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Effectiveness Of HVAC Sanitation Processes In Improving Indoor Air Quality - Phase II

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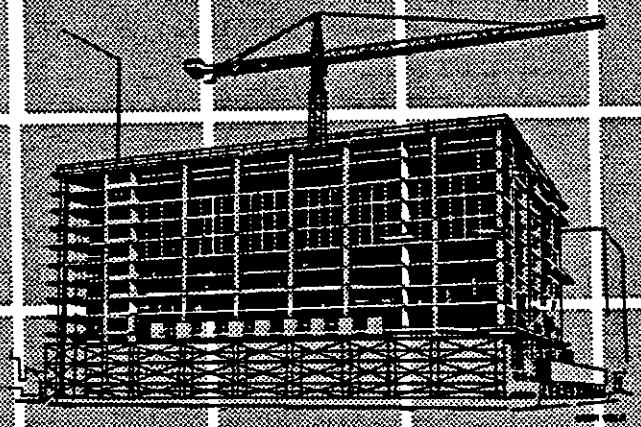

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1996

Effectiveness of HVAC Sanitation (Duct Cleaning) Processes in Improving Indoor Air Quality - Phase II

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Mr. Larry D. Robertson and **Mr. Robert A. Garrison** of Mycotech Biological, Inc. of Texas developed the study protocol, provided technical guidance and training for bioaerosol sample collection, and performed the subsequent laboratory analysis. Without their contribution this study would not have been possible.

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CLARIFICATION:

Although the word "sanitation" is used in the title of this research project and this report to refer to the cleaning processes, it should be noted that none of the cleaning procedures involved use of any chemicals.

EFFECTIVENESS OF HVAC SANITATION (DUCT CLEANING)
PROCESSES IN IMPROVING INDOOR AIR QUALITY - PHASE II

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EFFECTIVENESS OF HVAC SANITATION (DUCT CLEANING) PROCESSES IN IMPROVING INDOOR AIR QUALITY - PHASE II

Executive Summary

This project was initiated by the Building Construction Industry Advisory Committee (BCIAC) as a part of their continuing effort to aid the construction industry and the public in the state of Florida. A Phase I study was carried out by the investigators of this project to determine relative effectiveness of three main HVAC duct-work cleaning processes available in the market. This project, designated as Phase II, is a continuation of the Phase I study.

This phase of research was undertaken to determine the relative long-term effectiveness of the two rigorous commercial HVAC duct cleaning processes, namely, Air Sweep and Mechanical Brush, in reducing airborne contamination in residential homes. Two identical homes in the same neighborhood were selected to monitor the levels of airborne particulate matter and viable bioaerosols before, during and after cleaning for a period of one year at three months intervals. The same homes were also included in the Phase I study.

One home was cleaned using the Air Sweep method and the other was cleaned using the Mechanical Brush method. In Air sweep method compressed air is introduced into the duct for dislodging dirt and debris, which, becoming airborne, are drawn downstream through the duct and out of the system by the vacuum collection equipment. In Mechanical brush method, a rotary brush is inserted into the ductwork to agitate and dislodge the debris, that as with the air sweep method, are drawn through the duct out of the system by the vacuum collection equipment.

Airborne particulate matter readings were obtained using a particle analyzer. Viable bioaerosol concentrations were obtained using Andersen biological sampler and HVAC biological sampler.

We found that the HVAC systems of the two homes under

study were still in a relatively clean state one and a half year after the conclusion of the Phase I study. Comparison of data and samples collected in Phase I and II substantiate this observation.

The MechBrush method was found to be more effective than the AirSweep method in immediate reduction of particulate concentration. The AirSweep method was more effective regarding long-term effectiveness on the amount of particulate matter.

Major types of microbial contaminants were found to be Cladosporium, Penicillium, Curvularia, Aspergillus, Sterile Hyphae, Yeast, and Bacteria.

As was observed in the Phase I study, post-level bioaerosol concentrations, taken two days after cleaning, were, in most cases, lower than the pre-level concentrations. This observation suggests that cleaning procedures are effective in reducing microbial contamination.

In both phases of our study, homes cleaned with the Air Sweep procedure showed the highest amount of reduction in bioaerosol concentration. Although, long-term effectiveness of the MechBrush method on bioaerosol contamination was found to be somewhat better than the AirSweep method.

Qualitative results obtained from the HVAC sampling procedure were found to be in agreement with those obtained from the Andersen procedure. This procedure did not indicate a significant difference between the two cleaning processes. Although, long-term HVAC data of both homes indicated an increasing trend in bioaerosol concentration after a year of cleaning.

The conclusions of the study are highlighted below:

The effect of cleaning is more prominent on viable bioaerosol concentration than on airborne particulate matter. Both Andersen and HVAC biological sampling data suggested significant improvement in indoor air quality as

a result of cleaning.

Effects of cleaning last for a considerably long period of time. The initial data collected for the Phase II study, one and a half year after the Phase I investigation, and three months periodic data collected over a period of one year for the Phase II study, support this observation. Thus, if contaminant-concentrations remain within acceptable limit, another cleaning might not be necessary in three to five years. Further investigation is required to know exactly how long one should wait between two cleanings.

The MechBrush method indicated better results in immediate reduction of airborne particulate matter than the AirSweep method, although the long-term effectiveness of the AirSweep method was found to be better than the MechBrush method. On the other hand, the AirSweep method indicated better results in reducing bioaerosol concentrations, although, the MechBrush method showed a better long-term effectiveness. Thus, one method cannot be said to be better than the other in all respects. However, we must point out that the differences between them are not very significant.

The investigators recommend:

that the findings of this report, as well as the Phase I study report, be considered as case studies and should not be used to generalize or to draw definite conclusions without further investigation;

that measures be taken to increase public awareness regarding the importance of maintaining good indoor air quality; regular and proper maintenance of the HVAC unit; cleaning of the Air handling unit, the blowing coil and the drain pan on a regular basis; and using high-efficiency filters and replacing them on time will surely contribute toward improved indoor air quality;

that steps be taken to certify and regulate companies

that are engaged in commercial duct-cleaning business; specific guidelines for duct-cleaning be developed, disseminated and enforced; these guidelines should include information regarding the effectiveness of these procedures, frequency of cleaning, tolerable qualitative and quantitative limits, and steps that can be followed to keep level of pollution at a minimum;

that further investigations be carried out to develop tolerable qualitative and quantitative limits of airborne contamination, to determine the effectiveness of filer-media, cleaning practices and other controllable factors on indoor air quality of residential buildings.

A copy of this report may be obtained by contacting:
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EFFECTIVENESS OF HVAC SANITATION (DUCT CLEANING) PROCESSES IN IMPROVING INDOOR AIR QUALITY - PHASE II

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Findings

This research project was undertaken to determine the relative long-term effectiveness of the two rigorous commercial HVAC duct cleaning processes, namely, Air Sweep and Mechanical Brush, in reducing airborne contamination of residential homes. Two identical homes in the same neighborhood were selected to monitor the level of airborne particulate matter and viable bioaerosols before, during and after cleaning for a period of one year at three months intervals. One home was cleaned using the Air Sweep method and the other was cleaned using the Mechanical Brush method. These homes were included in the Phase I study. Relevant outdoor data were also collected.

In Air sweep method, compressed air is introduced into the duct for dislodging dirt and debris, which, becoming airborne, are drawn downstream through the duct and out of the system by the vacuum collection equipment. In Mechanical brush method, a rotary brush is inserted into the ductwork to agitate and dislodge the debris, that as with the air sweep method, are drawn through the duct out of the system by the vacuum collection equipment.

Airborne particulate matter readings were obtained using a particle counter and analyzer. Viable bioaerosol concentrations were obtained using Andersen biological sampler and HVAC biological sampler.

The major findings of this research study are summarized in the following.

- The homes under study were found to be in a relatively clean state when compared to what we found before the beginning of the Phase I study. Obviously, the effects of cleaning lasted for more than one and a half year between the conclusion of the Phase I and the commencement of the Phase II studies. Comparison of data collected in Phase I and Phase II substantiate this observation, particularly when bioaerosol concentrations are compared.

- The readings obtained from Particle Counter suggested that the concentration of particles were higher during the cleaning process than either before or after cleaning. This was due to disturbances caused by cleaning procedures employed and was consistent with the observations of the Phase I study.

- Indoor particle count readings were higher than corresponding outdoor readings. Indoor concentration of smaller particles, 0.3 micron and larger, was much higher than outdoor concentration.

- As in the Phase I study, it was found that cleaning, regardless of the type, reduces airborne particulate concentration.

- The MechBrush method was found to be more effective than the AirSweep method in reducing particulate concentration at both 0.3 and 1.0 micron levels, based on pre to post-48 hr comparison. Although, reduction was found to be more effective at the 1.0 micron level than at the 0.3 micron level.

- The AirSweep method was found to be more effective than the MechBrush method in regards to long-term effectiveness of cleaning as indicated by the periodic readings taken at three month intervals for a year.

- Both Andersen and HVAC biological sampling procedures revealed that the major types of microbial contaminants are Cladosporium, Penicillium, Curvularia, Aspergillus, Sterile Hyphae, Yeast, and Bacteria. This observation is consistent with the Phase I study except that in Phase II, we found significant amount of Curvularia and Aspergillus.

- As in the Phase I study, findings of Andersen procedure suggested that bioaerosol concentrations, in cfu's/m^3, during cleaning were higher than the pre-level concentrations. Post-level concentrations, taken two days after, were found to be lower than the pre-level

concentration. This observation suggests that both cleaning procedures are effective in reducing bioaerosol contaminants.

- In both phases of our study, a comparison of pre to post-48 hr concentration indicated that the AirSweep method was more effective in reducing concentration of bioaerosols than the MechBrush method.

- Long-term effectiveness of the MechBrush method on bioaerosol contamination was found to be somewhat better than the AirSweep method.

- Outdoor bioaerosol concentrations were found to be higher than the corresponding indoor concentrations in summer months. In winter, outdoor concentrations were typically on the lower side, as expected.

- Samples collected for the Phase II study indicated a lower bioaerosol concentration overall, by both Andersen and HVAC biological sampling, when compared to Phase I study collected before cleaning. This is an indication that the houses remained relatively clean during the one and a half year time period between the two phases of our study.

- HVAC sampling procedure did not indicate a significant difference between the two cleaning procedures. Although, long-term data of both homes

indicated an increasing trend in bioaerosol concentration after a year of cleaning.

Conclusions and Recommendations

This phase of the study had the same limitations as the Phase I study and it was not possible to collect sufficient data necessary for any statistical analysis. The results, reported herein, should be considered as case studies and the investigators are aware of the danger of generalizing these results. We believe, however, that findings of this study are very valuable and will provide important insight regarding the effects of HVAC duct-cleaning on indoor air quality of residential buildings.

The following conclusions and recommendations are outlined on the basis of the findings of the Phase II study:

- Duct-cleaning improves indoor air quality of residential buildings. The effect of cleaning is more significant on viable bioaerosol concentration than on airborne particulate matter. Residents of the two houses selected for the Phase II study reported to the investigators that they felt much better physically after duct-cleaning that was done for the Phase I study. We also observed that, in a relative sense, the homes were in a clean state one and a half year after first

cleaning. Both Andersen and HVAC biological sampling data suggested significant improvement in indoor air quality as a result of cleaning.

- Long-term effects of duct-cleaning on viable bioaerosols, as indicated by Phase II results, suggest that the effect of cleaning lasts for a long time. Depending on the acceptability of limits of concentration of certain aeroallergens, another cleaning might not be necessary in three to five years. One and a half year after the Phase I study, Andersen and HVAC samples did not show alarmingly high bioaerosol concentrations. The periodic readings taken at three months intervals for a year suggested that the contamination might just started to be on the rise after about a year. However, we suggest that more samples be collected and analyzed before drawing any definitive conclusion on this matter. We also suggest that physical conditions of the occupants be also monitored for a considerable period of time after cleaning to investigate any correlation that might exist between certain illnesses and the indoor air quality of residential buildings.

- We cannot overemphasize the importance of regular and proper maintenance of the HVAC unit; keeping the Air Handling Unit (AHU), the blower coil and the drain pan clean; using high-efficiency filters, and replacing them regularly in order to keep airborne particle and bioaerosol contaminations to a minimum.

- We suggest, as we did in the Phase I report, that cleaning of HVAC system and ductwork should be performed by professional duct cleaning specialists. Steps should be taken to certify and regulate companies and individuals that are engaged in commercial duct-cleaning business.

- Results of both Phase I and Phase II studies and similar studies should be utilized to develop specific guidelines for duct-cleaning. These guidelines should include information regarding the effectiveness of these procedures, frequency of cleaning, and steps that can be followed to keep level of pollution at a minimum.

- We found again that airborne particulate matter and bioaerosol concentrations are usually higher during cleaning was carried out. Occupants should not stay home during the cleaning procedure and the cleaning crew should wear masks for protection from breathing polluted air.

- The MechBrush method indicated better results in immediate reduction of airborne particulate matter than the AirSweep method, indicated by the pre to post-48 hr comparison. However, long-term effectiveness of the AirSweep method was found to be better than the MechBrush method. Based on the observations of this study, AirSweep method indicated the best results in reducing bioaerosol concentrations although the MechBrush method

showed a better long-term effectiveness. Thus we cannot recommend one method over the other. The difference between them, however, was not very significant. Either AirSweep or the MechBrush methods can be used, depending on the type of contamination that needs to be controlled and any health problems of the occupants.

- Qualitative results obtained from HVAC sampling procedure were comparable with those obtained from the Andersen procedure. It is a relatively inexpensive procedure. This procedure can be used as a screening method for limited purposes, such as, to decide if further investigation is necessary.

