INDOOR AIR QUALITY ASSESSMENT

Division of Capital Asset Management
One Ashburton Place
Boston, Massachusetts 02108

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health
Indoor Air Quality Program
May 2008

Background/Introduction

In response to a request from John O'Donnell of the Division of Capital Asset Management (DCAM), the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health (BEH) provided assistance and consultation regarding indoor air quality concerns at the DCAM headquarters, One Ashburton Place, Boston, Massachusetts. On March 5 and 6, 2008, visits were made to DCAM by Michael Feeney, Director of BEH's Indoor Air Quality (IAQ) Program, and James Tobin, an environmental analyst in the IAQ program, to conduct an assessment. The assessment was conducted to evaluate concerns about heat distribution and potential indoor air quality problems on the 10^{th}, 14^{th}, 15^{th} and 16^{th} floors.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID) and an Hnu, Model 102 Snap-on PID. Surface temperatures of window panes and induction units were measured with a ThermoTrace infrared thermometer. BEH staff also performed visual inspection of building materials for water damage and/or microbial growth.

Results

The DCAM has an employee population of approximately 150 and is visited daily by various members of the public as well as state and federal agencies. The tests were taken during normal operations and results appear in Tables 1 and 2. It is important to note that the names appearing in Tables 1 and 2 denote an area of cubicles tested around the particular desk noted.

Surface temperature readings were taken of window panes and induction units in a number of offices/areas on the 15th floor. Air temperature was also measured in the center of each office/area. Since offices/areas are not numbered, a floor plan with temperature of window panes, induction unit and air in center of each office is listed on a floor chart of the 15th floor (Figure 1).

Discussion

Ventilation

It can be seen from Tables 1 and 2 that carbon dioxide levels were below 800 parts per million (ppm) in all areas surveyed, indicating adequate air exchange in occupied spaces. On the DCAM floors, ventilation is provided by heating, ventilation and air-conditioning (HVAC) units. Fresh air is supplied to each floor by a combination of air diffusers located on the light fixtures in the suspended ceiling and induction units located at the base of the windows. On the 10th, 14th and 16th floors, exhaust ventilation is provided by ducted return air vents located on the light fixtures in the suspended ceiling. However, on the 15th floor, it appears that the HVAC system configuration has been substantially altered. Fresh air is supplied by ceiling mounted diffusers with exhaust ventilation provided by plastic grilles in the suspended ceiling, converting the HVAC system into a ceiling plenum return system.

Of note is the computer mainframe room on the 15th floor. No fresh air supply or exhaust system was identified in this area; however, the space is used as a permanent office space. Mainframe rooms are usually configured to regulate the temperature of the computer equipment. If this area is to be used for office space, fresh air supply and exhaust ventilation should be provided.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room, while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years (SMACNA, 1994). The date of the last balancing was not available at the time of the assessment.

The Massachusetts Building Code requires that each area have a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, consult Appendix A.

On March 5, 2008, temperature measurements in occupied areas were in a range of 70^{o} F to 76^{o} F (Table 1), and on March 6, 2008, from 72^{o} F to 76^{o} F (Table 2). On both days the temperature measurements were within the MDPH recommended comfort range. The MDPH recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

A lack of temperature control was expressed by individuals in a number of areas within DCAM occupied spaces, particularly on the 15^{th} floor. The excess heat or cold complaints on the 15^{th} floor can be attributed to the following conditions:

- The kitchen area does not have an exhaust vent that is separate from the general HVAC system. In this condition, waste heat from cooking and other kitchen appliances is allowed to enter the ceiling plenum.
- On the south side of the 15^{th} floor, the center aisle of this cubicle area does not have evenly spaced fresh air diffusers. The lack of fresh air diffusers can allow for heated air from computer equipment and the 15^{th} floor kitchen to remain and accumulate in this area.
- The computer mainframe room has a chiller system retrofitted into the suspended ceiling (Picture 2). The purpose of a chiller is to provide chilled coolant for wall-mounted air-conditioning units in the mainframe room. In order to chill the coolant, a chiller has a large fan to draw air over the coils to remove heat. The heated air from this chiller is

then *ejected into the 15th floor ceiling plenum*. The operation of this equipment would create a zone of heated air around the fan and disturb dust and other debris in the ceiling.

