PRODUCT APPLICATION

A technical bulletin for engineers, contractors and students in the air movement and control industry

Preventing Condensation and Thermal Expansion/Contraction in HVAC Grilles, Registers, and Diffusers

Finishing a newly constructed building is a moment of great joy and excitement for everybody involved. However, what if, after all the hard work and dedication, occupants begin to notice water dripping from the metal HVAC grilles when the air gets too cold? Or what if you hear clicking or popping noises coming from the linear diffusers as the air conditioning is cooling the space? These issues can be frustrating, and it's important to understand why these situations can occur and how to prevent them.

CONDENSATION

When the difference in temperature between the supply air and the room air is too great, one may observe small water droplets forming on the surfaces of metal HVAC grilles and diffusers. If these droplets persist and grow over time, water may eventually drip from the metal components onto the floor or even onto occupants in the space. This phenomenon is known as condensation.

The air we breathe is a mixture of various molecules, with nitrogen and oxygen being the predominant components. Additionally, water is present in the air, with its concentration fluctuating between 3-5% depending on temperature and pressure. While water molecules in the air typically remain in the vapor phase, they can condense back into liquid form when warm, moist air comes into contact with a cold surface.

Most HVAC grilles, registers, and diffusers are constructed from steel or aluminum, both recognized for their excellent heat conductivity. Consequently, as conditioned air flows through these components, the metal surface temperature gradually changes until it approaches the supply air temperature. For example, in scenarios where cool supply air, such as 65°F, is introduced into a space, the metal surfaces will progressively decrease in temperature over time until they closely match the 65°F temperature. Insulation can slow down this process, but when cold air directly contacts metal, the metal surface will transfer heat to the airstream by convection and the temperature will decrease over time.

If the metal surface temperature gets too low, droplets of water can form on this cold surface. This is usually not a problem, but it can become problematic when a space has high humidity and very cold air is being used to cool down the room.

What is dew point and how does it relate to condensation?

Air behaves differently depending on how much water vapor is in the air at a given air temperature and pressure. Psychrometrics is the field of engineering that studies the behavior and science of water vapor and air mixtures. In psychrometrics, the dew point is the temperature at which the air is fully saturated with water vapor. The dew point depends on the humidity in the space and the temperature in the space. Condensation can occur when the supply air temperature or any surface in the space is cooled beneath the dew point. The dew point signifies that the air has the maximum amount of water vapor dissolved before it will begin to condense into a liquid. If the supply air temperature is set below the dew point in a space, there can likely be condensation on the metal grilles once their temperature decreases beneath the dew point temperature.

This is the reason why a cold glass of water can have droplets of water condensing on the outside surface of the glass. Once the glass surface cools down to a temperature lower than the dew point, water will begin to condense out of the air onto the surface. Condensation can pose an issue in a building that has high humidity levels when the space needs to be cooled quickly. In this situation, the supply air temperature might be brought down lower than usual in an attempt to cool the building quickly, but this can cause problems if the humidity levels are too high. Unfortunately, as the relative humidity RH% increases, so does the dew point temperature in the space. And as the dew point increases, this means that water will more easily condense out of the air at those higher temperatures. In a very humid environment, the dew point could be as high as 75°F. A specific example would be a building with an air temperature of 85°F and a relative humidity of 70%. In this scenario, the dew point is 74.1°F. Due to this, any surface in that room with a temperature lower than 74.1°F will begin to condense water.

HOW TO AVOID CONDENSATION PROBLEMS

Condensation is a frustrating issue that can cause discomfort to occupants, or even cause water damage to walls or other surfaces. If you notice condensation in the building, or you fear it might occur, there are a few tactics you can employ to ensure it doesn't happen. Since the problem is caused by a combination of high humidity and low supply air temperatures, there are a few ways to avoid the issue.

SOLUTION 1: Decrease the humidity level in the space

The first solution to protect against condensation would be to ensure that the relative humidity in the space is as low as possible before the air conditioning is turned on. Maintaining the relative humidity level between 30 and 50% is optimal and will result in most occupants feeling thermally comfortable. If the building is exceptionally large, it will be difficult to reduce the overall humidity of the entire space. But for offices or small spaces, a dehumidifier can work well to reduce the overall relative humidity. In small rooms, desiccants such as Damp Rid, or rock salt can also be effective at absorbing water from the air to reduce the relative humidity level. Once the humidity level drops, the dew point will also drop.

