HVAC/IAQ DIAGNOSTIC EVALUATION
BENNINGTON STATE OFFICE BUILDING
200 VETERANS MEMORIAL DRIVE
BENNINGTON, VERMONT

REPORT COVERS SITE WORK
DECEMBER 7, 2006 THROUGH APRIL 1, 2007

July 2007

TURNER BUILDING SCIENCE & DESIGN, LLC

MECHANICAL ENGINEERS • BUILDING SCIENTISTS • IAQ CONSULTANTS

TURNER
GROUP

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July 13, 2007 via email: merle.miller @ state.vt.us

Mr. Merle Miller
Dept. of Buildings and General Services
2 Governor Aiken Ave., Drawer 33
Montpelier, VT 05633

SUBJECT: Report Regarding Detailed Diagnostic/Evaluation Scope
Emergency Response to Assist the Vermont Dept. of Buildings & General Services
Regarding Indoor Air Quality/HVAC and Building Science Concerns
200 Veterans Memorial Drive
Bennington, Vermont
TBS&D #S0682

Dear Mr. Miller:

In accordance with our approved Scope of Work, we are pleased to offer this report on our observations, testing results, and recommendations concerning the 200 Veterans Memorial Drive, Office Facility. We proposed to evaluate the building and systems compared to applicable guidelines established by ASHRAE, OSHA, ACGIH, US EPA, and the State of Vermont. The focus of this work effort included a general evaluation of the current adequacy of the indoor air quality being provided to the occupants of the facility in accordance with the accepted scope. Our determination of adequacy of the indoor air quality is based on our general knowledge of ASHRAE Standard 62-1999 and 55-1992, and Good Engineering Practice, ACGIH publication *Bioaerosols: Assessment and Control*, and OSHA Technical Manual (TED 1-0.15A), as these guidelines apply to mixed-use, office-type occupancy with a history of expressed indoor air quality concerns. It was requested that we conduct diagnostic evaluations with regard to the types of specific concerns in this facility of reported historical and current health symptoms (allegedly related to occupancy in the building), and to provide corrective action recommendations as warranted.

Our findings and corrective action recommendations made herein are based primarily on our observations and measurements collected in what we believe to be representative areas while on-site, a review of others' historical data as applicable, and pertinent guidelines.

The enclosed report is of a technical nature; therefore, the reader will need to have some technical knowledge of the facility to properly evaluate the findings and recommendations.

We are pleased to serve as professional consultants to The State of Vermont, Department of Buildings and General Services. As directed, we have also worked cooperatively with the Vermont Department of Health and the National Institute of Occupational Safety and Health. Please contact us if there are any questions on subjects presented here that need further clarification. You can reach us in our Harrison, Maine office at (800) 439-3446.

Sincerely,

TURNER BUILDING SCIENCE & DESIGN, LLC

William A. Turner, P.E.
President/CEO

Steven M. Caulfield, P.E., C.I.H.
Sr. Vice President

WAT/sai

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EXECUTIVE BRIEFING

Introduction: In accordance with our approved scope, Turner Building Science & Design, LLC (TBS) conducted appropriate routine measurements and comprehensive technical diagnostic (forensic) observations and analysis with respect to representative HVAC systems, suspect microbial dust, soot, and other pollutant sources, pollutant pathway diagnostics, infrared thermography, and moisture intrusion evaluations.

Results: From all of the data collected, there are only two main observations that we believe make this building stand out as different from many others, that could be related to the elevated disease that has been reported. Determination of any impact of these observations on health within the facility is beyond our scope

One, there is forensic evidence from both laboratory soot analysis and tracer gas studies that boiler soot has been and continues to be deposited throughout the facility.

Two, multiple (over 90) microbial reservoirs have been identified in various locations throughout the facility, and there is again forensic evidence that dissemination from these site will readily occur.

Details of the above results and many others are contained within the report and the Appendix. There are thirteen (13) corrective action recommendations listed below that address the above two (2) items and many other items within the facility.

RECOMMENDATIONS

In order to understand the details of these items listed below and the specific objectives of each recommendation, the reader is directed to Section 4.0 of this report pages 36 to 51.

Recommendation #1:	Replace the HVAC System and Controls
Recommendation #2:	Replace the Boiler System
Recommendation #3:	Evaluate the Chiller System
Recommendation #4:	Professionally Clean All Remaining Ductwork and Air Handlers
Recommendation #5:	Rebuild the 1978 Brick Veneer Exterior Walls from the Interior
Recommendation #6:	Reseal the Bermed 1991 Exterior Wall
Recommendation #7:	Professionally Seal the Gross Air Leakage
Recommendation #8:	Replace Failed Windows in the 1978 Wing and Add Operable Windows
Recommendation #9:	Eliminate Perimeter Thermal Bypasses and Gross Wetting in 1978 Floor Slab Areas
Recommendation #10:	Clean and Refinish Building Interior Surfaces
Recommendation #11:	Reduce Excess Outdoor Air Delivery
Recommendation #12:	Isolate and Exhaust All High-Use Photocopying
Recommendation #13:	Further Isolate Tobacco Smoke Away from the Building

1.0 INTRODUCTION AND EXECUTIVE SUMMARY

1.1 Executive Summary

At the request of the State of Vermont Department of Buildings & General Services (BGS), in cooperation with the Vermont Department of Health (VDOH) and the National Institute of Occupational Safety and Health (NIOSH), Turner Building Science & Design, LLC (TBS&D) was contracted to assist BGS and VDOH with diagnostic evaluation and corrective action planning for the Bennington State Office Building, located at 200 Veterans Memorial Drive, Bennington, Vermont. TBS&D determined the extent, type, and location of the diagnostic testing. The nature and extent of the work to be performed was reviewed by VDOH and NIOSH. TBS&D was in no way prevented from performing what we deemed necessary, beneficial, or prudent. Although BGS has at times questioned the need for certain tests, BGS has been careful to make resources available so that TBS&D would not be hindered from conducting recommended evaluations and diagnostic testing.

TBS&D has conducted rather comprehensive HVAC and IAQ evaluations of representative areas of the mixed-use office facility in accordance with original proposed tasks, and as modified to address additional items that arose during the course of our diagnostic services.

Continuous IAQ monitoring of multiple environmental parameters was conducted from January 23, 2007 until February 19, 2007 in selected areas. Many areas were selected to be similar to monitoring locations previously evaluated by ATC Associates, Inc. (ATC) in August through September 2006 for comparison purposes. The TBS&D diagnostic monitoring included near continuous monitoring of Carbon Dioxide (CO_2) (as an indicator of ventilation rate), Carbon Monoxide (CO), temperature, relative humidity, monitoring for inhaleable, respirable, and fine-fraction dusts (particles), and monitoring of several building pressures related to the Boiler Room operation.

We also conducted appropriate technical diagnostic observations and analysis with respect to representative HVAC systems, suspect microbial dust, soot, and other pollutant sources, pollutant pathway diagnostics, infrared thermography, and moisture intrusion evaluations. Our scope did not include conducting comprehensive interviews of occupants, which were primarily conducted by VDOH and NIOSH. However, when requested by management, we did meet with several occupants who had expressed concerns or complaints.

Our scope did not include an independent review of the current medically reported health concerns. However, we have worked closely with personnel of the Vermont Department of Health to initially understand some of the medical information that is available to the department regarding specific locations of disease incidence that could be related to building occupancy. This report concludes all currently approved observations, measurements, and reporting of data available to TBS&D as outlined in our general and additional approved Scope of Work and Budget.

In Section 1.2 that follows, we have presented a brief summary of findings/conclusions, followed by a listing of corrective action recommendations in Section 1.3. In order to understand the specific details and objectives of each recommendation, the reader is directed to Section 4.0 of this report, pages 36 to 51.

1.2 Findings/Conclusions Summary

1) **Measured Environmental Parameters are Typical:** *Based on relatively large volumes of high quality, representative, current, and recent historical <u>common environmental measurements</u>, (conducted by both ATC and TBS&D) current exposure to the air currently provided inside the facility would be considered similar to many typical office buildings located in a mixed-use, urban/rural setting.* These environmental measurements include the amount of outdoor air provided (apparent ventilation rate), which is based on Carbon Dioxide Measurements, typical temperature/humidity control, and eight-hour average inhalable and respirable particle exposures.

   It should be noted that unless these routine measurement results are very unusual compared to expected levels, these types of routine measurements are not likely to indicate conditions or sources that would be expected to exacerbate disease.

2) **Facility Provides Shelter to Some Outdoor Pollutants:** As tested, the particle data indicates that the building provides shelter from some outdoor pollutants that typically originate outside the building such as inhalable and breathable particles (dusts and fine dirt). This benefit is achieved through good particle filtration of supply air during the normal work week period. This observation appears to hold throughout the monitoring period, both before and after the introduction of the stand-alone HEPA filters that were added to the building complex during our monitoring period.

3) **The Building's Boilers Have a Direct and Indirect Impact on the Facility:** The overall data generated by TBS&D indicates that the building experiences a direct (internal) impact (transport) of combustion materials from its own boilers. The current rooftop discharge also impacts the air quality immediately adjacent to

both rooftops. Both occupant historical complaints and laboratory analyzed indoor soot deposits indicate that this situation has existed for quite a long period of time. The lab analysis data also indicates that the soot has been carried throughout the facility. Its distribution is facilitated in part by normal building air leakage (item #5) and associated stack effect (particularly in off-hours, cold weather operation when the HVAC systems are normally in the unoccupied mode, and the stack effect inside the facility would dominate air flow within the facility).

The direct impact of the boilers may have been more significant in previous years prior to some reported corrective action modifications and the current in-place abandonment of some ventilation systems. Also, the current direct impact, and indirect impact from re-entrainment, would be expected to be worse during late fall and early spring swing-season-weather when frequent cold firings occur (producing more soot and fumes), compared to the cold weather of February 2007 when TBS&D conducted the majority of our monitoring.

The oil-fired, hot water boiler and chimney configuration in this building complex is somewhat difficult to correct because of the Boiler Room's location. We have addressed some options for corrective action in the recommendations section of the report. Additionally, we have recommended that all deposited soot indoors be carefully removed with detergent washing of any large surface areas, and that all ductwork be professionally cleaned prior to re-occupancy. Information on the composition of typical soot is contained in Appendix B3.

4) **Settled Dust Microbial Analysis/Moisture Sources:** Based on TBS&D observations and representative sample laboratory data results, there are a few identified areas in the facility where moisture has been present in the past that contributed to small areas of localized hidden mold growth in some carpets, within walls, and above suspended ceilings.

   Some of these areas are perimeter wall locations that are currently observed to be wet where wind driven rainwater intrusion has occurred. One wall exposure in particular in the Court facility is explained further in the report. There are also locations above ceilings where heating system pipes have leaked in the past, and where pipe condensation, or roof leaks have dripped on ceiling tiles.

   Via intrusive disassembly, TBS&D has confirmed that there <u>are</u> in fact appropriate vapor barriers located under the slabs on the ground floor levels, and that the few local areas of hidden moisture in the exterior wall assemblies are <u>not</u> a widespread occurrence throughout the facility.

A few areas of settled dust tested on upper floors revealed elevated levels of specific organisms in carpet dust. We have no apparent explanations for these results. It is possible these upper floor areas have been impacted by HVAC reservoirs (see item #8), occupant traffic patterns, or maintenance practices.

A few known problem areas are detailed in the report and these areas need to be systematically addressed and eliminated prior to re-occupancy. TBS&D had also recommended to NIOSH, VDOH, and BGS that further extensive carpet dust evaluation might be useful. As of this writing, it is our understanding that NIOSH has provided additional funding to undertake a systematic look at carpet dust. These additional laboratory analyses may add additional information and insight beyond what has been generated to date through TBS&D settled dust analysis for microbial materials.

Based on TBS&D representative analysis, which showed elevated fungal levels, we have currently recommended the replacement of all carpets as a precautionary move, unless the carpet is proven to not have elevated microbial content, and is at the beginning of its useful life.

5) **Building Air Leakage:** Fan pressurization testing, combined with Infrared Thermography, indicated that this building has multiple significant perimeter air leakage sites typical of the construction vintage. Despite it having inoperable sealed windows, it is not a tight building. The air leakage increases energy bills during heating and cooling, allows wind carried boiler fumes to enter, makes the facility very dry in winter, and humid in the summer, and also allows insects (including cluster flies) easy access and refuge in the building interior above ceiling spaces. *Given all the above reasons, we have recommended that these Infrared identified air-leakage sites be systematically, professionally air sealed, prior to re-occupancy.*

   We have also recommended that in addition to the building air sealing, that some small percentage of the window area (±10%) be made operable to allow for improved emergency operation flexibility if the HVAC is non-operational, and to allow for enhanced building ambiance. With a balanced HVAC system, the impact of a small percentage of operable windows properly placed should not be an HVAC control issue or present an energy penalty.

6) **HVAC Design/Controls:** Observations of the HVAC controls reveal that the actual delivery of outside air supply is difficult to control and monitor. An additional concern is that most of the building' planned outside air and exhaust is

provided through heat recovery units, which have limited monitoring capabilities through the control system. This is also particularly a concern when areas are not heavily occupied such as in the Court Complex. This situation can lead to difficulties with keeping humidity levels under control during humid weather (as illustrated in August 2006 ATC data) potential occupant comfort/productivity issues, excess energy consumption, and exacerbation of any localized condensation and subsequent mold growth. As noted above, adequate humidity control is also difficult when uncontrolled air leakage is present. *We have recommended improvements in HVAC design and control to address this situation.*

7) **Building Related Disease:** Given the above mentioned scientific, environmental data (items #1 and #2), it could be concluded that the building is not unlike many other office facilities inhabited by the general population nationwide that are occasionally impacted by combustion byproducts (soot) from oil combustion, experience periodic, minor sewer gas smells from dry traps, have excess air leakage, and are extremely dry in winter, or which are periodically impacted by localized hidden moisture and mold growth.

