PHOTO 1 Pipe section left unsealed.

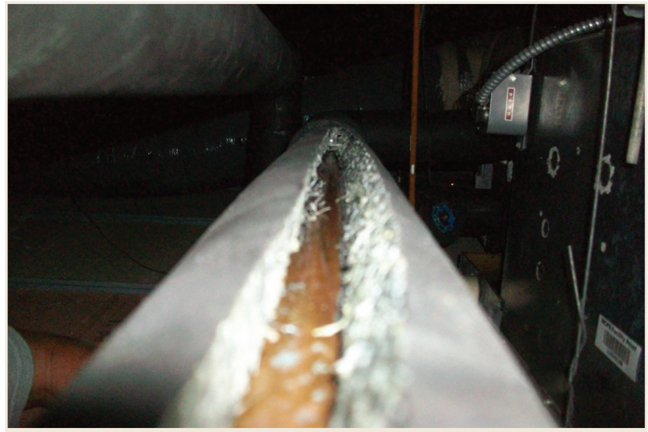

PHOTO 2 Insulator failed to seal top seam.

# Controlling Condensation On CWP Insulation

BY ED LIGHT, MEMBER ASHRAE; JAMES BAILEY, P.E., MEMBER ASHRAE; AND ROGER GAY

Although pipe sweating is the major source of dampness and mold growth in many buildings, control efforts during renovation and maintenance are often ineffective. Condensation from chilled water piping (CWP) is generally overlooked because it is hidden behind ceilings and walls or in mechanical spaces. Sweating occurs where there are insulation deficiencies.

Cooling is provided by a central plant in approximately 15% of commercial building floor space in the U.S., with cold water distributed to terminal units in occupied spaces through CWP. Buildings with CWP are used for offices, education, health care, shops, public assembly, lodging and storage.[1] Mechanical equipment conveying chilled water (i.e., pipes, fittings, tanks) is insulated to improve thermal efficiency and to control condensation.[2] The most common types of CWP insulation consist of resin-bonded fiberglass with a foil and Kraft paper vapor barrier or closed-cell elastomeric rubber material. Other insulating products are available with higher moisture resistance, but are beyond the scope of this study.

Condensation forms where insulation is missing or insufficient, or vapor barriers are not fully sealed (*Photos 1* and *2*). Condensation wets the insulation and this moisture can wick through fibrous pipe insulation for considerable distances. During the construction process, new insulation is often not inspected closely and thus, insulating deficiencies are often not repaired. As the building ages, insulation deteriorates and/or also can be damaged during repair work by maintenance personnel or renovation by contractors.

Energy codes generally dictate minimum insulation thickness. The amount of insulation needed to avoid condensation on outer surfaces is also an important consideration. Insulation design calculations are based on keeping surface temperature above the dew point temperature of surrounding air at a specified pipe temperature and space humidity.[3] When insulation thickness

Ed Light is president, James Bailey, P.E., is vice president and Roger Gay is senior industrial hygienist at Building Dynamics, LLC, Ashton, Md.

PHOTO 3 Stained ceiling tile under sweating chilled water pipe.

PHOTO 4 Major water damage.

PHOTO 5 Minor water damage.

is sufficient to control condensation, sweating may still occur unless vapor barriers are fully sealed at seams and joints.

Vapor retarders reduce the transmission of water vapor through the insulation system. A high quality vapor retarder material is essential for chilled water distribution systems to perform adequately. Design, installation and performance of the vapor retarder systems are key to an insulation system's ability to minimize water vapor ingress.[4] Factors such as vapor retarder structure, number of joints, mastics and adhesives used, and inspection procedures affect performance.[5] Faulty application or damage during installation can impair vapor retarder performance.

When condensation forms on CWP insulation, it degrades thermal performance, stains exterior jacketing, wets underlying surfaces and generates odors. Mold growth is often found on vapor barriers subject to heavy pipe sweating. Although occupant exposure may be limited in cases where growth is located behind ceilings and walls, occupants can be directly exposed to mold growth which forms on ceilings under sweating pipes (*Photo 3*) or where above-ceiling space acts as a return air plenum. Occupants are also exposed to general dampness created by evaporation from wet insulation.

This review is based on the authors' field experience assessing CWP insulation performance and managing the replacement of water damaged CWP insulation. Methods for remediating mold and insulating CWP varied in these projects, allowing for a comparison of different approaches.

## Assessment

The condition of CWP insulation with respect to condensation control can be assessed visually, by identifying insulation deficiencies and noting the relative severity and extent of water damage. Examples of staining patterns considered minor and major are illustrated in *Photos 4* and *5*. Suspect growth is often present in areas with major condensation. Where suspect spotting is not associated with water stains on the insulation—the root cause may be excessive space humidity—not insulating deficiencies (*Photo 6*).

## Removing Moldy Insulation

While occupants may not be directly exposed to mold growth on water-damaged CWP insulation, uncontrolled demolition can significantly degrade air quality during and after its removal. HVAC design engineers

PHOTO 6 Mold spotting caused by excessive humidity.