At a relative humidity of 50% and temperature of 85°F, the dew point will be lower than 55°F. This means it's highly unlikely that the supply air temperature will be cooled beneath this dew point which subsequently means that the metal products will not become cold enough to condense water droplets. Therefore, keeping the space humidity low (30-50%) is a surefire way to stop condensation.

SOLUTION 2: Increase the supply air temperature temporarily

The next solution to prevent condensation is to increase the supply air temperature so it's above the dew point. For example, if a room has a temperature of 80°F and the humidity is 60% RH, then the dew point is 64.8°F. Therefore, if the air conditioning is set to 64°F, then there will likely be condensation on metal HVAC products in the room after some time. However, if you can temporarily raise the supply air temperature a few degrees higher, such as to 68°F in this situation, then the air temperature will be above the dew point and this will eliminate the possibility of condensation occurring. This tactic of temporarily increasing the supply air temperature a few degrees is also useful because as you cool down the space, the dew point will decrease and then you can safely lower the supply air temperature without worrying about condensation.

An additional method to reduce the risk of condensation: Apply insulation

An additional method to minimize the risk of condensation is to apply insulation to the metal HVAC components. This approach functions by impeding the heat transfer process and slowing down the rate of heat exchange. However, it's crucial to note that utilizing insulation alone cannot entirely eliminate condensation. While insulation can indeed diminish heat transfer between the air and the metal products, it serves to decelerate the heat exchange rather than bring it to a complete halt.

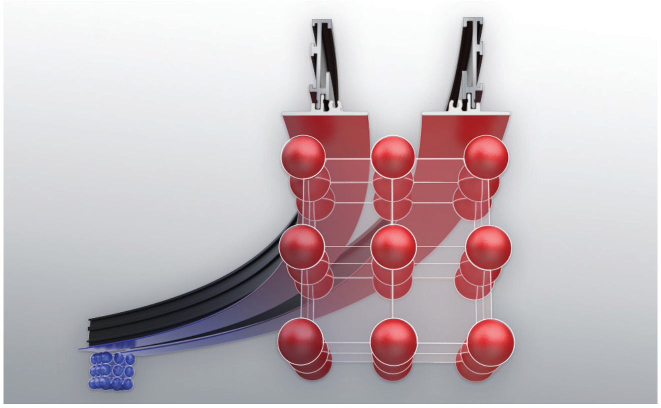
If any portion of the metal grille is in direct contact with the cold supply air, the cold air will carry away heat from the metal, causing the metal surface to cool down. While insulation can reduce the rate of heat transfer, it doesn't completely stop it. Therefore, condensation can still occur, but it might take a longer amount of time for droplets to begin to form. As such, the two solutions mentioned earlier remain the sole authentic remedies capable of effectively stopping condensation.

THERMAL EXPANSION/CONTRACTION

An issue that can occasionally arise in HVAC design is when a long HVAC grille or linear diffuser is installed and begins to pop or creak while the air conditioning is running. These sounds could be caused by thermal stresses within the linear diffuser due to the unit expanding or contracting. Since the majority of HVAC grilles and diffusers are made of metal, and most linear diffusers in the market are made of aluminum, thermal expansion is an important factor to consider. In general, metals can expand or contract in size when subjected to large temperature changes. Each material has its own unique coefficient of thermal expansion. The coefficient of thermal expansion (CTE) is defined as how much a material will expand/contract in size per each degree of temperature change.

Thermal expansion/contraction is typically unnoticeable on a relatively small product, but over a long length, it becomes a factor that must be considered. In general, linear slot diffusers are made of aluminum, which has a larger thermal expansion coefficient than steel, and this can amplify the issue. If the unit was installed in an unconditioned space with a temperature of 90°F, but then the air conditioning is turned on and set to 65°F, this 25-degree difference in temperature will cause the unit to contract in length. Depending on how large the temperature difference is will determine the extent of the thermal expansion/contraction.

