-0.8	392	0.10	0.13	0.07	0.20
O	13	121	4	2	9	2	1345	23.3	23.3	23.0	21.1	23.5	23.4	23.1	10.2	-0.4	1293	0.10	0.07	0.05	0.10
O	14	121	4	1	2	1	1352	22.9	23.6	23.0	20.0	23.2	23.6	22.9	10.3	-0.5	506	0.28	0.08	0.07	0.32
O	15	121	4	3	8	1	1404	22.6	22.7	22.5	22.2	22.8	22.8	22.4	10.3	-0.3	393	0.11	0.07	0.08	0.12
O	16	121	4	2	1	1	1412	23.1	22.7	22.6	22.2	23.2	22.6	22.6	10.3	-0.4	680	0.25	0.32	0.11	0.23
O	17	121	4	3	4	2	1419	23.2	23.0	22.8	24.4	23.3	23.1	22.8	10.2	-0.5	1242	0.14	0.08	0.06	0.13
O	18	121	4	3	6	1	1426	23.3	23.1	22.9	21.1	23.5	23.3	23.0	10.3	-0.6	1279	0.08	0.11	0.09	0.08
O	19	121	4	2	2	1	1454	23.1	23.5	22.9	20.0	23.2	23.5	22.9	10.1	-0.7	475	0.32	0.08	0.10	0.28
O	20	121	4	3	9	2	1503	23.4	23.4	23.0	18.3	23.5	23.4	23.1	10.1	-0.5	1316	0.11	0.08	0.06	0.05
O	21	121	4	3	7	2	1522	23.4	23.4	23.0		23.7	23.5	23.1	10.2	-0.5	1250	0.06	0.12	0.05	0.08
O	22	121	4	3	3	1	1534	23.4	23.3	23.1	23.3	23.6	23.2	23.2	10.2	-0.6	585	0.11	0.16	0.08	0.20
O	23	121	4	3	1	1	1548	23.2	22.9	22.8	21.1	23.2	22.8	22.7	10.1	-0.5	680	0.29	0.19	0.06	0.23
O	24	122	3	4	6	1	955	23.1	22.7	22.2	25.6	23.2	22.8	22.3	9.9	0.3	1312	0.08	0.06	0.05	0.06

O	25	122	3	3	2	1	1002	22.9	23.1	22.4	18.3	22.9	23.2	22.4	9.9	-0.6	463	0.28	0.11	0.09	0.31
O	26	122	3	4	1	1	1009	23.1	22.8	22.3	22.2	23.1	22.7	22.4	10.1	-0.4	681	0.08	0.08	0.06	0.07
O	27	122	3	4	3	1	1017	23.2	23.2	22.5	23.9	23.3	23.1	22.6	10.0	-0.4	577	0.10	0.15	0.07	0.13
O	28	122	3	4	8	1	1025	22.6	22.6	22.4	20.6	22.7	22.7	22.4	10.1	-0.6	455	0.15	0.11	0.07	0.16
O	29	122	3	4	4	2	1033	22.7	22.6	22.5	23.3	22.9	22.8	22.5	10.0	0.0	1209	0.12	0.09	0.05	0.15
O	30	122	3	4	7	2	1040	23.1	22.9	22.7		23.2	23.0	22.7	10.0	-0.2	1187	0.07	0.07	0.05	0.10
O	31	122	3	4	9	2	1047	23.0	22.8	22.7	10.0	23.1	22.9	22.8	10.1	0.0	1257	0.11	0.11	0.06	0.14
O	32	122	3	4	2	1	1101	23.1	23.4	22.9	19.4	23.3	23.4	22.9	10.2	-0.8	516	0.27	0.07	0.06	0.30
O	33	122	3	5	1	1	1108	23.0	22.6	22.5	21.1	23.0	22.6	22.5	10.1	-0.4	679	0.12	0.16	0.07	0.12
O	34	122	3	5	3	1	1119	23.4	23.5	22.9		23.6	23.4	22.9	10.1	-0.4	583	0.09	0.13	0.06	0.11
O	35	122	3	5	8	1	1128	23.0	23.0	22.8	21.1	23.2	23.1	22.7	10.1	-0.5	398	0.19	0.10	0.07	0.16
O	36	122	3	5	7	2	1136	23.3	23.2	22.9		23.5	23.4	22.9	9.9	-0.3	1247	0.08	0.06	0.06	0.08
O	37	122	3	5	9	2	1147	23.3	23.1	22.9	20.0	23.4	23.2	23.0	9.8	-0.1	1278	0.09	0.10	0.05	0.11
O	38	122	3	5	4	2	1154	23.2	23.1	22.9	25.6	23.4	23.2	23.0	9.8	0.0	1224	0.09	0.08	0.07	0.11
O	39	122	3	5	2	1	1440	23.6	23.8	23.3	20.0	23.4	23.9	23.2	9.9	-0.8	415	0.38	0.08	0.09	0.24

PHYSICAL
DATA

	Air TEMP 1.1m degC	Air TEMP 0.6m degC	Air TEMP 0.1m degC	Est. TEMP degC	Globe TEMP 1.1m degC	Globe TEMP 0.6m degC	Globe TEMP 0.1m degC	DEW POINT 0.6m degC	PRT DELTA 1.1m degC	ILLUM illumn. 1.1m lux	VELOC Ave 1.1m m/s	VELOC Ave 0.6m m/s	VELOC Ave 0.1m m/s	VELOC Brst Ave 1.1m m/s
Average	23.08	23.01	22.73	21.08	23.23	23.06	22.75	10.18	-0.36	886.21	0.14	0.11	0.07	0.14
Std. Dev.	0.25	0.34	0.27	2.97	0.27	0.34	0.27	0.21	0.27	380.05	0.08	0.06	0.02	0.07
Maximum	23.55	23.82	23.26	25.60	23.69	23.90	23.24	10.60	0.31	1316.00	0.38	0.32	0.11	0.32
Minimum	22.54	22.34	22.15	10.00	22.70	22.51	22.25	9.77	-0.83	392.00	0.06	0.06	0.05	0.05

						COMFORT QUESTIONS					AFFECT QUESTIONS								
						ASH Scale (-3,3)	McINT Scale (-1,1)	GEN COMF (1,6)	VENT COMF (1,6)	LIGHT COMF (1,6)	Frustrated	Comfortable	Happy	Fatigued	Uncomfortable	Relaxed	Sad	Energetic	Burdenec
VELOC Brst Ave 0.6m m/s	VELOC Brst Ave 0.1m m/s	VELOC Brst TI 1.1m	VELOC Brst TI 0.6m	VELOC Brst TI 0.1m	MAIN BATTERY VDC	cold hot	cooler warmer	uncomf. comf.	stuffy drafty	dim bright									
UBARM	UBARL	TIH	TIM	TIL	BAT	ASH	MC	COMF	VENT	LIGHT									
0.12	0.12	0.29	0.14	0.12	12.3	0	0	5	4	4	2	5	4	1	2	5	2	4	2
0.05	0.06	1.62	1.96	1.58	12.2	-1	0	5	4	4	2	6	4	2	2	4	1	3	4
0.09	0.05	0.22	0.26	1.40	12.2	1	1	3	3	3	4	4	2	5	4	3	5	3	4
0.08	0.07	0.50	0.45	0.19	12.1	-0.3	0	6	4	2	4	3	3	3	3	3	1	5	5
0.12	0.09	0.69	0.41	0.50	12.1	0.5	0	5	4	4	4	5	3	4	2	5	1	4	4
0.09	0.06	0.23	0.17	1.02	12.2	0	0	5	3	5	5	5	5	1	1	5	1	6	3
0.04	0.06	0.40	0.93	0.66	12.1	-0.1	-1	4	2	5	2	4	5	5	5	5	1	5	1
0.29	0.06	0.24	0.67	0.37	12.0	1	0	4	4	4	4	4	4	4	2	3	2	2	2
0.10	0.11	0.11	0.14	0.31	12.1	-0.8	0	5	4	4	3	5	4	2	2	5	4	5	4
0.09	0.07	0.14	0.24	0.91	12.0	0	0	6	4	5	1	6	4	1	1	6	1	5	1
0.15	0.11	0.76	0.29	0.13	11.9	3	0	5	4	4	2	5	4	2	2	5	1	4	2
0.11	0.07	0.26	0.16	1.49	11.9	-0.4	0	6	4	3	3	5	5	2	1	5	1	5	4
0.05	0.05	0.33	1.27	1.43	11.8	2.5	1	2	2	6	1	4	5	5	3	4	1	4	2
0.05	0.08	0.96	1.54	0.63	11.8	0	0	6	4	5	1	6	5	2	1	5	1	4	2
0.08	0.06	0.16	0.38	0.16	11.8	0.1	0	6	3	2	1	5	6	2	1	4	1	6	5
0.24	0.07	0.58	0.24	0.32	11.8	1	1	3	5	4	4	4	3	4	3	4	2	5	4
0.10	0.04	0.13	0.32	1.84	11.8	0.3	1	5	3	5	3	5	3	4	3	4	4	4	5
0.06	0.14	0.33	1.12	0.11	11.7	3	0	5	4	4	1	5	4	2	1	4	1	4	2
0.10	0.08	0.75	0.23	1.22	11.7	0	0	6	4	5	1	6	5	2	2	5	1	5	2
0.07	0.05	0.63	0.64	0.83	11.7	0	0	6	2	4	1	6	6	5	5	5	1	6	1
0.10	0.04	0.22	0.20	0.81	11.7	0	0	5	4	5	1	5	5	1	2	3	1	5	1
0.14	0.06	0.19	0.31	0.26	11.6	-1	0	5	4	4	2	5	5	2	2	4	2	4	4
0.20	0.06	0.82	0.83	0.41	11.6	0	0	6	4	5	3	5	4	3	3	4	1	4	3
0.07	0.03	0.37	0.16	0.18	12.4	3	0	5	4	4	2	5	3	2	1	5	1	4	2

