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Authors
Shendell, Derek G.
DiBartolomeo, Dennis
Fisk, William J.
et al.

Publication Date
2002-08-01

LBNL-51101

Final Methodology for a Field Study of Indoor Environmental Quality and Energy Efficiency in New Relocatable Classrooms in Northern California

Derek G. Shendell, Dennis Di Bartolomeo, William J. Fisk, Alfred T. Hodgson,

Tosh Hotchi, Seung-Min Lee, Douglas P. Sullivan, and Michael G. Apte

Lawrence Berkeley National Laboratory, Indoor Environment Department,
Environmental Energy Technology Division, Berkeley, CA

Leo I. Rainer

Davis Energy Group, Davis, CA

Submitted to the

California Energy Commission

August 2002

for the Public Interest Energy Research Program funded

LBNL High Performance Commercial Buildings Systems Program (HPCBS),

Element 6.2.2

ABSTRACT

The prevalence of relocatable classrooms (RCs) at schools is rising due to federal and state initiatives to reduce K-3 class size, and limited capital resources. Concerns regarding inadequate ventilation and indoor air and environmental quality (IEQ) in RCs have been raised. Adequate ventilation is an important link between improved IEQ and energy efficiency for schools. Since students and teachers spend the majority of a 7-8 hour school day inside classrooms, indoor contaminant concentrations are assumed to drive personal school-day exposures. We conducted a demonstration project in new relocatable classrooms (RCs) during the 2001-02 school year to address these issues. Four new 24' x 40' (960 ft^2) RCs were constructed and sited in pairs at an elementary school campus in each of two participant school districts (SD) in Northern California. Each RC was equipped with two heating, ventilation, and air conditioning (HVAC) systems, one per module. The two HVAC systems were a standard heat pump with intermittent 25-50% outdoor air ventilation and an energy-efficient advanced system, based on indirect-direct evaporative cooling with an integrated natural gas-fired hydronic heating loop and improved particle filtration, providing continuous 100% outdoor air ventilation at $\geq$ 15 ft^3 min^{-1} $occupant^{-1}$. Alternate carpets, wall panels, and ceiling panels were installed in two classrooms—one in each pair—based on the results of a laboratory study of VOC emissions from standard and alternate materials. Numerous IEQ and outdoor air quality and meteorological parameters were measured either continuously over the school year or as integrated school day samples during the fall cooling and winter heating seasons. Details of the RC designs, the field monitoring methodology including handling, storage, transport and management of chemical samples and data, and analyses to be conducted are presented.

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1.0 INTRODUCTION

The purpose of this report is to document the field study design and methods used in the California Energy Commission (CEC) funded High Performance Commercial Building Systems (HPCBS) Element 6 field study (Task 6.2.2). The overall goal of this task is to evaluate the costs and benefits of technologies simultaneously improving building energy efficiency and indoor environmental quality (IEQ). Building designs attempting to provide such simultaneous benefits are not typically considered. In this field study we have selected to demonstrate such benefits in relocatable classrooms (RCs). A number of commercial building types could be studied; however, RCs are particularly well suited and topical in an era of school facilities expansion and modernization, given societal energy efficiency concerns. Detailed monitoring data will simultaneously document energy usage and IEQ conditions since building usage patterns and environmental conditions strongly influence both.

The use of RCs in California schools has increased dramatically in recent years due to state and federal initiatives for class size reduction at K-3 grade levels, and increasing numbers of students due to population growth and immigration. An estimated 75,000-86,500 (as of 1997-98) RCs, or one of every three classrooms, are currently in place in California schools and house nearly two million students (EdSource, 1998; Waldman, 2001). The School Facilities Manufacturers Association, comprised of the major modular construction companies serving CA and western Nevada, have built and will continue to build an estimated 6000-8000 or more standard RCs each year during this decade, in addition to special orders, to meet demand (Sarich, 2001). The portable/relocatable classroom manufacturing industry estimated a projected growth rate of 20% per year nationwide for this decade (Lyons, 2001).

RCs are popular in school districts growing or changing demographically. In addition, RCs are often liked by teachers who have been instructing in smaller, older conventional classroom facilities with usually poorer quality of lighting and heating, ventilation, and air conditioning (HVAC) systems. Additionally, the teachers appreciate having air conditioning and individual control of the HVAC systems, which are standard equipment on most RCs. There are, however, many complaints, both documented and anecdotal, frequently discussed in the newspapers regarding the IEQ and especially air quality in the RCs. Most frequently, these issues stem from some type of water damage and/or from inadequate ventilation.

The cost of supplying energy for lighting, ventilation, and space conditioning to school facilities presents a burden on school districts with tight budgets. School energy use is a peak load burden on the electricity grid. The addition of conditioned floor space to schools, e.g., RCs, increases energy bills. Although provided with RCs and attractive to their occupants during hot and/or humid months, air conditioning presents a new cost for many schools. Energy efficiency in RCs is therefore compelling to many public and private stakeholders.

From the standpoint of energy usage and IEQ, the HVAC system is a critical component of RC design. Operating costs, electric demand, and environmental constraints influence design decisions such as equipment configuration, energy efficiency, and fuel source. The need to maintain minimum ventilation rate for removal of occupant bioeffluents and air contaminants emitted by building materials and classroom furniture, cleaning and teaching products requires consumption of additional energy to provide and condition outside air. The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) Standard 62-1999 (ASHRAE, 1999) recommends and the State of California Building Standards and Occupational

Safety and Health Codes require a minimum ventilation rate of 15 ft3 min^{-1} $person^{-1}$ (CFM) (CCR, 1995 and 2001; CCR, Title 8 and 24) in nonresidential buildings.

A methodology for the Element 6, Task 6.2.2 field study of energy use and IEQ in RCs was devised for the following purposes:

1.) To test and collect data on advanced HVAC technologies suitable for RCs to demonstrate energy efficient performance and IEQ improvements.

2.) To collect real-time and integrated sample data on energy use patterns, RC operation, and IEQ parameters in RCs to improve computer models which then can estimate the energy savings potential and IEQ effectiveness for advanced HVAC technologies in RCs and other building types for a range of California climate regions. This information is expected to help school districts and their consultants save energy and improve the IEQ of new and retrofitted California school classrooms.

3.) Evaluate source control measures for targeted toxic and odorous volatile organic compounds (VOCs) in RCs and share the results widely with RC manufacturers, materials manufacturers, and other stakeholders to promote healthier learning and teaching environments in California schools.

2.0 METHODOLOGY

The field study included specific phases. These were:

- School district and RC manufacturer recruitment
- RC design specification and construction
- RC siting at schools and installation of energy and IEQ monitoring instrumentation
- Field measurements for energy and IEQ data collection for 8-10 weeks during fall cooling and winter heating seasons and, as possible, transitional periods including unoccupied holidays during the 2001-02 traditional public school year. Unoccupied weeknights, weekends, and holidays are separately coded from school day hours.
- Data management and analysis with descriptive statistics and regression models

2.1 Overall Study Design

The HPCBS RC energy efficiency implementations were based upon earlier work by Davis Energy Group (DEG) with Pacific Gas and Electric Company (PG&E) which culminated in the PG&E Premium Efficient Relocatable Classroom (PERC) program (DEG, 1997). The energy upgrades of the basic RC structure common to the four new classrooms in this study are shown in **Table 1** (Apte et. al, 2001). The envelope energy efficiency measures selected for the HPBCS project were similar to the PERC Package 1 with two exceptions-- the HPCBS RCs have a white roof ("Cool Roof") coating (California AB 970, 2001) and a nearly continuous vapor barrier in the ceiling. In addition to the standard wall-mount heat pump system, each HPCBS RC has an Indirect/Direct Evaporative Cooler (IDEC) for cooling and an incorporated gas-heated hydronic coil for heating.

The overall study design followed the proposed protocol outlined below.

- Working collaboratively with the RC manufacturers, LBNL fabricated four RCs with the Package B HVAC system for this study. Each classroom had two simultaneously-installed HVAC systems: a reference-case heat-pump air conditioning system typical of those used routinely; the PERC Package B system. The participating schools had ordered standard RCs for the 2001-02 school year with summer 2001 delivery.
- On a weekly or bi-weekly schedule over a period of 8-9 weeks during the heating and cooling seasons, operation switched between the two installed HVAC systems. The non-operating system was sealed off to prevent routes of air leakage or pollutant migration.
- HVAC energy use and a number of IEQ and outdoor parameters including carbon dioxide concentrations as an indicator of per-occupant ventilation rates, air temperature and relative humidity at numerous indoor sites, noise, and particle counts and estimated concentrations in different aerodynamic diameter size ranges were continuously monitored.
- We periodically monitored other parameters, i.e., once a week, including the full array of thermal comfort parameters required to quantitatively assess comfort (ASHRAE 55, 1992) and indoor and outdoor target toxic and odorous VOC concentrations including formaldehyde and acetaldehyde.
- Weather stations were installed to collect wind speed and direction data at each study site. These data will become part of the energy data analysis and modeling by DEG.
- Daily occupancy data were obtained from class records as raw attendance figures from school administrative staff (see Appendix 4.1).

Energy and IEQ benefits will be based on a comparison of data from baseline HVAC operation to data from enhanced HVAC operation by season and school district (climate zone) and possibly by RC due to influences of human behavior.

2.2 Recruitment

We took the approach of locating Northern California RC manufacturers with the plan to develop working relationships leading to referrals to school districts (SDs) with RCs ordered for delivery in the summer of 2001 for the upcoming traditional academic calendar. We contacted five Northern California RC manufacturers and three in Southern California, by mail and/or by telephone follow-up. We visited five RC manufacturers, three in Northern California and two in Southern California, and described the project's goals and plans. Four manufacturers expressed interest in participating in the study by November-December 2000. LBNL staff met with the leadership of three Northern California RC manufacturers at their production facility offices in December 2000. Three manufacturers supplied lists of Northern California SDs with pending RC orders, which they believed would be interested in the project. Their recommendations were based on knowledge of the SD interests and/or maintenance practices.

From the SD lists we were able to target SD with cooling and heating demands suited for our studies. We selected two areas to provide varied performance data for the RCs based upon climate. These were the Central San Joaquin Valley and the Bay Area Transition Zone. We wrote letters to school facilities or maintenance and operations managers of the SDs on the manufacturer lists in these climate zones. We received favorable responses from three candidate school districts favoring one RC manufacturer, American Modular Systems (AMS). One other SD was interested but preferred a Southern California RC manufacturer, which only had an office in Northern California at the time. The three candidate SDs were Modesto City Schools (MCS), Lodi Unified SD, and Cupertino Union SD (CUSD).

Following meetings with SD staff in January 2001, each was interested but only two SD gained permission from their Superintendent and Board of Education to participate in the study—MCS and CUSD. After visits by LBNL staff to two possible school sites in each SD and meetings with those principals, each SD approved a primary school for the study. Each SD had RCs on order from AMS likely to serve grades K-4 at those schools.

2.3 RC design

2.3.1 Standard RC design

The most common RC configuration is the two module 24' by 40' (960 ft^2) classroom, although a number of other styles, including a three module 960 ft^2 unit and four module, two story design are available. Other than the modular steel framing system used in the RC, the construction methods and materials used are similar to those in site built school construction. A range of choices are available in the construction and interior finish materials market; building, fire and environmental codes, economics, and design goals and/or constraints by construction project determine SD selections in consultation with architects and engineers. For example, the T-12 ballast for overhead lighting is standard for many RC manufacturers, while T-8 may be ordered by a SD expecting to realize savings over time after higher initial costs.

2.3.2 HPCBS Modified RC design

The HPCBS RC design for this study used available energy efficient and low-emitting construction and interior finish materials and methods including additional wall, floor, and ceiling insulation; ceiling vapor barrier **(Figure 1)**; "Cool Roof" reflective roof coating **(Figures 2a-b)**; low-emissivity window glazing; and, efficient T-8 fluorescent lighting (DEG, 2000). Further details in each category will now be provided.

2.3.2.1 HVAC systems

Each of the four study RCs were equipped with two HVAC systems: a standard 10 SEER heat-pump system (Bard 3.5 ton unit, WA421-A, Geary Pacific, CA), and an energy-efficient IDEC **(Figure 3)**. CUSD paid for the optional Bard continuous room ventilator, which increases the percent of outdoor air in the filtered supply air from ~25% to 25-50% based on manual settings when operated. The IDEC supplies continuous ventilation at ≥7.5 L s^{-1} (15 CFM) per person even when heating or cooling is not required. Additionally, compared to the standard heat-pump system, an IDEC consumes about 70% less cooling energy. Furthermore, since the IDEC has no compressor and a very quiet fan, the noise output from the system is lower. Incorporated into the IDEC is an 85% efficient (AFUE) gas-fired hydronic space heating system and three-part inlet filter system **(Figure 4)** with 65% ASHRAE dust spot efficiency (Apte et al., 2001).

Both the IDEC and the heat pump controls, as currently designed using thermostats, require the systems be turned on manually to provide the required ventilation **(Figure 5)**. In the case of the heat pump system, this action is tied to the temperature set point; outside air is only supplied when heating or cooling is needed. For the last three weeks of school, LBNL and DEG installed motion/occupancy sensors (Watt Stopper CI-24, Santa Clara and Livermore, CA) connected to the IDEC fan. Field experience and data during the school year suggested teachers were not always operating the IDEC during occupied hours. The sensor, and an upgrade to the IDEC control program, ensured the minimum code ventilation would be provided whenever an occupant was in the room and the IDEC was not on for at least ten minutes.

Each of the four RCs was the standard 24’ by 40’ (960 ft^2) classroom configuration made from two individually constructed and shipped modules 12’ by 40’. The ceilings were 8’4” high from finished carpeted floor to acoustic ceiling tiles in T-bar grid, instead of the standard 8’6”, to accommodate the IDEC plenum with custom encasement and extra flexible ducting for runs to three supply air diffusers. **Figures 6a-c** are architectural engineering drawings with plan and outside back wall views of the RCs with the HVAC units and associated components located and mounted to meet California fire and construction codes. Each of the two modules for each of the four RCs had one of the two HVAC systems installed on the back wall and in the attic space.

For more details on the HVAC system selection, including individual components, please refer to Apte et. al (2001).

2.3.2.2 Building Shell

Each of the four RCs had the same basic California Division of the State Architect-approved building shell. Each module had one HVAC installed. The IDEC components including the heating system weighed less than the Bard packaged unit. The back wall was framed with 2” by 6” rather than the standard 2” by 4” wood studs to accommodate the addition of the IDEC plumbing.

Each RC received a “cool roof” application (**Figures 2a-b**) based on the implementation of California AB 970 using white elastomeric paint from National Coatings, Inc. (A500 AcryShield, three gallons/100 ft^2 applied in 2-3 coats, Camarillo, CA).

Table 1 describes the insulation specifications implemented in each RC. The areas of the RC considered with respect to insulation were walls (R-13), roof (R-30 for CUSD and R-19 for MCS), roof beam (R-13), and floor (R-19). Insulation batts for the roof and roof beam were covered with foil. LBNL technicians folded over the sides and tucked them into the roof beams, and carefully patched any holes made during construction with aluminum foil tape, to approach the continuous vapor barrier not available to AMS in fall 2001 (**Figure 1**).

2.3.2.3 Fenestration

Although the study of daylighting was not a goal of the HPCBS Element 6 RC package, energy efficient glazing and the provision of operable windows for optional natural ventilation was a priority. Each of the four field study RCs complied with SD architectural drawings for a large front wall 4'H by 8'W window with sliding panes from each side. The HPCBS Element 6 package, however, upgraded the quality of the window glass (Table 1) to Sungate 1000 Solar Control Low –E Glass (PPG, CA). This glass was characterized by a minimum visible transmission of 72% and a maximum solar heat gain coefficient of 46%. The SD specifications also included one 4'H by 4'W back wall window with a sliding pane from one side. The back window size had to be reduced to 3'H by 4'W windows for the CUSD RCs and 4'H by 2'W windows for the MCS RCs, with sliding panes from one side. CUSD RCs received Sungate 1000 Solar Control Low –E Glass for these back windows, while MCS RCs received the nearly identical Sungate 500 Low –E Glass. Given the small areas of these rear windows, these different coatings were not expected to have a significant effect on the two pairs of RCs.

2.3.2.4 Lighting

As previously stated (**Table 1**), each of the four field study RCs were outfitted with T-8 lighting fixtures. MCS had specified T-12 fixtures for their RCs, and while

CUSD had ordered T-8 fixtures, the HPCBS Element 6 package provided higher quality products, e.g., special reflectors. Each RC, to meet current requirements for a minimum of 50 foot-candles light at desk or working height, received 12, not the standard 10, fixtures; there were six, not the standard five, fixtures per module. Each fixture was a two-lamp T-8 fixture (Metal Optics, P/N A12125120GEBLP735, including 2x4-grid troffer with 0.125 acrylic lens and miro 4 80% efficient reflector, Lithonia Lighting) with electronic parallel 120-volt ballast (2G232, Lithonia Lighting). The standard RC configuration for AMS provided five fixtures per module, in a straight line down the center of each module. This would not have been possible on the IDEC sides of the study RCs due to the third flexible supply air ducting and the existing conduit runs, especially for CUSD RCs. Therefore, an alternative design was devised for the three fixtures in the back of each RC module. This alternative design ensured the two modules were mirror images of one another for aesthetics and to concentrate lighting in classroom areas most frequently used, including the student desk area, dry-erase board area, teacher work areas, and the sink area. **Figure 7** provides a simple sketch of this design.

2.3.2.5 Interior Materials

The two participating schools each received a pair of field study RCs located side-by-side. These RCs were designated “A” and “B” for simplicity. “RC A” received some alternative interior finish materials and “RC B” was constructed and finished with only standard materials. Standard materials were those generally used by RC manufacturers and/or ordered by the SD. Eight categories of interior finish and flooring construction materials, including adhesives and finishes, were inventoried and assessed qualitatively and quantitatively with environmental chamber tests. For details and results of the assessments, please refer to Hodgson et. al (LBNL-48490, July 2001) and Hodgson et. al (2002). Tables 11-12 of Hodgson et. al (2001) are provided in this report as **Tables 3**

and 4, respectively, for quick reference and to summarize the results of interior materials selection and testing criteria and results. As has been mentioned in the study goals, the school day integrated toxic and odorous VOC sampling, described in detail later, investigated the impacts of material selections as well as various teaching and cleaning products brought into the RCs on indoor air quality.

2.3.2.6 Modifications to Accommodate Environmental Monitoring Instrumentation

LBNL wanted to accommodate the IEQ and outdoor monitoring equipment in cabinets or enclosures to protect these sensitive, expensive apparatus and computers from the natural elements and vandalism. At the same time, LBNL did not want to impose on the teachers. The LBNL goal was to take up no storage or teaching space expected to be provided in a new RC by each SD. LBNL also realized young children are curious, learning through use of their senses including touch. Thus, instruments and computers needed to be out of sight and/or reach of 5-10 year olds.

Figure 8a shows the finished LBNL-designed indoor cabinet (18" H by 24" D by 48" W) built at AMS (Sierra Cabinets, CA). Each RC received this cabinet, located on top of the RC storage closet/cabinet (6'8" H by 24" D by 48" W) in the back corner of the CUSD RCs, or mounted on the back wall corner above the sink area in the MCS RCs.

Figure 8b shows a LBNL modified white, waterproof outdoor enclosure (Hoffman, Inc., San Francisco, CA). Outdoor enclosures were mounted at AMS prior to delivery of modules to the school sites. There was a larger and a smaller outdoor enclosure for RC A and RC B, respectively. Each SD already planned to build a fence around the backside of the RCs where the HVAC systems and utility hookups were located. At the CUSD site, their contractor did not provide ample space between the fence line and the back of the building, and especially between the mounted HVAC units and the fence line. To conduct field tasks, LBNL technicians devised a removable shelf system connected between the fence and the inside lip of the outdoor enclosure to allow the enclosure to open and to safely mount the flat-screen LCD computer monitor (**Figure 9a**).

For late fall 2001 and the heating season field work January-March 2002, LBNL technicians developed a system for rain protection during field visits by employing commercially available waterproof UV-resistant tarps at the larger RC A outdoor enclosures (**Figures 9b-d**). Field tasks at the smaller RC B outdoor enclosures required no special accommodations.

Specific locations of individual IEQ and outdoor monitoring instruments will be highlighted in later sections of this report.

2.4 Field Instrumentation and Data Collection Design

Sensors for quantitative measurements described in the energy and indoor and outdoor environment monitoring sections were analog, digital state, or digital pulse in nature. A majority of the sensors were connected with appropriate shielded cabling and conductor wiring (Belden) to a 32 channel analog multiplex board (P/N CIO-EXP32, Measurement Computing Computerboards, Inc., Middleboro, MA) which was then connected to a LBNL LabView 5 software-based central data acquisition system (CDAQS, **Figure 8a**). The components (Measurement Computing Computerboards, Inc., Middleboro, MA) of each CDAQS included:

- A 16 channel 200kHz 16-bit resolution A/D card with two channel 200kHz D/A 24DIO advanced triggers (P/N PCI-DAS1602/16)
- Two sets of interface cables and 2x50 connection blocks (C100FF-3 and SCB-50)

- A 48-bit high drive 64mA digital I/O board with 15 16-bit counters (PCI-DIO48H/CTR15)
- Various accessories (ICAHI507, ICADAMP, DCPG408).

A number of digital signals from sensors were connected directly to inputs on the digital I/O board. Appendix A.1 provides more detail. The CDAQS computer was an Intel Pentium III 800 MHz processor Micron PC --one per school site-- housed in the LBNL indoor cabinet of RC A. An uninterruptable battery backup power supply (UPS) was installed to provide temporary power to the CDAQS during short power blackouts.

2.4.1 Energy Monitoring

2.4.1.1 Electricity

The four parameters for assessing the use of electricity in each RC were total building power, conventional HVAC heat pump power, IDEC power, and lighting power. These were designated watt0, watt1, watt2, and watt3, respectively, for the CDAQS and for data management and analyses. Digital pulse generating P-Series WattNode sensors were used; these were set up in their own electrical access panel inside each RC (**Figure 10**). The specific types of P-Series WattNode sensors (Continental Control Systems, LLC, Boulder, CO) used for the four aforementioned parameters, each with accompanying digital pulse power meters (WNA-1P-240-P), were two 50A CTs (CTS-0750-050), two 50A CTs, one 15A CT (CTS-0750-015), and one 15A CT, respectively. The LBNL computer and indoor and outdoor environmental monitoring equipment plugged into RC outlets used a negligible amount of electricity, monitored with plug loads on watt0, relative to the lighting and HVAC system in operation. Each six-minute data point per energy sensor provided the total energy used by the circuit during the six-minute period.