- Further research should be carried out to determine "tolerable" quantitative and qualitative limits of airborne contamination taking into consideration the effects on health and physical condition of residents. Research project should be undertaken to determine the effects of type and efficiency of filter-media, household cleaning practices, cleanliness of the HVAC unit, and other controllable factors on the indoor air quality of residential buildings.

Chapter 1

INTRODUCTION

1.1 Background

A research project entitled "Effectiveness of Residential HVAC Sanitation Processes in Improving Indoor Air Quality" was granted by the Building Construction Industry Advisory Committee (BCIAC) in 1992 to the investigators of this project. The main objective of the previous (Phase I) research project was to assess the effectiveness of the three duct-cleaning procedures in reducing certain contaminants. The three methods were:

(1) Contact Vacuum method, in which the interior of the ductwork is cleaned using conventional cleaner;

(2) Air Sweep method, in which compressed air is used prior to vacuum-cleaning with high-powered negative air equipment for dislodging dirt and debris, which becoming airborne, are drawn downstream through the duct and out of the system by the vacuum collection equipment; and

(3) Mechanical Brush method, in which particles and contaminants inside the ductwork are dislodged using a rotary brush prior to vacuum-cleaning with high-powered negative air equipment.

These methods were investigated to determine their effectiveness in reducing concentration of airborne particulate matter and viable bioaerosols. Airborne particulate matter readings were obtained using Met-One particle analyzer. NIOSH 7400 and 0500 procedures were employed to collect fiber count readings and total nuisance dust readings, respectively. Viable bioaerosol concentrations were obtained using Andersen biological sampler, HVAC biological sampler, and Burkard procedure.

Major findings of the Phase I study were:

(1) Met-One readings taken two days after cleaning did not show substantial reduction from the pre-cleaning readings at 0.3 micron level, but indicated significant reduction at 1.0 micron level. Both the AirSweep and the MechBrush methods indicated a reduction at this level while one of the Contact homes experienced an increase; and

(2) Post level concentrations of Andersen biological sampling procedure, taken two days after cleaning were found to be lower than the pre-level concentrations. Based on the observations of the Phase I study, Air Sweep method indicated the best results in reducing bioaerosol concentrations.

1.2 The Problem Statement

Although, definite conclusions could not be drawn on the degree of relative effectiveness of the cleaning

procedures, the Contact method was not found to be as effective as either the AirSweep or the MechBrush methods.

Investigation of long-term effects of cleaning methods was recommended in the report of the Phase I study to answer questions such as how long the effectiveness of cleaning lasts, and how often duct work should be cleaned. To obtain dependable answers to questions such as these, one needs to know how the concentration levels of various pollutants vary with time.

1.3. Description of the Phase II Project

The Phase II study was conceived as a means to quantify the long-term effectiveness of the two cleaning methods, AirSweep and MechBrush. The research project involved selection of two homes included in the Phase I study. Air Sweep method of cleaning was used on one of the houses and Mechanical Brush on the other. In the Phase II study, data were collected on the concentration of airborne particulate matter using airborne particle analyzer and viable bioaerosols using Andersen and HVAC biological sampling techniques. The readings were taken and the samples were collected before duct-cleaning was performed. The same information was also collected during cleaning and 48 hours after cleaning. This procedure of data and sample collection was repeated four more times at three months interval. With each set of indoor readings, outdoor readings and samples were also

collected using the same procedures of data and sample collection.

The Phase II study commenced about one and a half year after the conclusion of the Phase I study and was funded by the Building Industry Advisory Committee (BCIAC), North American Insulation Manufacturer's Association (NAIMA), Florida Air Conditioning Contractors' Association (FACCA), and Indoor Air Quality Association, Inc. (IAQA).

Chapter 2
OBJECTIVES AND SCOPE OF RESEARCH

2.1 Objective

The main objective of this research project was to evaluate the two major duct cleaning processes, AirSweep and MechBrush, for their long-term effectiveness on indoor air quality. These two methods of duct-cleaning are described in detail in the next chapter. The two methods were studied to investigate their effectiveness in reducing total airborne particulate and viable bioaerosols in residential homes.

The findings of the previous study constituted the basis of this Phase of investigation. In the Phase I study post readings were collected only once, after forty eight hours of cleaning. In the Phase II study, readings and samples were taken every three months over a period of one year. Effects on the levels of particulate matter concentration and viable bioaerosols were observed for one year at three months interval on the two houses, one for each method of cleaning.

In specific terms, the following tasks were to be accomplished in this project:

a) Conduct investigation to determine relative long-term effectiveness of the two duct-cleaning processes on indoor air quality; and

b) Develop a list of recommendations on the basis of the findings of the study.

2.2 Scope of the Project

The residential homes selected for this and the Phase I study were furnished with fiberglass duct material. Accordingly, findings of these studies may not be applicable to metal duct-work. No chemicals were used for sanitizing the duct-work before, during or after cleaning. The homes were identical in layout, floor area and HVAC design. In Phase II, Only one home was studied for each method. Due to time and budget constraints sufficient data could not be collected for the results to be reported using statistical analysis. As such, findings of these projects are reported as results of the case studies.

2.3 Duct Cleaning Techniques

The two HVAC duct cleaning procedures employed for the purpose of this phase of the study are described in detail in Chapter 3 of this report. The procedures were applied according to the NAIMA (North American Insulation Manufacturers Association) guidelines for cleaning fiberglass-insulated ducts. The houses selected for this research project were identical, and all of them had fiberglass duct-work.

2.4 Organization of the Report

This report is subdivided into five major parts, as listed below:

SUMMARY AND CONCLUSIONS - This report begins with an executive summary of the research project and its results. Outcome of the study is outlined in detail in the section entitled "Findings, Conclusions and Recommendations."

INTRODUCTION AND OBJECTIVES (CHAPTERS 1 & 2) - In these chapters indoor air quality problems due to inadequate cleaning of HVAC duct-work are outlined. The background of the project is described and the justification for investigating the problem is given. In Chapter 2 scope and objectives of the study are explained.

RESEARCH METHODOLOGY (CHAPTER 3) - In this chapter, the approach used to conduct the research project, the study protocol, type of data collected and the collection procedures are described.

FIELD OBSERVATIONS AND DATA COLLECTION (CHAPTER 4) - In this chapter detailed results of observations and field data are reported.

ANALYSIS OF RESULTS (CHAPTER 5) - The results of the analysis are presented using charts, graphs and tables. Results are compared with the corresponding Phase I study results, where applicable. Both airborne particulate

matter and viable bioaerosol concentrations recorded before, during and after (48 hrs, 3 months, 6 months, 9 months, and 12 months) cleaning are reported and discussed in this chapter. The last part of the report contains appendices.

Chapter 3
RESEARCH METHODOLOGY

3.1 General

Two of the eight homes included in the Phase I study were selected for the Phase II investigation. The investigators were very fortunate that these two homeowners agreed to participate in this phase for a period of one year. The designations used in the Phase I report for these two homes were AirSweep I and MechBrush I. To maintain continuity, same designations will be followed in this report. The duct-work of the AirSweep I and the MechBrush I homes were cleaned again for the Phase II study using the AirSweep and the MechBrush methods respectively.

As was the case in the Phase I study the homeowners were offered to have their duct-work cleaned at no cost to them and were asked to allow the investigators to carry out the project for a period of one year. Our experience suggests, many homeowners are very interested to participate in this kind of study. However, they need to be assured: the procedure will not cause any harm or damage to their homes; the study results will not be used for any commercial purposes; the persons in charge of

investigation are trustworthy.

3.2 Study Protocol

The study protocol was developed by Larry Robertson and Robert Garrison of Mycotech Biological Inc. of Texas at the time of the Phase I study. The same protocol with some obvious modifications, due to the difference in scopes of the two projects, and a few minor omissions was followed for the Phase II. The protocol was included in detail in the Phase I report and is not repeated here.

In brief, indoor and outdoor readings of particulate matter were taken, indoor and outdoor Andersen biological sampling and HVAC sampling were carried out for subsequent laboratory analysis. Temperature and Relative humidity data were also recorded. All readings were taken and samples collected before, during (except HVAC sampling, which cannot be collected during cleaning) and 48 hrs after cleaning and every three months for a year thereafter.

3.3 Duct Cleaning Procedures

The two commercial HVAC duct cleaning procedures employed for the purpose of this study were described in detail in the Phase I report. The descriptions are based on NAIMA (North American Insulation Manufacturers Association) guidelines for cleaning fiberglass-insulated ducts. In the following, relevant parts of those descriptions are reproduced.

3.3.1 Air Washing or Air Sweep Method (abbreviated as "AirSweep"):

A vacuum collection device is connected to the downstream end of the section being cleaned through a predetermined opening. Compressed air is introduced into the duct through a hose terminating in a "skipper" nozzle. This nozzle is designed so that the compressed air propels it along inside the duct. This dislodges dirt and debris which, becoming airborne, are drawn downstream through the duct and out of the system by the vacuum collection equipment. The compressed air source should be able to produce between 160 and 200 psi air pressure, and have a 20-gallon receiver tank, for the air washing method to be effective.

All return and supply registers are removed for cleaning and to provide access into the duct-work. The duct system is then divided into sections using isolation bags and dividers. The negative air equipment is then attached to each section while a high pressure driven nozzle is inserted and used to dislodge the debris. The dislodged particles is pulled into the HEPA (High Efficiency Particle Arrestor) filtered negative air equipment. The mechanical air handling equipment is then cleaned.

3.3.2 Mechanical Brushing Method (abbreviated as "MechBrush"):

As with the air washing system, a vacuum collection device is connected to the downstream end of the section being cleaned through a predetermined opening. HEPA equipped negative air equipment is used on sections of the duct-work. Simultaneously, a rotary brush is inserted into the duct-work and then either mechanically or manually agitated (rotated) to dislodge the debris. In the current research project the brush was agitated manually although the process was termed MechBrush.

Once the isolated section of the duct to be cleaned is under negative pressure, the rotary brushing device is introduced into the duct at the opening furthest upstream. The brushes are worked downstream slowly to dislodge dirt and dust particles. When observation suggests the section of duct has been cleaned sufficiently, the brush is withdrawn from the duct and inserted in the next downstream opening, where the process is repeated.

3.4 Data Collection

The study consisted of collection of data in three main groups as described below.

3.4.1 Collection of General Field Data

Temperature and relative humidity were recorded both

indoor and outdoor every scheduled day of data collection during the study period. General descriptions and hygiene of each house; normal cleaning practice; history of home remodeling and/or repair; number, age, sex, and occupation of residents; and number and type of pets were noted.

3.4.2 Airborne Particulate Matter

Particle Counter: Particle Count-readings were taken using an automatic particle counter, both indoor and outdoor before (pre), during, and after (post-48 hrs) cleaning and every three months for a year thereafter.

The particle counter used was an all-in-one sampler and analyzer like the Met-One particle analyzer used in the Phase I study. It prints out the analytical data at the end of its sampling cycle. The data are quantitative only and are expressed in terms of particles/ft^3.

For both indoor and outdoor, 1 minute sampling time was used. Readings were taken at two levels: 0.3 micron and 1.0 micron.

3.4.3 Viable Bioaerosols

The following descriptions of the sampling procedures were written and provided by Larry Robertson, President of Mycotech Biological, Inc.

Andersen Biological Sampler: The Andersen package

contains the N-6 Single Stage Sampler, a volumetric pump, and connecting tubing. The Sampler must be calibrated to a flow rate of 28.3 l/min. Samples are collected on media plates that are subsequently analyzed for qualitative and quantitative data. Sampling was conducted in duplicate pre-cleaning outdoors and indoors, during cleaning indoors, post-cleaning outdoors and indoors.

HVAC Bioaerosol Sampling: The HVAC sampling capitalizes on the fan system located in the HVAC unit itself and does not require any additional equipment. However, it does require that the airflow be recorded at the air duct register to be tested. A specific air register is selected (the same for every home) to conduct the test. The airflow rate at the specific test vent is determined while the unit was on. Two media plates, to allow duplicate readings, are taped to the air-conditioning vent such that the airflow impacted the media surfaces at a 90^0 angle. The air-conditioning unit is then turned on and the fan is allowed to run continuously for 10 minutes. This procedure of collecting samples was originated by the Mycotech Biological, Inc. of Texas. HVAC analytical sampling was conducted pre-cleaning, post-cleaning.

Chapter 4
FIELD OBSERVATIONS AND DATA COLLECTION

4.1 General

Temperature and relative humidity were recorded by the particle counter both indoor and outdoor every time particle count readings were taken. General descriptions and hygiene of each house; normal cleaning practice; history of home remodeling and/or repair; number, age and sex of residents; and number and type of pets were noted. The exact dates of data collection are noted below:

Pre (before) and During cleaning - September 28, 1994;
Post (after) 48 hours - September 30, 1994;
Post 3 months - January 6, 1995;
Post 6 months - March 31, 1995;
Post 9 months - July 20, 1995; and
Post 12 months - September 28, 1995.

4.2 TEMPERATURE AND RELATIVE HUMIDITY

Table 4.1 shows the summary of the indoor and outdoor temperature and relative humidity before (pre) cleaning, post-48hr, and every three months thereafter for one year. The data do not indicate any significant differences from what is typical in southern Florida.

Table 4. 1 Temperature and Relative Humidity

Home	Temperature-Farenheit				Relative Humiidity-%				Temperature-Farenheit			
	Pre		Post-48 hr		Pre		Post-48 hr		3 month		6 month	
	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor
AirSweep-1	78.8	78.8	77	80.6	52	68	59	68	82.4	82.4	82.4	84.2
MechBrush-2	77	78.8	78.8	80.6	43	68	49	68	78.8	82.4	87.8	84.2

Table 4. 1 Temperature and Relative Humidity *(Continued)*

Home	Relative Humiidity-%				Temperature-Farenheit				Relative Humiidity-%			
	3 month		6 month		9 month		12 month		9 month		12 month	
	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor
AirSweep-1	53	51	53	50	86	n/a	78.8	78.8	52	n/a	69	80
MechBrush-2	54	51	43	50	82.4	n/a	80.6	78.8	47	n/a	52	80

Note: In some instances, AC units were turned off in the morning and as a result, indoor temperature were found to be higher than or equal to the corresponding outdoor temperature. On one occasion, indoor relative humidity was found to be quite high (AirSweep 1 12-mo reading), It was also due to the fact that the AC was not running for a considerable long period of time.