0.08	0.03	0.99	1.48	0.98	12.4	0	0	6	4	5	1	5	4	1	1	4	1	4	1
0.03	0.07	0.44	1.03	0.16	12.4	0.7	1	4	4	4	4	4	4	3	3	4	1	3	3
0.15	0.07	0.14	0.19	0.67	12.3	0	0	4	4	4	1	5	5	2	1	2	1	3	3
0.05	0.05	0.16	0.37	0.15	12.3	-0.3	0	6	4	2	1	5	6	1	1	2	1	6	5
0.05	0.06	0.16	0.80	1.87	12.4	-0.5	0	4	4	3	4	4	4	3	2	5	3	4	4
0.06	0.06	0.16	0.08	0.11	12.3	0	0	5	3	5	2	5	2	2	2	3	2	5	2
0.09	0.05	0.21	0.55	0.72	12.4	-2.7	-1	1	3	6	6	1	2	4	5	3	4	4	4
0.10	0.04	0.79	0.43	0.78	12.4	0	0	6	4	5	2	5	5	1	1	5	1	5	2
0.18	0.07	0.30	0.57	0.19	12.3	0	0	6	3	4	3	5	4	2	2	4	1	4	2
0.17	0.11	0.22	0.12	0.20	12.3	0	0	5	4	4	1	5	4	2	4	4	1	3	3
0.08	0.04	0.27	0.20	0.29	12.3	0	0	6	4	3	2	6	6	1	1	2	1	6	5
0.07	0.06	0.23	0.36	0.13	12.3	0	0	6	4	5	1	6	5	1	1	5	1	5	1
0.08	0.07	0.16	1.16	0.73	12.2	0	0	5	3	6	2	5	5	3	3	5	1	5	2
0.10	0.07	0.11	0.79	1.15	12.2	-0.3	0	5	4	4	4	3	4	2	5	2	3	4	5
0.10	0.05	0.67	0.35	0.40	12.1	0	0	5	4	5	1	5	5	1	1	5	1	5	1

						COMFORT QUESTIONS					AFFECT QUESTIONS								
VELOC Brst Ave 0.6m m/s	VELOC Brst Ave 0.1m m/s	VELOC Brst TI 1.1m	VELOC Brst TI 0.6m	VELOC Brst TI 0.1m	MAIN BATTERY VDC	ASH Scale (-3,3) cold hot	McINT Scale (-1,1) cooler warmer	GEN COMF (1,6) uncomf. comf.	VENT COMF (1,6) stuffy drafty	LIGHT COMF (1,6) dim bright	Frustrated	Comfortable	Happy	Fatigued	Uncomfortable	Relaxed	Sad	Energetic	Burdenec
0.10	0.07	0.41	0.55	0.65	12.07	0.22	0.08	4.95	3.67	4.23	2.36	4.79	4.26	2.44	2.23	4.10	1.56	4.41	2.87
0.05	0.02	0.32	0.46	0.52	0.26	1.10	0.42	1.17	0.66	1.01	1.37	0.98	1.07	1.29	1.29	1.05	1.07	0.97	1.38
0.29	0.14	1.62	1.96	1.87	12.44	3.00	1.00	6.00	5.00	6.00	6.00	6.00	6.00	5.00	5.00	6.00	5.00	6.00	5.00
0.03	0.03	0.11	0.08	0.11	11.59	-2.70	-1.00	1.00	2.00	2.00	1.00	1.00	2.00	1.00	1.00	2.00	1.00	2.00	1.00

d	COPING MECHANISMS													ACTIVITY FLAGS					
Restless	Opened/Closed window	Opened/Closed door to outside	Opened/Closed door to inside	Adjusted thermostat	Adjusted Drapes/Blinds	Space heater on/off	Local fan on/off	Adjust clothes	Hot or cold drink	Took a break	Talked to others	Talked to staff	Ignored	MET(estimated)	Eat food	Hot drink	Cold Drink	Caffeine	Smoke
														MET	FOOD	DHOT	DCLD	DCAF	CIG
2	9	9	9	9	9	9	9	0	0	0	0	0	0	1	1	1	0	0	0
4	9	9	9	0	9	0	0	0	0	0	0	0	2	1.2	0	1	0	1	0
5	9	9	9	9	9	9	9	0	1	1	0	0	2	1.2	0	1	0	1	0
5	9	9	9	0	9	0	0	0	0	0	0	0	1	1.2	0	0	0	0	0
2	9	9	9	0	9	0	0	0	0	0	0	0	1	1	0	0	0	0	0
1	9	9	9	9	9	9	9	0	0	0	0	0	1	1.4	0	0	0	0	0
3	9	9	9	9	9	9	9	0	1	2	0	0	2	1.2	0	0	1	0	0
3	9	9	9	0	9	0	3	0	0	0	1	0	0	1.2	0	1	0	1	0
4	9	9	9	9	9	9	9	0	0	0	0	0	0	1.2	0	0	1	1	0
1	9	9	9	9	9	9	9	0	0	0	0	0	1	1	0	0	0	0	0
2	9	9	9	9	9	9	9	0	0	0	0	0	0	1	0	0	0	0	0
3	9	9	9	0	9	0	0	0	0	0	0	0	1	1.2	0	0	0	0	0
2	9	9	9	9	9	9	9	2	2	4	0	0	2	1.4	0	1	1	0	0
2	9	9	9	0	9	0	0	0	0	0	0	0	0	1.4	0	0	1	0	0
4	9	9	9	0	9	0	0	0	0	0	0	0	1	1.2	1	0	1	0	0
2	9	9	9	0	9	0	4	0	2	0	0	0	0	1	0	0	1	0	0
4	9	9	9	9	9	9	9	0	0	0	0	0	0	1	0	0	0	0	0
2	9	9	9	9	9	9	9	0	0	0	0	0	0	1	0	0	0	0	0
2	9	9	9	0	9	0	0	0	0	0	0	0	0	1	0	1	0	1	0
1	9	9	9	9	9	9	9	0	2	3	0	0	4	1.2	1	0	1	0	0
2	9	9	9	9	9	9	9	0	0	0	0	0	4	1.2	0	0	0	0	0
4	9	9	9	0	9	0	0	0	0	2	0	0	0	1	0	0	0	0	0
3	9	9	9	0	9	0	0	0	2	1	0	0	1	1	0	0	1	0	0
1	9	9	9	9	9	9	9	0	0	0	0	0	0	1	1	1	0	1	0

d

	COPING MECHANISMS													ACTIVITY FLAGS					
Restless	Opened/Closed window	Opened/Closed door to outside	Opened/Closed door to inside	Adjusted thermostat	Adjusted Drapes/Blinds	Space heater on/off	Local fan on/off	Adjust clothes	Hot or cold drink	Took a break	Talked to others	Talked to staff	Ignored	MET(estimated)	Eat food	Hot drink	Cold Drink	Caffeine	Smoke
1	9	9	9	0	9	0	0	0	0	0	0	0	0	1	0	1	0	1	0
2	9	9	9	0	9	0	0	0	0	0	0	0	1	1	0	0	0	0	0
3	9	9	9	0	9	0	0	0	0	0	0	0	0	1.4	0	1	0	1	0
5	9	9	9	0	9	0	0	0	0	0	0	0	1	1.2	0	0	0	0	0
3	9	9	9	9	9	9	9	0	0	0	0	0	0	1	0	1	0	1	0
2	9	9	9	9	9	9	9	0	0	0	0	0	4	1.2	0	0	0	0	0
4	9	9	9	9	9	9	9	0	2	2	0	0	4	1.2	0	0	1	0	0
1	9	9	9	0	9	0	0	0	0	0	0	0	0	1	0	0	0	0	0
3	9	9	9	0	9	0	0	0	2	0	0	0	1	1	0	0	1	0	0
4	9	9	9	0	9	0	0	0	0	0	0	0	0	1.2	0	0	0	1	0
5	9	9	9	0	9	0	0	0	0	0	0	0	1	1	0	0	0	0	0
1	9	9	9	9	9	9	9	0	0	0	0	0	0	1	0	0	0	0	0
2	9	9	9	9	9	9	9	0	0	3	0	0	0	1.2	0	0	0	0	0
6	9	9	9	9	9	9	9	0	0	0	0	0	0	1	1	0	1	1	0
1	9	9	9	0	9	0	0	0	0	0	0	0	0	1	0	0	0	0	0
2.74	9.00	9.00	9.00	4.38	9.00	4.38	4.56	0.05	0.36	0.46	0.03	0.00	0.90	1.12	0.13	0.26	0.28	0.28	0.00
1.39	0.00	0.00	0.00	4.56	0.00	4.56	4.45	0.32	0.74	1.02	0.16	0.00	1.25	0.14	0.34	0.44	0.46	0.46	0.00
6.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	2.00	2.00	4.00	1.00	0.00	4.00	1.40	1.00	1.00	1.00	1.00	0.00
1.00	9.00	9.00	9.00	0.00	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
NO	0	0	0	20	0	20	18	38	31	31	38	39	20						
1	0	0	0	0	0	0	0	0	2	2	1	0	11						
2	0	0	0	0	0	0	0	1	6	3	0	0	4						
3	0	0	0	0	0	0	1	0	0	2	0	0	0						
4	0	0	0	0	0	0	1	0	0	1	0	0	4						
N/A	39	39	39	19	39	19	19	0	0	0	0	0	0						