- The configuration of the window system makes the building highly susceptible to uneven heating due to solar gain. The window system of the building consists of a single pane of glass installed inside a metal frame. When exposed to direct sunlight, the glass and metal of the windows become a significant heat source. BEH staff measured the temperature of the window glass around the most of the 15th floor (Figure 1) (outdoor temperature of 42°F at ground level/Table 2). Window glass on the 15th floor was in direct sunlight, partial sunlight or in shade. Windows on the south and west walls were in direct sunlight and temperature measurements ranged from 75°F to 92°F (Figure 1). Windows on parts of the west wall were in partial sunlight and temperature measurements ranged from 67°F to 80°F (Figure 1). . Windows on the north and east wall were in shade and temperature measurements ranged from 27°F to 47°F (Figure 1). Some offices had an extreme temperature range (over 40°F) between individual windowpanes in the same room. As an example, the commissioner's office located on the northeast corner of the 15th floor, had window pane temperatures that ranged from 38°F to 79°F (Figure 1).
- Temperatures of induction unit fresh air supply grilles were also measured. The surface temperature was measured in a range from 41°F to 58°F (Figure 1). The window systems in areas along the shaded side of the building (north and east walls) are *actually heated* by the induction units [window pane temperature ranges from 27°F to 47°F (Figure 1)]. This range in temperature may indicate that the induction unit boxes are also influenced by solar gain, as is the window system. If desks are located within the

airflow created by the induction units, occupants are likely to report uneven temperatures in these locations.

Each of these aforementioned conditions can contribute to the wide range of heat and cold concerns on the 15th floor.

On March 5, 2008, relative humidity measurements ranged from 34 to 46 percent (Table 1), and on March 6, 2008 from 20 to 36 percent (Table 2). These measurements were below the MDPH recommended comfort guidelines in the majority of areas surveyed. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial Growth/Moisture Concerns

Several potential sources of water damage and mold growth were observed. Of note is the air-conditioning equipment in the computer mainframe room (Picture 3). Each of these units generates condensation during operation, which must be appropriately drained. BEH staff checked the slope of the drain pipe and found it to be sloped away from the condensation pumps (Picture 4). In this condition, water will accumulate within this pipe. Standing water can be a mold growth medium.

A number of areas had water-damaged ceiling tiles which can indicate leaks from the plumbing system. Water-damaged ceiling tiles can provide a source of mold and should be replaced after a water leak is discovered and repaired.

A water bubbler was located over a carpeted area. The carpet below the water bubbler can become moistened by use of the cooler and spillage. Condensation can form on the surface of the water bubbler in a warm, moist environment and drip from the bubbler and moisten the carpet. Overflow of the water bubbler or spills that often occur around the water source can also moisten carpeting. Porous materials that are wet repeatedly can serve as media for mold growth.

The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If not dried within this time frame, mold growth may occur. Once mold has colonized porous materials, they are difficult to clean and should be removed.

Plants were observed in several areas. Plants, soil and drip pans can serve as sources of moisture, which can initiate mold growth. Thus, plants should be properly maintained. Over-watering of plants should be avoided and drip pans should be inspected periodically for mold growth. Moreover, a few areas had water coolers installed over carpeting. Water spillage or overflow of cooler catch basins can result in the wetting of the carpet, which can lead to mold growth.

Other IAQ Evaluations

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the office environment, BEH staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2006). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2006).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. On March 5 and 6, 2008, outdoor carbon monoxide concentrations were non-detect (ND) (Tables 1 and 2). Carbon monoxide levels measured indoors were also ND on both days of the assessment (Tables 1 and 2).

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2006). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA established a more protective standard for fine airborne particles. This more stringent PM2.5 standard requires outdoor air particle levels be maintained below 35 $\mu g/m^3$ over a 24-hour average (US EPA, 2006). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

On March 5, 2008, outdoor PM2.5 concentrations were measured at 6 $\mu g/m^3$ and indoor levels ranged from 5 $\mu g/m^3$ to 10 $\mu g/m^3$ (Tables 1). On March 6, 2008, outdoor PM2.5 concentrations were measured at 20 $\mu g/m^3$ and indoor levels ranged from 2 $\mu g/m^3$ to 8 $\mu g/m^3$ (Tables 2). On both days of the assessment, indoor PM2.5 levels were below the NAAQS PM2.5 level of 35 $\mu g/m^3$. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in buildings can generate particulates during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air concentrations can be greatly impacted by the use of products containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. On both March 5 and 6, 2008, outdoor TVOC concentrations were ND (Tables 1 and 2). Indoor TVOC concentrations were also ND on both days of the assessment (Tables 1 and 2).