   However, in addition to the facility having a history of air quality concerns, it is our understanding that in this facility, there are specific, elevated, inflammatory disease rates that are reported by VDOH that appear to be related to the facility's occupancy. The reported inflammatory disease is elevated asthma and asthma-like symptoms, and a disease reported as Sarcoidosis. Although the factors that exacerbate asthma and asthma-like symptoms are fairly well understood, it is our understanding from NIOSH and VDOH communications that the cause or causes of Sarcoidosis are not well understood.

   We regard the finding of boiler soot deposits throughout the facility as a possible health concern that needs further evaluation by qualified health professionals. Any determination of actual impact on health symptoms from observations that we have made is beyond our scope, and is left up to VDOH and NIOSH health professionals.

   Independent of any VDOH and NIOSH health related conclusions, based on our general knowledge of building design and the general principles conveyed in ASHRAE, ACGIH, and NIOSH guidelines, we have recommended in this report corrective actions concerning elimination of the boiler's impact, as well as other corrective action items, including wind driven rain moisture intrusion, identified and suspect microbial growth reservoirs, replacement of many HVAC systems *and controls, and professional cleaning of all ductwork and interior surfaces, prior to re-occupancy.*

8) **Suspect Microbial Reservoir Identified:** Within this building, TBS&D has identified what we consider a likely significant source of potential microbial exposure based on the principles conveyed in the ACGIH publication *Bioaerosols: Assessment and Control*. This suspect microbial source appears to grow within the condensate drainage system for the heat pumps, duct cooling coils, and heat recovery units, which serve many areas of the facility.

   Within this drainage system, we have observed (via tracer gas testing and pressure observations) several airflow mechanisms that will allow microbial materials that exist within the drainage system to be dispersed within the facility (See Appendix C3: Tracer Gas Study and Appendix D3: Condensate Line Plans). In response to requests by TBS&D and BGS, NIOSH and VDOH are in the process of further studying these reservoirs (and characterizing the materials found to be cultured from these locations) to further understand their potential health significance. Any determination of likely health impact from these reservoirs will be up to VDOH and NIOSH.

   Independent of VDOH and NIOSH's results, based on the principles conveyed in the ACGIH publication Bioaerosols: Assessment and Control, and good engineering practice, we have recommended in the report changes to the drainage system to reduce the magnitude of the suspected reservoir's future possible re-occurrence, and to eliminate some of the identified installation details that currently allow distribution to readily occur, prior to re-occupancy.

   However, as of this writing, the degree of decontamination needed to clean the surfaces of the facility from any impact of the materials contained within these reservoirs is currently not well defined. We would expect the level of cleaning for decontamination to be further understood and definable by the results of the NIOSH microbial reservoir laboratory evaluations, and hope to obtain additional recommendations from VDOH and NIOSH regarding the depth of corrective action cleaning warranted.

9) **Other Identified Sources of Irritants:** There are some additional sources of possible irritants that need to be corrected before the re-occupancy of this facility, as part of any modern healthy building design, which incorporates ASHRAE guidelines. Once incorporated, they should be maintained as a long-term building operation strategy. The term irritants is used to describe levels of contaminants well below classic enforceable health based exposure limits (classically

determined by Vermont OSHA or NIOSH), at levels that could be irritating for some individuals.

These sources include, as previously noted, limited moisture intrusion issues in certain specific locations, sewer gas smells from dry sanitary traps, discovered reservoirs of fungi growth in some carpeted areas, and the existence of local walk-up, high-use photocopiers in areas that are not exhausted in accordance with American Society of Heating, Refrigeration & Air-Conditioning Engineers Ventilation guidelines.

As has been reported in the literature (See Appendix D6) localized damp areas, fungi growth in carpets, and Volatile Organic Compounds (VOC's) emitted during reprographics activities, have been shown to potentially contribute to indoor air quality problems (as part of a multi-factorial analysis), and to building-related illness, consistent with some of the asthma-like health symptoms reported in this building. *Thus, in addition to listing these localized sources, we have recommended corrective actions for modifying the HVAC design and mitigation to reduce the identified sources, in order to reduce the environmental conditions that might trigger symptomatic responses.*

10) **Overall Statement:** From all of the data collected, there are only two main observations that we believe make this building stand out as different from many others, that could be related to the elevated disease that has been reported. #1, there is forensic evidence from both laboratory soot analysis and tracer gas studies that boiler soot has been and continues to be deposited throughout the facility. #2, multiple (over 90) microbial reservoirs have been identified in various locations throughout the facility, and there is, again forensic evidence that dissemination from these site will readily occur. Details of the above results and many others are contained within the report and the Appendix. There are thirteen (13) corrective action recommendations listed below that address the above two (2) items and many other items within the facility. Determination of any impact of these observations on health within the facility is beyond our scope.

1.3 Summary of Specific Corrective Action Recommendations

Our work has focused on diagnostic testing in order to identify all current factual information with regard to any building related items that need corrective action to bring them in line with a normal standard for a modern building design that would be suitable for another 20 to 30 years of projected occupancy (foreseeable near-term future). We have summarized the detailed recommendations contained in the report in the topic listing that follows. In order to understand the details of these items listed below and the specific objectives of each recommendation, the reader is directed to Section 4.0 of this report pages 36 to 51.

Recommendation #1: Replace the HVAC System and Controls

Recommendation #2: Replace the Boiler System

Recommendation #3: Evaluate the Chiller System

Recommendation #4: Professionally Clean All Remaining Ductwork and Air Handlers

Recommendation #5: Rebuild the 1978 Brick Veneer Exterior Walls from the Interior

Recommendation #6: Reseal the Bermed 1991 Exterior Wall

Recommendation #7: Professionally Seal the Gross Air Leakage

Recommendation #8: Replace Failed Windows in the 1978 Wing and Add Operable Windows

Recommendation #9: Eliminate Perimeter Thermal Bypasses and Wetting of 1978 Floor Slab

Recommendation #10: Clean and Refinish Building Interior Surfaces

Recommendation #11: Reduce Excess Outdoor Air Delivery

Recommendation #12: Isolate and Exhaust All High-Use Photocopying

Recommendation #13: Further Isolate Tobacco Smoke Away from the Building

1.4 Limitations of TBS&D Study

1.4.1 Environmental Monitoring Limitations

The findings, conclusions, and recommendations contained within this report are based on an intense, short-term monitoring and diagnostic effort by TBS&D to address multiple, significant building factors. We have worked within a short timeline of occupancy to conduct the building diagnostics, produce the data, analyze the data, and make the recommendations contained in our report. Our analysis is in some cases based on what is believed to be representative sampling, conducted over a short time period of remaining occupancy. This testing was often specifically conducted in areas with known possible sources, or in areas reported by occupants to sometimes experience symptoms of irritation. We believe all of the test data to be accurate, and likely representative of much of the overall conditions in the facility during our evaluation period. However, it is impossible to know if it is a good representation of all of the various zones or areas within the facility.

Intrusive disassembly of the suspect continued moisture intrusion locations has been performed as part of this study. There are areas where we have recommended that mitigation occur. During the process of this mitigation, continued investigation in the areas is warranted to determine if there are building characteristics revealed that may warrant additional evaluation regarding the cause of water intrusion, water leakage, or condensation occurrence.

Our study included limited dust sampling for molds and other materials in specific representative areas. Based on our representative findings, we have recommended further exploration of this source of possible irritants by NIOSH. Additional testing by NIOSH is planned. In the absence of further data from NIOSH measurements (as a precautionary move), we have recommended the removal and replacement of all carpeted surfaces within the facility, unless they are proven to not be contaminated with biological growth, and have extensive remaining useful life, along with the cleaning of all interior surfaces.

We have stated in several cases that some unknown factors may remain to be evaluated, but we believe we have identified the most prominent and likely conditions that may have contributed to occupant concerns, complaints, symptoms, or disease.

1.4.2 Medical Review Study Limitations

TBS&D has not conducted a detailed occupant survey, or a medical records review as it is beyond our scope and has been undertaken by VDOH and NIOSH. Any conclusions regarding relationships of the results of TBS&D building diagnostics to any disease related to occupancy by VDOH is the responsibility of VDOH/NIOSH.

2.0 APPROVED SCOPE OF WORK

2.1 General Scope

It is TBS&D's understanding, based on our review of documents, that BGS has invested a significant amount of time and resources investigating the Bennington State Office Building for over ten years. In spite of BGS's previous efforts, which were often assisted by the consulting firms of ATC Associates Inc., and Crothers Environmental Group, it was suggested that further, more in-depth and advanced testing needed to be done. As a result, upon the recommendation of VDOH, Turner Building Science & Design, LLC (TBS&D) was hired to do a diagnostic investigation of the building.

TBS&D's scope of service and recommended diagnostics has evolved with our understanding of the building's history, the building's various systems, and client needs. Our scope was initially proposed as stated in our approved contract dated November 30, 2006 (the proposed scope was based on discussions up to that point). The scope was further revised on December 19, 2006 after our first review of historical materials regarding the facility, our walk-through of December 7, 2006, and communication with VDOH. On January 9, 2007 we further updated the proposed scope after two conference calls with NIOSH, BGS, and VDOH. Finally, after completion of initial site work, TBS&D proposed a revised scope and updated budget on February 27, 2007. To date this final revised scope and budget has not changed.

Throughout all of TBS&D services, we have been in direct contact with NIOSH, VDOH, and BGS regarding scope, findings, and TBS&D recommendations. Status reports have been communicated as five draft documents dated January 30th, February 22nd, March 14th, April 11th, and May 4, 2007. On three occasions TBS&D staff have attended stakeholders meetings and made PowerPoint presentations (see Appendices E1 and E2 for materials). The goal of our efforts was to further understand medical concerns known to NIOSH and VDOH, and to determine if there were any existing building issues that could be scientifically measured that might be correlated to current reported occupant health concerns, symptoms, and disease by VDOH and NIOSH.

In our original proposal, we <u>did not</u> propose to duplicate extensive evaluation work/testing that has been historically conducted in a comprehensive manner. We expected to need to conduct limited HVAC observations in order to validate the most recent reports of existing conditions, conduct building interstitial space observations as warranted, and conduct representative building diagnostic testing, for specific parameters that had not been evaluated, that might be indicative of situations that could exacerbate health symptoms.

All detailed observations and testing were undertaken after we had communicated with NIOSH, VDOH, and BGS officials. All on-site work and communications were coordinated with BGS officials. Any intrusive disassembly or inspection work within the facility was coordinated with VDOH, NIOSH, and BGS officials.

Services were provided in a technical manner based on our contract with the State of Vermont (contract number 10811). All site work was followed-up with verbal reporting and status reports describing our general accomplishments, observations, and general recommendations for any short or long-term improvements, and/or further evaluation, if warranted.

Based on our area of building science expertise, industrial hygiene, mechanical engineering, and building operations, we have conducted diagnostic evaluations and formulated and offered professional opinions regarding the conditions in the building, and items that warrant addressing prior to re-occupancy.

Any recommendations for corrective action or improvements to the building have been developed based on the results of our analysis of measurement data and collected building science information, and any apparent possible relationships to current occupant health concerns, as well as medically reported information made available to us by VDOH. Our building science opinions have been scientifically based following the review and analysis of current data, reports from labs and others, industry standards/guidelines, and TBS&D's observations and building diagnostic evaluations/test results.

Our work has focused on trying to identify all current factual information with regard to any building related items that may need corrective action to bring them in line with a normal standard for a modern building design that would be suitable for another 20 to 30 years of projected occupancy.

The Scope of Work does not currently include the design of corrective measures, nor the surveying or testing for asbestos fibers, or any other pollutants not identified in the revised scopes that have been approved. Additional services could be provided if requested.

We have submitted verbal progress reports and a preliminary draft report for accuracy checks and clarification review, prior to the issuing of a Final Report.

3.0 TESTS PERFORMED TO EVALUATE THE BUILDING IAQ/HVAC

3.1 Carbon Dioxide Concentrations in Buildings

Testing: As part of our HVAC/IAQ evaluation, we measured Carbon Dioxide (CO_2) in occupied spaces to identify if there was potentially inadequate ventilation. Measurements were collected continuously during normal occupied and unoccupied times. Measurement of the CO_2 concentration in the air is one way to measure the amount of ventilation Outdoor Air (OA) delivered to a space. CO_2 concentration in the indoor air of a typical occupied space is a mixture of the CO_2 introduced to the occupied spaces from outdoor sources and from the occupants breathing. CO_2 is a byproduct of the metabolic process involved with respiration; i.e., people release CO_2 into the environment by exhaling.

Outdoor Air, as ventilation, is provided to the occupied spaces of this facility by two means. The first and most prominent is the mechanical ventilation system, which operates during occupied times, and should introduce a preset quantity of OA for ventilation; and second, from infiltration, which is air leaking into the building through cracks in the building envelope via air pressure differences, or operable doors. Based on the Infrared Thermography and fan pressurization data gathered in this facility, the areas where air leaks into the building are primarily at typical wall/roof interface junctions in areas hidden above the suspended ceilings.