CLOTHING

QUESTIONS(header for women's clothing only)

SURVEY

COMPLETION TIMES(seconds)

Underlayer			**Footware**			**Midlayer**						**Outerlayers**							
top	bottom	slip	socks	pantyhose	shoes	ss shirt	ls shirt	dress	skirt	pants	shorts	sweater	vest	jacket		Comfort	Affect	Activity	Clothing
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	CLO				
CL1	CL2	CL3	CL4	CL5	CL6	CL7	CL8	CL9	CL10	CL11	CL12	CL13	CL14	CL15					
2	1	0	1	0	0	0	0	0	1	2	0	0	0	0	0.36	49	72	117	150
2	1	0	0	2	0	0	0	0	2	2	0	0	0	0	0.43	30	41	23	130
1	1	2	0	1	2	0	0	2	0	0	0	0	0	0	0.62	45	71	23	89
0	1	0	1	1	0	0	0	0	1	2	0	0	0	0	0.5	36	78	15	81
0	1	0	1	1	0	0	0	0	1	2	0	0	0	0	0.5	29	66	14	80
1	1	1	0	1	1	0	0	1	0	0	0	0	0	1	0.49	63	77	28	42
1	1	1	0	1	1	0	0	0	2	0	0	2	0	0	0.52	57	63	22	100
2	1	0	0	2	0	0	0	0	2	2	0	0	0	0	0.43	21	21	14	6
1	1	2	0	1	2	0	0	2	0	0	0	0	0	0	0.62	31	71	30	17
1	1	1	0	1	1	0	0	1	0	0	0	0	0	0	0.35	26	43	15	21
2	1	1	1	0	0	0	0	0	1	2	0	0	0	0	0.48	18	34	29	39
0	1	0	1	1	0	0	0	0	1	2	0	0	0	0	0.5	39	105	13	54
1	1	1	0	1	2	0	0	0	2	0	0	2	0	0	0.54	27	52	30	71
0	1	0	2	2	0	0	0	0	2	2	0	0	0	0	0.57	19	36	24	82
0	1	0	1	1	0	0	0	0	1	2	0	0	0	0	0.5	53	85	19	18
0	1	1	0	1	0	0	0	0	1	2	0	0	0	0	0.43	23	41	18	30
1	1	2	0	1	2	0	0	2	0	0	0	0	0	0	0.62	29	51	22	9
2	1	0	1	0	0	0	0	0	1	2	0	0	0	0	0.36	19	34	14	57
0	1	0	2	2	0	0	0	0	2	2	0	0	0	0	0.57	14	25	19	15
1	1	1	0	1	2	0	0	0	2	0	0	2	0	0	0.54	31	45	22	18
1	1	1	0	1	1	0	0	1	0	0	0	0	0	0	0.35	22	36	17	9
2	1	0	0	2	0	0	0	0	2	2	0	0	0	0	0.43	25	26	17	6
0	1	1	0	1	0	0	0	0	1	2	0	0	0	0	0.43	13	35	15	30
2	1	0	1	0	0	0	0	0	1	2	0	0	0	0	0.36	124	37	30	103

0	1	0	2	2	0	0	0	0	2	2	0	0	0	0	0.57	10	25	20	50
0	1	0	1	1	0	0	0	0	1	2	0	0	0	0	0.5	28	37	13	24
2	1	0	0	2	0	0	0	0	2	2	0	0	0	0	0.43	17	21	21	58
0	1	0	1	1	0	0	0	0	1	2	0	0	0	0	0.5	20	46	11	36
1	1	0	0	1	2	1	0	0	0	0	1	0	0	0	0.26	21	49	26	47
1	1	2	0	1	2	1	0	0	1	0	0	1	0	0	0.57	16	63	10	40
1	1	0	0	1	2	1	0	0	1	0	0	0	0	0	0.28	18	49	18	41
0	1	0	2	2	0	0	0	0	2	2	0	0	0	0	0.57	9	27	10	5
0	1	0	1	1	0	0	0	0	1	2	0	0	0	0	0.5	35	47	9	28
2	1	0	0	2	0	0	0	0	2	2	0	0	0	0	0.43	44	29	119	21
2	1	0	1	1	0	0	0	0	1	2	0	0	0	0	0.57	17	43	12	17
1	1	2	0	1	2	1	0	0	1	0	0	1	0	0	0.57	19	31	14	6
1	1	0	0	1	2	1	0	0	1	0	0	0	0	0	0.28	17	35	11	21
1	1	0	0	1	2	1	0	0	0	0	1	0	0	0	0.26	30	51	31	8
0	1	0	2	2	0	0	0	0	2	2	0	0	0	0	0.57	8	28	10	3

CLOTHING QUESTIONS(header for women's clothing only)																SURVEY COMPLETION TIMES(seconds)			
Underlayer			Footware			Midlayer						Outerlayers							
top	bottom	slip	socks	pantyhose	shoes	ss shirt	ls shirt	dress	skirt	pants	shorts	sweater	vest	jacket		Comfort	Affect	Activity	Clothing
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	CLO				
0.90	1.00	0.49	0.56	1.15	0.67	0.15	0.00	0.23	1.13	1.23	0.05	0.21	0.00	0.03	0.47	30	47	24	43
0.79	0.00	0.72	0.72	0.59	0.90	0.37	0.00	0.58	0.73	0.99	0.22	0.57	0.00	0.16	0.10	20	20	23	36
2.00	1.00	2.00	2.00	2.00	2.00	1.00	0.00	2.00	2.00	2.00	1.00	2.00	0.00	1.00	0.62	124	105	119	150
0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	8	21	9	3