Although, statistical correlation studies could not be performed due to insufficient data, the indoor readings do not seem to have detectable correlation with the duct-cleaning procedures.

An earlier study reported by Garrison et al[1] found no evidence of correlation between bioaerosol concentrations, before and after cleaning, and relative humidity.

4.3 GENERAL DESCRIPTION AND HYGIENE

During the Phase I study, certain information that were thought to have an effect on the indoor air quality were collected for each house under study. Since the Phase II study was conducted on the two homes that were also included in the Phase I study, the information contained in the Phase I report applies to these two homes as well. The pertaining portion of that report is reproduced in the following.

All the homes had a total of 1,285 sq.ft. of indoor floor space. All the rooms were carpeted except the bathrooms and the kitchen, which were either tiled or covered with vinyl mat. The surroundings of the homes were mostly grass covered with white rocks in some spots.

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[1] Garrison, R.A., Robertson, L.D., Koehn, R.D., and Wynn, S.R. "Effect of heating-ventilation-air conditioning system sanitation on airborne fungal populations in residential environments," *Annals of Allergy*, Vol. 71, No. 6, December 1993, p. 552.

In the vicinity of the neighborhood, there was a fire station and the Motorola Cellular phone manufacturing plant was not too far away. The airport was about within 10 to 15 miles from the neighborhood and 5 to 6 miles from I-95.

The description of the interior, HVAC unit, occupants and other information are given in the following for each home.

4.3.1 AirSweep 1

Cleaning practice: Regular.
Filter type: spun fiberglass disposable/changed to washable metallic type after the Phase I study.
Any damage/repair: None.
Residents/allergy problems:
1 female 46 yrs, gets allergy from dust, cats; under medication. Felt better after cleaning during the Phase I study.
Pet: 1 dog
Furniture: fabric
Indoor plant: none
Cooking frequency: does not cook much
House Facing: North
Condition of the HVAC unit: Relatively clean.

4.3.2 MechBrush 1

Cleaning practice: Regular, vacuum 1/wk, wash 1/wk, dust every other week.
Filter type: fiberglass media with impregnated charcoal, using for two years as advised by the physician.

Any damage/repair: None between the Phase I and Phase II studies.
Residents/allergy problems:
1 female 48 yrs, smokes twice a day, has allergy from dust, has breathing problem and asthma.
Pet: none
Furniture: fabric/Vinyl
Indoor plant: none
Cooking frequency: not a lot
House Facing: South
Condition of the HVAC unit: Relatively clean inside AC unit.

4.4 RATED VS. ACTUAL CFM (cu ft./min)

Air volume rate readings were taken with the help of a Ballometer with the HVAC unit on. The ballometer was placed at the air duct register so that air can flow through the meter that indicates the reading. These readings were taken for each home before and after duct-cleaning as well as every three months for a year. The readings are shown in *Table 4.2*.

It should be noted that the rated CFM for these homes was 1000. The total actual CFM, as indicated in *Table 4.2* were found to be less than the rated CFM in both homes before cleaning. 48 hours after cleaning the actual CFM had improved as shown. The MechBrush home showed better improvement than the AirSweep home. Actual CFM in the MechBrush home remained at a level higher than

Table 4.2. Actual Air Volume rate (CFM - cu. ft/min)

Home	Pre					Post-48 hr				
	Living	M. Bed	C. Bed	Bath	Total	Living	M. Bed	C. Bed	Bath	Total
AirSweep 1	315	280	265	64	924	300	350	320	72	1042
MechBrush 1	210	220	192	45	667	350	440	410	74	1274

Table 4.2. (Continued) Actual Air Volume rate (CFM - cu. ft/min)

Home	3-mo					6-mo				
	Living	M. Bed	C. Bed	Bath	Total	Living	M. Bed	C. Bed	Bath	Total
AirSweep 1	330	350	310	75	1065	275	280	220	56	831
MechBrush 1	280	440	340	65	1125	295	315	330	70	1010

Table 4.2. (Continued) Actual Air Volume rate (CFM - cu. ft/min)

Home	9-mo					12-mo				
	Living	M. Bed	C. Bed	Bath	Total	Living	M. Bed	C. Bed	Bath	Total
AirSweep 1	320	400	320	80	1120	305	325	255	55	940
MechBrush 1	290	380	310	70	1050	280	440	340	65	1125

the rated CFM for the following year. The AirSweep home indicated a reduction in the 6-month and in the 12-month readings.

In AirSweep 1, an increase of about 13% (from 924 CFM to 1042 CFM) from pre- to post-48 hr level was noticed. The MechBrush 1 showed an increase of about 91% from pre- to post-48 hr level.

An increased CFM was observed in post-48 hrs readings for both methods. In AirSweep 1, the 6-month CFM reading (1065) was found to be significantly lower than 3-month reading (831); the 9-month reading was back up again (1120). Although, we did not for sure, it was possible that dirty filter was changed between 6-month and 9-month readings. Higher readings being indicative of clean filters. In MechBrush home, post-cleaning readings were consistent within a close range.

Chapter 5
RESULTS AND ANALYSIS

5.1 General

In this chapter, results and analysis of the study parameters are reported. The two parameters studied are airborne particulate matter and viable bioaerosols. Results of quantitative, and where appropriate, qualitative analysis were obtained for the two homes under study.

5.2 Airborne Particulate Matter

The procedure employed to collect readings of the airborne particulate concentration was the use of a device called particle counter. This particle counter was very similar to the Met-One particle counter used in the Phase I study of this project except that it had additional features. For example, this counter had the ability to record and print out temperature and relative humidity data.

5.2.1 The Particle counter

The particle counter provided particle counts per cubic foot at four levels - 0.3 micron and larger, 0.5 micron and larger, 1.0 micron and larger, and 5.0 micron and larger. In this report, readings at 0.3 micron and 1.0 micron are presented. In Phase I study, particle count at these two levels were obtained. In Phase II, readings were taken before, during and after cleaning. Subsequently, four additional sets of readings were taken

every three months for one year.

The average of 12-minutes readings are shown in *Table 5.1* and *Table 5.2* for 0.3 micron and 1.0 micron respectively. Several observations can be made from these two tables.

1. Particle concentration is higher during cleaning than either before or after (post-48 hr) cleaning, except for MechBrush 1, in which particle concentration before cleaning was found to be higher than during cleaning at 0.3 micron level. This observation is consistent with the results of the Phase I study. The increase in particle count during cleaning is due to disturbances caused by the cleaning procedures employed. A higher amount of particles become airborne during cleaning as a result of agitation caused by the cleaning processes. The process of settling down of this agitated particulate matter begins almost immediately as indicated by lower readings obtained 48-hrs after cleaning. The exception in MechBrush 1 might have been caused by cigarette smoking.

2. In general, indoor readings are higher than outdoor particle count readings. The difference is wider at 0.3 micron level than at 1.0 micron level. This observation is also consistent with our Phase I study.

3. It can be said that, cleaning, regardless of the type, does reduce airborne particulate concentration.

Table 5.1
Particle Count (Pre, During, 48-hr Post)
Size 0.3 micron and larger (Average of 12 minutes readings)
Phase II Study

	Indoor					*Outdoor*			
Homes	Pre	During	% Change Pre to During	Post - 48 hr.	% Change Pre to Post	Pre	Post - 48 hr.	% Change Pre-ind to Pre-outd	% Change Post-ind to Post-outd
AirSweep 1	15864	31432	98.13	13150	-17.11	10220	9552	-35.58	-27.36
MechBrush 1	77494	54644	-29.49	41721	-46.16	10220	9552	-86.81	-77.11

Table 5.2
Particle Count (Pre, During, 48-hr Post)
Size 1.0 micron and larger (Average of 12 minutes readings)
Phase II Study

	Indoor					*Outdoor*			
Homes	Pre	During	% Change Pre to During	Post - 48 hr.	% Change Pre to Post	Pre	Post - 48 hr.	% Change Pre-ind to Pre-outd	% Change Post-ind to Post-outd
AirSweep 1	1822	7913	334.30	1376	-24.48	1095	1379	-39.90	0.22
MechBrush 1	3015	7106	135.69	946	-68.62	1095	1379	-63.68	45.77

4. MechBrush method was found to be more effective than the AirSweep method at both 0.3 and 1.0 micron levels.

The readings obtained for particles 1.0 micron or larger follow similar patterns, although as expected, they were always less than the corresponding readings for particles 0.3 microns and larger.

Results of Phase I study on these two homes are reproduced in *Tables 5.3* and *5.4*.

In Phase I, post-48hr readings at the 0.3 microns level were not found to have been reduced significantly. In Phase II, however, we see a significant reduction. At 1.0 micron-level the results show comparable patterns between the Phase I and II studies. Both AirSweep and MechBrush homes in both phases indicated a reduction in particle counts two days after cleaning. It can be said, in general, that reduction is more effective at the 1.0 micron level than at the 0.3 micron level.

Particle count readings are also shown graphically in *Figures 5.1* to *5.8*. These graphical illustrations provide a pictorial representation of comparison between pre-, during-, and post-level as well as long-term (3 month, 6 month, 9 month and 12 month) concentrations of airborne particulate matter for the homes under study. As pointed out earlier, these figures indicate a consistent pattern. They show that the readings during cleaning, in most cases, are higher than the pre or post level readings. The post readings, in most cases,

Table 5.3
Particle Count (Pre, During, 48-hr Post)
Size 0.3 micron and larger (Average of 15 minutes readings)
Phase I Study

	Indoor					*Outdoor*			
Homes	Pre	During	% Change Pre to During	Post - 48 hr.	% Change Pre to Post	Pre	Post - 48 hr.	% Change Pre-ind to Pre-outd	% Change Post-ind to Post-outd
AirSweep 1	28180	208753	640.78	64917	130.37	40627	33404	44.17	-48.54
MechBrush 1	175612	332913	89.57	180024	2.51	49789	207188	-71.65	15.09

Table 5.4
Particle Count (Pre, During, 48-hr Post)
Size 1.0 micron and larger (Average of 15 minutes readings)
Phase I Study

	Indoor					*Outdoor*			
Homes	Pre	During	% Change Pre to During	Post - 48 hr.	% Change Pre to Post	Pre	Post - 48 hr.	% Change Pre-ind to Pre-outd	% Change Post-ind to Post-outd
AirSweep 1	5321	15561	192.45	4715	-11.39	1714	1904	-67.79	-59.62
MechBrush 1	7290	33373	357.79	3505	-51.92	3160	1031	-56.65	-70.58

FIG. 5.1

Particle Count 0.3 Micron - MechBrush
Phase II (Pre, During, Post-48 hrs)