PHOTO 7 Insulation removal following hazardous material procedure.

usually do not specify appropriate procedures for removal of CWP insulation contaminated with mold growth and construction contractors subsequently repair or replace moldy CWP insulation without precautions to protect workers and occupants.

EPA guidelines recommend removing mold growth with stringent site control procedures similar to those required for hazardous materials such as asbestos. However, unlike asbestos, health risks associated with mold exposure are limited to sensitive individuals and public health officials generally do not consider this a health hazard.[6] EPA guidelines recommend that demolition of insulation with mold growth exceeding 10 $ft^2$ (0.9 $m^2$) be conducted inside a negatively pressurized containment (*Photo 7*).[7] The degree of isolation specified in EPA guidelines may not be necessary where surrounding areas are vacated during the work. A more flexible approach to containment can reduce project time and cost.

An alternative method for remediating mold-contaminated CWP insulation replaces full containment with local exhaust ventilation. Insulation is removed over a portable hood and underlying surfaces are covered with plastic sheeting. The ventilation unit consists of an inverted exhaust hood atop an aluminum portable rolling containment, with a HEPA-filtered exhaust system. Height of the hood is adjustable and it is set just below the piping (*Photo 8*).

The authors conducted a pilot study to evaluate effectiveness of the hood method during insulation removal. Release of larger particles was evaluated by laying plastic sheets above the adjacent suspended

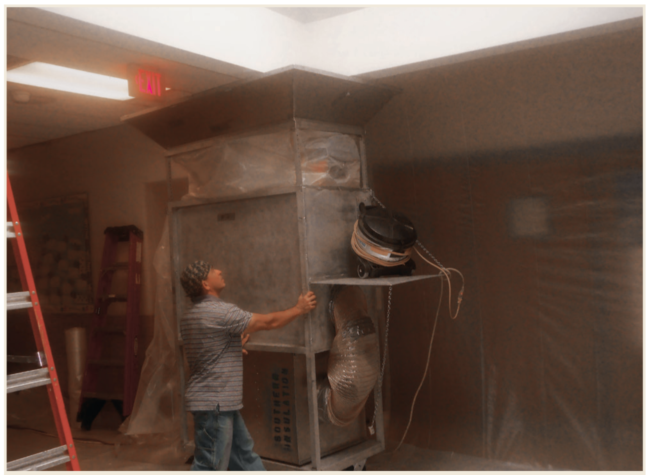

PHOTO 8 Insulation removal using portable hood.

ceiling and inspecting for settled dust after insulation was removed. The sheeting was generally found to be clean, with the exception of a few small pieces of debris. Capture of fine particulates was assessed by releasing smoke from air current tubes at the point of insulation removal. All visible smoke was drawn into the portable exhaust hood when it was located directly below the work. Based on these findings, insulation removal using the hood was permitted. To ensure that mold was fully controlled, the following steps were added to the process:

- Underlying surfaces below the ceiling must be draped with plastic sheeting for a minimum of 10 ft (3 m).
- Cleanup above and below the ceiling near the point of removal must be conducted with a vacuum cleaner equipped with a high-efficiency filter and a sanitizing solution wiped on surfaces.

*Advertisement formerly in this space.*

- Each removal site was visually inspected by the project engineer, with additional cleaning required where dust or debris was observed.

The authors' oversight of insulation removal using the portable exhaust procedure found that it effectively controlled mold where the contractor fully implemented control procedures. Observed contractor deficiencies in the field included:

- Insulation removed without use of the portable hood;
- Incomplete draping of plastic;
- Exhaust hood set too low under piping;
- Insulation removal extended beyond the hood;
- Restriction of exhaust outlet reducing airflow;
- Exhaust discharged too close to the removal area (air turbulence spread dust); and
- Incomplete cleanup after insulation removal.

Any dust remaining on surfaces as a result of these deficiencies was addressed by additional cleaning.

Close supervision was needed to ensure consistent implementation of dust control procedures. Workmanship issues observed during these projects are common in environmental mitigation, but often remain undetected due to lack of onsite inspection.

PHOTO 9 Incomplete insulation installed without enhanced quality control.

## Installing Chilled Water Insulation

Specifications for insulating CWP were based on the North American Insulation Manufacturers' Association (NAIMA) and National Commercial and Industrial Standards, which detail insulation thickness, coverage of the various piping components and sealing requirements.[8]

In typical construction and renovation projects, installation of CWP insulation is not closely inspected in the field for quality control by architects, engineers, contractor supervisors or building owner representatives. As a result, insulation may be insufficient or incomplete and vapor barriers may not be sealed, resulting in ongoing condensation and mold growth. Improperly installed CWP insulation can be costly, ultimately resulting in the need to replace large sections of insulation.

