BASE Quality Assurance Project Plan

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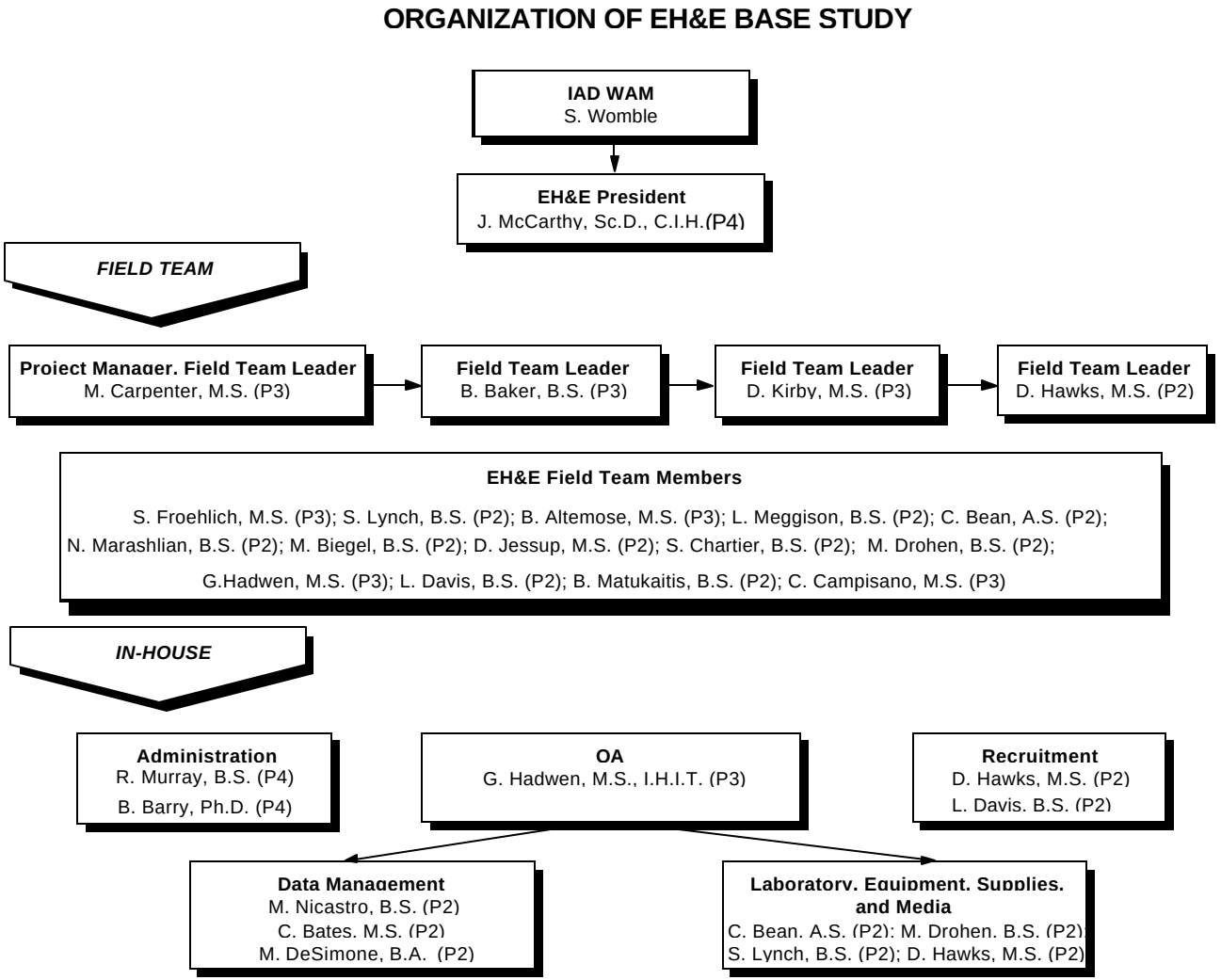
1) PROJECT DESCRIPTION

EH&E has been involved with EPA's cross-sectional nationwide BASE Study since the summer of 1993; in conjunction with EPA, EH&E has modified and implemented the BASE Study in order to garner information about the many factors within a building which affect indoor environmental conditions. The following BASE Quality Assurance Project Plan (QAPP) supplements EPA's Large Buildings QAPjP. This supplement describes QA/QC aspects of the implementation of the Office of Radiation and Indoor Air's BASE protocol including: recruitment of study buildings, execution of field studies in each building, and the processing and coordination of each building's data for final submittal to EPA.

2) PROJECT ORGANIZATION(S) AND RESPONSIBILITIES

In order to meet the above objectives, EH&E selected qualified and motivated personnel to conduct the BASE Study and its related QA/QC procedures, as shown on the following page in the BASE Winter '97 Main Study Organizational Chart.

Figure 1 BASE Study Organizational Chart



Each BASE field team is comprised of four persons, chosen for his/her expertise in the areas of HVAC assessment, air monitoring, field study management, and communications. The in-house positions of QA Officer and Equipment, Supplies, Media, and Data Support Personnel are also responsible for ensuring data quality with respect to the BASE QAPP.

Prior to each field study, EH&E conducts a training seminar with EH&E BASE team members to ensure consistency among field techniques and procedures. Participants are instructed to follow methods described in EH&E's Standard Operating Procedures (SOPs). This meeting also allows for the field team members to brainstorm on study improvements. Open discussions among participants fosters creative approaches and a better understanding of how to collect meaningful data.