2.4.1.2 Natural Gas

The advanced HVAC system's natural gas-fired hydronic loop used a commercially available instantaneous water heater; refer to Apte et. al (2001) for details. Water heater natural gas use was quantitatively assessed in two ways. First, for continuous measurements, a digital pulse sensor was used (Equimeter R275P, **Figure 11**). The sensor's pulse release was set to 1.0 ft^3 natural gas/pulse. For standard natural gas this is equivalent to approximately 0.01 therms or 1000 btu depending on the heating value of the gas. Pulses summed over six minutes were sent to the CDAQS. Second, LBNL technicians recorded the four-digit number off the gas meter once a week in the early morning and in the late afternoon. One unit of this meter was equal to 2.5 ft^3 of gas used.

2.4.1.3 HVAC Conditions and Set Point

The energy monitoring portion of the field study included assessment of HVAC conditions and the set points directed by the individual teachers during HVAC operation. LBNL technicians collected quantitative and qualitative information on checklists, including the HVAC settings used, the thermostat set points of both the conventional and advanced HVAC system (**Figure 5**) four times per day—before school, recess, lunch, after school—and teacher comments (Appendix A.3.2 and A.4.4). LBNL measured temperature (T) in the hydronic loop with analog sensors (YSI 44018 sensor and YSI 44303 resistor "Thermilinear Network," Yellow Springs Instruments) and the water T at the entrance and exit of the coil with threaded YSI 09x 316S stainless steel probes (Yellow Springs Instruments). Details on the YSI components are provided in the indoor and outdoor T monitoring section. The IDEC pump operation status during heating was monitored off of relay contacts located at the pump relay box. The IDEC set point was recorded with an analog sensor customized by DEG. The IDEC status, i.e., whether on or off in “auto” mode for ventilation, was recorded with a digital state sensor customized by DEG. Any IDEC operation in “cool” mode could be ascertained from T, RH, and watt2 data.

2.4.2 Air Quality Monitoring Indoors and Outdoors

LBNL technicians collected quantitative and qualitative information on checklists (see Appendix A.5.3 and A.5.4) and measured air concentrations of several parameters either continuously over the school year or as integrated school day samples during the fall cooling and winter heating seasons.

2.4.2.1 Carbon Dioxide

The system for each RC consisted of a continuous operation ZFP-9 carbon dioxide (CO_2) gas monitor (California Analytical Instruments, Orange, CA) for sampling indoors. The monitors collected samples at a flow rate of about 0.6 liters min^{-1}, with a response time no greater than ten seconds. This monitor had a repeatability of ±1% of full scale 0-3000 ppm, zero point drift of ±10% full scale in six months, and operated within T and RH ranges expected in the RCs year-round. LBNL checked zero and multipoint CO_2 outputs of the monitors on each weekly visit **(Figure 12)** and corrected in data reduction for calibration drift. Appendix A.3.1 provides the procedure and field data sheet, one per RC, for multipoint calibrations at percentage of 2788 ppm. In one RC of the pair of RCs at each participating SD’s elementary school, there was an automatic two-valve system to multiplex the indoor and outdoor sampling lines to the CO_2 monitor. Additionally, in each of the four RCs there was a manually operated sampling line point of disconnection, using luer fittings, to provide an inlet for calibration bag connection to the CO_2 monitor in the outdoor enclosures. For the automatic two-valve system, a signal from the CDAQS program coordinated valve operation.

CO_2 was measured continuously and the CDAQS logged voltage output from the monitor; data were saved as six-minute averages on a 0-2.5 V scale equal to 0-3000 ppm. The monitors were set to sample indoors except for in RC A, where three times a day 18 minute outdoor measurements were conducted and saved as three, six-minute averages. The RC A CO2 sampling valve at each SD was switched to outdoors at approximately 7:30-7:48, 13:30-13:48, and 15:30-15:48.

2.4.2.2 Particle Count and Size

Pacific Scientific Instruments (PSI, Grants Pass, OR) MetOne 237B particle counters with six size bins were used in this field study. The six size bin ranges, in aerodynamic diameter, were 0.3-0.5 µm, 0.5-0.7 µm, 0.7-1.0 µm, 1-2 µm, 2-5 µm, and 5-10 µm. The nominal factory-calibrated flow rate of the device was 0.1 CFM (2.83 liters min^{-1}). The instrument was run on 110 VAC but could rely on internal battery operation for eight hours before shutdown during a power blackout; combined with the CDAQS UPS this provided some protection against power outages with respect to data storage. Coincidence error of 3-6% was expected; the variation was a function of the specific instrument. PSI stated the coincidence error would be < 5% at 2 million particles per cubic foot of air sampled at 0.3 micrometers, the smallest size bin. Six instruments were used in this study; three were older (purchased 1995-96), while three were purchased new in 2001. New instruments could not report cumulative or differential particle counts over 9,999,999; the limit was 999, 999 for the older instruments. Thus, the limit LBNL considered was 999, 999.

LBNL determined the proper sampling cycle, composed of two variables “period” and “hold,” to avoid loss of overflow data to the alarm buffer. The “period” is the time the instrument is making particle counts, and the “hold” is the time when no counting is conducted, i.e., the time in between sampling cycles when it was possible to upload data from the instrument to the CDAQS. LBNL determined a sample cycle so each data point was a six-minute average of 12 sample cycles composed of a 29 second “period” and a one second “hold.” This cycle avoided overflow of data into the alarm buffer and accounted for the instrument’s coincidence error, and provided adequate sampling statistics. The audible count limit alarm beep for a sampling cycle was disconnected to avoid annoying classroom occupants. To achieve the greatest precision and to compensate for the slight delay—up to one second—during automatic downloading of data to the CDAQS, LBNL technicians completed setting date and time one second before the actual time during initial installation and configuration of each unit in the RCs. Counters were operated in automatic mode for indefinite cycling and continuous monitoring. The thermal printers were turned off. The baud rate was set to 1200 to allow for reliable data transfer to the CDAQS. Each counter was housed in, and plugged into a wall outlet, inside the LBNL indoor cabinet to provide sound attenuation. The location number of the unit was recorded and matched with the serial number.

For indoor sampling, 0.125” ID PVC Tygon tubing extended out from the MetOne 237B inlet, through a hole drilled in the front lower panel lip of the LBNL cabinet. The 237B “isokinetic probe” was connected to the inlet of the PVC Tygon tubing, and faced into the classroom space. This design allowed for minimal yet flexible bends and minimal tubing losses through impaction during sampling. The outdoor sampling configuration was a similar design. The PVC Tygon tubing extended from the MetOne 237B inlet, out of the indoor cabinet, through the back wall within a conduit, and emerged through a piece of copper tubing to an area immediately above the LBNL outdoor locker beneath the eaves of the RC roof. Thus, the sampling point reached ambient air ~2.25-2.50 m. above ground and ~1 ft. away from the back wall of RC A. The outdoor "isokinetic probe" was oriented nearly vertically downward but angled away from the wall. At the school in each participating SD, there were indoor samples for each RC and one outdoor sample to represent the pair of adjacent side-by-side RCs.

Each MetOne 237B received a factory calibration by PSI, with NIST traceable mono-dispersed polystyrene spheres. LBNL technicians also conducted an instrument comparison procedure in a laboratory room for the group of instruments during summer 2001. This process involved cross-comparison between and among older and newer instruments. PSI re-calibrated two units, one new and one old, in August 2001. Other instruments were later sent back during the school year due to circuitry or pump failure problems requiring professional maintenance or part replacement. Thus, some data were lost.

The flow rate of each particle counter was set and confirmed at PSI at the nominal 0.1 CFM(2.83 liters min^{-1}). The flow rate was measured for each PM counter once in the afternoon (cooling season) or morning and afternoon (heating season and transitional periods) during each LBNL field visit before calibrating CO_2 analyzers and switching HVAC systems. Flow rates were measured with BIOS DryCal with low-flow cell calibrator (available from SKC, Pittsburgh, PA) and recorded on field data sheets (see Appendix A.3.2). The BIOS was connected directly to the PSI "isokinetic sampler" at the indoor cabinet panel lip with flexible tubing and reducer fittings, allowing air flow to enter the system through the BIOS **(Figure 13).** After flow measurement, to set the flow rate as close as possible to the PSI nominal flow, a "set screw" of a valve in the MetOne 237B was adjusted. LBNL technicians confirmed both the operation settings and that the sampling lines were securely attached, unobstructed, and prepared for the continuation of sampling. In addition, if a counter was not operational, e.g., pump failure, it was maintained on-site or removed, repaired and replaced in the RCs at the next field visit.

LBNL operated the particle counters in cumulative mode to upload data, in ASCII, as cumulative counts to the CDAQS; differential counts for each of six size bins were computed during data reduction. Each data point saved by the CDAQS was a six minute average. RS-232 cables were connected from each PM counter to the CDAQS. The data port was open so each finished count, i.e., data of a sampling cycle, proceeded to the CDAQS to avoid loss of during a power blackout. As previously described, the established sampling cycle avoided the need to recognize and download data from the alarm buffer.

2.4.2.3 Toxic and Odorous Volatile Organic Compounds (VOC),
including Formaldehyde and Acetaldehyde

VOC and aldehyde active sampling systems, located on shelves in the previously described LBNL outdoor enclosures (**Figure 8b**), consisted of peristaltic pumps controlled by programmable timers (Fischer Scientific or VWR) and their respective multisorbent tube and DNPH cartridge samplers (**Table 5**; refer to Table 2, Hodgson et. al, 2001). The peristaltic pumps were constructed from a Masterflex 115V Standard pump drive (P/N 07543-xx, xx = 06 rpm for VOCs and 60 rpm for aldehydes) and a Masterflex Standard pump head (P/N 070yy-21, yy = 14 for VOCs and 16 for aldehydes, as Norprene tubing size for sampling lines) (Cole Parmer Instrument Company, Vernon Hills, IL). Sampling systems were used for measuring integrated school day air concentrations of two target aldehydes, formaldehyde (H_2CO) and acetaldehyde (CH_3CHO), and target toxic and odorous VOCs inside each RC and outdoors at each school. Specifically, sampling systems consisted of a double head pump controlled by the timers for collecting single or duplicate VOC samples, and a single head pump controlled by the timers for collecting an aldehyde sample.

The sampling pump tubing transitioned within the outdoor cabinet to 0.125” OD copper sampling lines (Figure 14a-b). The copper sampling lines then either:

- Traveled in a conduit into the LBNL indoor cabinet and transitioned to sampling ports on the cabinet’s 4” panel lip facing into the RC indoor air, ~2.25 m above the floor and ~0.7 m (26 in.) away from the back wall. The sampling ports had female luer fittings where aldehyde samplers with male luer fitting ends were attached, or 0.25” Swagelock fittings where VOC samplers were attached (Figure 15).
- Exited through holes out the side of the LBNL outdoor enclosure away from the walls and Bard HVAC unit if in operation. Copper outlet tubes extended ~3 ft. from RC back wall. Samplers were attached exactly as they were indoors.

Inlet and outlet sampling lines and locations were numbered as follows:

- RC A samples are 3 = ALD, 4 = ALD2 (duplicate), 1 = VOC1, 2 = VOC2
- Outdoor samples are 9 = VOC1, 10 = VOC2, 11 = ALD
- RC B samples are 7 = ALD, 8 = ALD2 (duplicate), 5 = VOC1, 6 = VOC2**.**

The sampling system was fully automated. The timers were programmed to start on Tuesday, Wednesday, or Thursday as established in the study design; programming was confirmed for the following week at the end of the present week’s sampling. The samplers operated from 7:00-7:20 AM and 8:15-15:35 at CUSD and 7:00-7:20 and 7:50-15:00 at MCS. The earlier run period was to warm up the pumps. LBNL technicians installed VOC tubes and aldehyde cartridges according to a tight schedule and protocol (refer to Appendix A.2.2.1 and A.2.2.2 for daily field work schedules in CUSD and MCS, respectively).

Sampling systems flow rate measurements, expected to be near 130-160 cc/min for aldehyde sampling and ~5-6 cc/min for VOC sampling, were conducted with sampling media in-line in the morning and afternoon within ~30 minutes after the start and before the end of sampling, respectively (**Figures 16**). Appendix A.3.3 shows field data sheets used by LBNL technicians. For flow measurements, a simple bubble tube with mild aqueous soap solution was used for VOC samples, and the previously described BIOS DryCal low flow cell calibrator was used for aldehyde samples. The required data and calculations included recorded times including the average in seconds (for VOCs, with bubble tube), calculated average flow rates in cc min^{-1}, sampling duration, and volumes of air sampled. Flow rate measurements were taken at the tubing exit of the respective active sampling system.

Before and after use, VOC multisorbent tube samples were capped with nylon caps and Teflon ferrules, and the DNPH cartridge aldehyde samples were capped as well. The VOC glass storage tubes and the aldehyde post-sampling foil storage pouches were labeled ahead of time to speed handling in the field; aldehyde cartridges were also labeled. The foil pouches and the aldehyde cartridges were labeled SCCL-MMDDYY (S = SD/school, CC = classroom number, L= location #, MM = month, DD = day, YY = year). The VOC tubes were permanently numbered; the glass storage tubes were similarly labeled SCCL-MMDDYY-NNN where NNN was the sorbent tube number. The outdoor sample labels included CC = "OA." The VOC and aldehyde field blanks were labeled with "SCCL = 0000."

Duplicate aldehyde samples, 10% overall and collected only inside the RCs, were collected with a separate but identical peristaltic pump located with the other pumps. Field blanks, 10% overall for each sample type, were collected. Duplicate samples and field blanks were collected in each season in each SD.

VOC tubes and aldehyde cartridges were transported to and from LBNL in a small cooler with blue ice packs. Samples were returned to LBNL the same evening if possible or the following morning. The samples were stored in a refrigerator until extraction and analysis. The capped VOC tubes, in their glass storage vials, were stored in sealed plastic bags. The capped aldehyde cartridges, each in a sealed foil pouch, were stored in aluminum cans with activated charcoal pellets.

Appendix A.3.3.3 and A.5.1-A.5.2 and **Table 5** provide further details on standard operating procedures for the field tasks and the chemical analyses regarding VOC samples (gas chromatography/mass spectroscopy with thermal desorption) and aldehyde samples (extraction in acetonitrile followed by high performance liquid chromatography with ultraviolet light detection).

2.4.3 Indoor Environment Attributes Monitored

2.4.3.1 Temperature

Temperature (T) was measured with epoxy-encapsulated thermistors (YSI 44018 sensor and YSI 44303 resistor "Thermilinear Network," Yellow Springs Instruments). LBNL technicians constructed the Thermilinear Networks, according to manufacturer specifications. The procedure included attachment of leads, which then would be connected by shielded cabling and shielded pair conductors to the CDAQS multiplex board in the RCs. The CDAQS stored T data points as six-minute averages.

The locations in each RC for continuous T measurements were:

- Bard supply air diffuser closest to air handler
- Bard supply air diffuser farthest from air handler
- IDEC supply air diffuser closest to air handler
- IDEC supply air diffuser farthest from air handler
- Bard return at inside edge of grille
- IDEC relief vent at inside edge of grille
- Discharge of air from IDEC to the plenum
- Center of RC ~1-2 ft below ceiling, i.e., 6.5 ft above carpeted floor, on mobile **(Figure 17a-b)**
- A vertical array with three heights (0.5 m., 1.0 m., 1.7 m.), flush with the side of the standard installed dry-erase board's marker/eraser rail. This array was protected with anodized perforated aluminum grillee covered with commercially-available speaker cloth **(Figure 18).**

2.4.3.2 Relative Humidity

Relative humidity (RH) was measured continuously outdoors at each school (see local meteorology section below) and at many locations in each RC using outdoor, space, and duct Microline Transmitters (MRH, General Eastern Instruments, Woburn, MA). The CDAQS stored data points as six-minute averages. Specifications for RH sensors were:

- 0-99% RH range non-condensing
- 2% accuracy over expected T range including hysteresis <1%, linearity, and repeatability 0.5% RH
- Sensitivity of 0.1% RH
- T effect less than 0.06% per ºF.

Technicians conducted additional testing of the Microline Transmitters in a laboratory tank set-up at LBNL, over a broad range of RH values.

The locations in each RC for continuous RH measurements were:

- Bard supply air diffuser closest to air handler
- IDEC supply air diffuser closest to air handler
- Bard return at inside edge of grille
- IDEC relief vent at inside edge of grille
- Center of RC ~1-2 ft below ceiling, i.e., 6.5 ft above carpeted floor, on mobile **(Figure 17a-b).**

2.4.3.3 Noise Levels, A-weighted

One Extech 407736 Sound Level Meter (SLM; available from Davis-Inotek Instruments, Baltimore, MD) measured decibels with A-weighting (dB (A)) in the teaching space of each relocatable classroom (RC). The SLM measured between 33.5 to 101.5 dB (A) (accuracy 1.5 dB (A), resolution 0.1 dB (A)) and was operated in slow response time mode, i.e., one sample per second. Calibration with a NIST certificate traceable device (Extech SLM calibrator 407744, available from Davis-Inotek Instruments, Baltimore, MD) was conducted during each LBNL field visit at 94.0 dB (A), a common recommendation among SLM and noise dosimeter manufacturers. Data from pre-and post-calibration dB (A) were recorded on a field sheet (see Appendix A.3.2). This SLM complied with IEC-651 and ANSI S1.4 Type II standards.

Based on discussions with LBNL Environmental Health and Safety (EH&S), given the majority of the RC floor area was carpeted, LBNL minimized potential confounding through measurement of sound reflecting off of the walls, ceiling panels, and cabinetry by locating the SLM on a mobile. The mobile was suspended ~1-2 ft. below the ceiling near the middle of the RC's occupied teaching space, i.e., ~6.5 ft. above the carpeted floor. The Lexan plastic mobile design (**Figure 17a-b**) accommodated T and RH sensors as well. LBNL technicians also conducted experiments with comparable Quest M-27 dosimeters, on loan from LBNL EH&S during the winter 2002 heating season. These afternoon experiments in one RC at the MCS site confirmed the orientation of the microphone with respect to the HVAC systems at the back wall was not significant. The results also showed the measurement of noise levels at the center of the RC representatively assessed average noise levels and thus occupant exposure in the RCs **(Figure 17c**; data available upon request).

An AC adapter replacing the 9 VDC battery and cabling connected the SLM with the CDAQS multiplex board above the ceiling panels. The SLM monitored noise levels continuously. The CDAQS stored data points as six-minute averages.

2.4.3.4 ASHRAE 55-1992-Based Thermal Comfort Assessment with LBNL Schools Cart

To quantitatively assess teacher and student thermal comfort (TC) with greater accuracy than estimates using room air T and RH at one or more representative locations and/or surveys and anecdotes, LBNL pursued an assessment based on ASHRAE Standard 55 (1992, addendum 55a-1995). This standard, which incorporated air T, mean radiant (globe) T, RH and air velocity measurements with technician observations and/or survey responses, however, was developed for adult office building occupants across gender and age, not young children. Children have a larger surface area-to-volume ratio and their sweat glands produce relatively less perspiration than adults, so they are less able to cool themselves (Healthy Schools Network, 2000). Furthermore, space conditioning in office buildings may be relatively closer to "steady-state" than RCs due to teacher control of and reported lack of use of HVAC systems, though both environments may be characterized by transient conditions which can affect TC assessments (Hensen, 1990). Nevertheless, this standard was the most accepted metric for TC assessment. Furthermore, LBNL researchers believed the three prescribed measurement heights, designed relative to the seated adult worker, were likely relevant to a child 5-10 years old. The lowest height, 0.1 m, represented occupant feet and ankles. The middle height, 0.6 m, represented the adult midsection and likely child torso and head while seated. The 1.1 m height represented a teacher's upper torso and head while seated, and likely a child's torso and head while standing. In a school classroom and especially smaller RCs, occupants are fairly sedentary for lessons and supervised activities, with recess and lunch outside.

Figure 19 shows the LBNL-designed TC assessment cart for use in public schools, building on the design developed and improved over time by the UC-Berkeley Center for Environmental Design Research (Benton et.al, 1990; Huizenga, 2001) and associates (Kwok, 1997). Each of two LBNL TC carts was powered by a pair of rechargeable batteries, providing up to 20 hours of operation, and each also contained a "Tattle Tale" data logger with prototyping board (TFX-11 with PR-11, Onset Corp., Bourne, MA). At each of the three aforementioned heights, globe and air T sensors, a space RH sensor and an air velocity thermal anemometer (**Table 2**; Apte et. al, 2002) were mounted in the same parallel plane at angles from each other. The T and space RH sensors were the same as those previously described in the T and RH monitoring sections, except the globe T sensor was placed inside a plastic ping pong ball painted gray according to ASHRAE Standard 55 (1992). The thermal anemometers for air velocity (Series HT-400 with probe HT-412 and transducer unit HT-428-02, Sensor Electronic and Measurement Equipment, Poland) incorporated omnidirectional, spherical sensors capable of measuring air velocity over a 0.05 to 5 m s^{-1} range. Repeatability in the 0.05-1.0 m s^{-1} range expected in this study was reported as ± 0.02 m s^{-1} ± 1% of readings, with automatic T compensation accuracy better than 0.1% ºK^{-1}. Voltage output to the data logger was converted to a velocity value with a non-linear set of equations provided by the manufacturer. The manufacturer's tests and validation of the set-up was published in 1998 in *ASHRAE Transactions* volume 1 (SF-98-20-5). In the field, the LBNL technician started and stopped TC cart operation, and downloaded raw data as text files from the TC cart to MS Excel in a laptop computer for rapid reduction and review.

TC cart assessments were conducted during the cooling and heating seasons once per week in each RC. The TC cart was sequentially positioned at three different locations around each RC. Selection of cart placements involved consideration of student safety, fire codes, teacher classroom organization and preferences, location of windows and HVAC system supply air diffusers, as well as the TC assessment protocol used in the U.S. EPA sponsored BASE study protocol. Appendix A.3.4 provides more detail on the TC assessment and movement of the carts during each LBNL field visit. Appendix A.4.2 presents the LBNL technician observation checklist of the average clothing ensembles by age and gender.

TC carts were transported to and from LBNL, and stored in the field van during the week and inside the office building on weekends. Due to frequent chance of rain during the winter heating season, protective covers were constructed of durable garbage bags. TC carts were charged weekly at LBNL.

Documentation of data management procedures and analyses used to complete the TC assessment based on ASHRAE Standard 55 (1992) will appear in future reports. The qualitative and quantitative data collected are used in these analyses, including globe T to calculate mean radiant T and indoor air T and mean radiant T to calculate operative T.

