The Impact of Internal Building Pressurization on Commercial Roofing Systems

Proper internal building pressurization is not only crucial for managing indoor air quality, maintaining occupant comfort and well-being, and maximizing the building's energy efficiency, but also for managing the performance and life-expectancy of the commercial roofing system. Understanding how internal building pressure affects roofing is essential for ensuring long-term and efficient roofing performance.

Building Pressurization and How it Works

Building pressure refers to the difference in air pressure between the inside and outside of a commercial structure. Building pressurization can be intentionally designed as part of the building envelope or can be the unintentional result of environmental or design issues. In some cases, building designers intentionally design for slight positive or negative pressure to achieve a desired internal environment. Cleanrooms, for example, can be designed with either positive or negative pressure, depending on the applications. Cleanrooms with high positive pressure inside are designed to keep air and contaminants from migrating to the inside.

In a positive internal pressure environment, fresh air is forced or brought into the structure with fans or mechanical means, and allowed to exit the building through louvers, doors, windows, or vents. Since the pressure inside is greater than the pressure outside the building, air is 'pushed out,' through openings (i.e., windows, doors, vents,) as well as through openings and separations in the envelope. This prevents outside air or particles from coming into the building and potentially impacting occupants, products, or processes. In short, positively internally pressured buildings 'push' air out of the structure to prevent outside contaminants from coming in.

The opposite is true in a negative internal pressure environment, where the inside pressure is less than the outside pressure. In this scenario, fans or mechanical equipment are used to evacuate air from the building that is coming in through doors, windows, vents, or louvers. This process to exhaust air from the building or from specific areas of the building to remove odors, chemicals, dust, etc., creates a reduced internal pressure within the structure that essentially 'pulls' air into the structure through openings in the building envelope.

It's important to note that many commercial buildings require both positive and negative pressure areas to address various processes and applications and must have mechanical systems designed specifically for the application. However, it is also possible that the building envelope is not properly designed for the building pressures it experiences in service.

There are four primary elements that impact the pressure differential in buildings: the stack effect, temperature, wind, and mechanical pressurization.

Stack Effect

The stack effect occurs when warm internal air rises inside a building. The warm air in the upper portions of the building increases the internal pressure in those areas, and simultaneously the internal pressure is decreased in the lower portions of the building. Typically, the stack effect is more prominent in high-rise buildings.

When warm air inside a building rises within the structure, a low-pressure area is created in the lower portion of the building. The low pressure in the lower portion of the building draws in external air. The higher pressure area inside the upper portion of the building pushes air to the exterior effectively pushing the warmer air, up and out of the upper floors of the building, through leaks or cracks in the envelope such as at the deck to wall joints, and penetrations through the roof.

The opposite happens in the lower portions of a building, as the cooler air creates a low-pressure area on the lower flows, which draws air from outside into the structure.

Buildings can have several different areas that act as chimneys and are affected by this type of air movement, including elevator shafts, stairwells, mechanical chases, garbage chutes, as well as space behind various types of cladding.

Addressing vertical air movement is primarily a design challenge. Owners and facility managers should work with a design professional to address this issue and ensure that stairwells, elevator shafts, and other floor openings are properly sealed to minimize air movement through the structure, and ultimately into the roofing assembly.

Moisture laden air can travel into the roofing assembly through deck-to-wall joints, gaps around penetrations into or through the roofing assembly, as well as through voids in the deck. Once in the assembly, the moist air can become trapped due to the impermeable roof membrane or cover. When this happens, condensation may occur, and if temperatures are below the freezing point, ice may form under the roof membrane within the roof assembly. If ice forms from condensation, when the ice melts, it can drip into the building and may create detrimental effects to components within the roofing assembly, and/or on the inside of the structure. The higher the level of interior relative humidity and the greater the temperature differential between the interior and the exterior of the building, the more moisture will collect, and the bigger the problem. In addition, biological growth can occur, causing other issues and potentially even long-term health problems for the building occupants. The use of air barriers at the roof deck can be effective at reducing the potential for warm, moist air to move from the interior into the roof assembly. Air barriers, to be effective, need to be well sealed at perimeters and penetrations.

In addition, well-designed roofing systems should incorporate air barriers and/or vapor retarders and adequate insulation materials; and well-designed structures should be properly ventilated to regulate temperature and moisture within a building in order to reduce the strain on the roofing structure, and minimize the risk of developing moisture from condensation in the roofing assembly.