3) QUALITY ASSURANCE OBJECTIVES

As outlined Section 3.0 of the EPA's Large Buildings QAPjP, a goal of paramount importance to the Large Building Studies, including BASE, is the standardization of methods for evaluating chosen buildings. Specifically, EH&E draws upon this document in meeting its QA/QC objectives of:

- Precision and accuracy (as set forth in Table 3-1, Measurement Performance Requirements)
- Representativeness (as set forth in Table 3-2, Representativeness for ORIA and ORD Building Studies)
- Completeness (as set forth in Table 3-3, Data Completeness Goals for Each Building).

This QAPP and its objectives are based on EH&E's management plan and standard operating procedures and serves as an instrument to provide data of the utmost quality.

4) SAMPLING PROCEDURES

In an effort to standardize BASE study data collection, EH&E developed SOPs, and supporting documentation modeled after the BASE protocol and the Large Building

QAPjP. Detailed procedures for all aspects of field work supplement the BASE protocol. They include:

- Building selection
- Study area selection
- Monitoring location selection
- Data collection checklist and questionnaire
- Sample location
- Real time measurements using the mobile cart
- Real time measurements at indoor and outdoor fixed sites
- Integrated samples
- HVAC real time measurements
- HVAC performance measurements
- Occupant Questionnaire

The standardization of field methods has contributed to EH&E's confidence in the accuracy, precision, and appropriateness of the collected data.

Weekly Schedule

The schedule for field work is rigorous, as many activities are conducted concurrently during the course of the day. In order to ensure that all field work tasks are met on a daily basis, and to ensure that tasks are performed at the appropriate time, EH&E has developed daily "To Do" lists that are reviewed each morning to optimize efficiency. The "To Do" list is based on the daily tasks listed in the BASE protocol and EPA's Large Buildings QAPjP, and has been continuously modified and supplemented to meet the needs of the field teams.

Although the "To Do" list has become a valuable field tool for ensuring the timely completion of daily field tasks, there are some instances where, due to circumstances unrelated to field preparation, the field team must diverge from the "To Do" list. This is usually due to an equipment malfunction or an unexpected change or modification in the field schedule. In these cases, the field team consults the EPA's Large Buildings QAPjP Table 1-3 Priority for Measurements, in order to reprioritize the daily events. This prioritization table is also appended to each "To Do" list posted in the staging area. Additional copies may also be located in EH&E's field crib sheets. This tool allows EH&E to continue to gain the most useful data for EPA's needs, while reorganizing the schedule to handle unexpected field crises.

Recordkeeping

All data generated during the performance of this study, except that generated by computer, is transcribed directly, promptly, and legibly into the appropriate collection forms which are subsequently stored in a single data collection binder. These entries are made in permanent ink, dated, and signed by the individual recording the data on the day of entry. Any changes in data entries are done in a manner that does not obscure the original entry. The reason for the revision is indicated, dated, and signed at the time of change.

Continuous Monitoring

Normally one field investigator takes the lead for sensor maintenance and performance during the field week. His/her duties include: coordination, understanding, and documentation of the sensors' performance during previous and current field weeks (referencing the EH&E verification logsheets), inspection of the sensors for obvious contamination, and battery change-out. Additionally, field investigators are required to conduct frequent verification and validation checks of sampling equipment. The primary reference for this task is the "Data Acceptability Criteria for Data Validation" found in EPA's Large Buildings QAPjP and described in Section 8 of this document.

The following section details how specific sampling parameters are handled with respect to this process:

1. Air Temperature

Before any equipment is deployed for sampling on Tuesday, all instruments which can be used to take temperature measurements are gathered and compared to NIST-traceable glass thermometers. This "cross check" procedure is important for the early identification of malfunctioning instrumentation, and as a means of understanding the range of variation within the instrumentation. Once continuous monitoring has begun, all temperature sensors are compared to NIST-traceable thermometers positioned at each fixed site every day of sampling (*i.e.,* from Tuesday to Thursday). Again, the sensors are monitored to determine their performance level with respect to EPA validation ranges. If sensor perfomance falls outside the secondary range of 2°C it is replaced (For more

detail on the data acceptibility ranges of all continuous monitoring, see Table 3.0 of this document). Finally, informal sensor performance checks are conducted throughout the day to see if the sensor reading "makes sense". Although not involving any other standard than the professional expertise of field personnel, these periodic qualitative checks have proven to be invaluable in the early identification and replacement of malfunctioning sensors.

2. Relative Humidity

As with the air temperature monitoring equipment, before any RH equipment is deployed for sampling it is compared to NIST traceable hygrometers. Once again, the "cross check" procedure is important for the early identification of malfunctioning instrumentation, and is important as a means to understand the range of variation within the instrumentation being used. Relative Humidity sensors in the field are also checked daily throughout the sampling week (e.g. from Tuesday through Thursday) against the NIST traceable hand-held hygrometer. If sensor perfomance falls outside the secondary range of 7% it is replaced. Furthermore, informal sensor performance checks are made throughout the day to see if the sensor reading seems reasonable.