2.4.4 Building Systems Monitoring

2.4.4.1 Windows, Use and Open Settings

Each RC had two windows. As part of the effort to characterize RC usage patterns, LBNL was interested in the frequency of window use and how far a window was open. LBNL technicians installed linear displacement potentiometers (LDP, passive three wire type, 500 mm nominal travel distance, ± 20% tolerance, linearity better than 1%, repeatability 0.1%; JK Controls, Limited, United Kingdom). The LDPs were mounted at the upper corner of the window frames. The larger front window had one LDP on each side, and the smaller window one LDP. Each LDP was connected to a DC bridge circuit and calibrated such that its response scaled 0.00 V to 1.00 V.

2.4.4.2 Door Operation

The RC doors were monitored for closure. AMS had installed door operation sensors in their modular construction products. Data were stored in the CDAQS indicating the number of seconds the door was open --to any degree-- during six minutes.

2.4.5 Local Meteorology

Local meteorological variables including wind speed, wind direction and outdoor T and RH (**Figure 20**) were monitored for energy analyses. The wind parameters were measured continuously with a black-anodized aluminum industrial anemometer (P/N 7914, Davis Instruments, Hayward, CA) constructed with polycarbonate wind cups and a magnetic switch for a pulse signal for wind speed, and a UV-resistant ABS wind vane and potentiometer with resistance proportional to wind direction. Digital filtering with a specified time constant was applied to wind direction measurements. The durability, range (0º-360º, 16 compass points) and accuracy of the anemometer (±5% speed, ±7º direction) were adequate for this field study. Each six-minute data point for wind direction and wind speed in miles per hour was an average of 360 samples and 160 samples, respectively. T was measured with an analog sensor (YSI 44018 sensor and YSI 44303 resistor "Thermilinear Network," Yellow Springs Instruments). RH was measured with an outdoor Microline Transmitter (MRH, General Eastern Instruments, Woburn, MA). Each six-minute data point for T and RH was an average. Details on the YSI components were provided in the indoor and outdoor T monitoring section.

2.5 RC Operation Conditions and Field Study Plan

2.5.1 RC HVAC commissioning

At the end of August 2001, prior to the start of the school year for each SD, LBNL technicians and a DEG consultant conducted flow measurements using a LBNL designed combination “flow hood-duct blaster” (Walker et. al, 2001; Wray et. al, 2002). The flow rate measurement accepted (in CFM) was the average of three measurements recorded when a zero pressure differential was achieved with the apparatus according to a digital manometer and accompanying laptop operation program. The procedure was carried out at each of the supply air diffusers for the two HVAC-- two for standard, three for advanced-- as well as the standard HVAC system’s outdoor air inlet. The participating SD set the standard HVAC systems airflow by specification to the RC manufacturer. LBNL and DEG calibrated the advanced HVAC system through the IDEC control board program. IDEC-related measurements were recorded for the minimum ventilation scenario in “auto” mode and the maximum cooling or heating demand scenario; the total flow of air supplied to the RCs under the minimum scenario was confirmed to meet the 15 $CFMperson^{-1}$ standard.

2.5.2 Schedule of RC Operation Conditions

In the case-crossover study design, each RC served as its own control because each was built with the standard and advanced HVAC systems, one per module. **Table 6** documents the operation of HVAC systems during the field study, including temporary changes due to problems or teacher comments and discomfort. This record highlights how LBNL technicians sealed and shut-off one HVAC system and activated the other during every field visit (cooling season 2001, transitional periods), or every other field visit (majority of heating season 2002). This table was prepared as a reference for LBNL statistical analyses and DEG analysis and modeling of energy and weather station data.

2.5.3 Schedule of Site Visits

Appendix A.2.1.1.1 and A.2.1.1.2 for the cooling season sampling in fall 2001, and A.2.1.2.1 and A.2.1.2.2 for the heating season sampling in winter 2002, provide the realized field work and school site visits to CUSD and MCS, respectively. Appendix A.2.2.1 and A.2.2.2 detail the realized approximate schedule of activities during a regular field visit to CUSD and MCS, respectively. Participant SD staff and school principals, head custodians, administrative staff and teachers each received a copy of the schedule. LBNL technicians provided necessary revisions in a timely manner by phone and/or email. The head custodian and/or teachers provided LBNL technicians access to the school campus, gated areas behind the RCs, and into the classrooms each morning and afternoon. LBNL technicians only had the key to the outdoor enclosures, and, in spring 2002, to the refurbished gated area behind the CUSD RCs. Clear consistent communication allowed field work to proceed without problems during both seasons regardless of conditions.

2.6 Continuous Real-Time Data Management

2.6.1 Data Collection, and Handling and Back-up Storage

Continuous monitoring for IEQ parameters and energy use resulted in data for each variable, recorded every six minutes as previously described, stored in a flat text file in the CDAQS. At the end of morning and afternoon tasks each week of the cooling and heating season, and at the end of each visit during the transitional periods, a LBNL technician stopped the CDAQS, downloaded data from the CDAQS to a zip disk, and then restarted the CDAQS. The CDAQS was operated using a custom control screen programmed using LabView5 software. The zip disk served as the data back-up storage media until files were permanently and securely backed-up on a LBNL computer system. Primary data reduction, cleaning, and review occurred each field visit on a laptop computer in MS Excel, which produced one file per week or two week period per RC.

3.0 DATA ANALYSIS PLAN

3.1 Data Cleaning

3.1.1 Continuous Data

Field data were grouped into the fall 2001 cooling season, the November-December 2001 fall-to-winter transitional period including January 1-7, 2002, the winter 2002 heating season, and the mid-March to mid-June spring-to-summer transitional period. Data cleaning at LBNL included identifying and removing false or noisy data. RC A and outdoor weather station variables and RC B and outdoor particle count variables were grouped for management and cleaning to match the flat file formats in the CDAQS.

Specific examples of data reduction and cleaning were:

- When the number of particles counted in each of the six size bins was zero, data were invalidated because only a small or zero count in the largest 5.0-10.0 µm bin was likely.
- For energy use and gas meter sensors, interrupted pulse counting sequences caused the first and last data points of each flat file to be erroneous.
- During the first two to three weeks of the fall 2001 cooling season periods the data for gas use, total building energy use, HVAC systems energy use, and T-8 lighting energy use was found to be incorrect due to a pulse signal processing problem. Careful data cleaning and management could not salvage these quantitative data, however, the data be usable for qualitative determination of HVAC or lighting system usage indicators. By mid-September 2001, the signal processing circuitry between

the WattNode sensors and the CDAQS was modified and energy monitoring data collection problems were remedied.

3.1.2 Integrated school day samples for target VOC and aldehydes

Data from field calculations were verified by LBNL technicians each week and again at the end of the season. Calculated average flow rates, volumes of air sampled, and any field comments related to data quality along with chemical analysis data were reviewed and entered into MS Excel. These files were reviewed again before conducting summary statistics and transposing data into MS Access databases for later use in statistical analyses. If data for a sample, duplicate or field blank was determined suspect or invalid, another injection of the sample was conducted the same day at the end of a sample run to ensure a valid analysis. Appendix A.5 presents details of the aldehyde analysis method. Hodgson et. al (2001) included identifications of the target toxic and odorous compounds.

3.2 Summary Descriptive Statistics

Desired descriptive statistics for continuously monitored variables and integrated school day average samples for target aldehydes and VOCs were arithmetic mean, standard deviation, median, minimum, maximum, 90th percentile and/or quartiles. Analytic and field duplicates of VOC and aldehyde samples will be used to evaluate analytic and overall method precision, respectively, to quantify experimental error and help evaluate uncertainty. Data will be stratified by SD, season, HVAC system in operation, and/or RC A versus B, the latter due to the difference in interior finish materials. For continuously monitored variables, data must first be parsed into six different time periods (TPs). The TPs in the two participating SD are shown in **Table 7**. TPs 1-4 combined represented the school day for teacher and students.

Specifically for the noise level data collected in a manner described earlier, L_{eq} is a time-weighted average of the human relevant, dB (A) measurements for a defined monitoring period. Monitoring periods will be defined as individual TP as well as each school day (TPs 1-4) and the morning (TPs 1-2) or the afternoon (TP 4) during occupied hours. TPs 1-4 were during expected operation of the standard or advanced HVAC system. The L_{eq} for lunch/recess (TP 3) and overnight (TP 5) and/or weekends and holidays (TP 6) may provide information on unoccupied, background noise levels, with and without a HVAC system in operation. This information can be compared with standards recently adopted or proposed, and to assess potential acoustic benefits of the alternative material selections, e.g., ceiling panels.

The difference between indoor and outdoor values and/or indoor/outdoor ratios will be assessed in the descriptive statistics. The indoor variables include:

- Target VOC and aldehyde data, by compound
- T and RH data from the mobile suspended from the ceiling near the center of the RC
- CO_2
- Particle counts, cumulative and in each size bin
- Calculated particle concentrations using a calculated flow ratio (field measurement or interpolated value/PSI nominal flow).

3.3 Proposed Multivariate Regression Models

Regression models will be constructed in SAS v.8.0 (Cary, NC). These models will be used to predict measured IEQ conditions based upon measured and estimated HVAC operation and environmental conditions during different TPs and over the school day (TPs 1-4). **Table 8** presents the variables to be used in the regression models in four categories: IEQ conditions, HVAC operation conditions, environmental conditions, and TPs of interest.

4.0 ACKNOWLEDGEMENTS

We acknowledge other LBNL researchers, summer students and staff who were involved in other aspects of this and related projects: Woody W. Delp, Rick C. Diamond, and Satish Kumar; Simon Allard and Shawna M. Liff; Olivia Salazar and Rhoda Williams; and, Leslie Striplin. We are grateful to Dick Schmidt for the construction of the school thermal comfort carts and his help in their design. We also thank D. Shendell's UCLA School of Public Health doctoral committee for feedback on specific aspects of the study design and data analysis strategy.

This research was sponsored by the California Energy Commission through the Public Interest Energy Research program as Element 6.2.2 of the Lawrence Berkeley National Laboratory High Performance Commercial Buildings Systems research CEC Contract Number 400-99-012. The study was additionally supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Technology Development, Office of Building Technologies of the U.S. Department of Energy under contract DE-AC03-76SF00098.

5.0 REFERENCES

Apte MG , Delp WW, Diamond RC, *et al*. 2001. *Report on HVAC Option Selections for a Relocatable Classroom Energy and Indoor Environmental Quality Field Study*, LBNL-49026, Lawrence Berkeley National Laboratory, University of California, Berkeley, CA 94720.

Apte MG, Hodgson AT, Shendell DG, Fisk WJ, Delp WW, Diamond RC, Lee S-M, Rainer LI, Sullivan DP. "Energy and Indoor Environmental Quality Relocatable Classrooms in Northern California." *Proceedings of Indoor Air 2002, The Ninth International Conference on Indoor Air Quality and Climate*, June 30-July 5, 2002, Monterey, CA.

ASHRAE. 1992. ANSI/ASHRAE Standard 55-1992, *Thermal Environmental Conditions for Human Occupancy*.Atlanta, GA, American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc.

ASHRAE. 1999. ANSI/ASHRAE 62-1999*, Ventilation for acceptable indoor air quality*. Atlanta, GA, American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc.

Benton, CC, Bauman, FS, and Foutain, ME. 1990 A Field Measurement System for the Study of Thermal Comfort. *ASRHAE Transactions*, 96 Part 1 (90-6-5, RP-462).

Davis Energy Group (DEG), 1997. "Energy Analysis and Review of Modular Classrooms", DEG, Davis, CA.

EdSource, 1998. "Portable School Buildings: Scourge, Saving Grace, or Just Part of the Solution?" http://www.edsource.org/pub_edfct_port.html

Healthy Schools Network. 2000*. Environmental Action Guide for New York State Schools*. Albany, NY, Healthy Schools Network, Inc.

Hensen, J.L.M. 1990. Literature Review on Thermal Comfort in Transient Conditions. Building and Environment, 25 (4): 309-316.

Hodgson AT, Fisk, WJ, Shendell DG, and Apte MG. Predicted Concentrations in New Relocatable Classrooms of Volatile Organic Compounds Emitted from Standard and Alternate Interior Finish Materials. LBNL-48490, Lawrence Berkeley National Laboratory, University of California, Berkeley, CA 94720.

Hodgson AT, Apte MG, Shendell DG, et al. "Implementing Source Reduction Practices in Manufactured Houses and Schools to Reduce Concentrations of Volatile Organic Compounds." *Proceedings of Indoor Air 2002, The Ninth International Conference on Indoor Air Quality and Climate*, June 30-July 5, 2002, Monterey, CA.

Huizenga, C, personal communication, 2001. Center for Environmental Design Research, University of California, Berkeley, Berkeley, CA.

Kwok, A. 1997. Thermal Comfort in Naturally-Ventilaed and Air-Conditioned Classrooms in the Tropics. Ph.D. Thesis. University of California, Berkeley.

Lyons, J.B. 2001. "Do School Facilities Really Impact a Child's Environment?" Issuetrak: A CEFPI/The School Building Association Brief on Educational Facility Issues, November 2001.

Sarich, D, personal communication, 2001. General Manager, American Modular Systems, Manteca, CA.

Waldman, JM, personal communication, 2001.Chief, Indoor Air Quality Section, California Department of Health Services, Berkeley, CA.

Walker, I.S.,Wray, C.P.,Dickerhoff, D.J.,Sherman, M.H. 2001. "Evaluationof flow hood measurements for residential register flows ". LBNL-47382
Wray, CP, Walker, IS, and Sherman, MH. 2002 "Accuracy of Flow Hoods in Residential Applications." In review for Proceedings - American Council for an Energy-Efficient Economy, Summer Study on Energy Efficient Buildings, Asilomar, CA, August 2002. LBNL-49697.

6.0 TABLES

Table 1: Specifications packages for RCs with respect to HVAC systems, energy efficiency, insulation, and lighting, including upgrades from the standard configuration most common among California SDs. (Apte et. al, 2001)

Building Material	***Base Case / Standard Practice***	***PERC Package B (Option 2)***	***HPCBS RC***
Wall Insulation	R11 Batt	R13 Batt	R13 Batt
Floor Insulation R-value	R11 Batt	R19 Batt	R19 Batt
Roof Insulation R-value	R19 Batt	R19 Batt	R19 Batt
Ceiling Vapor Barrier	No	Yes	Yes
Window Glass (double glaze)	2212 (grey tint)	2660 (selective surface)	2660 (selective surface)
Roof Absorptance	0.60 (bare metal)	0.60 (bare metal)	0.25 (white coating)
Roof Outside-Emissivity	0.50	0.50	0.95
Fluorescent lamps (kW)	T11 (1.66)	T8 (0.75)	T8 (0.75)
Heating	10 SEER Heat Pump W/ electric resistance pickup	Radiant electric ceiling panels	85% AFUE Hydronic gas-fired with in-duct fan coil
Cooling	10 SEER Heat Pump	Indirect-Direct Evaporative Cooling	Indirect-Direct Evaporative Cooling
Ventilation	On HVAC cycling or continuous (15 cfm/person)	Continuous (15 cfm/person)	Continuous (15 cfm/person)

Table 2. IEQ and energy monitoring instrumentation in study relocatable classrooms. (Apte et. al, 2002)

Parameter	*Method*[1]	*Mfr. / Model*	*Location*[2]
Continuous:			
Carbon Dioxide	NDIR	Fuji / ZFP-9	I, O
Particle size, count	Laser counter	Met One / 237B	I,O
Relative Humidity	Capacitance	General Eastern/MRH	I, O,HPD, ID, TC, C
Temperature	Thermistor	YSI/44018 and 44303	I, O,HPD, ID, TC, C,
Air Velocity	Thermo-anemometer	Sensor Elect. & Meas. Equip. / HT412-2	TC
Sound Level	dB, A-wtd., Leq	Extech/407736.	C
Door open	Door sensor	LBNL	Door
Window position	LDP	JK Controls/LDP-500	
Wind speed, dir.	Anemometer	Davis/Industrial #7914	O
Electricity	Current transducer	CCS/Wattnode	HVAC, Lights, Total
Natural Gas	Gas meter	Equimeter/pulse output	IDEC Heating
Time-averaged:			
VOC	Multisorb GC/MS	LBNL[3]	I, O
Formaldehyde, acetaldehyde	DNPH HPLC UV detector	LBNL[3]/Waters	I, O
Thermal Comfort	ASHRAE 55-1992	LBNL[4]	I (0.1m, 0.5m, 1.1m)

[1]NDIR=non-dispersive infrared; multisorb=multisorbent tubes GCMS=gas chromatography/mass spectrometry; HPLC=high performance liquid chromatography, LDP = linear displacement potentiometer; A-wtd=A-weighted, Leq = equivalent noise level
[2]I=Indoors, O=Outdoors, HPD=Heat pump system diffuser, ID=IDEC Diffuser, TC=thermal comfort cart, C=Indoors@ 2.5m, center of RC, m=meters above floor
[3]See Hodgson *et al.,* 2001 [4]See ASHRAE, 1992

Table 3. Summary of procedures for evaluating and selecting materials.
(see Table 11, Hodgson et. al, 2001)

Parameter	Evaluation Procedure
Chemicals of concern and odorous compounds	Estimate concentrations for ventilated and closed conditions using emission factors and classroom parameters
Compounds with RELs	Compare estimated concentrations with guideline values
Odorous compounds	Compare estimated concentrations with odor thresholds
Material performance	Consider appearance, durability, maintenance requirements, sound properties, etc.
Cost	Compare material and installed costs of standard and alternate materials
Acceptability	School districts and manufacturer can reject recommended alternate materials

Table 4. Projected surface areas of materials selected to finish the interiors of the four relocatable classrooms (RCs). (see Table 12, Hodgson et. al, 2001)

Material Description	Code	Surface Area, m^2			
		Sch. Dist. A		Sch. Dist. B	
		RC 1c	RC 2	RC 3c	RC 4
Floor					
Olefin fiber broadloom carpet bonded to plywood with solvent-free full-spread adhesive	BLC1-s			81.5	
Nylon 6,6 fiber, olefin hardback carpet bonded to plywood with adhesive tape	HBC				81.5
Nylon 6,6 fiber broadloom carpet bonded to plywood with solvent-free full-spread adhesive	BLC2	72.0	72.0		
Vinyl composition floor tiles	VCT-s			3.3	3.3
Sheet vinyl flooring	SVF-s	12.8	12.8		
Walls					
Vinyl covered fiberboard wall panels	VWP1	92.0		92.0	
Teflon-coated vinyl covered fiberboard wall panels	VWP2		92.0		92.0
Ceiling					
Fiberglass ceiling panels	FCP-s	84.8		84.8	
Mineral fiber ceiling panels	MCP2		84.8		84.8

Table 5: Summary of sampling and analytical methods and equipment for VOCs and low-molecular weight aldehydes. (see Table 2, Hodgson et. al, 2001)

Methods and Equipment
VOC Sampling
Tenax-TA sorbent tube; P/N CP16251, Varian Instr. Co. Modified by addition of Carbosieve S-III, 60/80 mesh backup section, P/N 10184, Supelco
VOC Analysis
Thermal desorption-gas chromatography/mass spectrometry (GC/MS); Model CP4020 TCT concentrator, Varian Instr. Co.; Models 6890 and 5973 MSD GC/MS system, Agilent
DB-1701 30-m, 0.25-mm, 1-µm film column; P/N 122-0733 J&W Scientific
Formaldehyde & Acetaldehyde Sampling
XPoSure Aldehyde Sampler; P/N WAT047205, Waters Corp.
Formaldehyde & Acetaldehyde Analysis
High performance Liquid Chromatography (HPLC); Model 1090M LC with DR-5 solvent delivery system & diode array detector, Hewlett-Packard
Symmetry C_{18} 5-µm 2.1 x 150-mm column; P/N WAT056975, Waters Corp.

Table 6: Actual operation of HVAC systems during the field study, including temporary changes due to problems or teacher comments and discomfort, as prepared for DEG's future analysis and modeling of energy and weather station data.

		CUSD RCs	**MCS RCs**
Season	**HVAC**	applicable dates	applicable dates
cooling, fall 2001	Bard	8/23-9/6/01	8/30-9/5/01 (RC A)
	Bard or IDEC	N/A	8/30-9/5/01 (RC B)
	IDEC	9/6-12/01	9/5-14/01
	Bard	9/12-18/01	9/14-20/01
	IDEC	9/18-27/01	9/20-25/01
	Bard	9/27-10/4/01	9/25-10/2/01
	IDEC	10/4-11/01	10/2-9/01
	Bard	10/11-16/01	10/9-18/01
	IDEC	10/16-23/01	10/18-25/01
	IDEC	10/23-31/01	10/25-11/1/01
fall-winter "transitional period" SEE "2nd Notes…" MS WORD FILE Bard seal-off panel off (CUSD) 11/9	IDEC	10/31-11/15/01, except RC B AM heat with Bard 11/8-14 if school	11/1-11/8/01
Bard seal-off panel not immediately removed at MCS.	Bard	11/15/01-1/7/02	11/8/01-1/7/02
heating, winter 2002	Bard	1/7-10/02	1/7-8/02
NOTE: Leo Rainer cleaned & checked Rinnai units, CUSD, 1/10	IDEC	1/10-17/02	1/8-15/02 (RC A), 1/8-10 (AM) /02 (RC B)
NOTE: Leo Rainer cleaned & checked Rinnai units, MCS 1/16 PM	Bard	N/A	Early to late AM heat 1/10&11&14/02, and 1/15-16/02 (RC B)
	IDEC	1/17-23/02;MLK day 1/21	1/15-24/02;MLK day 1/21
	Bard	1/23-29/02	1/24-31/02
	Bard	1/29-2/5/02	1/31-2/7/02
	IDEC	2/5-12/02	2/7-14/02
	IDEC	winter vacation period	2/14-20/02;PresDay 2/18
	Bard	2/12-28 (AM) /02	2/20-26/02
	IDEC	2/28-3/5/02	2/26-3/7/02
	IDEC	3/5-12/02; no school 3/11	3/7-13/02

Spring "transitional period"	IDEC	3/12-29(AM)/02	3/13-28(PM) /02
(likely to be considered cooling season 5/9-end of school year…)	Bard	3/29(AM)-4/23(AM)/02; vacation 4/13-21/02	3/28(PM)-4/22(PM)/02; vacation 3/29-4/7/02
	IDEC	4/23(AM)-5/9/02	4/22(PM)-5/9/02
Extra T.C. data MCS;	Bard	5/9-27/02;MemDay 5/27	5/9-24/02;MemDay 5/27
Extra T.C. data MCS; CUSD used Bard 5/30 PM (both RCs) and 5/31-6/4 (RC A in PM, AM and overnight was IDEC) due to high RH% problems causing condensation on desks and papers and a lack of cooling satisfaction communicated by occupants 5/30 and 5/31afternoons.	IDEC	5/28(AM)-6/13/02	5/28(AM)-6/13/02

Table 7: The six time periods to be used for coding, grouping, and analyzing continuously monitored IEQ, outdoor environment, building operation, HVAC operation and energy data.

