Building as a System

Mechanical Systems - Multifamily

Key Terminology

Conduction

Domestic Hot Water (DHW)

Infiltration

Make-up air

Stack effect

Thermal boundary

Section Transition

Learning Objectives (Slide #3)

By attending this session, participants will:

- Be introduced to the concept of a building as a system.
- Understand the location and function of the building envelope.
- Be able to identify common sources of building heat loss and gain.
- Learn about some common energy hogs in multifamily buildings.

Your Building as a System (Slide #4)

- Many people think buildings don't change, but in reality, a building constantly changes to maintain a healthy and comfortable interior environment.
- Your building has an envelope.
    - Every building has an envelope or shell that divides the interior of the building from the world outside. The envelope includes the walls, floors, windows, roofs, and doors that make up the building's boundary. The envelope may contain insulation or not and it may be airtight or not, but it's still what separates the inside from the outside. A building's envelope has a big influence on how well it performs in terms of health, comfort, and energy efficiency.
- A building also has equipment.
    - Many other parts of the system are located inside the envelope. These include the heating and cooling equipment that conditions the space inside, ***domestic hot water (DHW)*** heaters and the rest of the plumbing system, the fans and air handlers that make up a building's ventilation system, lighting, appliances, elevators, and anything else that uses energy.
- All of these things are connected to the most important part of the system…the building's occupants.
- Changes to any one of these components—the envelope, equipment, or occupants—affect the others. That is what we mean when we talk about the building as a system.

Thermal Boundary (Slide #5)

- One of the building envelope's main functions is to regulate the temperature inside the building by providing a ***thermal boundary*** around the building.
- The thermal boundary prevents heat transfer. In the winter, this boundary keeps the heat inside the building and the cold outside. In the summer, it does the reverse.

Building Heat Losses (Slide #6)

- In the winter in a heating climate, a building loses heat to the outside.

  Q: Ask students to name the three types of heat transfer. This will be covered in more detail in the next section.

  A: Conduction, convection, and radiation.

- Some of this heat is lost via ***conduction*** through the envelope.
  - The amount of heat lost through conduction depends on the difference between the inside and outside temperatures. The greater the temperature difference, the more heat is lost through conduction.
  - Heat loss also depends on the amount of insulation in the roof, walls, and other parts of the envelope. Insulation resists conduction, so the more insulation a building has, the less heat it will lose through conduction.
- Ventilation is another source of heat loss in winter.
  - Buildings need to have some ventilation to remove moisture, odors, and other contaminants from the inside.
  - This ventilation can be through natural means, like open windows, or mechanical means, like rooftop exhaust fans. Typically, multifamily buildings have exhaust fans or other means of ventilation in apartment kitchens and bathrooms, which have the most contaminants.
- While ventilation is necessary to keep the interior of a building healthy and comfortable, it also removes conditioned air from the living space. And since any air that is removed from the building must be replaced with fresh outdoor air, this means that unconditioned air will enter the building and need to be heated or cooled.
  - Sometimes this ***make-up air*** is provided by a mechanical fan, like a rooftop air handler, but typically the make-up air enters the building via ***infiltration***.
- Infiltration, or air leakage, is the process by which outdoor air enters a building through the many openings in a building's envelope.
  - Some of these openings are necessary, such as an opening in a boiler room that provides combustion air to the boiler. However, a lot of infiltration occurs through less obvious holes, like construction defects and gaps between envelope components.
  - While some fresh air is needed to ensure adequate indoor air quality (IAQ), leaving buildings leaky doesn't guarantee adequate fresh air at all times, and this can be a huge source of heat loss and energy waste.

  Refer to the "Mechanical Ventilation" section of the Installer Intermediate curriculum for more details about providing healthy IAQ.

Stack Effect (Slide #7)

This illustration shows the ***stack effect*** at work.