COMFORT MODEL

INPUT AND OUTPUT VARIABLES

TOTAL	TAAV	TRAV	PAAV	VELAV	TCR	TSK	PWET	ET*	SET*	DISC	TSENS	PMV	PMV*	HSI
388	22.60	22.80	9.45	0.10	36.81	31.95	6.00	22.66	20.45	0.00	-0.26	-0.35	-0.40	2.72
224	22.67	22.66	9.51	0.10	36.83	32.75	6.00	22.61	21.33	-0.09	-0.09	-0.33	-0.38	7.23
228	22.63	22.90	9.51	0.10	36.83	33.62	7.88	22.71	23.05	-0.01	-0.01	-0.11	-0.12	11.11
210	22.43	22.64	9.57	0.10	36.83	33.08	6.00	22.50	21.83	-0.06	-0.06	-0.29	-0.32	7.86
189	22.47	22.66	9.57	0.10	36.82	32.47	6.00	22.54	21.44	0.00	-0.17	-0.22	-0.24	4.68
210	23.13	23.27	9.57	0.10	36.85	33.55	9.70	23.09	22.76	-0.01	-0.01	-0.13	-0.21	13.68
242	23.00	23.07	9.51	0.10	36.83	33.50	6.25	22.97	22.48	-0.02	-0.02	-0.24	-0.27	8.81
62	23.07	23.46	9.26	0.17	36.83	33.13	6.00	23.19	21.93	-0.05	-0.05	-0.28	-0.35	8.36
149	22.97	23.17	9.32	0.11	36.83	33.68	8.59	22.97	23.31	0.00	0.00	-0.05	-0.07	12.21
105	23.17	23.56	9.38	0.10	36.82	32.26	6.00	23.32	21.09	0.00	-0.20	-0.26	-0.32	4.33
120	23.17	23.50	9.38	0.11	36.82	32.80	6.00	23.29	22.08	0.00	-0.12	-0.14	-0.17	6.21
211	22.83	23.05	9.45	0.13	36.83	33.35	6.00	22.89	22.22	-0.03	-0.03	-0.26	-0.30	8.52
180	23.20	23.47	9.32	0.10	36.85	33.69	11.13	23.18	23.31	0.00	0.00	-0.03	-0.10	15.69
161	23.17	23.31	9.38	0.15	36.85	33.73	11.71	23.09	23.51	0.01	0.02	0.01	-0.04	17.06
175	22.60	22.73	9.38	0.10	36.83	33.16	6.00	22.61	21.94	-0.05	-0.05	-0.28	-0.32	8.01
112	22.80	22.80	9.38	0.18	36.81	32.01	6.00	22.73	20.56	0.00	-0.25	-0.33	-0.41	3.45
111	23.00	23.13	9.32	0.10	36.82	33.23	6.00	23.01	22.81	0.00	-0.06	-0.05	-0.06	7.50
124	23.10	23.43	9.38	0.10	36.82	32.25	6.00	23.21	21.06	0.00	-0.21	-0.26	-0.33	4.23
73	23.17	23.24	9.26	0.15	36.82	33.00	6.00	23.13	22.42	0.00	-0.09	-0.10	-0.13	7.04
116	23.27	23.40	9.26	0.10	36.83	33.60	7.41	23.23	22.91	-0.01	-0.01	-0.14	-0.18	10.45
84	23.27	23.60	9.32	0.10	36.83	32.76	6.00	23.36	21.39	-0.09	-0.09	-0.32	-0.41	7.41
74	23.27	23.41	9.32	0.13	36.82	32.58	6.00	23.27	21.68	0.00	-0.15	-0.18	-0.23	5.53
93	22.97	22.81	9.26	0.16	36.81	32.17	6.00	22.80	20.87	0.00	-0.22	-0.29	-0.36	3.99
294	22.67	22.86	9.14	0.10	36.81	31.97	6.00	22.70	20.50	0.00	-0.26	-0.34	-0.40	2.89

105	22.80	22.87	9.14	0.14	36.82	32.86	6.00	22.77	22.17	0.00	-0.11	-0.13	-0.14	6.41
102	22.73	22.74	9.26	0.10	36.82	32.54	6.00	22.67	21.58	0.00	-0.16	-0.20	-0.22	5.04
117	22.97	23.03	9.20	0.12	36.85	33.35	7.65	22.90	22.00	-0.03	-0.03	-0.29	-0.38	10.94
113	22.53	22.67	9.26	0.10	36.83	33.11	6.00	22.54	21.87	-0.06	-0.06	-0.29	-0.33	7.92
143	22.60	22.87	9.20	0.10	36.81	31.54	6.00	22.68	19.62	0.00	-0.35	-0.47	-0.55	1.12
129	22.90	23.03	9.20	0.10	36.83	33.57	7.14	22.88	22.81	-0.01	-0.01	-0.16	-0.19	10.07
126	22.83	23.04	9.26	0.10	36.83	32.02	6.00	22.86	20.21	-0.18	-0.18	-0.42	-0.53	5.82
51	23.13	23.29	9.32	0.15	36.82	33.01	6.00	23.14	22.44	0.00	-0.09	-0.10	-0.12	7.07
119	22.70	22.70	9.26	0.12	36.82	32.52	6.00	22.63	21.54	0.00	-0.16	-0.20	-0.23	5.02
213	23.27	23.33	9.26	0.13	36.83	33.15	6.00	23.22	21.95	-0.05	-0.05	-0.28	-0.35	8.21
89	22.93	23.07	9.26	0.10	36.82	32.98	6.00	22.94	22.38	0.00	-0.09	-0.10	-0.12	6.68
70	23.13	23.40	9.14	0.10	36.82	33.13	6.00	23.20	22.65	0.00	-0.08	-0.07	-0.09	7.21
84	23.10	23.30	9.07	0.10	36.83	32.17	6.00	23.11	20.48	-0.16	-0.16	-0.40	-0.51	6.25
120	23.07	23.33	9.07	0.10	36.81	31.77	6.00	23.13	20.13	0.00	-0.30	-0.39	-0.48	2.45
49	23.57	23.42	9.14	0.13	36.82	33.25	6.00	23.39	22.84	0.00	-0.06	-0.05	-0.07	7.75

COMFORT MODEL

INPUT AND OUTPUT VARIABLES

TOTAL	TAAV	TRAV	PAAV	VELAV	TCR	TSK	PWET	ET*	SET*	DISC	TSENS	PMV	PMV*	HSI
143	22.95	23.10	9.31	0.11	36.83	32.85	6.60	22.95	21.84	-0.02	-0.11	-0.22	-0.27	7.36
71	0.27	0.30	0.13	0.02	0.01	0.61	1.40	0.26	0.98	0.04	0.09	0.12	0.14	3.46
388	23.57	23.60	9.57	0.18	36.85	33.73	11.71	23.39	23.51	0.01	0.02	0.01	-0.04	17.06
49	22.43	22.64	9.07	0.10	36.81	31.54	6.00	22.50	19.62	-0.18	-0.35	-0.47	-0.55	1.12

APPENDIX G

Complete Test 2 Data Spreadsheet
16, 17 September 1992

THERMAL COMFORT ASSESSMENT

Survey Data - Advanced Office Systems Tested (AOST) Test #2 - 16,17 Sept., 1992

Building Science Group - Center for Environmental Design Research - UC Berkeley

SITE VISIT SPECIFICS	**PHYSICAL DATA**

BLDG.	MEA.	JULIAN	CART	VISIT	SUBJ	GEND	TIME	AIR	AIR	AIR	EST.	GLOB	GLOB	GLOB	DEW	PRT	ILLUM	VELOC	VELOC	VELOC	VELOC	VELOC	VELOC
CODE	NO.	DATE	PSHR	CODE		(1M)		TEMP	TEMP	TEMP	TEMP	TEMP	TEMP	TEMP	POINT	DELTA	illumn.	AVE.	AVE.	AVE.	Brst Ave	Brst Ave	Brst Ave
						(2F)		1.1m	0.6m	0.1m		1.1m	0.6m	0.1m	0.6m	1.1m	1.1m	1.1m	0.6m	0.1m	1.1m	0.6m	0.1m
								degC	degC	degC	degC	degC	degC	degC	degC	degC	lux	m/s	m/s	m/s	m/s	m/s	m/s
CO	NO	DATE	PSHR	VST	SUB	GEN	TIME	TAH	TAM	TAL	Etmp	TGH	TGM	TGL	TD	PRTD	LUX	VELH	VELM	VELL	UBARH	UBARM	UBARL
T	1	260	3	1	9	2	923	22.72	22.46	22.41	25.60	22.74	22.37	22.30	10.85	0.03	1345	0.14	0.10	0.13	0.15	0.15	0.09
T	2	260	3	1	6	1	934	22.42	22.26	22.09	20.00	22.61	22.30	22.17	11.27	-0.09	1388	0.07	0.07	0.07	0.09	0.10	0.06
T	3	260	3	1	1	1	941	22.30	22.24	21.96	20.60	22.41	22.23	21.98	11.34	-0.38	883	0.09	0.07	0.07	0.10	0.05	0.11
T	4	260	3	1	3	1	1007	22.67	22.62	22.18	23.90	22.92	22.90	22.32	11.56	-0.59	1216	0.09	0.12	0.06	0.16	0.13	0.06
T	5	260	3	1	2	1	1016	23.14	22.98	22.53	18.30	23.20	23.15	22.53	11.66	-0.60	975	0.19	0.08	0.07	0.22	0.10	0.09
T	6	260	3	1	4	2	1027	22.91	22.69	22.51	17.80	23.03	22.79	22.58	11.54	-0.08	1406	0.12	0.09	0.09	0.07	0.09	0.08
T	7	260	3	1	10	1	1123	22.94	22.87	22.50	20.60	23.03	22.92	22.51	11.57	-0.15	627	0.09	0.07	0.06	0.11	0.04	0.05
T	8	260	9	2	6	1	1135	23.04	22.93	22.61	20.00	23.23	23.04	22.70	11.33	-0.29	1255	0.08	0.11	0.06	0.13	0.09	0.06
T	9	260	9	1	7	2	1206	23.19	23.02	22.68		23.39	23.18	22.84	11.23	-0.07	1316	0.07	0.07	0.07	0.06	0.05	0.05
T	10	260	4	2	2	1	1341	22.89	23.86	23.37	21.10	23.26	23.94	23.31	11.49	-0.67	922	0.83	0.08	0.06	0.80	0.06	0.07
T	11	260	4	2	4	2	1401	23.55	23.38	23.18	18.90	23.68	23.54	23.26	10.84	-0.25	1358	0.07	0.10	0.07	0.11	0.10	0.07
T	12	260	4	2	7	2	1413	23.57	23.39	23.10		23.75	23.62	23.20	10.59	-0.62	1348	0.08	0.08	0.07	0.09	0.08	0.07
T	13	260	4	2	1	1	1432	23.03	23.13	22.65	21.70	23.10	23.24	22.75	10.71	-0.55	855	0.14	0.06	0.08	0.14	0.08	0.08
T	14	260	4	3	6	1	1508	23.26	23.22	22.91	20.00	23.46	23.39	23.01	10.64	-0.38	1283	0.09	0.09	0.06	0.08	0.10	0.06
T	15	260	4	2	10	1	1550	22.89	22.83	22.60	20.60	23.05	23.01	22.61	10.55	-0.25	548	0.13	0.06	0.10	0.14	0.10	0.10
T	16	260	4	2	3	1	1558	23.45	23.21	22.85	25.60	23.60	23.43	22.96	10.63	-0.73	1442	0.12	0.12	0.06	0.12	0.11	0.08
T	17	260	4	3	10	1	1637	22.69	22.69	22.56	20.60	22.89	22.88	22.59	10.52	-0.23	604	0.11	0.08	0.07	0.09	0.13	0.06
T	18	261	4	4	10	1	927	22.50	22.34	22.54	20.60	22.78	22.52	22.71	10.72	-0.45	659	0.20	0.11	0.07	0.19	0.16	0.10
T	19	261	4	3	4	2	936	22.69	22.58	22.46	20.00	22.90	22.66	22.54	10.76	-0.09	1263	0.10	0.09	0.05	0.10	0.07	0.07
T	20	261	4	3	9	2	946	22.81	22.73	22.66	22.20	22.86	22.73	22.57	10.96	0.03	1380	0.19	0.12	0.16	0.21	0.11	0.21