SD	CUSD	MCS
Time Period (T.P.)		
1	8:15-10:40	7:45-10:10
2	10:40-12:30	10:10-11:40
3	12:30-13:15	11:40-12:30
4	13:15-15:36	12:30-15:00
5	15:36-8:15 next day, M-Th	15:00 -7:45 next day, M-Th
6	15:36 F to 8:15 M	15:00 F to 7:45 M

Table 8: Variables to be used in regression models (SAS v.8.0) in four categories.

IEQ conditions	HVAC operational conditions	Environmental conditions	Time periods of interest
CO_2 concentration, indoor-outdoor	HVAC system operated	T outdoors	Time periods 1-6
VOC concentration indoor-outdoor, for each target VOC and aldehyde	HVAC system on/off	RH outdoors	School day (time periods 1-4)
Particle counts, indoor-outdoor, by size bin and cumulative count	Back window open/closed	Indoor T at mobile	Day of week
Particle concentration, indoor-outdoor, by size bin and cumulative count	Front window open/closed	Indoor RH at mobile	Season
Noise levels, dB (A), by time period	Front door open/closed		
Noise level for school day AM (time period 1-2)	Lights on/off		
Noise level for school day PM (time period 4)	Heating, either HVAC		
Noise level for school day Leq (time period 1-4)	Cooling, either HVAC		
Indoor T at mobile, etc. e.g. wall array sensors	Ventilation on/off, IDEC		
Indoor RH at mobile			
Thermal comfort			

7.0 FIGURES

Figure 1: Photograph of the foil vapor barrier provided with roof insulation for the four HPCBS Element 6 RCs.

Figure 2 (a-b): Photographs of the application of the white paint "cool roof" provided for the four HPCBS Element 6 RCs.

Figure 3: Photograph of the back walls of joining modules for a HPCBS Element 6 RC, each with mounted components of the standard or IDEC HVAC system.

Figure 4: Photograph of the IDEC with LBNL customized inlet filtration system (65% ASHRAE dust spot efficiency DuraMax filters, two DM-603 and one DM-602, Koch Filter Corporation, Louisville, KY) mounted on the back wall of each RC.

Figure 5: Side-by-side control thermostats for IDEC and standard HVAC systems in each field study RC. Plastic lock boxes and notes were used to remind teachers which system to use during the school year, given the case-crossover study design.

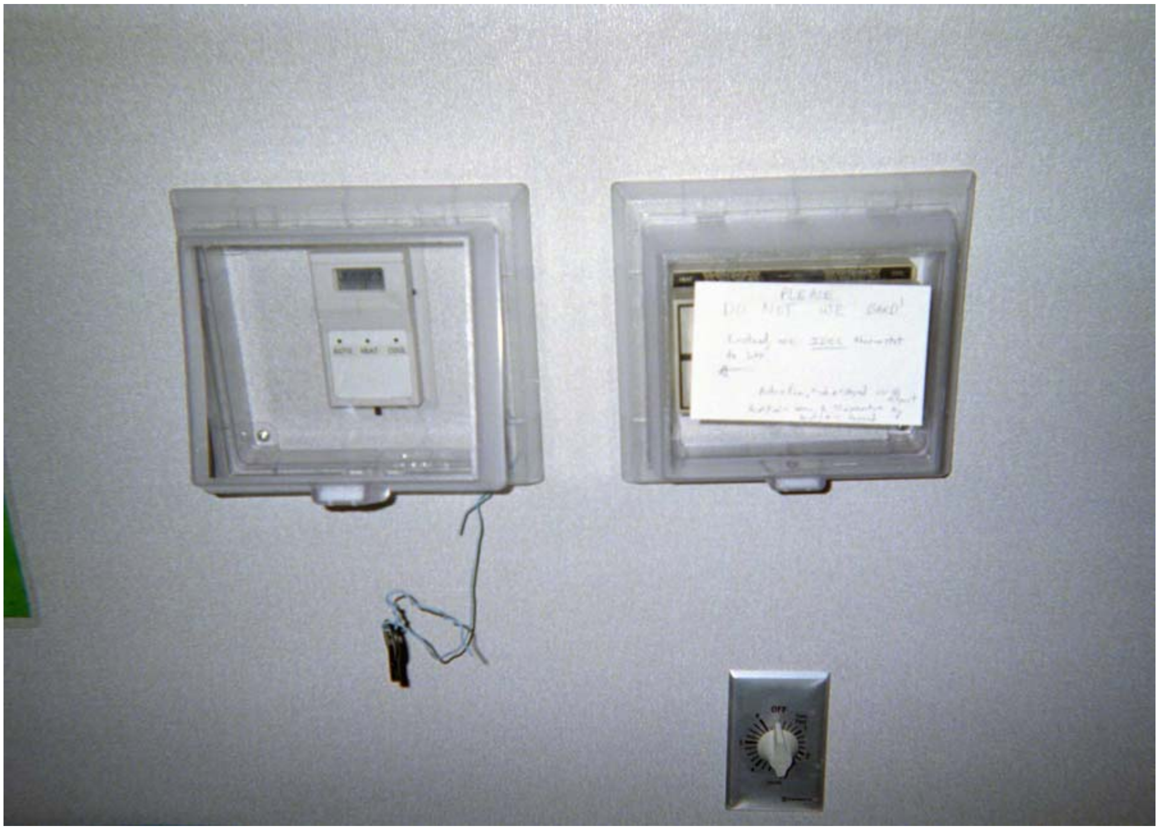
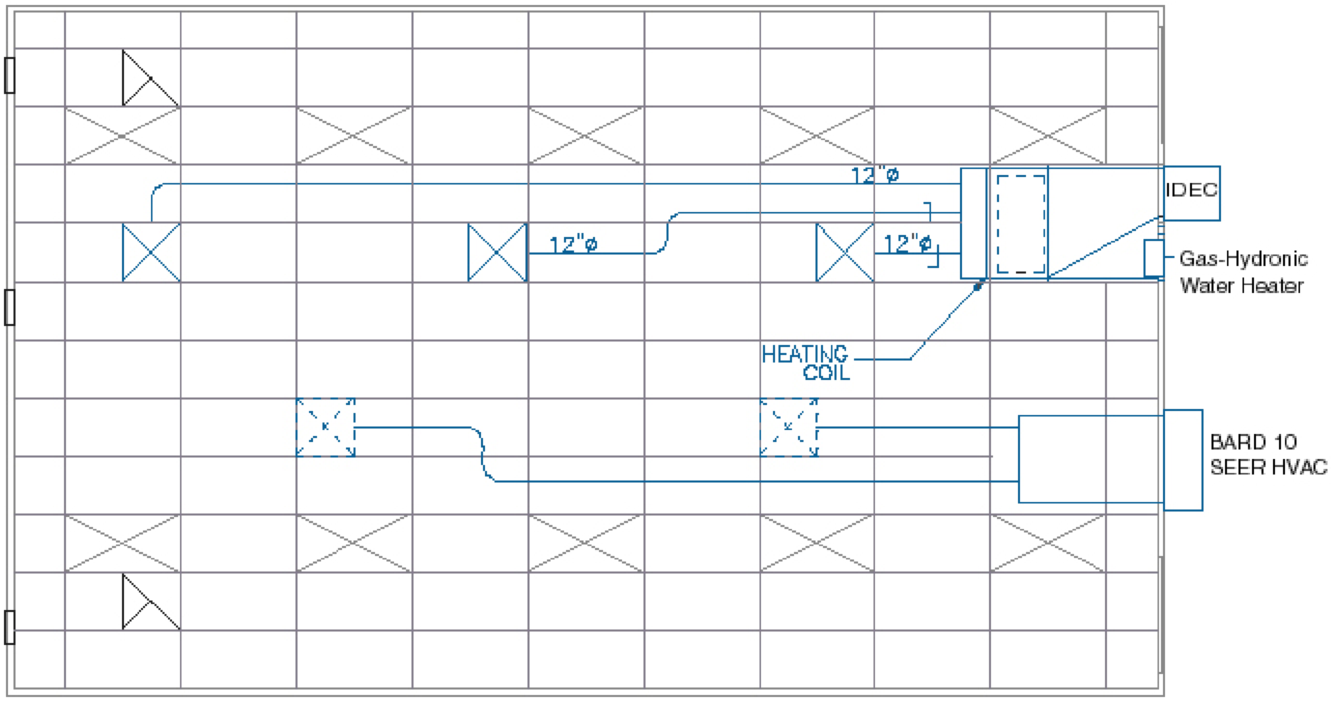
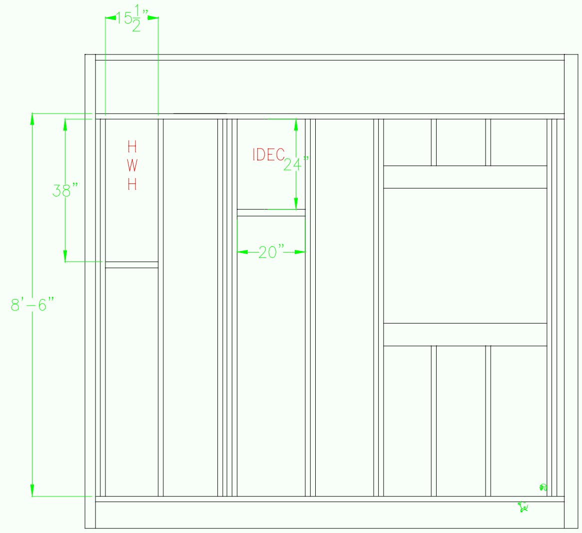


Figure 6 (a-c): Architectural engineering drawings showing plan (a) and back wall (b) views of the HVAC systems in each HPCBS Element 6 RC, along with a detailed legend (c) (see Figures A1, A3 and A6, respectively, Apte et. al, 2001).

24'x40' Modular Relocatable Classroom with Conventional and Test HVAC Systems





HVAC EQUIPMENT SCHEDULE

IDEC	INDIRECT/DIRECT EVAPORATIVE COOLER, WALL MOUNT 110V, 1 PH, 1600 CFM COOLING, 400 CFM HEATING, VARIABLE SPEED FAN.
HWH	INSTANTANEOUS GAS WATER HEATER, RINNAI REU-2424W, 19-180 kBtu INPUT, FULLY MODULATING. WALL MOUNTED IN RGB-24 RECESS BOX.
COIL	HEATING COIL. HEATCRAFT 3WZ1002C-14.00x41.00 OR EQUIV. 14"x41" COPPER TUBE, ALUM. FINNED HYDRONIC COIL. MIN. 35 kBtu @ 32F EAT, 140F EWT, 400 CFM, 4 GPM. MAX. 0.12" PRESSURE DROP AT 1600 CFM.
P1	HOT WATER CIRC PUMP, TACO 009-F5 OR EQUIV. 4GPM @ 24 FTHD. 110V, 1 PH, 3/4" FLANGED.
ET	EXPANSION TANK. FLEXCON VHT15 OR EQUIV. 2 GAL VOLUME 1.5 GAL MAX ACCEPTANCE VOLUME.
AV	AIR VENT. TACO 418 OR EQUIVALENT. 3/4" MALE, 150 PSIG MAX.
BD	BALANCING DAMPERS ON TWO SHORTEST DUCT RUNS.
SAD	SUPPLY AIR DIFFUSERS. TITUS TMS OR EQUIVALENT. HIGH PERFORMANCE SQUARE CEILING DIFFUSERS. 12" ROUND NECK, 24"X24" LAY-IN MODULE.
RAD	RELIEF AIR DIFFUSERS. TITUS PAR OR EQUIVALENT. SQUARE PERFORATED CEILING DIFFUSERS. 14" ROUND NECK, 24"X24" FLUSH-FACE, LAY-IN MODULE.
DAMP	RELIEF AIR DAMPERS. GREENHECK ES-30 OR EQUIVALENT. VERTICAL MOUNT BACKDRAFT DAMPERS, OPENED BY AIR PRESSURE DIFFERENTIAL AND CLOSED BY GRAVITY. 14"W X 8"H EXTRUDED ALUMINUM, HORIZONTAL AIRFLOW, 0.2" @ 600FPM.
R1	PUMP RELAY, STEVCO MODEL 90-113 OR EQUIV. 40 VA TRANSFORMER, 13.8A/120VAC SPDT RELAY.
Ts	SUPPLY AIR TEMPERTURE SENSOR. BAPI MODEL 13A/592-D-4"-WP

Figure 7: Simple sketch of LBNL-AMS lighting fixture location design for HPCBS Element 6 field study RCs. Each rectangle estimates a 5'Wx8'L area of the 960 ft^2 RC. The front of the RC is on the left and the back wall with wall-mounted HVAC systems on the right. LLLL = lighting fixture locations in each module, separated by the bold line.

LLLL	LLLL	LLLL	LLLL	
		LLLL		LLLL
		LLLL		(MCS RCs, CUSD A) LLLL
LLLL	LLLL	LLLL	LLLL	**LLLL** (CUSD B)

Figure 8a: Photographs of the completed (a) LBNL designed indoor cabinet (constructed for AMS and LBNL by Sierra Cabinets, CA for environment monitoring and computer equipment.

Figure 8b: Photographs of the completed (b) LBNL modified white, waterproof steel outdoor enclosure (Hoffman, Inc., San Francisco, CA) for environment monitoring and computer equipment.

Figure 9 (a-d): LBNL designed rain protection for areas around the RC A outdoor enclosures during the winter 2002 heating season (a-b, CUSD, and c, MCS) and a special removable shelf for CUSD (d) to protect equipment and allow LBNL technicians to conduct field tasks regardless of ambient conditions or time of day.

Figure 10: Photograph of P-Series WattNode digital pulse sensors (50A CT and 15A CT type), concealed in an electrical panel, used in each of the four RCs to measure total building (watt0), conventional HVAC heat pump (watt1), IDEC (watt2), and lighting (watt3) power for the electricity monitoring component of the field study.

Figure 11: Photograph of the advanced HVAC system's water heater gas usage sensor (Equimeter 275P) for the energy monitoring component of the field study.

Figure 12: Photograph of LBNL technician conducting calibration protocol for CAI ZFP-9 CO_2 gas analyzers with calibration bags at percentages of 2788 ppm.

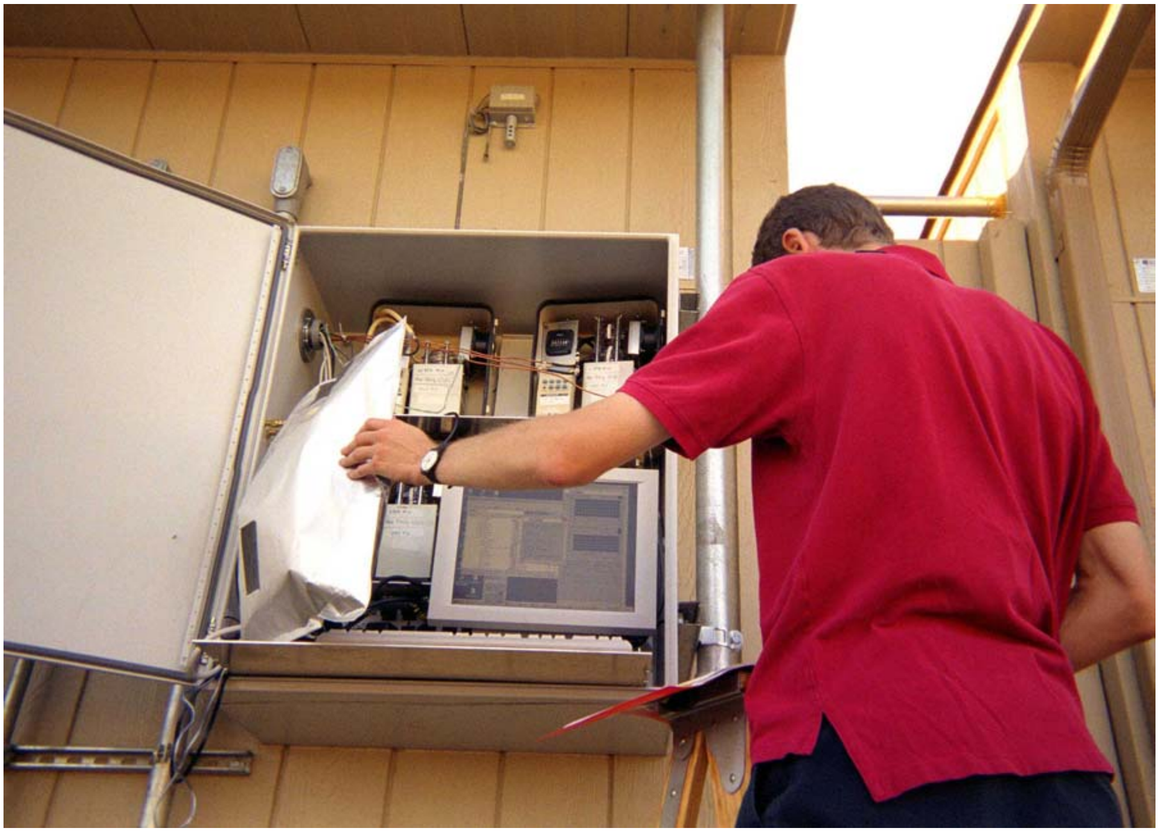


Figure 13: Photograph of LBNL technician conducting flow rate measurements of the PSI MetOne 237B particle counters with a BIOS DryCal low flow cell calibrator.

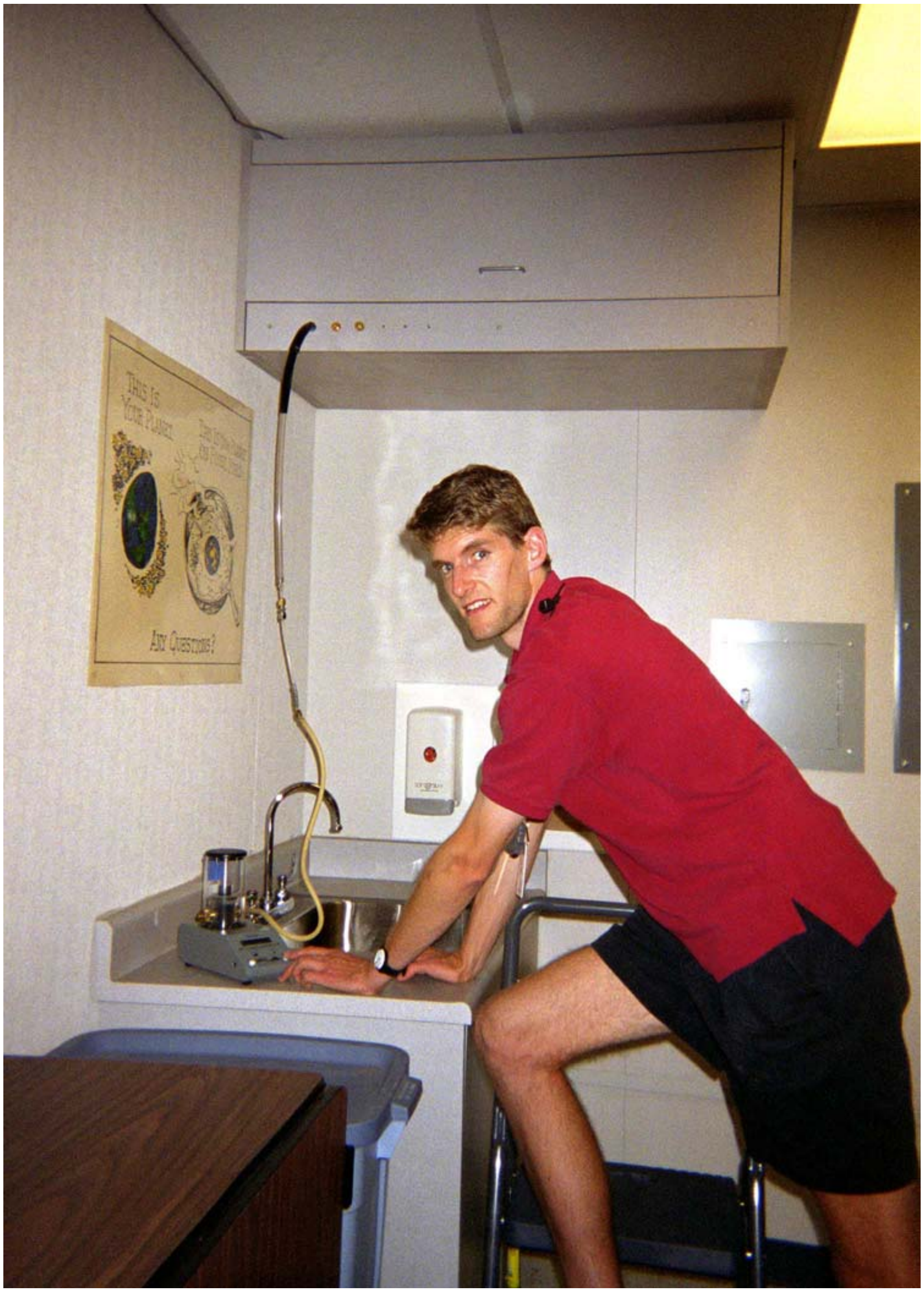


Figure 14 (a-b): Photograph of LBNL outdoor enclosure with (a) VOC and aldehyde sampling systems and (b) sampling lines for outdoor samples.

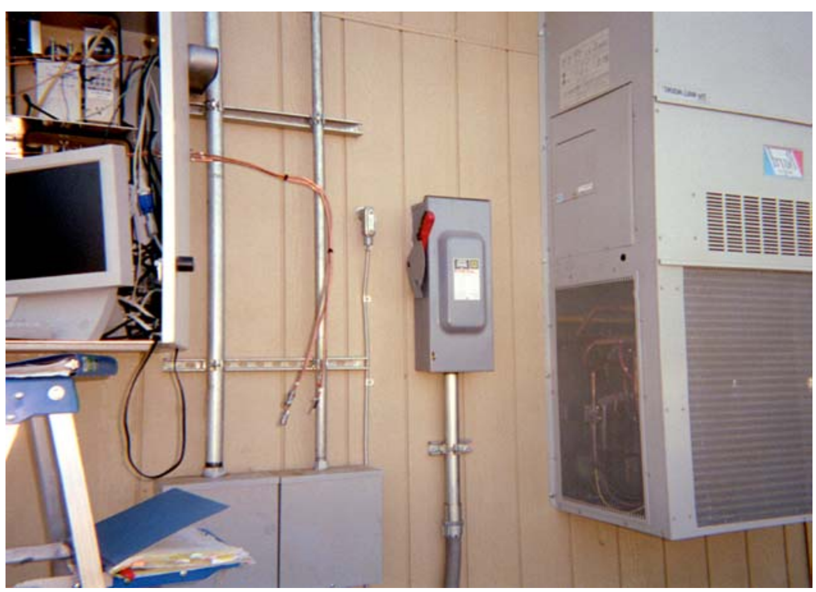


Figure 15: Photograph of LBNL technician placing indoor VOC and aldehyde samples.