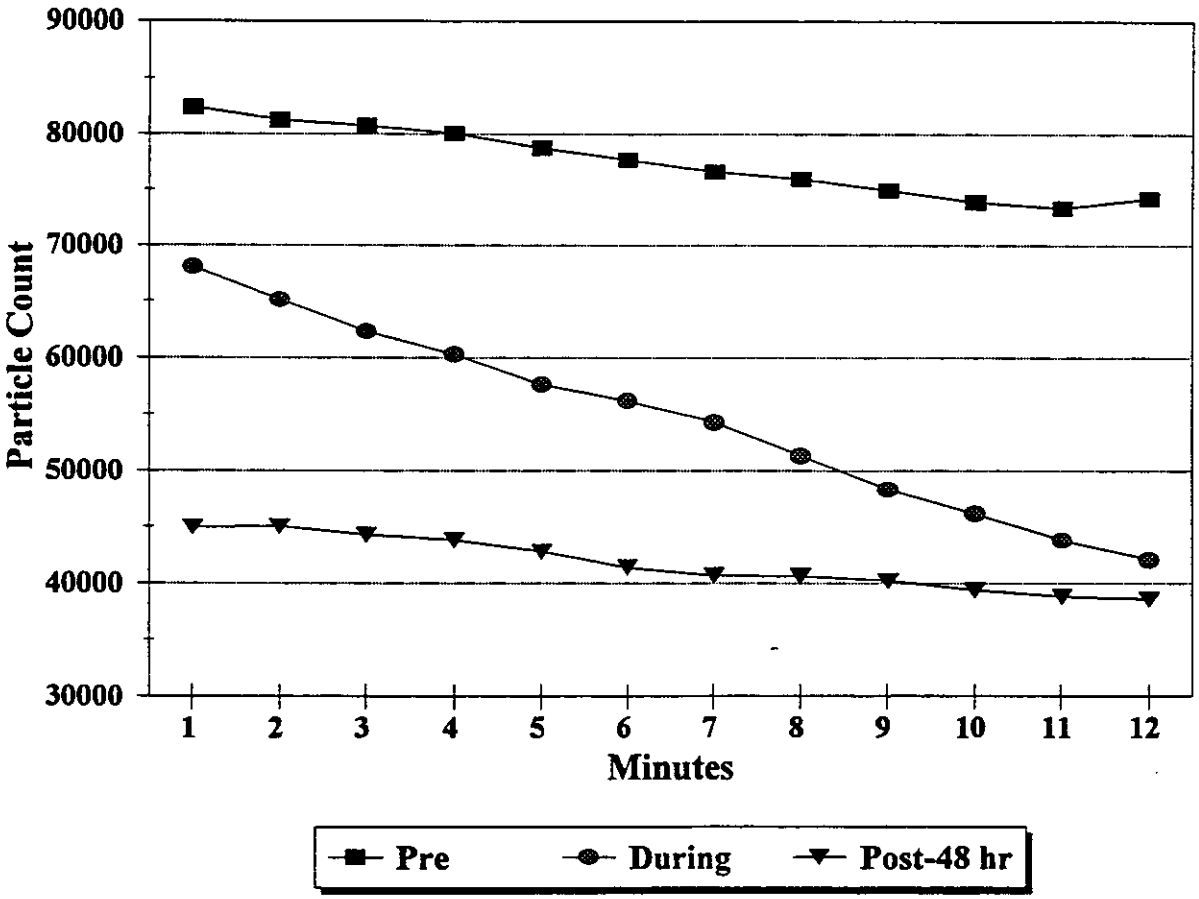


FIG. 5.2

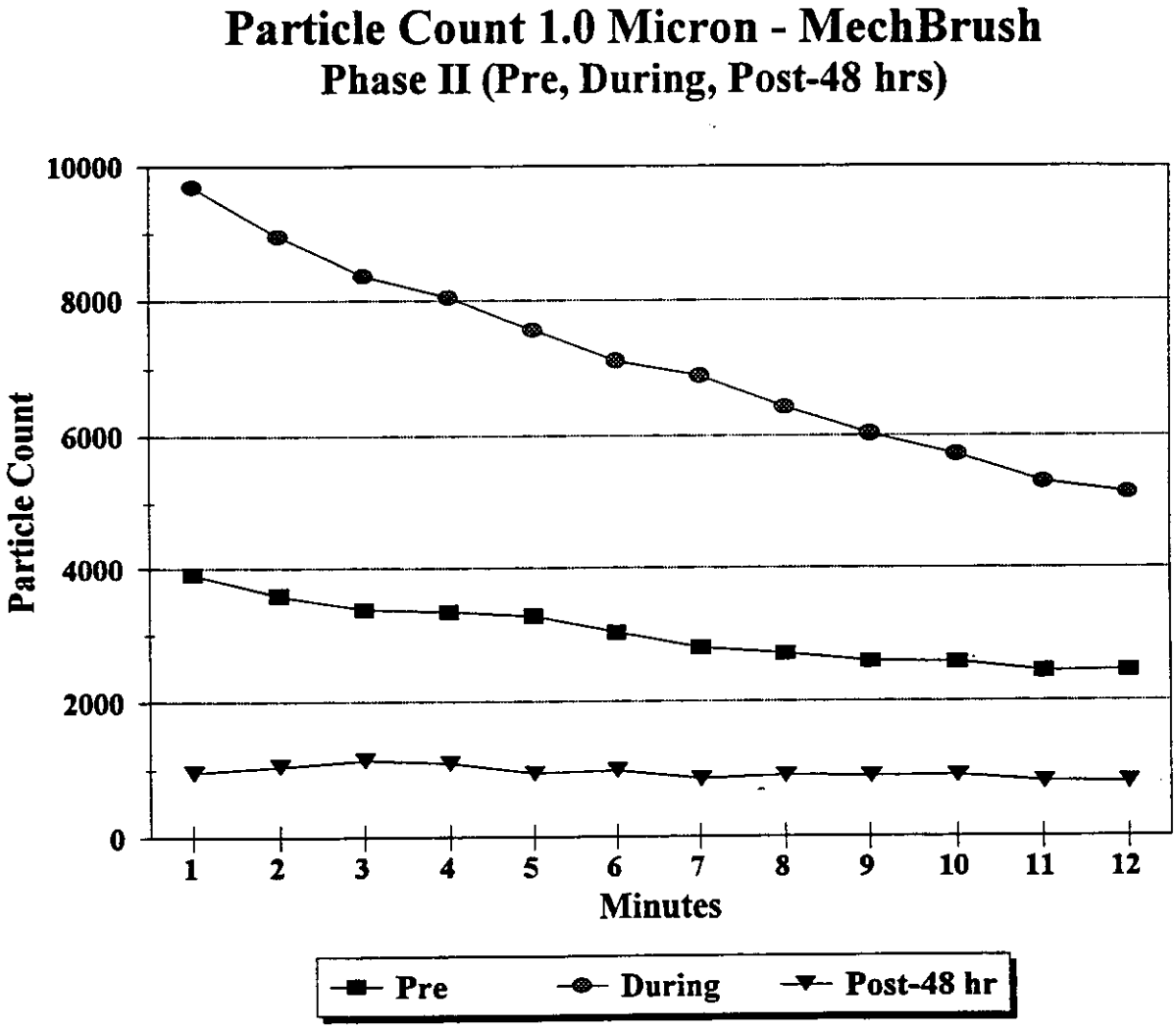

Particle Count 1.0 Micron - MechBrush
Phase II (Pre, During, Post-48 hrs)
Particle Count
10000
8000
6000
4000
2000
0
1
2
3
4
5
6
7
8
9
10
11
12
Minutes
Pre
During
Post-48 hr

FIG. 5.3

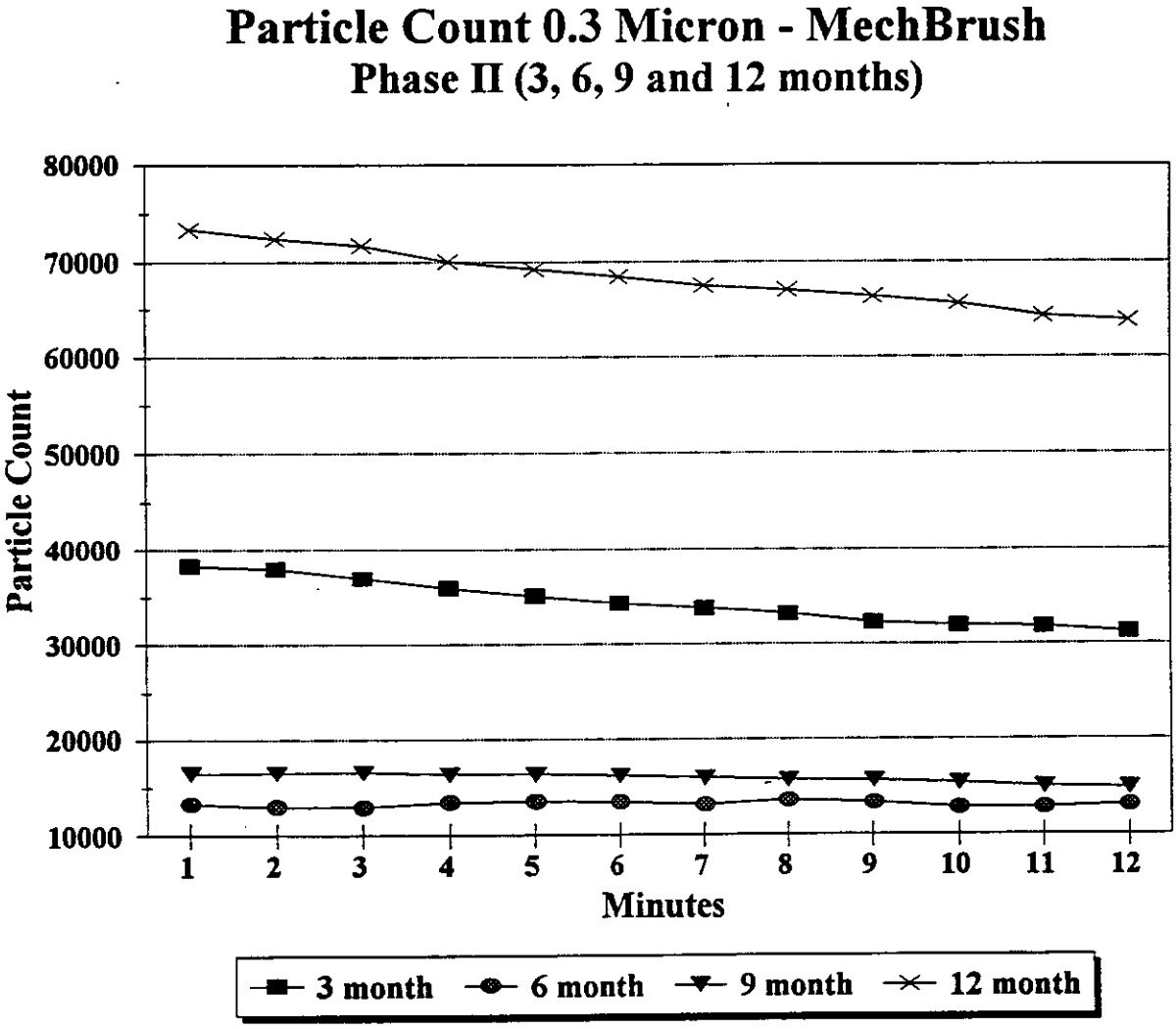

Particle Count 0.3 Micron - MechBrush
Phase II (3, 6, 9 and 12 months)
80000
70000
60000
50000
40000
30000
20000
10000
Particle Count
1
2
3
4
5
6
7
8
9
10
11
12
Minutes
3 month
6 month
9 month
12 month

FIG. 5.4

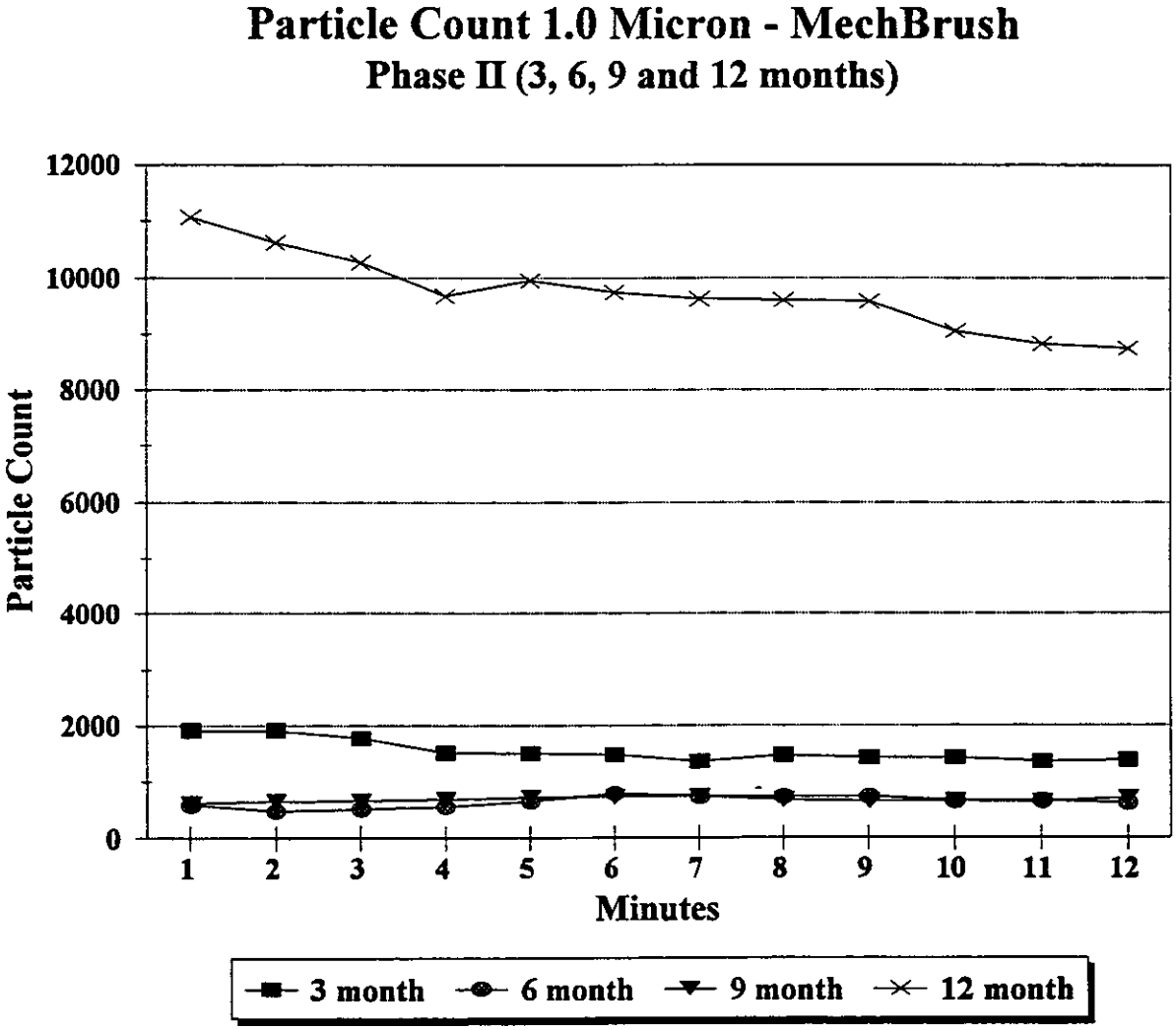

Particle Count 1.0 Micron - MechBrush
Phase II (3, 6, 9 and 12 months)
Particle Count
12000
10000
8000
6000
4000
2000
0
1
2
3
4
5
6
7
8
9
10
11
12
Minutes
3 month
6 month
9 month
12 month