Photocopiers were present in a number of areas throughout the floors occupied by DCAM. These areas were not equipped with local exhaust ventilation to help reduce excess heat and odors. VOCs and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, 1992).

Several areas contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat. Moreover, cleaning products and air fresheners were seen in some areas (Tables 1 and 2). Like dry erase materials, cleaning products and air fresheners contain VOCs and other chemicals that can be irritating to the eyes, nose and throat of sensitive individuals. In addition, air fresheners do not remove but mask odors that may be present.

Numerous personal fans were observed throughout each floor. It is important that fan blades be cleaned of accumulated dirt, dust and debris because this material can become aerosolized when the fan is reactivated. Further, a high efficiency particulate air (HEPA) purifier was noted. Air purifiers should be placed within the breathing zone rather than at floor level. It is important to note that this equipment is normally equipped with filters that should be cleaned or changed as per manufacturer's instructions to prevent build up and re-aerosolization of dirt, dust and particulate matter.

Conclusions/Recommendations

Based on the observations made during this assessment, the perceived lack of uniform temperature within the DCAM offices areas is related to the following conditions:

- Lack of exhaust ventilation for the kitchen;
- Uneven placement of fresh air supply vents on the south side of the 15th floor;
- The addition of a chiller for the mainframe room in the ceiling plenum;
- Solar gain from the building window system;
- Temperature of air provided by the induction units; and
- Office desks located next to the induction units to place office occupant in air flow of the induction unit.

In view of the findings at the time of the visit, the following recommendations are made:

1. Provide a fresh air supply and exhaust system for the computer mainframe room if used as office space. If not feasible, do not use this location as office space.
2. Examine the various methods that can be used to direct the heated airflow produced by the operation of the chiller fan above the computer mainframe room to the return vent for the main building's HVAC system.
3. Examine the feasibility of providing exhaust ventilation for the 15th floor kitchen.
4. Examine the feasibility of reconfiguring offices to remove desk chairs from close proximity to induction units.

5. Examine the feasibility of adding more fresh air supply vents the center of the 15th floor cubicles.
6. BEH staff could not readily determine how the temperature of the induction units is controlled. The following options should be explored to gain better control over temperature.
    a. Examine the feasibility of whether induction unit air temperature can be increased in areas that are prone to having cold window panes in the heating season.
    b. Examine the feasibility of whether induction unit air temperature can be decreased in areas that are prone to having warm window panes in the heating season.
    c. Examine induction units to determine whether the inclusion of insulation can provide better temperature control.
7. Consider balancing mechanical ventilation systems every 5 years, as recommended by ventilation industrial standards (SMACNA, 1994).
8. Ensure plants have drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial where necessary.
9. Place plastic mats beneath water bubbler and coolers.
10. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

11. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website at http://mass.gov/dph/indoor_air.

References

ACGIH. 1989. Guidelines for the Assessment of Bioaerosols in the Indoor Environment. American Conference of Governmental Industrial Hygienists, Cincinnati, OH.

ASHRAE. 1989. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-1989

BOCA. 1993. The BOCA National Mechanical Code-1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL.

M.G.L. 1986. Stopped motor vehicles; Operation of Engine; Time Limit; Penalty. Massachusetts General Laws. M.G.L. c. 90:16A.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R. 1910.1000 Table Z-1-A.

Sanford. 1999. Material Safety Data Sheet (MSDS No: 198-17). Expo® Dry Erase Markers Bullet, Chisel, and Ultra Fine Tip. Sanford Corporation. Bellwood, IL.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0

Schmidt Etkin, D. 1992. Office Furnishings/Equipment & IAQ Health Impacts, Prevention & Mitigation. Cutter Information Corporation, Indoor Air Quality Update, Arlington, MA.