Clean OA will normally have a CO_2 concentration of 375 PPM (Part Per Million) +/- 25 PPM, and the concentration of CO_2 in air exhaled by human occupants exceeds 35,000 PPM. Our measurements of CO_2 in the occupied space are the result of the combined sources, occupants, and OA. By applying normalized occupant density factors (from ASHRAE) and typical occupant respiration rates, we can estimate the quantity of OA introduced into the space.

The concentration of CO_2 typically found in office spaces (375 PPM to 3,000 PPM) is <u>not</u> known to present a health hazard to occupants. OSHA has set a limit of 5,000 PPM as the maximum allowable in an occupied workspace. The OSHA limit, however, is not to be confused with ASHRAE or NIOSH guidelines used to evaluate indoor settings. Published data from ASHRAE and NIOSH indicate that CO_2 concentrations more than 600-800 PPM in occupied spaces, when the ambient (outdoor) conditions are in the range of 350 PPM, and indoor population densities are greater than seven (7) people per 1,000 sq. ft., can be <u>expected</u> to result in an increased incidence of reports of poor indoor air quality from the occupants of the space.

Carbon Dioxide concentration in excess of 800-1,000 PPM under normalized measuring conditions are likely an indicator that ventilation rates are less than current ASHRAE recommendations (typically 15-20 CFM per occupant in an office environment).

Note: It should also be noted that levels less than 700 PPM during normally occupied periods are likely an indicator of over-ventilation and typically will be accompanied by excess dryness during cold winter weather periods, and possible excess humidity during humid weather.

Carbon Dioxide was monitored and data logged in the occupied space with TSI Model 8551 portable CO_2 gas monitors, Serial #30071 and Serial #51580.

Results of Data Logging: Levels of Carbon Dioxide were measured near continuously in eight different locations within the facility over four weeks from January 23, 2007 until February 19, 2007. Equipment was checked for calibration at each download period. The data collected generally confirm delivery of outdoor ventilation rates in accordance with current ASHRAE guidelines of 20 CFM per person <u>or greater</u> during the hours of operation of 8:00 a.m. to 4:00 p.m. There are three anomalies in the data worth mentioning.

1) During the four weeks of monitoring in two locations each week, (eight locations total) there are two rooms (#14 and #210), which were identified with somewhat elevated Carbon Dioxide (low ventilation rates) for a period of hours.

   During the week of January 30, 2007 to February 7, 2007, the equipment logged some slightly elevated levels of Carbon Dioxide data in Room #14 during January 31, 2007, accompanied by elevated temperatures. We do not know the cause of this occurrence. The measured low ventilation rates were accompanied by very elevated temperatures during these periods. It appears from what we can determine that the rooms were under normal use during these occasions. If this is the case, the data would imply a local HVAC equipment malfunction or an inadequacy for the occupancy involved. The cause of these excursions is unknown. In a building with continued occupancy, the data would give one occasion to look further to attempt to determine the cause or causes of the short periods of unusual data, to further determine the potential for local or system wide HVAC control, or room overloading problems.

2) During the week of February 6, 2007 to February 14, 2007 the levels in the Family Court Area Room #210 during February 7th and February 8th indicate that the ventilation would not meet ASHRAE guidelines. It is reported that during this time period the rooms were at normal occupancy. The Carbon Monoxide

data for this same time period also appear slightly elevated, 1-2 PPM. However, it is possible that the instrument was affected by the drift of the zero, caused by elevated temperatures, as the temperature data for the same time period also was elevated. We do not know the cause of this occurrence.

3) During the monitoring in the Court Clerk Area from February 14th to February 19th, the data appears to have been collected when the area was clearly unoccupied, as reported was likely to occur. The data is normal for an unoccupied space.

With the exception of the elevated data on February 7th and 8th, the data is similar to Carbon Dioxide data previously collected by ATC in August of 2006 in various locations.

Although the current ventilation rates are adequate for dilution of human body odor (based on the Carbon Dioxide survey data), by observation, the current ventilation design in areas where high-use, walk-up photocopying is conducted in this facility would not meet ASHRAE Standard 62 design guidance for isolation and exhaust of reprographics areas. We have elaborated on this in Section 4.5 of the report.

Recorded measurements of CO_2 concentrations in this facility as measured from January 23, 2007 to February 19, 2007 are found in Appendix A1 of this document. Data for each room monitored is also plotted from 8:00 a.m. to 4:00 p.m., showing maximum, minimum, and average values. Photos of the monitoring locations are found in Appendix D1: Section 3, photo 41,42, Sec. 4, pht. 13 -16, Sec. 5, pht. 3-6, Sec. 7, pht. 16-21.

Results of Spot Carbon Dioxide Checking: Levels of Carbon Dioxide in twelve generally representative areas of the facility were spot-checked for comparison to logged data during walkthrough evaluations on three days when we were on-site to download data loggers, January 30, 2007, February 6, 2007, and February 13, 2007. Equipment was checked for calibration at each download period. The spot-check data is found in Appendix A8. The data is similar to the logged data, and similar to Carbon Dioxide data previously collected by ATC in August of 2006 in various locations.

FINDING/CONCLUSION: The Carbon Dioxide spot measurement and logged data collected by TBS&D, when used as a typical indicator of ventilation air delivery, does not indicate a current routine ongoing problem with lack of enough ventilation air delivery within this facility. To the contrary, it indicates many time periods of apparent over-ventilation. See Section 4.4 and Recommendations #1 and #4.

3.2 Carbon Monoxide within Occupied Spaces

Testing: Carbon Monoxide (CO) is a harmful byproduct of the combustion of carbon containing fuels. Fossil fuel burning equipment located within a building space must be properly vented to the ambient (outside) to limit the spillage of CO and other combustion byproducts into the occupied spaces. Additionally, to prevent CO from tailpipe emissions from entering the building, vehicles must not be allowed to idle in close proximity to the building. NFPA (National Fire Protection Association) publishes guidelines on the proper installation of fossil fuel appliances with respect to CO emissions.

The following list of limits of Carbon Monoxide exposure has been set by each of the listed agencies for specific environments.

- The American Conference of Governmental and Industrial Hygienists (ACGIH)
- The Occupational Safety and Health Administration (OSHA)
- The National Institute of Occupational Safety and Health (NIOSH)

Exposure limits, Threshold Limit Value (TLV) for CO in an industrial setting:

- 35 PPM Time Weighed Average (TWA-10 Hr) NIOSH
- 50 PPM Time Weighed Average (TWA-8 Hr) OSHA
- 200 PPM Ceiling Limit, NIOSH

(OSHA, 29 CFR 1910.1000, Table Z-1, C-12)

(VOSHA 1910.1000 PELs) is 35 PPM 8hr TWA, 200 PPM ceiling limit.

> The above limits are considered industrial workplace guidelines, and are considered extreme upper limits to be applied to work areas where occupants are expecting to receive some exposure to CO fumes. The limits are also intended for workplaces where the airborne concentrations are monitored and controlled to prevent unsafe conditions.

The US EPA National Air Quality Standards

- 9 PPM as a limit for an 8-hour average
- 35 PPM as a limit for a 1-hour average

(EPA, 40 CFR 50.8, C9)
The above guidelines are intended to protect the general public.

The World Health Organization (WHO)

- List concentrations greater than 5 PPM for more than one hour as a concern.

We collected data utilizing TSI Q-Trak data loggers, Model 8551 (Serial #30071 and Serial #51580) with a CO sensor in multiple areas over a four-week period. The sensors were calibrated at the beginning of the study, checked during each download, and validated at the completion of testing.

Results: We observed one brief period of time during our entire four week study when the CO concentrations appeared clearly above the normal zero (0-1) PPM routine zero drift of the instrumentation used. This observation occurred during a short time period in Room #210 on February 7, 2007, which was also accompanied by excess heat. It is possible that the slightly elevated CO reading is a byproduct of zero drift in the instrumentation from the increased room temperatures. Laser particle count data for 0.5 microns does not indicate elevated particles of combustion size during the same time period in this room. The monitoring equipment was checked for calibration at each download period.

The logged, near zero, Carbon Monoxide data throughout the facility is similar to Carbon Monoxide data previously collected by ATC in August of 2006 in various locations.

Results of Spot Checking: Levels of Carbon Monoxide in twelve representative areas of the facility were spot-checked for comparison for logged data during walkthrough evaluations on three days (when we were on-site). Data loggers were downloaded on January 30, 2007, February 6, 2007, and February 13, 2007. Please see Appendix A8 for data results. The spot check data is similar to the logged data, and similar to Carbon Monoxide data previously collected by ATC in August of 2006 in various locations.

> **FINDINGS/CONCLUSIONS:** The Carbon Monoxide data logging information collected by TBS&D during this time period, when used as an indicator of combustion impact, does not indicate any current concern or routine problem with Carbon Monoxide being present in the facility at elevated levels which would be considered hazardous or irritating.

3.3 Building Temperature and Humidity Testing

Testing: Space air temperatures and humidity were monitored in the selected locations within the occupied areas and outdoors. The thermometer and humidity sensor in the TSI Model 8551 IAQ monitor (Serial #30071 and Serial #51580) was used to measure the space dry bulb temperatures and relative humidity values.

ASHRAE (American Society of Heating, Refrigeration, and Air-Conditioning Engineers) provides guidelines for thermal comfort in office environments. The recommended temperature and relative humidity ranges are based on the type of activities typically performed within the environment. These guidelines are a subset of the acceptable temperature and humidity conditions for human occupancy, as presented in ASHRAE Standard 55-1992 "Thermal Environmental Conditions for Human Occupancy". The ASHRAE recommended temperatures and humidity of office and classroom spaces are provided in Chapter 3 of the ASHRAE 2003 "HVAC Applications" and are summarized in Table 1 "General Design Criteria". ASHRAE recommends temperatures in the range of 70 to 74^{o}F based upon a humidity range of 20 to 30% in winter seasons, and 74 to 78^{o}F based upon a humidity range of 40 to 50% during the summer season. It has been our experience that office buildings with consistent predictable temperatures in the range of 72-74 ^{o}F appear to satisfy the majority of people and produce the fewest complaints.

As with many office facilities, this building has no humidifiers, and based on our measured Carbon Dioxide data, appears to have high ventilation rates, during both occupied and unoccupied hours. A byproduct of high ventilation rates in winter months is often very low relative humidity, as we have measured in this facility where it is (typically at 15%) in the winter months. Also, there are no enthalpy energy recovery devices in the ventilation system of the facility (which can recover occupant moisture). Thus, no moisture in the exhaust air is captured to minimize dryness during cold weather.

Additionally, high humidity can be expected during damp weather (i.e., the indoor dew point will track closely with the outdoor dew point), unless the DX air-conditioning systems have multiple stages of cooling during low level, air-conditioning periods. If the DX systems short cycle, due to design or operational issues, they will contribute to cool and clammy conditions and poor occupant comfort. Poor humidity and temperature control appear to be demonstrated in the ATC data collected in August of 2006. We do not know the cause of the issues when the ATC data was collected.

In a New England climate it is important to limit elevated relative humidity during humid weather to reduce the likelihood of mold growth on surfaces where dew point temperatures can be reached. If for some reason humidity is not controlled as a byproduct of properly designed air-conditioning, use of energy efficient commercial dehumidifiers may be warranted.

Results (Temperature): Temperature levels logged in various locations over the four week period in general indicate some intent of the equipment automatic temperature controls to meet ASHRAE thermal comfort guidelines during occupied periods. However, there is varied inconsistency in the performance of the equipment. Some areas appeared hot, some cold, some with night setbacks, and some with large daily variance in observed control points. Of concern from a control perspective in many of the thermal trend logs, is the drifting of temperatures with time over the course of a day, and week, and the inconsistencies of temperatures in different locations.

See Appendix A3 for graphs of the temperature and humidity conditions monitored in the occupied spaces and outdoors.

Results (Relative Humidity): Relative Humidity levels logged in various locations over the four week period in general indicate extreme dryness with data often in the range of 10-15% RH during most periods. This level of dryness is significantly below ASHRAE thermal comfort overall guidelines during occupied periods. The extreme dryness is likely due to a combination of high ventilation and low-occupancy, inadequate outdoor air control (leading to excess supply of outdoor air) during occupied periods, excess building air leakage (during unoccupied periods), and use of energy recovery ventilation equipment that does not include total (enthalpy [moisture]) energy recovery.

The generous ventilation rates observed to be supplied for hours before normal occupancy and many hours after normal occupancy (5:30 a.m. till 10:00 p.m.), may also be part of a natural and normal response to ongoing historic air quality complaints within this facility where windows are not operable and concerns/complaints have occurred for a long time.

See Appendix A3 for graphs of the humidity conditions monitored in the occupied spaces and outdoors.

> **FINDING/CONCLUSIONS CONCERNING TEMPERATURE:** The near continuously logged temperature data collected by TBS&D, when used as an indicator of room temperatures, reveals inconsistencies in temperature control through various areas of the facility on a daily and weekly basis. As monitored, the temperature control would not meet ASHRAE recommendations. See Section 4.15 and Recommendation #1.