T	21	261	4	3	7	2	1003	23.03	22.92	22.61		23.22	23.05	22.72	10.91	-0.32	1265	0.08	0.05	0.07	0.08	0.08	0.07
T	22	261	4	4	6	1	1012	22.82	22.72	22.48	18.30	23.03	22.84	22.54	10.90	-0.33	1301	0.08	0.12	0.07	0.08	0.11	0.07
T	23	261	4	3	1	1	1049	22.37	22.71	22.31	20.00	22.72	22.77	22.40	11.03	-0.34	887	0.17	0.06	0.05	0.11	0.03	0.07
T	24	261	4	3	3	1	1057	23.04	23.16	22.54	23.90	23.15	23.01	22.64	11.08	-0.38	1241	0.14	0.13	0.05	0.15	0.14	0.04
T	25	261	4	4	9	2	1111	23.48	23.21	22.85	18.90	23.44	23.22	22.98	11.21	-0.15	1396	0.12	0.10	0.07	0.15	0.07	0.08
T	26	261	4	4	4	2	1153	23.12	22.97	22.77	18.90	23.26	23.15	22.89	10.89	-0.15	1378	0.09	0.10	0.06	0.10	0.08	0.07
T	27	261	4	4	7	2	1208	23.27	23.14	22.81		23.48	23.31	22.96	10.98	-0.45	973	0.08	0.05	0.09	0.08	0.06	0.10
T	28	261	4	3	2	1	1231	23.21	23.61	23.09	21.10	23.35	23.64	23.14	11.06	0.24	711	0.18	0.07	0.08	0.17	0.08	0.07
T	29	261	4	5	10	1	1247	23.55	23.39	23.46	20.60	23.70	23.50	23.53	10.96	-0.67	722	0.21	0.11	0.08	0.23	0.07	0.08
T	30	261	4	5	4	2	1327	23.65	23.43	23.25	18.30	23.77	23.63	23.35	10.86	-0.25	950	0.08	0.10	0.07	0.06	0.10	0.07
T	31	261	4	4	1	1	1344	22.98	23.38	22.98	21.70	23.25	23.36	22.99	10.85	-0.61	800	0.26	0.08	0.07	0.10	0.08	0.07
T	32	261	4	4	2	1	1352	23.16	23.57	23.09	20.00	23.47	23.63	23.17	10.90	0.04	845	0.13	0.06	0.08	0.18	0.06	0.10
T	33	261	4	5	7	2	1411	23.41	23.32	23.03		23.61	23.52	23.15	10.76	-0.52	972	0.07	0.05	0.07	0.06	0.06	0.06
T	34	261	4	4	3	1	1450	23.09	23.34	22.95	24.40	22.87	23.35	23.03	10.08	-0.50	967	0.28	0.13	0.05	0.30	0.15	0.07
T	35	261	4	5	6	1	1459	23.19	23.16	22.88	19.40	23.38	23.32	22.97	10.38	-0.51	1100	0.09	0.11	0.07	0.12	0.14	0.05
T	36	261	4	5	9	2	1506	23.78	23.52	23.17	21.70	23.68	23.55	23.25	10.41	-0.41	1122	0.15	0.10	0.06	0.18	0.10	0.06
T	37	261	4	5	1	1	1525	22.85	23.10	22.66	21.10	23.06	23.11	22.72	10.38	-0.46	822	0.10	0.09	0.07	0.07	0.06	0.08
T	38	261	4	5	3	1	1532	23.15	23.68	22.87	24.40	23.29	23.66	22.99	10.33	-0.44	1111	0.19	0.13	0.06	0.17	0.24	0.05

PHYSICAL DATA

	AIR TEMP 1.1m degC	AIR TEMP 0.6m degC	AIR TEMP 0.1m degC	EST. TEMP degC	GLOB TEMP 1.1m degC	GLOB TEMP 0.6m degC	GLOB TEMP 0.1m degC	DEW POINT 0.6m degC	PRT DELTA 1.1m degC	ILLUM illumn. 1.1m lux	VELOC AVE. 1.1m m/s	VELOC AVE. 0.6m m/s	VELOC AVE. 0.1m m/s	VELOC Brst Ave 1.1m m/s	VELOC Brst Ave 0.6m m/s	VELOC Brst Ave 0.1m m/s
Mean	23.05	23.05	22.74	20.93	23.20	23.14	22.81	10.91	-0.33	1069	0.14	0.09	0.07	0.15	0.09	0.07
Std. Dev.	0.36	0.40	0.34	2.09	0.34	0.41	0.35	0.38	0.23	270	0.13	0.02	0.02	0.12	0.04	0.03
Minimum	22.30	22.24	21.96	17.80	22.41	22.23	21.98	10.08	-0.73	548	0.07	0.05	0.05	0.06	0.03	0.04
Maximum	23.78	23.86	23.46	25.60	23.77	23.94	23.53	11.66	0.24	1442	0.83	0.13	0.16	0.80	0.24	0.21

				COMFORT QUESTIONS					AFFECT QUESTIONS										COPING MECHANISMS					
VELOC Brst TI 1.1m	VELOC Brst TI 0.6m	VELOC Brst TI 0.1m	MAIN BATTERY VDC	ASH Scale (-3,3) cold hot	McINT Scale (-1,1) coole warm	GEN COMI (1,6) uncor comf.	VENT COMI (1,6) stuffy drafty	LIGHT COMF (1,6) dim bright	Frustrated	Comfortable	Happy	Fatigued	Uncomfortable	Relaxed	Sad	Energetic	Burdened	Restless	Opened/Closed window	Opened/Closed door to outside	Opened/Closed door to in	Adjusted thermostat	Adjusted Dra	Space
TIH	TIM	TIL	BAT	ASH	MC	COMI	VENT	LIGHT																
0.20	0.20	0.26	12.29	1	1	4	3	6	2	5	5	3	4	5	1	5	4	4	9	9	9	9	9	9
0.19	0.11	0.29	12.28	0	0	5	4	5	2	5	4	1	1	5	1	3	2	2	9	9	9	9	9	9
0.33	0.37	0.17	12.27	-1	-1	5	4	4	4	4	4	2	2	4	1	4	2	3	9	9	9	0	9	0
0.23	0.13	0.36	12.32	0	0	5	4	4	4	4	4	5	2	4	1	1	5	4	9	9	9	0	9	0
0.15	0.21	0.19	12.23	-0.3	0	5	4	4	1	5	5	2	1	5	1	5	1	2	9	9	9	0	9	0
0.32	0.28	0.23	12.22	-2.5	-1	2	5	4	5	1	3	2	5	1	4	5	4	6	9	9	9	9	9	9
0.12	0.57	0.10	12.17	0	-1	5	4	4	1	4	4	2	3	5	1	4	2	2	9	9	9	0	9	0
0.12	0.21	0.37	12.15	0	0	5	4	5	1	5	3	2	1	5	1	4	2	1	9	9	9	9	9	9
0.39	0.27	0.15	12.12	-1	0	5	4	5	2	5	4	1	1	4	1	5	2	3	9	9	9	9	9	9
0.41	0.31	0.23	12.01	1	1	5	5	5	1	5	5	1	1	5	1	6	1	2	9	9	9	0	9	0
0.10	0.15	0.36	12.06	-1	0	5	4	3	4	3	3	3	3	3	4	4	5	3	9	9	9	9	9	9
0.19	0.35	0.93	11.97	-0.6	0	5	4	5	2	5	4	2	1	4	1	6	1	2	9	9	9	9	9	9
0.36	0.07	0.26	12.01	0.8	0	5	4	4	4	4	3	3	3	4	2	4	2	3	9	9	9	0	9	0
0.25	0.17	0.31	11.90	0	0	5	4	5	1	5	4	2	1	5	1	3	2	1	9	9	9	9	9	9
0.18	0.14	0.42	11.84	0	-1	5	4	5	1	4	4	2	2	5	1	5	2	1	9	9	9	0	9	0
0.17	0.17	0.68	11.83	1	1	4	3	4	4	3	2	4	4	2	3	2	5	5	9	9	9	0	9	0
0.20	0.14	0.18	11.85	0	-1	4	4	4	1	5	5	1	4	5	1	4	3	2	9	9	9	0	9	0
0.18	0.16	0.47	12.31	0	-1	5	4	5	2	4	4	2	3	4	1	4	2	2	9	9	9	0	9	3
0.20	0.15	1.54	12.31	1	1	5	4	3	2	5	4	2	3	4	4	5	4	2	9	9	9	9	9	9
0.19	0.28	0.15	12.29	1	1	3	2	6	2	4	6	1	4	5	1	6	4	2	9	9	9	9	9	9