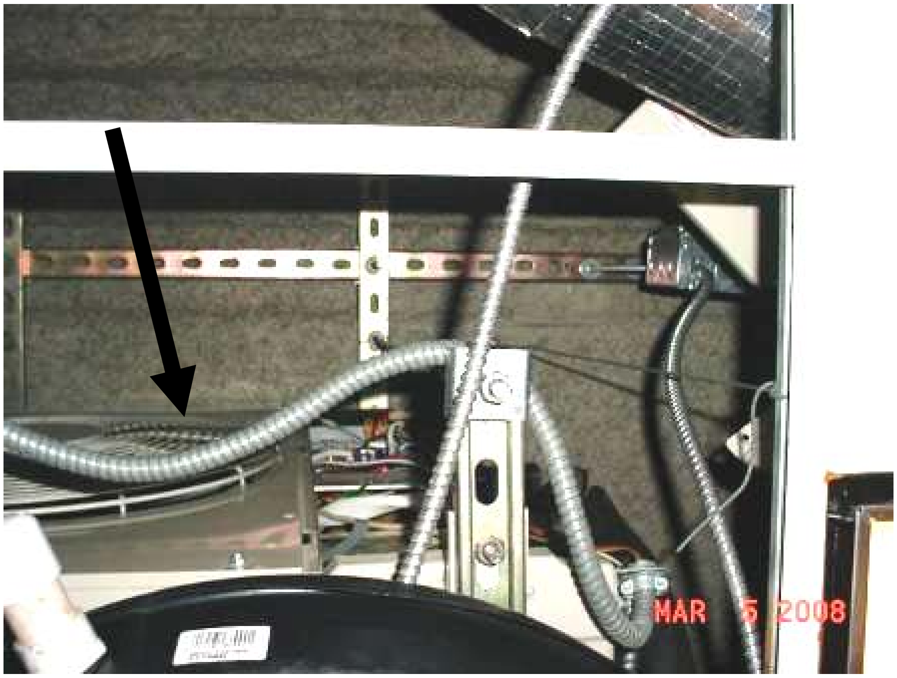
SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

US EPA. 2001. Mold Remediation in Schools and Commercial Buildings. US Environmental Protection Agency, Office of Air and Radiation, Indoor Environments Division, Washington, DC. EPA 402-K-01-001. March 2001.

Picture 1

Ceiling Mounted Air Diffusers

Picture 2

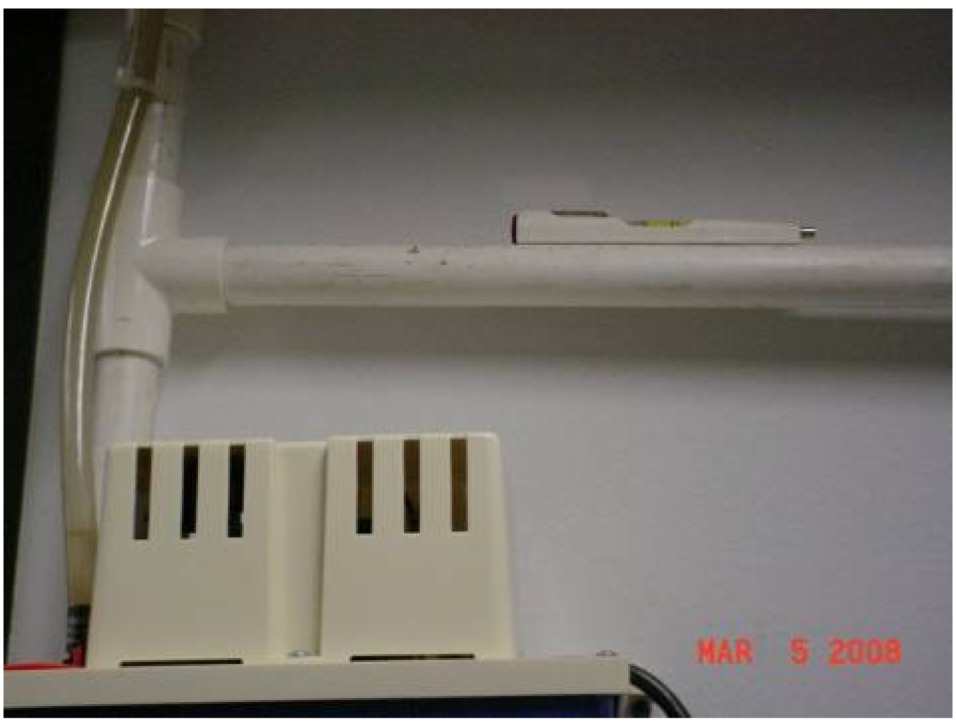


Chiller Located In the Ceiling Plenum above the Computer Mainframe Room
Note Fan

Picture 3

Wall-Mounted Air Conditioner in Mainframe Room

Picture 4



Drain Pipe for Wall Mounted Air Condition
Note the Pipe Is Sloped Away From the Condensation Pump