When a material is constrained in one or more dimensions, and is then subjected to a large temperature difference, this will lead to large 'thermal stresses' within the material. These thermal stresses will increase as the internal temperature of the material changes. In an HVAC application, flowing hot/cold air through a metal product will facilitate the heat transfer that changes the internal temperature of the material. In general, "stress" is defined as a force applied over an area of a material, and the four main types of stress are compressive stress (squeezing), tensile stress (stretching), torsional stress (twisting), and shear stress. In the context of this paper, we are only discussing thermal stresses due to compressive or tensile forces. When a material is constrained and subjected to a temperature change, the internal thermal stresses will increase as the temperature difference increases. This will also depend on the type of material being used and its shape. If the thermal stress becomes too high, it can cause cracking, buckling, bending, or can cause sudden movements that can manifest as popping, clicking, or creaking noises.



Explaining Thermal Expansion and Contraction with Physics

For example, to put this into perspective, let's imagine you just installed a linear diffuser that is 96 inches long in a single section. A linear diffuser is typically made of several assembled components. These components include the frame, the spacer blocks, and internal components called pattern controllers which help to direct the air in specific directions. These pattern controllers are usually able to be adjusted and moved by an occupant to change the airflow pattern.

If you install this linear in 90°F temperatures, but the air conditioning provides 65°F air to the unit, the temperature of the material will begin to cool down until it eventually reaches the air temperature of 65°F. This 25-degree negative temperature difference is the driving force behind the contraction of the linear diffuser.

Aluminum has a coefficient of thermal expansion of $13.1\text{x}10^{-6}$ in/in·°F. This means that for every degree of temperature difference, the unit's length will change by 0.0131%.

Using this coefficient, it's possible to calculate how much the linear will contract due to the temperature difference it is experiencing.

Example

Temperature Difference = $\Delta T = T_{final} - T_{initial}$

Temperature Difference = 65°F – 90°F = -25°F

Initial Length = $L_{initial}$ = 96 inches

Aluminum Coefficient of Thermal Expansion = $CTE_{Aluminum}$ = $13.1\text{x}10^{-6}$ in/in·°F

Total Change in Length = $L_{initial} * CTE_{Aluminum} * \Delta T$

Total change in Length = 96 in * ($13.1\text{x}10^{-6}$ in/in·°F) * -25°F= -0.03144 inches

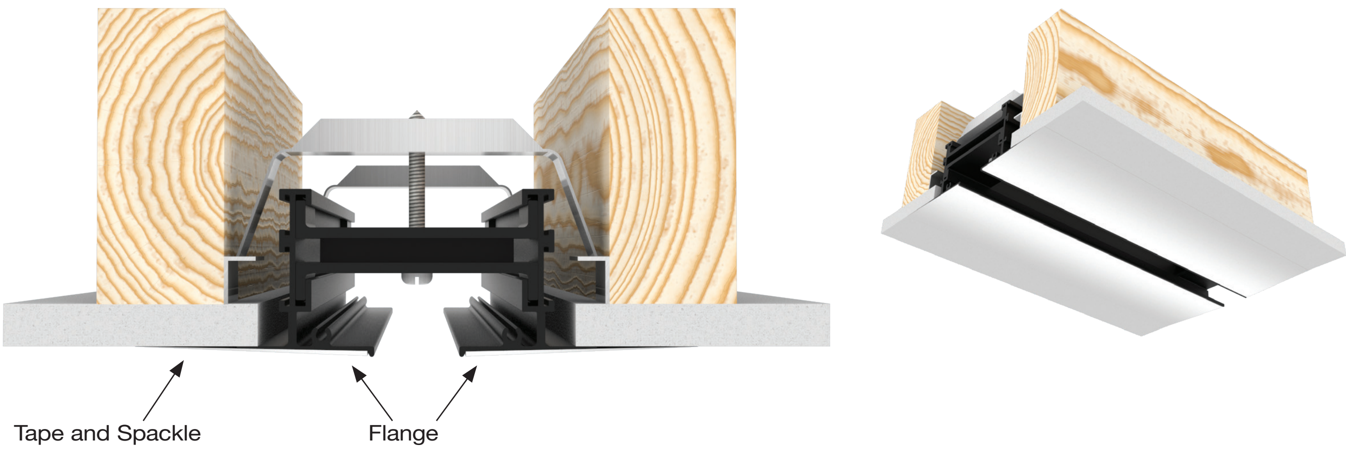
New Overall Length =
96 inches – 0.03144 inches = **95.9685 inches**

