Department of Facilities Management
Environmental Safety/Indoor Air Quality

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2002 – IAQ/PM Program Evaluation

EXECUTIVE SUMMARY

Performance of the Montgomery County Public Schools (MCPS) Indoor Air Quality (IAQ) Preventive Maintenance (PM) Team was evaluated using data collected by the team since its inception in 1999. Data, obtained during 37 initial team visits and 13 annual team visits (return visits conducted one to two years after initial visits), were reviewed to identify quantifiable improvements in IAQ conditions at schools following PM work. The data were also used to determine the program implementation rate, the amount of time required to complete team visits, and reductions in school staff dissatisfaction with indoor environmental conditions following team visits.

The team evaluates the PM program's effectiveness by obtaining measurement data during each site visit. The team collects data for seven IAQ parameters related to temperature, air circulation, humidity, ventilation equipment operation, and cleanliness. The seven parameters are:

- Grab temperature (instantaneously measured)
- Extended temperature (measured over two to four weeks)
- Grab carbon dioxide concentration
- Grab relative humidity
- Extended relative humidity
- Volumetric air flow supplied by ventilation units
- Settled dust levels

The data indicate that the team has successfully improved IAQ conditions for schools in the PM program. Measurement results obtained for initial team visits show mean improvements for five measurable IAQ parameters following initial PM work. Improvements were observed for:

- Grab temperature
- Extended temperature
- Grab carbon dioxide concentration
- Extended relative humidity
- Settled dust levels

Comparisons of data obtained after initial PM work was completed and one to two years later show continuing improvements for grab temperature, extended temperature, and settled dust levels. Additionally, comparisons of data representing pre-existing conditions and conditions after one to two years in the program indicate overall mean improvements for the following four parameters:

- Grab temperature

- Extended temperature
- Grab carbon dioxide concentration
- Settled dust levels

The program's implementation rate, which is measured as the number of building maintenance plans (BMPs) delivered per quarter, was evaluated based on the original goal of six equivalent BMPs per quarter. BMPs, building-specific operations manuals, are developed and issued at the conclusion of each initial and annual team visit. Between June 2000 (delivery of the first BMP) and December 2002, the team delivered a total of 35 initial BMPs and 12 annual BMPs (updated versions of initial BMPs). Overall, the team averages approximately four equivalent BMP deliveries per quarter. (Initial BMPs are considered one equivalent BMP each, while annual BMPs are considered 0.5 equivalent BMPs each.) Without a considerable staff increase, the data suggest that the PM program would require numerous modifications to substantially increase the BMP delivery rate.

Team efficiency was evaluated based on the number of on-site worker-days required to complete initial and annual visits. Worker-days are calculated as units representing eight hours of recorded work by a team member. The data indicate that initial visits require an average of 89.8 worker-days to complete, and annual visits require an average of 54.7 worker-days. In order to identify factors that potentially affect the on-site time required for team visits, statistical tests were used to determine any correlations between the numbers of worker-days used for team visits and associated building conditions (age, size, percent enrollment capacity, number of ventilation units). No statistically significant correlations were found between building age, size, or percent enrollment capacity and the number of worker-days for initial or annual visits. *However, the presence of a statistically significant positive correlation between the number of ventilation units and the number of worker-days required to complete initial visits is indicated.*

Customer satisfaction is evaluated using questionnaires distributed to school staff. The questionnaires are designed to gather staff perceptions related to four parameters: temperature, humidity, air circulation, and cleanliness. The data indicates:

- Improved customer satisfaction for temperature, air circulation, and cleanliness after the team completes initial PM work
- Decreased customer satisfaction at the start of annual team visits for all four parameters
- Decreased customer satisfaction with conditions at the beginning of annual visits than with pre-existing conditions for temperature, humidity, and cleanliness

Based on the apparent incongruity between the IAQ measurements and the questionnaire responses, statistical tests were performed to identify an association between the two sets of data. The results indicate that questionnaire responses are not correlated with IAQ measurement data suggesting that conditions meeting accepted guidelines (based on MCPS and industry standards) might not be considered comfortable by school staff or improved communication of the program's expectations are needed.

In conclusion, the data indicate that improvements achieved during initial visits are not consistently maintained after the team leaves. As a result, additional measures appear to be required to ensure that conditions continue to improve between initial and annual team visits. Necessary actions might include follow-up training for building service managers, follow-up school staff meetings after the team completes initial PM work, and a more aggressive approach in the creation of in-school IAQ committees.

The data used for this evaluation were collected from schools designated for priority inclusion in the PM program. These schools were identified as having histories of IAQ-related concerns or known deficiencies. As a result, the data might not accurately represent potential team performance or building conditions for schools that enter the program in the future. The results, however, provide a means for generating data-driven projections of the program implementation rate in the future.

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1. INTRODUCTION

The Montgomery County Public Schools (MCPS) Indoor Air Quality (IAQ) Preventive Maintenance (PM) Team was created in FY2000 to improve indoor environmental conditions in MCPS facilities, primarily schools. Two environmental safety specialists supervise the team, which currently consists of one IAQ/PM supervisor; four heating, ventilating, and air-conditioning (HVAC) mechanics; one electrician; and six IAQ technicians. The electrician and two of the HVAC mechanics joined the team during January and February of 2003. Typically, team members require approximately six months to achieve peak proficiency. Three environmental safety coordinators, who make up the Environmental Safety/IAQ Unit, provide oversight and direction for the program.

The team improves IAQ conditions by conducting initial and subsequent annual site visits to each facility in the PM program. During initial visits, the team thoroughly cleans and repairs all ventilation equipment and provides training to school staff. Annual visits involve additional preventive maintenance procedures and evaluations of improvements or degradations in conditions since the initial visit. Upon completing each visit, the team presents school staff with a written building maintenance plan (BMP) that provides specific information and procedures necessary for maintaining favorable IAQ conditions. As of December 2002, the team had completed 35 initial visits and 12 annual visits. For detailed team operating procedures, refer to Appendix C.

An internal evaluation of the team's performance was conducted by reviewing data collected during site visits. Various statistical methods were used to determine if PM activities are associated with improvements in IAQ conditions and customer satisfaction. The data were also used to determine the rate at which the team completes site visits and to identify factors that potentially affect the amount of on-site time required to complete visits. Section 2 of this report discusses the data sources and statistical methods used for the evaluation.

The evaluation addresses four performance measures:

- Effectiveness (the ability of the team to generate measurable improvements in IAQ conditions)
- Program implementation rate (the rate at which the team delivers BMPs)
- Efficiency (the time required to complete visits)
- Customer satisfaction (the ability of the team to improve school staff satisfaction with IAQ conditions)

The data related to each of the performance measures are discussed in Section 3, Program Evaluation Findings. Related tables are presented in Appendix A, and related figures are presented in Appendix B. In addition, factors that can potentially affect team performance are discussed in Section 4, and recommendations for improving team performance are presented in Section 5.

2. PROGRAM EVALUATION METHODS

2.1 Data Sources

Data related to team effectiveness, program implementation rate, team efficiency, and customer satisfaction were selected and reviewed. The primary data sources were three spreadsheets (Team Performance, IAQ Team Building List, Master Time and Unit) maintained by the team. The Team Performance spreadsheet includes sample measurement data for various IAQ parameters and response data for questionnaires issued to school staff. The IAQ Team Building List spreadsheet contains data for the durations of team visits. The Master Time and Unit spreadsheet tracks the number of ventilation units completed per month, available team time per month, and the numbers of BMPs delivered per month and per quarter. Department of Planning and Capital Programming data for building ages, sizes, and enrollment were also used.

2.1.1 Team Performance Spreadsheet

The Team Performance Spreadsheet presents IAQ measurement data for each school visited by the team. Three sets of data are collected during the PM process for each school:

- Pre-initial data (obtained at the beginning of initial team visits before the team starts PM work)
- Post-initial data (collected during follow-up walkthrough visits conducted after initial PM work is completed)
- Annual data (obtained at the beginning of annual team visits before the team starts annual PM work)

Pre-initial data represent existing conditions at schools before they enter the PM program, **post-initial** data indicate conditions a few months after the team completes initial PM work, and **annual** data represent conditions approximately one to two years after initial visits are completed. The spreadsheet presents the three types of data separately for both buildings and portables.

The IAQ measurement data include the percent of sample readings outside acceptable ranges for several IAQ parameters:

- Grab temperature (measured instantaneously)
- Extended temperature (measured over several weeks)
- Grab relative humidity (RH)
- Extended relative humidity
- Grab carbon dioxide (CO_2) concentration
- Grab carbon monoxide (CO) concentration
- Volumetric air flow introduced by ventilation units [average cubic feet per minute (CFM) relative to design specifications]

Acceptable ranges were derived from MCPS energy conservation guidelines and a voluntary industry standard developed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) in coordination with the American National Standards Institute (ANSI), ANSI/ASHRAE 55-1992, *Thermal Environmental Conditions for Human Occupancy*. The acceptable ranges for the parameters were:

- Temperature [67-73F (heating season), 73-79F (cooling season)]
- Relative Humidity (25-60 percent)
- CO_2 (average concentration within the outdoor CO_2 concentration + 700 ppm CO_2)
- CO (average concentration no higher than 3 ppm, with no peak concentrations exceeding 6 ppm)
- Air flow (volumetric air flow within ±10 percent of design specifications)

The Team Performance spreadsheet also presents values used to rate settled dust levels for each school. The values indicate the effectiveness of building housekeeping practices. Three values are used: 1 (low dust), 2 (moderate dust), and 3 (high dust). Dust values of 1 and 2 are considered acceptable for maintaining favorable IAQ conditions.

In addition to IAQ measurement data, the Team Performance spreadsheet includes the results of questionnaires distributed to school staff during each visit. Three forms of questionnaires are presented to staff:

- Pre-initial questionnaires are distributed before initial PM work starts
- Post-initial questionnaires are distributed after initial PM work is completed
- Annual questionnaires are distributed shortly before annual PM work starts

The questionnaire data include the percent of staff that returned questionnaires indicating dissatisfaction with indoor environmental conditions (temperature, humidity, CO_2, cleanliness). The results are presented separately for different visits and for buildings and portables.

2.1.2 IAQ Team Building List Spreadsheet

The IAQ Team Building List spreadsheet provides data for the years of construction/modernization of schools in the PM program and building sizes. The spreadsheet also tracks the number of on-site worker-days used to complete each team visit.

Worker-days are units representing eight hours of recorded work by team members (excluding environmental safety specialists). For example, 24 hours of work (completed over any number of calendar days) are equivalent to three worker-days. Worker-days are calculated using the combined number of recorded work hours for all the team members. In the example, the three worker-days could be based on 24 total hours of work completed by one or more team members (e.g., 24 hours by one worker, four hours by each of six workers, eight hours by each of three workers, etc.). Because of variations in the number of available team members and scheduling, the durations of visits requiring the same number of worker-days can differ substantially. Visits requiring similar numbers of worker-days can also vary in duration because of other factors: distances from sites to the team offices (since worker-days include driving time), extended wait times for replacement part orders and equipment repairs by other MCPS Divisions, and mobilizations of team members for special IAQ projects.

2.1.3 Master Time and Unit Spreadsheet

The Master Time and Unit spreadsheet tracks data related to the program implementation rate and team efficiency. The spreadsheet includes the number of BMPs delivered per month and per quarter; available worker hours per month; time spent on special projects; the number of team visits per month; and the number of HVAC units serviced per visit. Since school ventilation systems vary in the types of units and their condition, the spreadsheet provides a weighting scale for units serviced by the team. The scale allows for more accurate evaluations of team efficiency at each site. The scale consists of weighted values that account for differences in the amount of time required to service units. The values, which range from 0.25 to 3.0, are based on the type and condition of units. The values reflect the amount of time and effort required to service different types of units. For example, a typical exhaust fan is assigned a value of 1; a typical unit ventilator, which requires disassembly of several components and insulation repair, is assigned a value of 3. Multiplying the total number of units by their corresponding weighted values provides the number of weighted units. The spreadsheet also tracks worker-days spent on special IAQ projects.

The current evaluation process targets building conditions only. There are substantial differences in construction and ventilation equipment that prohibit comparisons of buildings and portables. Commingling data for portables and buildings could skew the overall statistics for schools. Certain schools also received portables between initial and annual team visits, which resulted in the use of different PM routines during the same visit: annual PM work for the building and initial PM work for the portables. As a result, data for portable classrooms were excluded to avoid combining data associated with the same visits but substantially different conditions and types of PM work.

2.2 Statistical Methods

Various statistical tests were used to identify significant differences in IAQ measurements and questionnaire data following team PM work. Additionally, statistical tests were completed to determine correlations between building conditions and on-site team time for site visits, and also between questionnaire responses and IAQ measurements. Although these tests can provide indications of the PM team's performance, they cannot present conclusive evidence that the team's activities have caused (or failed to cause) improvements in IAQ conditions for schools in the program. Additionally, statistical tests are not commonly used to evaluate IAQ programs because of the variable nature of indoor environmental conditions and the use of subjective perceptions of IAQ parameters. As a result, the ability of statistical tests to accurately evaluate IAQ programs has not been established. The specific methods used for each element of the evaluation are described in the following paragraphs.

2.2.1 PM Team Effectiveness

Team effectiveness was evaluated using data presented in the Team Performance spreadsheet for the IAQ parameters of grab temperature, extended temperature, grab relative humidity, extended relative humidity, grab CO_2, and volumetric airflow relative to design specifications. CO data were excluded because the team did not obtain any readings indicating unacceptable concentrations. The data were used to calculate the percents of readings *within* the acceptable ranges, and then averaged to calculate mean percents for each parameter and site visit type (pre-initial, post-initial, and annual data). In order to evaluate building cleanliness, mean settled dust values were calculated for each site visit type. Data were available for 32 buildings; however, pre-initial, post-initial, and annual data were not available for each building.

To identify improvements or degradations in IAQ conditions during the stages of the PM process, IAQ measurement data obtained during successive visits to individual schools were compared. The percent change (the difference between the percent of acceptable readings) was calculated for six parameters:

- Grab temperature
- Extended temperature
- Grab relative humidity
- Extended relative humidity
- Grab CO_2
- Volumetric air flow

Settled dust levels were compared by calculating the difference between dust values obtained during successive visits. Pre-initial and post-initial data were compared to identify improvements or degradations in conditions occurring after initial PM work was completed. This comparison was used to evaluate the effectiveness of initial PM activities. Post-initial and annual data were compared to determine changes occurring during the time period between initial and annual team visits, allowing an evaluation of PM work completed by building service and maintenance staff after initial visits were completed. Pre-initial and annual data were compared to identify improvements or degradations in conditions after one to two years in the program (from the start of the initial visit to the start of the annual visit). Mean percent changes (mean changes for dust values) were then calculated to evaluate the overall effectiveness of the program at the various stages of the PM process.

The data was further evaluated using statistical tests. Hypothesis tests, to include Wilcoxon paired-sample signed-rank test; paired z-test; and paired t-test, were used to determine if PM activities are associated with statistically significant (significance level 0.05) improvements in measurable IAQ conditions.

2.2.2 Program Implementation Rate

Program implementation rate was evaluated based on the number of equivalent BMPs completed per quarter. An equivalent BMP is a unit representing the work output required to generate an initial BMP. As a result, each initial BMP delivery corresponds to one equivalent BMP. Because annual visits are expected to require approximately one-half the time needed to complete initial visits, annual BMP deliveries are considered 0.5 equivalent BMPs each. Data collected since the first BMP delivery in June 2000 were used to calculate the mean number of equivalent BMPs presented per fiscal quarter. Bar charts were constructed to illustrate any variations in the number of initial and annual BMPs delivered per quarter and per month. The number of worker-days spent on special IAQ projects, which can affect BMP deliver rates, are also presented.

2.2.3 PM Team Efficiency

Team efficiency was evaluated using data from the *IAQ Team Building List* and *Master Time and Unit* spreadsheets. Data for initial and annual visits were evaluated independently because the team uses substantially different PM routines during the two types of visits: initial visits involve extensive cleaning of ventilation units, while annual visits are intended primarily for minor repair work and inspections of units for proper functioning and cleanliness. The mean numbers of on-site worker-days required by the team to complete initial and annual visits were calculated. Additionally, scatter diagrams and correlation coefficients (Spearman's rank correlation coefficient or Pearson's product moment correlation coefficient) were used to identify any statistically significant (significance level 0.05) associations between on-site team time and factors such as effective building age, size, and percent capacity; total number of ventilation units; and weighted number of ventilation units. Effective building age, size, and percent enrollment capacity were determined using Department of Planning and Capital Programming data, which are included in BMPs.

Effective building age was calculated as the number of years from the construction date to the date of the initial visit. For buildings that were modernized, effective building age was calculated as the number of years from the modernization date to the date of the team visit (under the assumption that modernization activities involved improvements in ventilation). Percent building capacity was calculated for each school using the reported student enrollment and the total capacity of the building at the time of the visit. The total number of ventilation units (gross units) represents the number of units serviced by the team during each visit. Ventilation units include:

- air handlers
- unit ventilators
- baseboard/floor heaters
- exhaust fans
- heat pumps
- variable air volume boxes
- portable air conditioners
- condensers
- air stations

The weighted numbers of ventilation units were calculated by multiplying the numbers of different units by the relevant weighted values.

2.2.4 Customer Satisfaction

Customer satisfaction was evaluated using questionnaire response data presented in the Team Performance spreadsheet. The evaluation was restricted to data for questions related to four topics:

- Temperature
- Humidity
- Air circulation
- Cleanliness

These topics were selected because they correspond with the four IAQ parameters of temperature, relative humidity, CO_2 concentration (air circulation), and settled dust levels (cleanliness). As a result, school staff perceptions (as determined by the questionnaire responses) can be compared to objective IAQ measurements made by the team. Dissatisfaction related to these parameters was evaluated with questions asking if staff members felt their primary work environments were "too hot" or "too cold" (temperature); "too dry" or "too humid" (humidity); "too stuffy" (air circulation); and "too dusty" (cleanliness). Possible responses to the questions were "never", "rare", "sometimes", "often", and "always". Questionnaire responses of "often" or "always" were considered negative responses, indicating dissatisfaction.

Mean percentages of staff submitting negative questionnaire responses were calculated using the number of returned questionnaires containing negative responses and the total number of staff members per building. To identify improvements or degradations in IAQ conditions during the stages of the PM process, questionnaire response data obtained during successive visits to individual schools were compared. The percent change (the difference between the percent of staff submitting negative responses) was calculated for temperature, humidity, air circulation, and cleanliness at each school with available data.

Pre-initial and post-initial data were compared to identify improvements (measured as reductions in the percent of staff submitting negative questionnaire responses) or degradations in staff satisfaction with IAQ conditions after initial PM work was completed. This comparison was used to evaluate the effectiveness of initial PM activities.

Post-initial and annual data were compared to determine changes occurring during the time period between initial and annual team visits, allowing an evaluation of PM work completed by building service and maintenance staff after initial visits were completed.

Pre-initial and annual data were compared to identify improvements or degradations in staff satisfaction with conditions after one to two years in the program (from the start of the initial visit to the start of the annual visit).

Mean percent changes (mean changes for dust values) were then calculated to evaluate the overall effectiveness of the program at the various stages of the PM process. Hypothesis tests (Wilcoxon paired-sample signed-rank test, paired z-test, or paired t-test) were used to determine if PM activities are associated with statistically significant (significance level 0.05) changes in staff perceptions of IAQ conditions. Finally, scatter diagrams were constructed to identify potential correlations between school staff perceptions of IAQ conditions and IAQ measurement data obtained by the team.

3. PROGRAM EVALUATION FINDINGS

3.1 PM Team Effectiveness

3.1.1 Summary

The data indicate that the team has successfully improved IAQ conditions for schools in the PM program, and improvements generated by team activities can be observed throughout the school year. As shown in Tables 2 and 4, initial PM activities are associated with statistically significant improvements in three parameters:

- Grab temperature
- Extended temperature
- Grab CO_2

Lesser improvements (which do not achieve statistical significance) are seen for extended relative humidity and housekeeping (Tables 2, 4).

Comparisons of post-initial and annual data show continued improvements for temperature control during the time period after the team completes initial visits and starts annual visits (Table 2). As shown in Table 4, housekeeping improves significantly as indicated by a statistically significant reduction in settled dust values. Humidity control, however, worsens significantly (Table 2). The data also show degradations in CO_2 control and volumetric air flow from supply devices (Tables 2).

After one to two years in the program, statistically significant improvements are seen for grab and extended temperature (Table 2). Improvements are also seen for CO_2 control and housekeeping, but relative humidity control continues to worsen significantly (Tables 2, 4).

The data indicate that initial visits result in statistically significant improvements for three parameters. However, significant improvements are observed for only one parameter during the time period after initial visits are completed and annual visits are started. Reduced improvements in IAQ conditions after the team leaves can occur when building service and maintenance staffs do not comply with the PM routines presented in the BMPs. An additional possibility is that substantial improvements over those resulting from initial visits are difficult to achieve at certain schools because of the limited capabilities of the ventilation systems. More detailed discussion of the results is presented in sections 3.1.2 through 3.1.4.

3.1.2 IAQ Conditions

Table 1 presents the mean percents of readings within the acceptable range for six IAQ parameters:

- Grab temperature
- Extended temperature
- Grab relative humidity
- Extended relative humidity
- Grab CO_2
- Average CFM relative to design

The data are presented separately for pre-initial, post-initial, and annual walkthrough visits. All available data for each parameter and site visit type were included. Figure 1 presents the mean percents from Table 1 in graphical form. Table 3 shows mean dust values associated with different visits.

Table 1 shows that the mean percents of acceptable readings obtained at the start of initial visits through the start of annual visits. The results appear to indicate that IAQ conditions typically improve after the team completes initial PM activities. The results also suggest that while conditions generally degraded between initial and annual visits, overall improvements were observed for temperature and CO_2 control.

3.1.3 Differences Between Observed IAQ Conditions During Successive Team Visits

Table 2 shows the mean percent change (increase or decrease) in acceptable readings for grab and extended temperature, grab and extended relative humidity, grab CO_2, and average CFM relative to design. Percent change was calculated as the difference in the percent of acceptable readings obtained at individual schools during successive team visits. As a result, the table only shows calculations for schools with available data for multiple visits. Percent changes between pre-initial and post-initial, post-initial and annual, and pre-initial and annual data were calculated. Table 4 presents mean differences between pre-initial and post-initial, post-initial and annual, and pre-initial and annual settled dust values. In order to determine if calculated differences were statistically significant, hypothesis tests were used. Bold type is used in Tables 2 and 4 to indicate statistically significant increases or decreases. In addition, detailed data used for the hypothesis tests for grab/extended temperature, grab/extended relative humidity, and grab CO_2 are presented in Tables 5, 6, and 7. The tables are intended to illustrate the methods used in conducting hypothesis tests for the evaluation. As a result, similar tables are not presented for additional hypothesis tests.