Location: DCAM, 15th Floor

Address: One Ashburton Place, Boston, MA

Table 1

Indoor Air Results

Date: 3-5-2008

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 ($\mu g/m^3$)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
background		54	40	370	ND	ND	6				Overcast; Windy
Conference	4	70	46	461	ND	ND	10	N	Y	Y	Return vent BD, not ducted
Tivnan	1	71	45	447	ND	ND	8	N	Y	Y	PF
Meeker	0	72	44	464	ND	ND	7	N	Y	Y	
Kern	1	72	44	458	ND	ND	9	N	Y	Y	
Swingle	0	72	44	477	ND	ND	8	N	Y	Y	Clutter
Copy Room	0	73	43	466	ND	ND	8	N	N	N	PC-odor; PF
Planning Area	1	74	42	469	ND	ND	8	N	Y	Y	PC; Blueprint machine; Paper Shredder

ppm = parts per million
$\mu g/m^3$ = micrograms per cubic meter
ND = non detect

AD = air deodorizer
AP = air purifier
BD = backdraft
CT = ceiling tile

DEM = dry erase materials
PC = photocopier
PF = personal fan
WD = water-damaged

Comfort Guidelines

Carbon Dioxide:	< 600 ppm = preferred	Temperature:	70 - 78 °F
	600 - 800 ppm = acceptable	Relative Humidity:	40 - 60%
	> 800 ppm = indicative of ventilation problems	Particle matter 2.5	< 35 ug/m^3

Location: DCAM, 15th Floor

Address: One Ashburton Place, Boston, MA

Indoor Air Results

Date: 3-5-2008

Table 1 (continued)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m³)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
O'Connor	1	74	40	454	ND	ND	7	N	Y	Y	
Lambert	0	72	40	445	ND	ND	7	N	Y	Y	DEM
Shah	2	73	41	458	ND	ND	8	N	Y	Y	PFs; Clutter
Harvey	1	74	40	481	ND	ND	8	N	Y	Y	PF; Clutter
Morse	1	74	40	474	ND	ND	8	N	Y	Y	PF
Ford	0	75	40	477	ND	ND	7	N	Y	Y	Clutter
Tagan	1	75	39	484	ND	ND	8	N	Y	Y	AP on desk; PF
Reardon	1	75	39	466	ND	ND	7	N	Y	Y	PF
Anderson	1	75	39	585	ND	ND	9	N	Y	Y	PC; Clutter

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Indoor Air Results

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Table 1 (continued)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (μg/m³)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
O'Donnell	0	74	37	423	ND	ND	7	N	Y	Y	PF; Clutter
Lynna	0	73	37	465	ND	ND	8	N	Y	Y	PF; Clutter; DEM
Assar	0	74	38	428	ND	ND	7	N	Y	Y	Clutter
Nelson	1	74	39	455	ND	ND	6	N	Y	Y	PF; DEM
Cassidy	2	74	39	481	ND	ND	7	N	Y	Y	PF
Cyr	5	75	39	508	ND	ND	8	N	Y	Y	PF; Clutter
Kitchen	1	76	39	556	ND	ND	9	N	Y	Y	Refrigerator; Microwave; Soda Machine
Klayman	2	76	38	561	ND	ND	9	N	Y	Y	
Fielding	1	76	37	515	ND	ND	8	N	Y	Y	PF

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Location: DCAM, 15th Floor **Indoor Air Results**

Address: One Ashburton Place, Boston, MA **Date: 3-5-2008**

Table 1 (continued)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (μg/m^3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Grant	1	76	37	507	ND	ND	8	N	Y	Y	
McKimmey	1	73	36	440	ND	ND	7	N	Y	Y	
Mailloux	1	74	37	479	ND	ND	9	N	Y	Y	PF; Plant-vines hanging
Rafuse	1	74	37	517	ND	ND	9	N	Y	Y	PF
Freeman	2	75	37	494	ND	ND	7	N	Y	Y	Cleaners; PF
Campos	2	75	38	496	ND	ND	7	N	Y	Y	Plants
Clare	2	75	37	503	ND	ND	8	N	Y	Y	Plants; Clutter; PF
Walsh	2	75	37	507	ND	ND	7	N	Y	Y	PF
Gray	1	75	37	511	ND	ND	8	N	Y	Y	Clutter; PF