0.64	0.99	0.49	12.28	0.2	0	5	4	5	2	5	4	1	1	4	1	4	1	1	9	9	9	9	9	9
0.46	0.37	1.13	12.26	-1	-1	5	4	5	2	5	4	2	2	5	2	3	2	1	9	9	9	9	9	9
0.49	5.73	0.98	12.21	-1	-1	4	5	4	4	3	2	2	4	4	2	3	4	3	9	9	9	0	9	0
0.13	0.11	2.23	12.20	0	0	4	3	4	2	4	4	2	3	2	1	2	3	5	9	9	9	0	9	0
0.32	1.11	1.67	12.18	0	0	6	3	4	1	5	6	1	1	5	1	5	4	2	9	9	9	9	9	9
0.18	0.43	0.81	12.12	0.3	1	5	4	3	3	5	4	2	2	5	2	5	4	2	9	9	9	9	9	9
0.85	1.77	0.38	12.09	0	0	5	4	5	2	5	4	1	1	4	1	5	2	1	9	9	9	9	9	9
0.28	0.87	0.36	12.11	1	1	5	4	4	1	5	5	1	2	5	1	5	2	2	9	9	9	0	9	0
0.19	0.51	0.25	12.07	0	-1	5	4	5	2	5	4	3	2	2	1	5	6	2	9	9	9	0	9	2
0.43	0.21	0.18	11.94	0	0	5	4	4	2	5	5	2	2	3	2	5	4	5	9	9	9	9	9	9
0.38	0.93	0.78	11.91	0.8	0	5	4	4	6	4	3	3	3	4	2	3	4	4	9	9	9	0	9	0
0.17	0.34	0.81	11.90	0	0	6	4	4	1	5	5	1	1	5	1	6	1	2	9	9	9	0	9	0
0.77	0.51	1.51	11.88	0.6	0	5	4	5	1	6	4	1	1	5	1	4	1	1	9	9	9	9	9	9
0.63	0.20	1.65	11.83	2	1	4	3	4	2	2	4	3	4	2	2	2	3	3	9	9	9	3	9	0
0.24	0.15	0.55	11.82	0	0	5	4	5	1	5	4	2	1	3	1	3	2	1	9	9	9	9	9	9
0.26	0.46	1.56	11.81	0	1	5	2	5	2	5	6	4	2	5	1	5	4	4	9	9	9	9	9	9
1.20	1.31	0.58	11.85	0	0	5	4	4	5	4	4	3	3	4	2	3	3	3	9	9	9	0	9	0
0.32	0.48	0.43	11.77	-0.9	0	5	4	4	1	4	4	3	2	2	5	3	3	3	9	9	9	0	9	0
				COMFORT QUESTIONS					AFFECT QUESTIONS										COPING MECHANISMS					
VELOC Brst Tl 1.1m	VELOC Brst Tl 0.6m	VELOC Brst Tl 0.1m	MAIN BATTERY VDC	ASH Scale (-3,3) cold hot	McINT Scale (-1,1) coole warm	GEN COMI (1,6) uncor comf.	VENT COMI (1,6) stuffy drafty	LIGHT COMF (1,6) dim bright	Frustrated	Comfortable	Happy	Fatigued	Uncomfortable	Relaxed	Sad	Energetic	Burdened	Restless	Opened/Closed window	Opened/Closed door to outside	Opened/Closed door to in	Adjusted thermostat	Adjusted Dra	Space
0.33	0.55	0.63	12.07	0.04	0.00	4.76	3.84	4.42	2.26	4.39	4.11	2.11	2.26	4.03	1.61	4.11	2.84	2.55	9.00	9.00	9.00	4.58	9.00	4.63
0.23	0.94	0.54	0.18	0.81	0.70	0.71	0.64	0.72	1.37	0.97	0.92	0.98	1.18	1.15	1.05	1.25	1.35	1.31	0.00	0.00	0.00	4.51	0.00	4.46
0.10	0.07	0.10	11.77	-2.50	-1.00	2.00	2.00	3.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	9.00	9.00	9.00	0.00	9.00	0.00
1.20	5.73	2.23	12.32	2.00	1.00	6.00	5.00	6.00	6.00	6.00	6.00	5.00	5.00	5.00	5.00	6.00	6.00	6.00	9.00	9.00	9.00	9.00	9.00	9.00

ACTIVITY
FLAGS

CLOTHING
QUESTIONS(header for women's clothing only)

Local fan on/off
Adjust clothes
ıside
Hot or cold drink
t
Took a break
ıpes/Blinds
Talked to others
ɜ heater on/off
Talked to staff
Ignored

MET(estimated)
Eat food
Hot drink
Cold Drink
Caffeine
Smoke

Underlayer
top
bottom
slip

Footware
socks
pantyhose
shoes

Midlayer
ss shirt
ls shirt
dress

													1	2	3	4	5	6	7	8	9
							MET	FOOD	DHOT	DCLD	DCAF	CIG	CL1	CL2	CL3	CL4	CL5	CL6	CL7	CL8	CL9
9	0	0	0	0	0	1	1.2	0	0	0	0	0	1	1	1	0	0	2	0	0	1
9	0	1	0	0	0	0	1.2	1	1	0	1	0	2	1	0	1	0	0	0	0	0
0	0	0	1	0	0	1	1.2	0	0	0	0	0	0	2	0	2	2	0	0	0	0
0	0	0	0	0	0	0	1.2	0	0	1	0	0	0	1	1	0	2	0	0	0	0
0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	2	0	3	0	0	0	0
9	0	0	0	0	0	1	1.2	0	0	1	1	0	1	1	1	0	1	2	1	0	0
0	0	0	2	0	0	2	1.2	0	0	0	0	0	0	1	1	0	2	0	0	0	0
9	0	0	0	0	0	0	1	0	0	0	0	0	2	1	0	1	0	0	0	0	0
9	0	0	0	0	0	1	1.2	0	0	0	0	0	1	1	2	0	1	2	0	0	1
4	0	2	0	0	0	0	1.2	1	1	1	0	0	0	1	2	0	3	0	0	0	0
9	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	0	1	2	1	0	0
9	0	0	0	0	0	1	1	1	0	0	0	0	1	1	2	0	1	2	0	0	1
0	2	0	0	0	0	1	1	0	0	0	0	0	0	2	0	2	2	0	0	0	0
9	0	0	0	0	0	0	1	0	0	0	0	0	2	1	0	1	0	0	0	0	0
0	0	3	1	0	0	1	1.2	0	0	1	1	0	0	1	1	0	2	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	2	0	0	0	0
0	0	0	0	0	0	0	1.2	0	0	0	0	0	0	1	1	0	2	0	0	0	0
0	0	3	0	0	0	2	1	0	1	0	0	0	0	1	1	0	1	0	0	0	0
9	0	0	0	0	0	1	1.2	0	0	0	0	0	1	1	2	0	2	2	0	0	2
9	0	0	0	0	0	1	1.2	0	0	0	0	0	1	1	1	0	0	2	0	0	0