FIG. 5.5

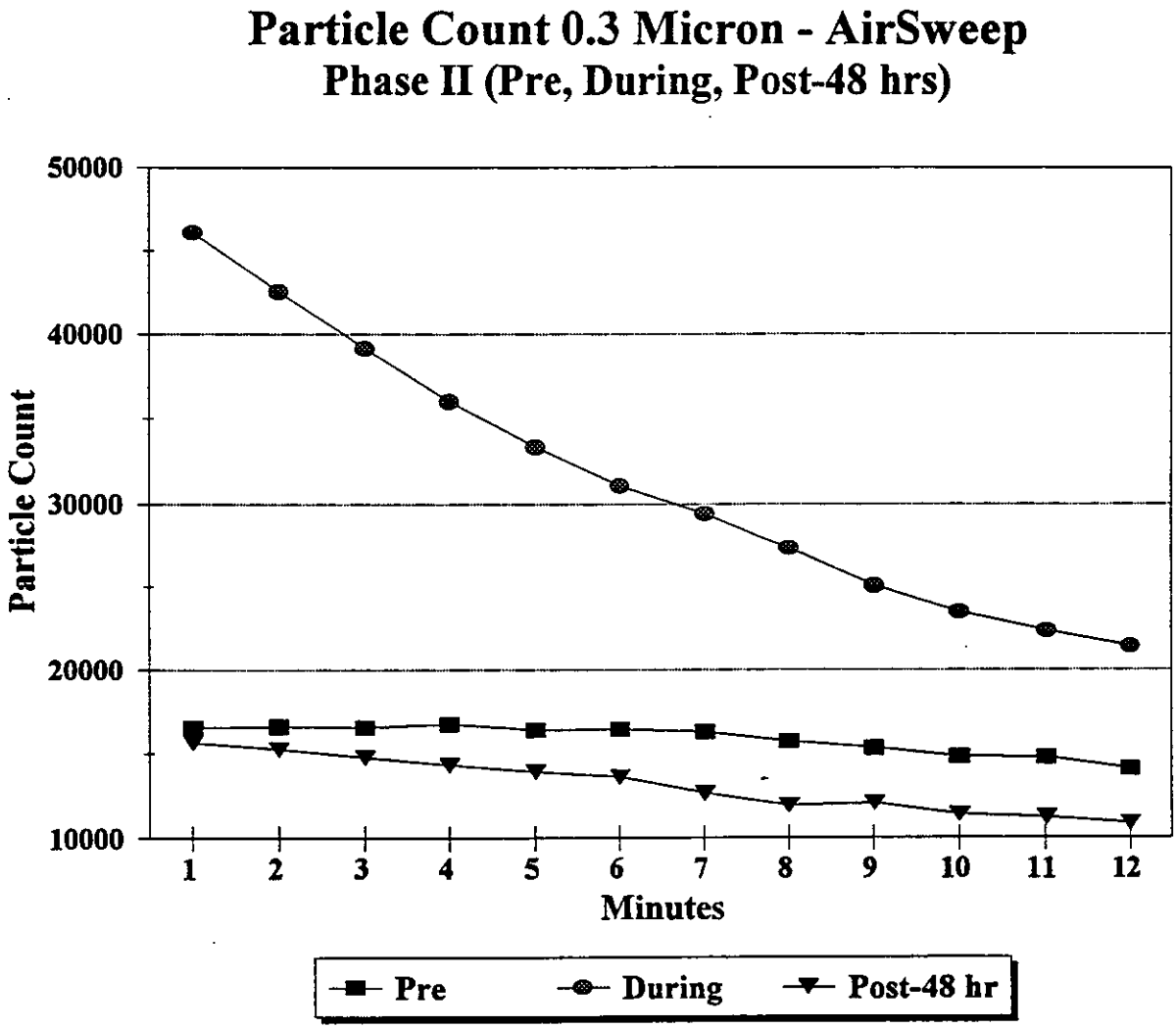

Particle Count 0.3 Micron - AirSweep
Phase II (Pre, During, Post-48 hrs)
50000
40000
30000
20000
10000
Particle Count
1
2
3
4
5
6
7
8
9
10
11
12
Minutes
Pre
During
Post-48 hr

FIG. 5.6

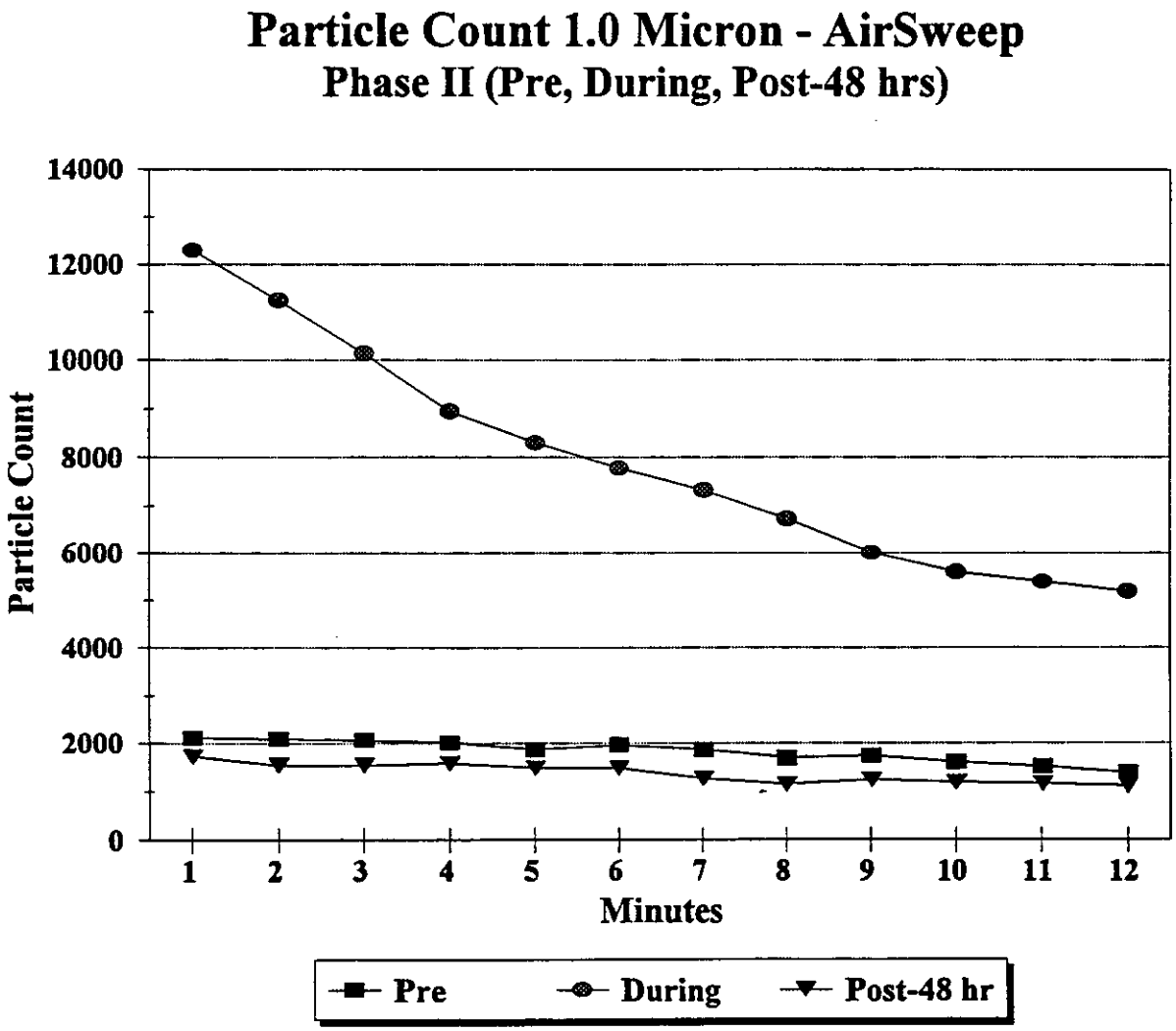

Particle Count 1.0 Micron - AirSweep
Phase II (Pre, During, Post-48 hrs)
Particle Count
14000
12000
10000
8000
6000
4000
2000
0
1
2
3
4
5
6
7
8
9
10
11
12
Minutes
Pre
During
Post-48 hr

FIG. 5.7

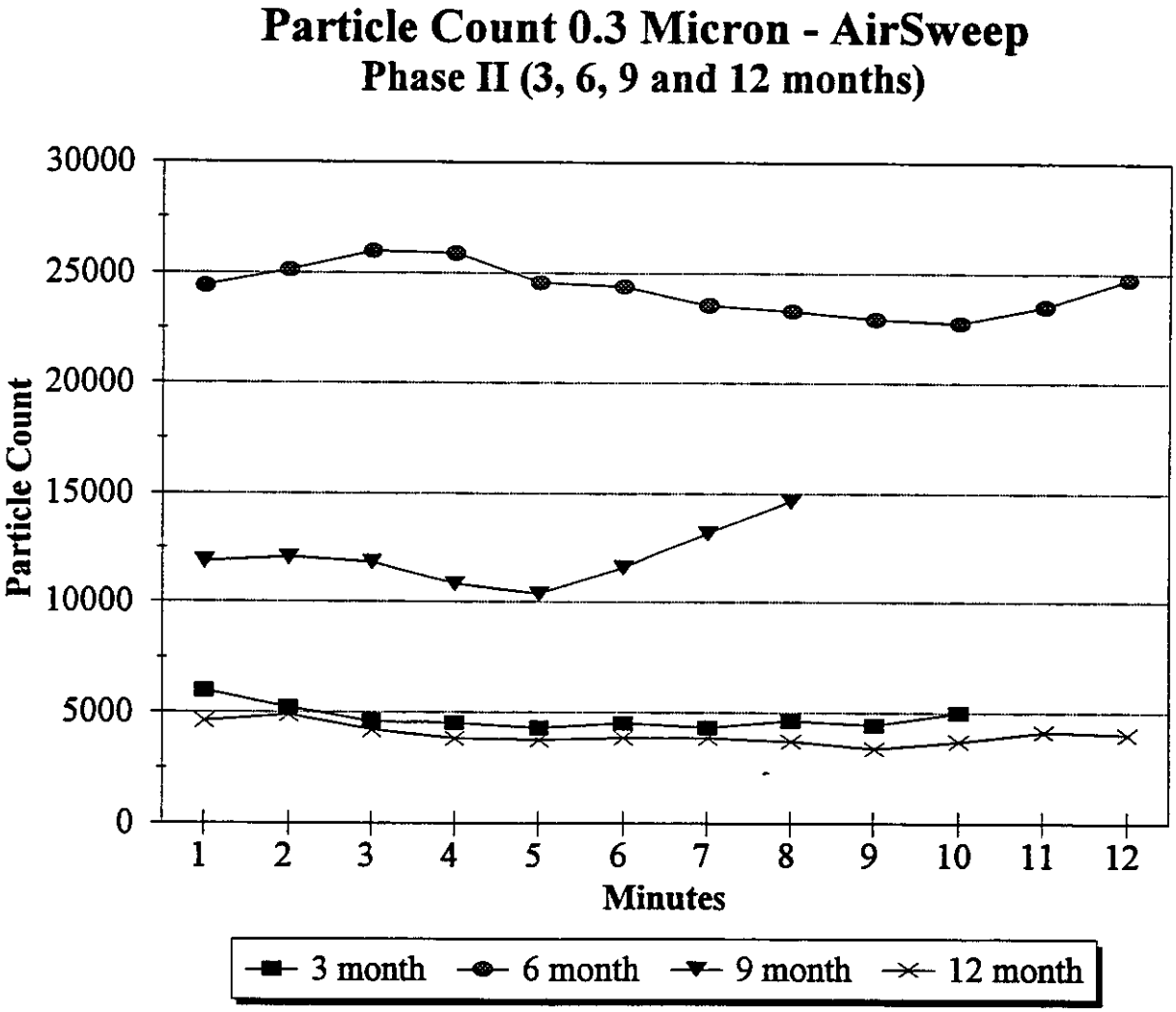
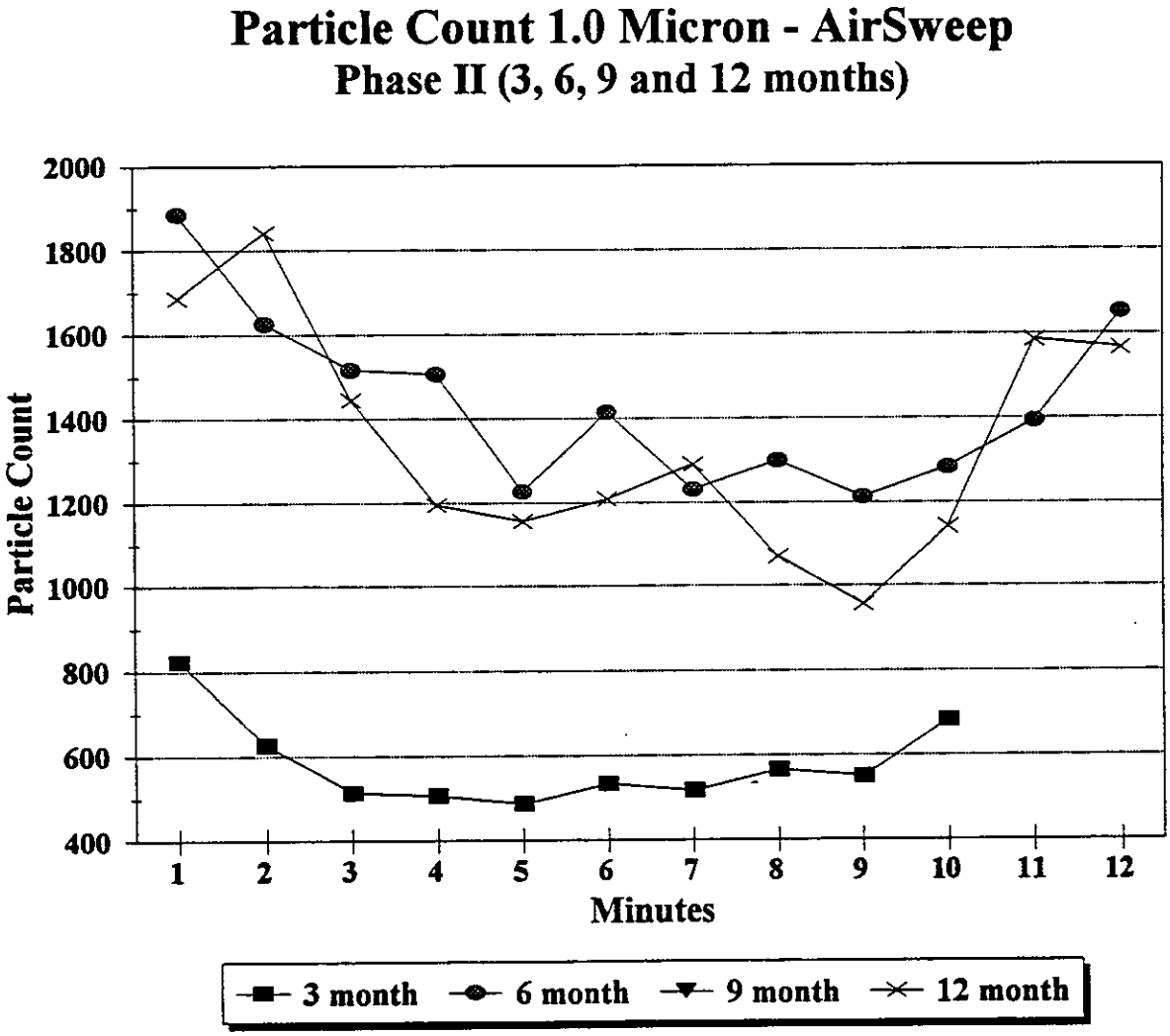

Particle Count 0.3 Micron - AirSweep
Phase II (3, 6, 9 and 12 months)
30000
25000
20000
15000
10000
5000
0
Particle Count
1
2
3
4
5
6
7
8
9
10
11
12
Minutes
3 month
6 month
9 month
12 month

FIG. 5.8


Particle Count 1.0 Micron - AirSweep
Phase II (3, 6, 9 and 12 months)
Particle Count
2000
1800
1600
1400
1200
1000
800
600
400
1
2
3
4
5
6
7
8
9
10
11
12
Minutes
3 month
6 month
9 month
12 month

dropped to at or near the pre-level readings.