As shown in Table 2, comparisons of pre-initial and post-initial data indicate mean increases in the percents of acceptable grab temperature, extended temperature, extended relative humidity, and grab CO_2 readings. Hypothesis tests indicate statistically significant increases for three parameters:

- Grab temperature
- Extended temperature
- Grab CO_2

Changes in volumetric air flow could not be determined because no schools had both pre-initial and post-initial air flow data. Table 4 indicates a mean decrease in dust values, representing decreased settled dust levels, after initial PM work was completed. The data suggest that initial PM activities result in substantial improvements in temperature and CO_2 control, and lesser improvements in humidity control and dust levels.

Table 2 shows mean increases in acceptable grab/extended temperature readings between post-initial and annual; however, mean decreases in acceptable grab/extended relative humidity, CO_2, and air flow readings are also shown. As detailed in Table 6, the decrease in acceptable extended relative humidity readings is statistically significant. Table 4 indicates a statistically significant decrease in settled dust levels. The data suggest that housekeeping improves substantially during the time period between the initial and annual visits, but humidity control worsens and significant continued improvements are not achieved for the other parameters.

Comparisons of pre-initial and annual data indicate statistically significant increases in acceptable grab and extended temperature readings and a statistically significant decrease in acceptable extended relative humidity readings (Tables 2, 7). No statistically significant changes were detected for grab relative humidity, grab CO_2, or settled dust (Tables 2, 4, 7). The results suggest that substantial improvements in temperature control are realized, with lesser improvements in CO_2 control and housekeeping, after one to two years in the program. Humidity control, however, appears to be a continuing problem for schools in the program.

3.1.4 Potential Effects of HVAC Season

Since the IAQ Team operates year-round, team visits are initiated during both HVAC seasons, the heating season and the cooling season. As a result, successive visits to certain schools occur during opposite seasons. Although team PM work is expected to result in improvements that will be noticeable during both seasons, the possibility that greater effects are typically observed when successive readings are obtained during the same season (the same type of season, not necessarily the same season of the same year) was considered. The data for five IAQ indicators (grab temperature, extended temperature, grab relative humidity, extended relative humidity, grab CO_2) were separated into two groups: one group for schools at which successive visits occurred during the same season and one group for schools at which successive visits occurred during opposite seasons.

In order to determine if measured improvements (or degradations) in IAQ conditions were greater for either group, mean percent changes in acceptable readings were calculated for both groups and hypothesis tests (significance level approximately 0.05) were performed to determine if the mean percent changes were statistically significant. Additionally, the mean number of months between successive visits was determined for each group to identify any substantial differences that could indicate a potential confounding effect resulting from the amount of time between visits. Only data for schools with available information for the relevant team visits were included in each group comparison.

Tables 8, 9, and 10 present the mean changes in the percent of acceptable IAQ readings for schools at which **pre-initial** and **post-initial** data were obtained during either the same or opposite HVAC season. Table 8 shows increases in mean percents of acceptable grab and extended temperature readings for both groups; however, only the increases observed for schools at which pre-initial and post-initial measurements were taken during opposite seasons achieved statistical significance. Tables 9 and 10 show that the mean percent changes for relative humidity and CO_2 were not statistically significant for either group of schools.

Tables 11, 12, and 13 present the mean changes in the percent of acceptable IAQ readings for schools at which **post-initial** and **annual** data were obtained during either the same or opposite HVAC season. Table 11 shows a statistically significant increase in the mean percent of acceptable extended temperature readings for schools at which post-initial and annual measurements were obtained during the same season. Table 12 indicates a statistically significant decrease for acceptable grab relative humidity readings for the same season group and a statistically significant decrease for acceptable extended relative humidity readings for schools at which readings were obtained during opposite seasons. Table 13 indicates that no significant change in the mean percent of acceptable CO_2 readings was measured for either group.

The results do not appear to indicate that HVAC season exerts a consistent effect on measured improvements or degradations in temperature, relative humidity, or CO_2 control. Comparisons of pre-initial and post-initial data show statistically significant improvements in grab and extended temperature during the opposite season. Comparisons of post-initial and annual data show a significant improvement in extended temperature during the same season, a significant degradation in grab relative humidity during the same season, and a significant degradation in extended relative humidity during the opposite season. The mean number of months between the groups was similar for all of the data comparisons, suggesting that there were no effects resulting from the duration between visits that would have obscured seasonal effects. The data indicate that improvements resulting from team activities can be observed throughout the school year.

3.2 Program Implementation Rate

3.2.1 Summary

From June 2000 to December 2002, the team delivered 41 equivalent BMPs (35 initial BMPs, 12 annual BMPs). The team has averaged approximately four equivalent BMP deliveries over the last 11 fiscal quarters, meeting the current performance goal of six quarterly equivalent BMP deliveries three times (27 percent) (Table 14). The team has averaged approximately one initial and one annual BMP delivery per month (Figure 3). The data indicate that the team has not consistently achieved the current performance goals related to program implementation rate. This is a result of several factors: an inaccurate estimation of the effort required for PM activities when the team was developed, a shortage of available team members (especially HVAC mechanics), poor maintenance of ventilation equipment by school-based staff, and considerable use of team members for special IAQ projects. To meet current goals, the team's operating procedures would require considerable modifications resulting in shorter site visit durations. These modifications, however, could substantially reduce team effectiveness and customer satisfaction.

3.2.2 BMP Delivery Rate

Table 14 shows the number of initial, annual, and equivalent BMPs delivered per quarter. The team delivered 41 equivalent BMPs from June 2000 (fourth quarter 2000) to December 2002 (second quarter 2003). The data indicate that the team delivers an average of 3.7 equivalent BMPs per quarter. In addition to presenting the BMP delivery rate, the table provides BMP completion periods: the time periods during which the team completed on-site PM work for the BMPs presented each quarter. The table also shows data for the number of worker-days spent on BMPs and special IAQ projects and the number of available team members during each BMP completion period.

The leftmost column of Table 14 presents the fiscal quarters during which the team delivered BMPs. The third and fourth columns from the left show the number of initial and annual BMPs delivered in each quarter; the fifth column shows the corresponding number of equivalent BMPs. BMP completion periods are presented in the second column of the table. BMP completion periods are the time intervals from the earliest start date to the latest completion date of on-site PM work for corresponding BMPs. The periods do not necessarily include dates of walkthrough assessments and meetings occurring prior to on-site work or BMP assembly and presentation occurring after on-site work. As shown in the table, BMP completion periods vary in duration and successive periods can overlap substantially. The total numbers of on-site worker-days spent on the corresponding BMPs are presented in the eighth column, with the numbers of worker-days spent on initial and annual BMPs shown separately in the sixth and seventh columns. The ninth column indicates the worker-days spent on special IAQ projects during the corresponding BMP completion periods, and the tenth column shows the total worker-days spent on IAQ work (BMP-related PM work and special project work). The last column presents the number of available team members per month during the corresponding BMP completion periods.

As an illustration of the table's arrangement, the first row of data indicates that the team delivered six initial BMPs (corresponding to six equivalent BMPs) during the fourth quarter of FY 2000. On-site PM work corresponding to these six BMPs was conducted during the period from December 14, 1999 through May 3, 2000. As indicated in the sixth, seventh, and eighth columns, the team spent a total of 349 on-site worker-days on the six equivalent BMPs: all 349 on-site worker-days were used for initial BMPs because the team had not yet started conducting annual visits. The ninth column shows that the team did not spend any worker-days on special IAQ projects. As a result, the team recorded a total of 349 worker-days on IAQ work (shown in the tenth column) during the corresponding BMP completion period. The eleventh column notes that six to eight team members, two to four of whom were HVAC mechanics or IAQ supervisors, recorded worker-days for IAQ work during the BMP completion period.

3.2.3 Potential Variables Affecting Program Implementation Rate

As Table 14 and Figures 2 and 3 indicate, the BMP delivery rate per quarter and month varies considerably. The quarterly rate has ranged from one to seven equivalent BMPs per quarter, and the monthly rate has ranged from zero to six equivalent BMPs per quarter. This variability can be attributed to several factors, such as pre-existing building conditions (number of ventilation units, cleanliness and functional condition of units) and availability of team personnel. Poorly-maintained ventilation equipment typically require additional time for initial cleaning and repairs, extending site visit durations. In addition, inoperable equipment or poorly-designed ventilation systems can require extensive repairs and modifications that substantially increase the amount of time required for site visits. BMP deliveries can also be delayed by extended wait-times for repairs by the Division of Maintenance or repair/replacement part deliveries by vendors.

Variations in available team time resulting from team use for special IAQ projects, leave, and personnel vacancies also appear to have affected the BMP delivery rate. As Table 14 indicates, the team has spent 380.6 worker-days on special projects. Based on the data for total worker-days spent on BMP-related PM work (3,694.0) and the total number of equivalent BMPs completed (41), the team spends an average of 90.1 worker-days on each equivalent BMP. Using this figure, the 380.6 worker-days spent on special projects might have effectively reduced total BMP production by four equivalent BMPs (a reduction of approximately 9 percent). Leave and personnel vacancies can decrease BMP production by reducing available worker-days for on-site PM work.

3.3 PM Team Efficiency

3.3.1 Summary

The team uses an average of 89.8 on-site worker-days to complete initial visits and 54.7 on-site worker-days to complete annual visits (Table 15). Current team performance goals for on-site time spent for visits are 10 to 20 business days for initial visits and 5 to 10 business days for annual visits. These figures can correspond to a variable number of worker-days depending on the number of available team members. The PM team has fluctuated in size since it was established, having six to 10 team members available for on-site PM work. For an average initial visit requiring 89.8 worker-days, a team of six available workers (working on-site for eight hours per day) could complete the visit in approximately 15 business days. If all six team members were available to work at the site on consecutive business days, on-site PM work would be completed in three calendar weeks. Under the same conditions, 10 team members could complete the visit in approximately nine business days (two calendar weeks). Since leave and team use for special IAQ projects can reduce the number of team members available for PM work, visits requiring similar numbers of worker-days can vary in duration (as measured by business or calendar days).

In order to identify additional factors potentially affecting on-site team time, statistical tests were used to determine associations between the number of worker-days used per visit and various building conditions. The results indicate that the number of worker-days used for initial visits is positively correlated with the number of ventilation units in buildings (Table 17). The results also suggest that on-site time for initial and annual visits is not affected by building age, size, or percent capacity (Tables 17, 18).

3.3.2 On-Site Time and Building Conditions

As shown in Table 15, initial visits require an average of 89.8 worker-days and annual visits require an average of 54.7 worker-days. The mean effective age of buildings at the time of initial and annual visits is 21 years. The mean building size at the time of initial visits is 76,617 square feet and the mean student enrollment is 631 students, resulting in a mean capacity of 92 percent. The mean building size at the time of annual visits is 87,304 square feet with a mean enrollment of 792, resulting in a mean capacity of 105 percent.

Table 16 shows mean values for on-site worker-days, gross units, and weighted units for schools with data for on-site team time and numbers of ventilation units. The team services an average of 76.5 gross units (172.9 weighted units) during initial visits and an average of 88.3 gross units (158.9 weighted units) during annual visits.

3.3.3 Potential Variables Affecting On-Site Time for Initial Visits

Table 17 presents correlation coefficients (R values) and probabilities (P-values) calculated to identify associations between building conditions and the number of on-site worker-days required for initial visits. Statistically significant positive correlations were found between gross ventilation units and on-site worker-days (R Value = 0.331, P-value = 0.030, n = 33). A slight correlation, which does not achieve statistical significance, appears to exist between the number of weighted ventilation units and on-site worker-days (R Value = 0.276, P-value = 0.060, n = 33). Correlation coefficients were then calculated with six outlying data points excluded. The outliers are associated with atypical visits requiring extensive repair work, sometimes involving substantial modifications to existing ventilation equipment. With the six outliers removed, statistically significant correlations were found for gross and weighted units [R Values = 0.567 (gross units), 0.622 (weighted units); P-values = 0.0010 (gross units), 0.00018 (weighted units); n = 27]. Scatter diagrams presented in Figures 4 through 7 show the data in graphical form (along with best-fit lines). The data appear to confirm that the amount of on-site team time required for initial visits can be predicted based on the number of ventilation units present at schools.

As shown in Table 17, no statistically significant correlations were found between on-site team time for initial visits and building age, size, or percent capacity [R Values = 0.134 (age), 0.191 (size), -0.112 (percent capacity); P-values = 0.22 (age), >0.05 (size), 0.26 (percent capacity); n = 36]. Figures 10 through 12 graphically illustrate the results. The data suggest that building age, size, and percent capacity do not substantially affect the amount of time required to complete initial visits.

The results, which indicate a statistically significant positive association between worker-days and numbers of gross units but not building size, suggest that building size is not correlated with numbers of ventilation units. In order to confirm this observation, the data for building size and number of gross units were compared. As shown in Figure 16, the data indicate a weak positive correlation (R Value = 0.280), indicating that the amount of on-site team time required for initial visits cannot be reliably predicted based on building size alone.

3.3.4 Potential Variables Affecting On-Site Time for Annual Visits

Table 18 presents correlation coefficients and probabilities calculated to identify associations between building conditions and the number of on-site worker-days required for annual visits. Scatter diagrams presented in Figures 8, 9, 13, 14, and 15 show the data graphically. No statistically significant correlations were found between worker-days and building age, size, or percent capacity [R Values = -0.078 (age), 0.301 (size), -0.127 (percent capacity); P-values = 0.40 (age), 0.17 (size), 0.35 (percent capacity); n = 12]. Statistically significant correlations were also not found between worker-days and the numbers of gross and weighted units [R Values =0.324 (gross units), 0.393 (weighted units); P-values = >0.05 (gross, weighted units); n = 7)]; however, scatter diagrams in Figures 8 and 9 indicate weak positive correlations. A weak positive correlation between on-site worker-days and size also appears to exist (Figure 14). It is possible that statistically significant correlations will become evident as additional annual visits are completed, resulting in greater sample size.

3.4 Customer Satisfaction

3.4.1 Summary

Customer satisfaction with team activities was evaluated using questionnaire response data related to four topics: temperature, humidity, air circulation, and cleanliness. These topics correspond with the IAQ parameters of temperature, relative humidity, CO_2 concentration, and settled dust levels. Based on the responses, initial PM work appears to result in improved staff satisfaction with temperature, air circulation, and cleanliness. However, the data indicate that staff dissatisfaction for all four parameters increases during the time period after initial visits are completed and before annual visits are started. Overall, the data suggest that staff dissatisfaction with temperature and humidity is substantially greater for conditions after one to two years in the PM program than for pre-existing conditions (Table 22).

The data indicate that school staffs are satisfied with initial PM work completed by the team, but they are not satisfied with PM activities conducted after the team leaves. This appears to indicate dissatisfaction with the results of PM work completed by building service and/or maintenance staff. Comparisons of pre-initial and annual response data also suggest an overall increase in staff dissatisfaction with temperature and humidity control after one to two years in the program. This increase in staff dissatisfaction with humidity is consistent with IAQ measurement data indicating consistent, substantial degradations in extended relative humidity control after initial visits are completed (Table 2). However, the increase in dissatisfaction with temperature is not consistent with data indicating substantial improvements in temperature control (Table 2). In addition, independent comparisons of questionnaire response data and IAQ measurement data for the four parameters show no correlation between school staff perceptions of IAQ conditions and IAQ readings (Figures 18 – 23). *The results suggest that measurable IAQ improvements do not necessarily result in increased staff satisfaction with IAQ conditions.*

The apparent inconsistency between school staff perceptions of IAQ and measurement data might be a result of several factors. The performance criteria used for IAQ parameters might not correspond well with staff perceptions of comfortable conditions. The questionnaires, which have since been revised, might not have accurately gauged staff perceptions. Questionnaire responses might also reflect unrealistic expectations for improvements, especially when considering the limited capabilities of the ventilation systems in some schools. Additional factors that might affect questionnaire responses are staff dissatisfaction with unrelated work conditions and dissatisfaction with unsuccessful IAQ-related corrective action completed prior to the establishment of the PM program.

3.4.2 Questionnaire Response Rates

Table 19 presents the mean percent response rates obtained for pre-initial, post-initial, and annual questionnaires and the total response rate. Response rates were calculated as the percent of building staff that returned completed questionnaires to the team. The table indicates that response rates consistently decrease throughout the PM process at the schools. It is possible that the mean response rate is highest for the pre-initial questionnaire because it is typically distributed and returned during staff meetings that school personnel are encouraged to attend.

3.4.3 Mean Percents of Negative Questionnaire Responses

Table 20 shows the mean percent of staff submitting negative responses related to temperature, relative humidity, CO_2 concentration, and settled dust for each type of questionnaire. Figure 17 presents the data in graphical form. The results suggest greatest staff dissatisfaction with temperature control. The data do not appear to indicate substantial differences in the percent of staff submitting negative responses for successive questionnaires.

3.4.4 Percents of Schools Exceeding Performance Criterion

Table 21 presents data related to the team performance criterion for acceptable levels of negative questionnaire responses related to any IAQ indicator. The criterion (20 percent) applies to post-initial and annual questionnaires, which are completed after the team performs PM work. In order to make comparisons to staff satisfaction with pre-existing conditions, the criterion was also applied to pre-initial questionnaire response data. The table presents the percent of schools at which more than 20 percent of staff returned questionnaires with negative responses related to temperature, humidity, air circulation, or cleanliness. Temperature conditions appear to be the most common source of staff dissatisfaction. The results indicate that the team achieves the performance criterion for acceptable levels of negative questionnaire responses for the majority of schools included in the PM program. Specifically, the results suggest a substantial reduction in school staff dissatisfaction with temperature and air circulation by the time the team initiates annual visits.

3.4.5 Differences in Staff Satisfaction with IAQ Conditions During Successive Team Visits

Table 22 presents the mean percent change in the percent of staff submitting negative questionnaire responses related to temperature, humidity, air circulation, and cleanliness. The data indicate a statistically significant reduction in the percent of staff submitting negative responses related to air circulation after initial PM work is completed. However, comparisons between response data for pre-initial and annual questionnaires indicate statistically significant increases for temperature and humidity. Comparisons between post-initial and annual data do not show statistically significant changes.

3.4.6 Consistency of Questionnaire Responses With Measured IAQ Conditions

Questionnaire response data were also compared with IAQ measurement data to determine if staff perceptions of temperature and humidity conditions are consistent with IAQ readings. Figures 18 through 23 present scatter diagrams for questionnaire data (percent of staff submitting negative questionnaire responses) and IAQ outlier data (percent of readings outside the acceptable range) for temperature, relative humidity, CO_2 concentration, and settled dust levels. Questionnaire response data related to temperature control were plotted separately against extended temperature data (Figure 18) and grab temperature data (Figure 19). Similarly, questionnaire response data related to humidity control were plotted against extended relative humidity data (Figure 20) and grab relative humidity data (Figure 21). Additionally, response data for air circulation were plotted against CO_2 data (Figure 22), and response data for cleanliness were plotted against settled dust data (Figure 23). The diagrams do not appear to show any association between the percent of staff submitting negative questionnaire responses and the percent of outlier readings for any of the parameters. The results suggest that quantifiable improvements to indoor environmental conditions do not ensure more favorable questionnaire responses.

4. POTENTIAL FACTORS AFFECTING TEAM PERFORMANCE

Various factors can affect team effectiveness, the program implementation rate, team efficiency, and customer satisfaction. Internal factors, which originate from team activities, can include personnel availability, technical expertise, current performance measures, and job vacancies. Potential external factors, which involve actions by other MCPS divisions, include the pre-existing conditions of ventilation systems serviced by the team, maintenance and knowledge of ventilation equipment by building service staff, timeliness of repairs by the Division of Maintenance, and Energy Management operations.

4.1 Internal Factors

4.1.1 Personnel Availability

Visit durations are commonly affected by the availability of team members. Reductions in available team members, as a result of leave or team use for special IAQ projects, can extend site visits considerably. This delays the transition to the next school, which can reduce the program implementation rate.

4.1.2 Technical Expertise

Team effectiveness and efficiency are positively affected by the technical capabilities of the team. Team members' knowledge of HVAC and electrical equipment regularly enable the team to successfully identify deficiencies and repair equipment at schools in the program. Familiarity with school-based ventilation and electrical components among team members with experience as former building service managers also allows the team to locate and service equipment efficiently.

4.1.3 Current Performance Measures

Current performance measures can affect measured team effectiveness and customer satisfaction. The performance measures for team effectiveness are based on acceptable ranges for the IAQ parameters of temperature, relative humidity, CO_2 concentration, supply air flow rate, and settled dust levels. The team has determined that ventilation systems in certain schools appear to be incapable of establishing conditions that consistently meet the performance criteria for these parameters, particularly relative humidity and CO_2. Many ventilation systems show reduced effectiveness resulting from excessive wear and poor maintenance. Additionally, most systems for schools in the program were not designed to meet current ventilation standards (upon which the team's performance criteria are based) or increased student populations. As a result, substantial improvements that do not result in consistent acceptable IAQ readings might not be reflected by the current performance criteria.

As discussed in Section 3.4, Customer Satisfaction, questionnaire response data does not appear to be correlated with IAQ measurement data. This inconsistency suggests that the acceptable ranges for temperature, relative humidity, and CO_2 concentration do not correspond with conditions considered comfortable by school staff. In addition, staff regularly request that the team adjust ventilation equipment to generate classroom temperatures below the acceptable range during the cooling season and above the acceptable range during the heating season. Such adjustments can result in a decrease in the percent of acceptable grab and extended temperature readings obtained during visits, reducing measured team effectiveness. Refusing to make such adjustments, however, can result in staff dissatisfaction with the team's efforts, resulting in decreased customer satisfaction.

4.1.4 Job Vacancies

Team performance has also been affected by job vacancies. Difficulties finding qualified personnel for additional positions with the team have delayed the completion of a second PM unit. The team expanded with the additions of two HVAC mechanics and an electrician during January and February of 2003. Because of the complexity of school-based mechanical systems, however, team members are typically not considered proficient for six months. With the new team members, completion of a second unit by hiring an additional IAQ/PM supervisor would allow schools to enter the program at a higher rate. The availability of a second unit could also ensure that schools receive timely annual visits, limiting any degradation in conditions that occurs between team visits.