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Address: One Ashburton Place, Boston, MA

Indoor Air Results

Date: 3-5-2008

Table 1 (continued)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (μg/m^3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Tanin	1	75	36	508	ND	ND	7	N	Y	Y	Clutter; PF
File Room	0	75	35	429	ND	ND	8	N	Y	Y	
Courts Conference	0	74	36	407	ND	ND	9	N	Y	Y	PF
Wiggin	4	75	37	504	ND	ND	8	N	Y	Y	Odors and Debris from Suppy; PF
Mulla	0	74	36	435	ND	ND	8	N	Y	Y	2 WD CT along window; Plants-dirty drip pan; DEM; PF
Copy Room (Mulla)	0	73	37	456	ND	ND	8	N	N	N	2 PCs-odor; PF
Minnis	0	73	37	414	ND	ND	7	N	Y	Y	Plant
Rosenberg	1	73	36	432	ND	ND	7	N	Y	Y	Plants; Clutter; PF
Benson	2	73	37	468	ND	ND	7	N	Y	Y	

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Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%
Particle matter 2.5 < 35 ug/m^3

Location: DCAM, 15th Floor

Address: One Ashburton Place, Boston, MA

Indoor Air Results

Date: 3-5-2008

Table 1 (continued)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m³)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Server Room	2	73	40	508	ND	ND	7	N	N	N	ACs; WD CT; Exposed chiller with no drip
Deknatel	1	71	39	462	ND	ND	7	N	Y	Y	Plants; Clutter
Meyer	1	72	40	462	ND	ND	7	N	Y	Y	Plants
McMahon	1	72	39	490	ND	ND	8	N	N	Y	Clutter
Loeb	1	72	38	446	ND	ND	8	N	N	Y	
Goldfischer	0	72	37	419	ND	ND	7	N	N	Y	PF
Law Library	0	72	36	383	ND	ND	7	N	Y	Y	Bubbler on Carpet
Matthews	0	72	37	397	ND	ND	7	N	N	Y	PF
Farrell	1	72	38	441	ND	ND	9	N	N	Y	

ppm = parts per million
µg/m³ = micrograms per cubic meter
ND = non detect

AD = air deodorizer
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BD = backdraft
CT = ceiling tile

DEM = dry erase materials
PC = photocopier
PF = personal fan
WD = water-damaged

Comfort Guidelines

Carbon Dioxide:	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature:	70 - 78 °F
Relative Humidity:	40 - 60%
Particle matter 2.5	< 35 ug/m³

Table 1 (continued)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (μg/m³)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Executive Conference	0	72	37	437	ND	ND	7	N	Y	Y	
Commissioner Conference	0	72	37	386	ND	ND	7	N	Y	Y	Plants; PF
Coakley	1	72	37	431	ND	ND	7	N	Y	Y	
McGinness	0	73	37	458	ND	ND	6	N	N	Y	Plants
Wilson	1	73	38	514	ND	ND	7	N	Y	Y	PF
Casey	4	73	37	459	ND	ND	7	N	Y	Y	PF
Main Entrance	1	73	36	468	ND	ND	7	N	Y	Y	
Carr	1	73	36	450	ND	ND	6	N	Y	Y	
Planning Library	0	74	34	448	ND	ND	6	N	Y	N	

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Comfort Guidelines

Carbon Dioxide:	< 600 ppm = preferred	Temperature:	70 - 78 °F
	600 - 800 ppm = acceptable	Relative Humidity:	40 - 60%
	> 800 ppm = indicative of ventilation problems	Particle matter 2.5	< 35 ug/m³

Location: DCAM, 15th Floor

Address: One Ashburton Place, Boston, MA

Indoor Air Results

Date: 3-5-2008

Table 1 (continued)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 ($\mu g/m^3$)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Commissioner Office	1	73	35	428	ND	ND	5	N	N	Y	
Elevator Area	0	74	36	461	ND	ND	6	N	Y	Y	

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Carbon Dioxide:	< 600 ppm = preferred	Temperature:	70 - 78 °F
	600 - 800 ppm = acceptable	Relative Humidity:	40 - 60%
	> 800 ppm = indicative of ventilation problems	Particle matter 2.5	< 35 ug/m^3