We attempted to monitor the long-term effects of duct-cleaning by collecting readings at every three months after cleaning. *Tables 5.5* and *5.6* show average particle count taken every three months for four times for 0.3 and 1.0 micron levels respectively. The results are also shown graphically in *Figures 5.3 and 5.4* for the MechBrush method and in *Figures 5.7 and 5.8* for the AirSweep method for 0.3 and 1.0 micron respectively. The AirSweep home did not show a significant rise in the 12-month reading. The 9-month reading for this home at 1.0 micron level could not be obtained due to equipment malfunction. AirSweep method showed better results at both 0.3 and 1.0 micron levels. Indoor readings are less than corresponding outdoor readings. The fluctuation is not too high. On the other hand, the MechBrush home showed an increasing trend as the 12-month readings at both 0.3 and 1.0 micron levels are much higher than the corresponding 9-month readings, as well as, than the corresponding outdoor readings. Based on these limited observations it can be said, that the immediate effect of cleaning by the MechBrush procedure is better than the AirSweep procedure but the long-term effect of the AirSweep procedure is better than the MechBrush procedure.

5.3 VIABLE BIOAEROSOL

Two procedures were employed to collect the readings of bioaerosol concentrations. The two methods are

Table 5.5
Particle Count (3, 6, 9 and 12 month readings)
Size 0.3 micron and larger (average of 12 minutes readings)
Phase II Study

	Indoor				*Outdoor*			
Homes	3 month	6 month	9 month	12 month	3 month	6 month	9 month	12 month
AirSweep 1	4752	24256	12040	3986	12894	28052	24582	7231
MechBrush 1	34432	13231	15939	68297	12894	28052	24582	7231

Table 5.6
Particle Count (3, 6, 9 and 12 month readings)
Size 1.0 micron and larger (average of 12 minutes readings)
Phase II Study

	Indoor				*Outdoor*			
Homes	3 month	6 month	9 month	12 month	3 month	6 month	9 month	12 month
AirSweep 1	581	1437	n/a	1345	2243	1893	n/a	2920
MechBrush 1	1545	638	672	9727	2243	1893	n/a	2920

Andersen and HVAC.

5.3.1 Andersen Biological Sampler

The samples were collected in duplicate both indoor and outdoor for the two homes before (pre), during, and after (post) duct cleaning. Samples were also collected every three months thereafter in a similar manner. The detailed results of analysis (both qualitative and quantitative) in terms of Colony Forming Units/m^3 (cfu's/m^3) are shown in *Appendix A*. Laboratory analyses of the samples were carried out by the Texas-based Mycotech Biological Inc. Results of two samples, A16 and A27, were found to be unusably high. Although the reason for these apparent anomaly could not be determined, these results were ignored and the corresponding duplicate samples, A15 and A28, were utilized for analysis. For all other cases, an average of both samples were used.

It is evident from *Appendix A* that the major types of microbial contaminants are Cladosporium, Penicillium, Curvularia, Aspergillus, Sterile hyphae, Yeast, and Bacteria. According to Mycotech[1] Cladosporium, Penicillium, Curvularia, Aspergillus, and yeast are known and documented aeroallergen. These fungi cause an allergic reaction to hypersensitive individuals at low airborne concentrations. Chronic exposure to these

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[1] Comment Reference Page attached with reports, Mycotech Biological Inc. Jewett, Texas.

fungi, at moderate to high airborne concentrations, may also result in the sensitization and development of allergic disease in previously unaffected individuals. In addition, Curvularia and Aspergillus are also noted as opportunistic pathogen. Some diseases may remain localized in certain areas or tissues, while others may become widely disseminated through the body. Many factors affect host contraction; however, these fungi will typically infect only those who are immuno-compromised. Immuno-compromization may be a function of age, sex, race, state of health, or nutrition. Individuals exposed to immunotherapy, chemotherapy, radiotherapy, immunosuppressant drugs, or who have contracted an immunological disorder, are at greater risk of infection. Mycotech further notes that Sterile hyphae is believed to be an aeroallergen; however, this fungus did not produce spores in laboratory culture. Without sporulation a formal taxa cannot be determined and are collectively termed "sterile hyphae."

Table 5.7 shows the total CFU's/m^3 for the two homes under study with percent changes from pre to during, pre to post, pre-indoor to pre-outdoor, and post-indoor to post-outdoor. The pre, during, and post concentrations are also shown graphically in *Figure 5.9*. These results indicate that CFU's/m^3 are higher during cleaning than the pre-level and that the post-level readings are lower than the pre-level readings. This is consistent with the results of the Phase I study, as reproduced in *Table 5.8*. These observations suggest that cleaning procedures are effective in reducing the level of bioaerosol

Table 5.7
Andersen - cfu's/m3 (Pre, During, 48-hr Post)
Total (Average of 2 samples)
Phase II Study

	Indoor					*Outdoor*			
Homes	Pre	During	% Change Pre to During	Post - 48 hr.	% Change Pre to Post	Pre	Post - 48 hr.	% Change Pre-ind to Pre-outd	% Change Post-ind to Post-outd
AirSweep 1	256	293	14.45	112	-56.25	1172	204	357.81	82.14
MechBrush 1	98	212	116.33	66	-32.65	1172	204	1095.92	209.09

FIG.5.9-Andersen - cfu's/m3 (Total)

Phase II (Pre, During, 48-hr Post)

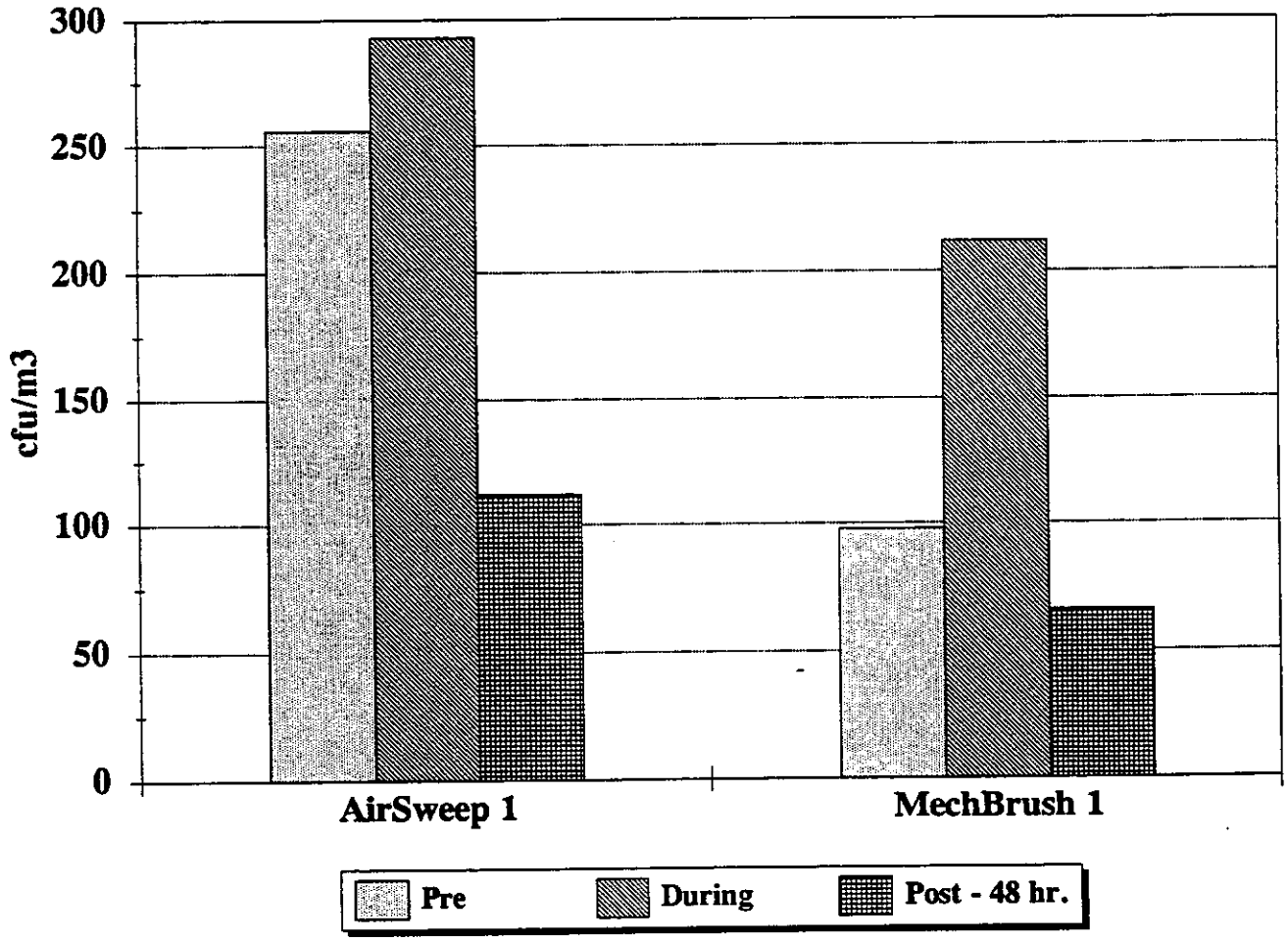

Table 5.8
Andersen - cfu's/m3 (Pre, During, 48-hr Post)
Total (Average of 2 samples)
Phase I Study

	Indoor					*Outdoor*			
Homes	Pre	During	% Change Pre to During	Post - 48 hr.	% Change Pre to Post	Pre	Post - 48 hr.	% Change Pre-ind to Pre-outd	% Change Post-ind to Post-outd
AirSweep 1	563	657	16.70	154	-72.65	158	507	-71.94	229.22
MechBrush 1	283	723	155.48	157	-44.52	673	376	137.81	139.49

contaminants. In both Phases of our study the AirSweep method was found to be more effective in reducing the concentration of bioaerosols than the MechBrush method.

The results of Andersen sampling of the long-term effects of cleaning are shown in *Table 5.9* and *Figure 5.10*. The 12 month sample collected from the AirSweep home showed a higher contamination than the previous 9 month sample, perhaps an indication that the contamination is growing. In the MechBrush home, however, all four readings were found to be falling within a close range. On the basis of these limited observations it can be said that the longer-term effectiveness of the MechBrush method on bioaerosol contamination is better than the AirSweep method.

Outdoor fungal bioaerosol concentrations were found to be higher than corresponding indoor readings except for the 3-month samples, which were collected in the month of January. In winter months outdoor concentrations are typically on the lower side. Outdoor samples collected in September and July are on the higher side as expected.