FINDING/CONCLUSIONS CONCERNING RELATIVE HUMIDITY: The near continuously logged indoor relative humidity data collected by TBS&D, when used as an indicator of expected occupant comfort, reveals extreme dryness (typically 15% RH) indoors over the entire four week winter monitoring period. This condition is likely exacerbated by poor outdoor air control (too much outdoor air during occupied periods) and excess building air leakage. As monitored, the humidity levels would not meet ASHRAE recommendations. It is also our understanding that this degree of dryness could be expected to exacerbate health symptoms in some individuals. Any impact on health at this low level of humidity should be evaluated by VDOH and NIOSH. *We have recommended improvements in temperature control and humidity control during renovations.* See Section 4.15 and Recommendation #1.

3.4 Particle (PM-10) Concentrations in Buildings

Testing: Four calibrated, real-time Dustrak Inhaleable Particle Monitor Model #8520, Serial #14169, 15049, 15048, 14167 were employed to collect airborne inhaleable particle (PM-10) data for the period of our site work. Each particle counter was set in a noise reduction box, with a suitable short sampling tube extended out of the box in the occupied zone, and an air circulation fan located within the box. The particle counter used in this sample series counts the total number of particles in the air stream passed through the counting chamber (during a two minute interval) that are smaller than 10µ (microns) in aerodynamic diameter. The particle counters were on loan from NIOSH for use in this study. This type of device was located in two indoor rooms each week, on the third floor rooftop, and on a first floor rooftop. The first floor rooftop unit appears to have failed during part of its deployment. The zero value for each instrument was checked at each download. The range of values measured by this equipment is at the low end of the instrument's capabilities. Thus, the accuracy between each instrument may vary slightly at these low levels.

We do not use this device to assess OSHA limits for dusts in offices. They are used to look for patterns in particle levels, to compare levels over a period of time. Periods with elevated levels over background indoor particle counts typically are indicative of occupant activity within the rooms during normally occupied daytime hours. Spikes of extreme elevation above background indoor particle counts typically suggest that housekeeping or other activities are somehow effecting the area, either by introduction of a source such as combustion emissions or windblown dusts, or re-suspending of previously settled materials from the floors or other horizontal surfaces.

Increases in particle counts during occupied times when people are moving about can most often be attributed to activities in the space, or in rare cases, possible entrainment of combustion related fumes, as this instrument counts particles and calculates a mass concentration based on a standardized road dust calibration (relatively large particles). Thus, fine particles make the instrument read high compared to the true mass concentration.

It is important to note, that changes in the quantities of particulate indicated by the particle counter that cannot be attributed to ambient air conditions, or local sources of combustion (from cigarette smoke, fossil fuel combustion, etc.), may be an indication of large reservoirs of settled particulate matter that might be removed from increased and more effective cleaning efforts of the horizontal surfaces, especially floors.

For comparison purposes, typical PM-10 particle concentrations in schools not found to have IAQ complaints associated with dusty conditions, are in the range of 50 micrograms per cubic meter or less. Offices are on average much cleaner, typically at a maximum of half the level of schools in the range of 25 micrograms per cubic meter. It is important to note that this equipment does not indicate the composition of recorded particle concentrations.

In some cases, a small concentration of a particular known contaminant may result in reports of poor IAQ and occupant-related symptoms. The identification of these particles cannot be established by the particle counter, and would need to be identified by other means (observation, occupant interviews regarding activities that occur within the space, or unusual odor occurrence) with lab analysis of samples.

As noted in Section 3.8, elemental analysis of collected particles did not identify unusual levels of elements, but did identify some likely boiler fume impact.

Results: The low levels of airborne respirable particulate we recorded and measured are unlikely to pose any significant health exposure (as nuisance dust) to the majority of occupants in this building. Continuous monitoring data for PM-10 during the normally occupied periods tended to vary depending on week and location. In general, indoor levels appeared lower than outdoor rooftop levels, and other limited times the reverse was true. Levels indoors were often as clean as would be expected in offices with filtered air, and occasionally appeared dirtier, more like a school environment in need of better cleaning.

The daytime peak levels may depend on the degree of floor cleaning and occupant activities in the area. On some occasions of variable low wind speeds, it appears that outdoor sources such as boiler exhaust are impacting the third floor rooftop units. Additionally, in areas close to the Boiler Room, it appears that direct impact may be happening from indoor transmission of fugitive boiler soot. See Appendix A5 for trend graphs of PM-10 continuous monitoring data.

This Dustrak data is very similar to PM-10 Dustrak data previously collected by ATC in August of 2006 in various locations.

> **FINDINGS/CONCLUSIONS:** The near continuously logged PM-10 Particle Data collected by TBS&D, and the Gravimetric Measurement of PM-10 (Section 3.8) when used as an indicator of breathable dust and dirt, reveals normal average levels for offices or schools comparable to those monitored in the US EPA BASE national office building study. However, given the excellent air filters in use in the facility, the data indicates that improved floor cleaning methods may be useful. It is possible that the indoor data is occasionally impacted for very short time periods by fugitive tobacco smoke or some other fine particulate matter.
>
> Additionally, the outdoor rooftop data appears to be somewhat impacted by boiler fumes during some specific, low variable wind speed and direction conditions, as would be predicted by ASHRAE exhaust re-entrainment calculations for the building complex located in Appendix D4. See Sections 3.14, 4.1.6, and Recommendations #1 and #10.

3.5 Airborne Mold Sampling (Not Conducted)

Testing: There are no nationally accepted standards for airborne mold levels inside facilities. All current guidelines direct that the data be viewed with regard to respective indoor and outdoor levels, type of molds, time of year, and observed conditions at the time of sampling.

No Results: Airborne mold spore testing in this facility was not conducted. TBS&D did not propose typical five minute airborne mold spore sampling as it has not proven to be a very useful diagnostic tool. It has proven to be a useful tool if obvious growth is found in an area such as inside an HVAC supply duct, and the diagnostician would like to answer a specific question such as: Does starting up the HVAC supply increase airborne counts? Additionally, past data sets of airborne mold sampling in this building did not confirm unusual levels in the air.

TBS&D did pursue suspect source sampling for microbial sources, and we have noted various locations and materials that warrant remediation within this report as a result of that evaluation.

3.6 Laser Particle Counting

Testing: Calibrated, real-time particle counters (Climet model CI-4100) Serial #903953, 904187, were employed to collect airborne particulate concentrations within selected, occupied spaces over the monitoring period. The particle counters were set to log for two minute intervals in the selected spaces to establish peak particle loading and the time of day of peak occurrences. Both units were run indoors for approximately four weeks in various locations for a total of eight sampling locations.

The data collected by the counters are presented in two size fractions:

1) Particles larger than 0.5 microns (0.5µ).
2) Particles larger than 5.0 microns (5.0µ).

The respirable size fraction is the 0.5µ count minus the 5.0µ count. These particles are small enough to pass uninhibited through our respiratory system filters (mucus membranes), and are then available for deposition within the depths of the lungs.

The increased number of airborne particles larger than 0.5µ (micron) during occupied times can be attributed to activities in the space, such as the introduction of combustion particles from cigarette smoke or the boilers, or migration of similar combustion particles from another location, such as exhaust from auto and bus engines. It is our experience that typical particle concentrations in buildings not found to have IAQ complaints associated with dusty or boiler fume conditions are in the range of 30,000 to 60,000 particles per cubic foot larger than 0.5µ or less.

It is important to note that the particle counter does not determine the composition of recorded particle concentration. We have found that in some cases a small concentration of some known contaminants may result in reports of poor IAQ and occupant related symptoms. The identification of these particles cannot be established by this device, and will need to be determined by other means including observation, sampling, and occupant interviews.

As noted in Section 3.4, as part of our Scope of Work, we also collected particle data using a TSI Dust Trak Model 8520 particle sampling device. This device measures the number of particles smaller than 10 microns and converts this count into a concentration in micrograms per cubic meter ($\mu g/m^3$), based on data from a standard road dust size and weight distribution. The Dustrak equipment inherently assumes that the particles it is measuring are a typical distribution as road dust would be, and thus is subject to over reading errors if the majority of the particles are very small.

3.6.1 Fine Particles as an Indicator of Combustion Impact

Testing: A calibrated, real-time laser particle counter, (as would normally be used in clean room monitoring), was used to detect the level of 0.5 micron and larger particles inside the building (as described above in Section 3.6). The particle counter used in this sample series counts the total number of particles in the airstream passed through the counting chamber that are larger than 0.5 microns in aerodynamic diameter. High fine particle counts measured by this device typically suggests that combustion emissions are impacting the unit. See the end of Appendix A6 for trend graphs of Laser Particle count data.

Results: Extensive laser particle counting was conducted near continuously over a four week period. In general, levels inside the building remained low during occupied periods with a few exceptions in Ground Level Rooms #14 and #100, and one spike in Room #123. Based on the data collected, and the general lack of elevated Carbon Monoxide being currently indicated within the facility, it does not appear that combustion particles were impacting the facility in a major way, on a routine basis, during our monitoring period in February 2007.

The spikes that are noted could be caused by boiler fumes, fugitive tobacco smoke, or less likely wood smoke. The graphed results of the particle data are presented in Appendix A6 and A7. As noted elsewhere in the report, the measured boiler fume impacts are likely reduced during extended periods of sub freezing weather, when cold firing happens less often.

> **FINDINGS/CONCLUSIONS:** In this building, the near continuously logged laser particle count data, when used as an indicator of either fine particles (greater than 0.5 microns), or coarse particles (greater than 5.0 microns), reveals typically normal levels for offices and schools, with minor exceptions likely related to boiler fumes. The only areas (where monitoring was conducted during this time period) that appeared to be occasionally impacted by combustion fume size particles are located near the Boiler Room, Rooms #14 and #100. Also of note, on multiple occasions in ground floor locations, including one particular occasion on February 8, 2007, the Court Area laser unit and the third floor PM-10 device registered elevated readings during local, variable wind speeds. Our reentrainment calculations indicate that the impact from boiler discharge is likely in all of these areas. Tracer gas testing also indicates rapid movement of boiler room air into nearby spaces and the rest of the facility. As the device measures any combustion size particle, it is also possible that these elevated levels were caused by regional wood smoke vs. local boiler re-entrainment. See Section 4.1.6 and Recommendations #1 and #2.

3.7 Occupant Interviews (Only Specific Interviews Were Requested)

Testing: As noted in the Executive Summary, NIOSH and VDOH have conducted building wide interviews. It was not within the scope of TBS&D to repeat this type of survey, nor did we recommend it. We did conduct specific interviews on February 8, 2007 with eleven employees.

Results: During these interviews, temperature control concerns, as well as health and odor concerns were frequently verbalized by individuals we met with.

> **FINDINGS/CONCLUSIONS:** The above concerns expressed by individuals that TBS&D interviewed, would be expected to be addressed by implementation of the Recommendations contained within this report. *Remediation has been recommended.*

3.8 PM-2.5 & PM-10 Particles, Gravimetric, and Elemental Analysis

Testing: TBS&D conducted an evaluation and sampling of airborne respirable PM-2.5 dusts, and PM-10.0 dusts utilizing Impactor size separation technology that was originally pioneered at Harvard School of Public Health for sampling very low levels of indoor particles. We conducted particle sampling and subsequent laboratory elemental analysis for four weeks during normally occupied times, in order to determine the elemental makeup of the particles. Sampling Pumps Serial #30660, 30667, 30664, 30663, 30666, 30661, 30657, 30659 were utilized on loan from NIOSH. A separate sampling head was used with each mass flow controlled pumping device.

We sampled the air for particles during a 40-hour sampling period (8:00 a.m. to 5:00 p.m. each work day) at a flow rate of 10 liters per minute, through 2.0 micron pore size Teflon filters. Filters were submitted for elemental analysis of 48 elements, via X-ray techniques (XRF), through the services of Chester LabNet, located in Tigard, Oregon. These samples were collected from January 24, 2007 until February 19, 2007, during normal daytime hours with a digital, programmable timer with the HVAC on its normal schedule within the facility. Results of this analysis are reported in Appendix B1, PM-2.5 and PM-10.0 Lab Data.

Results: Levels of respirable particles measured during normal daytime, weekday periods, were always lower indoors than outdoors. Results of the elemental analysis of the collected particles indicate similar compositions of the indoor particles vs. the outdoor ones for most elements, with a few exceptions as noted by Mr. John Cooper whom we asked to review the data. *There are no health implications for this data set that we are aware of as the levels of elemental materials identified are extremely low.*

However, we recommend that VDOH and NIOSH review the data set and assess it for health impacts. As noted by Mr. John Cooper, there is some indication of a possible combustion impact in the elemental analysis. It also appears that the first floor roof data located near the boiler discharge at roof-level, is elevated. Results of this analysis are reported in Appendix B1, PM-2.5, PM-10.0 Lab Data. Photos Appendix D1: Section 3, photo 60, 85, Sec. 5, photo 3-6, and Section 8, photo 63,65,66.

> **FINDINGS/CONCLUSIONS:** The gravimetric and elemental analysis of thirty-one (31), five-day work week, eight-hour samples, collected in this facility, revealed low levels of respirable particles with normal routine elemental composition. Indoor gravimetric (mass) levels were lower than outdoor levels in all cases. TBS&D had a knowledgeable expert review the materials and his comments are included with the data in Appendix B1. Mr. John Cooper suggests that the data is normal and that boiler fume impact was likely on certain limited occasions during our monitoring. VDOH and NIOSH should review this data and any health implications.

3.9 Dry Cleaning Fluid Testing

Testing: At the request of BGS, TBS&D conducted an evaluation for volatile organic compounds. In accordance with standard procedures used for ultra-low level, organic vapor testing, stainless steel evacuated canisters (Summa Canisters) were prepared and shipped to TBS&D by Columbia Analytical Services, Inc., with a 24-hour bleed valve. Sample canisters were deployed on February 7, 2007 and retrieved on February 8, 2007. Samples were analyzed in accordance with the laboratory's quality assurance program, including a Blank Analysis. The samples were analyzed by combined gas chromatography/mass spectrometry (GCMS) in selective ion monitoring (SIM) mode for selected volatile organic compounds. Analysis was performed according to methodology outlined in EPA Method TO-15.

Results: Analysis of samples (collected and analyzed for ultra-low levels of typical, dry cleaning fluids and degradation [break-down] products) revealed all levels below detection levels for all compounds, with the exception of one compound tetrachloroethene or PCE. This compound showed levels slightly above detection levels outdoors and indoors ranging from 0.15-0.16 $\mu g/m^3$ outdoors to 0.29 to 0.30 $\mu g/m^3$ indoors. The reported Vermont Median Background Concentration Range is 0.42 $\mu g/m^3$ to 0.87$\mu g/m^3$. The 0.16 $\mu g/m^3$ is within some of the lowest background annual average concentrations reported by Vermont Department of Health, similar to Waterbury and Winooski (0.10 – 0.20 $\mu g/m^3$. Thus, the levels measured are below the normal background concentrations for the State, and are normal for this specific compound.

Results of this analysis and the Vermont Guidelines are reported in Appendix B2, PCE Airborne Testing Lab Data. Photos Appendix D1: Section 6, photos 1-4

> **FINDINGS/CONCLUSIONS**: Representative sampling for suspect, dry cleaning fluid from the soil (soil gas emissions), reveal that the levels are at, or below, Vermont median background concentration range. Based on this data, we are aware of no reason to suspect the facility is, or has been, impacted by materials that have been dumped into the soil adjacent to, or under the facility. This data should be reviewed by VDOH and NIOSH.

3.10 Deposited Soot Analysis (Black Stain Sampling)

Testing: Eleven representative air filter samples (including one material sample conveyed to TBS&D which was reported to fall from a duct) and eight dust samples were sent to Dr. Lori Streit at United Engineering for analysis of particle size and morphology by three techniques. Dark field microscopy, polarized dark-field microscopy, and GC/MS (gas chromatography with mass spectrometry detection) were utilized when warranted to determine the type of black particles and composition.

All wipe (dust) samples were initially collected with alcohol soaked cotton balls, and subsequently with dry cotton balls (in accordance with standard procedures). The dry wipe sampling was a repeat of the alcohol sampling after a question of glycerin contamination of the cotton balls arose during the analysis. Further details, analysis, and results are reported in Appendix B3: Deposited Soot Analysis Lab Data.

Results of the Air Filter Analysis: Analysis of air filters removed from rooftop HVAC units on the first floor roof, and air filters from indoor first floor units, indicated that a significant fraction typically 35% or greater of the dust on the filters to be soot from oil fuel combustion. One sample that was reported by occupants to fall out of ductwork was confirmed to be rust particles.

Results of the Wipe Sample Analysis: Wipe samples from indoor areas indicate soot deposits on all floors that chemically match the boiler stack soot samples. Based on these soot analysis results, pressure analysis, tracer gas testing, and ASHRAE reentrainment calculations conducted by TBS&D, it is apparent that there has been a historic impact on the indoor environment of the facility from soot from the boilers, both directly and indirectly, and that it continues to occur to some degree.

As noted in other areas of the report, for various reasons, the impact of the boilers on the facility during our testing in February was likely minimal compared to other seasons of the year, and prior to attempts during 2006 to reduce the impact by HVAC equipment modifications. Results of this analysis are reported in Appendix B3, Deposited Soot Analysis Lab Data. Photos Appendix D1: Section 3, Photos 1-32, Section 9, photo 3-5.

> **FINDINGS/CONCLUSIONS:** Analysis of representative air filters removed from rooftop HVAC units on the first floor roof, and air filters from indoor first floor units, indicated that a significant fraction (typically 35% or greater) of the dust collected on the filters to be soot, from oil fuel combustion. Wipe samples from indoor areas also confirm soot deposits on all floors of the facility that chemically match the soot samples from the boiler stacks. All analysis conducted by TBS&D to date confirm long-term historic impact on the indoor environment of the facility from soot from the boilers, both directly and indirectly. The situation matches some of the long-term expressed occupant concerns for IAQ in the facility that we have reviewed in the historic documents. *Remediation has been recommended.* See Section 4.1.6 and Recommendation #2.

While this report makes no attempt to make any connections between contamination levels and effects on health, as a point of note we have included in Appendix B3 a report on soots from the Federal Department of Health and Human Services for informational purposes only that indicates soots are generally undesirable.

3.11 Settled Dust Sampling

Testing: TBS&D conducted <u>three types</u> of settled dust analysis in order to attempt to quantify any potential for:

1) <u>Allergen reservoirs</u> that could lead to airborne exposures.
2) <u>Mold reservoirs</u> that could lead to airborne exposures.
3) <u>Possible fiberglass reservoirs</u> that could lead to airborne or skin exposure from disturbing settled dusts.

Discussion of the data in this report, and the location of the laboratory data in the Appendix are located as noted below, under each of the three categories of evaluation. For photos of the sampling locations see Appendix D1: Section 8, photo 67-72, 79-91.

The sampling and analysis we conducted are identified as follows:

1) **Settled Dust Evaluation for Allergens:** Vacuum dust samples were collected using samplers supplied by DACI Reference Lab at John Hopkins University School of Medicine. Eleven vacuum samples were collected from representative areas (Rooms #14, 33, 35, 53, 95, 123, 145, 210, 325, 356, Clerk) and submitted for <u>analysis for dust mites, cat allergen, dog allergen,</u>

cockroach allergen, mouse urinary allergen, and viable mold spore count. Results are located in Appendix B7: DACI Lab Allergen Report, and dated March 2, 2007.

Results: Samples of dust that showed elevated levels of mold compared to the DACI Lab home standards criteria included Rooms #14, 35, 53, 95, 123, 325, 356. Many rooms tested positive for dog allergen and cat allergen, and four tested positive for dust mite allergen.

2) **Settled Dust Evaluation for Microscopic and Culturing of Mold and Bacteria:** In addition to the eleven DACI Lab vacuum dust samples collected for allergen culturing, eleven vacuum dust samples were collected from representative areas (Rooms #14, 33, 35, 53, 95, 123, 145, 210, 325, 356, Clerk) and submitted for laboratory microscopy, and mold and bacterial culturing and analysis. The dust samples were conveyed to EMLabs for analysis, and the data is contained in Appendices B4, B5, B6: EMLabs Report #282496, dated March 5, 2007.

   Results: Samples of dust that showed signs of mold growth included Rooms #33, 53, 123, 145, 210, 325. Samples with somewhat elevated bacteria cultures for various types included Rooms #35, 53, 123, 145, 325, 356, and Court Clerk.

3) **Settled Dust Evaluation for Microscopy Analysis of Materials and Fiberglass:** To further understand the composition of the settled dusts (particle morphology) within the facility, eleven micro-vacuum dust samples were collected for analysis by Polarized Light Microscopy, by the Severn Trent Labs in Billerica, MA, (now Aerotech P&K). Two of the samples were also mounted for Scanning Electron Microscope Evaluation to further understand their materials. The samples were conveyed to the lab for analysis. The analysis report and the data (including photos) are contained in Appendix B8, Aerotech P&K Report #760-702-0149, dated March 9, 2007.

   Results: Most samples contained a normal mixture of general dust consisting of building materials, printing residue, cellulose fibers, biologicals (skin-scale, etc.), and various other trace level particles. Soot was present in a few samples at low levels.

Overall Results: Elevated levels of materials that would cause concerns for potential daily airborne exposures to allergens, mold, or fiberglass during routine activities within the facility were not widespread in the samples collected and analyzed. Some areas indicated elevated mold growth in limited areas and evidence of some past combustion impact in settled dusts. See individual lab reports in Appendices for further details. VDOH and NIOSH should review this data.

> **FINDINGS/CONCLUSIONS:** Representative sampling for settled dusts were collected and sent to three labs for specific, different types of analysis. Overall analysis results would generally be considered normal. However, test data indicated some spotty elevated mold levels and some indication of historical combustion impact in settled dusts. *Remediation of long time accumulated settled dusts are recommended as a precaution in this facility, given the historic symptoms and health concerns of the occupants.* VDOH and NIOSH should review this data. See Section 4.3 and Recommendation #10 regarding precautionary cleaning recommendations.

3.12 Pollutant Pathway Diagnostic Testing

3.12.1 Sanitary Venting Tracer Smoke Diagnostic Testing: TBS&D conducted an evaluation of the sanitary venting system on February 19, 2007. During this testing, scented theatrical fog was pumped under very low pressure into the sanitary (sewer) vent lines (with a low pressure blower) until it exited the roof vents. Each vent was restricted till fog was visibly exiting all roof vents in the zone under testing. After the fog was determined to have exited all rooftop locations, an interior survey was conducted to locate any areas indicative of where sewer gas could enter the facility from either dry traps or hidden leaks within the plumbing system.

Results: No hidden sewer gas leakage sites were located with this diagnostic testing. Eighteen dry traps were located and are detailed in Appendix C2 of the report. See Photos Appendix D1: Section 3, photo 33-40.

3.12.2 Boiler Room Fugitive Air Tracer Gas Diagnostic Testing: TBS&D conducted an evaluation for mechanisms of fugitive Boiler Room air to escape the Boiler Room and find its way into occupied spaces using an ASTM Tracer Gas technique, with low concentrations of Sulfur Hexafluoride Tracer Gas. This inert gas is used for tracer testing, in medical settings, and for deep diving. The boilers in this facility (in particular the oldest unit) have been noted to have poor draft when fired cold, and on most occasions to release a small amount of soot into the Boiler Room whenever the units fire. It is reported to us that some equipment had been abandoned in place (its use discontinued), and attempts at wall sealing were undertaken to reduce the movement of Boiler Room air, and accompanying odors into occupied areas.

To accomplish this tracer gas evaluation, Sulfur Hexafloride Gas was released into the Boiler Room for a defined period at a definite rate. Then air sampling was conducted throughout the facility to determine if this released gas found its way into the building under normal operating conditions.

Results: This diagnostic test procedure determined that Boiler Room air currently finds its way into adjoining spaces almost immediately and then is distributed to other areas of the facility. The results of the detailed testing are found in Appendix C3. Photos are located in Appendix D1: Section 3 photo 47,48,49.

3.12.3 Condensate Drain Line System Fugitive Air Diagnostic Testing: TBS&D conducted two types of testing on the condensate lines. On February 9, 2007, we placed a scented fog tracer into exit points of several condensate drainage systems for heat pumps located within the facility. This tracer smoke was noted to be drawn into multiple areas of the building confirming communication (air flow) between the condensate drain line exit points, and multiple occupied areas throughout the facility as indicated by graphs in the Tracer Gas Report.

On February 23-24, 2007 in order to further understand how airflow within the condensate drain lines actually behaved under normal operation of the HVAC system, TBS&D injected Sulfur Hexafloride Tracer Gas into two exit points of several condensate drainage systems for the heat pumps.

Results: The tracer gas was confirmed to move into multiple locations within the facility almost immediately as indicated by graphs in the Tracer Gas Report. These two tests confirmed that air from within the condensate drainage system was freely moving into occupied zones of the facility during routine operation at the time of our testing. The reasons for this air movement are multifaceted and we have developed a diagram to explain one aspect of air movement in this particular system. Testing details and illustrative condensate line airflow maps are located in Appendix C3 and D3 respectively. Photos of fog injection and pressure testing are located in Appendix D1: Section 3, photo 50-53, Sec. 8, photo 1-7.

Overall Results: Three types of tracer gas testing were conducted as outlined above. Each type of testing was intended to answer a specific question. Tracer testing confirmed three items in this facility.

a) Eighteen dry sanitary traps throughout the facility.
b) Movement of fugitive air from the Boiler Room directly into occupied spaces.
c) Movement of air from the enclosed heat pump condensate drainage system into occupied areas throughout the facility.

FINDINGS/CONCLUSIONS: Diagnostic tracer testing confirmed several items as follows:

- Eighteen dry sanitary traps throughout the facility.
- Movement of air from the Boiler Room directly into occupied spaces.
- Movement of air from the enclosed heat pump condensate drainage system to occupied areas throughout the facility.

- All three pathways identified would lead to occupant exposures to known irritants of various materials. Health implications of any of these types of irritants are to be determined by VDOH and NIOSH.

Within the report we have recommended specific corrections to reduce or eliminate the re-occurrence of these identified air movement pathways (Section 4, Recommendations #1 and #2).

3.13 Air-Conditioning Condensate Drain Line Installation and Aerosolization

Observations of the Condensate Drain Line System Inspections: As noted previously in Section 3.11.3, TBS&D conducted two types of testing on the condensate lines which confirmed pathways into occupied areas and breathing zones. On April 30, 2007 and May 1, 2007, (after ceiling tiles were removed, while assisting NIOSH) we observed the actual installation of the drain lines and the piping system, which joins the various systems together.

Results: During these visual observations, we found that the drainage system piping system connects to condensate drains from rooftop heat recovery units, ducted cooling coils, and heat pump units.

Several of the sections of clear plastic tubing forming the drain traps were found to be dry, allowing air to flow through the piping system. Airflow within the drain pipes is likely to aerosolize liquid that is flowing through the piping, and can introduce the aerosol into the air handling system downstream of air filtration. Illustrative sketches and a description of the airflow pathways are located in Appendix D3. Photos Appendix D1: Section 2, photo 6-11, Section 3, photo 115-121, and Section 8, photo 23-49.

FINDINGS/CONCLUSIONS: Visual observations and diagnostic testing on segments of the air-conditioning condensate drain installation by TBS&D and NIOSH confirmed large reservoirs of stagnant water and microbial activity. Airflow testing and physical inspection also confirmed multiple mechanisms for aerosolizing the materials and dissemination of the materials into the breathing zone of occupants. The microbial reservoirs of materials are either pulled into the air handlers downstream of the building particulate air filters, or pushed directly into rooms from air escaping under pressure from the drain lines. These mechanisms are illustrated in Appendix D3. The details of the combined piping systems traps and lack of venting observed in this piping situation would not meet guidelines provided by manufacturers and ASHRAE today. Health implications of any exposure to the materials in the condensate drainage reservoirs are to be determined by VDOH and NIOSH.

Within the report we have recommended specific corrections to reduce or eliminate the re-occurrence of this situation (See Recommendation #1).

3.14 Moisture Intrusion Diagnostics

Infrared Thermal Imaging Diagnostic Testing: When current wetting in wall or roof assemblies is suspected, powerful infrared cameras can be used to look for patterns of temperature change created by evaporating moisture or changes in conductive temperatures driven by moisture. Infrared diagnostic techniques were used in this facility to attempt to locate any current wind driven rainwater intrusion in the exterior wall envelope. Work was conducted on January 23-24, 2007 by a Certified Infrared Operator, who was contracted by TBS&D. See report Appendix C1, testing photos Appendix D1, Section 3, photo 43 and 44.

Intrusive Disassembly and Pin Moisture Meter Diagnostic Testing: On April 9-10, 2007, moisture meter testing with a calibrated pin-type moisture meter was conducted along with intrusive disassembly under containment of multiple areas in both the old building and new building on ground floors and upper levels. As noted above, this evaluation work was initially conducted in areas that had been identified as potentially wetted by infrared testing (infrared imaging). (See Appendix D1: Section 10 photo 1-101 for photos of all areas.) A moisture reading above 19% with a pin meter generally indicated wet materials capable of supporting mold growth.

Floor Hole Cutting and Calcium Chloride Moisture Diagnostic Testing: On April 9-10, 2007, holes approximately 4 inches by 6 inches were cut into two first floor areas of the slab (old and new construction) for visual verification. This test confirmed installation of the vapor diffusion retarder under both of the floors. The old wing had the vapor barrier installed under the concrete, and the new wing had a layer of sand placed over the vapor barrier as shown on the drawings. Representative calcium chloride floor moisture emission rate testing confirmed generally low levels of moisture emission rates as had been previously reported by ATC testing, with the exception of one area in their report, which was marginally elevated, located where an exterior roof drain scupper has historically dumped water on the wall, (Scupper photos, Appendix D1: Section 1, photo 7, Section 9, photo 1,2,7,8, Section 10, photo 17-19) and immediately adjacent foundation perimeter. Results are contained in the report, located in Appendices C7, photos in Appendix D1 Section 10 photos 23,24 and 39-46.

Overall Moisture Results: Professional Infrared Thermography conducted on January 23 and 24, 2007 indicated eight suspect areas of general moisture intrusion. Intrusive disassembly of these and other areas was conducted by TBS&D under local containment conditions on April 9, 2007. Limited areas were found to have dampness in walls, and in one case signs of obvious suspect mold growth in the south wall of the Court facility. Photos are located in Appendix D1, Section 10, photo 31.

Additionally, intrusive disassembly of two first floor slab areas was conducted, which confirmed installation of the vapor diffusion retarder. Finally, representative calcium chloride floor moisture emission rate testing confirmed generally low levels of moisture transport as had been previously reported by ATC testing with the exception of one area which was marginally elevated. This one area was located where a reported plumbing leak had wetted the concrete slab. Results are contained in the report, located in Appendices C7.

> **FINDINGS/CONCLUSIONS:** Intrusive disassembly of suspect wall areas identified by infrared analysis revealed limited areas of microbial activity within specific exterior wall assemblies at only the first floor level. Based on the areas opened up, the damp areas are not believed to be widespread throughout the complex (on multiple wall exposures), and would not be expected to have contributed microbial materials into the breathing air of the facility on a widespread basis. Holes cut in the slab in first floor areas also revealed the installation of a vapor barrier under the first floor as noted on drawings. *Corrective action recommendations are made for the areas where observations revealed moisture concerns.* See Recommendations #5, #6, and #7. VDOH and NIOSH should review this data.

3.15 Technical Review of Possible Impact of Boiler Exhaust on HVAC Systems

Methodology: In order to better understand the possible reentrainment impact of the boiler stack (chimney) on the air intakes and building air leakage sites, we have conducted re-entrainment calculations in accordance with ASHRAE (American Society of Heating Refrigerating and Air-Conditioning Engineers), Publication “Fundamentals” Chapter 15 *Air Flow Around Buildings.* See Appendix D4: Re-entrainment Calculations.

Results: The results of the calculations reveal that increasing the boilers discharge height by 10 feet approximately twelve years ago would be expected to significantly reduce re-entrainment of the stack fumes vs. its original height. The increase in height by 10 feet could be the limit of the current boilers natural draft as on-site observations by TBS&D with the current configuration on February 8, 2007 revealed that the current design produces marginal draft in the oldest boiler when cold firing occurs.

Detailed stack gas re-entrainment calculations by TBS&D reveals that to adequately reduce the current remaining re-entrainment impact (to virtually eliminate it, as is needed) would require venting the stack above the level of the three-story facility, immediately adjacent to the facility. This could require a horizontal run, power venting, or other complicated controls. Design is beyond our scope. Our calculations suggest a boiler stack would need to exit at least 25 feet above the third floor roof to escape capture in the wake of the building and re-entrainment at the third floor rooftop. Recommendations are presented in Section 4.1.6, Recommendation #2 of this report. See Calculations, Appendix D4.

> **FINDINGS/CONCLUSIONS:** It is reported that the boiler discharge was increased in height by 10 feet approximately twelve years ago. This increase in height is predicted to reduce the boiler's impact on the rooftop air intakes compared to its original shorter stack. However, detailed re-entrainment calculations (utilizing ASHRAE guidance), conducted by TBS&D reveals that to adequately reduce the current remaining re-entrainment impact (to virtually eliminate it, as is needed) would likely require a horizontal run to the side of the three-story building, and an uncapped discharge exiting approximately 25 feet or move above the roof of the three-story facility. Although an upper level discharge may be feasible, it also may be desirable to consider the life cycle benefits of improving the building shell performance and the HVAC features of the facility during a rehab, and then taking advantage of the resulting energy efficiency benefits to install a geothermal heat pump/solar assisted heating and cooling system to eliminate the combustion source from the facility. Design of a system that would incorporate these features is beyond our scope. See Recommendation #2.

3.16 Boiler Room Pressure Monitoring Diagnostic Testing

TBS&D conducted an evaluation of ongoing pressure monitoring for four weeks between the Boiler Room and outdoors, and Boiler Room and hallway. Digital micromanometers and data loggers were used to capture pressure monitoring continuously every two minutes. The plotted data is located in Appendix C4: Boiler Pressure Testing, photos of the test equipment are located in Appendix D1: Section 3, photos 47-49.

Results: This diagnostic test procedure determined that current Boiler Room pressures allow air to move from the Boiler Room into nearby spaces.

FINDINGS/CONCLUSIONS: Diagnostic pressure testing confirmed long-term pressures that will allow air movement from the Boiler Room into nearby spaces. In this building, this situation would lead to occupant exposures to known irritants of various materials related to fugitive emissions from the boiler combustion. Health implications of any of these types of irritants are to be determined by VDOH and NIOSH.

Within the report we have recommended specific corrections to reduce or eliminate the re-occurrence of these identified air movement pathways (Section 4, Recommendations #1 and #2).

4.0 OBSERVATIONS AND CORRECTIVE ACTION RECOMMENDATIONS

Background: It is our understanding that the State would like us to address corrective action recommendations for the facility to make it habitable for the next 20-30 years (foreseeable near-term future). In recent years, the State has invested significant funding to attempt to identify the source or sources of Indoor Air Quality concerns, to address thermal comfort concerns, and to address aged, failing HVAC equipment that served the first floor areas. Additionally, efforts have been made to improve overall HVAC functioning with additional computer controls to make the building more comfortable and less thermally distracting for the occupants.

It has been our experience over the past 30 years in this field, that a healthy building design includes HVAC systems that avoid long-term irritation by reducing exposures to known identifiable, expected irritants, and which meets ASHRAE guidelines. Additionally, it must enhance occupant comfort in order to maintain occupant productivity. It has also been our experience that these two design and operation considerations are also important for reducing occupant complaint levels, and especially important to restore confidence in a building where a history of health concerns has existed.

Our 30 years of experience in building evaluations has shown us that facilities often fall somewhere on a continuum between an "unhealthy" or "sick" building, and a modern, healthy building design, such as a LEED (Leadership in Energy and Environmental Design) rated modern, healthy building design.

Mission/Objective: It is our understanding that the Bennington State Office facility has been vacated because it was determined (by VDOH and NIOSH) to be a facility with medically diagnosed "building related illness" in addition to having a history of occupant expressed concerns regarding IAQ. Given this current label and vacated situation, the history of the occupancy, and the results of our diagnostic testing evaluations, it is important to <u>address all identified building related items</u> that may have contributed to occupant irritation and the elevated inflammatory-type disease rates within this facility, before attempts are made to re-occupy the facility.

It is our experience that the redesign and rebuilding of the facility needs to be approached as the design of a facility that is clearly intended as a modern "healthy building" redesign. Additionally, complete commissioning and some follow-up diagnostic testing is warranted before any re-occupancy occurs, such that the facility is proven to function as designed before it is re-occupied. Once it is re-occupied, meticulous, prompt follow-up to occupants concerns need to remain a priority for those operating the facility.

In the sections that follow, we have outlined items that based on the results of diagnostic evaluation, warrant corrective action prior to any attempt at re-occupancy. When appropriate, we have identified possible alternate approaches to accomplish the corrective action task, especially when the approach may offer additional long-term improvements or benefits (such as better moisture resistance or increased energy efficiency) within the facility.

To the best of our knowledge, properly addressing the presented corrective action items should eliminate any identifiable building factors that could have lead to the current building related illness situation, and should bring the facility up to the level of a more modern, healthy building design. This above statement, and the recommendations should be reviewed by VDOH and NIOSH for their adequacy regarding health concerns.

Many of the issues that this building faces are not unique, and may be common with this vintage facility and distributed heat pump systems. We realize that properly implementing these corrective action recommendations will involve a relatively large sum of money. We understand that BGS staff is aware that many of the various current building system components are in need of replacement as they are near the end of their typical useful service life. In most all cases, implementing the corrective action recommendations with the preferred life cycle costing solution would be expected to significantly improve both the Indoor Air Quality and thermal comfort issues that the diagnostic testing has revealed, and to improve the long-term energy efficiency of the facility.

4.1 HVAC System Observations and Recommendations

Members of the TBS&D team conducted observations of many of the air handling units and heating devices serving the facility on January 24, 2007, and on multiple other occasions when evaluating moisture intrusion issues and the condensate drain lines, while assisting NIOSH with collection of the drain line tubing for laboratory analysis. Photos of system observations are located in Appendix D1: Section 3, photos 54-121.

4.1.1 New Packaged Rooftop Units: We observed that the building continues to be served by ten packaged rooftop air handlers #1 to #8, #8A, and #9, located on the first floor roof, all of which are very new having been replaced in recent years (2005). Seven of the units serve the Court Area and three serve the remainder of the 1978 first floor facility. The new packaged rooftop units appear to be in a good state of repair, although the outside air supplied by them appears difficult to control, because of the simplicity of the equipment and controls, and subsequently the excess air leakage rate at the outside air (OA) dampers. Within the current design, there are no variable speed drives to assist with air pressure or air leakage control at the OA dampers or to assist with energy savings. In the larger units serving multiple spaces in the 1978 Non-Court Wing, there are also no computer controlled VAV zones, and limited overall computer controls for the areas served.

Many new rooftop units in the Court Wing serve a rather defined, small area with widely variable loads in each of these areas making temperature and good outdoor air control (avoiding over ventilation in humid weather and excess dryness in winter), difficult if not impossible to effectively manage when the current units are running in the occupied mode, due to damper leakage.

Laboratory analysis from the air filters taken from the rooftop units show clear evidence of ongoing impact by the re-entrainment of the boiler stack emissions. See Appendix B3.

4.1.2 Heat Recovery Devices: There are five older (fixed plate, HRV) heat recovery units. These units do not recover winter moisture, or pre-dry outside air in the summer. Two of HRV units are located on the first floor roof and three on the third floor roof. These five units were observed to be in various states of functionality and repair. In addition to providing the outside air for the majority of the building, these units also provide toilet and general exhaust functions. Therefore, it is important for the ventilation and exhaust from these units to be provided continuously during occupied hours.