3*. Carbon Dioxide*

Before continuous sampling begins, all fixed site and HVAC CO_2 sensors undergo zero checks against a zero air gas and span checks (against 1000 ppm for the indoor system, and 350 ppm for the outdoor setup). Investigators are responsible for consulting the validation table to determine the performance level of the sensors. During the sampling period, each CO_2 sensor is checked daily using the same zero and span procedure followed on Monday. All zero and span checks are recorded on field log sheets, so that drift of sensor response can be tracked through the course of the week and through the course of the study. In addition, voltage outputs corresponding to the standard concentrations are also recorded to ensure that the data logger is operating properly. Finally, informal sensor performance checks are performed throughout the day to see if the sensor reading seems reasonable for each particular site.

4. Carbon Monoxide

As with the CO_2 sensors, all indoor and outdoor CO sensors are subject to zero checks against a zero air gas, and span checks against a 10 ppm span gas on the Monday before sampling begins. Once sampling begins, each fixed site CO sensor is checked daily using the same zero and span procedure followed on Monday. All zero and span checks are recorded on field log sheets, so that drift of sensor response can be tracked through the course of the week and through the course of the study. In addition, voltage outputs corresponding to the standard concentrations are also recorded to ensure that the data logger is operating properly. Lastly, unscheduled sensor reasonableness checks are conducted by field personnel to ensure meaningful data collection.

5. Illuminance

Light meters used in the field are checked for reasonableness of response prior to the commencement of the logging period; for example, field investigators will "zero" the instrument by covering it with their hand. The light meters also undergo periodic informal evaluation as mentioned above. Factory calibrations of the instrumentation occurs on an annual basis. As of November, 1994, there were no applicable Data Acceptability Criteria for Validation for light measurements listed in Table 8-4 cited above.

6. Noise

Noise meters are verified and, if need be, calibrated before sampling with a 114 dB calibration instrument to ensure that they are operating within EPA's specifications. In addition, to ensure that the collected data are accurate and precise, the dosimeter is again verified after sampling.

Record Keeping of Continuous Monitoring Files

In order to keep track of the various continuous data files, a filing and naming system has been developed that allows the investigators to clearly differentiate between files by type and location; for example, "MN2S3R1M." Files are organized by state, by number (in which the building was evaluated in the preliminary visit), by site location, by day, by number of times downloaded per day, and by logging instrument. This example would indicate that the file represented continuous data from Minnesota 02, at fixed site 3, on Thursday of the sampling week, the first downloaded file, and the Metrosonics

datalogger. More detailed information about the file naming procedures employed by EH&E are outlined in Admin 4: File Naming of the Field Crib Sheets.

Integrated Sampling

The current BASE protocol requires the measurement of particulate matter, volatile organic compounds, aldehydes, radon, aerobiologicals, bulk biologicals, and antigens. For each of these EPA specifies the use of certain QA/QC samples, as per the table on the following page.

Table 1.0 QA/QC Samples

Sample Type	Definition
Duplicate Sample	A sample run concurrently with a field sample to assess repeatability of methods as well as a redundant safeguard in case a sample is voided.
Field Blank	A sample prepared by the filed team that represents the procedure for preparing integrated sampling, but that is not sampled as a regular sample. This is sent blindly to the laboratory. The results of the field blanks can be used to determine whether there was any contamination in the preparation or shipping process of the other samples, or during the analysis of the samples by the laboratory.
QC Spike	A sample that is spiked by the analytical laboratory, sent to the field team, then sent back to the analytical laboratory within a regular sample shipment. This sample is sent blindly to the laboratory. The results of a QC spike can be used to determine if laboratory analytical procedures are precise and accurate.
Shipping Blank	An unused sample that is incorporated into a regular sample shipment and sent blindly to the laboratory. The results of shipping blanks can be used to determine whether there was any contamination during the shipping process.
Lab Sample (Blanks or Spikes)	A sample that is prepared by the analytical laboratory prior to the sample shipment delivery to the field. This sample type is not sent into the field. It is however, analyzed along with the field samples. These samples are used as in-house guides to laboratories regarding the precision and accuracy of their analytical techniques.
Performance Sample (Evaluations or Demonstrations)	A sample that is prepared by EPA's primary QA contractor and sent directly to the analytical laboratory without blinding is a Performance Demonstration sample. A sample that was prepared by EPA's QA contractor, sent to the field team, and then incorporated into a regular sample shipment in a blind manner is a Performance Evaluation sample.

In addition to the use of different QC samples in the field, QA of integrated samples is monitored via pump flows. Pump flows are verified by a calibrated rotameter at the start and end of the sampling period. The flows taken from the rotameter readings are validated against EPA's primary (+/-10%) and secondary (+/-15%) ranges, averaged, translated into volumes, and corrected to Standard Temperature and Pressure (STP)--

defined by EPA as 25°C and 760 mmHg. Shipping and storage procedures are outlined in the parameter-specific SOPs. Typically, the media is shipped to the laboratory for analysis the day after sampling is conducted (Thursday) via overnight express delivery. The exception includes the aerobiological and bulk samples, which are shipped out immediately after sampling via overnight express delivery. The samples are accompanied by a chain of custody form which inventories the contents of the delivery, and allows participating parties to acknowledge receipt of the package for tracking purposes.

The following sections outline QA procedures specific to the different integrated sampling methodologies.

1. Inhalable and Respirable Particulate Matter

Inhalable and respirable particulate material are collected using candlestick impactors connected to a high flow pump that can be adjusted to the specified sampling rate of 20 liters per minute. These impactors are cleaned and prepared using time tested methods developed by Harvard School of Public Health, as described in EHE's ASOP Int 5: Impactor Assembly. Pump filters are inspected periodically for particulate build-up, in order to reduce pressure drop and increase the life of the pumps.