Mycotech Biological Inc. issued Fungal Bioaerosol Guidelines[1] as attachment to their reports of sample analysis. On comparison between indoor and outdoor concentration Mycotech states,

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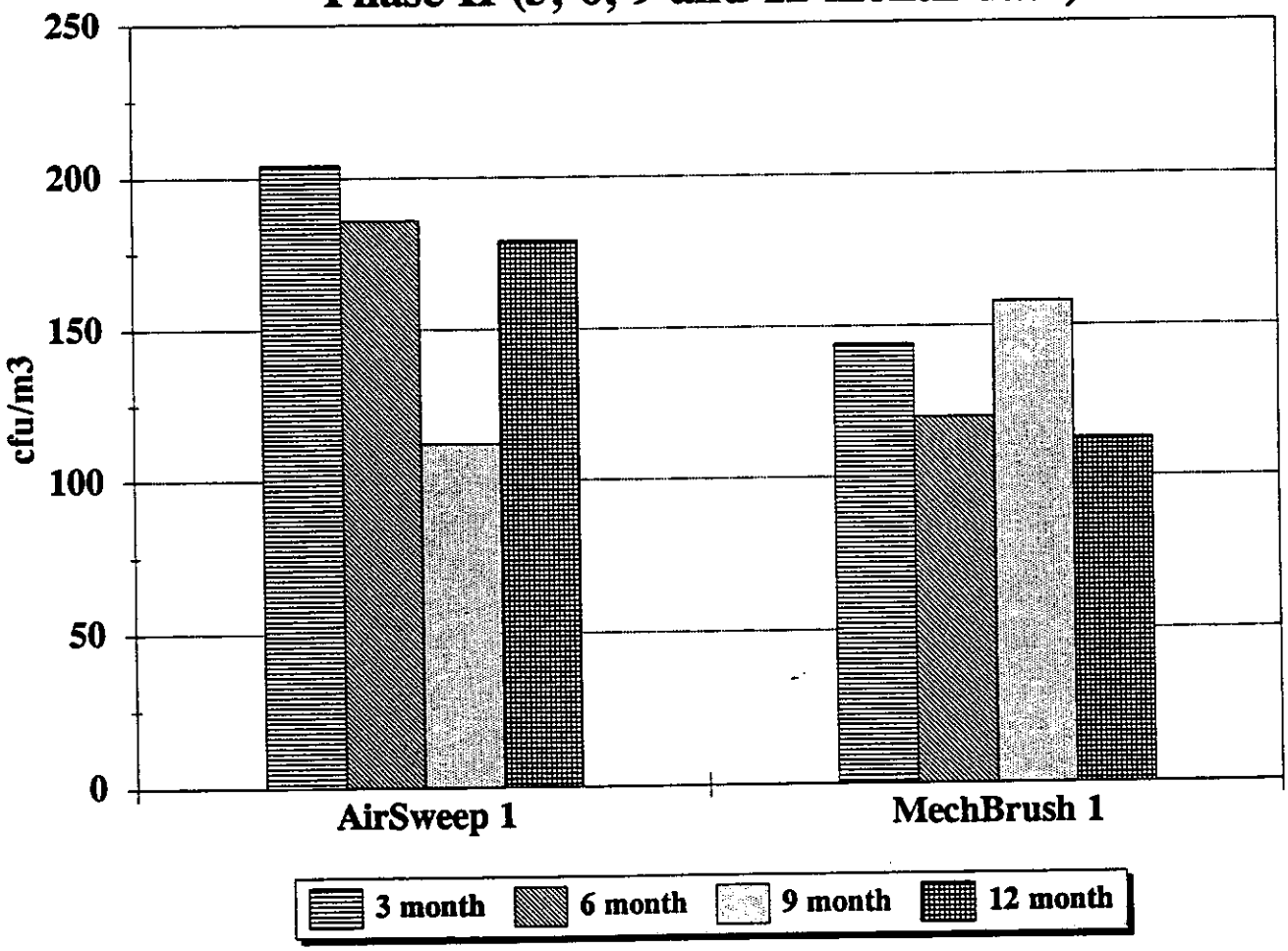
[1]Fungal Bioaerosol Guidelines, 1995, Mycotech Biological Inc., Jewett, Texas.

Table 5.9
Andersen - cfu's/m3 (3, 6, 9 and 12 month data)
Total (Average of 2 samples)
Phase II Study

	Indoor				*Outdoor*			
Homes	3 month	6 month	9 month	12 month	3 month	6 month	9 month	12 month
AirSweep 1	204	186	112	179	123	254	690	636
MechBrush 1	144	120	158	113	123	254	690	636

FIG.5.10-Andersen - cfu's/m3 (Total)

Phase II (3, 6, 9 and 12 month data)



"As a general rule, outdoor and indoor fungal populations (type of organisms) should be similar (Reynolds 1990[1], ACGIH[2], Adams and Hyde 1965[3], Solomon et al 1980[4]). Several references cite the comparison of outdoor and indoor concentrations as a means to evaluate indoor bioaerosols. In 1987, the ACGIH cited that indoor fungal counts should be less than half - or a 33% indoor/outdoor ratio - of the outdoor level in mechanically ventilated buildings. Adams and Hyde 1965, and Solomon et al 1980 cite that indoor levels should be lower than outdoor levels. Toth 1992[5] cite that mechanically ventilated buildings should have fungal counts less than half those of outdoor levels. Despite these referenced documents, a strict comparison of indoor/outdoor concentration as a means to evaluate

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[1]Reynolds,S.J., A.J.Streifel, and C.E.McJilton. 1990. Elevated airborne concentrations of fungi in residential and office environments. *American Industrial Hygiene Association Journal*. Vol. 51:pp 601-604.

[2]American Conference of Governmental Industrial Hygienists (ACGIH). 1989. *Guidelines for the Assessment of Bioaerosols in the Indoor Environment*. ACGIH, Cincinnati, Ohio, USA.

[3]Adams, K.F., and H.A. Hyde. 1965. Pollen grains and fungal spores indoors and out at Cardiff. *Journal of Palynology*. Vol. 1:p. 67.

[4]Solomon, W.R., H.P.Burge, and J.R.Boise. 1980. Exclusion of particulate allergens by window air conditioners. *Journal of Allergy and Clinical Immunology*. Vol. 65:p. 305.

[5]Toth, C. 1992. Microbials in the overall context of indoor air quality investigation. Proceedings of the First Annual IAQ Conference and Exposition. pp. 255-259.

indoor fungal bioaerosols should generally be avoided. Outdoor levels have been documented to range from 1000 cfu/m^3 to 10,000 cfu/m^3 in summer months. A false negative would result if indoor/outdoor comparison guidelines were applied to this maximum summer concentration. 5000 cfu/m^3 or one-half of the outdoor 10,000 cfu/m^3, is not considered tolerable for an indoor environment. Additionally, a false positive would result if indoor/outdoor comparisons were made in winter months, especially in certain geographical locations that exhibit very low outdoor bioaerosol concentrations due to snow cover. It should be noted that the revised 1989 Guidelines for the Assessment of Bioaerosols in the Indoor Environment, ACGIH, has omitted verbiage citing of indoor and outdoor comparison."

It was noted that the samples collected for the Phase II study indicated a lower counnt of cfu/m^3 when compared to Phase I study samples before cleaning. This might be an indication of the fact that the houses remained relatively clean during the one and a half year time period between the two Phases of our study.

On the limits of fungal bioaerosol concentration the Mycotech Guidelines state:

"Fungal bioaerosol concentrations of 1000 cfu/m^3 have been reported as tolerable for indoor environments

(Morey et al 1984[1], Brief and Bernath 1988[2]),however, more data suggest that the health effects from the inhalation of these spore quantities may be severe enough to recommend considerably lower tolerance limits (Etkin 1994[3])."

Mycotech guidelines further state, "Indoor airborne samples should contain less than 300 cfu/m^3 of common fungi (e.g. Cladosporium) and less than 150 cfu/m^3 of all other mixed species, other than pathogenic and toxigenic species (Miller et al[4] 1988). Indoor levels under 100 cfu/m^3 are of no concern unless dealing with an immunocompromised population (Toth[5] 1992). Fungal spore levels in excess of 500 cfu/m^3 (in winter) indicate that a building or residence has abnormal sources and/or

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[1]Morey, P.R. 1984. Environmental studies in moldly office buildings: Biological agents, sources, preventive measures. *Annals of the American Conference of Governmental Industrial Hygienists*. Vol.10:pp. 21-36.

[2]Brief, R.S. and T. Bernath. 1988. Indoor pollution: Guidelines for prevention and control of microbiological respiratory hazards associated with air conditioning and ventilation systems. *Applied Industrial Hygiene*. Vol. 3: pp. 5-10.

[3]Etkin, D.S. 1994. Biocontaminants in indoor environments. *Update: A Guide to the Practical control of Indoor Air Problems*. Cutter Information Corp. Arlington, MA. P.60.

[4]Miller, J.D., A.M.LaFlamme, Y.Sobol, P.Lafontaine, and R.Greenhalgh. 1988. Fungi and fungal products in some Canadian houses. *International Biodeterioration*. Vol. 24:pp. 103-120.

[5]Toth, C. 1992. Microbials in the overall context of indoor air quality investigation. *Proceedings of the First Annual IAQ Conference and Exposition*. pp. 255-259.

insufficient ventilation (Reponen et al[1] 1990)."

5.3.2 HVAC Biological Sampler

As stated earlier, the HVAC method is a simpler version of biological sampling that can be used in lieu of sophisticated and expensive methods (such as Andersen) for limited purposes. It can be used as a screening method to decide if further investigation is necessary. The samples were collected in duplicate for every home before (pre) and after (post). Samples were collected only indoor for obvious reasons. During readings were not collected since the AC unit could not be turned on during cleaning. Samples were also collected every three months for four more times after cleaning in a similar manner.

The results of the complete analysis, expressed in terms of CFU's/sample are shown in *Appendix B*. Again, as in the Andersen procedure, the major contaminants were found to be Cladosporium, Penicillium, Sterile Hyphae, Yeast, and Bacteria. Samples numbered, H4, H5, and H12 indicated inconsistent results and were not considered to compute the average. The corresponding duplicate samples H3, H6, and H11 were used, instead. In all other cases, an average value was obtained from the two duplicate

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[1]Reponen, T., A.Nevalainen, M.Jantunen, M.Pellikka,and P.Kalliokoski. 1990. Proposal for an upper limit of the normal range of indoor air bacteria and fungal spores in the subarctic climate. *Proceedings of Indoor Air `90: 5th International Conference on Idoor Air Quality and Climate*. Vol. 2:pp. 47-50.

samples for analysis.

According to Mycotech Biological, Inc., relative amounts of cfu's can be utilized to identify the level of biological contamination originating from HVAC unit; cfu values between 0-5 are considered typical; cfu values between 6-10 suggest moderate contamination; cfu values greater than 10 may suggest severe HVAC contamination.

Results of sample analysis using this procedure is shown in *Table 5.10*. Again, it is worth noting that the concentrations are on the lower side when compared to the corresponding Phase I study results, shown in *Table 5.11*. Long-term resuslts (3,6,9 and 12 months) are shown in *Table 5.12* and *Figure 5.11*. Although, results are relatively low, the 12-month data of both AirSweep and MechBrush homes indicate a rising trend in fungal bioaerosol concentraion.

Air velocities, in terms of ft/min, taken at the master bedroom air register while the AC unit was kept on, are shown in *Table 5.13* for pre, and post-48 hr data and in *Table 5.14* for 3,6,9 and 12 month data.

The readings reported in Tables 5.13 and 5.14 are taken using hand-held velocity measurement device. As such variations in the order of 10% are expected. Therefore, a negative change of less than 10% in AirSweep 1 48-hr after cleaning, can be attributed to such variations. It should be pointed out that a positive change was expected after cleaning. Nevertheless, we can

conclude that, velocity did not increase significantly in the AirSweep method. An increase in velocity was observed in this house in the 9-month reading. It could have been caused by replacement of the old dirty filter by a new clean one. This is also consistent with our CFM readings reported in Table 4.2.

Table 5.10
HVAC - cfu's/sample (Pre, During, 48-hr Post)
Total (Average of 2 samples)
Phase II Study

	Indoor		
Homes	Pre	Post-48 hr	% Change Pre to Post
AirSweep 1	5	8	60.00
MechBrush 1	0	3.5	

Table 5.11
HVAC - cfu's/sample (Pre, During, 48-hr Pos
Total (Average of 2 samples)
Phase I Study

	Indoor		
Homes	Pre	Post-48 hr	% Change Pre to Post
AirSweep 1	108.5	16	-85.25
MechBrush 1	79	17	-78.48

Table 5.12
HVAC - cfu's/sample (3, 6, 9 and 12 month data)
Total (Average of 2 samples)
Phase II Study

	Indoor			
Homes	3 month	6 month	9 month	12 month
AirSweep 1	4	6	2.5	9
MechBrush 1	7.5	4.5	5.5	11

FIG. 5.11-HVAC - cfu's/sample (Total)

Phase II (3, 6, 9 and 12 month data)

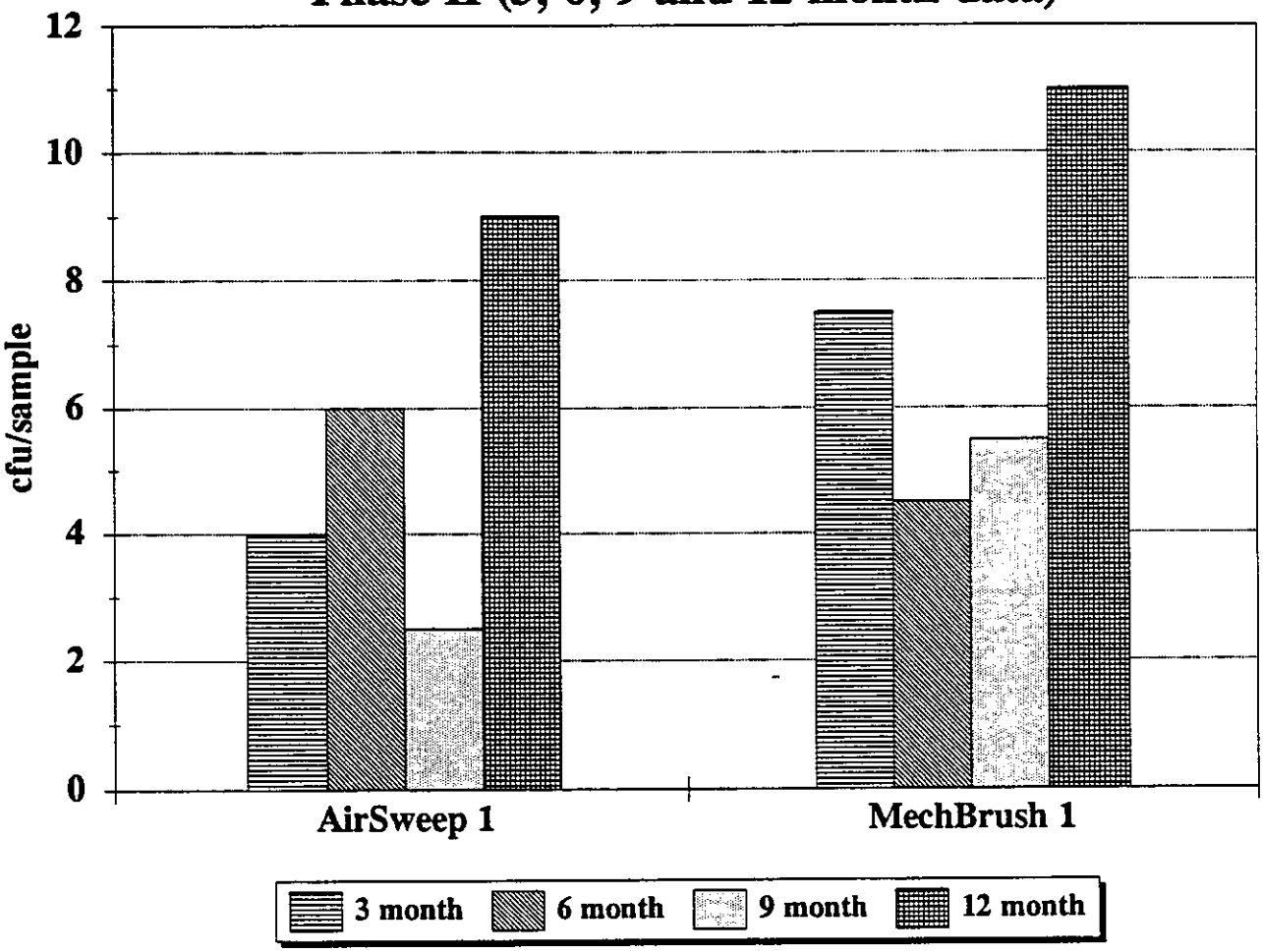

Table 5.13. HVAC Velocities in ft/min. - Pre/Post Comparison

Home	Pre				Post-48 hr				% Change Pre to Post
	Test 1	Test 2	Test 3	Average	Test 1	Test 2	Test 3	Average	
AirSweep 1	1000	810	990	933	955	1040	610	869	-6.86
MechBrush 1	610	540	480	543	550	1040	540	710	30.8