Figure 16: Photograph of LBNL technician conducting flow rate measurements of the aldehyde sampling system with a BIOS DryCal low flow cell calibrator. VOC sampling system flow rates were taken nearby with a simple bubble tube protocol.

Figure 17 (a-c): Photographs of LBNL designed Lexan mobile located at the center of each RC 1-2 ft down from ceiling, i.e., 6.5 ft above carpeted floor, for SLM (noise level, dB (A)), T and RH measurements, including (a) installation, (b) SLM calibration and (c) co-located Quest M-27 noise dosimeters to validate the orientation and location of the SLM microphone.

Figure 18: Photograph of the LBNL designed vertical T measurement array at three heights (0.5 m., 1.0 m., 1.7 m.). The location was flush with side of the standard installed dry-erase board and as far out from the wall as the metal ledge used by the teacher to store markers and erasers. This array was protected with anodized perforated aluminum covered with commercially available speaker cloth. NOTE: In this picture, go to far right side near flag.

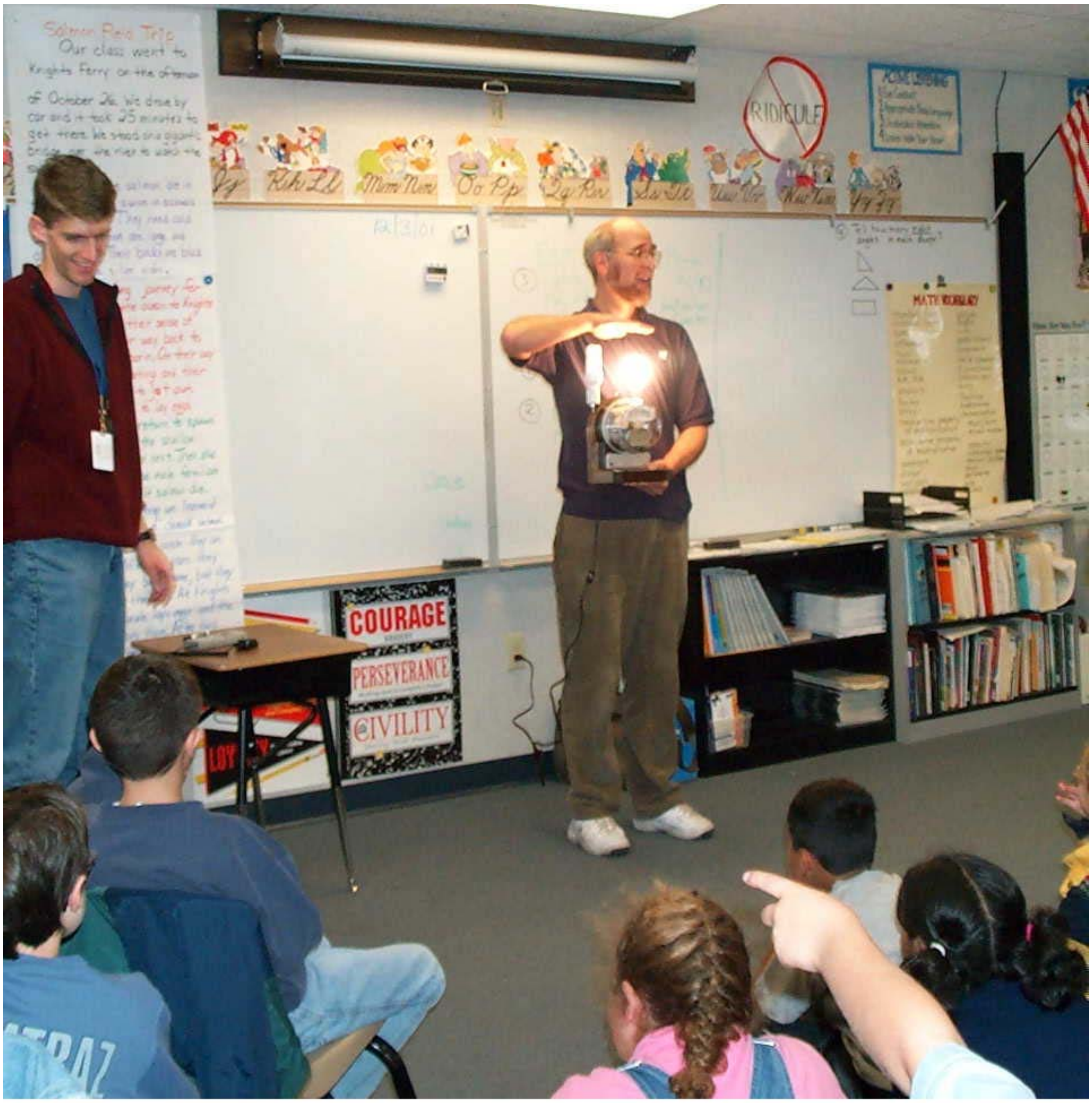


Figure 19: LBNL technician was operating the thermal comfort monitoring cart to power on and off and to download, save, and review data.

Figure 20: Photograph of the outdoor weather station to continuously measure local wind speed, wind direction, outdoor T and outdoor RH.

Final Methodology for a Field Study of Indoor Environmental Quality and Energy Efficiency in New Relocatable Classrooms in Northern California

Appendix

for CDAQS, one per SD/school, i.e., pair of RCs: locations, wiring/connectivity needs, required power (V)

Modesto City Schools	AND	Cupertino Union SD		(for <u>all Temp</u>, in F or C)

Let A= 1st RC, B= 2nd RC *dotted lines-- > wires from T (2) and RH% (4) sensors into a shielded cable at a given location/region, then bundled and directed to mux board*

sections separated by charcoal bar--> different HVAC and/or group of variable.s Let "YES T" = yes, use thermister

Sampler or Sensor, RC, I/O location	required power (in **V**AC etc.) **Provided by LBNL (cabling, CDAQS) unless noted.*	required wiring (details)	required conduits (details or "see (with) above")	connect <u>first</u> to "<u>mux board</u>" and then (second)to CDAQS at PC? (Y/N)	<u>direct connect</u> to <u>CDAQS</u> at PC? (Y/N)	<u>Shielded Cable (for wiring) Code</u>
Indoor A cumulative and by channel (n=6) PM count	120 V AC, from provided outlet set	local, within I cabinet	NO	NO	YES, RS-232	NONE
Outdoor cumulative and by channel (n=6) PM count	120 V AC, from provided outlet set	local, within I cabinet	NO	NO	YES, RS-232	NONE
Indoor A and Outdoor A CO2 (one monitor, with valve switch system)	120 V AC, from provided outlet set	local, within I cabinet	NO	YES	YES,Valve Cntl	NONE
Indoor A Temp, F, Bard inside edge return grill	*N/A*	1 shielded cable with 3 individual shielded pairs	NO	YES T	NO	ACRT
Indoor A RH%, Bard inside edge return grill	15V	*(signal combined with cable above)*	NO	YES	NO	
Indoor A Temp, F, nearest Bard supply	*N/A*	1 shielded cable with 3 individual shielded pairs	NO	YES T	NO	ACNS
Indoor A RH%, nearest Bard supply	15 V	*(signal combined with cable above)*	NO	YES	NO	
Indoor A Temp, F, farthest Bard supply	*N/A*	shielded 2 conductor cables	NO	YES T	NO	ACFS

Appendix A.1.1 (continued)					Page 2 of 7	
Indoor A Temp, F, IDEC discharge air @ plenum	*N/A*	shielded 2 conductor cables	NO	YES T	NO	AIDP
Indoor A Temp, F, nearest IDEC supply	*N/A*	1 shielded cable with 3 individual shielded pairs	NO	YES T	NO	AINS
Indoor A RH%, nearest IDEC supply	15 V	*(signal combined with cable above)*	NO	YES	NO	
Indoor A Temp, F, farthest IDEC supply	*N/A*	shielded 2 conductor cables	NO	YES T	NO	AIFS
Indoor A Temp, F, IDEC inside edge middle relief vent	*N/A*	1 shielded cable with 3 individual shielded pairs	NO	YES T	NO	AIRT
Indoor A RH%, IDEC inside edge middle relief vent	15 V	*(signal combined with cable above)*	NO	YES	NO	
Indoor A Sound Level dB (A-weighted)	9V (mux board)	1 shielded cable with 2 individual shielded pairs	NO	YES	NO	A0DB
Indoor A Temp, F, middle of RC@ 6.5 ft	*N/A*	1 shielded cable with 3 individual shielded pairs	NO	YES T	NO	A0MID
Indoor A RH%, middle of RC @ 6.5 ft	15 V	*(signal combined with cable above)*	NO	YES	NO	
Indoor A Temp, F, near side wall, 0.5 m	*N/A*	1 overall shielded cable with 4 individual conductors	NO	YES T	NO	A0WAL
Indoor A Temp, F, near side wall, 1.0 m	*N/A*	*(signal combined with cable above)*	NO	YES T	NO	
Indoor A Temp, F, near side wall, 1.7 m	*N/A*	*(signal combined with cable above)*	NO	YES T	NO	

Appendix A.1.1 (continued)					Page 3 of 7	
Sampler or Sensor, RC, I/O location	required power (in **V**AC etc.)	required wiring (details)	required conduits (details or "see (with) above")	connect <u>first</u> to "<u>mux board</u>" and then (second)to CDAQS at PC? (Y/N)	<u>direct connect</u> to <u>CDAQS</u> at PC? (Y/N)	<u>Shielded Cable (for wiring) Code</u>
Modesto City Schools		AND	Cupertino Union SD		(for <u>all Temp</u>, in F or C)	
Let A= 1st RC, B= 2nd RC	*dotted lines-- > wires from T (2) and RH% (4) sensors into a shielded cable at a given location/region, then bundled and directed to mux board*					
sections separated by charcoal bar--> different HVAC and/or group of variable.s			Let "YES T" = yes, use a		thermister	
Outdoor Air Temp, F	*N/A*	1 shielded cable with 3 individual shielded pairs	**yes, from O cabinet**	YES T	NO	A0OTR
Outdoor Air RH%	15 V	*(signal combined with cable above)*	**to I cabinet,**	YES	NO	
Outdoor Wind Speed	*N/A*	1 shielded cable with 2 individual shielded pairs	**per LBNL**	NO	YES, BD CNTR	A0OW
Outdoor Wind Direction	5Vref (mux bd)	*(signal combined with cable above)*	**specs**	NO	YES, for practical reasons	
Main Door (of RC "A") Open?	*N/A*	1 shielded cables, 2 conductors	NO	NO	YES, 1 bit (digital)	A0DR
Front 4'by8' Window (of RC "A") Open?	2.5, 5V ref (mux board)	sum 2 LDP; 1 shielded cable with 3 individual shielded pairs	NO	YES	NO	A0FW2
Rear 4'by4' Window (of RC "A") Open?	5V ref (mux board)	one LDP; 1 shielded cable with 4 conductors or 2 individual shielded pairs	NO	YES	NO	A0RW1
Main Door (of RC "B") Open?	*N/A*	1 shielded cables, 2 conductors	NO	NO	YES, 1 bit (digital)	B0DR
Front 4'by8' Window (of RC "B") Open?	2.5, 5V ref (mux board)	sum 2 LDP; 1 shielded cable with 3 individual shielded pairs	NO	YES	NO	B0FW2
Rear 4'by4' Window (of RC "B") Open?	5V ref (mux board)	one LDP; 1 shielded cable with 4 conductors or 2 indiv. shielded pairs	NO	YES	NO	B0RW1

Appendix A.1.1 (continued)					Page 4 of 7	
Sampler or Sensor, RC, I/O location	required power (in **V**AC etc.)	required wiring (details)	required conduits (details or "see (with) above")	connect first to "mux board" and then (second)to CDAQS at PC? (Y/N)	direct connect to CDAQS at PC? (Y/N)	Shielded Cable (for wiring) Code
Modesto City Schools	Rose Avenue Elementary	AND	Cupertino Union SD	Stevens Creek Elementary	(for all Temp, in F or C)	
Let A= 1st RC, B= 2nd RC	*dotted lines-- > wires from T (2) and RH% (4) sensors into a shielded cable at a given*	*location/region, then bundled and directed to mux board*				
sections separated by charcoal bar--> different HVAC and/or group of variable.s			Let "YES T" = yes, use thermister			
Indoor B cumulative and by channel (n=6) PM count	120 V AC	local, within I cabinet	NO	NO	YES, RS-232	NONE
Indoor B CO2	120 V AC	local, within I cabinet	NO	YES	YES	NONE
Indoor B Temp, F, Bard inside edge return grill	*N/A*	1 shielded cable with 3 individual shielded pairs	NO	YES T	NO	BCRT
Indoor B RH%, Bard inside edge return grill	15 V	*(signal combined with cable above)*	NO	YES	NO	
Indoor B Temp, F, nearest Bard supply	*N/A*	1 shielded cable with 3 individual shielded pairs	NO	YES T	NO	BCNS
Indoor B RH%, nearest Bard supply	15 V	*(signal combined with cable above)*	NO	YES	NO	
Indoor B Temp, F, farthest Bard supply	*N/A*	shielded 2 conductor cables	NO	YES T	NO	BCFS
Indoor B Temp, F, IDEC discharge air @ plenum	*N/A*	shielded 2 conductor cables	NO	YES T	NO	BIDP
Indoor B Temp, F, nearest IDEC supply	*N/A*	1 shielded cable with 3 individual shielded pairs	NO	YES T	NO	BINS
Indoor B RH%, nearest IDEC supply	15 V	*(signal combined with cable above)*	NO	YES	NO	
Indoor B Temp, F, farthest IDEC supply	*N/A*	shielded 2 conductor cables	NO	YES T	NO	BIFS

Appendix A.1.1 (continued)					Page 5 of 7	
Indoor B Temp, F, IDEC inside edge middle relief vent	*N/A*	1 shielded cable with 3 individual shielded pairs	NO	YES T	NO	BIRT
Indoor B RH%, IDEC inside edge middle relief vent	15 V	*(signal combined with cable above)*	NO	YES	NO	
Indoor B Sound Level dB (A-weighted)	9V (mux bd)	1 shielded cable with 2 individual shielded pairs	NO	YES	NO	B0DB
Indoor B Temp, F, middle of RC @ 6.5 ft	*N/A*	1 shielded cable with 3 individual shielded pairs	NO	YES T	NO	B0MID
Indoor B RH%, middle of RC @ 6.5 ft	15 V	*(signal combined with cable above)*	NO	YES	NO	
Indoor B Temp, F, near side wall, 0.5 m	*N/A*	1 overall shielded cable with 4 individual conductors	NO	YES T	NO	B0WAL
Indoor B Temp, F, near side wall, 1.0 m	*N/A*	*(signal combined with cable above)*	NO	YES T	NO	
Indoor B Temp, F, near side wall, 1.7 m	*N/A*	*(signal combined with cable above)*	NO	YES T	NO	

Appendix A.1.1 (continued)					page 6 of 7	
Modesto City Schools	AND		Cupertino Union SD		(for all Temp, in F or C)	
Let A= 1st RC, B= 2nd RC	*dotted lines-- > wires from T (2) and RH% (4) sensors into a shielded cable at a given*	*location/region, then bundled and directed to mux board*				
sections separated by charcoal bar--> different HVAC and/or group of variable.s			Let "YES T" = yes, use thermister			
A overall power	*N/A*	**(must keep 4 lines separate)**	**RE: yes, between**	NO	YES, Xtra Cntr Bd	A0WM
A IDEC	*N/A*	**1 shielded cable with 4**	**RC "A"**	NO	YES, Xtra Cntr Bd	
A lighting	*N/A*	**individual shielded**	**and**	NO	YES, Xtra Cntr Bd	
A Bard	*N/A*	**pairs**	**RC "B"**	NO	YES, Xtra Cntr Bd	
Coil H2O Temp	*N/A*	1 shielded cable with 4 conductors or 2 individual shielded pairs	NO	YES T (100C)	NO	A0SET
IDEC set pt	*N/A*	(analog)	NO	YES	NO	
Pump Status	*N/A*	1 shielded cable with 4 conductors or 2 individual shielded pairs	NO	NO	YES, 1 bit	A0STA
IDEC status	*N/A*	(digital)	NO	NO	YES, optoiso,1 bit	
B overall power	*N/A*	**(must keep 4 lines separate)**	**RE:yes, between**	NO	YES, Xtra Cntr Bd	B0WM
B IDEC	*N/A*	**1 shielded cable with 4**	**RC "A"**	NO	YES, Xtra Cntr Bd	
B lighting	*N/A*	**individual shielded**	**and**	NO	YES, Xtra Cntr Bd	
B Bard	*N/A*	**pairs**	**RC "B"**	NO	YES, Xtra Cntr Bd	
Coil H2O Temp	*N/A*	1 shielded cable with 4 conductors or 2 individual shielded pairs	NO	YES T (100C)	NO	B0SET
IDEC set pt	*N/A*	(analog)	NO	YES	NO	
Pump Status	*N/A*	1 shielded cable with 4 conductors or 2 individual shielded pairs	NO	NO	YES, 1 bit	B0STA
IDEC status	*N/A*	(digital)	NO	NO	YES, optoiso,1 bit	

[redacted]

Control: valve, 12 V DC; 4 multiplexor board address bits	*CUSTOM CABLING, BUILT AT LBNL*	A0MUX

Notes: LBNL would like cabling to be ordered by AMS for LBNL from Belden or known distributor AMS has quantity discount with.

Belden cabling required are part numbers 9330, 8450, 9406, 5504FE, 8723, 9302, and 8767.

LBNL will install cabling at school sites, after technician cuts appropriate lengths while working at AMS.

The wires from the window LDPs mounted at the top of the window frames will go up to the ceiling space and then will be routed to the "mux board."

AMS to mount door sensor alone, AMS/LBNL to mount LDPs on window frames.

Cabling codes	Thermister RC, I/O location	ate and excess (linear)		second estimate and excess (diagonal)	
		to 1/2 above ceiling	to max or DAQS	to 1/2 above ceiling	to max or DAQS
AINS	Indoor A Temp, F, nearest IDEC supply	2'	10' 2"	n/a	n/a
AIDP	Indoor A Temp, F, IDEC discharge air @ plenum	2'	10' 2"	n/a	n/a
AIFS	Indoor A Temp, F, farthest IDEC supply	2'	33'	n/a	n/a
AIRT	Indoor A Temp, F, IDEC inside edge relief vent on IDEC side	2'	47'	2'	38' 5"
ACNS	Indoor A Temp A , F, nearest Bard supply	2'	9' 4"	n/a	n/a
ACFS	Indoor A Temp, F, farthest Bard supply	2'	32'	n/a	n/a
ACRT	Indoor A Temp A , F, Bard inside edge return grill	3'	15'	n/a	11'
AOWAL (0.5 m)	Indoor A Temp, F, near side wall, 0.5 m	7' 8"	38'	7' 8"	29' 4"
AOWAL (1 m)	Indoor A Temp, F, near side wall, 1 m	6' 4"	38'	6' 4"	29' 4"
AOWAL (1.7 m)	Indoor A Temp, F, near side wall, 1.7 m	4'	38'	4'	29' 4"
AOMID (& AODB)	Indoor A Temp, F, middle of RC @ 6.5 ft	2'	15' each	n/a	n/a
AORW 1	Rear 4' by 4' Window (of RC "A") Open ?	3'	48'	3'	20' 3"
AOFW 2	Front 4' by 8' Window (of RC "A") Open ?	3'	37'	3'	34'
AOFW 2	Front 4' by 8' Window (of RC "A") Open ?	3'	43'	3'	36'
AODR	Main Door (of RC "A") Open ?	3'	50' 6"	3'	44'

RH % sensor RC, I/O location	Type of sensor	Cabling codes	For estimated distances
ACRT	Space	Indoor A RH %, Bard inside edge return grill	see table for ACRT Indoor A Temp, F, Bard inside edge return grill
ACNS	Duct	Indoor A RH %, nearest Bard supply	see table for ACNS Indoor A Temp, F,farthest Bard supply
AINS	Duct	Indoor A RH %, nearest IDEC supply	see table for AINS Indoor A Temp, F nearest IDEC supply
AIRT	Space	Indoor A RH %, F, IDEC inside edge relief vent on IDEC side	see table for AIRT Indoor A Temp, F, IDEC inside edge relief vent on IDEC side
AOMID	Space	Indoor A RH %, middle of RC @ 6.5ft	see table for AOMID Indoor A Temp, F, middle of RC @ 6.5 ft
A0OW	Outdoor	Outdoor Air RH %	see table for A0OTR Outdoor Air Temp, F

AOWM	20'
AOGS	50'
AOSET 1&2	10' if plenum, 30' if control board
AOSTA 1& 2 (with Belden #8450)	30' if plenum, 50' if control board
AOOTR	50'
AOOWS	50'
AOOWD	50'

Cabling codes	Thermister RC, I/O location	first estimate and excess (linear)		second estimate and excess (diagonal)	
		to 1/2 above ceiling	to max or DAQS	to 1/2 above ceiling	to max or DAQS
BINS	Indoor B Temp, F, nearest IDEC supply	2'	10' 2"	n/a	n/a
BIDP	Indoor B Temp, F, IDEC discharge air @ plenum	2'	10' 2"	n/a	n/a
BIFS	Indoor B Temp, F, farthest IDEC supply	2'	33'	n/a	n/a
BIRT	Indoor B Temp, F, IDEC inside edge relief vent on IDEC side	2'	47'	2'	38' 5"
BCNS	Indoor B Temp, F, nearest Bard supply	2'	9' 4"	n/a	n/a
BCFS	Indoor B Temp, F, farthest Bard supply	2'	32'	n/a	n/a
BCRT	Indoor B Temp, F, Bard inside edge return grill	3'	15'	n/a	11'
BOWAL (0.5 m)	Indoor B Temp, F, near side wall, 0.5 m	7' 8"	38'	7' 8"	29' 4"
BOWAL (1 m)	Indoor B Temp, F, near side wall, 1 m	6' 4"	38'	6' 4"	29' 4"
BOWAL (1.7 m)	Indoor B Temp, F, near side wall, 1.7 m	4'	38'	4'	29' 4"
BOMID (& BODB)	Indoor B Temp, F, middle of RC @ 6.5 ft	2'	15' each	n/a	n/a
BORW 1	Rear 4' by 4' Window (of RC "B") Open ?	3'	48'	3'	20' 3"
BOFW 2	Front 4' by 8' Window (of RC "B") Open ?	3'	37'	3'	34'
BOFW 2	Front 4' by 8' Window (of RC "B") Open ?	3'	43'	3'	36'
BODR	Main Door (of RC "B") Open ?	3'	50' 6"	3'	44'