There is also one energy wheel recovery unit that is located on the first floor roof that has been abandoned in place because of reported ongoing boiler fume re-entrainment issues. There is very little, actual computer control and feedback from these heat recovery systems.

The multiple condensate drain lines from these HRV systems are tied into other condensate drainage systems within the facility, and subsequently, adversely effect pressures and airflow within the condensate drainage system. See Appendix D1: Section 8, photo 25-49 and Appendix D3.

4.1.3 Distributed Water Source Heat Pump System: There are eighty-three (83) heat pump units located throughout the three-story structure, which are of similar 1991 vintage. The heat pump units are in general installed in a manner that makes the majority of them very difficult to access during normal work hours for maintenance of filters, drain pans, or condensate drain lines, repairs, or replacement of compressors. The compressors have begun to fail at a high rate as they have seen approximately 17 years of use, often with extended hours of operation per day.

Detailed observations of the installation of the air conditioning condensate drain systems serving the heat pumps reveals that the current hygiene of the drainage system is very undesirable, allowing large reservoirs of stagnant water with microbial activity to be readily aerosolized into occupied areas bypassing any air filters. Maintenance of good hygiene and avoiding aerosolization of stagnant water within the current condensate line system is virtually impossible given the current configuration of the drainage system installation.

The distributed water source heat pump design that is installed in the facility is by nature a lower first cost system, makes noise management difficult, and comes with significantly elevated, long-term maintenance costs, compared to central type air handlers.

4.1.4 Perimeter Radiation in Old Building: The perimeter fin tube radiation that was retrofitted in 2001 in the older one-story facility to improve temperature control in exterior offices has by observation experienced multiple, ongoing heating water leaks for various reasons. See Appendix D1: Section 10, photos 9-14 &16. The installation detail makes it difficult to prevent, discover, and manage hidden, small leaks onto porous materials, or to provide long-term permanent repairs that will not lead to future leaks and hidden wetting. There are multiple piping connections of dissimilar metals, and the entire perimeter heat system is installed on top of carpeting and hides the interior paper covered gypsum wallboard located behind it. Additionally, the fiberglass insulation that covers the hidden return piping, which sits on the carpeting, is covered with a paper covering which is subject to mold growth when wet.

4.1.5 HVAC Controls: The facility has a good quality retrofitted computerized control system that provides limited control of multiple units and very limited feedback to the operator regarding actual operation or the status of primary heat recovery equipment. By design, the heat recovery equipment is responsible for delivering the majority of the ventilation air to the three-story building, and also providing general and bathroom exhaust. Therefore, it is important for these systems to run continuously during occupied hours, and for the operator to be able to verify operation remotely through the controls system.

Additionally, the large rooftop units #8 and #8a that have been installed in the first floor areas have variable flow air diffusers included as part of the supply air system that are not, and cannot be, integrated into a computer controlled system. Thus, the operator has no computer control over their functioning regarding local air supply or distribution, or computer feedback regarding their proper functioning.

Temperature monitoring by TBS&D and others indicates inconsistent and inadequate temperature control in almost all areas that have been monitored to date by TBS&D or ATC.

4.1.6 Oil Fired Boilers and Boiler Room Design: The oil-fired boilers consist of two units. The first is an older, original unit (1978 vintage) without pre- and post-purge cycles, with a history of reliability and draft problems, and the second is a newer unit of 1991 vintage. Both units are reported to have some usable life left. The Boiler Room does not have an exposed exterior wall, and relies on unconditioned, fan powered makeup air from the roof supplied to the room with poor distribution. The controls, which attempt to balance the correct amount of makeup air with the firing rates of the two boilers are obsolete and currently non-existent (permanently bypassed). On-site testing by boiler technicians in the presence of TBS&D personnel confirmed poor draft in the oldest boiler, which results in a discharge of fumes and soot into the Boiler Room whenever the older unit fires, especially during warmer weather. Black staining is observed in the rear stair tower. See Appendix D1: Section 1, photos 18,19,24,25,26,27, and Section 8, photos 73-78.

The boiler stack discharges well below the level of the third floor roof. Due to the interior location of the Boiler Room, its current discharge stack configuration, and associated HVAC equipment duct locations, TBS&D analysis confirmed ongoing movement of boiler fumes and soot both directly into nearby rooms, and indirectly into occupied spaces via re-entrainment of boiler discharge at the roof into rooftop air intakes. Based on lab analysis, the air filters in both the immediately adjoining spaces and the rooftop units had a high content of boiler soot on them.

4.1.7 Air Cooled/Chilled Water Plant: TBS&D staff did not investigate the current operation of the chilled water plant or observe its operation, because our work was conducted during the heating season. It is our limited understanding that the system was in need of repair and not completely functional for part of the 2006 cooling season. Additionally, for part of the cooling season room control temperatures may have been directed by the State Administration to be set so high as to prevent any reasonable (compared to ASHRAE recommended) humidity or temperature control within the facility.

It is our understanding that all of the ASHRAE guidelines for appropriate building ventilation rates assume that ASHRAE recommended thermal comfort control will be achieved during the time periods that they are being applied. The minimum ventilation rates internationally are based primarily on dilution of human bioeffluants from occupant activities. If temperatures and humidity are allowed to rise beyond normal recommended ranges, bioeffluent emission rates from the occupants will also rise significantly, likely rendering the resultant odors and irritants during the recommended, minimum ventilation rates unacceptable to the majority of the occupants and visitors.

4.1.8 Air Filters: TBS&D staff observed appropriate particulate air filters to be installed in most of the air handlers. In general, MERV 8 filters were observed with a few exceptions in the newest rooftop units. Upon discovery of the less efficient filters, BGS staff installed the proper MERV 8 filters in the units. As noted, most filters removed from heat pump units serving areas located near the Boiler Room, and from rooftop units, contained high levels of boiler soot. The current good quality, pleated surface MERV 8 filters which are used would be normal and adequate for an office facility, and would be expected to provide normal adequate filtration for pollen and mold spores. It is impossible for a standard filter such a MERV 8 grade filter to adequately remove combustion byproducts from direct or re-entrainment boiler fume contamination, due to the extremely small size of such combustion byproducts. Even a MERV 18-20 hospital grade filter would have limited effectiveness on sub-micron size combustion particles. See photos, Appendix D1:

4.1.9 OVERALL HVAC FINDINGS/CONCLUSIONS: It is our understanding that all the HVAC equipment and the associated components that are not newly installed (including the current installation of the retrofitted fin tube radiation in the older facility) has effectively served its useful life with regard to being fully functional and highly reliable for another 20 to 30 years. Given the current vacancy of the facility and the reason if was vacated, it is an appropriate time to either completely overhaul/rebuild the existing units, or to replace them with new systems. Additionally, based on our laboratory soot analysis, building pressure monitoring, and re-entrainment calculations, all of the current HVAC equipment, and all ductwork that exist within the facility should be assumed to have a fine coating of boiler soot within it, and is in need of thorough professional cleaning if it is to be reused. Corrective action recommendations are stated below.

RECOMMENDATION #1: REPLACE THE HVAC SYSTEM AND CONTROLS.

With the exception of the newest packaged rooftop air handlers, it is our understanding that all the HVAC equipment has served the majority of its useful, high reliability life, and is in need of replacement or a complete and careful overhaul/rebuilding to allow it to operate reliably for another 20 to 30 years. We have addressed six HVAC items that follow.

1) The New Rooftop Units: Careful consideration should be given to evaluate the reuse of the newly installed, packaged rooftop equipment and the additional features which are needed to improve the current rooftop design to allow the

equipment to adequately control outdoor air and zonal airflow during low occupancy periods, and under varying internal loads. Currently, many areas served by the rooftop equipment are observed to be unacceptably dry during winter conditions due to over-ventilation, and very damp during humid conditions, due to over-ventilation and lack of dehumidification capability. At least two of the large rooftop units (#8 and #8a) serve large areas and have variable flow diffusers that are not, and cannot be controlled by computer. It is our opinion that these areas would be better controlled with a true VAV system.

2) The Distributed Water Source Heat Pumps: It is our recommendation that careful consideration and life cycle analysis should be given to replacing the current water source heat pump design in the three-story facility, with central-type, ducted, variable air volume system with fixed plate, enthalpy energy recovery features for minimum ventilation air, and air economizer cooling. If a replacement water source heat pump system is reinstalled, the AC condensate drainage system must be design and installed so that it is readily serviceable, can be maintained in a suitable hygiene condition and such that inappropriate air flows are not created in the drain line system. Based on observations, the current installed heat pump drain line system does not have these features.

3) Perimeter Fin Tube Heating: The perimeter fin tube heating system needs to be removed and completely rebuilt (or replaced) with piping and installation features which will stop current ongoing water leakage onto hidden porous surfaces.

4) The DDC Controls: DDC Controls which allow proper controlled ventilation (especially in lightly or heavily occupied areas), good automatic thermal control, and provide adequate feedback to the operator need to be a feature of the new HVAC system. It is extremely desirable to have all variable flow devices and the perimeter fin tube controls to be part of the DDC Control System such that the operator will have a readout of air delivery at every VAV diffuser and VAV box control point, as well as water control valves.

5) Control Set Points: It is TBS&D's experience that operating a modern office building with normal low ceilings (without large operable window wall areas), with AC control points which allow temperatures to be controlled at up to 80 degrees, with no consideration of humidity levels or effects, and the subsequent risk of dew point condensation should be avoided. Additionally, guidance directing facility managers to operate a modern facility in this manner should be carefully reviewed. There may well be unintended, consequential mold amplification or significant lack of occupant productivity that counter the small

amount of energy savings that would be expected in a properly run and controlled building, that does not have excess air leakage during unoccupied periods.

6) Cleaning for Reuse: Any part of the air conveyance system that is reused must be carefully cleaned inside and out as outlined in Recommendation #4 below.

RECOMMENDATION #2: REPLACE THE BOILER SYSTEM.

Soot from the boilers has been identified throughout the facility. There are many options to consider stopping this situation from re-occurring that should be explored. They do not necessarily have to include replacing the actual boilers, although this should be a life cycle cost consideration. The options include, but are not limited to:

Option 1 (Minimum): Install a Very High Chimney:
Provide a boiler fume discharge point that exits a considerable distance (estimated 25 feet) above the third floor roof to stop re-entrainment into the facility.

Option 2a: In Addition to Option #1, Move Boiler Room to an Outside Wall:
Move the boilers to an outside wall area, with no ductwork passing through the Boiler Room, and meticulously fire stop seal all penetrations. This will allow the Boiler Room to receive combustion air passively, rather than through a forced supply system.

Option 2b: Automatic Boiler Room Pressure Control:
Provide and maintain a very sophisticated and reliable distributed boiler makeup air system that automatically senses and controls Boiler Room pressures (to be clearly negative) with respect to the rest of the facility, 24-hours a day, in addition to meticulous fire stop sealing, and removal of all HVAC ductwork passing through the Boiler Room.

Option 3: Geothermal Source Heating and Cooling:
Consider the long-term benefits or life cycle analysis of eliminating the boilers via use of a closed-loop, geo-borehole system, and geothermal heat pump units for heating and cooling, coupled with a tightened building envelope.

RECOMMENDATION #3: EVALUATE THE CHILLER SYSTEM.

The current condition of the chiller system is unknown. The condition and life should be carefully reviewed. If its current design includes an open-loop tower cooling system it should be replaced with a closed-loop system, as the drift from the unit at its present location will microbially contaminate the air intake on the first floor roof. If attempts were made to properly manage an open-type system with biocides in its current location, the drift and accompanying biocides would contaminate the rooftop air inlets with the biocide.

RECOMMENDATION #4: PROFESSIONALLY CLEAN ALL REMAINING DUCTWORK AND AIR HANDLERS.
Based on TBS&D diagnostic testing results, all of the current air handlers, heat pumps, and associated ductwork should all be assumed to be coated with a fine layer of accumulated, sticky boiler soot. Before re-occupancy, we recommend that this material be removed from all of the systems.

Additionally, a thorough professional cleaning of the unlined ductwork should remove any deposited microbial growth that has originated from the condensate line growth aerosolization, or from deposits of microbial growth from activity in the carpets that has entered the ductwork.

4.2 Building Envelope Design, Moisture and Air Intrusion Observations, and Recommendations

4.2.1 **<u>1991 Building</u>:** TBS&D diagnostic testing reveals the walls of the 1991 three-story building to be built as designed with exterior gypsum sheathing and a synthetic building wrap exterior drainage plane, behind the brick and a one-inch air space. We only located two small areas where the interior gypsum had become wet and supported limited mold growth within the walls. One small leak appears to be related to window flashing or below grade (berm) leakage in the Northeast Corner. See Appendix D1: Section 10, photos 20-22. The other leak was located in a spandrel wall system near the back stairwell. See Appendix D1: Section 10, photo 65-78.

4.2.2 **<u>1978 Building</u>:** Diagnostic testing of the wall system of the 1978 single-story structure reveals that the walls are not constructed as shown on the design drawings. Intrusive disassembly conducted in multiple areas revealed that there is not half an inch CDX plywood located behind the brick veneer and air space. We found half inch exterior paper covered gypsum and no exterior building wrap/drainage plane, located where plywood is indicated on the drawings. Based on observations in several other areas, on different wall exposures, this assembly appears to exist throughout the structure.