9	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	0	1	2	0	0	1
9	0	2	0	0	0	0	1	1	1	0	1	0	2	1	0	1	2	0	0	0	0
0	0	0	2	0	0	0	1.4	0	0	0	0	0	0	1	0	2	2	0	0	0	0
0	0	0	0	0	0	0	1.2	1	0	1	0	0	0	1	0	1	2	0	0	0	0
9	0	3	3	0	0	1	1.2	1	1	1	0	0	1	1	1	0	0	2	0	0	0
9	0	0	0	0	0	0	1.2	0	1	0	1	0	1	1	2	0	2	2	0	0	2
9	0	0	0	0	0	0	1	1	1	0	1	0	1	1	1	0	1	2	0	0	1
0	0	0	0	0	0	0	1.2	0	0	0	0	0	2	1	0	0	2	0	0	0	0
0	0	0	1	0	0	0	1.2	0	0	0	0	0	0	1	1	0	1	0	0	0	0
9	0	0	0	0	0	0	1	0	0	1	0	0	1	1	2	0	2	2	0	0	2
0	2	0	0	0	0	0	1.2	0	0	0	0	0	0	1	2	0	2	0	0	0	0
0	0	0	0	0	0	0	1.4	1	0	1	0	0	2	1	0	0	2	0	0	0	0
9	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	0	1	2	0	0	1
3	0	0	0	0	0	0	1.4	1	0	1	0	0	0	1	0	1	2	0	0	0	0
9	0	0	0	0	0	0	1	0	0	0	0	0	2	1	0	1	2	0	0	0	0
9	0	2	2	0	0	4	1.2	0	1	1	0	0	1	1	1	0	0	2	0	0	0
0	0	0	1	0	0	0	1.2	0	0	0	0	0	0	1	2	0	2	0	0	0	0
0	0	0	0	0	0	0	1.2	1	0	0	0	0	0	1	0	1	2	0	0	0	0

side
t
pes/Blinds
heater on/off

							ACTIVITY FLAGS						CLOTHING QUESTIONS(header for women's clothing only)								
													Underlayer			**Footware**			**Midlayer**		
Local fan on/off	Adjust clothes	Hot or cold drink	Took a break	Talked to others	Talked to staff	Ignored	MET(estimated)	Eat food	Hot drink	Cold Drink	Caffeine	Smoke	top	bottom	slip	socks	pantyhose	shoes	ss shirt	ls shirt	dress
													1	2	3	4	5	6	7	8	9
4.68	0.11	0.42	0.34	0.00	0.00	0.47	1.14	0.26	0.24	0.26	0.18	0.00	0.74	1.05	0.89	0.37	1.45	0.74	0.05	0.00	0.32
4.44	0.45	0.95	0.75	0.00	0.00	0.83	0.12	0.45	0.43	0.45	0.39	0.00	0.76	0.23	0.76	0.63	0.86	0.98	0.23	0.00	0.62
0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	2.00	3.00	3.00	0.00	0.00	4.00	1.40	1.00	1.00	1.00	1.00	0.00	2.00	2.00	2.00	2.00	3.00	2.00	1.00	0.00	2.00

			Outerlayers				SURVEY COMPLETION TIMES(sec.)					COMFORT MODEL INPUT AND OUTPUT VARIABLES									
skirt	pants	shorts	sweater	vest	jacket		Comfort	Affect	Activity	Clothing											
10	11	12	13	14	15	CLO					TOTAL	TAAV	TRAV	PAAV	VELAV	TCR	TSK	PWET	ET*	SET*	DISC
CL10	CL11	CL12	CL13	CL14	CL15																
0	0	0	0	0	0	0.36	26	71	18	80	195	22.53	22.40	9.74	0.13	36.83	32.22	6.00	22.43	20.50	-0.16
1	2	0	0	0	0	0.36	41	57	29	143	270	22.26	22.46	10.01	0.10	36.83	32.18	6.00	22.35	20.42	-0.16
2	2	0	0	0	0	0.69	24	49	18	58	149	22.17	22.25	10.06	0.10	36.83	33.64	8.26	22.21	23.14	-0.01
1	2	0	0	0	0	0.46	19	34	24	66	143	22.49	22.95	10.21	0.12	36.83	33.01	6.00	22.73	21.71	-0.06
2	2	0	0	0	0	0.55	18	31	19	54	122	22.88	23.05	10.27	0.13	36.82	32.93	6.00	22.96	22.26	0.00
2	0	0	0	2	0	0.62	28	86	31	122	267	22.70	22.90	10.19	0.10	36.83	33.64	8.19	22.79	23.13	-0.01
1	2	0	0	0	0	0.46	46	222	29	132	429	22.77	22.87	10.21	0.10	36.83	33.07	6.00	22.81	21.79	-0.06
1	2	0	0	0	0	0.36	15	33	15	17	80	22.86	23.12	10.05	0.10	36.81	32.13	6.00	22.98	20.80	0.00
0	0	0	0	0	0	0.42	26	77	17	44	164	22.96	23.32	9.98	0.10	36.83	33.03	6.00	23.11	21.76	-0.06
2	2	0	0	0	0	0.55	23	22	14	7	66	23.37	23.75	10.16	0.31	36.83	33.51	6.38	23.51	22.51	-0.02
2	0	0	0	2	0	0.62	24	47	26	10	107	23.37	23.61	9.73	0.10	36.82	33.51	6.00	23.45	23.26	0.00
0	0	0	0	0	0	0.42	19	45	14	8	86	23.35	23.69	9.57	0.10	36.82	32.65	6.00	23.47	21.82	0.00
2	2	0	0	0	0	0.69	28	37	14	48	127	22.94	23.12	9.64	0.10	36.82	33.53	6.00	23.00	23.30	0.00
1	2	0	0	0	0	0.36	16	29	15	21	81	23.13	23.45	9.60	0.10	36.82	32.27	6.00	23.25	21.10	0.00
1	2	0	0	0	0	0.46	41	110	19	119	289	22.77	23.02	9.54	0.11	36.83	33.08	6.00	22.85	21.84	-0.06
1	2	0	0	0	0	0.46	24	45	15	6	90	23.17	23.49	9.59	0.10	36.82	32.72	6.00	23.29	21.93	0.00
1	2	0	0	0	0	0.46	19	39	15	24	97	22.65	22.93	9.52	0.10	36.83	33.01	6.00	22.75	21.73	-0.06
1	2	0	0	0	0	0.43	30	91	21	67	209	22.46	22.94	9.65	0.15	36.81	32.17	6.00	22.69	20.88	0.00
0	0	0	0	0	0	0.63	38	96	19	53	206	22.58	22.82	9.68	0.10	36.83	33.63	8.00	22.66	23.09	-0.01
1	0	0	1	0	0	0.4	24	71	15	59	169	22.73	22.71	9.81	0.17	36.83	32.62	6.00	22.68	21.13	-0.11

0	0	0	0	0	1	0.51	23	68	14	29	134	22.85	23.15	9.77	0.10	36.82	32.76	6.00	22.98	21.98	0.00
1	2	0	0	0	0	0.6	17	40	28	60	145	22.67	22.93	9.77	0.10	36.82	33.03	6.00	22.78	22.44	0.00
2	2	0	0	0	0	0.57	15	47	10	44	116	22.46	22.80	9.85	0.10	36.85	33.60	10.51	22.58	23.02	-0.01
2	2	0	0	0	0	0.54	20	42	17	58	137	22.91	22.95	9.89	0.11	36.83	33.52	6.54	22.89	22.57	-0.02
1	0	0	1	0	0	0.4	26	36	17	8	87	23.18	23.24	9.97	0.10	36.83	32.95	6.00	23.17	21.64	-0.07
0	0	0	0	0	0	0.63	23	64	19	19	125	22.95	23.25	9.76	0.10	36.83	33.71	9.06	23.04	23.46	0.00
0	0	0	0	0	1	0.51	11	37	16	6	70	23.07	23.43	9.82	0.10	36.82	32.90	6.00	23.23	22.24	0.00
2	2	0	0	0	0	0.43	14	51	27	304	396	23.30	23.46	9.87	0.11	36.83	33.24	6.00	23.33	22.07	-0.04
1	2	0	0	0	0	0.43	18	51	19	19	107	23.47	23.71	9.81	0.13	36.83	33.38	6.00	23.53	22.28	-0.03
0	0	0	0	0	0	0.63	16	47	15	5	83	23.44	23.72	9.74	0.10	36.82	33.61	6.00	23.54	23.43	0.00
2	2	0	0	0	0	0.52	14	38	12	24	88	23.11	23.29	9.74	0.10	36.83	33.54	6.74	23.15	22.65	-0.02
2	2	0	0	0	0	0.43	8	15	22	4	49	23.27	23.58	9.77	0.11	36.85	33.46	8.79	23.33	22.42	-0.02
0	0	0	0	0	1	0.51	13	34	11	4	62	23.25	23.61	9.68	0.10	36.82	33.00	6.00	23.40	22.42	0.00
2	2	0	0	0	0	0.54	16	23	20	6	65	23.13	23.01	9.25	0.17	36.85	33.63	10.54	22.93	23.08	-0.01
1	2	0	0	0	0	0.6	16	23	11	9	59	23.08	23.36	9.43	0.10	36.82	33.25	6.00	23.18	22.84	0.00
1	0	0	1	0	0	0.4	19	44	16	7	86	23.49	23.49	9.45	0.11	36.83	33.10	6.00	23.41	21.88	-0.06
2	2	0	0	0	0	0.52	11	34	10	15	70	22.87	23.05	9.43	0.10	36.83	33.48	6.00	22.90	22.41	-0.02
2	2	0	0	0	0	0.54	16	27	21	5	69	23.23	23.41	9.40	0.15	36.83	33.59	7.42	23.23	22.91	-0.01