After thermal contraction, the length of the linear diffuser only changed by a fraction of an inch, but it decreased by about 1/32" which wasn't accounted for when it was installed. This would usually not pose a problem if the linear is mounted in a way that allows slight movement. However, if the linear is installed very securely and constrained with no ability to expand or contract, then the thermal stresses will begin to build up in the unit's material. Since the separate components that comprise a linear diffuser could be different thicknesses or even different types of material, this means that each of them could experience a unique amount of thermal expansion depending on the temperature.

For example, since the pattern controllers in a linear diffuser are exposed directly to airflow, these components could cool down or heat up faster than the frame material in the product. As thermal stresses build up between components within the linear, these stresses will continue to increase until they suddenly release their energy by sudden movements, and this would manifest as clicks, creaks, or loud popping noises. In other situations, if the unit is unable to move at all on either end and the thermal stresses continue to increase, this could cause buckling, cracking, or bending of the material in extreme situations.

Another situation to consider is if the linear diffusers are 'tape and spackled' into a sheetrock ceiling. In this case, the perimeter flanges of the linear are covered in spackle to help blend the linear diffusers into the sheetrock ceiling to conceal the metal frame. This leads to a clean installation with only the slot opening visible with the unit being spackled into place. When the tape/spackle dries it is very brittle. If this unit is subjected to a large temperature difference and the unit begins to contract or increase in length, the tape and spackle finish could begin to crack along the length as the metal flange underneath begins to stretch or contract. To ensure that thermal expansion/contraction does not pose an issue, one can follow a few steps that can greatly reduce the possibility of this occurring.

Figure 1. Linear Slot Diffuser installed in sheetrock ceiling with tape and spackle flange



How to avoid thermal expansion/contraction issues in the field

Thermal expansion/contraction is a rare problem to encounter in the field but there are a couple of important steps that one can take to avoid this from happening. The key is to avoid large temperature differences between the installation temperature and the normal average working temperatures.

Sometimes, HVAC grilles or components could be kept outside at a jobsite or in a location that reaches higher temperatures, such as 90-100°F before they are installed. If the unit is installed while it still retains this high temperature, and then cold air is supplied through the unit, there could be problems related to thermal expansion or contraction. In this case, the unit could be subjected to a temperature difference of 40-50 degrees and this can create large thermal stresses and strains that can cause the aforementioned popping or creaking noises. To avoid this, contractors need to keep the products in the shade, or indoors, before installation. If this is not possible, the units should be put aside for them to cool down before they are installed.

The best solution would be to install the linear diffusers at a temperature that's within 10-15 degrees of the intended working temperature of the space to minimize the maximum temperature difference. For example, if the plan is to keep the supply air temperature at 72°F during working conditions, then installing the unit at a temperature between 62-82°F will ensure that there's a low probability of having thermal expansion-related clicking/popping sounds. Ideally, one would want to ensure that the installed unit will not be subjected to a temperature difference of more than 15 degrees from when it is installed. Or if it's known that the unit will be subjected to large temperature differences, one should mount them in a way that allows for slight expansion or contraction to minimize the buildup of internal stresses. There can also be similar thermal issues if the unit is installed in very cold environments, and then hot air is supplied through the unit during heating mode. The only difference is that in this example, the unit will increase in length instead of contracting in length. The solution however is the same; the unit should be installed at a temperature close to the desired working temperature of the space.

Condensation and thermal expansion/contraction can be frustrating issues for contractors and occupants of new buildings. Having water dripping from the ceiling, or hearing popping noises can be annoying, but by following the steps above, you can greatly reduce the chance of those issues occurring.

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