Table 5.14. HVAC Velocities in ft/min. - Long term readings

Home	3-month				6-month			
	Test 1	Test 2	Test 3	Average	Test 1	Test 2	Test 3	Average
AirSweep 1	980	820	730	843	850	1000	680	843
MechBrush 1	910	1080	1050	1013	750	1020	550	773

Table 5.14 (Continued). HVAC Velocities in ft/min. - Long term readings

Home	9-month				12-month			
	Test 1	Test 2	Test 3	Average	Test 1	Test 2	Test 3	Average
AirSweep 1	1050	1150	830	1010	860	1040	740	880
MechBrush 1	720	810	900	810	680	920	840	813

APPENDIX A

Andersen Sampling

ANDERSEN SAMPLING (CFU's/m3)

SAMPLE	HOME DESIGNATION	TIME-LOCATION	TOTAL	Alternaria	Aspergillus	Paecilo-myces	Mucor	Auerobasi-dium	Cladosporium	Curvuiaria	Geotrichum	Penicillium
A1	AirSweep 1	Pre-Indoor	203		7		7	7	98	28		
A4	AirSweep 1	Pre-Indoor	310		7			14	113	7		21
A6	AirSweep 1	During-Indoor	184			7			28	71		7
A8	AirSweep 1	During Indoor	402		14		14		127	21		163
A10		Pre-Outdoor	1313		7				1130			64
A12		Pre-Outdoor	1031						841			85
A13	MechBrush 1	Pre-Indoor	112		14	7			28			14
A14	MechBrush 1	Pre-Indoor	84		14	7			14			7
A15	MechBrush 1	During-Indoor	212	21	28		7		64	21		14
A16	MechBrush 1	During-Indoor	847		650	7			21			35
A17	AirSweep 1	48hr-Indoor	140		7				21	21		49
A18	AirSweep 1	48hr-Indoor	84		7		7			28		7
A19		48hr-Outdoor	218			42			14			14
A20		48hr-Outdoor	190			21			35			21
A21	MechBrush 1	48hr-Indoor	98						28			7
A22	MechBrush 1	48hr-Indoor	56					7	21		7	
A23	MechBrush 1	3mo-Indoor	133	21					49	28		14
A24	MechBrush 1	3mo-Indoor	155						42	85		14
A25		3mo-Outdoor	70	21					35	7		
A26		3mo-Outdoor	176						99			7
A27	AirSweep-1	3mo-Indoor	1045						671	21		311
A28	AirSweep-1	3mo-Indoor	204						141			49
A29	AirSweep-1	6mo-Indoor	126	7					42	7		28
A30	AirSweep-1	6mo-Indoor	246						134	14		42
A31		6mo-Outdoor	282						170	14		14
A32		6mo-Outdoor	225						141	7		14
A33	MechBrush 1	6mo-Indoor	113		14				7	7		
A34	MechBrush 1	6mo-Indoor	126						135			14

ANDERSEN SAMPLING (CFU's/m3) *(Continued)*

SAMPLE	HOME DESIGNATION	TIME-LOCATION	TOTAL	Alternaria	Aspergillus	Paecilo-myces	Mucor	Auerobasi-dium	Cladosporium	Curvuiaria	Geotrichum	Penicillium
A35	MechBrush 1	9mo-Indoor	225		28					49		
A36	MechBrush 1	9mo-Indoor	91		21					35		
A37	AirSweep 1	9mo-Indoor	49		14				7			
A38	AirSweep 1	9mo-Indoor	175		35					49		7
A39		9mo-Outdoor	636							247		106
A40		9mo-Outdoor	743							177		
A41	AirSweep 1	12mo-Indoor	112		14					35		49
A42	AirSweep 1	12mo-Indoor	246			64				42		21
A43		12mo-Outdoor	600							141		353
A44		12mo-Outdoor	671						35	71		353
A45	MechBrush-1	12mo-Indoor	148							14		14
A46	MechBrush-1	12mo-Indoor	77								7	49

ANDERSEN SAMPLING (CFU's/m3) *(Continued)*

SAMPLE	HOME DESIGNATION	TIME-LOCATION	Fusarium	Phoma	Rhizopus	Stachy-botrys	Sterile hyphae	Yeast	Bacteria	Epicoccum	Acremonium	Monilia
A1	AirSweep 1	Pre-Indoor					42	14				
A4	AirSweep 1	Pre-Indoor			14		85	35	14			
A6	AirSweep 1	During-Indoor					57	14				
A8	AirSweep 1	During Indoor					42	21				
A10		Pre-Outdoor	21		7		21	42	21			
A12		Pre-Outdoor	7	7			28		14			
A13	MechBrush 1	Pre-Indoor					21					28
A14	MechBrush 1	Pre-Indoor					7	14				21
A15	MechBrush 1	During-Indoor	57									
A16	MechBrush 1	During-Indoor					85	35				14
A17	AirSweep 1	48hr-Indoor			7		21	14				
A18	AirSweep 1	48hr-Indoor					7	14	14			
A19		48hr-Outdoor					120	28				
A20		48hr-Outdoor	7				57	21	7			
A21	MechBrush 1	48hr-Indoor					28	21	14			
A22	MechBrush 1	48hr-Indoor					14		7			
A23	MechBrush 1	3mo-Indoor				21				14		
A24	MechBrush 1	3mo-Indoor										
A25		3mo-Outdoor					7					
A26		3mo-Outdoor	35					35				
A27	AirSweep-1	3mo-Indoor					21	21				
A28	AirSweep-1	3mo-Indoor					14					
A29	AirSweep-1	6mo-Indoor					35		7			
A30	AirSweep-1	6mo-Indoor					28	14	14			
A31		6mo-Outdoor					49	14	7			
A32		6mo-Outdoor					21	14	14		14	
A33	MechBrush 1	6mo-Indoor					64	7	14			
A34	MechBrush 1	6mo-Indoor					35	28	14			

ANDERSEN SAMPLING (CFU's/m3) *(Continued)*

SAMPLE	HOME DESIGNATION	TIME-LOCATION	Fusarium	Phoma	Rhizopus	Stachy-botrys	Sterile hyphae	Yeast	Bacteria	Epicoccum	Acremonium	Monilia
A35	MechBrush 1	9mo-Indoor					71	21	56			
A36	MechBrush 1	9mo-Indoor					21		14			
A37	AirSweep 1	9mo-Indoor					7	21				
A38	AirSweep 1	9mo-Indoor					21	14	49			
A39		9mo-Outdoor					141	71	71			
A40		9mo-Outdoor	71				318	71				106
A41	AirSweep 1	12mo-Indoor					7	7				
A42	AirSweep 1	12mo-Indoor					42	7	70			
A43		12mo-Outdoor					106					
A44		12mo-Outdoor					212					
A45	MechBrush-1	12mo-Indoor					14		106			
A46	MechBrush-1	12mo-Indoor					14		7			

ANDERSEN SAMPLING (CFU's/m3) *(Continued)*

SAMPLE	HOME DESIGNATION	TIME-LOCATION	Tricho-derma	Pleospora
A1	AirSweep 1	Pre-Indoor		
A4	AirSweep 1	Pre-Indoor		
A6	AirSweep 1	During-Indoor		
A8	AirSweep 1	During Indoor		
A10		Pre-Outdoor	49	
A12		Pre-Outdoor		
A13	MechBrush 1	Pre-Indoor		
A14	MechBrush 1	Pre-Indoor		
A15	MechBrush 1	During-Indoor		
A16	MechBrush 1	During-Indoor		
A17	AirSweep 1	48hr-Indoor		
A18	AirSweep 1	48hr-Indoor		
A19		48hr-Outdoor		
A20		48hr-Outdoor	21	
A21	MechBrush 1	48hr-Indoor		
A22	MechBrush 1	48hr-Indoor		
A23	MechBrush 1	3mo-Indoor		
A24	MechBrush 1	3mo-Indoor		
A25		3mo-Outdoor		
A26		3mo-Outdoor		
A27	AirSweep-1	3mo-Indoor		
A28	AirSweep-1	3mo-Indoor		
A29	AirSweep-1	6mo-Indoor		
A30	AirSweep-1	6mo-Indoor		
A31		6mo-Outdoor		7
A32		6mo-Outdoor		
A33	MechBrush 1	6mo-Indoor		
A34	MechBrush 1	6mo-Indoor		

SAMPLE	HOME DESIGNATI	TIME-LOCATION	Tricho-derma	Pleospora
A35	MechBrush 1	9mo-Indoor		
A36	MechBrush 1	9mo-Indoor		
A37	AirSweep 1	9mo-Indoor		
A38	AirSweep 1	9mo-Indoor		
A39		9mo-Outdoor		
A40		9mo-Outdoor		
A41	AirSweep 1	12mo-Indoor		
A42	AirSweep 1	12mo-Indoor		
A43		12mo-Outdoo		
A44		12mo-Outdoo		
A45	MechBrush-	12mo-Indoor		
A46	MechBrush-	12mo-Indoor		

APPENDIX B

HVAC Sampling

HVAC SAMPLING (CFU's/Sample)

SAMPLE	HOME DESIGNATION	TIME	TOTAL	Aspergillus	Cldosporium	Curvularia	Nigrospora	Penicillium	Sterile hypha	Yeast	Bacteria
H1	AirSweep 1	Pre	1						1		
H2	AirSweep 1	Pre	9					2	7		
H3	MechBrush 1	Pre	0								
H4	MechBrush 1	Pre	45	45							
H5	AirSweep 1	48hr-Post	34	3	1						
H6	AirSweep 1	48hr-Post	8		1		2		1		4
H7	MechBrush 1	48hr-Post	4							1	2
H8	MechBrush 1	48hr-Post	3							3	
H9	MechBrush 1	3mo-Post	5		3			2			
H10	MechBrush 1	3mo-Post	10		7				3		
H11	AirSweep-1	3mo-Post	4						1		3
H12	AirSweep-1	3mo-Post	24		2			19	1		2
H13	AirSweep-1	6mo-Post	10	1	1				4		4
H14	AirSweep-1	6mo-Post	2						1		
H15	MechBrush 1	6mo-Post	5		1	1				1	1
H16	MechBrush 1	6mo-Post	4			1		1		1	1
H17	MechBrush-1	9mo-Post	9	2	5			1		1	
H18	MechBrush-1	9mo-Post	2				1				1
H19	AirSweep-1	9mo-Post	5			2	1				1
H20	AirSweep-1	9mo-Post	0								
H21	AirSweep-1	12mo-Post	8		3	2		1			2
H22	AirSweep-1	12mo-Post	10						2		8
H23	MechBrush-1	12mo-Post	7					7			
H24	MechBrush-1	12mo-Post	15					15			

HVAC SAMPLING (CFU's/Sample) *(Continued)*

SAMPLE	HOME DESIGNATION	TIME	Phoma	Sporobolo-myces	Monilla
H1	AirSweep 1	Pre			
H2	AirSweep 1	Pre			
H3	MechBrush 1	Pre			
H4	MechBrush 1	Pre			
H5	AirSweep 1	48hr-Post			30
H6	AirSweep 1	48hr-Post			
H7	MechBrush 1	48hr-Post			
H8	MechBrush 1	48hr-Post	1		
H9	MechBrush 1	3mo-Post			
H10	MechBrush 1	3mo-Post			
H11	AirSweep-1	3mo-Post			
H12	AirSweep-1	3mo-Post			
H13	AirSweep-1	6mo-Post			
H14	AirSweep-1	6mo-Post		1	
H15	MechBrush 1	6mo-Post			
H16	MechBrush 1	6mo-Post			
H17	MechBrush-1	9mo-Post			
H18	MechBrush-1	9mo-Post			
H19	AirSweep-1	9mo-Post	1		
H20	AirSweep-1	9mo-Post			
H21	AirSweep-1	12mo-Post			
H22	AirSweep-1	12mo-Post			
H23	MechBrush-1	12mo-Post			
H24	MechBrush-1	12mo-Post			