Location: DCAM

Address: One Ashburton Place, Boston, MA

Indoor Air Results

Date: 3-6-2008

Table 2

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (μg/m^3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
background		42	41	393	ND	ND	20				Partly Cloudy
!0th Floor Sainsbury	1	74	20	516	ND	ND	3	N	Y	Y	PC; PF; DEM; Refrigerator; Microwave
10th Floor Melendez	1	73	20	499	ND	ND	4	N	Y	Y	PF
14th Floor Copy Area	0	76	32	469	ND	ND	3	N	Y	Y	PC; Bubbler on carpet
14th Floor File Room	0	76	32	445	ND	ND	2	N	Y	Y	
14th Floor 14035	0	74	34	419	ND	ND	5	N	Y	Y	PF
14th Floor 14006	0	73	35	439	ND	ND	4	N	Y	Y	
14th Floor 14007	0	74	34	455	ND	ND	4	N	Y	Y	PC; Plot Machine; Bubbler on carpet
14th Floor 14011	1	73	35	445	ND	ND	4	N	Y	Y	WD CT
14th Floor 14014	1	72	35	505	ND	ND	4	N	Y	Y	

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Temperature: 70 - 78 °F
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Table 2 (continued)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (μg/m^3)	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
14th Floor 14016	1	72	35	424	ND	ND	5	N	Y	Y	WD CT
14th Floor 14018	1	72	35	446	ND	ND	5	N	Y	Y	
14th Floor 14022	2	72	36	443	ND	ND	6	N	Y	Y	
14th Floor 14029	0	72	36	438	ND	ND	5	N	Y	Y	Plants
14th Floor 14032	0	72	35	413	ND	ND	5	N	Y	Y	
14th Floor 14033	0	73	34	392	ND	ND	5	N	Y	Y	Plants; PF
14th Floor 14038	1	73	35	452	ND	ND	8	N	Y	Y	Plants; PF
14th Floor Bender	2	74	34	489	ND	ND	3	N	Y	Y	PF
14th Floor Buckley	2	73	35	520	ND	ND	3	N	Y	Y	PF

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Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%
Particle matter 2.5 < 35 ug/m^3

Table 2 (continued)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (μg/m^3)	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
14th Floor Conference	0	76	32	440	ND	ND	3	N	Y	Y	
14th Floor DeCilio	1	74	34	455	ND	ND	3	N	Y	Y	PF
14th Floor Falasca	0	74	34	475	ND	ND	3	N	Y	Y	Plants
14th Floor Keane	1	75	34	527	ND	ND	4	N	Y	Y	PF
14th Floor Kowalski	1	76	34	486	ND	ND	3	N	Y	Y	Cleaners; DEM; PF; Refrigerator; Microwave; Toaster
14th Floor Pierce	0	73	34	468	ND	ND	3	N	Y	Y	Cleaners
16th Floor Barr	0	72	20	494	ND	ND	4	N	Y	Y	Plants; Bubbler on Carpet; Refrigerator; Microwave; Toaster
16th Floor Bid Area	0	73	21	525	ND	ND	5	N	Y	Y	PC
16th Floor Bizanos	1	72	20	486	ND	ND	4	N	Y	Y	PF

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Table 2 (continued)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (μg/m³)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
16th Floor Brown	1	73	21	517	ND	ND	5	N	Y	Y	Plants; AD
16th Floor Ciarlante	1	72	20	490	ND	ND	4	N	Y	Y	Plants; DEM
16th Floor Conference	0	73	20	487	ND	ND	4	N	Y	Y	
16th Floor Copy Room	1	72	22	518	ND	ND	5	N	Y	Y	PC; Paper Shredder; Cleaners; Refrigerator; Microwave
16th Floor Federico	0	72	20	511	ND	ND	4	N	Y	Y	Plants; Spray Cleaners; PFs
16th Floor Flanigan	1	72	20	532	ND	ND	4	N	Y	Y	PF
16th Floor Harris	2	72	21	501	ND	ND	4	N	Y	Y	Ventilation on Light Fixtures; Bubbler on Carpet
16th Floor Judge	0	72	20	477	ND	ND	5	N	Y	Y	Plants
16th Floor McClain	1	73	20	508	ND	ND	5	N	Y	Y	

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Table 2 (continued)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (μg/m³)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
16th Floor Wheeler	2	72	20	508	ND	ND	5	N	Y	Y	Plants; Clutter