At one indoor station and at the outdoor station, duplicate sampling trains for inhalable (*i.e.,* less than 10 micrometers) and respirable (*i.e*., less than 2.5 micrometers) particulate material are run. With every sample batch taken in each building, EH&E prepares a field blank to assess if there is any media contamination in the preparation or shipping process.

Media is stored at EH&E Field Operations Support Center (FOSC) and is shipped directly to the field team prior to sampling. After sampling, the media is stored in its filter case for shipping the following day.

2. Volatile Organic Compounds using the SUMMA canister

SUMMA canister flow controllers are re-calibrated and conditioned by Performance Analytical, Inc. on a weekly basis for optimal quality assurance. Care is taken to protect

the canisters from radiant heat as well as moisture prior to, during, or after sampling. Duplicate sampling is done at one indoor site and at the outdoor site; QC spikes are sent to the analytical laboratory blinded.

Recently, QC field blanks have been prepared by EH&E and sent to the laboratory as blind samples. The purpose of this procedure is to assess the probability of canister contamination during shipping, preparation or analysis of the samples.

3. Volatile Organic Compounds using Multisorbent Samplers

Multisorbent samplers are prepared and conditioned by Berkeley Analytical Associates prior to the field week. Care is taken to protect the samplers from conditions of excessive heat and humidity, which may impact the recovery of VOCs from the sorbent material. Duplicate samplers are run at each of the indoor sites as well as the outdoor site to assess the precision of the method. While only one duplicate from the indoors and outdoors is analyzed, this collection method allows for flexibility in the analysis strategy, and provides contingencies for damaged samplers. In order to assess the accuracy of the samples and analytical methods, the multisorbent samplers are spiked at Berkeley Analytical and sent to the field. The sample is then blinded and returned to the laboratory for analysis. Field blanks are also prepared to assess sample contamination during shipping and preparation procedures.

4. Formaldehyde and Acetaldehyde

Formaldehyde and acetaldehyde are collected using Waters' Sep-Pak cartridges. These dinitrophenyl hydrazine (DNPH) cartridges are connected to an ozone scrubber and low flow personal sampling pumps adjusted to 200 ml/min. Pump filters are inspected and batteries conditioned (*i.e.*, run down and charged) before each sampling period in order to prolong the life of the pumps and to reduce the possibility of faults during sampling. Pump flows are verified by a calibrated rotameter at the start and end of the sampling period; the flows taken from the rotameter readings are averaged, translated into volumes, and corrected to EPA's defined STP (25°C and 760 mmHg).

At one indoor station and at the outdoor station, duplicate sampling trains for formaldehyde and acetaldehyde are run to assess repeatability of these methods as well

as to ensure data is not lost if one of the samples is voided. Field blanks, QC spikes and samples are refrigerated before and after the sampling day and are sent to the analytical laboratory blinded.

4. Radon

Radon is sampled using activated charcoal canisters supplied by EPA. As with other integrated sampling sets, duplicate samplers are deployed to increase the quality assurance of the sample set. In addition, field blanks are prepared which mimic the preparation each sampling canister undergoes before and after deployment.

5. Bioaerosols

Aerobiological samples are taken on Wednesday morning and afternoon of the study week. The samples are collected using Andersen N-6 Impactors connected to 1 cfm pumps. Flow rates are verified using in-line calibrated rotameters. As with other integrated sampling sets, duplicate samples are taken indoors and outdoors. Because of the variability of biological sampling, field and shipping blanks are sent. By procedure, biological samples are shipped the same day as sampled and arrive at the analytical laboratory the next day.

Rotameter Calibration

Rotameters are calibrated at EH&E using a primary standard for volumetric flow (i.e., a soap bubble meter) before and after the study season. For each rotameter used in BASE, volumetric flows are measured at approximately five rotameter points in the region of interest (e.g., 200 mi/min for formaldehyde sampling, and 20 l/min for particulate sampling). A linear regression equation can be modeled to describe the relationship between volumetric flow and rotameter float height. These values are then corrected to EPA defined STP of 25°C and 760 mmHg to account for the varying environmental conditions in which the rotameters were calibrated. Additional rotameter curves must be generated in order to determine standardized volumes from variable field environmental conditions. Rotameter calibration procedures are further detailed in Section 4.6 of EH&E's Data Processing and Data Management SOP.

HVAC Measurements

Core HVAC measurement parameters are shown in Table 4-3 of EPA's Large Buildings QAPjP. Specific operating procedures are covered in the HVAC section of EH&E's SOPs; these are used to measure supply/return airflow rate, percent outdoor air intake rate, outdoor air intake rate, and supply/return air temperature, RH, and CO_2 concentration. Continuous monitoring of supply and return air CO_2 is also conducted. Schedules for diffuser measurements and mobile cart monitoring are shown in EH&E's field crib sheets entitled: Daily Schedule/BASE To Do List. Calibration procedures for HVAC measurement devices are outlined in Table 2.0 of this document. Additional measurements to further characterize the buildings' mechanical system are performed during the sampling week if time permits. Typically, one senior mechanical engineer is responsible for the following during a given sampling week:

- Defining building characteristics with respect to the HVAC Section (4.8.4) of EPA's Large Buildings QAPjP
- Coordinating and reviewing building plans
- Evaluating the reasonableness of all HVAC measurements (*e.g.*, comparing HVAC system measurements with system design ratings)

Questionnaire Distribution

One field investigator each week is assigned to distributing, collecting, and calculating initial response rates from questionnaire distribution. This task is extremely important, as all occupants working in the study area must be contacted in order to garner enough subjective data to make comparisons to the objective data collected during the field week.