RH % sensor RC, I/O location	Type of sensor	Cabling codes	For estimated distances
BCRT	Space	Indoor B RH %, Bard inside edge return grill	see table for BCRT Indoor B Temp, F, Bard inside edge return grill
BCNS	Duct	Indoor B RH %, nearest Bard supply	see table for BCNS Indoor B Temp, F,farthest Bard supply
BINS	Duct	Indoor B RH %, nearest IDEC supply	see table for BINS Indoor B Temp, F nearest IDEC supply
BIRT	Space	Indoor B RH %, F, IDEC inside edge relief vent on IDEC side	see table for BIRT Indoor B Temp, F, IDEC inside edge relief vent on IDEC side
BOMID	Space	Indoor B RH %, middle of RC @ 6.5ft	see table for BOMID Indoor B Temp, F, middle of RC @ 6.5 ft
B0OW	Outdoor	Outdoor Air RH %	see table for A0OTR Outdoor Air Temp, F

BOWM	25'
BOGS	50'
BOSET 1&2	10' if plenum, 30' if control board
BOSTA (with Belden #8450)	30' if plenum, 50' if control board

Appendix A.2.1.1.1

LBNL/CEC Field Study: Estimated Time Schedule of Key Activities

FINAL VERSION

PART I = CUSD, 8/27/01 through 11/2/01, "cooling season"

El. 6 Project Yr	**Week of**	LBNL Holidays	Staff Taking Holiday between M-F?	Known Meetings/ Conference	School Holidays (CUSD; MCS)	Tasks during LBNL visits to the schools (approximately 6:30/7 AM to 4:30 PM)
2	8/27-31/01, first week	NO	Dennis, Doug	NO	only teachers present week of 8/20 (CUSD)	**Meeting between CUSD and LBNL staff at participating school 8/20/01 2-3:15 PM, and, if necessary, another for thermostat training and further Q&A** CUSD: initial CO2 decay, VOC and aldehyde sampling 8/20 PM; systems check and IDEC "seal off" Thursday 8/30 PM; Bard mode for "air out"
2	9/3-7/01	9/3 (M, Labor Day)	NO	NO	9/3 (M, Labor Day, MCS) 9/3 (M, Labor Day, CUSD)	CUSD: sampling on opposite day from other school district = Thursday, Bard mode
2	9/10-14/01	NO	NO	9/10-11 (M-Tu, DGS in D.C.)	NO	CUSD: sampling on opposite day from other school district = Wed., IDEC mode
2	9/17-21/01	NO	NO	NO	NO	CUSD: sampling on opposite day from other school district = Tuesday, Bard mode
2	9/24-28/01	NO	NO	NO	NO	CUSD: sampling on opposite day from other school district = Thursday, IDEC mode
2	10/1-5/01	NO	NO	NO	NO	CUSD: sampling on opposite day from other school district = Thursday, Bard mode
2	10/8-12/01	NO	NO	NO	NO	CUSD: sampling on opposite day from other school district = Thursday, IDEC mode
2	10/15-19/01	NO	NO	NO	NO	CUSD: sampling on opposite day from other school district = Tuesday, Bard mode
2	10/22-26/01	NO	NO	NO	NO	CUSD: sampling on opposite day from other school district = Tuesday, IDEC mode
2	10/29-11/2/01, opt. 10th week	NO	NO	*11/3-8/01 ISEA in Charleston, SC*	NO, but *BOTH have 3-day 11/10-12*	CO2 decay and short-term sampling (like late 8/01), IDEC ABOVE PLAN EQUALS 9 WEEKS WITH TEACHERS & STUDENTS; 4-5 IDEC, 4-5 Bard.

First of two environmental education classes, on energy and the environment,

Thurs 11/15/01 14:00-15:00 (30 min/class), with data download&equipment maintenance.

NOTE: "Sampling" includes thermal comfort cart monitoring.

goal = in each operating mode, for each school/SD, 4 weeks Tu /W, 4 weeks Th

Appendix A.2.1.1.2

LBNL/CEC Field Study: Estimated Schedule of Key Activities

FINAL VERSION

PART II = MCS, 8/27/01 through 11/2/01, "cooling season"

El. 6 Project Year	Week of	LBNL Holidays	Staff Taking Holiday between M-F?	Known Meetings/ Conference	School Holidays (CUSD; MCS)	Tasks during LBNL visits to the schools (approximately 6:30/7 AM to 4:30 PM)
2	8/27-31/01, first week	NO	Dennis, Doug	NO	only teachers present (MCS)	**Meeting between CUSD and LBNL staff at participating school 8/27/01, 8:30-9:30 AM (+/- 15 minutes), and, if necessary, another for thermostat training and further Q&A at end of week.** MCS: initial CO2 decay, VOC and aldehyde sampling as well as IDEC "seal off" Wednesday 8/29; Bard on for "air out"
2	9/3-7/01	9/3 (M, Labor Day)	NO	NO	9/3 (M, Labor Day, MCS) 9/3 (M, Labor Day, MCS)	MCS: sampling on Wednesday, Bard mode
2	9/10-14/01	NO	NO	9/10-11 (M-Tu, DGS in D.C.)	NO	MCS: sampling on Thursday, IDEC mode
2	9/17-21/01	NO	NO	NO	NO	MCS: sampling on Thursday, Bard mode
2	9/24-28/01	NO	NO	NO	NO	MCS: sampling on Tuesday, IDEC mode
2	10/1-5/01	NO	NO	NO	NO	MCS: sampling on Tuesday, Bard mode
2	10/8-12/01	NO	NO	NO	NO	MCS: sampling on Tuesday, IDEC mode
2	10/15-19/01	NO	NO	NO	NO	MCS: sampling on Thursday, Bard mode
2	10/22-26/01	NO	NO	NO	NO	MCS: sampling on Thursday, IDEC mode
2	10/29-11/2/01, opt. 10th week	NO	NO	*11/3-8/01 ISEA in Charleston, SC*	NO, *but BOTH have 3-day 11/10-12*	CO2 decay and short-term sampling (like 8/30/01), IDEC ABOVE PLAN EQUALS 8 WEEKS WITH TEACHER AND STUDENTS (MCS), 4-5 with Bard, 4-5 with IDEC

First of two environmental education classes, on energy and the environment,

Monday 12/3/01 12:30-13:20, with data download and equipment maintenance.

NOTE: "Sampling" includes thermal comfort cart monitoring.

goal = in each operating mode, for each school/SD, 4 weeks Tu /W, 4 weeks Th

Appendix A.2.1.2.1
LBNL/CEC Field Study: Estimated Schedule of Key Activities
FINAL VERSION
PART III = CUSD, 1/2/02 through 3/15/02, "heating season"

El. 6 Project Year	**Week of**	LBNL Holidays	Staff Taking Holiday	Known Meetings/ Conference	School Holidays (CUSD; MCS)	Tasks during LBNL visits to the schools (approximately 6:30/7 AM to 4:30 PM)
2	12/31/01-1/4/02	12/31/01 to 1/1/02	????	NO	12/31/01-1/6/01 (MCS) 12/31/01-1/6/01 (CUSD)	**NONE** **NONE** Preparations for wintertime "heating" season.
2	1/7-11/02	NO	NO	NO	NO	CUSD: sampling on opposite day from MCS = Thursday, Bard mode
2	1/14-18/02	NO	??1/18??	NO	NO	CUSD: sampling on opposite day from MCS = Thursday, IDEC mode
2	1/21-25/02	1/21 (M, MLK Day)	NO	NO	1/21 (M, MLK Day, MCS) 1/21 (M, MLK Day, CUSD)	CUSD: sampling on opposite day from MCS = Wednesday, IDEC mode; aldehydes only (no VOCs)
2	1/28-2/1/02	NO	NO	NO	NO	CUSD: sampling on opposite day from MCS = Tuesday, Bard mode
2	2/4-8/02	NO	NO	NO	NO	CUSD: sampling on opposite day from MCS = Tuesday, Bard mode; aldehydes only (no VOCs)
2	2/11-15/02	NO	??2/15??	NO	2/11 (M, Lincoln's birthday, MCS)	CUSD: sampling on opposite day from MCS = Tuesday, IDEC mode
2	2/18-22/02	2/18 (M, Pres. Day)	NO	NO	2/18 (M, Washington's birthday, MCS); 2/16-2/24/02 Winter Break Week (CUSD)	NONE (keep in IDEC mode through 2/15/02 Friday, then have Bard starting 2/25/02 Monday)
2	2/25-29/02	NO	NO	NO	NO	CUSD: sampling on opposite day from MCS = Thursday, Bard mode
2	3/4-8/02	NO	NO	NO	NO	CUSD: sampling on opposite day from MCS = Tuesday, IDEC mode
2	3/11-15/02, opt. 10th week	NO	NO	NO	STAR Stanford 9 testing & make-ups likely to begin weeks of 3/10, 3/17, 3/24, and/or 3/31	CO2 decay and short-term sampling, IDEC, and second of two environmental education classes, as a "show and tell" of sampling equipment in the study, given ABOVE PLAN EQUALS 8 WEEKS WITH TEACHERS & STUDENTS (CUSD), 4-5 IDEC, 4-5 Bard. **NOTE:** "Sampling" includes thermal comfort cart monitoring; goal = in each operating mode, for each school/SD, 4 weeks Tu /W, 4 weeks Th

Appendix A.2.1.2.2
LBNL/CEC Field Study: Estimated Schedule of Key Activities
FINAL VERSION
PART IV = MCS, 1/2/02 through 3/15/02, "heating season"

El. 6 Project Year	**Week of**	LBNL Holidays	Staff Taking Holiday	Known Meetings/ Conference	School Holidays (CUSD; MCS)	Tasks during LBNL visits to the schools (approximately 6:30/7 AM to 4:30 PM)
2	12/31/01-1/4/02	12/31/01 to 1/1/02	????	NO	12/31/01-1/6/01 (MCS) 12/31/01-1/6/01 (CUSD)	**NONE** **NONE** Preparations for wintertime "heating" season.
2	1/7-11/02	NO	NO	NO	NO	MCS: sampling on Tuesday, Bard mode
2	1/14-18/02	NO	??1/18??	NO	NO	MCS: sampling on Tuesday, IDEC mode
2	1/21-25/02	1/21 (M, MLK Day)	NO	NO	1/21 (M, MLK Day, MCS) 1/21 (M, MLK Day, CUSD)	MCS: sampling on Thursday, IDEC mode; aldedhyes only (no VOCs)
2	1/28-2/1/02	NO	NO	NO	NO	MCS: sampling on Thursday, Bard mode
2	2/4-8/02	NO	NO	NO	NO	MCS: sampling on Thursday, Bard mode; aldedhyes only (no VOCs)
2	2/11-15/02	NO	??2/15??	NO	2/11 (M, Lincoln's birthday, MCS)	MCS: sampling on Thursday, IDEC mode
2	2/18-22/02	2/18 (M, Pres. Day)	NO	NO	2/18 (M, Washington's birthday, MCS) 2/16-2/24/02 Winter Break Week (CSD)	MCS: sampling on Wednesday, IDEC mode; aldehydes only (no VOCs)
2	2/25-29/02	NO	NO	NO	NO	MCS: sampling on Tuesday, Bard mode
2	3/4-8/02	NO	NO	NO	NO	MCS: sampling on Thursday, IDEC mode
2	3/11-15/02, optional 10th week	NO	NO	NO	STAR Stanford 9 testing & make-ups likely to begin weeks of 3/10, 3/17, 3/24, and/or 3/31	CO2 decay and short-term sampling, IDEC, and second of two environmental education classes, as a "show and tell" of sampling equipment in the study, given ABOVE PLAN EQUALS 9 WEEKS WITH TEACHERS & STUDENTS (MCS), 4-5 IDEC, 4-5 Bard **NOTE:** "Sampling" includes thermal comfort cart monitoring. Goal = in each operating mode, for each school/SD, 4 weeks Tu /W, 4 weeks Th

Appendix A.2.2.1

LBNL/CEC Relocatable (RC) Classrooms Study, Year Two—Field Study

v061801, then 071101-071901-082201 FINAL, then 060702 with additions/comments based on field experiences

Cupertino Union School District (CUSD)
Estimated "sampling day" schedule of activities-- Tuesday, Wednesday, or Thursday—at the participating school in a participating school district (n=2) (2 RCs, side-by-side, at each school).
NOTE: Please refer to MS Excel workbook containing detailed draft schedule for sampling during the cooling and heating seasons, including thermal comfort cart measurements.
Assumption:
The head custodian at CUSD arrives by 7:00 AM (maybe as early as 6:00 AM), and school begins about 9:05 AM and ends 3:05 PM.

*Since two 4th grade classes, 30-32 students each on <34'L by 24'W carpeted floor area.

Monday (for Tuesday), Tuesday (for Wednesday, if Monday is LBNL and/or school holiday), and/or Wednesday (for Thursday):
Preparations for the field visit the following day include picking up LBNL van by 3 PM Monday; loading thermal comfort carts into the van; VOC multisorbent tubes and DNPH cartridges into cooler with ice and then into the van; preparing pre-printed field data sheets and checklists in binders; bringing laptop computer and RS232 cables for HOBO.

<u>Tuesday/Wednesday or Thursday (one day at each school)</u> = **Daily Sampling Schedule**
OVERVIEW:
Duration of travel time from Walnut Creek (safety margin included for traffic scenarios):
to school in Cupertino = 1.5 hours

Duration of school day for LBNL SRA/RA= 9 hours, with short breaks

Duration of travel time back to LBNL, Berkeley (safety margin included for traffic scenarios):
from school in Cupertino = 1.5-2 hours, per freeways and bridge

Duration of time needed to unload car, store samples in fridge, return car, etc. = 0.5 hour

TOTAL TIME REQUIRED OF STAFF, 2 DAYS/WEEK =
about 13-14 hrs/day, 26-28 hrs/week

TOTAL TIME REQUIRED OF STAFF A WEEK, INCLUDING LBNL PREP =
about 30 hrs

NOTE: SRA/RA (DGS) will have laptop to do work when not inside/outside test RCs

TIME/TIME PERIOD	LOCATION	ACTIVITY
5:15 AM – 6:30 AM	Walnut Creek toCupertino	outbound commute
6:30 AM- 8:15 AM (+/- 5 minutes at end)	Participating School in Cupertino	unload, sampler set-ups, pump calibrations
6:30/6:40 AM – 7:05AM	Participating school available parking nearest the two RCs	Unload cooler with samples, thermal comfort(TC)carts, tool box, monitor, zip drive, etc and bring to RCs

NOTE: move van off-campus by 8:30 AM

NOTE: by between 7:00 AM – 7:10 AM Gain access to RCs with custodian.

7:00 AM – 7:20 AM (10 minutes outdoors, 5 minutes in each RC)	In RCs	Set up LBNL shelf once cabinets opened, set up monitor, keyboard and mouse. Conduct classroom conditions checklist, check teacher's T setting.
7:20-7:35 AM (5 minutes per RC or outdors)		Measure PM counter flow rates, and calibrate as necessary to adjust to PSI nominal flow. Inspect and fix as needed. Confirm proper operation settings. Record important observations.

NOTE: from end of cooling season through remainder of field study

7:35 AM – 8:00 AM (10 minutes each RC, inc. outdoors)	In RCs, sampler pump box	Remove samples from cooler. Open cabinet, start and inspect pumps for VOC and DNPH aldehydes samples. Record sample ID number, date, pump number, school, and classroom number on field sheet. (Pre-programmed pump, start time.) Include any duplicates. Handle field blanks.
during 7:20 AM – 8:00 AM (7-8 minutes in each RC)	In RCs	Calibrate noise sound level meter (SLM, Extech). Visual inspection of CO_2, CDAQS noise, and T/RH/door/window samplers and sensors for physical integrity. Pack cooler and equipment finished with.

** Complete tasks in one RC, then move to the other.

8:00 AM-8:10 AM - (5 minutes in each RC)	In RCs, first location, TC cart	Start TC cart measurements at 1st location.
8:10 AM – 8:30 AM - (<10 minutes in each RC)	In RCs	Download previous "week" (5-9 days) data from HOBOs to laptop, "relaunch" HOBOs.

NOTE: can be done in AM or duirng morning recess or during lunch period as well.

8:15 AM – 8:25 AM	Around/in the RCs	Pack equipment and tools finished with.

Appendix A.2.2.1 (continued)

NOW, OTHER ACTIVITIES OCCUR OUTSIDE

TIME/TIME PERIOD	LOCATION	ACTIVITY
8:30 AM- 8:55 AM (At each RC, 3-5 min. each sampling system/set of pumps)	LBNL locker outside behind RC (unlock/lock with padlock & key)	Record flow rates of peristaltic pumps** used for the VOC and DNPH sampling.

***Start with indoor pumps, then the outdoor pumps.*

8:55 AM – 9:05 AM	Outside back side RC,	Visual inspection of components "weather station" and samplers and connection to central DAQS by conduit. Check gas/H20 lines to IDEC & heater.
9:05-9:25	LBNL locker outside behind RC (unlock/lock with padlock & key)	Confirm proper operation of continuous samplers for indoor T and RH% sensors, indoor /outdoor CO2, door and window sensors, particle counts, outdoor T and RH%, and outdoor wind speed and direction <u>via CDAQS operation, i.e., data collection.</u> Check for any leaks/moisture.
By 9:30-10:00 AM	*Project Cell Phone*	Call LBNL (MGA, DPS, Dennis), report "all checks made, all O.K." and/or issues. Also, confirm check in w/ office, prinicipal.

end of phone call until 10:30 am In town, and/or in van

Breakfast break; read, do paperwork = sources checklist (outdoor,start indoor with AM observations). Start review of previous week data in MS Excel templates.

10:40 AM – 10:55 AM (2-6 minutes per classroom per task)	In RCs	move TC cart to 2nd location if no rain, conduct classroom conditions checklist
until school's lunch break	**In van**	work with laptop work with previous week data cont.
12:30 PM- 1:10 PM (during lunch break) (20 minutes per classroom)	In RCs	move TC cart to 3rd location (2nd if rain), conduct classroom conditions checklist, finish sources checklist (indoor with cleaning compounds, etc.), TC clo checklist (based on AM observations)
from end of school's lunch until near end (3:15PM) of student's day (3:35 PM)	**In van/in town**	work on laptop, break

Appendix A.2.2.1 (continued)

TIME/TIME PERIOD	LOCATION	ACTIVITY
3:20 PM—3:30 PM	** Save work tasks on personal computer and prepare for final field work!	

3:30 PM – 5:30/6:00 PM In/Outside RCs
Calibrate peristaltic pumps; stop, cap, and store integrated school day VOC and DNPH samples in cooler for transport; view and inspect continuous sensors and sampler data; complete TC cart measures; HOBO and noise data.

3:35 PM – 4:00 PM (10 minutes in each RC, including outdoor pumps)	In RCs, sampler pump boxes	Record final flow rates for peristaltic pumps for VOC&DNPH samples and duplicates, and note any unusual physical conditions of pump and cartridge or noise made by pump. Confirm sample ID number, pump number, and classroom number on field sheet. Turn off pump and record pump time. Collect field blanks (if not done in AM).. Store samples in cooler.
4:00 PM – 4:30 PM - (up to 10 minutes in each RC)	In RCs, first location, TC cart	Stop TC cart measurements at last location; end data collection, review data, save file.
Also 4:00 PM – 4:30 PM (3-5 minutes in each RC)	In RCs	Check teacher's HVAC T setting; conduct classroom conditions checklist
4:30-PM – 5:00 PM (12-15 minutes per RC)	In RCs	Record flow rate of indoor and outdoor MetOne 237B particle counters with BIOS DryCal or Gilibrator bubble flow meter. Calibrate CO2 monitors using protocol.
by 4:00, 6:00 PM		Check out with main office and principal. Remind them (night custodians) LBNL on campus until about 6:00 PM.
5:00 PM – 5:10 PM	LBNL locker outside behind RC (unlock/lock with padlock & key)	Confirm proper operation of continuous samplers for indoor T and RH% sensors, indoor/outdoor CO2, door and window sensors, particle counts, outdoor T and RH%, and outdoor wind speed and direction by viewing parts of day's data. Download this week's data to a zip disk. Remove monitor and zip drive.
5:10 PM – 5:40 PM	In RCs	TC carts stored in van. Load cooler with samples, calibration equipment tool box, laptop PC, etc. into van. Bring monitor, zip drive and disk to van. Get HVAC system "seal off" panels.

Appendix A.2.2.1 (continued)

5:40 PM – 5:55 PM
AT SCHOOL: at the end of the sampling day, before leaving the school for LBNL

After school day is over, shut down the HVAC system operating the previous week. This includes sealing off, with method to be determined, the supply side at the air filters and relief vents (IDEC only). Then, open and start the other HVAC system for the present week.

PROTOCOL:

Bard HVAC system: seal off 28" by 9.5" air intake opening/relief opening outdoors on the Bard unit with LBNL designed Al panel and 3M velcro. Turn Bard "off" at indoor thermostat, and timer to zero, then lock its plastic box.

IDEC HVAC system and relief vents: seal off three parts of the LBNL designed inlet filter racks with appropriately sized Lexan panels and 3M velcro.
Switch master electrical disconnect outdoors at circuit breaker box to off.
Turn IDEC "off" at indoor thermostat, then lock its plastic box.

---

by 6:00-6:15 PM	*Project Cell Phone*	Call LBNL (MGA, DPS, Dennis), report "all checks made, all O.K." and/or issues. Organization and final review of field data sheets and checklists from the day.
~6:15-7:30/7:45	Cupertino to LBNL Inbound commute, after a drink/snack Park LBNL van at Bldg. 90 or W.C.	Unload cooler with samples**, and tools (as necessary), laptop PC, checklists, data sheet binder, disks.

**Samples go into home refrigerator overnight (cooling season) or kept in van cargo area overnight (heating season) and then to Al Hodgson, building 70-221, the following morning

Appendix 2.2.2

LBNL/CEC Relocatable (RC) Classrooms Study, Year Two—Field Study

v061801, then 071101-071901-082201 FINAL, then 060702 with additions/comments based on field experiences

Modesto City Schools (MCS)

Estimated "sampling day" schedule of activities-- Tuesday, Wednesday, or Thursday—at the participating school in a participating school district (n=2) (2 RCs, side-by-side, at each school).
NOTE: Please refer to MS Excel workbook containing detailed draft schedule for sampling during the cooling and heating seasons, including thermal comfort cart measurements.
Assumption:
The head custodian at Modesto arrives by 7:00 AM, and school begins about 8:30 AM +/- five min. and ends about 2:35 PM +/- five min.

AT LBNL: *Monday (for Tuesday), Tuesday (for Wednesday, if Monday is LBNL and/or school holiday), and/or Wednesday (for Thursday):*
Preparations for the field visit the following day include picking up LBNL van between 1-3 PM Monday; loading thermal comfort carts into the van; VOC multisorbent tubes and DNPH cartridges into cooler with ice and then into the van; preparing pre-printed field data sheets and checklists in binders; CO_2 "cal bags;" bringing laptop computer and RS232 cables for HOBO.

Tuesday/Wednesday or Thursday (one day at each school)
Daily Sampling Schedule
OVERVIEW:
Duration of travel time from Walnut Creek (safety margin included for traffic scenarios):
to school in Modesto = 1.5 hours

Duration of school day for LBNL staff = 9.5-10 hours, with short snack breaks

Duration of travel time back to LBNL, Berkeley (safety margin included for traffic scenarios):
from school in Modesto = 1.5-2 hours, per I-580 situation and town

Duration of time needed to unload car, store samples in fridge, return car, etc. = 0.5 hour

TOTAL TIME REQUIRED OF SRA/RA, 2 DAYS/WEEK =
about 13-14 hrs/day, 26 hrs/week
TOTAL TIME REQUIRED OF SRA/RA A WEEK, INCLUDING LBNL PREP =
about 30 hrs
NOTE: SRA/RA (DGS) will have laptop to do work when not inside/outside test RCs

TIME/TIME PERIOD	LOCATION	ACTIVITY
5:20 AM – 6:50 AM or earlier	Walnut Creek to Modesto	outbound commute

Appendix 2.2.2 (continued)

TIME/TIME PERIOD	LOCATION	ACTIVITY
6:50 AM- 8:15 AM (+/- 5 minutes at end)	Participating School in Modesto	unload, sampler set-ups, pump calibrations
6:50 AM – 7:10 AM	Participating school available parking nearest the two RCs	Unload and carry cooler with samples, thermal comfort(TC) carts, tools, monitor, zip drive. Assumes access to RCs gained.
7:10 AM – 7:20 AM (5 minutes in each RC)	In RCs	Conduct classroom conditions checklist, check teacher's T setting.
7:20 AM – 7:45 AM (10 minutes each RC, inc. outdoors)	In RCs, sampler pump box	Remove samples from cooler. Open cabinet, start and inspect pumps for VOC and DNPH aldehydes samples. Record sample ID number, date, pump number, school, and classroom number on field sheet. (Pre-programmed pump, start time.) Include any duplicates and field blanks.
during 7:45 AM – 7:55 AM (5 minutes in each RC)	In RCs	Calibrate noise sound level meter (SLM, Extech). Visual inspection of CO2, particle count, CDAQS, noise, and T/RH/door/window samplers and sensors for physical integrity.
** Complete tasks in one RC, then move to the other.		
7:55 AM-8:05 AM - (5 minutes in each RC)	In RCs, first location, TC cart	Start TC cart measurements at 1st location.
8:05 AM – 8:10 AM	In RCs	Pack up cooler and equipment finished with.
NOW, OTHER ACTIVITIES OCCUR OUTSIDE		
8:10 AM- 8:30 AM (At each RC, 3-5 min. each sampling system/set of pumps)	LBNL locker outside behind RC (unlock/lock with padlock & key)	Record flow rates of peristaltic pumps** used for the VOC and DNPH aldehyde sampling pumps.
	***Start with indoor pumps, then the outdoor pumps*.	
8:30 AM – 8:40 AM	Around the RCs	Pack equipment and tools finished with.
8:40 AM – 8:45 AM	Outside back side RC, "weather station" and samplers	Visual inspection of components and connection to central DAQS by conduit. Check gas/H20 lines to IDEC & heater.
8:45 AM – 9:15 AM (NOTE: set-up of monitor can be <6:45 as well)	LBNL locker outside behind RC	Set-up monitor and zip drive in locker. Confirm proper operation of continuous samplers for indoor T and RH% sensors,

Appendix 2.2.2 (continued)

TIME/TIME PERIOD	LOCATION	ACTIVITY
		indoor /outdoor CO_2, door and window sensors, particle counts, outdoor T and RH%, and outdoor wind speed and direction via CDAQS operation, i.e., data collection. Check for any leaks/moisture in and around LBNL locker..
after AM work	*Project Cell Phone*	Call LBNL (MGA, DPS, Dennis), report "all checks made, all O.K." and/or issues. Also, confirm check in w/ office, prinicipal.
end of phone call until 10:15 am	***In van***	*Breakfast break; read, do paperwork = sources checklist (outdoor,start indoor with AM observations) and start review of previous week data in MS Excel templates.*
10:15 AM – 10:30 AM (during recess break, if no rain) (5 minutes per classroom)	In RCs	move TC cart to 2nd location; classroom conditions checklist
until school's lunch break	**In van**	work with previous week data cont.
11:45 AM- 12:25 PM (during lunch break) (20 minutes per classroom)	In RCs	move TC cart to 3rd location (2nd if rain); classroom conditions checklist, finish sources checklist (indoor with cleaning compounds, etc.) and TC clo checklist (based on AM observations)
from end of school's lunch until near end (2:20 PM) of student's day (2:35 PM)	**In van/in town**	work on laptop, read, class attendance checklist (for today and since previous week's field visit) through school secretary, break with drink/snack

Appendix 2.2.2 (continued)

TIME/TIME PERIOD	LOCATION	ACTIVITY
2:25 PM—2:40 PM		** Save work tasks on laptop and prepare for final field work!
2:40 PM – 4:15-4:30 PM	In/Outside RCs	

Calibrate peristaltic pumps; stop, cap, and store integrated school day VOC and DNPH samples in cooler for transport; view and inspect continuous sensors and sampler data; complete TC cart measures; HOBO and noise data.

2:40 PM – 3:10 PM (10 minutes in each RC, including outdoor pumps)	In RCs, sampler pump boxes	Record final flow rates for peristaltic pumps for VOC&DNPH samples and duplicates, and note any unusual physical conditions of pump and cartridge or noise made by pump. Confirm sample ID number, pump number, and classroom number on field sheet. Turn off pump and record pump time. Collect field blanks (if not done in AM).. Store samples in cooler.
3:10 PM – 3:35 PM - (up to 10 minutes in each RC)	In RCs, first location, TC cart	Stop TC cart measurements at last location; end data collection, save and review files.
Also 3:10 PM – 3:35 PM	In RCs	Check teacher's HVAC T setting; conduct classroom conditions checklist
3:35 PM – 4:30 PM (20 minutes per RC)	In RCs	Record flow rate of indoor and outdoor MetOne 237B particle counters with BIOS DryCal or Gilibrator bubble flow meter. Calibrate CO_2 monitors using protocol.

NOTE: during heating season weekly visits winter 2002 and spring 2002 bi-/tri-weekly visits, measured flow rate of particle counters once in both AM and PM, performing necessary calibration to nominal flow.

4:30 PM – 4:40 PM	In RCs	TC carts stored in van. Check out with main office and principal, but remind them (PM custodian) LBNL on campus to ~5-6PM.
4:40 PM – 4:50 PM -	In RCs	Download previous "week" (5-9 days) data from HOBOs to laptop, "relaunch" HOBOs, put back in RCs.

NOTE: during heating season weekly visits winter 2002, HOBOs during lunch period or after school.

4:50 PM – 5:00 PM	LBNL locker outside behind RC (unlock/lock with padlock & key)	Confirm proper operation of CDAQS and continuous samplers for indoor T and RH%, indoor/outdoor CO_2, door and window sensors, particle counts, outdoor T and RH%, and outdoor wind speed and direction by viewing parts of day's data. Download this week's data to a zip disk. Remove monitor and zip drive.
5:00 PM – 5:10 PM	Participating school, available	Load cooler with samples, calibration equipment tool box, laptop PC, etc. into van. Get HVAC system "seal off" Lexan or Al panels.

Appendix 2.2.2 (continued)

5:10– 5:20 PM

AT SCHOOL: at the end of the sampling day, before leaving the school for LBNL

After school day is over, shut down the HVAC system operating the previous week. This includes sealing off, with method to be determined, the supply side at the air filters and relief vents (IDEC only). Then, open and start the other HVAC system for the present week.

PROTOCOL:

Bard HVAC system: seal off 28” by 9.5” air intake opening/relief opening outdoors on the Bard unit with LBNL designed Al panel and 3M velcro. Turn Bard “off” at indoor thermostat, and timer to zero, then lock its plastic box.

IDEC HVAC system and relief vents: seal off three parts of the LBNL designed inlet filter racks with appropriately sized Lexan panels and 3M velcro. Switch master electrical disconnect outdoors at circuit breaker box to off. Turn IDEC “off” at indoor thermostat, then lock its plastic box.

by 6:00 PM	*Project Cell Phone*	Call LBNL (MGA, DPS, Dennis), report “all checks made, all O.K.” and/or issues. Organization and final review of field data sheets and checklists from the day.
~6:00 – 7:30/8:00 PM	Modesto to LBNL or W.C. Inbound commute, after a drink/snack Park LBNL van at Bldg. 90 or W.C.	Unload cooler with samples**, and tools (as necessary), laptop PC, checklists, data sheet binder, disks.

**Samples go into home refrigerator overnight (cooling season) or kept in van cargo area overnight (heating season) and then to Al Hodgson, building 70-221, the following morning.

Appendix A.3.1

CO_2 Monitoring System Calibration—Relocatable Classrooms (RC) Study

FROM: v. 06/19/01, FINAL revision 8/30/01, additions based on field experience 061002, by DGS

original draft adapted from Vallejo Building Study (written by Doug Sullivan and David Faulkner)

2.) Calibrate

The monitor will be operating before school hours and will be sampling air indoors when we will calibrate. The manual disconnect point (leur fittings) is located upstream of the outdoor sampling point (above LBNL outdoor locker, away from wall) to provide a connection for the technician to connect the calibration bags in front of the LBNL outdoor locker to sampling line attached to the ZFP-9.
Refer also to daily activities schedule and page 1.

Step #1 Open the LBNL indoor cabinet and look in at the CO2 system. Visually check to see sampling lines are intact. Verify voltage readings are being logged for "CO2 in, A: and B:" by CDAQS with "COOLMAIN" screen of LabView 5 program on monitor.

Step #2 Disable automatic sequencing, i.e., use manual disconnect system—sampling line open so end connected to ZFP-9, which has a knot, is open for the calibration procedure. This end of the tubing (no. 16 Masterflex Norprene tubing, Cole-Parmer Instrument Corporation, Vernon Hills, IL) has a female leur fitting, since the calibration bags have male leur fittings.

Step #3 For calibration, connect the "cal bags" one at a time to tubing extending from outdoor enclosure, starting from lowest to highest concentration. Leave each bag connected for 60 (or 120) seconds.
Record connect time on data sheet. **The concentration range, as % of 2788 ppm, used for this study were zero air, 10%, 20%, 30%, 40%, and 50%.**

Step #4 Check the data in real-time using LabView 5 programs, "CO2Cal_A" and "CO2Cal_B" during the calibration procedure. The program ran five minutes, i.e., included three "cal bags" in each file labeled a, b, c, etc, and must be manually restarted using mouse and keyboard.

Step #5 Re-enable automatic sequencing by connecting the sampling line manually so it is closed and the system is ready for the continuation of indoor sampling. Confirm new RC A indoors and RC B indoors data with CDAQS.

Step #6 Download calibration data, saving data as a text file to the C:/ and zip drives with standardized file name Cal RCXYYMonthDDZ.dat (Cal = calibration, X= RC A or B, Z= file a, b, c, DD= day, YY= year).
NOTE: file name may be the same as week's data file, but with suffix "b" ("a" is suffix for data set).
If data were examined graphically on a laptop PC with MS Excel, the individual "cal bags" should show up as ~square peaks of ever increasing height/voltage values.

Step #7 Calibration must be completed and deemed reasonable, and systems checked and indoor sampling reconfirmed, before starting to monitor a new school week with the other HVAC system, i.e., restart CDAQS and save present week's data files to C:/ and zip drive.

Appendix A.3.1 (continued)

Relocatable classroom (RC) study, ____(school name), CUSD or MCS

CO2 Monitor Data Sheet

LBNL Relocatable Classroom ____ (fill in A or B) = Room # ____

(circle one) HEATING SEASON COOLING SEASON Transitional Period

HVAC SYSTEM FOR THIS SAMPLING WEEK (circle one) Bard 10 SEER IDEC-hydronic heat coil

Sampling Period = school day hours on a (circle one) TUESDAY WEDNESDAY THURSDAY

Date _______ Technician _________________

Monitor ID number ____

Does this RC have valve switch for outdoor sampling? Yes No

Backup of data downloaded to CDAQS saved, as part of overall flat file, for week at end of day. Saved data (file name RCXYYMonthDDZ.dat, where date was start of week(s) of monitoring)

c:_____________________

Backup to floppy (a:/) or zip disk (d:/) **(check)** ________

Calibrate

CONFIRM at position for indoor sampling (check) _______

Manual disconnect-- sampling line open so end connected to ZFP-9, which has a knot, is open for calibration____

Time ___:_____ AM PM

Calibration Bags, 60-120 seconds per bag **(record time, and check)** **START: ______**

STOP: ______

Of ____ ppm CO2 as prepared at LBNL Bldg. 63

0%, connect time_______________ ____ 0.__ volts

10%, connect time______________ ____ 0.__ volts

20%, connect time ______________ ____ 1.__ volts

30%, connect time______________ ____ 1.__ volts

40%, connect time ______________ ____ 1.__ volts

50%, connect time ______________ ____ 1.__ volts

Download cal data

Calibration data looks good graphically on monitor in LabView 5 **(check)** __________

Saved data as text file, name: **c:**________________

Calibration file description **(**file name **CAL RCXYYMonthDDZ.dat)**

Backup to floppy (a:/) or zip disk (d:/) **(check)** ________

Restart CO2 Monitoring

Reconnect sampling line manually so it is closed and the system is ready for continuation of indoor sampling ____

Time ___:_____ AM PM **back to ____ volts at __:__ on CDAQ**

Appendix A.3.2

LBNL Relocatable Classrooms Field Study (Element 6)

Field Data Sheet: Particle Counters (MetOne 237B) Flows, Sound Level Meters, Gas Use, HOBOs

SCHOOL NAME/ID: ________ **SCHOOL DISTRICT:** ________

Circle One: **Bard** **IDEC** *Circle One:* Cooling Season Heating Season Transitional Period

SAMPLING PERIOD DATES: __________

	Particle Counter Flow Rate Measurements			
Classroom/Room #	Date **(mmddyy)**	Day of Week	Time	Flow Rate **(cc/min or L/min)**
LBNL RC A = Room #____:……				
LBNL RC B = Room # ____:				
Outdoor PM counter:				
COMMENTS:				

AM field technician comments:

PM field tech nician comments:

HOBO (Temp/RH%), near teacher workstation/desk		
	LBNL RC A = Room #____	LBNL RC B = Room # ____
ID number		
Start Date (mm/dd/yy)		
Starting Time (hh/mm)		
End Date (mm/dd/yy)		
Ending Time (hh/mm)		
Location (Floor-Room)		

COMMENTS:

Gas Meters (Rinnai-IDEC)		
Classroom, # and RC A/B	AM check (time = ____)	PM check (time = ____)
RC A, Rm. 31		
RC B, Rm. 30		
Sound Level Meters	calibration target	= 94.0 dB(A)
Classroom, # and RC A/B	AM check	Reading after calibration
RC A, Rm. 31		
RC B, Rm. 30		

Appendix A.3.3

Data sheet for VOC and DNPH aldehydes sampling in public school relocatable classrooms

School District/School ______________________________________
Relocatable Classroom (INDOOR A) # ____ Relocatable Classroom (INDOOR B) # ____
(circle one) HEATING SEASON COOLING SEASON
(circle one) Bard 10 SEER HVAC IDEC & hydronic heat coil for HVAC
Sampling Period = 7:50-15:00 (MCS) / 8:15-15:35 (CUSD) on (circle one)
TUESDAY WEDNESDAY THURSDAY
Date _______ Technician _________________
Field Work/SAMPLING Start Time ___________
NOTE: warm up pumps for 15 minutes…START WARM-UP ______*AM, END WARM-UP*______*AM*

Record INDOOR A

Peristaltic Pump ID# ________________
Record Elapsed Time Left Timer___________ Right Timer_____________
Clock correct (**check**) Left Timer____ Right Timer____
Set to "AUTO" (**check**) Left Timer____ Right Timer____
Programming Correct (**check**) Left Timer____ Right Timer____
Return to clock (**check**) Left Timer____ Right Timer____

In **location # 3**, install and record ALD cartridge # _______
(In **location # 4**, install and record dup ALD cartridge # ______)
In **location #1**, install and record VOC sorbent tube # ____________
In **location #2,** install and record VOC sorbent tube # ____________

Record OUTDOOR

Peristaltic Pump ID# ________________
Record Elapsed Time Left Timer___________ Right Timer_____________
Clock correct (**check**) Left Timer____ Right Timer____
Set to "AUTO" (**check**) Left Timer____ Right Timer____
Programming Correct (**check**) Left Timer____ Right Timer____
Return to clock (**check**) Left Timer____ Right Timer____

In **location # 11**, install and record ALD cartridge # _______
In **location #9**, install and record VOC sorbent tube # ____________
In **location #10,** install and record VOC sorbent tube # ____________

Record INDOOR B

Peristaltic Pump ID# ________________
Record Elapsed Time Left Timer___________ Right Timer_____________
Clock correct (**check**) Left Timer____ Right Timer____
Set to "AUTO" (**check**) Left Timer____ Right Timer____
Programming Correct (**check**) Left Timer____ Right Timer____
Return to clock (**check**) Left Timer____ Right Timer____

In **location # 7**, install and record ALD cartridge # _______
(In **location # 8**, install and record dup ALD cartridge # ______)
In **location #5**, install and record VOC sorbent tube # ____________
In **location #6,** install and record VOC sorbent tube # ____________

Appendix A.3.3 (continued)

School District/School ___________________________________
Relocatable Classroom (INDOOR A) # ____ Relocatable Classroom (INDOOR B) # ____
(circle one) HEATING SEASON COOLING SEASON
(circle one) Bard 10 SEER HVAC IDEC & hydronic heat coil for HVAC
Sampling Period = approximately 8:00 to 15:00 on a (circle one)
TUESDAY WEDNESDAY THURSDAY
Date _______ Technician _________________
Field Work/SAMPLING Start Time ___________
NOTE: DNPH cartridge in **location (Loc) #3(and #4)**, VOC sorbent tube in **Loc #1**, Duplicate VOC sorbent tube in **Loc #2**
NOTE: warm up pumps for 15 minutes…START WARM-UP ______*AM, END WARM-UP*______*AM*

Flow rate measurements

AM measurements START TIME __________

INDOOR A____Temp_______ Loc#3 Flowrate ____________
Loc#1 Flowrate ____________
Loc#2 Flowrate ____________
OUTDOOR____Temp_______ Loc#11 Flowrate ____________
Loc#9 Flowrate ____________,
Loc#10 Flowrate ____________
INDOOR B____Temp_______ Loc#7 Flowrate ____________ (Loc#8-dup Flowrate ____________),
Loc#5 Flowrate ____________
Loc#6 Flowrate_____________

AM measurements END TIME __________

PM measurements START TIME__________

INDOOR A____Temp_______ Loc#3 Flowrate ____________
Loc#1 Flowrate ____________
Loc#2 Flowrate ____________
OUTDOOR____Temp_______ Loc#11 Flowrate ____________
Loc#9 Flowrate ____________
Loc#10 Flowrate ____________
INDOOR B____Temp_______ Loc#7 Flowrate ____________ (Loc#8-dup Flowrate ____________),
Loc#5 Flowrate ____________
Loc#6 Flowrate____________

PM measurements END TIME __________

End of run Elapsed time measurements

INDOOR A Remove and store samples (check) __ Left Timer______ Right Timer______
OUTDOOR Remove and store samples (check) __ Left Timer______ Right Timer______
INDOOR B Remove and store samples (check) __ Left Timer______ Right Timer_____

Appendix A.3.4

LBNL Field Study: Thermal Comfort Assessment with LBNL TC carts

final version 6/19/01 with field experience notes added 061002, DGS

Part IV: Measurements during a school day with the Thermal Comfort Cart for T, RH%, air velocity

NOTE: refer to attached classroom diagram for graphic description of the areas, within which will be the four TC cart locations (#1/2, 3, 6).
NOTE: IDEC and Bard 10 SEER HVAC unit ceiling air diffusers (set of three and two, respectively) are parallel to each other on opposite sides of modline
FIRST PLAN IS CHOSEN:
LBNL CONSTRUCTS TWO THERMAL COMFORT CARTS...

Scenario A: cooling season or heating season sampling, no rain

Monitor each classroom at least four Tuesdays and four Thursdays, at three positions per day.
A POSITION = TIME INTERVAL
Enter classroom to set up/place TC cart or end assessment before school, at recess, at lunch, and at end of school day.
First time interval is on the side of the RC with HVAC in operation for a given week, with only teacher present.

TC cart can be near diffusers but not directly underneath within (3-4 ft)2 area.

Loc	TIME INTERVAL	TC CART PLACED WITHIN AREA:	EST. TIME PERIOD	DESCRIPTION OF CLASSROOM…
1	1	1 (if IDEC), 2 (if Bard)	~8:15 TO 10:20-10:30 (MCS) or ~ 8:30 TO 10:40-10:50 (CUSD)	at least 30 minutes unoccupied, about 2 hours occupied
2	2	3	10:20-10:30 TO 11:45-11:55 (MCS) or 10:40-10:50 TO 12:30-12:40 (CUSD)	about 10-15 minutes unoccupied, about 1-1.5 hours occupied
3	3	6	11:45-11:55 TO ~15:45-16:00 (MCS) or 12:30-12:40 TO ~16:10-16:30 (CUSD)	at least 30 minutes unoccupied, about 2-2.25 hours occupied, 5 or 10 to 30 minutes occupied by teacher only

Appendix A.3.4 (continued)

final version 6/19/01 with field experience notes added 061002, DGS

Part IV: Measurements during a school day with the Thermal Comfort Cart for T, RH%, air velocity

Scenario B: when raining on a sampling day during (most likely the) heating season sampling period

Monitor each classroom at two positions per day. A POSITION = TIME INTERVAL

Enter classroom to set up/place TC cart or end assessment before school, at lunch, and at end of school day.