4.2 External Factors

4.2.1 Pre-Existing Conditions of Ventilation Systems

As discussed in Section 3.3.2, On-Site Time and Building Conditions, the mean effective age for buildings visited by the team is 21 years. Of the 36 schools receiving initial visits, 31 (86 percent) were more than 10 years old at the time of the visit and 21 (58 percent) had an effective age of 20 years or more. As a result, the team typically encounters ventilation systems that were not designed to meet current ventilation standards or accommodate current student populations. In addition, the effectiveness of ventilation systems at certain schools have been further reduced by partitioning classrooms or converting rooms not designed for continuous occupancy into classrooms. Ineffective ventilation systems for schools visited by the team typically show poor temperature control, poor humidity control and inadequate air circulation. Such systems often require additional repairs and modifications that extend visit durations. Additionally, certain systems do not generate conditions meeting all of the team's performance criteria even after substantial improvements are established. This can negatively affect measured team effectiveness and customer satisfaction.

4.2.2 Building Staff Maintenance and Knowledge of Ventilation Equipment

The effectiveness of building service staff's maintenance procedures for ventilation equipment can also affect team performance. Well-maintained equipment typically require less time for cleaning and repairs, which can reduce visit durations, while poorly-maintained equipment often require the team to spend more time on cleaning and repairs, increasing visit durations.

Visit durations can also be affected by building service staff knowledge of school equipment. Team activities include locating electrical panels and circuit breakers used to de-energize ventilation equipment prior to performing PM work. The team also uses mechanical prints to locate ventilation components throughout each building and determine the relevant design specifications. At schools where the building service staff is familiar with the locations of electrical and ventilation units and can provide necessary prints, the team can accomplish its tasks more readily.

4.2.3 Maintenance Repairs

Team performance can be affected by the timeliness of repairs by the Division of Maintenance. Schools visited by the team often show damage to ventilation equipment or structural components that negatively affects IAQ conditions. As a result, the team frequently coordinates activities with the Division of Maintenance and submits equipment, such as fan motors, for repair. Extended wait-times for these repairs can increase visit durations.

4.2.4 Energy Management

Energy Management operations can also affect team performance. Malfunctioning school-based energy management equipment can disrupt the operation of ventilation units, which can cause temperature, humidity, or CO_2 control problems. These IAQ problems can then reduce measured team effectiveness and customer satisfaction by affecting IAQ readings and staff perceptions of conditions. Additionally, extended wait-times for repairs of energy management equipment can extend site visit durations.

5. RECOMMENDATIONS

Various recommendations are presented for improving team performance. Team effectiveness, the program implementation rate, and team efficiency can potentially be improved by increasing the team's capabilities through hiring additional team members, modifying current performance goals and operating procedures, and conducting follow-up training for building staff. The team can potentially improve customer satisfaction by holding follow-up meetings with school staff to present and clarify the results of PM activities.

5.1 Increase Team Capabilities

The team's capabilities have recently increased with the addition of two HVAC mechanics and an electrician. After a six-month period, the new team members are expected to possess technical expertise that will decrease the amount of time required to identify deficiencies and perform repairs, which will reduce site visit durations and enable an increased program implementation rate. With the new team members, the addition of a second IAQ/PM supervisor is also now appropriate in order to complete a second unit. With two units, the team could noticeably increase the number of schools entering the program and ensure that schools receive timely annual visits.

5.2 Review Current Performance Goals

Current performance goals should be reviewed to determine if they allow a more meaningful evaluation of team effectiveness. As discussed in previous sections, ventilation systems at certain schools might not be capable of establishing conditions meeting the performance criteria for IAQ parameters. Because the team does not possess the capability to substantially modify such systems, the performance criteria might require adjustments to account for system limitations.

The team should consider further adjustments to establish consistency between the performance criteria for IAQ parameters and staff perceptions of favorable conditions. Such adjustments could improve the likelihood that efforts to achieve the performance criteria would result in increased staff satisfaction with IAQ conditions.

The team should also consider adopting additional performance criteria to better evaluate the effectiveness of PM activities. One option is a criterion based on the environmental safety specialist's professional judgment of IAQ conditions before and after the team completes PM work. This judgment would be based on overall observations of various factors, such as air temperatures, humidity, air circulation, odors, and staff attitudes.

5.3 Review Team Operating Procedures

The team should review current operating procedures to identify methods that could increase effectiveness and decrease site visit durations. Visit durations could be reduced by decreasing the scope of initial PM work: excluding units for locations that are not continuously occupied, such as hallways and locker rooms; excluding additional units in serviceable condition. Reducing the volume of initial PM activities could increase the program implementation rate but could decrease effectiveness and customer satisfaction. Thorough cleaning of units that appear serviceable might be necessary at certain schools to create IAQ conditions resulting in consistent acceptable parameter readings and staff satisfaction.

5.4 Follow-Up Training for Building Service Staff

As discussed in Section 3.1, PM Team Effectiveness, IAQ conditions at schools in the program appear to degrade during the period between initial and annual team visits. In addition, the team often finds evidence of ineffective ventilation equipment maintenance and poor BMP compliance. These observations suggest that the effectiveness of PM activities performed by building service staff needs to be improved. As a result, the team should consider conducting follow-up training for building service managers and plant equipment operators after initial visits are completed. The training would supplement direction provided by the BMPs and by team members during initial visits. Training sessions, which could be conducted during post-initial follow-up visits or shortly after initial visits are completed, would involve detailed discussion of the ventilation equipment and necessary PM routines. To minimize the effects of building personnel changes on the PM process, training sessions could also be conducted when new building service managers or plant equipment operators are assigned to schools in the PM program.

5.5 Follow-Up Meetings for General Staff

The review of questionnaire response data indicates that staff perceptions of IAQ conditions do not appear to correspond with IAQ measurement results. While this could be a result of poor consistency between the performance criteria for IAQ parameters and staff perceptions of favorable conditions, it could also indicate disappointment based on unrealistic expectations for improvements. As a result, the team should consider methods for improving staff understanding of IAQ issues and the PM program. One possible method is holding a follow-up meeting for school staff after each initial visit is completed. The meeting would provide an opportunity for the team to describe the PM work completed during the visit and any measured improvements. The team could also present information related to the school’s ventilation system, the system's limitations, scheduled repairs, PM work that must be completed by building staff to ensure continuing improvements, and the necessity/feasibility of more extensive repair work. Follow-up meetings could enable school staff to become better informed about the program, resulting in increased customer satisfaction. Distributing follow-up staff questionnaires during the meetings might also increase response rates for the post-initial questionnaire.

An additional option for improving staff awareness would involve encouraging schools to form *in-school IAQ committees*. The committees would allow general staff to gain a better understanding of the PM program and the actions required by building staff to maintain favorable IAQ conditions. This could lead to increased customer satisfaction and improved BMP compliance by building staff.

APPENDIX A. Tables

A.1 PM Team Effectiveness

Table 1. Mean Percentages of Readings Within Acceptable Ranges[1, 2]						
IAQ Indicator	Pre-Initial[3]		Post-Initial		Annual	
	n	Mean Percent (Range)	n	Mean Percent (Range)	n	Mean Percent (Range)
Grab Temperature	32	62 (0-100)	31	74 (14-100)	12	71 (25-100)
Extended Temperature	29	28 (0-75)	29	43 (0-100)	10	56 (20-100)
Grab Relative Humidity	28	88 (0-100)	27	84 (0-100)	11	69 (25-100)
Extended Relative Humidity	29	75 (0-100)	29	83 (0-100)	10	31 (0-80)
Grab CO_2	32	69 (17-100)	31	77 (25-100)	12	72 (29-100)
Average CFM relative to design	1	0	10	35 (0-84)	5	61 (8-88)

[1] Mean percentages were calculated using data available November 22, 2002 in the Team Performance spreadsheet. Available data for each parameter and site visit type were included. Data were available for 32 buildings; however, Pre, Post, and Annual data were not available for all buildings. Data for portables were not included.
[2] Acceptable ranges: Temperature [67-73F (heating season), 73-79F (cooling season)]; Relative Humidity (25-60%); CO_2 (Outdoor CO_2 + 700 ppm CO_2; Average CFM relative to design (measured air flow from supply units within 10% of design specifications).
[3] Pre-Initial data were collected at the start of initial visits before team activities commenced; Post-Initial data were collected during follow-up visits after initial team activities concluded; Annual data were collected at the start of annual visits before annual team activities began. Data for combined follow-up and annual visits (labeled 'post/annual' in the Team Performance spreadsheet) were categorized as Post-Initial data.

Table 2. Mean Percent Change of Readings Within Acceptable Ranges[1]						
IAQ Indicator	Pre-Initial/Post-Initial[2]		Post-Initial/Annual		Pre-Initial/Annual	
	n[3]	Mean Percent Change[4]	n	Mean Percent Change	n	Mean Percent Change
Grab Temperature	30	**+11**[5]	12	+2	12	**+25**
Extended Temperature	28	**+15**	10	+23	10	**+39**
Grab Relative Humidity	24	-3	12	-12	12	-15
Extended Relative Humidity	15	+12	10	**-51**	10	**-64**
Grab CO_2	30	**+8**	12	-7	12	+5
Average CFM relative to design	0	--	1	-17	0	--

[1] Percent changes were calculated as the difference between the percents of acceptable readings obtained during different visits to each school. Means were calculated from the percent changes for individual schools. Data for portables were not included.
[2] The percents of acceptable readings obtained during initial visits and follow-up visits was calculated for each school with available Pre-Initial and Post-Initial data. For each school, the percent change was calculated by subtracting the Pre-Initial percent from the Post-Initial percent. Means were then calculated for the percent changes associated with each IAQ indicator.
[3] The number of schools with available Pre-Initial and Post-Initial data for each IAQ indicator.
[4] A plus sign (+) indicates a mean increase in percent acceptable readings; a minus sign (-) indicates a mean decrease in percent acceptable readings.
[5] Figures displayed in bold font indicate statistically significant increases or decreases (significance level approximately 0.05).

Table 3. Mean Overall Settled Dust Value[1]					
Pre-Initial[2]		Post-Initial		Annual	
n	Mean Value (Range)	n	Mean Value (Range)	n	Mean Value (Range)
25	2.1 (1.2-2.8)	27	2.1 (1.3-3.0)	10	2.0 (1.6-2.4)

[1] Settled dust was evaluated using a gloss meter and visual observations. Dust levels were rated using three possible values: 1 (low dust), 2 (moderate dust), 3 (high dust). At least six locations (window sills, ledges, TVs, computers, shelves, window blinds, return grills, etc.) were evaluated and rated in each sample area. The ratings were averaged to determine the dust value for the sample area. The sample area values were then averaged to determine the overall settled dust value for the building. Low and moderate dust levels are considered acceptable for maintaining favorable indoor environmental conditions. Data for portables were not included.
[2] The mean overall settled dust value measured for buildings during pre-initial walkthrough visits.

Table 4. Mean Change of Overall Settled Dust Values[1]					
Pre-Initial/Post-Initial[2]		Post-Initial/Annual		Pre-Initial/Annual	
n[3]	Mean Change[4]	n	Mean Change	n	Mean Change
23	-0.1	6	**-0.4**[5]	3	-0.2

[1] Mean change was calculated as the mean difference between overall settled dust values obtained during different visits to each school. Data for portables were not included.
[2] The overall dust value obtained during initial visits and follow-up visits was calculated for each school with available Pre-Initial and Post-Initial data. For each school, the change was calculated by subtracting the Pre-Initial percent from the Post-Initial percent. Means were then calculated for the changes.
[3] The number of schools with available Pre-Initial and Post-Initial dust values.
[4] A plus sign (+) indicates a mean increase in percent acceptable readings; a minus sign (-) indicates a mean decrease in percent acceptable readings.
[5] A statistically significant decrease in mean overall settled dust value (significance level 0.05).

Table 5. Comparison of Pre-Initial and Post-Initial Data (Hypothesis Tests)[1]					
IAQ Indicator	**n[2]**	**Statistical Test**	**Significance Level**	**Hypotheses**	**Results**
Grab Temperature	30	Paired t-test (right-tailed)	0.05	H_0 (null hypothesis): $\mu_1 = \mu_2$ (mean percent of readings within the acceptable range after the initial visit is not greater) H_a (alternative hypothesis): $\mu_1 > \mu_2$ (mean percent of readings within the acceptable range after the initial visit is greater) μ_1: mean percent of readings within the acceptable range (post-initial) μ_2: mean percent of readings within the acceptable range (pre-initial)	The test results are statistically significant at the 5% level; the data provide sufficient evidence to conclude that the mean percent of grab temperature readings within the acceptable range at schools that have received an initial IAQ Team visit is greater than the mean percent of grab temperature readings within the acceptable range at schools that have not received an initial visit.
Extended Temperature	28	Paired t-test (right-tailed)	0.05	H_0: $\mu_1 = \mu_2$ (mean percent of readings within the acceptable range after the initial visit is not greater) H_a: $\mu_1 > \mu_2$ (mean percent of readings within the acceptable range after the initial visit is greater) μ_1: mean percent of readings within the acceptable range (post-initial) μ_2: mean percent of readings within the acceptable range (pre-initial)	The test results are statistically significant at the 5% level; the data provide sufficient evidence to conclude that the mean percent of extended temperature readings within the acceptable range at schools that have received an initial IAQ Team visit is greater than the mean percent of extended temperature readings within the acceptable range at schools that have not received an initial visit.
Grab Relative Humidity	24	Paired z-test (left-tailed)	0.05	H_0: $\mu_1 = \mu_2$ (mean percent of readings within the acceptable range after the initial visit is not greater) H_a: $\mu_1 < \mu_2$ (mean percent of readings within the acceptable range after the initial visit is greater) μ_1: mean percent of readings within the acceptable range (post-initial) μ_2: mean percent of readings within the acceptable range (pre-initial)	The test results are not statistically significant at the 5% level; the data do not provide sufficient evidence to conclude that the mean percent of grab relative humidity readings within the acceptable range at schools that have received an initial IAQ Team visit is less than the mean percent of grab relative humidity readings within the acceptable range at schools that have not received an initial visit.
Extended Relative Humidity	15	Paired t-test (right-tailed)	0.05	H_0: $\mu_1 = \mu_2$ (mean percent of readings within the acceptable range after the initial visit is not greater) H_a: $\mu_1 > \mu_2$ (mean percent of readings within the acceptable range after the initial visit is greater) μ_1: mean percent of readings within the acceptable range (post-initial) μ_2: mean percent of readings within the acceptable range (pre-initial)	The test results are not statistically significant at the 5% level; the data do not provide sufficient evidence to conclude that the mean percent of extended relative humidity readings within the acceptable range at schools that have received an initial IAQ Team visit is greater than the mean percent of extended relative humidity readings within the acceptable range at schools that have not received an initial visit.

Table 5. Comparison of Pre-Initial and Post-Initial Data (Hypothesis Tests)[1]					
IAQ Indicator	**n[2]**	**Statistical Test**	**Significance Level**	**Hypotheses**	**Results**
Grab CO_2	30	Paired t-test (right-tailed)	0.05	H_0: $\mu_1 = \mu_2$ (mean percent of readings within the acceptable range after the initial visit is not greater) H_a: $\mu_1 > \mu_2$ (mean percent of readings within the acceptable range after the initial visit is greater) μ_1: mean percent of readings within the acceptable range (post-initial) μ_2: mean percent of readings within the acceptable range (pre-initial)	The test results are statistically significant at the 5% level; the data provide sufficient evidence to conclude that the mean percent of grab CO_2 readings within the acceptable range at schools that have received an initial IAQ Team visit is greater than the mean percent of grab CO_2 readings within the acceptable range at schools that have not received an initial visit.

[1] Results were calculated using data available November 22, 2002 in the Team Performance spreadsheet. Pre-Initial data were compared with Post-Initial data for the same buildings; data for buildings without both Pre-Initial and Post-Initial data presented in the spreadsheet were not included. Data for portables were also excluded.
[2] The number of buildings with both Pre-Initial and Post-Initial data. Data for combined follow-up and annual visits (labeled 'post/annual' in the Team Performance spreadsheet) were considered Post-Initial data.

Table 6. Comparison of Post-Initial and Annual Data (Hypothesis Tests)[1]					
IAQ Indicator	**n[2]**	**Statistical Test**	**Significance Level**	**Hypotheses**	**Results**
Grab Temperature	12	Paired t-test (right-tailed)	0.05	H_0: $\mu_1 = \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is not greater) H_a: $\mu_1 > \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is greater) μ_1: mean percent of readings within the acceptable range (annual) μ_2: mean percent of readings within the acceptable range (post-initial)	The test results are not statistically significant at the 5% level; the data do not provide sufficient evidence to conclude that the mean percent of grab temperature readings within the acceptable range at schools approximately one year after they have received an initial IAQ Team visit is greater than the mean percent of grab temperature readings within the acceptable range at schools immediately following an initial visit.
Extended Temperature	10	Paired t-test (right-tailed)	0.05	H_0: $\mu_1 = \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is not greater) H_a: $\mu_1 > \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is greater) μ_1: mean percent of readings within the acceptable range (annual) μ_2: mean percent of readings within the acceptable range (post-initial)	The test results are not statistically significant at the 5% level; the data do not provide sufficient evidence to conclude that the mean percent of extended temperature readings within the acceptable range at schools approximately one year after they have received an initial IAQ Team visit is greater than the mean percent of extended temperature readings within the acceptable range at schools immediately following an initial visit.
Grab Relative	12	Wilcoxon	0.049	H_0: $\mu_1 = \mu_2$ (mean percent of readings within the acceptable	The test results are not statistically significant

Table 6. Comparison of Post-Initial and Annual Data (Hypothesis Tests)[1]					
IAQ Indicator	**n^2**	**Statistical Test**	**Significance Level**	**Hypotheses**	**Results**
Humidity		paired-sample signed-rank test (left-tailed)		range approximately one year after the initial visit is not greater) H_a: $\mu_1 < \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is greater) μ_1: mean percent of readings within the acceptable range (annual) μ_2: mean percent of readings within the acceptable range (post-initial)	at the 4.9% level; the data do not provide sufficient evidence to conclude that the mean percent of grab relative humidity readings within the acceptable range at schools approximately one year after they have received an initial IAQ Team visit is less than the mean percent of grab relative humidity readings within the acceptable range at schools immediately following an initial visit.
Extended Relative Humidity	10	Wilcoxon paired-sample signed-rank test (left-tailed)	0.049	H_0: $\mu_1 = \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is not greater) H_a: $\mu_1 < \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is greater) μ_1: mean percent of readings within the acceptable range (annual) μ_2: mean percent of readings within the acceptable range (post-initial)	The test results are statistically significant at the 4.9% level; the data provide sufficient evidence to conclude that the mean percent of extended relative humidity readings within the acceptable range at schools approximately one year after they have received an initial IAQ Team visit is less than the mean percent of extended relative humidity readings within the acceptable range at schools immediately following an initial visit.
Grab CO_2	12	Paired t-test (left-tailed)	0.05	H_0: $\mu_1 = \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is not greater) H_a: $\mu_1 < \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is greater) μ_1: mean percent of readings within the acceptable range (annual) μ_2: mean percent of readings within the acceptable range (post-initial)	The test results are not statistically significant at the 5% level; the data do not provide sufficient evidence to conclude that the mean percent of grab CO_2 readings within the acceptable range at schools approximately one year after they have received an initial IAQ Team visit is less than the mean percent of CO_2 readings within the acceptable range at schools immediately following an initial visit.

[1] Results were calculated using data available November 22, 2002 in the Team Performance spreadsheet. Post-Initial data were compared with Annual data for the same buildings; data for buildings without both Post-Initial and Annual data presented in the spreadsheet were not included. Data for portables were also excluded.
[2] The number of buildings with both Post-Initial and Annual data.

Table 7. Comparison of Pre-Initial and Annual Data (Hypothesis Tests)[1]					
IAQ Indicator	**n[2]**	**Statistical Test**	**Significance Level**	**Hypotheses**	**Results**
Grab Temperature	12	Paired t-test (right-tailed)	0.05	H_0: $\mu_1 = \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is not greater) H_a: $\mu_1 > \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is greater) μ_1: mean percent of readings within the acceptable range (annual) μ_2: mean percent of readings within the acceptable range (pre-initial)	The test results are statistically significant at the 5% level; the data provide sufficient evidence to conclude that the mean percent of grab temperature readings within the acceptable range at schools approximately one year after they have received an initial IAQ Team visit is greater than the mean percent of grab temperature readings within the acceptable range at schools that have not received an initial visit.
Extended Temperature	10	Paired t-test (right-tailed)	0.05	H_0: $\mu_1 = \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is not greater) H_a: $\mu_1 > \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is greater) μ_1: mean percent of readings within the acceptable range (annual) μ_2: mean percent of readings within the acceptable range (pre-initial)	The test results are statistically significant at the 5% level; the data provide sufficient evidence to conclude that the mean percent of extended temperature readings within the acceptable range at schools approximately one year after they have received an initial IAQ Team visit is greater than the mean percent of extended temperature readings within the acceptable range at schools that have not received an initial visit.
Extended Relative Humidity	12	Paired t-test (left-tailed)	0.05	H_0: $\mu_1 = \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is not greater) H_a: $\mu_1 < \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is greater) μ_1: mean percent of readings within the acceptable range (annual) μ_2: mean percent of readings within the acceptable range (pre-initial)	The test results are not statistically significant at the 5% level; the data do not provide sufficient evidence to conclude that the mean percent of grab relative humidity readings within the acceptable range at schools approximately one year after they have received an initial IAQ Team visit is less than the mean percent of grab relative humidity readings within the acceptable range at schools that have not received an initial visit.

Table 7. Comparison of Pre-Initial and Annual Data (Hypothesis Tests)[1]					
IAQ Indicator	**n[2]**	**Statistical Test**	**Significance Level**	**Hypotheses**	**Results**
Extended Relative Humidity	10	Paired t-test (left-tailed)	0.05	H_0: $\mu_1 = \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is not greater) H_a: $\mu_1 < \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is greater) μ_1: mean percent of readings within the acceptable range (annual) μ_2: mean percent of readings within the acceptable range (pre-initial)	The test results are statistically significant at the 5% level; the data provide sufficient evidence to conclude that the mean percent of extended relative humidity readings within the acceptable range at schools approximately one year after they have received an initial IAQ Team visit is less than the mean percent of extended relative humidity readings within the acceptable range at schools that have not received an initial visit.
Grab CO_2	12	Paired t-test (right-tailed)	0.05	H_0: $\mu_1 = \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is not greater) H_a: $\mu_1 > \mu_2$ (mean percent of readings within the acceptable range approximately one year after the initial visit is greater) μ_1: mean percent of readings within the acceptable range (annual) μ_2: mean percent of readings within the acceptable range (pre-initial)	The test results are not statistically significant at the 5% level; the data do not provide sufficient evidence to conclude that the mean percent of grab CO_2 readings within the acceptable range at schools approximately one year after they have received an initial IAQ Team visit is greater than the mean percent of CO_2 readings within the acceptable range at schools that have not received an initial visit.