Specific instructions are described in EH&E's Field Crib Sheet entitled: Questionnaire Distribution. Additional instructions are detailed in EH&E's SOP entitled: Distribution of Occupant Questionnaire, where the following elements are detailed:

- Consistent explanation of questionnaire's importance to occupants
- Personalized reminders to building occupants who have not returned questionnaires
- Tracking and cataloguing response rates

5) SAMPLE CUSTODY

The Sample Custodian (SC) is responsible for ensuring that all media is properly cared for before, during, and after sampling. Individual SOPs are consulted to obtain specific information on how to handle each type of sample, how many samples will be taken each week, and special labeling, storage, and shipping requirements for each media type.

All media under the supervision of the SC has affixed to it, an IADCS generated label. Each label has a distinct identification number that is recorded on the field sample log sheets prior to sampling. All log sheets are stored in a master binder during the study week. While in the field, the SC is responsible for knowing the whereabouts of that week's sample media at all times; the SC is especially careful during personnel changeover weeks that all media is accounted for.

Although the SC position is shared by several individuals during the course of the study, all SCs work together to ensure timely shipments of media to and from the field and correct coding and storage of samples. This is especially important with regard to the coordination of drop shipments of media and spikes to the field for the sampling week.

6) CALIBRATION PROCEDURES, REFERENCES, AND FREQUENCY

All measuring, monitoring, and sampling instrument calibrations, except those specifically requiring factory calibrations, will be performed in EH&E's Field Operations Support Center (FOSC). All calibrations will be performed prior to shipment of instruments to the field. Prior to use, and following the calibration schedule set forth in the SOPs of each monitoring or sampling procedures, the instruments will be zero & span-checked or flow checked to insure that they are operating within specification.

Laboratories performing analyses of samples will be required to follow calibration procedures of their instruments consistent with the specifications given in the Large Building Studies' QAPjP.

Table 2.0, modified from EPA's Large Buildings QAPjP Table 6-1 Calibration Methods, summarizes the calibration procedures for instruments used in EPA's BASE study. Equivalent procedures will be developed for measurements necessary for other work assignments.

Table 2.0 Calibration procedures

Parameter	Instrument type	Calibration Method	Frequency
Air temperature	Thermistor	Comp. NIST Traceable Thermometer in aluminum block, with documented thermal characteristics, immersed in temperature bath	Pre- and post-field measurements
Air temperature	Mercury thermometer	Comp. NIST Traceable Thermometer in aluminum block, with documented thermal characteristics, immersed in temperature bath	Annually
Relative humidity	Capacitive sensor	Gas humidifier + chilled mirror dew point detector	Pre- and post-field measurements
Relative humidity	Port. hygrometer	Comp. to calibrated sensor. Initial calibration performed by manufacturer	Annually
Carbon dioxide	Non-dispersive infrared sensor	Multipoint with standard gas mixtures ranging from 0 to 2000 ppm along linear response curve.	Pre- and post-field measurements
Carbon monoxide	Electrochemical sensor	Multipoint with standard gas mixtures ranging from 0 to 20 ppm along linear response curve	Pre- and post-field measurements
Illuminance	Light sensor	Factory calibration	Annually
Noise	Noise Dosimeter (dB)	In field: against manufacturer's portable standard: response corrected to meet portable calibrator output to within +/- 1 dB.	Annual factory calibration
$PM_{2.5}/PM_{10}$ particulates	Filters/microbalance	NIST-traceable weights	Each weighing session and after every 10 weighings
VOCs: SUMMA	GC/MS	Multipoint w. spiked Tenax cartridges	Immediately prior to analysis of sample. Ea. 8 h. thereafter.
VOCs: Multisorbent	GC/MS	Multipoint w. static dilution bottles	Immediately prior to analysis of sample. Ea. 8 h. thereafter.
Aldehydes	HPLC	Multipoint with solutions of DNPH-formaldehyde derivative.	Immediately prior to analysis of sample. Ea. 8 h. thereafter.

Table 2.0 Continued

Parameter	Instrument type	Calibration Method	Frequency
Formaldehyde	Pump flows	Compared against calibrated rotameter.	Pre and post measurements
Radon	Canister	EPA	
Bioaerosols	Pumps	Compared against a calibrated rotameter.	For each sample. Rotameter calibrated pre and post measurements
Bioaerosols	Incubators	NIST traceable standard	Quarterly thermometer calibration
Air velocity	Hot-wire anemometer	Wind tunnel calibrations performed by the factory	Annual
Air flow rate	Flow capture hood	Calibrations performed by the factory	Annual

7) ANALYTICAL PROCEDURES

1. VOCs: SUMMA Method

VOC samples are analyzed using gas chromatography/mass spectrometry (GC/MS). The analyses are performed according to the methodology outlined in EPA Method TO-14 from EPA's *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*. The analyses are performed by GC/MS utilizing thermal desorption/cryogenic concentration. The instrumentation used is comprised of an HP5989A GC/MS/DS interfaced to Entech 2000 automated whole air inlet system/cryogenic concentrator. A thick film (3 micron) crossbonded 100% Dimethylpolysiloxane megabore column was used to achieve chromatographic separation.