First time interval is on the side of the RC with HVAC in operation for a given week, with only teacher present.

TC cart can be near diffusers but not directly underneath within (3-4 ft)2 area.

Loc	TIME INTERVAL	TC CART PLACED WITHIN AREA:	EST. TIME PERIOD	DESCRIPTION OF CLASSROOM…
1	1	1 (if IDEC), 2 (if Bard)	8:00 TO 11:45-11:55 (MCS) or 12:30-12:40 (CUSD)	at least 30 minutes unoccupied, about 3-3.50 hours occupied
2	2	between/including 3 and 6	11:45-11:55 TO ~15:45-16:00 (MCS) or 12:30-12:40 TO ~16:15-16:30 (CUSD)	at least 30 minutes unoccupied, about 2-2.5 hours occupied, 5 or 10 to 30 minutes occupied by teacher only

Appendix A.4.1

LBNL Relocatable Classrooms Study		
Classroom Attendance and Temporary Absenteeism Spreadsheet-->		

(name of school district) **(name of elementary school)**	SAMPLING PERIOD: ________ to ________, 200_.		
	Circle One: COOLING SEASON HEATING SEASON		*Circle One*: IDEC Bard
	Dates (mm/dd -- mm/dd, yyyy): ________________		
	Classroom #: ____		
Max. # students/teacher in RC =	19-20 (MCS), 29 or 31 (CUSD)	+ teacher	

# students arriving to school (date) =	____	____	____	____	____	____	____	____
Time Interval	Student leaves early/arrives late at parent or caregiver's request? ___ *(write Y, or leave blank= N)*	Date (mmddyy, Day of Week)	If Y, how many? (#)	Extra recess time, class field trip, or class held elsewhere in school? *(write Y, or leave blank = N)*	Date (mmddyy, Day of Week)	RC occupancy increases? Estimate by how many students. *(write Y, or leave blank = N)*	Date (mmddyy, Day of Week)	
before 9:00 AM, school started 8:25 AM								
9:00 AM - AM recess								
AM recess - lunch time								
lunch time - 2:00 PM								
after 2:00 PM								

NOTE: 1 student represents only 5% of students, and under 5% of occupants, I.e., no detectable influence since CO2 can drop by chance alone.
Therefore, no need to keep track of student trips to use bathroom, to nurse, to main office (Principal).

(circle correct choice)		
Regular Teacher present?	Y	N
Substitute Teacher present (regular teacher absent)?	Y	N

Appendix A.4.2

LBNL Relocatable Classrooms Study						
Field Data Spreadsheet-->		Teacher and Student Clothing Checklist, re: "clo" values, thermal comfort statisitical assessment				
(school district name)	SAMPLING PERIOD:	_________				
(school name)	Season, *Circle One:* COOLING HEATING					
	Sampling Week No. (enter 1-9):	____				
	Day of week (enter Tu, W, or Th):	____			Classroom #: ____	

bold means assumed or default (CHECK BOX CORRESPONDING TO CLOTHING TEACHER, AND AVERAGE STUDENT, WAS WEARING, BY SEX)

CLOTHING OR FOOTWEAR	**Male Teacher**	*clo value*	**Female Teacher**	*clo value*	**Male Child**	*clo value*	**Female Child**	*clo value*	Legend:
bra and/or panties			X	0.04; *0.03*			X	0.03; *0.03*	0.__ ASHRAE 55-1992
men's briefs/boy's underwear	X	0.04; *0.04*			X	0.04; *0.04*			*0.__ ISO 7730:1994 (E)*
short-sleeve T-shirt		0.08; *0.09*		0.08; *0.09*		0.08; *0.09*		0.08; *0.09*	Field Technician Comments
long-sleeve T-shirt		*0.12*		*0.12*		*0.12*		*0.1*	
short-sleeve, collared knit sport shirt		0.17; *0.15*		0.17; *0.15*		0.17; *0.15*		0.17; *0.15*	
tank-top t-shirt or blouse				0.13		0.13		0.13	
long-sleeve, thin cotton SHIRT		*0.2*		*0.2*		*0.2*		*0.2*	
long-sleeve, thin cotton BLOUSE		*0.15*		*0.15*		*0.15*		*0.2*	
long-sleeve "reg." cotton shirt		0.25; *0.25*		0.25; *0.25*		0.25; *0.25*		0.25; *0.25*	
long-sleeve sweatshirt		0.34		0.34		0.34		0.34	
thin cotton sweater		0.25; *0.20*		0.25; *0.20*		0.25; *0.20*		0.25; *0.20*	
thick cotton/thin wool sweater		0.36: *0.28*		0.36: *0.28*		0.36: *0.28*		0.36: *0.28*	
light, spring/summer jacket		*0.25*		*0.25*		*0.25*		*0.3*	
thin skirt (cooling season)				0.14; *0.15*				0.14; *0.15*	
walking/Bermuda/denim shorts		0.08		0.08		0.08		0.08	
athletic shorts						0.06; *0.06*		0.06; *0.06*	
lightweight cotton trousers/pants		0.15; *0.20*		0.15; *0.20*		0.15; *0.20*		0.15; *0.20*	
normal weight trousers/pants, jeans		0.24; *0.25*		0.24; *0.25*		0.24; *0.25*		0.24; *0.25*	
sweatpants						0.28		0.28	
ankle-length cotton socks		0.02; *0.02*		0.02; *0.02*		0.02; *0.02*		0.02; *0.02*	
pantyhose/stockings(*nylon*)				0.02; *0.03*				0.02; *0.03*	
cotton, or cotton/wool, baseball hat/cap		0.01		0.01		0.01		0.01	
sandals/thongs/Tevas		0.02		0.02		0.02		0.02	
thin-soled shoes, sneakers		0.02*; 0.02*		0.02*; 0.02*		0.02*; 0.02*		0.02; *0.02*	

thick-sole shoes, hiking (cotton/canvas boots)		0.04		0.04		0.04		0

Appendix A.4.3

LBNL Relocatable Classrooms Study

Field Data Spreadsheet-->

Qualitative Walk-Through Assessment by Technician (DGS) of RC environment and potential sources of indoor and outdoor target chemical and physical pollutants, and biological contaminants.

(name of school district)
(name of elementary school)

Circle One: COOLING SEASON HEATING SEASON

Circle One: BARD IDEC

Date (MMDDYY): ________________

Day of Week (enter Tu, W, Th): ____

Classroom #: ____

	OUTDOOR SOURCES IN IMMEDIATE VICINITY				VISIBLE, OR POTENTIAL FOR, H2O DAMAGE			
Classroom ID/#	Garbage Dumpsters	Freeways, i.e., heavier motor vehicle traffic	Construction Activities (dust, noise, etc.)	Truck loading/ unloading area	What is RC sited on? (asphalt pad, concrete slab/pad, grass turf, soil, gravel)	RC raised above the ground? (If Y, estimate height from front door/ramp or stairs)	Current leaks? (If Y, state where: roof, walls, floor, sink, etc.)	Visible water damage or stains? (If Y, state where: carpet, walls, ceiling tiles, wet tile areas)

LBNL Relocatable Classrooms Study			
Field Data Spreadsheet-->			
CONTINUED…	Qualitative Walk-Through Assessment by Technician (DGS) of RC environment and potential sources of indoor and outdoor target chemical and physical pollutants, and biological contaminants.		
(name of school district) **(name of elementary school)**	Season, *Circle One:* Cooling Heating		*Circle One:* BARD IDEC
	Date (MMDDYY): ____________		
	Day of Week (enter Tu, W, Th): ____		
	Classroom #: ____		

INDOOR SOURCES

CLEANING BY HEAD CUSTODIAN/PLANT MGR AND/OR TEACHER

	General, e.g., dusting			Floor Cleaning--Dry Mop			Floor Cleaning--Wet Mop			Vacuum Carpet/Area Rug			What cleaning materials used?	Where are cleaning materials stored inside RC?
Classroom ID/#	(Y or N)	(# times/ week)	AM or PM	(Y or N)	(# times/ week)	AM or PM	(Y or N)	(# times/ week)	AM or PM	(Y or N)	(# times/ week)	AM or PM	(Label name, key ingredient if available)	(Note location: cabinet, under sink)

Appendix A.4.4

LBNL Relocatable Classrooms Study										
Field Data Spreadsheet-->										
Qualitative Assessment of Indoor Physical Environment										
including lights, doors, HVAC functioning, and odors.Summary of sentence(s) written on data sheets.										
(name of school district)	Season, *Circle One:* COOLING		HEATING		*Circle One:* BARD IDEC					
(name of elementary school)	Date (MMDDYY): ________________		Day of Week (enter Tu, W, Th): ____ Class #: ____							
(Technician writes when observations were inventoried) AM SET-UP, RECESS, LUNCH, END OF SCHOOL, or PM TAKEDOWN	**(on/off, #;** if on and not all on, _ of _ = %**)** LIGHTING FIXTURES	**(open/closed;** *if open, estimate if 30/60/90 angle AND write if kept open by door stop or chair?***)** DOORS	**(by sound)** HVAC SYSTEM	**(open/ closed;** *if open, estimate how far, i.e., "a crack," half, or full?***)** WINDOWS	**(Technician Comments:** Perfume/cosmetics? Food smells? Musty/"damp basement" smells? Chemical solvent-type odors from cleaning and teaching products? Other?**)** Description of Odors	**Bard** (off, auto, fan)**; IDEC** (off, heat, cool, auto) HVAC System Thermostat Setting	**(degrees F)** Thermostat Reading	**(Technician Comments: four categories, use Y or N, plus any key details)** Describe cleanliness (surface dust; tiled wet areas; carpets--soiled,stained?; water damage anywhere?)	**(Technician writes Y or N, and if Y which ones observed)** Pollutant sources present and/or open? (adhesives/glues; non-H2O based paint; cleaners for carpet, desk, sink/counter; pesticides; other)	**Y/N (If Y, # and left on?)** Computers & Monitors?
AM SET-UP										
RECESS										
LUNCH										
End of school/PM takedown										
Extra Comments by Technician:										

Standard Operating Procedures: Target toxic and odorous VOC, formaldehyde and acetaldehyde sampling

The sampling system is fully automated. The timers on all samplers are programmed to start on Tuesday, Wednesday, or Thursday as established in the study design; programming is confirmed for the following week at the end of the present week's sampling. The samplers run from 7:00-7:20 AM and 8:15 AM-15:35 PM (CUSD) or 7:50 AM UNTIL 15:00 PM (MCS). The earlier run period is to "warm up" the pump. The technician must install all VOC tubes and aldehyde cartridges between 7:30-8:00 (CUSD) or 7:20-7:50 (MCS). VOC tubes and aldehyde cartridges will be transported to and from the lab in a small cooler with an ice pack. The VOC tube holders and the aldehyde foil pouches are labeled ahead of time to speed handling in the field; aldehyde cartridges are also labeled, in the lab or at the school. The aldehyde cartridges and the foil pouches for transporting completed samples will be labeled SCCL-MMDDYY (S = SCHOOL DISTRICT/SCHOOL, CC = CLASSROOM NUMBER, L= Location #, MM =Month, DD =Day, YY = YEAR. The aldehyde field blank will be labeled with SCCL = 0000. The VOC tubes are permanently numbered; the tube holder will be labeled SCCL-MMDDYY-NNN (S = SCHOOL DISTRICT/SCHOOL, CC =CLASSROOM NUMBER, L =location (inlet #), MM =Month, DD =Day, YY = YEAR, NNN= sorbent tube number). The VOC field blank will be labeled with SCCL = 0000. Outdoor samples will be labeled with CC = "OA."

Field procedures

1.) ARRIVE AT THE SCHOOL. UNLOAD CAR, CARRY SAMPLERS TO STUDY RCs.

2.) Proceed to the SAMPLING EQUIPMENT FOR LOCATION INDOOR RC "A."

Open the cabinet and record the values on the left and right elapsed time indicators. Verify the time and day of week are correct on both timers by pressing the clock button on the timer. Time and day can be corrected by holding down the clock button while hitting the day, hour and minute buttons. Verify the control indicator in the lower right corner of the screen is set to "AUTO," which is ensured by pressing the "ON/AUTO/OFF" button, and that the programming is correct. Pressing the "PROG" button will scroll through the six programs. 1ON should be set for Tuesday/WEDNESDAY/THURSDAY at 7:00 AM. 1OFF should be set for Tuesday/WEDNESDAY/THURSDAY at 7:20 AM. 2ON should be set for Tuesday/WEDNESDAY/THURSDAY at 8:15 AM (CUSD) or 7:50 AM (MCS). 2OFF should be set for Tuesday/WEDNESDAY/THURSDAY at 15:35 (CUSD) or 15:00 (MCS). The four other programs should not have times in them. Any of these other programs with time settings should be erased; press the "RST/RCL" button. Press the "CLOCK" button to return the timer to clock mode.

Entering the classroom, you will see the four numbered copper tubes ending in appropriate fittings out the front lower panel lip of the LBNL closest located at a corner of the back wall. Tubes #3 (and #4) have a male leur fitting. This is for the ALD sample (and duplicate ALD sample). Remove an aldehyde cartridge from its sealed pouch. Remove the leur plugs from both ends, and securely install the cartridge on location #3 or 7. Save the leur plugs with the pre-labeled foil pouch for this location. (Repeat if a duplicate ALD sample at location #4 or 8 will be taken.) Next, locate the two VOC sorbent tubes. Remove the tube for location #1 from its holder and remove the nylon caps from the sorbent tube. Store the caps in the holder. Install the sorbent tube in VOC sample location #1. The end with the black carbon sorbent goes into the sample fitting. Repeat this procedure for VOC sample location #2.

3-4.) Repeat entire procedure for RC "B" indoors and outdoor samples before 8:00 (CUSD) or 7:50 (MCS).

5.) Wait at least 15 minutes after 7:50 AM and proceed to each location—RC "A" indoors followed by outdoors and then RC "B" indoors-- to measure the sample flow rates. Open the cabinet/locker. The outlet lines from each pump are bundled with the inlet. Flow rates are measured with a BIOS DryCal with a low-flow cell for aldehydes and a manually operated bubble tube and timer for VOCs. Connect the inlet of the BIOS DryCal to the outlet of each aldehyde sample pump so air continues to flow out of this in-line system through the BIOS outlet. Measure and record the average of ten flow measurements at each location; Loc#3, 7 and 11 (and #4 and 8) should be ~150 ml/min. Repeat the process for VOCs using the bubble tube and timer. Record three or four sets of measurements, which are the time required for a bubble to travel up the bubble tube a distance equivalent to 0.5 cc (ml). After a series of field calculations, Loc#1-2, #5-6, and #9-10 should be ~5 ml/min, definitely < 6 ml/min. Record the air temperature from the temperature sensor installed in the BIOS carrying case.

6.) Collect one aldehyde sample and one VOC sorbent tube as field blanks. These blanks should be removed from their sealed pouch or holder. The plugs and nylon caps should be removed and then replaced. Place the ALD blank in its pre-labeled foil pouch; and return the VOC blank to its pre-labeled holder.

7.) At around 15:10 (CUSD) or 14:35 (MCS), repeat the flow measurement at all locations. This must completed before sampling stops at 15:35 (CUSD) or 15:00 (MCS).

8.) After sampling stops collect samplers. Record the elapsed time of both timers. Remove the aldehyde cartridge. Take correct foil-lined pouch by verifying the sample ID number, replace the leur plugs, and put the ALD cartridge(s) in the pouch. Fold the pouch and seal the end with white tape. Remove the VOC tubes. Verifying the sample ID numbers, take correct tube holders, install the nylon caps finger tight onto the sorbent tubes, and return each tube to its respective holder. Store/transport samplers and field blanks in cooler with ice.

LBNL Relocatable Classroom Field Study-- Laboratory Procedures

Extraction and analysis of Waters (part number WAT047205) DNPH-coated cartridges for formaldehyde and acetaldehyde (and Acetone)

Based on "5.0 Extraction of DNPH-coated (Supleco) C18 Sample Cartridges," RIOPA Study, written by J. Zhang et. al with final editing by D. Shendell and N. Yamamoto

v. 04/02/01 by D.Shendell, revised as final version 03/22/02 by D. Shendell

1.1 Prepare 2-ml test tube/vials for sample extraction

1.1.1 Get a number of 2-ml glass test tubes needed for Waters cartridge extraction. Label test tubes 1-n to match number of samples to analyze; 0 is internal standard.

1.1.2 Pipet 2-ml of acetonitrile (ACN) into each test tube, cap with glass stopper, lightly shake ACN. The bottom of the meniscus should be at white mark.

1.1.3 Rinse the test tube and dump the ACN into the (non-halogenated) waste. Place the test tube back in the rack.

1.2 Extraction of the carbonyl-DNPH samples from the Waters cartridges

1.2.1 Get sample cartridges from the freezer, each of which are in foil-lined white envelopes sealed with white tape.

1.2.2 Label with the lab pencil each test tube and vial with a number, the vial number in the day's sequence for HPLC analysis staring with n=1. A data sheet is created in MS Excel to match this number with the sample ID number and hence the date and location of the sampler. Numbers are entered on the data sheet in the appropriate column next to the appropriate sample ID number. Replace the test tube in the rack, and vials placed in order adjacent to an empty HPLC cartridge.

1.2.3 Get 2-ml glass syringe, one for all Waters cartridge/samples. The 2ml syringe, if not already, should be rinsed with ACN by filling and emptying them using the plunger and gravity.

1.2.4 Match the first test tube with the appropriate Waters cartridge sample, and remove from envelope. Attach piece used to connect syringe to cartridge during extraction; this piece has a silver colored metal ring on it.

1.2.5 Fill the syringe with 2-ml of ACN.

1.2.6 2-ml of ACN from the syringe drains through the cartridges by gravity. Give a little push on the plunger of the syringe as necessary. This process should be relatively slow, i.e, do not force ACN through the cartridge, avoiding spills of sample extract as well.

1.2.7 After all ACN has passed through, displace any ACN left in the cartridge using the plunger by raising and suppressing the plunger. Repeat this 2-4 times, and remove syringe from cartridge while raising plunger each time.

1.2.8 Remove the syringe from the extraction set-up, remove the Waters cartridge from the test tube and place the used cartridge in the appropriate beaker to air dry and later be discarded.

1.2.9 Add enough ACN to each extraction to fill to the 2-ml mark. Cap test tube, mix by gravity by turning it upside down two times.

1.2.10 The same syringe can be reused for all extractions, i.e., sample sequences, performed in one day.

1.2.11 Clean up equipment, seal test tubes and beakers with caps and Parafilm to preserve extract until HPLC/UV analysis initiated and completed, and
properly discard of non-halogenated solvent waste. Discard used cartridges,
wrapped in aluminum foil, in the garbage.

REPEAT STEPS 1.2.3 to 1.2.9 FOR EACH WATERS CARTRIDGE SAMPLE

1.3. Analysis of the carbonyl-DNPH sample extracts by HPLC with UV detection

1.3.1 Analyze the sample extracts as soon as possible or store the sample extract in the freezer until analysis

1.3.2 Preparing the sample extracts for placement in the Hewlett Packard HPLC 1090/ChemStation

1.3.2.1 Pour out about 1ml of sample extract into vials used for the HPLC. The vials are numbered with the same number appearing on the glass test tube/vials (see 1.2.2).

1.3.2.2 Cap the vial with the blue cap containing red septa with Teflon-lined backside. Tightness should be a little beyond "finger tight." Make sure red septa not pinched.

1.3.2.3 Confirm the vials are placed in the black cartridge in the right order, i.e., samples 1-10 should be in vial holder slots 0-9, respectively.

1.3.2.4 Place the black cartridge in the correct position in the HPLC after opening the top door/hood of the instrument. The order, if running multiple "0-9" sequences at once during a day, is 1-10, 11-20, etc. up to n=50 or 60.
N=1-50 or 60 corresponds to the row number in the ChemStation "sample sequence file."

1.3.3 HPLC with UV detection analysis: information entry, and
method, sequence, and data files

HPLC autoinjection, HP 1090-1 software, method file "ALD 8B" by AT Hodgson

1.3.1.1 Make new and/or filter mobile phase solvent "A" (65% H_2O, 35% ACN) and "B" (100% ACN).

1.3.1.2 Install appropriate column (Waters C_{18} 50 mm micropore column, part number WAT056975), connect only to sample injection system at first. Run pump 5-10 minutes to flush column. Connect column on other side to detector, then run pump and detector ~30 minutes; observe flat line—no spikes, no bubbles in column or system-- on computer monitor graph before proceeding with sequence.

1.3.1.3 Check to see compressed air pressure ~ 80 psi, and compressed He (g) ~ 2psi; for mobile phases and autoinjector.

1.3.1.4 Prepare and then save sequence table and data file, named using nomenclature YMMDD**A**.s and YMMDD**A**.d The bold type letter (A) can be changed to B, C, etc. for future table on same day.

1.3.1.5 Prepare one dilution of internal standard stock solution containing target compounds and acetone in known quantity; glass beaker, sealed, was removed from freezer > 30 minutes prior to use.
"vpets 2-7," made by Brett C. Singer (LBNL, IED/EETD) 9/2/99
1/40 dilution = 25 microliters to 1 milliliter with ACN
"vpets 2-7) prepared with, in nanograms per microliter,
38.37 H_2CO, 39.68 CH_3CHO, and 63.63 acetone.

Thus, with 1/40 dilution and 10 microliters injected per sample run into the HPLC/UV, the analysis results are expected to be, within 5-10%, 9.6 nanograms H_2CO and 9.9 nanograms CH_3CHO. The graph must show no contaminants or bubbles interfering with retention times (~ 7.6 +/- 0.2 minutes and ~ 9.6 +/- 0.2 minutes, respectively) or peak magnitudes. If there are, then second injection.

1.3.1.6 Extract samples while 1/40 dilution of internal standard solution in HPLC/UV

1.3.1.7 For each set of sample injections, inject one sample twice for analytic precision analysis. If sample size exceeds 10-12, inject one sample twice for every 10.

(NOTE: we chose for 9/01-3/01 to inject 1/40 dilution of internal standard solution twice, and disregarded first injection's data due to delayed retention times, likely due to infrequent use of column or HPLC/UV maintenance issues.)

1.3.1.8 Review data analysis for each sample completed. Confirm autointegration of peaks was correct, i.e., correct baselines drawn and no interference; redraw baselines as necessary. Confirm proper retention times for each target compound. Confirm data make sense, e.g., for CEC RC study RC A < or ~ RC B and both RCs are < outdoors. Raw data presented in nanograms per microliter.

1.3.1.9 Print analysis reports, save data files to floppy disk in folder with data file's name.

1.3.1.10 Raw data and field-based calculations entered into appropriate MS Excel files.