Quality control of the installation process can be enhanced by detailed field checking of all new insulation. To accomplish this, the authors inspect all CWP insulation at completion for compliance with specifications. Early experience revealed that a single "punch-out" inspection performed at the end of the project can be unwieldy. At one school, the CWP insulation replacement project generated a punch list of more than 200 defects (*Table 1*).

A more efficient approach to enhanced quality control used by the authors in later projects had an insulator accompany the inspector at the completion of each area, correcting observed deficiencies on the spot.

## Follow-Up Evaluation

The performance of new CWP insulation, installed with and without enhanced quality control, was compared by inspection during the next cooling season. Insulation in areas with enhanced quality control was generally found to be dry and in good condition. In those schools, maintenance personnel noted that they no longer needed to change stained ceiling tiles in CWP areas. Occupants reported that musty odors were eliminated and also recognized that a major mold issue was resolved.

In contrast, major condensation associated with vapor barrier defects was observed from insulation installed without enhanced QC measures (*Photo 9*).

TABLE 1 Punch list for school CWP insulation replacment.

| INSULATION DEFICIENCY | NUMBER OF OCCURRENCES | OCCURRENCE PERCENTAGE |
|---|---|---|
| Incomplete Seal: Mastic/Adhesive/Tape | 51 | 25.0 |
| No Seal: Missing Mastic/Adhesive/Tape | 75 | 36.7 |
| Missing Insulation/Bare Pipe | 30 | 14.7 |
| Penetration of Insulation by Object | 2 | 1.0 |
| Perforations/Tears of Insulation | 5 | 2.5 |
| Old Insulation Left in Place | 39 | 19.1 |
| Leaks/Saturated New Insulation | 2 | 1.0 |
| Total | 204 | 100.0 |

*Advertisement formerly in this space.*

## Conclusions

Condensation on chilled water piping can be a major contributor to dampness and mold growth in buildings, with condensation generally forming where insulation is insufficient or vapor barriers are not fully sealed. Vapor barrier deficiencies are commonly overlooked during construction and installation of insulation or can become damaged during maintenance or renovations. This is also an issue on refrigerant lines, which are a common source of condensation when associated with self-contained HVAC units.

Replacement of water-damaged CWP insulation can significantly improve indoor environmental quality.

Control procedures are needed during demolition of water damaged insulation to prevent occupant exposure to mold. An alternative to full containment uses local exhaust, removing moldy material over a portable, inverted exhaust hood. This may also be accomplished using a portable HEPA-filtered air cleaner with intake air from a flex-duct extended to the point of demolition. Local exhaust potentially allows demolition with mold control to be completed quicker and at a lower cost.



Close supervision is needed to ensure consistent implementation of remediation procedures. While deficiencies were observed with use of the portable exhaust hood, these are common to environmental mitigation projects in general. Deficiencies often remain undetected due to lack of onsite inspection.

Detailed attention to quality control during installation of CWP insulation is necessary to ensure elimination of pipe sweating. Resolution of observed deficiencies is facilitated by an insulator accompanying the inspector and correcting problems on the spot, rather than creating an end-of-project punch list.

Follow-up inspections after one year confirmed that exposure to dampness, mold growth and CWP sweating was generally eliminated where enhanced quality control measures ensured new insulation was installed in compliance with specifications.

Ongoing condensation from defective insulation was observed from new CWP insulation installed without enhanced quality control measures. Enhanced quality control over the insulating process can reduce future costs associated with sweating from defective CWP insulation.

In some areas, the underlying cause of suspect spotting on CWP insulation is not defective workmanship, but excessive space humidity. Improved humidity control is needed to protect CWP insulation in these areas.

## Acknowledgments

Appreciation is expressed for the field work and advice of Kate Leyva, Lee Salter and Emily Trumbull of Building Dynamics, LLC.

## References

1. Westphalen, D. and S. Koszalinski. Arthur D. Little Inc. for US Department of Energy. 1999. *HVAC Systems Vol. II: Thermal Distribution, Auxiliary Equipment and Ventilation, DE–AC01–96CE23798, Consumption Characteristics of Commercial Buildings.*

2. Hart, G. 2011. “Saving energy by insulating pipe components.” *ASHRAE Journal* (10):42–48.

3. *2013 ASHRAE Handbook–Fundamentals.*

4. Mumaw, J.R. 2001. “Below ambient piping insulation systems.” Insulation Outlook-National Insulation Association (9):19–30.

5. *2013 ASHRAE Handbook–Fundamentals.*

6. Light, E., J. Bailey and R. Gay. 2011. “New protocol for the assessment and remediation of indoor mold growth.” *Proceedings of 12th International Conference on Indoor Air Quality and Climate* (1):163–69.

7. United States Environmental Protection Agency. 2008. “Publication #402–K–01–001, Mold Remediation in Schools and Commercial Buildings.”

8. Midwest Insulation Contractors Association. 2011. *National Commercial and Industrial Insulation Standards.* ■

*Advertisement formerly in this space.*