2. VOCs: Multisorbent Method

VOC samples are analyzed using gas chromatography/mass spectrometry (GC/MS). The analyses are performed according to a modified version of the methodology outlined in EPA Method TO-1 from EPA's *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air.* The samplers are thermally desorbed, and the samples are introduced into a Hewlett-Packard 5971A GC/MS system using a UNACON

810 concentrating system (Envirochem, Inc.). Prior to analysis, an internal standard (121 ng bromofluorobenzene) is added to each sampler and is used to check on the operation of the system, to provide a retention time marker, and for quantitative analysis. For quantitative analysis, the spectra of peaks from the total-ion-current chromatograms are first compared to a spectra contained in a data base of commonly occurring VOCs. The data base was created by Berkeley Analytical Associates from analyses of pure standards. When the spectra of a compound does not match these standards, then the spectrum is compared to the spectra contained in the NIST database of approximately 75,000 spectra.

2. Aldehydes

Formaldehyde and acetaldehyde is sampled using a sorbent tube containing silica gel coated with 2,4-dinitrophenyl hydrazine (DNPH). Formaldehyde and other aldehydes react with DNPH to form stable hydrazones, which are extracted from the silica gel and analyzed by high performance liquid chromatography (HPLC). The samples are taken at 200 ml/min for approximately nine hours.

3. Inhalable and Respirable Particulate Material (PM10/PM2.5)

The samples are gravimetrically tare weighed and reweighed using a Cahn 31 microbalance, loaded in dichot filter holders, and then shipped out to the field team. Ten per cent of the filters prepared for field use are kept as lab blanks at the analyzing laboratory. The samples received from the field team are then weighed; 10% are reweighed for QC purposes. All weighing is done in a humidity and temperature controlled room.

4. Aerobiological, Dust Biological, and Bulk (Liquid and Solid) Biological Samples

<u>Sample Preparation</u>

Dust samples are processed by suspending between 10 and 50 mg of sifted dust (425 micron mesh) in 1 or 2 ml 0.02% Tween 20 in distilled water. A 10X serial dilution is made from this suspension and 0.1 ml of each dilution in inoculated (spread) onto agar filled 100 mm diameter petri dishes as follows: full strength to 10 E-3 onto malt extract agar (MEA) for fungi (RT incubation for 7-10 days), full strength to 10 E-2 onto trypticase

soy agar (TSA) for thermophiles (55°C incubation for 4 - 6 days), and 10 E-3 to 10 E-7 onto TSA for mesophilic bacteria (30°C incubation for 2-4 days). Bulk samples are handled in a similar fashion; suspended (for dry samples only), diluted (dry and liquid samples), and inoculated. Aerobiological samples are incubated in the aforementioned manner.

Sample Results and Reporting

Fungal colonies on the plates having an optimal colony density are counted and identified to the generic level (where possible) by colony and microscopic morphology. *Aspergillus* isolates are identified to sub-genus ("group"). Predominant mesophilic bacteria are Gram stained. Actinomycetes are reported as such but not identified. Recoveries are reported as colony forming units (cfu) per gram (dust and dry bulk samples) or per ml (liquid bulk samples). Aerobiological samples are reported as cfu/ cubic meter of air.

5. Radon

Radon sampling is conducted through the placement of an EPA-approved charcoal canister to collect gas. The canisters are placed at 5,000 ft^2 intervals throughout the ground contact floor including elevator lobbies and adjacent emergency stairwells. Sampling locations also include the fixed site locations. The canisters are analyzed by EPA.

8) DATA REDUCTION, VALIDATION, AND REPORTING

EH&E employs a four-tiered philosophy to ensure data quality, as described below:

Calibration

Before each field study, EH&E researches equipment and monitoring methods. Accuracy, instrument stability, adaptability to field conditions, and ease of use are considered. Once equipment is selected for purchase or rental, it is bench-tested at EH&E and calibrated against primary standards.

Verification

Verification in the field includes: weekly side-by side comparisons of similar field instruments and daily comparisons of sensors' response to known standards (*e.g.*, zeros and spans). These decisions are based upon EPA's Large Buildings QAPjP Table 8-4, Data Acceptability Criteria for Validation.

Validation

Field validation involves the comparison of instrument readings to reasonableness criteria provided by EPA. Each investigator is required at all times to be aware of whether the data makes sense (*i.e.*, the investigator is expected to consult EPA reasonableness criteria outlined in the QAPjP documents).

Review of Trends

Post-field data processing includes examination of data for trends or unusual occurrences which might affect the data. In addition, the instrument of site logbook is reviewed for any unusual events which might have compromised the data.

As stated above, field personnel are required to conduct frequent verification and validation checks of sampling equipment throughout the sampling week. Shown below is Table 3.0, which describes the related criteria.

Table 3 Data Acceptability Criteria for Validation
(from: Section 8, *The United States Environmental Protection Agency's Large Building Studies Quality Assurance Document*, November 1, 1994.)