[1] Results were calculated using data available November 22, 2002 in the Team Performance spreadsheet. Pre-Initial data were compared with Annual data for the same buildings; data for buildings without both Pre-Initial and Annual data presented in the spreadsheet were not included. Data for portables were also excluded.
[2] The number of buildings with both Pre-Initial and Annual data.

Table 8. Mean Percentages of Acceptable Temperature Readings (Controlled for HVAC Season)[1]								
IAQ Indicator	**Readings Obtained During Same Season**				**Readings Obtained During Opposite Season**			
	n	**Pre-Initial**	**Post-Initial**	**Percent Change**	**n**	**Pre-Initial**	**Post-Initial**	**Percent Change**
Grab Temperature	13[2]	62	68	+6	17[3]	63	78	**+15[6]**
Extended Temperature	13[4]	33	54	+21	15[5]	22	33	**+10[6]**

[1] Percentages were calculated using data available November 22, 2002 in the Team Performance spreadsheet. Percent change was calculated as the mean of the percent changes for each sample school. Pre-Initial data were compared with Post-Initial data for the same buildings; data for buildings without both Pre-Initial and Post-Initial data presented in the spreadsheet were not included. Data for portables were also excluded.
[2] The number of months between Pre-Initial and Post-Initial data collection ranged from 1 to 14 months with a mean of 8.1 months.
[3] The number of months between Pre-Initial and Post-Initial data collection ranged from 1 to 19 months with a mean of 8.4 months.
[4] The number of months between Pre-Initial and Post-Initial data collection ranged from 1 to 14 months with a mean of 8.1 months.
[5] The number of months between Pre-Initial and Post-Initial data collection ranged from 3 to 19 months with a mean of 8.2 months.
[6] Statistically significant change (significance level approximately 0.05).

Table 9. Mean Percentages of Acceptable Relative Humidity Readings (Controlled for HVAC Season)[1]								
IAQ Indicator	**Readings Obtained During Same Season**				**Readings Obtained During Opposite Season**			
	n	**Pre-Initial**	**Post-Initial**	**Percent Change**	**n**	**Pre-Initial**	**Post-Initial**	**Percent Change**
Grab Relative Humidity	9[2]	84	78	-5	15[3]	87	84	-2
Extended Relative Humidity	13[4]	82	86	-5	15[5]	70	81	+12

[1] Percentages were calculated using data available November 22, 2002 in the Team Performance spreadsheet. Percent change was calculated as the mean of the percent changes for each sample school. Pre-Initial data were compared with Post-Initial data for the same buildings; data for buildings without both Pre-Initial and Post-Initial data presented in the spreadsheet were not included. Data for portables were also excluded.
[2] The number of months between Pre-Initial and Post-Initial data collection ranged from 1 to 14 months with a mean of 8.9 months.
[3] The number of months between Pre-Initial and Post-Initial data collection ranged from 3 to 19 months with a mean of 9.2 months.
[4] The number of months between Pre-Initial and Post-Initial data collection ranged from 1 to 14 months with a mean of 8.1 months.
[5] The number of months between Pre-Initial and Post-Initial data collection ranged from 3 to 19 months with a mean of 8.2 months.

Table 10. Mean Percentages of Acceptable Carbon Dioxide Readings (Controlled for HVAC Season)[1]								
IAQ Indicator	Readings Obtained During Same Season				Readings Obtained During Opposite Season			
	n	Pre-Initial	Post-Initial	Percent Change	n	Pre-Initial	Post-Initial	Percent Change
Grab CO_2	13[2]	66	78	+11	17[3]	68	69	+6

[1] Percentages were calculated using data available November 22, 2002 in the Team Performance spreadsheet. Percent change was calculated as the mean of the percent changes for each sample school. Pre-Initial data were compared with Post-Initial data for the same buildings; data for buildings without both Pre-Initial and Post-Initial data presented in the spreadsheet were not included. Data for portables were also excluded.
[2] The number of months between Pre-Initial and Post-Initial data collection ranged from 1 to 14 months with a mean of 8.1 months.
[3] The number of months between Pre-Initial and Post-Initial data collection ranged from 3 to 19 months with a mean of 9.1 months.

Table 11. Mean Percentages of Acceptable Temperature Readings (Controlled for HVAC Season)[1]								
IAQ Indicator	Readings Obtained During Same Season				Readings Obtained During Opposite Season			
	n	Post-Initial	Annual	Percent Change	n	Post-Initial	Annual	Percent Change
Grab Temperature	5[2]	69	70	+1	7[3]	67	71	+4
Extended Temperature	3[4]	10	88	**+78**[6]	7[5]	44	43	-1

[1] Percentages were calculated using data available November 22, 2002 in the Team Performance spreadsheet. Percent change was calculated as the mean of the percent changes for each sample school. Post-Initial data were compared with Annual data for the same buildings; data for buildings without both Post-Initial and Annual data presented in the spreadsheet were not included. Data for portables were also excluded.
[2] The number of months between Pre-Initial and Post-Initial data collection ranged from 13 to 25 months with a mean of 17.6 months.
[3] The number of months between Pre-Initial and Post-Initial data collection ranged from 4 to 20 months with a mean of 12.7 months.
[4] The number of months between Pre-Initial and Post-Initial data collection ranged from 13 to 25 months with a mean of 20.7 months.
[5] The number of months between Pre-Initial and Post-Initial data collection ranged from 4 to 20 months with a mean of 12.7 months.
[6] Statistically significant change (significance level approximately 0.05).

Table 12. Mean Percentages of Acceptable Relative Humidity Readings (Controlled for HVAC Season)[1]								
IAQ Indicator	**Readings Obtained During Same Season**				**Readings Obtained During Opposite Season**			
	n	**Post-Initial**	**Annual**	**Percent Change**	**n**	**Post-Initial**	**Annual**	**Percent Change**
Grab Relative Humidity	5[2]	94	87	**-7**[6]	7[3]	80	59	-21
Extended Relative Humidity	3[4]	40	38	+2[7]	7[5]	100	28	**-72**[6]

[1] Percentages were calculated using data available November 22, 2002 in the Team Performance spreadsheet. Percent change was calculated as the mean of the percent changes for each sample school. Post-Initial data were compared with Annual data for the same buildings; data for buildings without both Post-Initial and Annual data presented in the spreadsheet were not included. Data for portables were also excluded.
[2] The number of months between Pre-Initial and Post-Initial data collection ranged from 13 to 25 months with a mean of 17.6 months.
[3] The number of months between Pre-Initial and Post-Initial data collection ranged from 4 to 20 months with a mean of 12.7 months.
[4] The number of months between Pre-Initial and Post-Initial data collection ranged from 13 to 25 months with a mean of 20.7 months.
[5] The number of months between Pre-Initial and Post-Initial data collection ranged from 4 to 20 months with a mean of 12.7 months.
[6] Statistically significant change (significance level approximately 0.05).
[7] Not enough sample readings to perform a statistical test for significance.

Table 13. Mean Percentages of Acceptable Carbon Dioxide Readings (Controlled for HVAC Season)[1]								
IAQ Indicator	**Readings Obtained During Same Season**				**Readings Obtained During Opposite Season**			
	n	**Post-Initial**	**Annual**	**Percent Change**	**n**	**Post-Initial**	**Annual**	**Percent Change**
Grab CO_2	5[2]	85	71	-14	7[3]	75	73	-2

[1] Percentages were calculated using data available November 22, 2002 in the Team Performance spreadsheet. Percent change was calculated as the mean of the percent changes for each sample school. Post-Initial data were compared with Annual data for the same buildings; data for buildings without both Post-Initial and Annual data presented in the spreadsheet were not included. Data for portables were also excluded.
[2] The number of months between Pre-Initial and Post-Initial data collection ranged from 13 to 25 months with a mean of 17.6 months.
[3] The number of months between Pre-Initial and Post-Initial data collection ranged from 4 to 20 months with a mean of 12.7 months.

A.2 Program Implementation Rate

Table 14. BMPs Delivered Per Fiscal Quarter; Associated Worker-Days for On-Site PM Work and Special IAQ Projects; and Available Team Members

Fiscal Quarter (FQ)	BMP Completion Period[1]	BMP Deliveries Per Fiscal Quarter[2]			Worker-Days Corresponding to BMP Deliveries[4]					Available Team Members Per Month (HVAC Mechanics and IAQ Supervisors)[8]
		Initial BMPs	Annual BMPs	Total Equivalent BMPs[3]	BMP-Related On-Site Worker-Days[5]			Special IAQ Projects[6]	Total Worker-Days[7]	
					Initial Visits	Annual Visits	Total			
Fourth Quarter ’00	12/14/99 – 05/03/00	6	--	**6**	349.0	--	**349.0**	--	**349.0**	6 – 8 (2 – 4)
First Quarter ’01	12/16/99 – 06/28/00	6	--	**6**	329.3	--	**329.3**	--	**329.3**	6 – 8 (2 – 4)
Second Quarter ’01	02/03/00 – 09/22/00	5	--	**5**	334.3	--	**334.3**	--	**334.3**	8 (2 – 4)
Third Quarter ’01[9]	03/23/00 – 01/14/01	7	--	**7**	592.2	--	**592.2**	14.8	**607.0**	8 – 9 (4 – 5)
Fourth Quarter ’01	12/04/00 – 02/22/01	1	--	**1**	110.0	--	**110.0**	3.3	**113.3**	8 – 9 (4 – 5)
First Quarter ’02	01/16/01 – 06/29/01	4	--	**4**	567.8	--	**567.8**	14.3	**582.1**	8 (4 – 5)
Second Quarter ’02	07/16/01 – 01/28/02	2	2	**3**	160.8	74.0	**234.8**	47.1	**281.9**	7 – 10 (3 – 4)
Third Quarter ’02	06/04/01 – 01/31/02	1	5	**3.5**	166.0	238.3	**404.3**	47.1	**451.4**	7 – 10 (3 – 4)
Fourth Quarter ’02	11/01/01 – 03/18/02	1	2	**2**	138.3	91.0	**229.3**	41.1	**270.4**	7 – 10 (4)
First Quarter ’03	04/09/02 – 06/14/02	1	0	**1**	218.0	0.0	**218.0**	131.5	**349.5**	9 – 10 (3 – 4)
Second Quarter ’03	07/16/02 – 09/25/02	1	3	**2.5**	117.0	208.0	**325.0**	81.4	**406.4**	10 (4)
Total	--	**35**	**12**	**41**	**3,082.7**	**611.3**	**3,694.0**	**380.6**	**4,074.6**	--
Mean Per FQ	--	**3.2**	**2.4**[10]	**3.7**	--	--	--	--	--	--

[1] The period of time during which on-site PM work was completed for BMPs delivered during corresponding fiscal quarters (e.g., on-site work was conducted between 12/14/99 and 05/03/00 for the six BMPs delivered during the fourth quarter of FY 2000). As indicated in the table, considerable overlap between successive periods is common.
[2] The number of BMPs delivered during each fiscal quarter. The first initial BMP was delivered in June 2000; the first annual BMP was delivered in November 2001.
[3] Equivalent BMPs represent the number of BMPs equivalent to initial BMPs. Since annual visits typically require less time to complete, annual BMPs are considered equivalent to 0.5 initial BMPs each. As a result, each initial BMP is considered one equivalent BMP, and each annual BMP is considered 0.5 equivalent BMPs.
[4] Worker-days used to complete on-site PM work for initial and annual BMPs, and worker-days used for special projects during corresponding BMP completion periods.
[5] The number of worker-days used to complete on-site PM work for corresponding BMPs (e.g., 117 on-site worker-days were used to complete the initial BMP delivered during the second quarter of FY 2003, and 208 on-site worker-days were used to complete the three annual BMPs delivered during the same quarter).
[6] The number of worker-days spent by team members on special projects during corresponding BMP completion periods. In calculating worker-days for overlapping periods, the number of worker-days for each month of overlap was divided by the number of periods to determine worker-days for the periods during the month.
[7] The total number of worker-days spent on BMP-related PM work and special projects for each BMP completion period.
[8] The number of team members (and the number of HVAC Mechanics and IAQ Supervisors) who worked per month during corresponding BMP completion periods.
[9] The last BMP delivered during this quarter and all initial BMPs delivered after this quarter are associated with a revised SOP (involving more extensive work and longer visit durations) for initial visits.
[10] Calculated for the five fiscal quarters since the team started delivering annual BMPs.

A.3 PM Team Efficiency

Table 15. On-Site Worker-Days and Building Conditions Associated With Team Visits						
Site Visit Type	**n**	**Mean Worker-Days**[1]	**Mean Effective Building Age (Years)**[2]	**Mean Building Size (Square Feet)**	**Mean Student Enrollment**	**Mean Percent Building Capacity**[3]
Initial	37	89.8 (14.5-220.5)[4]	21 (5-35)[5]	76,617 (35,131-226,901)[5]	631 (294-1,647)[5]	92 (60-117)[5]
Annual	13	54.7 (25.0-101.0)	21 (6-31)[6]	87,304 (41,175-226,901)[6]	792 (484-1,872)[6]	105 (78-126)[6]
All	50	80.7 (14.5-220.5)	21 (5-35)[7]	79,289 (35,131-226,901)[7]	671 (294-1,872)[7]	95 (60-126)[7]

[1] The data represent conditions at buildings during team site visits. Mean worker-days were calculated from the number of on-site worker-days for each site visit. On-site worker-days were calculated based on the number of team members that worked at each building and the number of days they spent at the building.
[2] Effective building age was calculated as the number of years from the building construction date to the date of the initial visit. For buildings that were modernized, the effective age was calculated as the number of years from the modernization date to the date of the initial visit.
[3] Percent building capacity was calculated using MCPS Department of Planning and Capital Programming data presented in initial BMPs.
[4] Mean (Range).
[5] Calculated using available data for 36 facilities.
[6] Calculated using available data for 12 facilities.
[7] Calculated using available data for 48 facilities.

Table 16. On-Site Worker-Days and Numbers of Ventilation Units Serviced During Team Visits[1]				
Site Visit Type	**n**	**Mean Worker-Days[2]**	**Mean Gross Units[3]**	**Mean Weighted Units[4]**
Initial	37	89.8 (14.5-220.5)[5]	76.5 (33-179)[6]	172.9 (14.8-425.0)[6]
Annual	13	54.7 (25.0-101.0)	88.3 (6.0-205.0)[7]	158.9 (12.0-380.0)[7]
All	50	80.7 (14.5-220.5)	78.4 (6.0-205.0)[8]	170.5 (12.0-425.0)[8]

[1] Ventilation units include air-handling units, unit ventilators (wall and ceiling-mounted), baseboard/floor heaters, exhaust fans, heat pumps, variable air volume boxes, portable air-conditioning units, condensers, and air stations.
[2] Mean worker-days were calculated from the number of on-site worker-days for each site visit. On-site worker-days were calculated based on the number of team members that worked at each building and the number of days they spent at the building. Data were excluded for one initial visit to a school with newly installed ventilation equipment because the team did not perform typical, extensive PM procedures.
[3] Mean gross units represents the average number of total ventilation units serviced by the team.
[4] Mean weighted units represents the average number of total weighted ventilation units serviced by the team. Weighted units are calculated by multiplying the numbers of different units by weighting factors (0.25-3). Weighting factors were generated based on consistent observations of variations in the amounts of time required to service different types of units.
[5] Mean (Range).
[6] Calculated using available data for 35 facilities.
[7] Calculated using available data for seven facilities.
[8] Calculated using available data for 42 facilities.

Table 17. Correlation Between On-Site Worker-Days and Building Conditions (Initial Visits)			
Building Condition	**n[1]**	**R Value**	**P-value**
Gross Ventilation Units[2]	33	**0.331**[4]	0.030
Weighted Ventilation Units[3]	33	0.276	0.060
Gross Ventilation Units (outliers excluded)[5]	*27*	***0.567***[4]	*0.0010*
Weighted Ventilation Units (outliers excluded)[5]	*27*	***0.622***[4]	*0.00018*
Effective Age	36	0.134	0.22
Size	36	0.191	>0.05
Percent Capacity	36	-0.112	0.26

[1] The number of schools with available data used for the calculation (data for two atypical site visits, which did not involve PM work, were excluded).
[2] The total number of HVAC units.
[3] The sum of the number of HVAC units multiplied by their corresponding weighted values.
[4] Statistically significant positive correlation (significance level 0.05).
[5] Calculations based on data with 6 additional outliers excluded.

Table 18. Correlation Between On-Site Worker-Days and Building Conditions (Annual Visits)			
Building Condition	**n[1]**	**R Value**	**P-value**
Gross Ventilation Units[2]	7	0.324	>0.05
Weighted Ventilation Units[3]	7	0.393	>0.05
Effective Age	12	-0.078	0.40
Size	12	0.301	0.17
Percent Capacity	12	-0.127	0.35

[1] The number of schools with available data used for the calculation.
[2] The total number of HVAC units.
[3] The sum of the number of HVAC units multiplied by their corresponding weighted values.

A.4 Customer Satisfaction

Table 19. Questionnaire Response Rate (Building Staff)[1]							
Pre-Initial[2]		Post-Initial		Annual		Total[3]	
n[4]	Mean Percent Response Rate (Range)	n	Mean Percent Response Rate (Range)	n	Mean Percent Response Rate (Range)	n[7]	Mean Percent Response Rate (Range)
13	50 (19-96)	26	36[5] (11-57)	10	24[6] (1-55)	49	37 (1-96)

[1] Response rate was calculated as the percent of total building staff that returned completed questionnaires to the IAQ Team. Mean response rates were calculated using the response rates for individual schools. All available data for each site visit type were included. Questionnaire response data were available for 32 buildings; however, Pre, Post, and Annual data were not available for all buildings. Data for staff members working primarily in portables were not included.
[2] Pre-Initial questionnaires were distributed to school staff at the start of initial visits before team activities commenced; Post-Initial questionnaires were distributed during follow-up visits after initial team activities concluded; Annual questionnaires were distributed at the start of annual visits before annual team activities began. Questionnaire data for combined follow-up and annual visits (labeled 'post/annual' in the Team Performance spreadsheet) were categorized as Post-Initial data.
[3] Mean response rate for all site visits.
[4] Number of schools with available data.
[5] Of the 13 schools with available Pre-Initial and Post-Initial data, 9 (69%) schools showed a decreased response rate for the Post-Initial questionnaire.
[6] Of the 5 schools with available Post-Initial and Annual data, 3 (60%) schools showed a decreased response rate for the Annual questionnaire.
[7] The total number of response rate data points: response rate data for multiple site visits were available for certain schools.

Table 20. Mean Percentages of Staff Submitting Negative Questionnaire Responses[1, 2]						
Question Category	**Pre-Initial[3]**		**Post-Initial**		**Annual**	
	n	**Mean Percent (Range)**	**n**	**Mean Percent (Range)**	**n**	**Mean Percent (Range)**
Temperature ("too hot" or "too cold")	30	22 (2-85)	29	17 (0-34)	10	14 (2-22)
Relative Humidity ("too dry" or "too humid")	30	8 (0-30)	30	9 (0-28)	10	8 (1-23)
Carbon Dioxide ("too stuffy")	30	14 (1-36)	30	9 (0-26)	10	9 (4-19)
Settled Dust ("too dusty")	30	14 (1-41)	30	12 (0-31)	10	12 (3-30)

[1] Mean percentages were calculated using data available November 22, 2002 in the Team Performance spreadsheet. Percentages indicate the percent of building staff that submitted negative questionnaire responses related to temperature or humidity conditions. Dissatisfaction with temperature conditions was evaluated with questions asking if staff members felt their primary indoor work environments were "too hot" or "too cold" during the previous month. Dissatisfaction with humidity conditions was evaluated with questions asking if staff members felt their primary indoor work environments were "too dry" or "too humid". Possible responses to these questions were "never", "rare", "sometimes", "often", and "always". Questionnaire responses of "often" or "always" were considered negative responses. Mean percentages were calculated using the number of returned questionnaires containing negative responses and the total numbers of staff members per building. All available data for each question category and site visit type were included. Questionnaire response data were available for staff members working in 32 buildings; however, Pre, Post, and Annual data were not available for all buildings. Data for staff members working primarily in portables were not included.

[2] Questionnaire responses indicating that conditions occurred "often" or "always" over the month prior to receiving the questionnaire were considered negative responses.

[3] Pre-Initial data were collected at the start of initial visits before team activities commenced; Post-Initial data were collected during follow-up visits after initial team activities concluded; Annual data were collected at the start of annual visits before annual team activities began. Data for combined follow-up and annual visits (labeled 'post/annual' in the Team Performance spreadsheet) were categorized as Post-Initial data.

Table 21. Percentages of Schools With Greater Than 20 Percent of Staff Submitting Negative Questionnaire Responses[1, 2]						
Question Category	**Pre-Initial[3]**		**Post-Initial**		**Annual**	
	n	**Percent**	**n**	**Percent)**	**n**	**Percent**
Temperature (“too hot” or “too cold”)	30	40	29	45	10	20
Relative Humidity (“too dry” or “too humid”)	30	13	30	13	10	10
Carbon Dioxide (“too stuffy”)	30	23	30	10	10	0
Settled Dust (“too dusty”)	30	23	30	17	10	20

[1] Mean percentages were calculated using data available November 22, 2002 in the Team Performance spreadsheet. Percentages indicate the percent of building staff that submitted negative questionnaire responses related to temperature or humidity conditions. Dissatisfaction with temperature conditions was evaluated with questions asking if staff members felt their primary indoor work environments were “too hot” or “too cold” during the previous month. Dissatisfaction with humidity conditions was evaluated with questions asking if staff members felt their primary indoor work environments were “too dry” or “too humid”. Possible responses to these questions were “never”, “rare”, “sometimes”, “often”, and “always”. Questionnaire responses of “often” or “always” were considered negative responses. Mean percentages were calculated using the number of returned questionnaires containing negative responses and the total numbers of staff members per building. All available data for each question category and site visit type were included. Questionnaire response data were available for staff members working in 32 buildings; however, Pre, Post, and Annual data were not available for all buildings. Data for staff members working primarily in portables were not included.

[2] Questionnaire responses indicating that conditions occurred “often” or “always” over the month prior to receiving the questionnaire were considered negative responses.