- Tall buildings can also lose energy through the stack effect. Warm air rises and exits the building through the many unsealed holes at the top of typical buildings. Cold air is drawn in at the bottom of the building to replace it. The stack effect increases the amount of air movement through the building and thus increases the heating load.
- Because the heated air rises to the top floor apartments, those units get overheated. Frequently, there is no way to turn off their heat, so residents in top floor units open their windows to cool down. This creates more large holes at the top of the building through which the hot air can escape. This causes more cold air to come in at the bottom of the building, further increasing the load on the heating system.
- To reduce the stack effect and save energy, it's important to seal all unintentional holes in a building and compartmentalize the floors. Compartmentalizing the floors means separating the units from each other and from common areas by sealing air leaks.

Q: What type of heat transfer is prevalent in the stack effect?

A: Convection.

Building Heat Gains (Slide #8)

- Buildings also *gain* heat from many sources. The heat gains help to offset some of the losses in the winter, and can reduce the load placed on a building's heating system. In a cooling climate, these heat gains make cooling equipment work harder.
- The sun is an obvious source of heat gain.
- Anything that uses electricity gives off some heat. Every light and every appliance, whether it's an oven, a TV, or a stereo, provides some heat gain to the building interior.
- People also give off heat. An average person gives off heat equivalent to a 100-watt light bulb.

How do we heat? (Slide #9)

A building needs a heating system to make up for all this heat loss and to keep the interior safe and comfortable for the occupants. How do we provide this heat?

- Boilers are a common way to heat multifamily buildings. There are two types of boiler systems: those that heat with hot water as the distribution medium and those that heat with steam.
- Furnaces, which distribute heat through forced air, are another common heating system.
- Heat pumps are simply air conditioners running in reverse—they pump the heat in and the cold out.
- Some buildings use electronic resistance heaters. Often, heat pumps have electronic resistance heaters built in as backup for when the outside temperature drops very low.
- We'll cover all of these types of systems in more detail in subsequent sections of this curriculum.

No building component is an island (Slide #10)

- Since people give off heat to their surroundings, an occupied building will use less energy for heating than a vacant one if the two buildings are being maintained at the same temperature.
- Here are some examples of how changing one building system can affect the others:
    - Replacing single-pane windows with low-e, argon-filled, double-pane units will reduce the building's heat loss. The heating system will then be oversized for the building's load and may actually cause overheating if no adjustments are made.
    - Roof insulation considerably reduces heat loss from the top floor apartments. It also reduces heat gain from the sun. As a result, tenants on the top floor will have a lower cooling load, and therefore lower electric bills, in the summer.

The Most Common Energy Hogs #1 (Slide #11)

The picture shows an infrared image of deteriorating insulation in a roof system. The red areas are hotter and show where the building's heat is escaping through the degraded insulation.

- Poorly functioning parts of the building envelope are one of the most common energy hogs.
    - Open windows in a heating climate (which in winter are a sign of a poorly controlled heating system), an uninsulated roof, and excessive air leakage through unsealed holes are typical causes of energy waste. Upgrading a building's heating or cooling system without examining the performance of the envelope may not save as much energy as estimated.
- Since the heating system is just one part of the overall building system, it is important to inspect the rest of the building for obvious flaws and energy waste.

The Most Common Energy Hogs #2 (Slide #12)

This picture shows a big leak in a heating pipe. A rag is being used to stop it, but it is obviously not working very well.

- Equipment – The building's equipment may also be inefficient and use too much energy.
    - A poorly performing heating distribution system can be a big waste of energy; it can also cause balancing problems.
    - Missing or malfunctioning controls can lead to energy waste. Without properly functioning controls, the heating system doesn't know when to operate or how to do so efficiently.
    - An inefficient or incorrectly sized heating system wastes energy because it isn't well-matched to the building's heat load.
    - Uninsulated heating system piping or duct runs, as well as leaks (whether water or steam from pipes or conditioned air from ductwork), are a significant source of energy waste.

Summary (Slide #13)

- Every building is a system, and making changes to one part of a building may affect the performance of other parts of the building.
- The building envelope separates what is indoors from outdoors.
- Common sources of building heat loss are air leakage and lack of insulation.
- Common sources of building heat gain are the sun, electronics, lighting, and people.
- Common energy hogs in multifamily buildings include building envelope shortfalls, duct or heating system leakage, poor controls, and poor balancing or distribution.