The entire south wall area of the Court facility is indicated (by infrared imaging) to be suspect of being damp. In this south wall exposure, in three separate areas where intrusive disassembly was conducted, very damp or wet gypsum sheathing was found and in some cases mold growth on the paper covered gypsum was obvious. See Appendix D1: Sections 10, photos 25 -35. In other wall areas of the 1978 facility, with different exposures, current dampness or wetness was not located, although infrared imaging suggests it may be present, or have been present at the time of the IR imaging survey.

Many of the high windows in the 1978 walls appear to have served their useful life, are fogged from moisture intrusion, and are very unattractive. The flashing under the windows in some areas appears tired (almost 30 years old), questionable, and failing, and may be contributing to moisture in the south wall of the Court areas.

Infrared imaging and blower door testing revealed typical gross air leakage at almost all of the wall/roof interface areas. See Appendix C1, pages 14-24.

In certain areas of the facility inadequate roof scuppers are soaking the exterior brick walls and there are floor slabs that by design extend to the exterior of the facility with no thermal break. See Appendix D1: Section 1, photo 7, and Section 9, photo 1,2,7,8.

RECOMMENDATION #5: REBUILD THE 1978 BRICK VENEER EXTERIOR WALLS FROM THE INTERIOR.
Based on TBS&D diagnostic testing results, the 1978 exterior wall system is currently failing in some areas and remains subject to future failure from moisture reaching paper covered gypsum sheathing. It is our recommendation to rebuild the entire perimeter of the 1978 building such that current and future water intrusion to porous materials will be very unlikely. TBS&D and Henri Fenell of FOAMTECH ™, located in North Thetford, Vermont have developed and published a proven methodology for rebuilding moisture failures in this vintage wall from the interior, without disturbing the brick veneer, which initially appears to be in good condition on this facility. See Appendix D-5 for *Pre-release Technical Publication*. Rebuilding this wall from the interior with three inches of spray-foam urethane insulation and using interior gypsum with a fiberglass covered side that faces the interior of the wall (Dens Armor™ or equal), should eliminate future moisture concerns within the wall, and will significantly improve the insulation value of the rebuilt wall.

RECOMMENDATION #6: RESEAL THE BERMED 1991 EXTERIOR WALL.
Based on TBS&D diagnostic testing results, during this renovation it would be prudent to excavate the bermed perimeter of the 1991 wall, and carefully inspect it and water proof the area. Based on the drawing details, there is no rigid insulation on the exterior of the concrete. It would likely be prudent at this time to add two inches of blue or pink exterior foam insulation to this location while the area is excavated. The foam insulation will also serve to permanently protect the waterproofing on the exterior of the concrete wall.

RECOMMENDATION #7: PROFESSIONALLY SEAL THE GROSS AIR LEAKAGE.

Based on TBS&D diagnostic testing results, there is clearly gross air leakage at the wall roof interface throughout most areas of the facility. This leakage should be eliminated with professional application of suitable spray or expanding foam materials on the interior of the joint during the building renovation. Properly sealed, this will greatly reduce cluster fly invasions without the use of pesticides and significantly reduce stack effect, and accompanying excess heat loss during the heating season, especially at night and on windy days.

RECOMMENDATION #8: REPLACE FAILED WINDOWS IN THE 1978 WING AND ADD OPERABLE WINDOWS.

Based on visual observations many of the seals in the double pane high windows in the 1978 wing have failed and are in need of replacement. This is evidenced by moisture between the two panes of glass. The window system in the 1978 part of the facility should be carefully evaluated for its remaining useful life regarding 30-year old flashing and sealants. During this renovation, when replacements are made, we recommend that approximately 10% of the overall window areas be made operable. This approach can serve as emergency ventilation, and should not significantly affect building performance with a well balanced HVAC system, especially after the current gross air leakage is eliminated.

RECOMMENDATION #9: ELIMINATE PERIMETER THERMAL BYPASSES AND GROSS WETTING IN 1978 FLOOR SLAB AREAS.

There are several concrete floor slabs near entrances on the northwest exposure (as indicated on drawings) where the slab extends all the way to the exterior. In this location, the slab is profusely wet by roof scupper drainage. These areas need to be redesigned and rebuilt to include a suitable thermal break in the slab between the interior and exterior, and to stop the scuppers from soaking the sides of the facility and wetting the floor slab.

4.3 Settled Dust & Condensate Drain System Reservoir Analysis Observations and Recommendations

Three types of representative settled dust sampling by TBS&D and subsequent lab analysis revealed reservoirs indicative of boiler soot deposition, some elevated mold growth in various locations, typical low levels of animal allergen when people who own pets occupy a facility, and barely measurable levels of dust mite allergen. Data revealed no indication of rodent or cockroach infestations.

The analyzed data reveals that a few of the carpets within the first floor of the facility have amplified mold levels present. Additionally, by visual observation it is also apparent that some areas of carpet have served their useful life with insufficient dirt extraction. In other areas, the carpets appear in good condition; however, mold amplification was indicated in one upper floor sample. Note: NIOSH at some point in the future will be able to provide more information on carpet dust materials as they plan to collect and analyze 120 additional samples.

When carpets on any floor are replaced, they should be replaced with readily cleanable, commercial, non-flow-through synthetic materials or suitable monolithic flooring.

Initial analysis of a few of the condensation drain line tubes reveal significant mold activity within the tubing. TBS&D visual observations of the 80 plus tubes removed for further laboratory analysis by NIOSH also suggest that they are a significant mold reservoir that had opportunity to be aerosolized and disseminated within the facility.

Unless future NIOSH laboratory data and VDOH analysis confirm other mitigation activities are warranted, based on the identified representative reservoirs, and ACGIH Bioaerosols guideline publications, we are recommending eliminating the reservoirs, efforts to prevent their re-occurrence, and detailed cleaning/refinishing of the interior of the facility.

RECOMMENDATION #10: CLEAN AND REFINISH BUILDING INTERIOR SURFACES.

Unless NIOSH and VDOH recommend more stringent protocols for clean up (on the basis of sample analysis results in the future) it is the opinion of TBS&D that all interior surfaces should be appropriately cleaned and refinished. For flooring, we suggest removing carpeting under low dust generation procedures, such as dampening the material with a wetting agent before removal and discarding and replacement with suitable new flooring that can be properly maintained. If attempts are made to reuse carpet tiles from upper floors that have many years of useful life remaining, they should be professionally machine cleaned off-site and proven to have no mold or dirt reservoirs in them before reinstallation.

For wall surfaces, we suggest wet washing with appropriate paint cleaning detergents for removing deposited boiler soot and any deposited microbial organisms, and repainting with appropriate finishes.

For ceilings, we suggest replacement of the current ceiling panels, as the most practical approach vs. attempts at cleaning to remove deposited, sticky boiler soot and dust.

Once ceiling tiles are removed, and suspended HVAC equipment is removed as required, it would also be prudent to HEPA vacuum any visible dust accumulation from beams, the top of walls, and the exterior of HVAC materials that will be reused, that are located in the interstitial ceiling space. Careful remedial cleaning (with HEPA vacuuming) of all significant visual deposits of settled dust throughout the building should be achieved prior to reconstruction of HVAC systems, which would make cleaning access more difficult.

Additionally, some type of suitable plan needs to be developed and implemented for future routine cleaning of heavily trafficked first floor areas, horizontal desks and other work surfaces (beyond dusting) that do not re-release settled materials into the air. When routine vacuuming is done, the vacuums should be equipped with HEPA rated particle capture filters. Hard surface floors should be cleaned with HEPA vacuuming, treated dust mops, and wet methods that remove dirt, and do not redistribute it into the breathing air.

4.4 Excess Outdoor Air Supply and Current Operation, Observations, and Recommendations

As noted in the Carbon Dioxide and Relative Humidity Data Section, this facility did not experience a lack of ventilation air during our monitoring, even before the occupancy was reduced as occupants moved out. In general, there is almost always excess ventilation air supplied which contributes to excess dryness during the heating season and can make humidity control difficult during damp periods, especially during cool, damp periods if no air-conditioning or heating is needed.

To date, we have not conducted an analysis of specifically where all the outside air is entering or leaving the building. However, it is likely based on CO_2 readings, that 50% of the outdoor air in the facility during our monitoring period is not serving the intended purpose of being delivered to the high occupancy areas to dilute indoor sources. This situation is wasting significant energy during peak heating and cooling periods. During humid weather in the cooling season, this excess quantity of damp air places a large moisture (latent energy) load on the mechanical equipment that is unnecessary, and during dry winter weather, a large heating load, that will contribute to excess dryness.

Also, the addition of enthalpy energy recovery devices (fixed plate type, not wheels) to building wide exhausts would provide much better, year round humidity control, better moisture management during cool, damp weather, vastly reduce coil size for dehumidification, and improved occupant comfort. This redesign would also reduce long-term energy operating costs.

RECOMMENDATION #11: REDUCE EXCESS OUTDOOR AIR DELIVERY. As noted above, during many hours of operation, the Carbon Dioxide data reveals a minimum outdoor air delivery rate of approximately 30-40 CFM per person or more. This delivery rate is high by any of today's standards and is energy inefficient. Careful evaluation of the situation should be conducted, and consideration should be given to an appropriate long-term solution for eliminating the observed excess outdoor air supply, which should reduce excess winter dryness. A detailed engineering analysis of this situation and corrective action recommendations are beyond our current scope. Fixed plate enthalpy energy recovery should be considered as part of a long-term solution for improving occupant comfort and indoor air quality.

4.5 High-Use Photocopier Observations and Recommendations

While walking through the facility on several occasions the odor of photocopying was noticeable to TBS&D staff. All ASHRAE recommended minimum ventilation rates are based on occupant body odor. ASHRAE specifically recommends that photo reprographics be maintained in areas that are under isolation or effective exhaust. Volatile organic emissions released from melting toner and bonded to paper represent a possible significant VOC source located within the building that is distributed throughout many areas. Toner is a mixture of iron powder and carbon black, with a bonding agent such as styrene monomer or other plastics. It has been reported by US EPA pollution prevention researchers that the levels of emissions from one batch of toner to another can vary widely, and that the emission levels are not generally predictable. Technical papers authored by Xerox researchers have conveyed that they have eliminated carcinogenic materials from the carbon black in their toners. It is also reported that the plastic agents used to bond the carbon black to the paper are proprietary to the manufacturer and constantly being reformulated. The byproducts of high volume printing/photocopying include fugitive gaseous emissions of the plastics that bond the carbon and iron powder to the paper, possibly ozone as a byproduct of a high intensity lamp, and fugitive toner. It is known by many that exposure to copy emissions has been reported in the medical literature to exacerbate known asthmatic conditions under research conditions. See Appendix D6.

Based on simple visual observations, the few walk-up, high-use copy machines that are located in the facility do not meet the ASHRAE Standard 62 recommended practices for HVAC design in printing and photo duplication areas. These guidelines specify a minimum of three air changes per hour with adequate local exhaust to prevent dissemination of irritant materials into adjoining spaces. The term irritants is used to describe levels of contaminants well below classic enforceable health based exposure limits, at levels that may pose a mucous membrane and lower respiratory irritation to some sensitized individuals. For more information on low-level VOC irritation effects see Appendix D6 LBNL Report #51570, dated October 16, 2002.

It is our experience that all high-use photocopiers should be equipped with the optional heat extractor (exhaust fan and duct) when they are available, and if installed, the exhaust should be ducted directly to the outdoors. Additionally, whether the optional exhaust is available or not, they should be located in a room within a room that is also exhausted. Based on the first principal of industrial hygiene engineering controls, i.e., local exhaust is the most cost effective approach for exposure reduction. This approach is in accordance with ASHRAE Standard 62 recommended practice. Thus, the air from the room the machines are located in should be exhausted directly to the outdoors and discharged out of the aerodynamic wake of any nearby air intakes.

RECOMMENDATION #12: ISOLATE AND EXHAUST ALL HIGH-USE PHOTOCOPYING.

The first principle of Industrial Hygiene ventilation control is isolation and exhaust. We recommend that all high-use copy machines be equipped with any exhaust features if they are available from the manufacturers, and that the dedicated exhausts are conveyed to the outdoors. Additionally, whether they are available with exhaust or not, the isolation rooms (room within a room) that the machines are located in should be proven to be isolated from the general HVAC system, and exhausted to the outdoors, (i.e., air from the copying area should not be re-circulated to other parts of the facility). This recommended approach is in accordance with ASHRAE Standard 62 guidelines for printing and photo-duplicating areas.

4.6 Reported Tobacco Smoke Odors, Observations, and Recommendations

It is our understanding that current smoking activity occurs adjacent to entrance doors in various locations around the facility. During our occupancy of the facility, tobacco smoke smells within the facility were sometimes noticeable. In addition, brief elevated levels of Very Small (>0.5 μm) Particles measured during occupied hours are likely due to the introduction of tobacco smoke through entrance doors. In order to prevent the occasional exposure of occupants to secondhand smoke, which is currently regarded as a carcinogenic material, and may trigger asthma attacks, these occasional exposures should be stopped.

RECOMMENDATION #13: FURTHER ISOLATE TOBACCO SMOKE AWAY FROM THE BUILDING, SO THAT THE INTERIOR OF THE BUILDING IS NEVER IMPACTED WITH ODORS.

The emissions from tobacco smoke are periodically noted within the facility. In order to prevent the occasional exposure of occupants to secondhand smoke within the facility, causing possible asthma exacerbation, smoking areas should be moved at least a recommended 50 feet away from any building feature, or to the property line, as has been done in other states.