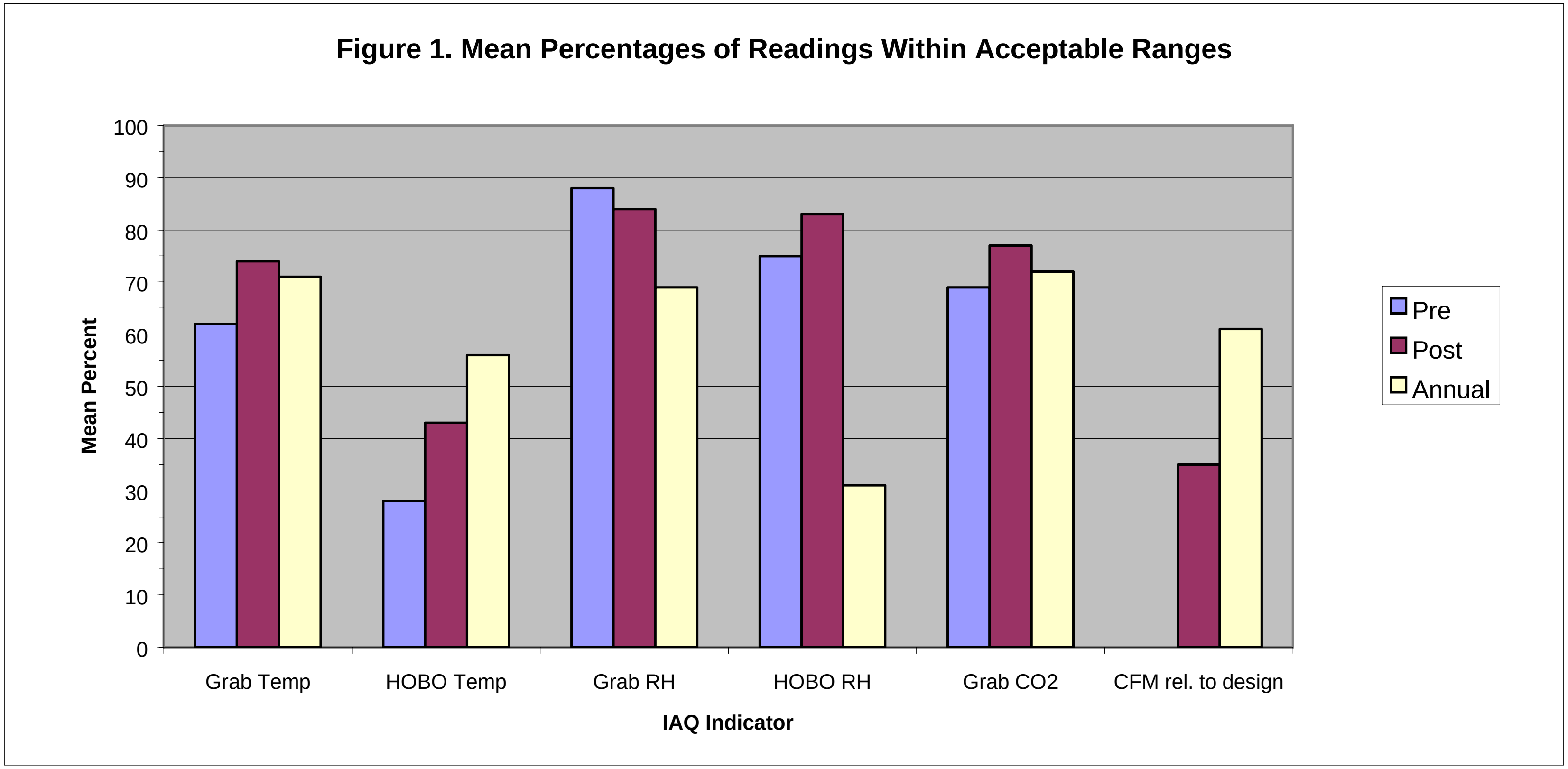
[3] Pre-Initial data were collected at the start of initial visits before team activities commenced; Post-Initial data were collected during follow-up visits after initial team activities concluded; Annual data were collected at the start of annual visits before annual team activities began. Data for combined follow-up and annual visits (labeled ‘post/annual’ in the Team Performance spreadsheet) were categorized as Post-Initial data.

Table 22. Mean Percent Change of Staff Submitting Negative Questionnaire Responses [1, 2]						
IAQ Indicator	**Pre-Initial/Post-Initial[2]**		**Post-Initial/Annual**		**Pre-Initial/Annual**	
	n[3]	**Mean Percent Change[4]**	**n**	**Mean Percent Change**	**n**	**Mean Percent Change**
Temperature	27	-4	10	+4	10	**+6**[5]
Relative Humidity	28	+2	10	+2	10	**+6**[5]
Carbon Dioxide	28	**-5**[6]	10	+1	10	-3
Settled Dust	28	-2	10	+3	10	+1

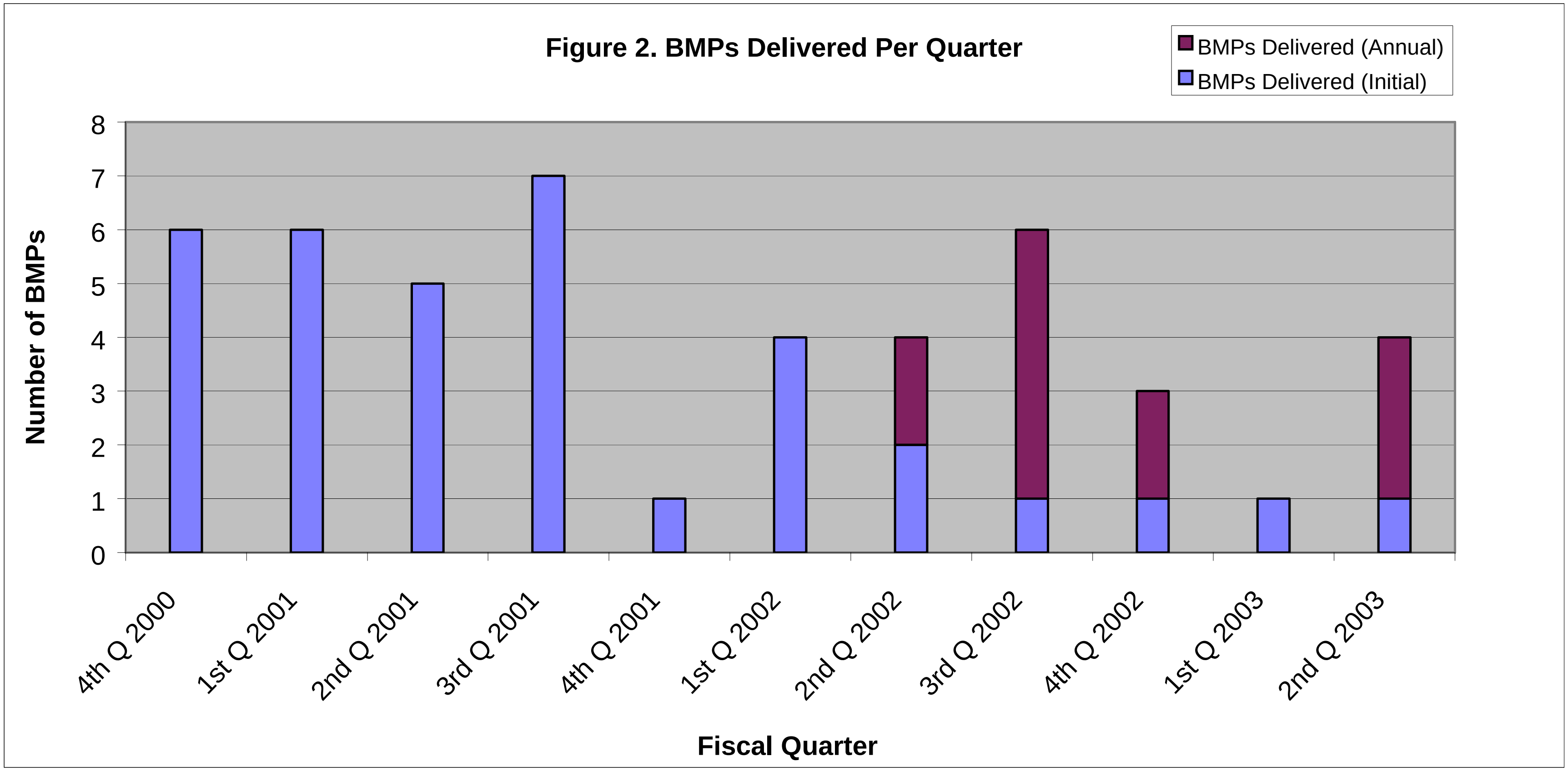
[1] Percent changes were calculated as the difference between the percents of staff submitting negative questionnaire responses during different visits at each school. Means were calculated from the percent changes for individual schools. Questionnaire responses submitted by staff working primarily in portables were not included.
[2] The percents of staff submitting negative questionnaire responses during initial visits and follow-up visits were calculated for each school with available Pre-Initial and Post-Initial questionnaire data. For each school, the percent change was calculated by subtracting the Pre-Initial percent from the Post-Initial percent. Means were then calculated for the percent changes associated with each IAQ indicator.
[3] The number of schools with available Pre-Initial and Post-Initial questionnaire response data.
[4] A plus sign (+) indicates a mean increase in percent of staff submitting negative questionnaire responses; a minus sign (-) indicates a mean decrease in percent of staff submitting negative questionnaire responses.
[5] A Wilcoxon paired-sample signed-rank test (significance level 0.049) indicates a statistically significant increase in negative questionnaire responses.
[6] A Paired z-test (significance level 0.05) indicates a statistically significant decrease in negative questionnaire responses.

APPENDIX B. Figures

B.1 PM Team Effectiveness



B.2 Program Implementation Rate



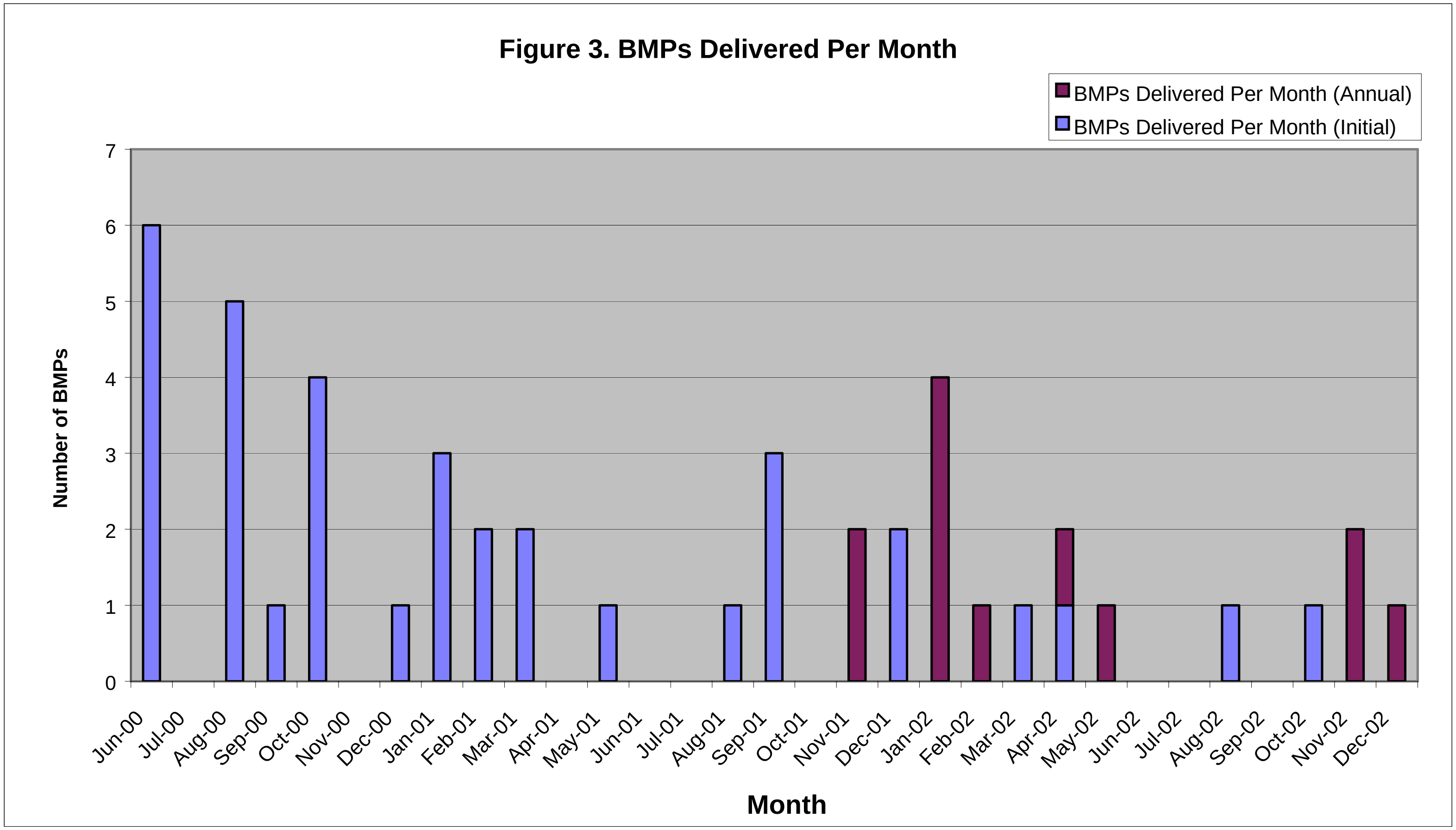
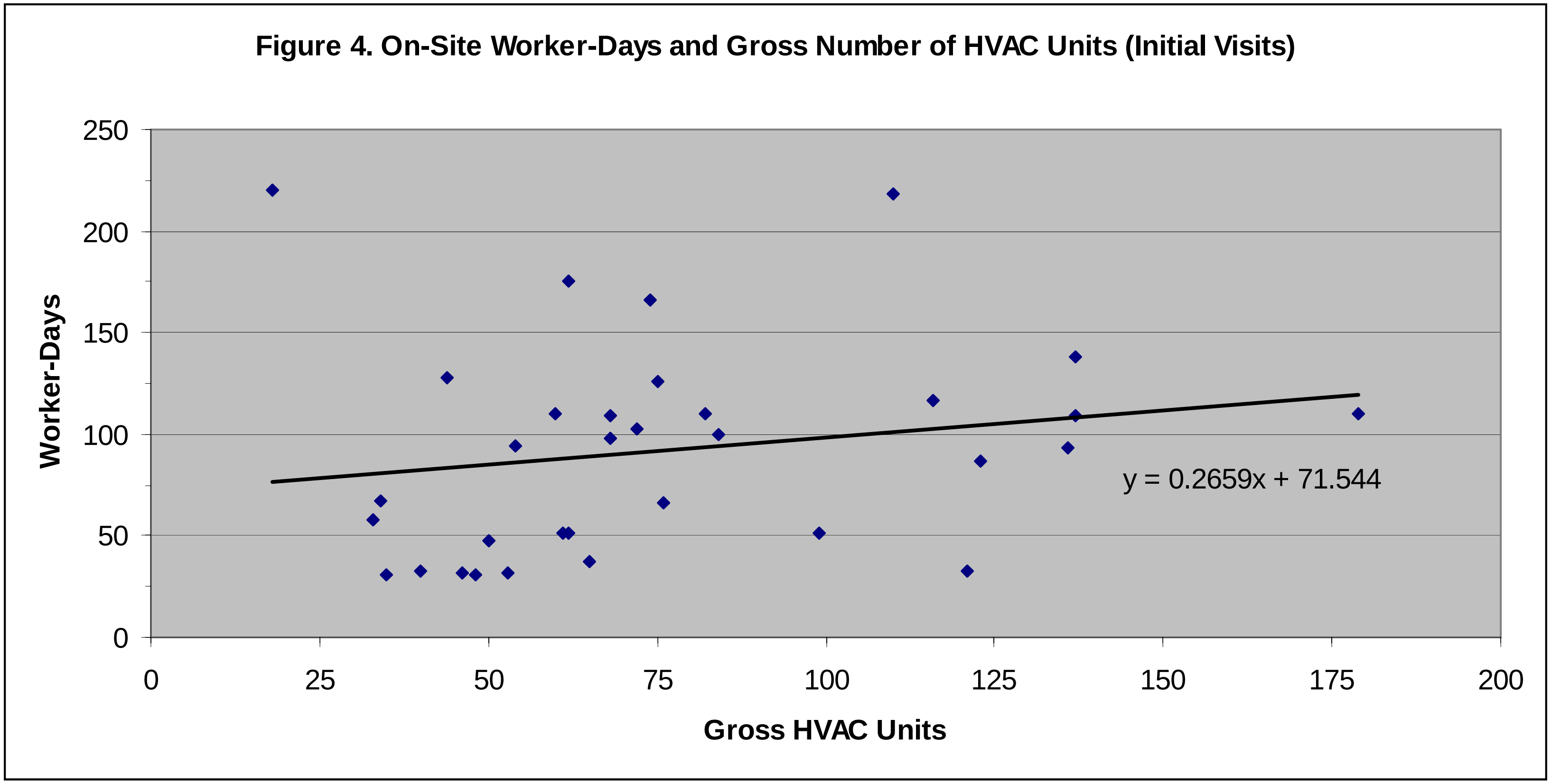


Figure 3. BMPs Delivered Per Month
BMPs Delivered Per Month (Annual)
BMPs Delivered Per Month (Initial)
Number of BMPs
0
1
2
3
4
5
6
7
Jun-00
Jul-00
Aug-00
Sep-00
Oct-00
Nov-00
Dec-00
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
Jan-02
Feb-02
Mar-02
Apr-02
May-02
Jun-02
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Month

B.3 PM Team Efficiency



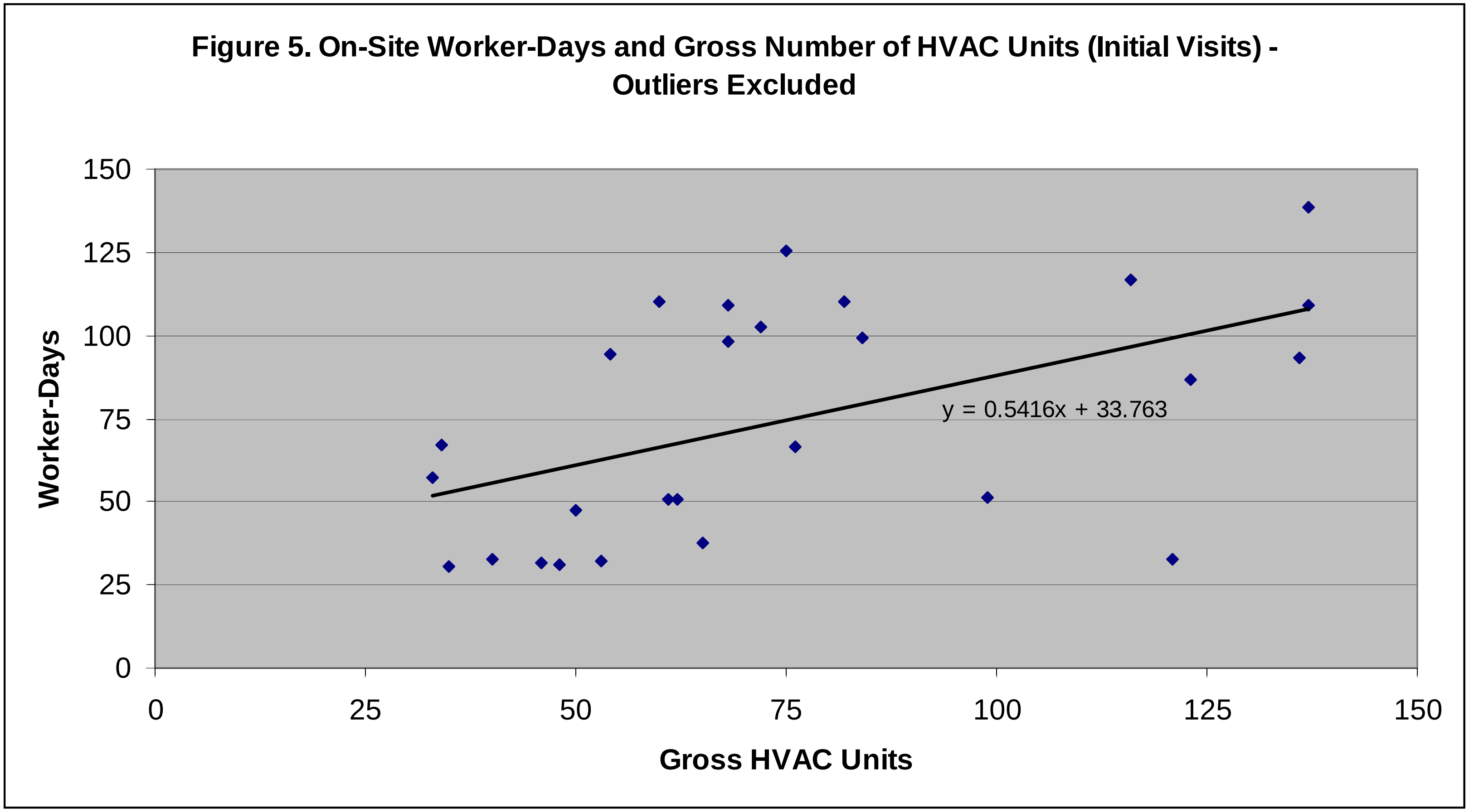


Figure 5. On-Site Worker-Days and Gross Number of HVAC Units (Initial Visits) - Outliers Excluded
150
125
100
75
50
25
0
Worker-Days
y = 0.5416x + 33.763
0
25
50
75
100
125
150
Gross HVAC Units

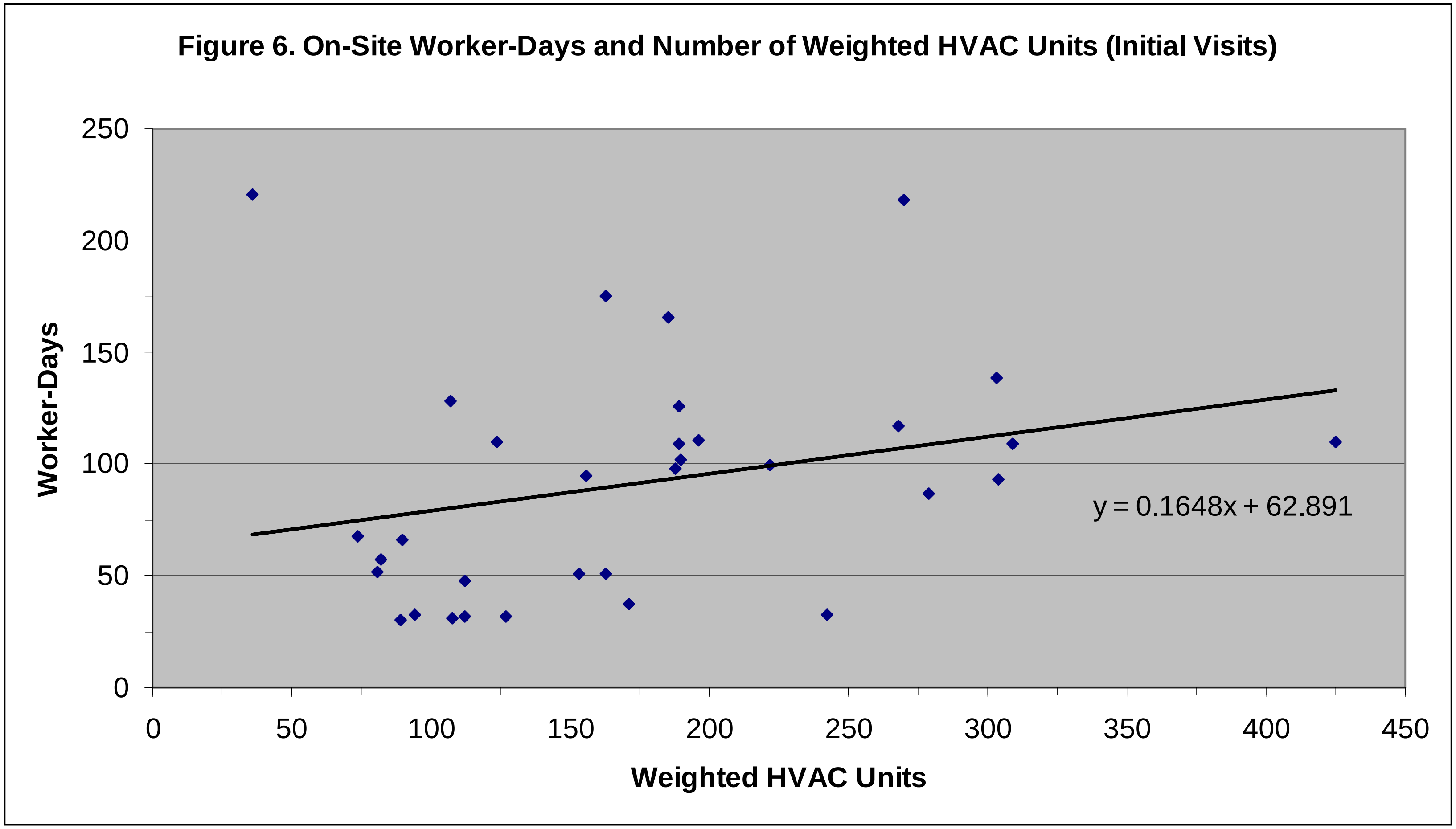


Figure 6. On-Site Worker-Days and Number of Weighted HVAC Units (Initial Visits)
250
200
150
100
50
0
Worker-Days
0
50
100
150
200
250
300
350
400
450
Weighted HVAC Units
y = 0.1648x + 62.891

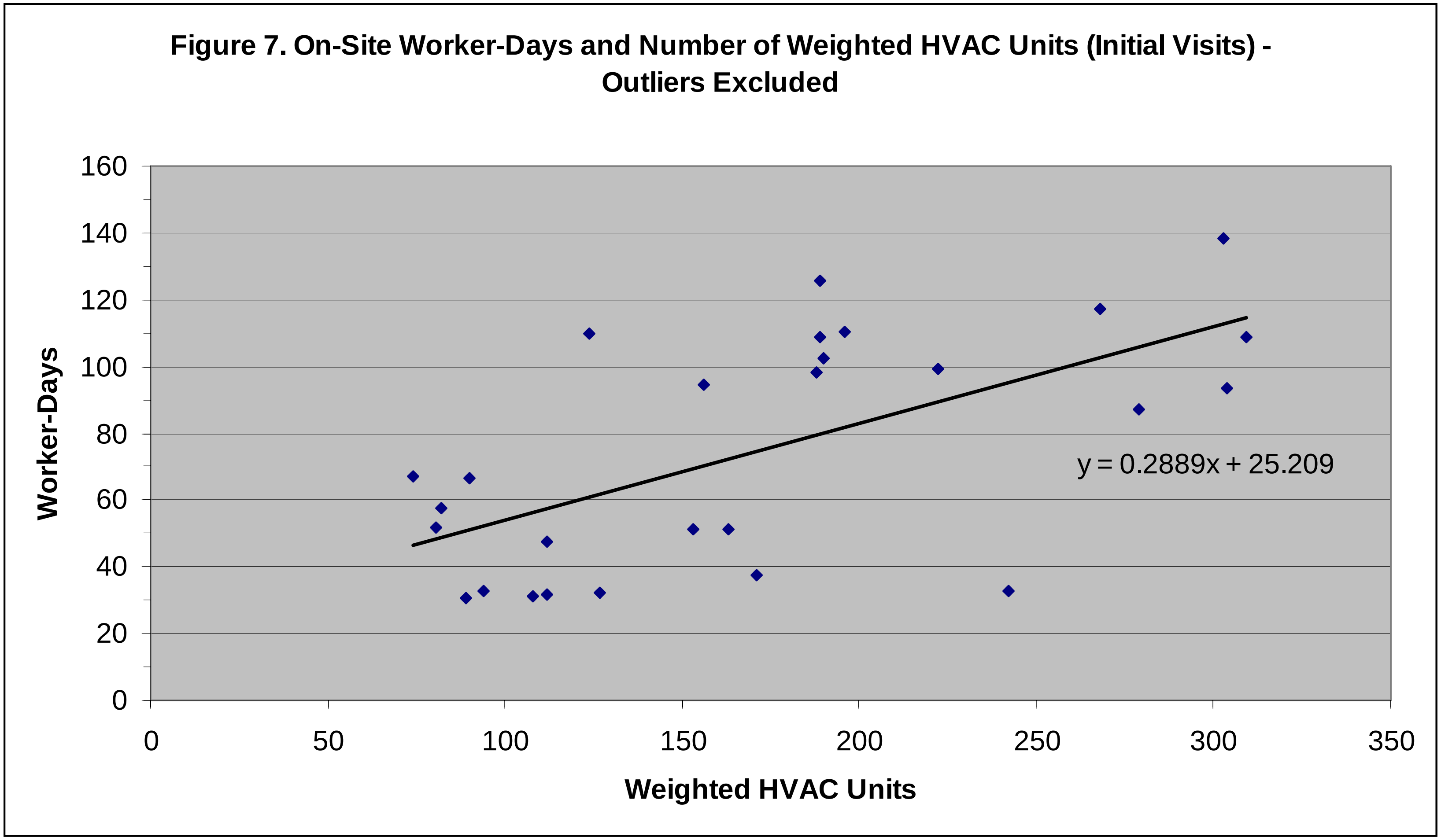


Figure 7. On-Site Worker-Days and Number of Weighted HVAC Units (Initial Visits) - Outliers Excluded
160
140
120
100
80
60
40
20
0
Worker-Days
y = 0.2889x + 25.209
0
50
100
150
200
250
300
350
Weighted HVAC Units

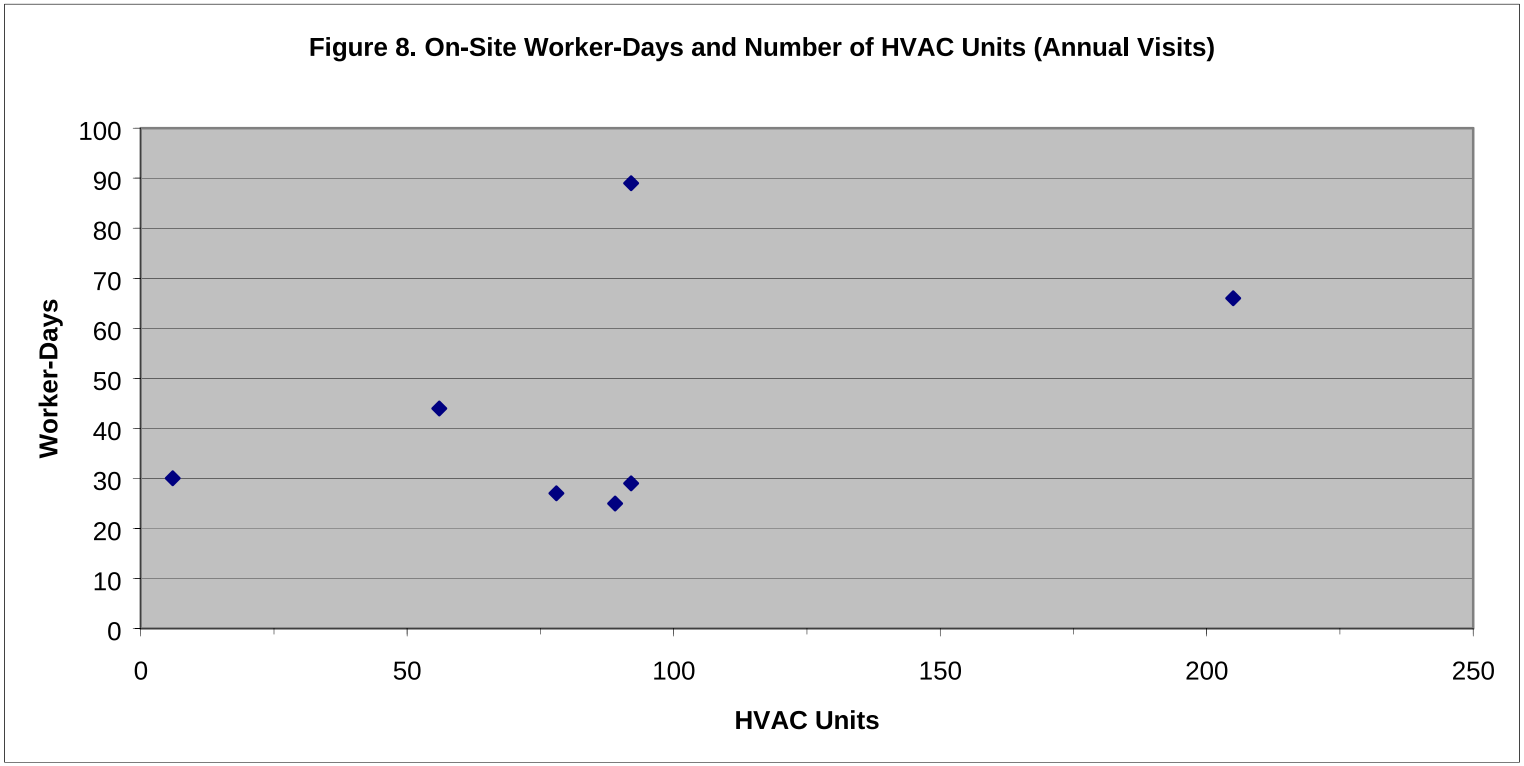


Figure 8. On-Site Worker-Days and Number of HVAC Units (Annual Visits)
Worker-Days
100
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
HVAC Units

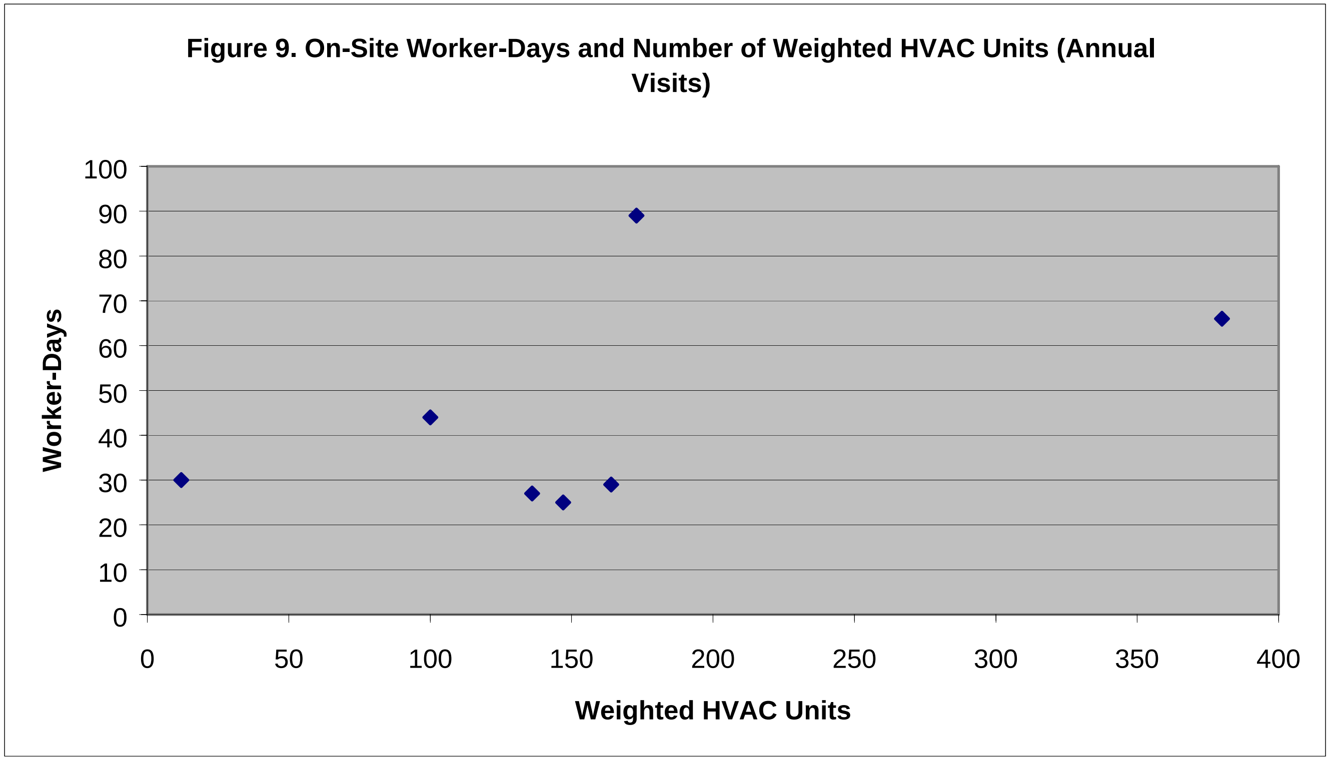


Figure 9. On-Site Worker-Days and Number of Weighted HVAC Units (Annual Visits)
Worker-Days
100
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
Weighted HVAC Units

Figure 10. On-Site Worker-Days and Building Age (Initial Visits)

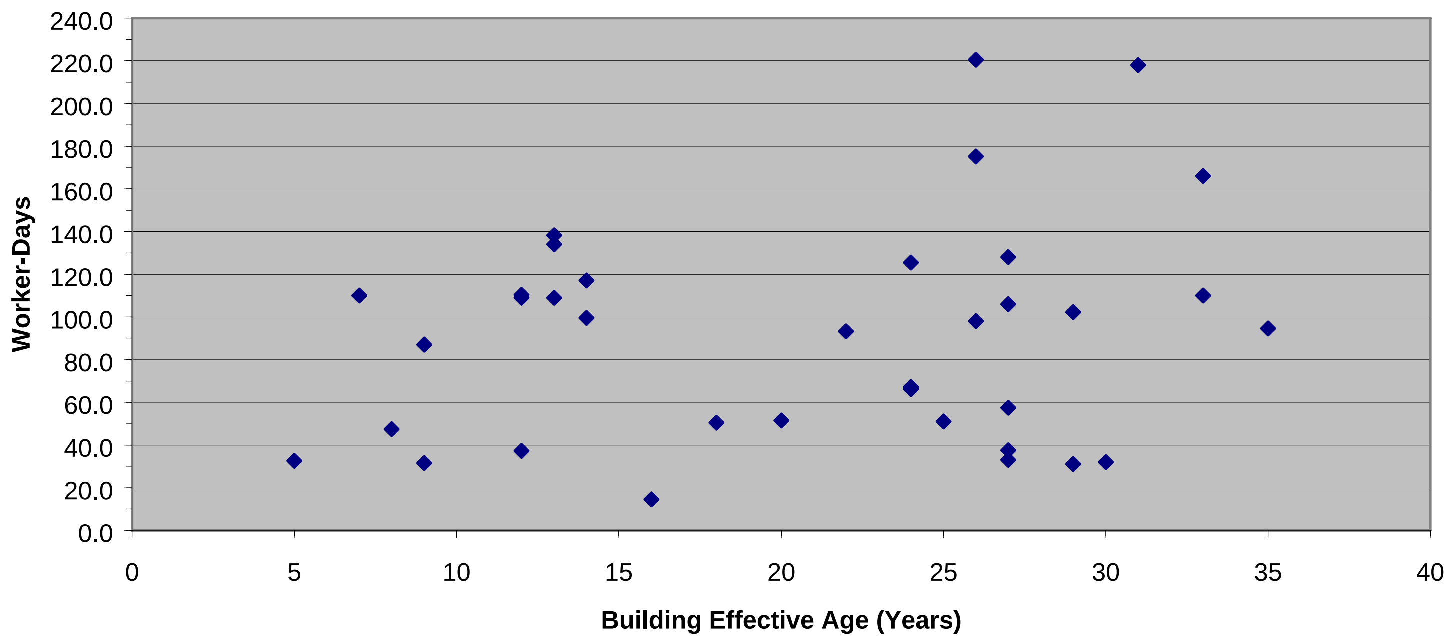


Figure 11. On-Site Worker-Days and Building Size (Initial Visits)

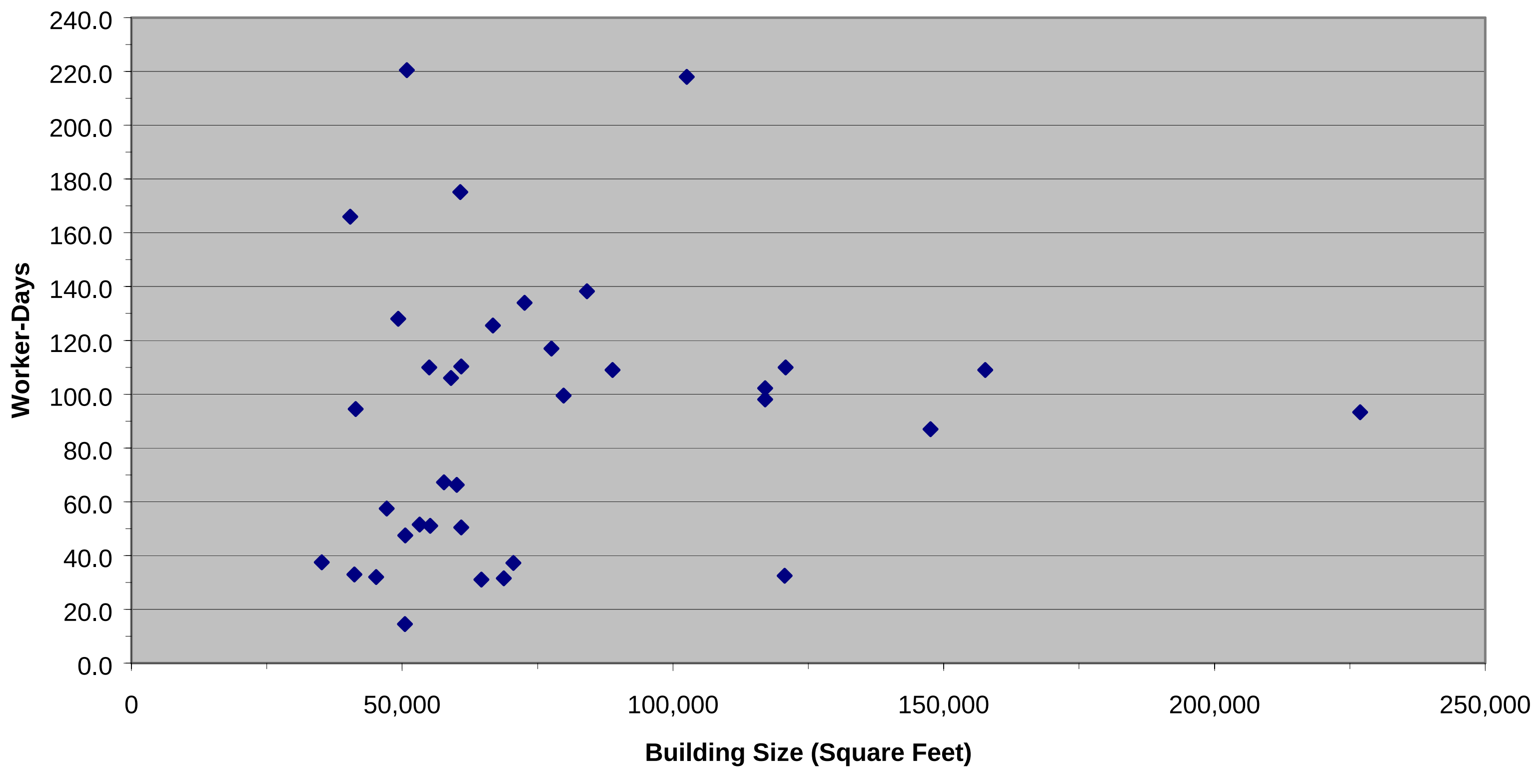
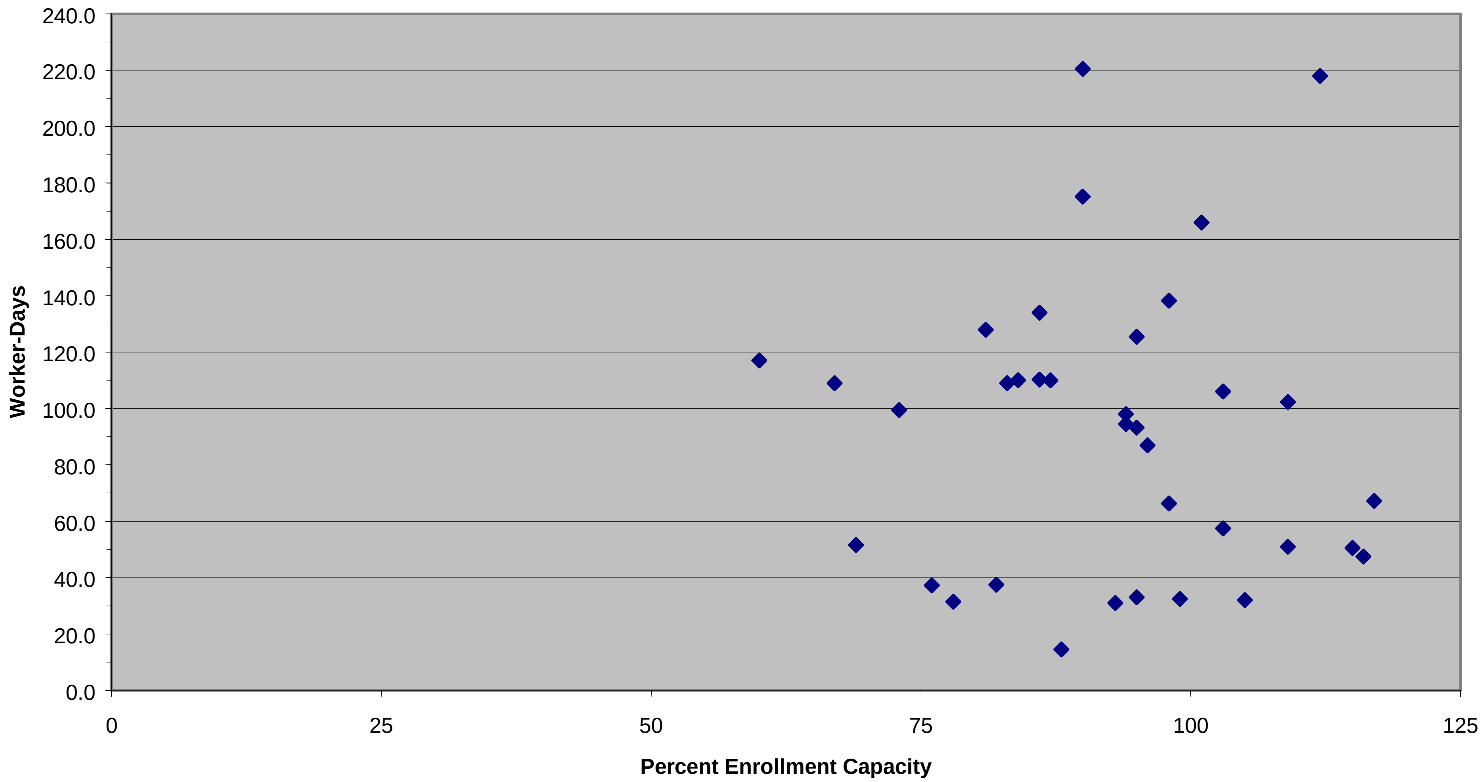


Figure 12. On-Site Worker-Days and Percent Enrollment Capacity (Initial Visits)



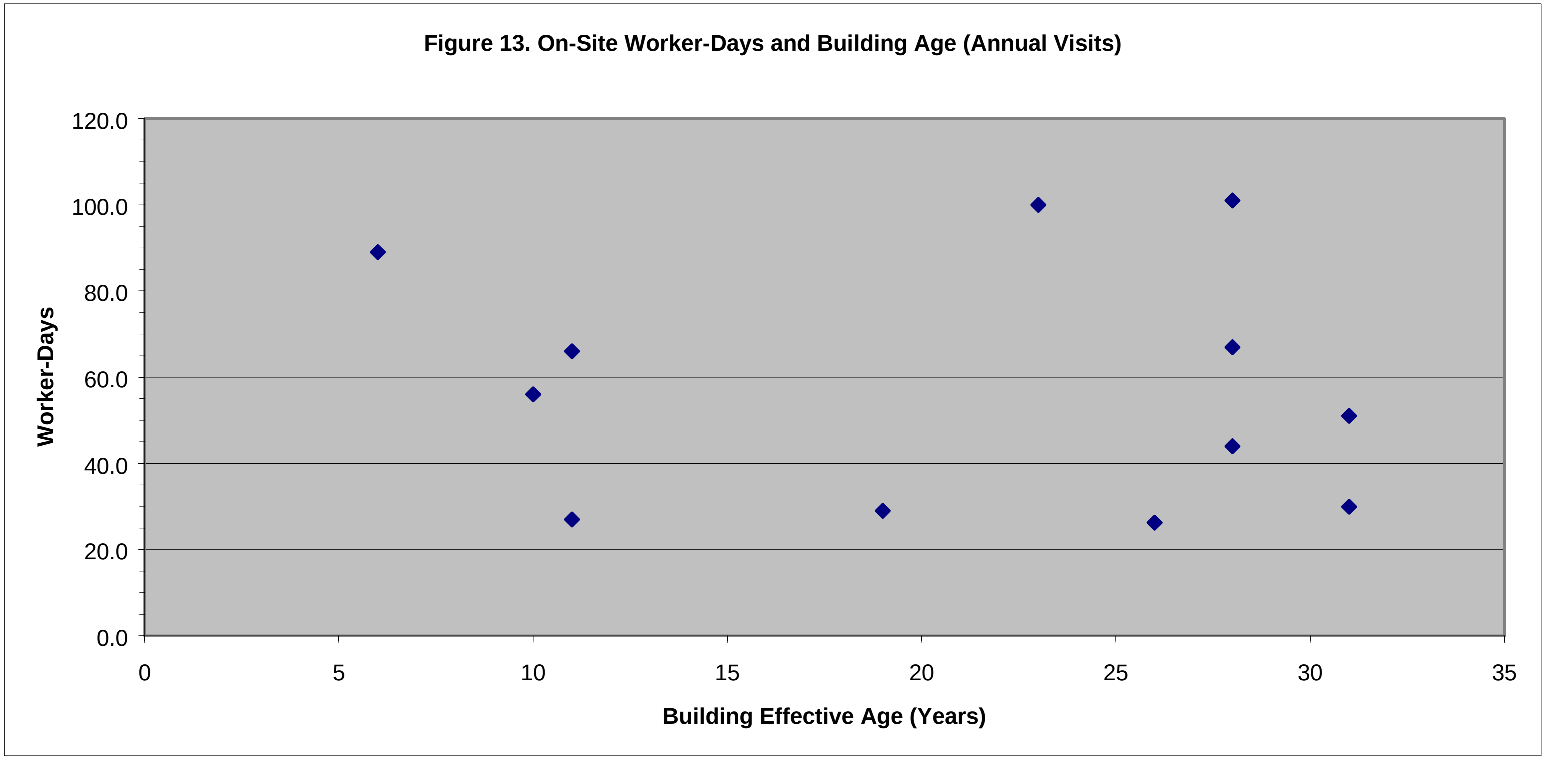


Figure 13. On-Site Worker-Days and Building Age (Annual Visits)
Worker-Days
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0
5
10
15
20
25
30
35
Building Effective Age (Years)

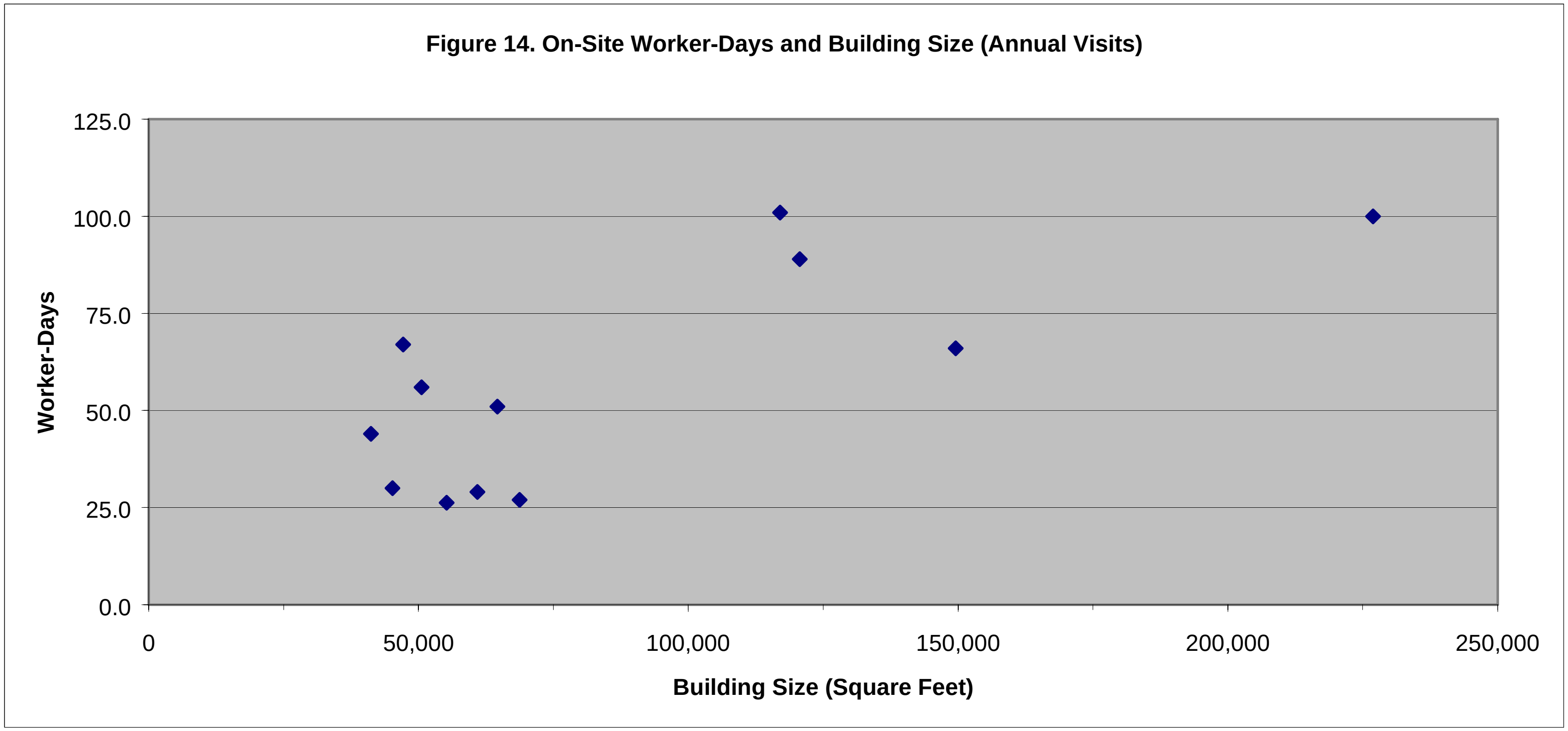


Figure 14. On-Site Worker-Days and Building Size (Annual Visits)
Worker-Days
125.0
100.0
75.0
50.0
25.0
0.0
0
50,000
100,000
150,000
200,000
250,000
Building Size (Square Feet)

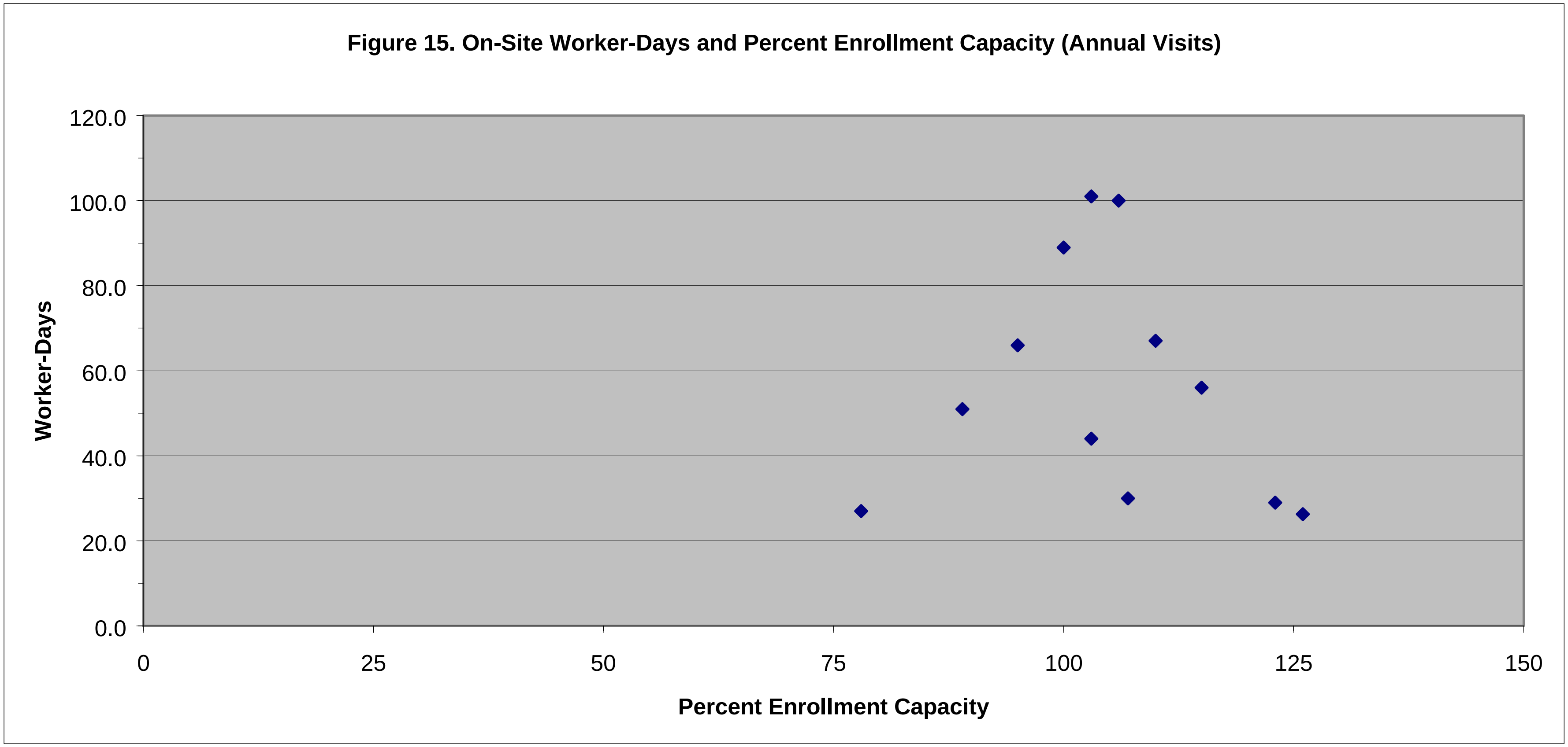
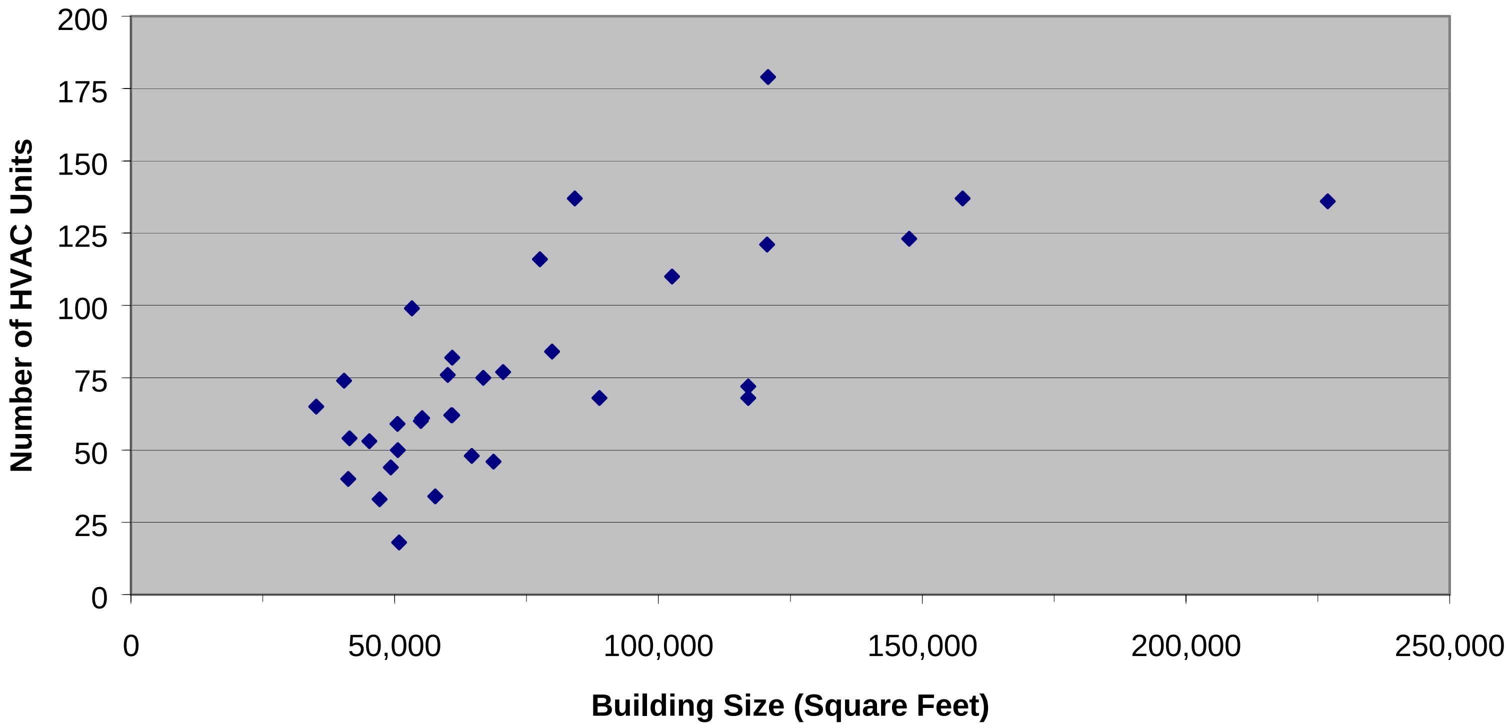


Figure 15. On-Site Worker-Days and Percent Enrollment Capacity (Annual Visits)
Worker-Days
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0
25
50
75
100
125
150
Percent Enrollment Capacity

Figure 16. Building Size and Number of HVAC Units



B.4 Customer Satisfaction

Figure 17. Mean Percentages of Staff Submitting Negative Questionnaire Responses Related to IAQ Parameters

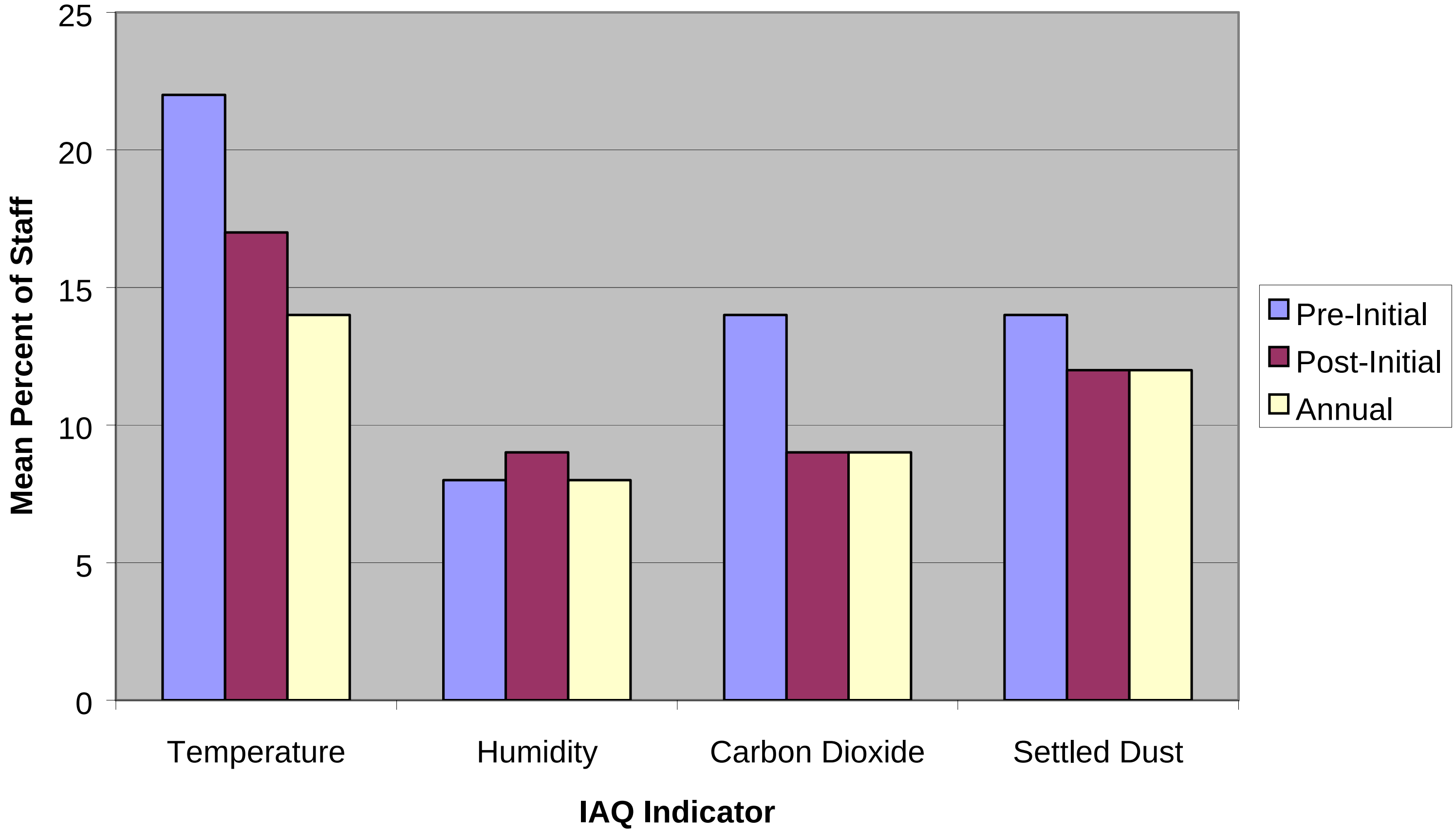


Figure 18. Percent Extended Temperature Outliers and Percent Negative Questionnaire Responses Related to Temperature

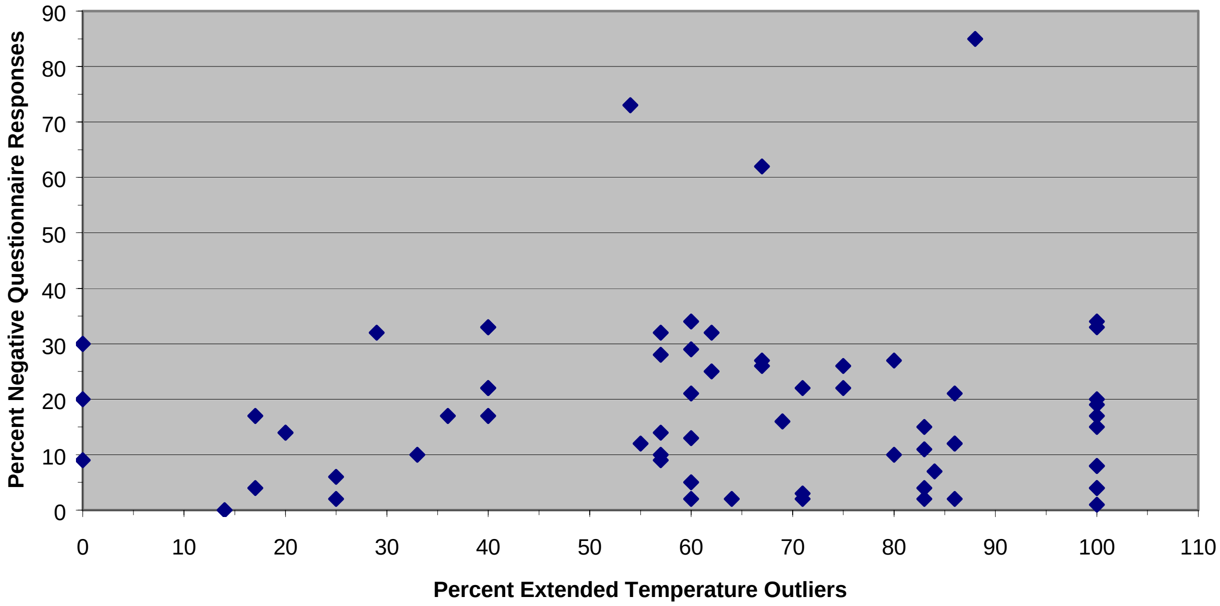


Figure 19. Percent Grab Temperature Outliers and Percent Negative Questionnaire Responses Related to Temperature

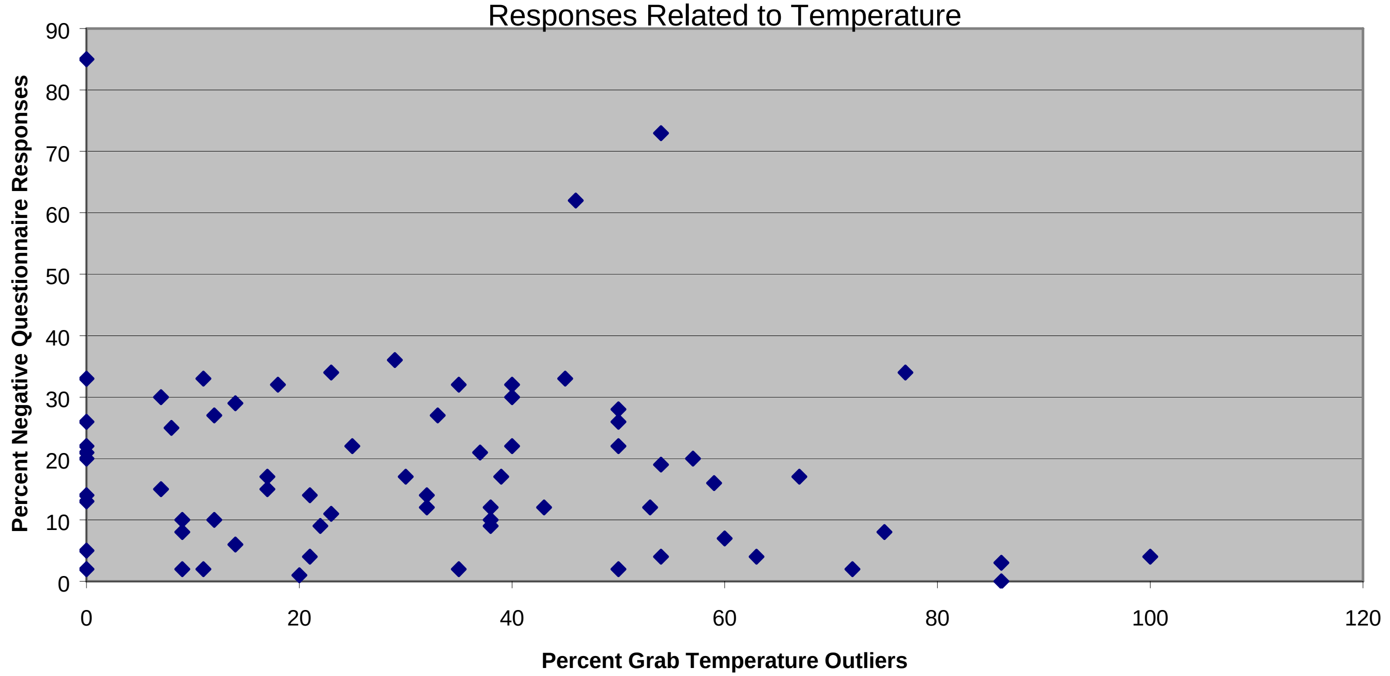


Figure 20. Percent Extended Relative Humidity Outliers and Percent Negative Questionnaire Responses Related to Humidity

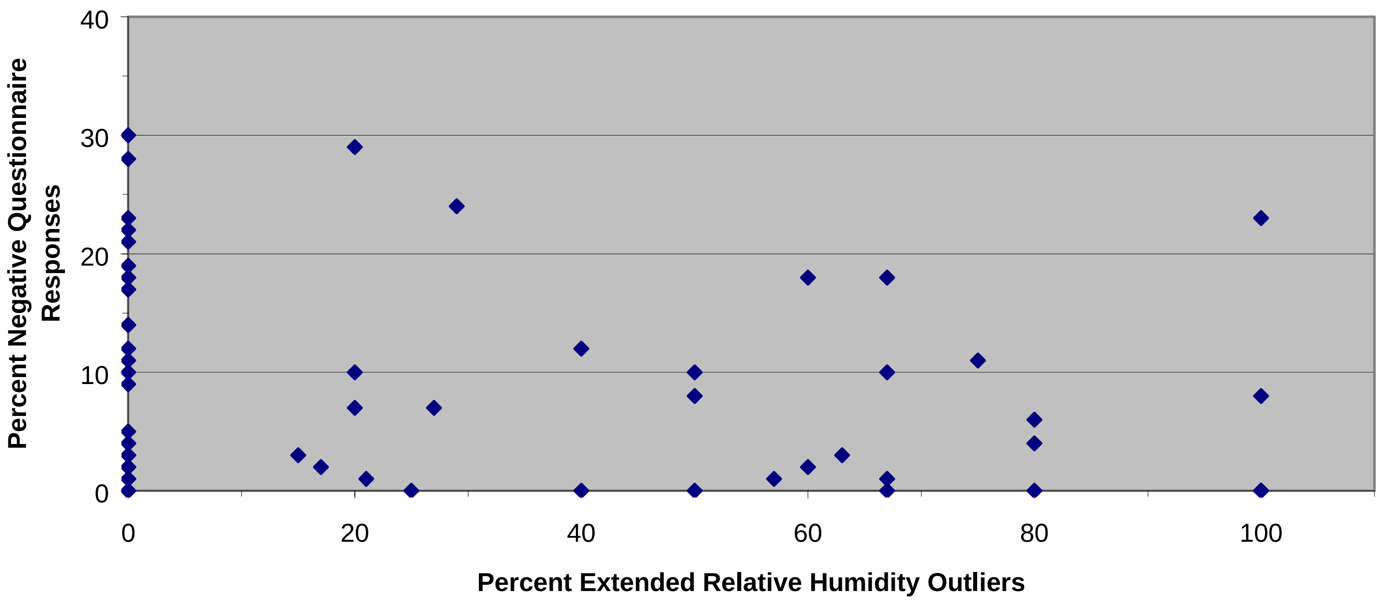
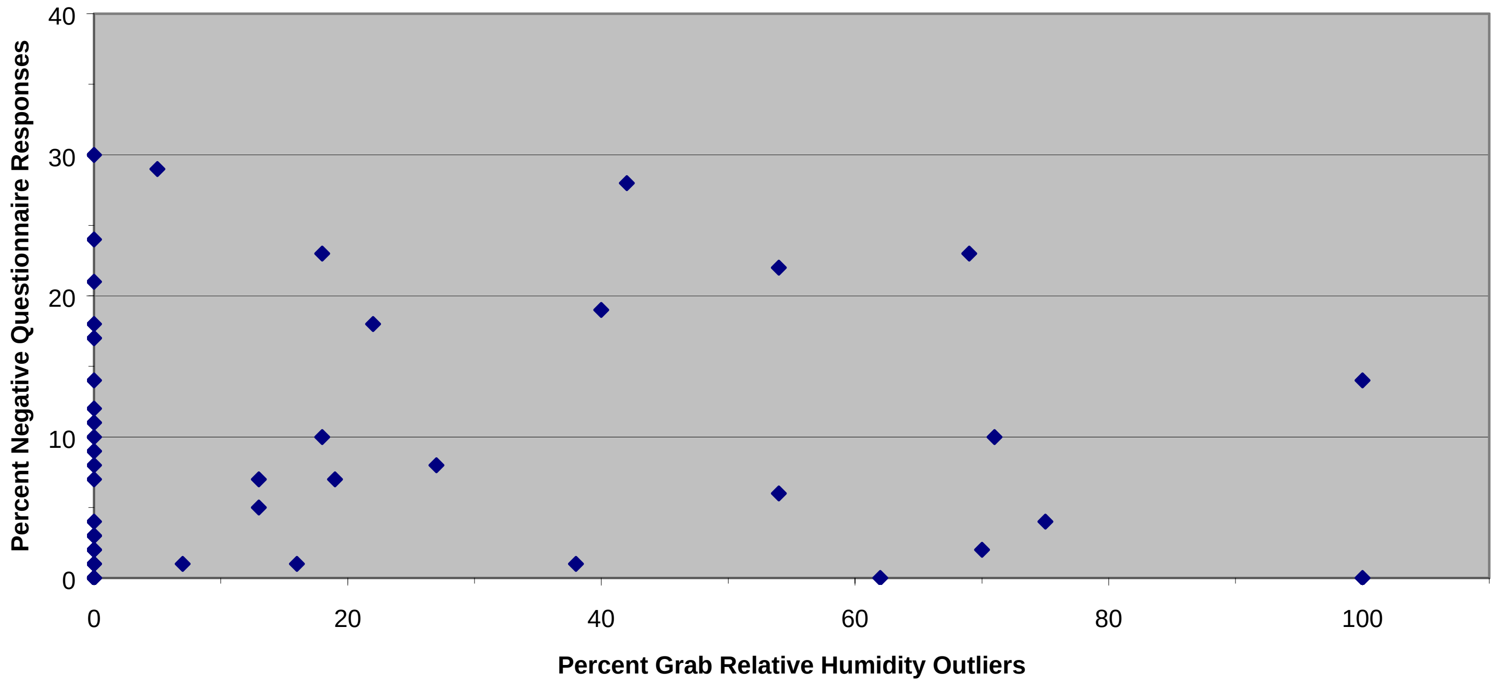


Figure 21. Percent Grab Relative Humidity Outliers and Percent Negative Questionnaire Responses Related to Humidity



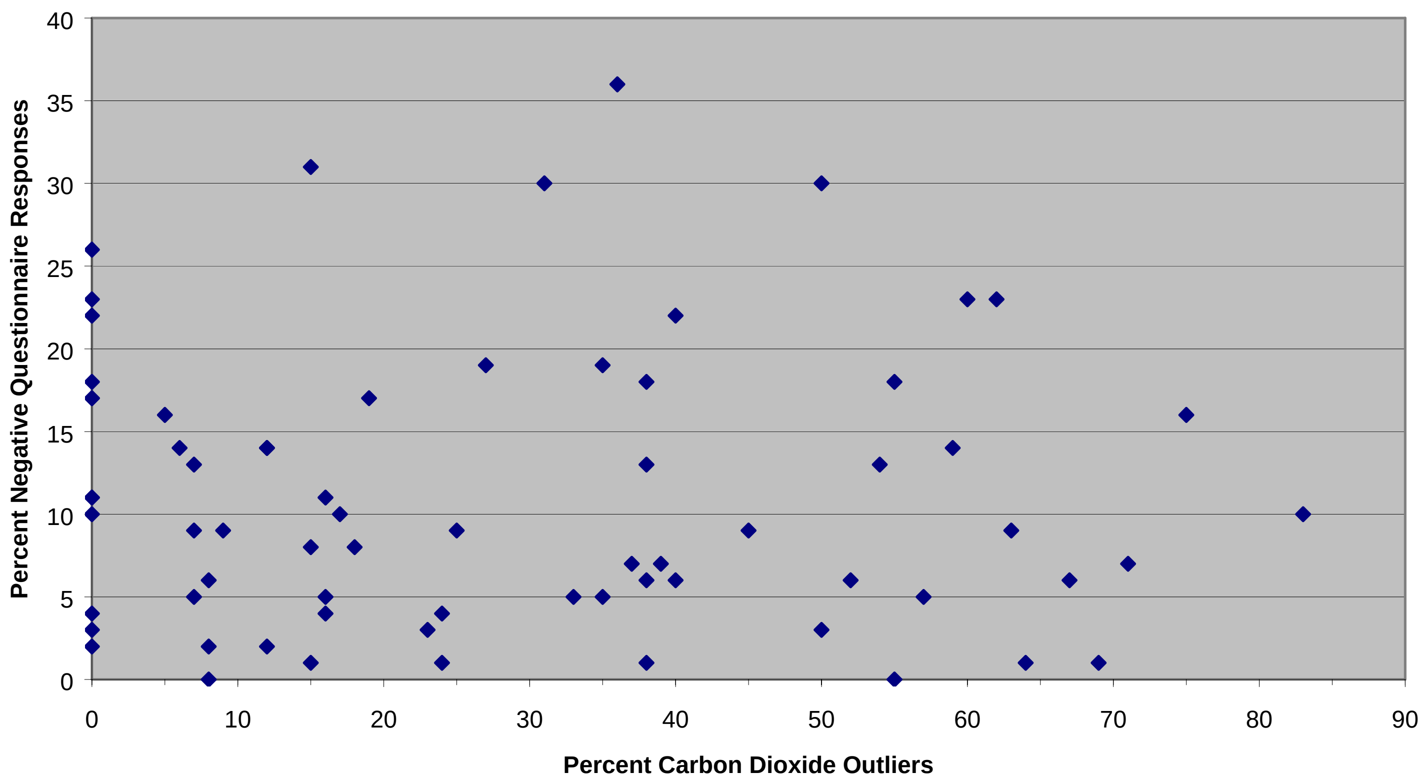
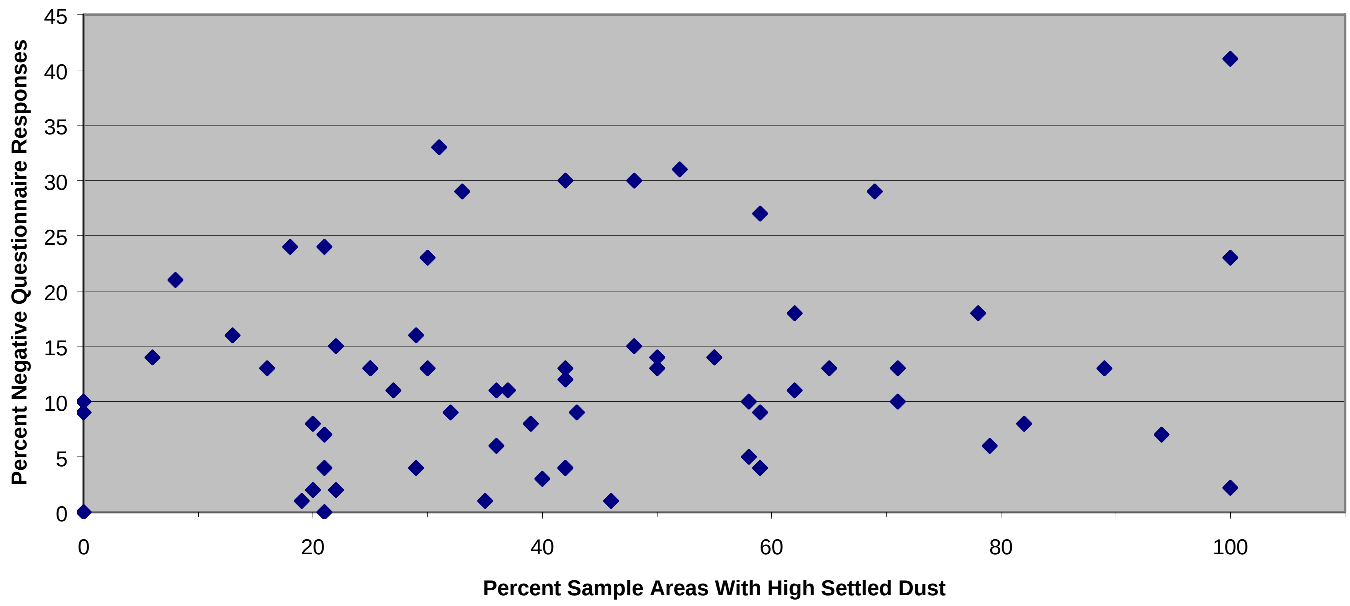


Figure 22. Percent CO_2 Outliers and Percent Negative Questionnaire Responses Related to CO_2 Concentration

Figure 23. Percent Sample Areas With High Settled Dust and Percent Negative Questionnaire Responses Related to Dust Levels



APPENDIX C. PM Team Standard Operating Procedure for Site Visits

INDOOR AIR QUALITY (IAQ) TEAM

Standard Operating Procedure for IAQ
Team Preventive Maintenance (PM) Visits (Initial & Annual)

The following procedure is applied to buildings undergoing Initial and Annual IAQ Team PM Visits. Some modifications to this procedure may occur and are usually due to scheduling constraints. This SOP does not address program performance.

1. **Informational Meetings**
    a. **Initial-**Meet with building manager, depot HVAC supervisor (or his designee), IAQ Team HVAC II and IAQ Tech II, Occupational Safety Specialist and other invited guests to discuss the IAQ Team work plan for the building. Discuss and set schedule for site work, known HVAC problems and their resolution, and general layout of the HVAC system. Distribute appropriate work plan. Review any concerns about site access by the Team.
    b. **Annual-**If considered necessary, meet with building manager, depot HVAC supervisor (or his designee), IAQ Team HVAC II and IAQ Tech II, Occupational Safety Specialist and other invited guests to discuss the IAQ Team work plan for the building. Discuss and set schedule for site work, known HVAC problems and their resolution, and general layout of the HVAC system. Briefly review implementation of the BMP with the Building Service Manager. Distribute appropriate work plan. Review any concerns about site access by the Team.

2. **Team Visit**
    a. **Job Assignments**
        1. **IAQ Techs-**Each IAQ Tech will be assigned a zone, hall, or section of rooms. The IAQ Tech is responsible for the completion of all cleaning and disinfection of supply air (and exhaust air, if considered necessary) equipment, re-insulation (if considered necessary), and other work as assigned by a supervisor.

2. **HVAC Techs-**Each HVAC Tech will be assigned a zone, hall, or section of rooms. HVAC Techs will work closely with HVAC II and IAQ Tech II to complete all equipment evaluation and repair in his assigned area**.**
3. **IAQ and HVAC Supervisors-**The Team supervisors work together with the OSS to verify completion of the work plan and identification and correction of other HVAC deficiencies noted during the visit. Supervisors are responsible for completion of all needed field work sheets (identified later). Supervisors are responsible for their respective technicians. In the event that a supervisor is absent, supervision responsibilities go to a temporally assigned supervisor or the remaining Team supervisor. In the event that both supervisors are absent, supervision responsibilities go to temporally assigned supervisors or the Occupational Safety Specialist.

b. Tools-Each tech will be issued a set of tools. Tools will be identified either by color or inscribed with a set number. It is the responsibility of the tech to keep his tools properly identified and in proper working condition

c. Trucks & Truck Stock-Each tech will be assigned to a truck. Only one set of keys will be issued for each vehicle. A second set of keys will be kept in the Team office. Supervisors will have access to the second set of keys. Truck stock is the responsibility of technicians assigned to each truck. Technicians must inform their supervisor when their inventory is at a five day supply or less. A written list of supplies should be given to the supervisor.

d. Storage shed-Located at Shurgard (19900 Goshen Rd, Gaithersburg, unit #474). Supervisors will have access to the keys and access code for the shed.

e. Radios-Each person will have a multi-channel radio. IAQ Techs will use channel 1, HVAC techs will use channel 2, and supervisors will use channel 3. Each person is responsible for his radio and any needed batteries.

f. Field Forms-Three field forms are used during Team visits. Completion of the forms is the responsibility of supervisors, who may delegate form completion to technicians.

1. **IAQ Team HVAC Supply Check List** (See Attached)
2. **IAQ Team HVAC Exhaust Check List** (See Attached)
3. **IAQ Team Area Evaluation Form** (See Attached)
4. **IAQ Team Volumetric Flow Rate Form** (See Attached)

3. **General Schedule**

a. **Meet Building Administration/Suggestion Box Placement**-Make every effort to gather all team members together to meet the principal, assistant principal, office administrative secretary and any other school administrators. Review of the Team members, hours of operation, and general scope of work will be the topics of the meeting. Announce the placement of the suggestion box and request that a general announcement be made to staff about the box, its use and the presence of the Team in the building. Place the suggestion box in the staff lounge during the first day of work in the building. Check for written comments in the box at least one time per work day.

b. **Building access confirmed**-The supervisors are responsible for obtaining building lock-up procedures from building services prior to the first night of work. Securing the building is the responsibility of the Team supervisors.

c. **Work Plan review**-The work plan created by the OSS should be reviewed by the supervisors and technicians prior to beginning work in the building

d. **Mechanical plan review**-Obtain current mechanical blueprints. The supervisors and OSS should review them as needed.

e. **Building service staff training**-Team supervisors are responsible for the scheduling of brief training sessions with the building service staff. Purpose of the sessions is to inform BS Staff (BS Manager, in particular) what is involved to maintain ventilation equipment using procedures described in the building maintenance plan. General topics will include unit cleaning & disinfection, filter changing, belt changing, mechanical operation checks. The training should occur toward the middle or end of the Team's visit to the building.

f. **LO/TO**-Prior to PM work beginning on ventilation equipment, circuit breakers and breaker panels serving equipment must be identified. If electrical cut-offs or plugs are used, they need to be identified. Electrical lock-out/tag-out information is recorded on the appropriate field forms.

g. **Flow Readings**- Several sets of volumetric airflow reading are taking on a sampling of ventilation equipment, depending on the type of Team visit.

   1. **Initial Visit**-Flow readings at supply units need to be measured before and after PM work has been completed. Obtain readings on all fan speed settings. Obtain total supply reading and total outside air supply (measured at the outside air intake grill). For typical sized elementary schools, select six rooms at random to use of these measurements. For larger buildings select ten rooms

for these measurements. Also select six restroom exhaust grills for flow rate measurements, before and after PM work has been completed.

2. **Annual Visits-**Select the same rooms/areas as during the initial visit for flow rate measurements prior to PM work being completed. Outside air should be measured at the same time and all fan speeds selected. Repeat flow rate measurements at previously measured restroom exhausts.