Parameter	Primary Range	Secondary Range
Temperature	+/- 1.0 deg C	+/- 2.0 deg C
Relative Humidity	+/- 5%	+/- 7%
Carbon Dioxide	Zero +/- 50 ppm Span +/- 75 ppm	Zero +/- 75 ppm Span +/- 150 ppm
Carbon Monoxide	Zero +/- 2 ppm Span +/- 3 ppm	Zero +/- 3 ppm Span +/- 5 ppm
Noise	+/- 4 dB	+/- 6 dB
Illuminance	Not applicable	Not applicable
Sample Flows	+/- 10 %	+/- 15%

EH&E interprets the primary and secondary ranges as follows:

Table 4 Primary and Secondary Ranges

Within Primary Range	Within Secondary Range	Out of Secondary Range
System is operating optimally	System is operating acceptably, however, warrants more frequent checks to ensure accurate and precise data collection.	System is operating unacceptably, and must be adjusted or replaced without delay.

If the system goes out of secondary range, all data acquired between the last acceptable verification check and the next acceptable verification check will not be submitted to EPA.

Data Validation for Integrated Sampling

Concentrations of VOCs, formaldehyde, PM-10, PM-2.5, bioaerosols, and radon should be compared to reasonable levels expected in office building environments. When unexpectedly high or low concentrations are measured, explanations are investigated.

Data validation for integrated samples will include the following checks on data quality.

- The concentration calculations of a random subset (5-10%) of the raw data are re-calculated. This consists of re-entering the input data on computer programs used originally for this purpose

- Compare values against reasonableness criteria as outlined in EPA's Large Buildings QAPjP Table 8-3. Values beyond reasonableness criteria are examined in order to determine potential contaminant sources

Data Reduction

All data is handed over to EH&E's in-house Data Support Personnel (DSP) on Wednesday morning following the field week. There are five steps to the initial data processing:

1. The continuous data is transferred to files on one of the BASE in-house computers and organized by site. Macros have been written that automate the following with respect to continuous data processing: 1) opening the files; 2) formatting the data; 3) generating charts and 4) saving the data in an Excel spreadsheet. Macros are also applied as required to the Novalynx (outdoor temperature and dew point) and Quest (indoor sound) continuous data. Calibration points are removed from the data spreadsheet, operator presence flags are added, and the chart is reviewed by the field team leader for reasonableness. The data is then imported into the SAS program where validation programs are executed.

2. The integrated data is received in electronic format from the subcontractor labs and loaded onto EH&E's file server by the DSP. Site, time, duplicate and blank types are entered into the comments section of the integrated files, and some QC samples are transferred to a QC file. The reliability of the data is verified, and each file is saved as a database file.

3. Prints, slides and diskette copies of the photographs taken in the field are processed by EH&E's photographic subcontractor, and then sent to the DSP at EH&E in the form of slides, prints and diskettes. The slides and prints are then reviewed by the DSP and the Field Team Leader, and each is named and labeled. Inappropriate shots are deleted from each set, and the slides and prints are placed in protective covers. The diskette copies are imported into a single file and processed.

4. The plans and blueprints are brought back by a field team member and reviewed. All building identifiers are eliminated, and the plans are QC'd before being placed in protective covers.

5. The questionnaires are also brought back by a field team member, entered into IADCS, and reviewed for QA purposes. Ten percent of the questionnaires within each batch are randomly selected for reprocessing. If an unacceptable number of errors are found in the subset, the QA reviewer reviews the entire set and determines why entry was incorrect. In such a case, corrective measures are taken.

All of the above data from each building are placed into two copies of a single data package; one for EPA and one for EH&E's records. Currently, the following elements comprise the final data package:

1. IADCS building survey data (SVY).
2. IADCS environmental monitoring data (MTR).
3. IADCS questionnaire data (QSN).
4. Integrated and Continuous data results in SAS electronic format.
5. Building summary documentation in electronic and hard copy formats.
6. Hard copies of the building design documentation (floor plans, mechanical plans, etc.).
7. Electronic & Photographic slides depicting various aspects of the building.
8. Weather data for the study week in electronic format.

Data Reporting

All electronic data for each building is sent overnight delivery to EPA in electronic format using a 100MB zip drive by overnight delivery. Those elements of the data package that are not conducive to electronic submittal (building plans, maps etc.) are sent to EPA in notebooks via overnight delivery.

9) INTERNAL QUALITY CONTROL CHECKS AND FREQUENCY

Internal QC procedures and requirements are described in Table 9-1 of EPA's Large Buildings QAPjP. QA/QC requirements and frequency are further elaborated upon in Section 4 of this document.

10) QA PERFORMANCE AUDITS, SYSTEM AUDITS AND FREQUENCY

As part of the EPA BASE Study, field auditing is conducted to evaluate and assess the total measurement process, analytical methods and techniques, and completeness and representativeness of data.

EH&E's QA Officer will conduct an internal quality control evaluation during each study season. For EH&E's internal QA evaluation an assessment of personnel and procedures will be based on Tables 10.1 and 10.2 from EPA's Large Buildings QAPjP.

Field Performance Audits

A field audit is performed at least once per year on equipment and procedures using an independent EPA QA contractor. Field performance audits evaluate data forms, entry of field and survey data into the IADCS software, and general completeness and representativeness of the data.

System and Laboratory Audits

EPA's independent QA auditing contractor is responsible for the evaluation of laboratory performance before and during the study. The results of this assessment are important to determine the potential bias and imprecision of analytical data. Prior to the commencement of each field study, EPA's QA contractor provides EH&E's analytical laboratories with performance demonstration samples (PDs) of concentrations and analytes similar to those being measured. Concentration values are provided to the laboratories to allow for the assessment of their own analytical capabilities in conjunction with the QA contractor. If discrepancies are encountered with the PDs, EH&E works closely with the Work Assignment Manager to remedy the situation prior to the analysis of any field samples.

