CAMBRIDGE PUBLIC SCHOOLS

BUILDING INTERIOR MOISTURE & HUMIDITY ISSUE ANALYSIS

December 21, 2018

Prepared for:

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Cambridge Public Schools – Building Interior Moisture & Humidity Issue Analysis
Cambridge, MA
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GGD Consulting Engineers was hired to perform a building HVAC system study related to excess interior moisture and humidity levels experienced within the Baldwin, Morse and Peabody Schools. It is our understanding that these Cambridge Public School Buildings have experienced excessive condensation during the summer of 2018. Condensation damaged many finishes which resulted in various levels of mildew and mold in several rooms. Removal and replacement of the damaged finishes were required. The condensation occurred on multiple surfaces including on insulated pipes.

The following buildings have been reported on:

- Baldwin School, 85 Oxford Street
- Morse School, 40 Granite Street.
- Peabody School, 70 Rindge Avenue

All three schools utilize two pipe heating and cooling with changeover in Spring/Fall.

All three schools have central water chillers operating at fixed chilled water temperatures, that depending on load. The chillers normally operate at 44 degrees F to 50 degrees F at the Morse and Baldwin School. Higher outdoor temperatures effect the Peabody School most with CHWS temperatures reported as high as 58 degrees F.

Morse and Peabody Schools utilize room fan coil units with outdoor air intakes by GGD virtually every classroom. Baldwin utilizes 15 air handling units (AHUs) that serve classrooms and common areas.

Trend data was provided by the Cambridge Public Schools and utilized in to perform our evaluation of the systems.

Baldwin School – Building Interior Moisture & Humidity Issue Analysis
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BALDWIN SCHOOL

General:

Fan coil units and indoor air-handling units with hot water/chilled water coils serve all spaces within the building to provide heating, ventilation, and cooling (where available). Chilled water is produced by a 205 Ton split "McQuay" Model PEH205 water-cooled chiller coupled with an outdoor "Baltimore Air Coil" cooling tower. This chiller delivers chilled water to all of the fan-coil units and indoor-mounted air handling units. Various roof-mounted exhaust fans are ducted to remove excess building pressure resulting from the introduction of outdoor air to the building interior via fan coils and air-handling units.

Field Observations:

Floors, pipes, walls, and windows were observed to be wet to the touch at the time of observation (November 06, 2018), thereby confirming the necessity of this analysis. There were a number of concerns noted at the time of the building survey that all factor-in to the current high-moisture condition that occurs during the cooling season; these factors include: building envelope infiltration, inadequate mechanical insulation, HVAC controls sequence of operation, building pressurization, and inadequate de-humidification capabilities of the installed HVAC systems.

- The building maintenance staff reported closing outdoor air dampers associated with unit ventilators and other HVAC equipment during the cooling season in order to avoid pulling in humid air from the outdoors. This attempt to alleviate building interior moisture concerns is falling short of its goal because the exhaust fans throughout the building continue to run at the same speed, creating a negative pressure within the building with respect to the outdoors. This negative pressure encourages humid outdoor air to seep in through exterior doors, windows, and leaks within the building envelope. While this humid outdoor air would be coming in through the HVAC equipment if the outdoor air dampers were open, less of this humid air would be introduced to the above-ceiling areas where condensation forming on chilled water piping has been an on-going issue.
- The chilled water piping routed throughout the building is generally concealed above ceilings and insulated. However, there were many fittings and valves observed to be missing insulation. Much of the insulation currently installed is loosely-fitting and compromised by a non-continuous vapor barrier. The insulation that is currently installed seemed to fall short of current code minimum requirements for thickness and density. 1/2" thick and 1" thick insulation was observed where current code requires a minimum thickness of 1-1/2" (for dual-temperature use). Portions of missing and/or damaged insulation were observed above the ceilings throughout the building, thereby compromising the vapor barrier that is provided for much of the installed insulation. Condensation builds up on chilled water piping concealed in the humid ceiling cavity, causing "leaks" and damage to building interior finishes, as well as accelerated corrosion of valves and

pipe fittings. This condition also promotes the growth of mold which is a health concern for the educational facility.

- It is understood that the heating/ cooling piping system is a dual temperature change-over system. Th system distributes hot water to terminal units during the heating season and chilled water to all of the same terminal units during the cooling season. Some of these terminal units are not designed to provide cooling and may be receiving chilled water through their heating coils due to heating control valves being open when not in use. If this condition is indeed occurring; it is wasting valuable cooling capacity on coils of terminal units that may not even be operating (or intended to be operated with chilled water) during the cooling season such as unit heaters, convectors, radiators, and heating-only air-handling units.
- Daylight is visible through sections of the building envelope from within the indoor ceiling cavity. This condition allows for un-resisted infiltration from the outdoors and must be improved upon in order to alleviate the building interior environment issues.
- An analysis of all connected cooling equipment design capacities based on unit nameplate tag information and existing building record documents indicates that the installed air-cooled chiller is undersized by 8%-9% (The Chiller capacity is 4,080 MBH and the connected cooling load is 4,440 MBH). This is common design practice to allow for diversity in building use and differing cooling loads throughout the building. However, considering the building has excessive infiltration, the building could benefit from additional cooling capacity.
- The Building Chilled water supply temperature set-point is reported as being 44 degrees Fahrenheit throughout the cooling season. This temperature is below the average indoor dew point of a commercial building during the cooling season and creates a situation where condensate is forming on pipes and equipment. This chilled water supply temperature is also typical for the installed air conditioning system, and the installed cooling equipment is design to receive 45 degree chilled water. Increasing this chilled water supply temperature set-point would reduce the amount of condensation formed; however, it would also result in even less cooling and dehumidification capacity for the building HVAC systems as a whole as long as the existing equipment remains in service.
- In addition to condensation often present on the HVAC piping systems, the ductwork and air terminals are showing signs of damage from excessive condensation due to failed or missing insulation and vapor barriers.

Visible Gap in the Building Envelope from within the Ceiling Space

Recommendations:

Our recommendations for improving the indoor environment at the Baldwin School are as follows:

- General Building exhaust systems intended to maintain building pressure should be provided with building pressure sensors to modulate their speeds; the installed fans may need to be replaced with variable speed fans or supplemented with variable frequency drives to achieve this sequence of operation. A slightly-positive overall building pressure is desired to mitigate infiltration through the building envelope.
- Re-insulate entire dual-temperature HHW/ CHW piping system including all valves and fittings with 2” thick fiberglass insulation including a continuous vapor barrier, as is required by the current mechanical code for the heating hot water temperatures carried through these pipes. Any cooling-only branch piping may be provided with 1-1/2” thick insulation with a continuous vapor barrier.
- Verify that all heating-only control valves associated with the dual-temperature HVAC piping system are closed during the cooling season.
- The building envelop must be repaired in order for any HVAC system revisions or improvements to be effective. Currently, the HVAC system is attempting to cool the outdoors, in essence.

- Repair all duct insulation & provide insulation where currently missing. Insulation with vapor barrier should be continuous from the discharge of the associated air-handling unit to each diffuser including the neck and duct connection.

Morse School – Building Interior Moisture & Humidity Issue Analysis
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MORSE SCHOOL

General:

Unit Ventilators with hot water/chilled water coils serve all the typical classrooms while roof-mounted air-handling units equipped with hot water heating and chilled water-cooling coils (included on a select few of the units) provide heating, ventilation, and cooling (where available) to other areas of the building. Chilled water is produced by a 244 Ton "McQuay" Model ALS 250 A air-cooled chiller located on the roof. This chiller delivers chilled water to all of the classroom unit ventilators and cooling coils installed in various roof and interior-mounted air handling units throughout the school. Various roof-mounted exhaust fans are ducted to remove excess building pressure resulting from the introduction of outdoor air to the building interior via unit ventilators and air-handling units.

Field Observations:

Floors, pipes, walls, and windows were observed to be wet to the touch at the time of observation (November 06, 2018), thereby confirming the necessity of this analysis. There were a number of concerns noted at the time of the building survey that all factor-in to the current high-moisture condition that occurs during the cooling season; these factors include: building envelope infiltration, inadequate mechanical insulation, HVAC controls sequence of operation, building pressurization, and inadequate de-humidification capabilities of the installed HVAC systems.

- The building maintenance staff reported closing outdoor air dampers associated with unit ventilators and other HVAC equipment during the cooling season in order to avoid pulling in humid air from the outdoors. This attempt to alleviate building interior moisture concerns is falling short of its goal because the exhaust fans throughout the building continue to run at the same speed, creating a negative pressure within the building with respect to the outdoors. This negative pressure encourages humid outdoor air to seep in through exterior doors, windows, and leaks within the building envelope. While this humid outdoor air would be coming in through the HVAC equipment if the outdoor air dampers were open, less of this humid air would be introduced to the above-ceiling areas where condensation forming on chilled water piping has been an on-going issue.
- The chilled water piping routed throughout the building is generally concealed above ceilings and insulated. However, there were many fittings observed to be missing insulation. Much of the insulation currently installed is loosely-fitting and compromised by a non-continuous vapor barrier. The insulation that is currently installed seemed to fall short of current code minimum requirements for thickness and density. 1/2" thick and 1" thick insulation was observed where current code requires a minimum thickness of 1-1/2" (for dual-temperature use). Portions of missing and/or damaged insulation were observed above the ceilings throughout the building, thereby compromising the vapor barrier that is provided for much of the installed insulation. Condensation builds up on chilled water piping concealed in the humid ceiling cavity, causing "leaks" and damage to building interior finishes, as well as accelerated corrosion of valves and

pipe fittings. This condition also promotes the growth of mold which is a health concern for the educational facility.

- It is understood that the heating/ cooling piping system is a dual temperature change-over system. The system distributes hot water to terminal units during the heating season and chilled water to all of the same terminal units during the cooling season. Some of these terminal units are not designed to provide cooling and may be receiving chilled water through their heating coils due to heating control valves being open when not in use. If this condition is indeed occurring; it is wasting valuable cooling capacity on coils of terminal units that may not even be operating (or intended to be operated with chilled water) during the cooling season such as unit heaters, convectors, radiators, and heating-only air-handling units.
- Daylight is visible through sections of the building envelope from within the indoor ceiling cavity. This condition allows for un-resisted infiltration from the outdoors and must be improved upon in order to alleviate the building interior environment issues.
- An analysis of all connected cooling equipment design capacities based on unit nameplate tag information and existing building record documents indicates that the installed air-cooled chiller is undersized by 5%-6% (The Chiller capacity is 2,940 MBH and the connected cooling load is 3,135 MBH). This is common design practice to allow for diversity in building use and differing cooling loads throughout the building. However, considering the building has excessive infiltration, the building could benefit from additional cooling capacity.
- The Building Chilled water supply temperature set-point is reported as being 50 degrees Fahrenheit throughout the cooling season. This temperature is below the average indoor dew point of a commercial building and creates a situation where condensate is forming on pipes and equipment. This chilled water supply temperature is also typical for the installed air conditioning system, and the installed cooling equipment is design to receive 45 degree chilled water and is therefore currently providing less cooling to the building spaces than designed. Increasing this chilled water supply temperature set-point would reduce the amount of condensation formed; however, it would also result in even less cooling and dehumidification capacity for the building HVAC systems as a whole as long as the existing equipment remains in service..
- In addition to condensation often present on the HVAC piping systems, the ductwork and air terminals are showing signs of damage from excessive condensation due to failed or missing insulation and vapor barriers.

Ceiling Damage Caused by Failed Insulation & High Ceiling Cavity Humidity

Recommendations:

Our recommendations for improving the indoor environment at the Morse School are as follows:

- General Building exhaust systems intended to maintain building pressure should be provided with building pressure sensors to modulate their speeds; the installed fans may need to be replaced with variable speed fans or supplemented with variable frequency drives to achieve this sequence of operation. A slightly-positive overall building pressure is desired to mitigate infiltration through the building envelope.
- Re-insulate entire dual-temperature HHW/ CHW piping system including all valves and fittings with 2” thick fiberglass insulation including a continuous vapor barrier, as is required by the current mechanical code for the heating hot water temperatures carried through these pipes. Any cooling-only branch piping may be provided with 1-1/2” thick insulation with a continuous vapor barrier.
- Verify that all heating-only control valves associated with the dual-temperature HVAC piping system are closed during the cooling season.
- The building envelop must be repaired in order for any HVAC system revisions or improvements to be effective. Currently, the HVAC system is attempting to cool the outdoors, in essence.
- Upon making all improvements recommended above, the chilled water temperature set-point should be decreased to 45 degrees Fahrenheit to allow the installed cooling equipment to provide maximum cooling as-designed.
- Repair all duct insulation & provide insulation where currently missing. Insulation with vapor barrier should be continuous from the discharge of the associated air-handling unit to each diffuser including the neck and duct connection.

Peabody School – Building Interior Moisture & Humidity Issue Analysis
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PEABODY SCHOOL

General:

Unit Ventilators with hot water/chilled water coils serve all the typical classrooms while roof-mounted air-handling units equipped with hot water heating and chilled water-cooling coils (included on a select few of the units) provide heating, ventilation, and cooling (where available) to other areas of the building. Chilled water is produced by a 340 Ton "McQuay" Model ALS 340 B air-cooled chiller located on the roof. This chiller delivers chilled water to all of the classroom unit ventilators and cooling coils installed in various roof-mounted air handling units. Various roof-mounted exhaust fans are ducted to remove excess building pressure resulting from the introduction of outdoor air to the building interior via unit ventilators and air-handling units.

Field Observations:

Floors, pipes, walls, and windows were observed to be wet to the touch at the time of observation, thereby confirming the necessity of this analysis. There were a number of concerns noted at the time of the building survey (November 06, 2018) that all factor-in to the current high-moisture condition that occurs during the cooling season; these factors include: building envelop infiltration, inadequate mechanical insulation, HVAC controls sequence of operation, building pressurization, and inadequate de-humidification capabilities of the installed HVAC systems.

- The building maintenance staff reported closing outdoor air dampers associated with unit ventilators and other HVAC equipment during the cooling season in order to avoid pulling in humid air from the outdoors. This attempt to alleviate building interior moisture concerns is falling short of its goal because the exhaust fans throughout the building continue to run at the same speed, creating a negative pressure within the building with respect to the outdoors. This negative pressure encourages humid outdoor air to seep in through exterior doors, windows, and leaks within the building envelope. While this humid outdoor air would be coming in through the HVAC equipment if the outdoor air dampers were open, less of this humid air would be introduced to the above-ceiling areas where condensation forming on chilled water piping has been an on-going issue.
- The chilled water piping routed throughout the building is generally concealed above ceilings and insulated. However, there were many fittings and valves observed to be missing insulation. Much of the insulation currently installed is loosely-fitting and compromised by a non-continuous vapor barrier. The insulation that is currently installed seemed to fall short of current code minimum requirements for thickness and density. 1/2" thick and 1" thick insulation was observed where current code requires a minimum thickness of 1-1/2" (for dual-temperature use). Portions of missing and/or damaged insulation were observed above the ceilings throughout the building, thereby compromising the vapor barrier that is provided for much of the installed insulation. Condensation builds up on chilled water piping concealed in the humid ceiling cavity, causing "leaks" and damage to building interior finishes, as well as accelerated corrosion of valves and

pipe fittings. This condition also promotes the growth of mold which is a health concern for the educational facility.

- It is understood that the heating/ cooling piping system is a dual temperature change-over system. the system distributes hot water to terminal units during the heating season and chilled water to all of the same terminal units during the cooling season. Some of these terminal units are not designed to provide cooling and may be receiving chilled water through their heating coils due to heating control valves being open when not in use. If this condition is indeed occurring; it is wasting valuable cooling capacity on coils of terminal units that may not even be operating during the cooling season such as unit heaters, convectors, radiators, and heating-only air-handling units.
- Daylight is visible through sections of the building envelope from within the indoor ceiling cavity. This condition allows for un-resisted infiltration from the outdoors and must be improved upon in order to alleviate the building interior environment issues.
- An analysis of all connected cooling equipment design capacities based on unit nameplate tag information and existing building record documents indicates that the installed air-cooled chiller is undersized by approximately 28% (The Chiller capacity is 2,460 MBH and the connected cooling load is 3,420 MBH). This is common design practice to allow for diversity in building use and differing cooling loads throughout the building. However, considering the building has excessive infiltration, the building could benefit from additional cooling capacity.
- In addition to condensation often present on the HVAC piping systems, the ductwork and air terminals are showing signs of damage from excessive condensation due to failed or missing insulation and vapor barriers.

Un-insulated & corroded HVAC Piping Above Corridor Ceiling

Recommendations:

Our recommendations for improving the indoor environment at the Peabody School are as follows:

- General Building exhaust systems intended to maintain building pressure should be provided with building pressure sensors to modulate their speeds; the installed fans may need to be replaced with variable speed fans or supplemented with variable frequency drives to achieve this sequence of operation. A slightly-positive overall building pressure is desired to mitigate infiltration through the building envelope.
- Re-insulate entire dual-temperature HHW/ CHW piping system including all valves and fittings with 2" thick fiberglass insulation including a continuous vapor barrier, as is required by the current mechanical code for the heating hot water temperatures carried through these pipes. Any cooling-only branch piping may be provided with 1-1/2" thick insulation with a continuous vapor barrier.
- Verify that all heating-only control valves associated with the dual-temperature HVAC piping system are closed during the cooling season.
- The building envelop must be repaired in order for any HVAC system revisions or improvements to be effective. Currently, the HVAC system is attempting to cool the outdoors, in essence.
- Upon making all improvements recommended above, the chilled water temperature set-point should be set to 45 degrees Fahrenheit to allow the installed cooling equipment to provide maximum cooling as-designed.
- Repair all duct insulation and provide insulation where missing. Insulation with vapor barrier should be continuous from the discharge of the associated air-handling unit to each diffuser including the neck and duct connection.