Temperature

Warm air moves to areas of colder air. During cooling months, warm exterior air wants to move through the building enclosure into the interior where the air is cooler. The opposite is true during heating months where the warm internal air wants to move through the building enclosure to the exterior where the air is cooler. When warm air moves into a building, the building can be positively internally pressurized, and when warm air moves out of a building, the building can be negatively internally pressurized.

The effects of temperature are relatively small compared to stack effect, wind, and mechanical pressurization.

Wind

It may be obvious, but wind can be a significant contributor to pressures the building will experience in service. This includes both internal and external pressures, which are well known and understood by the design community and are generally not a major issue. Both types of pressure are included in building design practices when designing in accordance with model building codes and generally do not create many issues unless the building has very unique design characteristics.

Mechanical Pressurization

Controlling air-infiltration may be adequately addressed by proper design of mechanical equipment such as HVAC and air handling units, calibrated to provide a larger quantity of incoming outside air than the amount of internal air being evacuated from the building. This will result in a positively internally pressurized building. Improper or ineffective maintenance of mechanical equipment can also cause issues, in terms of air volume.

Pressurization Sources Not Accounted for in Basic Wind Design

Properly designed and installed HVAC systems are calibrated specifically for the building in which they operate. The past few years have reinforced that wherever groups of people spend time together in enclosed and dedicated spaces, airborne germs and particulate matter can spread diseases such as COVID-19. As a result, many building owners and facility managers have adjusted HVAC systems to increase filtration of internal air and bring in larger quantities of external air, in an attempt to remove 'dirty' air from the facility. This has resulted in an increase in internal building pressurization, which has been shown to have negative effects on roofing system performance and longevity in some cases.

SPRI recommends building owners and facility managers work closely with qualified HVAC engineers to follow industry guidelines and best practices from reputable sources, such as ASHRAE, when adjusting HVAC systems looking to increase internal air turnover and filtration.

Designing for Building Pressurization

Commercial roof assemblies, which typically include the deck, insulation, coverboard and waterproofing layer, play an important role when it comes to internal building pressure. Unfortunately, all too often, roofing membrane manufacturers are called in after the fact to identify and address problems caused by improper ventilation and condensation in the assembly.

Vapor retarders and air barriers used in the roofing assembly – particularly in cooler climates -- are designed to prevent moisture and air, respectively, from moving freely from the interior of a building to the roofing system. Reducing air and moisture intrusion into a roof will reduce the possibility of condensation in the roofing assembly. The roofing industry uses the term "vapor retarder" colloquially to mean the membrane that reduces or prevents moisture and air movement. The term "air barrier," by contrast, is typically used by the wall industry to mean the membrane that is used to reduce or prevent moisture and air movement.

To be effective, the location of the 'vapor retarder' within the roofing assembly is an important consideration. For most commercial applications, vapor retarders are typically installed under the roofing insulation, where it is 'warmer' than the outside air temperature and dew point. Preventing warm, moist interior air from reaching the dew point location means condensation will not occur within the roofing assembly.

Roof system vapor retarders should also be connected to the air barriers in the walls to prevent air movement through the roof-to-wall transitions. Roof system vapor retarders should also be sealed around roofing penetrations to prevent air movement. This type of detailing can help to regulate the indoor climate by preventing air and related moisture from transferring from the interior to the exterior of the building or from the exterior to the interior.

Exterior air barriers are available in several configurations including sheet membranes that are either mechanically attached, fully adhered, or self-adhered. They can also be liquid applied membranes, sheets of polyethylene, foil covered products, or bituminous in nature.

In addition, some roofing materials can manage moisture and air-infiltration better than others. It’s always best to work with the roof system manufacturer and a qualified roof system designer to select the proper products and design the roof assembly that best meets the specific needs of the facility.

When addressing pressure issues and the roof assembly, it’s particularly important that the system details, particularly at the air and vapor control layer, are handled properly and with care. Furthermore, it is imperative to ensure that the vapor retarder is properly sealed at all penetrations and openings to avoid creating an open pathway for moisture and air migration. Air movement in any areas not detailed properly can result in poor roof performance and a shorter life expectancy.

Change is Inevitable

In a report published by Statista.com, the size of the commercial property remodeling market in the United States reached $51 billion in 2022. With this continued expansion of building re-use and adaptation it is important that building owners and facility managers recognize the potential impact that changing a building’s use can have on the facility’s internal air pressure and the roofing system. Buildings repurposed to include industrial processes for which they were not originally designed, such as processing food, distilling liquor and, housing industrial painting processes, etc., can increase internal building pressures and potentially change internal moisture conditions that impact internal air quality. All of which can negatively impact the performance of the roofing system.