			Outerlayers				SURVEY COMPLETION TIMES(sec.)					COMFORT MODEL INPUT AND OUTPUT VARIABLES									
skirt	pants	shorts	sweater	vest	jacket		Comfort	Affect	Activity	Clothing											
10	11	12	13	14	15	CLO					TOTAL	TAAV	TRAV	PAAV	VELAV	TCR	TSK	PWET	ET*	SET*	DISC
1.13	1.26	0.00	0.08	0.11	0.08	0.50	22	53	18	46	139	22.94	23.17	9.78	0.12	36.83	33.11	6.64	23.02	22.21	-0.03
0.78	0.98	0.00	0.27	0.45	0.27	0.10	9	36	6	58	89	0.34	0.38	0.25	0.04	0.01	0.48	1.27	0.34	0.82	0.04
0.00	0.00	0.00	0.00	0.00	0.00	0.36	8	15	10	4	49	22.17	22.25	9.25	0.10	36.81	32.13	6.00	22.21	20.42	-0.16
2.00	2.00	0.00	1.00	2.00	1.00	0.69	46	222	31	304	429	23.49	23.75	10.27	0.31	36.85	33.71	10.54	23.54	23.46	0.00

TSENS	PMV	PMV*	HSI
-0.16	-0.39	-0.46	6.18
-0.16	-0.40	-0.46	5.90
-0.01	-0.09	-0.06	11.64
-0.06	-0.30	-0.33	7.85
-0.10	-0.11	-0.11	6.58
-0.01	-0.09	-0.09	11.55
-0.06	-0.29	-0.33	7.86
-0.23	-0.29	-0.34	3.54
-0.06	-0.29	-0.35	7.82
-0.02	-0.22	-0.30	9.85
-0.03	-0.01	-0.01	8.33
-0.14	-0.17	-0.21	5.73
-0.03	0.00	0.01	8.39
-0.20	-0.26	-0.32	4.30
-0.06	-0.29	-0.34	7.95
-0.13	-0.15	-0.19	5.89
-0.06	-0.30	-0.35	7.76
-0.22	-0.29	-0.34	3.79
-0.01	-0.10	-0.11	11.28
-0.11	-0.34	-0.40	7.29

-0.12	-0.15	-0.17	5.90
-0.09	-0.09	-0.09	6.77
-0.01	-0.09	-0.12	14.81
-0.02	-0.21	-0.24	9.29
-0.07	-0.30	-0.36	7.69
0.00	-0.02	-0.02	12.78
-0.10	-0.12	-0.14	6.46
-0.04	-0.27	-0.33	8.26
-0.03	-0.26	-0.32	8.59
-0.02	0.01	0.01	8.60
-0.02	-0.19	-0.23	9.51
-0.02	-0.20	-0.29	12.48
-0.09	-0.10	-0.12	6.81
-0.01	-0.07	-0.14	15.51
-0.06	-0.05	-0.06	7.56
-0.06	-0.29	-0.36	8.05
-0.02	-0.25	-0.29	8.55
-0.01	-0.14	-0.18	10.80

TSENS	PMV	PMV*	HSI
-0.07	-0.19	-0.22	8.37
0.06	0.11	0.13	2.73
-0.23	-0.40	-0.46	3.54
0.00	0.01	0.01	15.51

APPENDIX H

Recommendations to Improve Localized Thermal Distribution System Performance

Recommendations to Improve Localized Thermal Distribution System Performance

Based on our research work on localized thermal distribution (LTD), or task conditioning, systems during the past five years and the results of this study, the following general recommendations can be made regarding improving the performance of LTD systems.

1. Careful attention should be paid to integrating the design and operation of the LTD system with the overall HVAC system design and operation.
2. Individual units should be controlled by nearby building occupants to adjust their local thermal environments to satisfy their personal comfort preferences. At a minimum, occupants should have control over a suitably wide range of supply directions and velocities. We currently recommend that individually-controllable units supply up to a maximum of at least 1 m/s at the work location and possibly up to 1.5 to 2 m/s depending on future research findings.
3. An occupancy sensor should be associated with each occupant-controlled unit to respond to the presence/absence of the nearby office worker and to turn the unit on/off accordingly, provided minimum ventilation rates are maintained within the space. This will minimize the load from local fans and other components.
4. Units containing variable speed fans will have the best performance in response to occupant control and are recommended. Efficient fan motors should be incorporated into these designs.
5. Unit controls should be accessible and easy to use by the office worker. For example, controls located on the desktop are preferred over those at floor level. Inconvenient controls will not be used, defeating their main purpose.
6. Supply outlets should be designed to perform in a manner that responds quickly and effectively to occupant control. While diffusers with high induction ratios (e.g., swirl diffusers) reduce the risk of draft discomfort, jet diffusers may be preferred in circumstances where a broader range of control is desired. In addition, the location of the supply outlet in relation to the user may affect acceptability. More data on occupant satisfaction and use patterns with different systems are needed, and will presumably be obtained as experience with these systems grows.
7. The potential advantages of providing environmental control features beyond the basic supply direction and velocity (e.g., the Johnson Controls Personal Environmental Module) must be evaluated in relation to the added complexity, cost, and energy use of such a system. Additional performance data are needed to resolve this issue.
8. When possible, use an underfloor air distribution system due to advantages in reduced ductwork, reduced static pressures (distribution losses), reconfigurability, and convenient distribution of building services.
9. In retrofit applications where floor-based systems are not possible, supply units must be able to accommodate connection to an existing overhead air distribution system.
10. The widespread use of repeatable patterns of partitions and furniture in open plan offices presents an opportunity to develop LTD designs that are well-integrated into the office furnishings. Just as a floor-based LTD systems are easily adaptable to different configurations, a desk- or partition-based system that is compatible with an underfloor air distribution system by being "plugged into" specially-designed access floor panels could

increase flexibility and reduce installation costs associated with adapting to the requirements of changing tenants over the lifetime of the building.

11. Consider using a combination of supply outlet configurations to more closely match the spatially-varying conditioning requirements.
12. For cooling applications, to the extent possible, take advantage of the benefits over conventional well-mixed room air distribution associated with the upward movement of room air produced by supplying air at or near the floor level and returning it at ceiling level.
13. Optimize the range of occupant-controlled supply air conditions to provide the necessary local environmental control while limiting its impact to room air conditions within the occupied zone of the space (up to 1.8 m height). Allow temperatures and contaminant levels to increase above the occupied zone.
14. The positioning of the PEM's occupancy sensor is critical. If it is in direct view of the entrance to the workstation, the PEM can be turned on every time someone walks past. In addition to being properly shielded against walk-by turn-ons, the occupancy sensor should also be adjusted (using a filter or time delay) to ignore quick workstation visits, such as a co-worker dropping off some papers in an empty workstation. Of course, a time delay of this nature should not be too long, or the workstation occupant will be dissatisfied with the response time of the system.
15. When the workstation is unoccupied it may be desirable to allow the PEM air supply to completely shut off, provided there is adequate ventilation air being supplied at other locations in the space. If, for example, the PEM units were combined in an office with an overhead air distribution system, the overhead system could take care of minimum ventilation rates when large numbers of PEM units were turned off.
16. When an occupant calls for more air flow from the PEM, an improved strategy may be to open the return air damper (pulling air from the kneespace under the desk), thereby providing the requested air flow without having to increase the delivery of primary air.
17. Improvements should be made in the PEM task light dimming control to allow compatibility with a wider range of desk lights now available in the industry.
18. Local supply outlet temperatures should be maintained above 63°F to 64°F (17°C to 18°C) to avoid uncomfortably cool conditions for the nearby occupant.
19. Building operators and occupants who have access to local supply units should be properly trained to allow the operation and control of the LTD system to be optimized.
20. Control strategies for the building's central mechanical system should be well coordinated with the local control units. For example, since most LTD systems are used for cooling applications, if the ambient office space is overcooled by the ambient air distribution system, the cool air provided by local supply units will be unwanted by the occupants. By allowing the overall space temperature to rise, local cooling can then be used as needed to satisfy individual comfort preferences.
21. Space temperature control within the building should be adjusted to realize potentially available cooling energy savings. (1) Due to the increased air movement and controllability provided by the local supply units, maintain higher average space temperatures and allow greater temperature variations (slow drifts) to occur in response to the outside daily cycle. (2) Allow properly controlled thermal stratification to occur using an overall upward flow of air in the space. (3) Use zoning control strategies in which temperature setpoints can be

relaxed in less critical building zones, while occupied areas can be well conditioned by the local supply units.

22. Cost analyses should consider all aspects of LTD systems over the lifetime of the building, including first costs, maintenance and operating costs, adaptability costs, and potential cost savings associated with improved thermal comfort, ventilation efficiency, and worker productivity.