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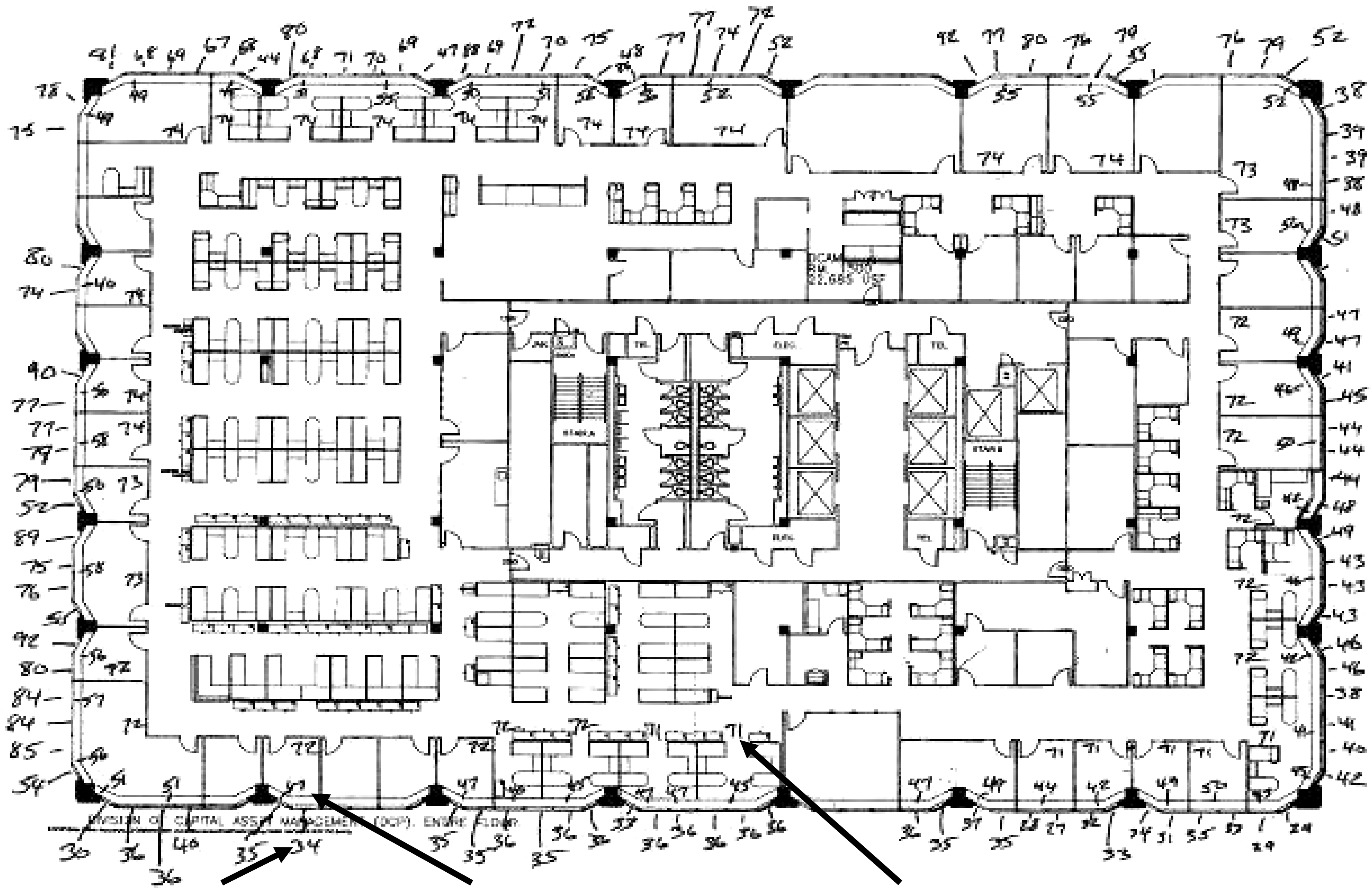
Figure 1
Figure of Surface Temperatures of Window Panes and Induction Units; and Room Temperatures of Various Locations on the outer wall of the 15th floor One Ashburton Place, Boston, MA



Window Pane Temperature　　Induction Unit Temperature　　Room Temperature

Figure 1

Figure of Surface Temperatures of Window Panes and Induction Units; and Room Temperatures of Various Locations on the outer wall of the 15th floor One Ashburton Place, Boston, MA

Note: Temperature is in degrees Fahrenheit