During the sampling period, performance evaluation samples (PEs) are sent by EPA's QA contractor to the field team and included for analysis as part of the samples taken during the sampling week. Because EH&E's analytical laboratories are unaware of which samples are PEs versus regular samples, the results of this audit are unbiased.

EPA's QA contractor may also be elicited to perform laboratory systems audits of the analytical laboratories each year and evaluate data forms, training of laboratory

personnel, the use of field data, the entry of laboratory data into automated systems, calculation of final concentrations, and, in general, the completeness and representativeness of the laboratory and final data.

11) PREVENTIVE MAINTENANCE PROCEDURES AND SCHEDULES

To ensure that all BASE instruments operate effectively, preventive maintenance must be performed properly and frequently. Maintenance procedures are outlined in EH&E's parameter-specific SOPs.

For each instrument, written records are kept of all routine and non-routine maintenance. While not in the field, instrument documentation is maintained and compiled in a notebook devoted exclusively to this purpose. Such records document the nature of the work completed, any difficulties or malfunctions, and any corrective action taken. For each instrument, written records are kept of all calibration and/or standardization operations. This information is also recorded in the instrument notebook. While in the field, instrument documentation is maintained and tracked on appropriate forms and compiled in the field master binder. Spare parts (*e.g.,* oil, O-rings, fuses, filters, swage locks, ozone scrubbers, etc.) are allotted their own packing module in the field, and used as necessary to maintain the integrity of the field instrumentation.

12) SPECIFIC PROCEDURES TO EVALUATE PRECISION, ACCURACY, AND COMPLETENESS

The QA Officer is responsible for reviewing the field and laboratory records of calibrations and verifications in terms of data precision, accuracy, and completeness. At EH&E, the precision of an instrument reading is defined in terms of the standard mean square deviation of individual readings from the calibration line (or curve) obtained in multipoint calibration. This standard deviation "s" is defined as:

$$s = \sqrt{\sum_{i=1}^{n} \frac{(y_i - \bar{y})^2}{n-1}}$$

where

y_i = measured value of parameter

$\bar{y}$ = value of parameter calculated from least squares fit of calibration data

n = number of data points in multipoint calibration

The accuracy of an instrument is estimated from the change in multipoint calibration lines (curves) with time. This reflects long-term drifts in instrument response and gives an estimate of the maximum error in readings made at times between two multipoint calibrations. A record of calibrations of each instrument is kept at EH&E's Field Operations Support Center and evaluated periodically to identify those instruments that show instability and require refurbishing or must be removed from field use. The accuracy, %Δy, is defined by this criterion is calculated as:

$$\%\,\Delta y = \frac{100}{n} \sum_{n=1}^{n} \frac{y_i(1) - y_i(2)}{y_i(1)}$$

where

$y_i(1)$ = value of parameter calculated by least squares fit of previous calibration data

$y_i(2)$ = value of parameter calculated by least squares fit of last calibration data

n = number of data points in multipoint calibration

Verification checks done routinely in the field are used for early detection of onset of instabilities by deviations beyond the range of acceptable accuracy. Generally the instrument is considered stable if the accuracy is no less than twice the mean square deviation.

For measurements where matrix spikes are used (*e.g*. chemical analyses by instrumental methods) accuracy is reported as percent recovery (%R) calculated as:

$$\%R = 100\% \times \left[\frac{S - U}{C_{sa}} \right]$$

where

S = measured concentration in spiked aliquot
U = measured concentration in unspiked aliquot
C_{sa} = actual concentration of spiked aliquot

The completeness of measurements is a quantitative measure of instrument failure for whatever reason as reflected by the number of invalid measurements. This criterion is used to evaluate overall dependability of instruments and to assist in decisions on instrument or method replacement, when necessary. Completeness (%C) is defined as:

where

$$\%C = 100\% \times \frac{[V]}{n}$$

V = number of measurements judged valid
n = total number of measurements

13) CORRECTIVE ACTION

External audits, internal QC checks, or observations during routine sampling and analyses may identify problems requiring corrective action. If the criteria presented in Tables 3-1 or 9-1 of EPA's Large Buildings QAPjP are not met, corrective action may be required. For example, during pre-field multi-point calibration, if instruments do not hold their calibration set-points, they are reported to the EH&E BASE Project Manager and QA Officer and are not sent to the field. Similarly, while in the field, if a sensor or instrument falls out of EPA's defined secondary range, the field team leader is notified and a decision is made regarding the adjustment or replacement of the equipment. Finally, during data review after the field work, data is critically reviewed to ensure it is reasonable.

All discrepancies are investigated. Those that can be explained by instrument malfunction are removed from the data set, while those related to operator presence are coded. Those that cannot be explained are noted. EH&E puts a great deal of emphasis on documenting any corrective action taken.

All required corrective action requests will be documented in a corrective action request form similar to that presented in figure 13.1. Corrective action requests will not be limited to instrument and data collection discrepancies, but will cover all appropriate categories encompassed by the EPA BASE study.

Figure 13.1 Corrective Action Request Form

Corrective Action *27-Nov-96*

Counter:

Requested By:

Category:

Date Requested:

Person Receiving Request:

Description of Request/Nature of Problem:

Action Recommended:

Person Responsible for Resolution:

Problem Corrected By:

Date Corrective Action Taken:

Detail of Action Taken:

Effectiveness of Corrective Action: