The effect of mechanical cooling on lamp colour and efficiency

When choosing an integrated lighting and cooling solution for an office development, potential colour shift and efficiency problems must be taken into account. Lamps and LED arrays are designed to give their optimum output and stated colour temperature at a given atmospheric temperature. If lamps are cooled below this temperature, their colour will shift and their efficiency will fall. This can result in the lighting installation delivering below its design intentions. The Society for Light and Lighting provides us with insight into how to take these considerations into account.

Cooling methods

Traditionally, mechanical cooling in office spaces has been dealt with either by cooling air before it is supplied into a room, or using local cooling units that use a fan to force air across a cool surface. Either method can result in differing temperatures across an office ceiling.

Centralised cooling systems

In large buildings, the air supplied to its office space can be chilled centrally and supplied via insulated ductwork to where the cool air is needed. Air, supplied by diffusers positioned within the ceiling, is typically cooled to 6 - 8 degrees centigrade below the ambient temperature of the space to be cooled. The chilled air flows from these cooled spaces via either dedicated extract grilles or a plenum ceiling that incorporates perforated ceiling tiles.

Whilst such a system has no obvious connection to the lighting within the space, care should be taken that the luminaires are not positioned too closely to the supply diffusers due to the 'Coanda effect'. This phenomenon (first applied by Henri Coanda) results in air that leaves a confinement (through, for example, a supply diffuser) tracking a surface close to its exit point (for example, the ceiling). As long as the surface remains smooth, the effect can carry air across a ceiling for some distance, depending on its discharge rate. Where a luminaire is recessed into a ceiling and has a smooth curving reflector, it is possible for air to flow into the luminaire and across the lamp.

Where air is extracted via a ceiling plenum, the rate of any air flow through the ceiling will depend on the location of the extract ductwork above it. For example, a space 20 metres long and 7 metres wide with an extract point above the ceiling at one end of the room will see a higher volume of air extracted close to that end. The end of the room farthest away will consequently have a lower level of extract volume.

Again, this may not appear to be related to the lighting installation, however, higher extract air flow at one end of a room can result in the luminaires, particularly if they are open, being subject to different ambient conditions across the space. This leads to slight changes in light output and possibly colour from the lamps in these luminaires.

Image of supply diffuser and suspended luminaire

Fan coil units

The principal of operation is to run a cooling medium, such as chilled water, through a series of finned pipes, similar in look to a car radiator, and known as a ‘cooling coil’. A fan is then used to push air across that cooling coil and into the space to be cooled.

These units are usually referred to as ‘fan coil units’ (FCU) and, whilst they can be wall- or floor-mounted, they are usually hidden away in ceiling voids with only their supply diffusers and, sometimes, extract grilles, readily visible. Often, the system will supply air to a space via supply diffusers and extract it to ceiling voids through perforated ceiling tiles, similarly to centralised systems. This latter method can give a more balanced flow of air across the luminaires in a space than can be achieved through specific extract grilles. It also eliminates the possible problems found with the single-point extract in centralised systems because each FCU deals with a proportion of the air.

The natural cycle

By its very nature, cool air will fall to the ground and displace warm air, which then rises. If the supply of cool air is maintained, a cycle will develop. However, it is not simply a case of providing a space with cool air at any given point and expecting such a cycle to begin and be effective at providing cool air to the whole space. Inevitably, such an approach would lead to localised stagnation and the cooling effect would not be uniform. In addition, condensation could build up on the outer surface of any pipe or duct carrying a cooling medium, such as chilled water or air, if the coolant temperature was too low. Any condensation finding its way into luminaires could lead to component failure, in addition to the associated , such as the risk of electrocution.

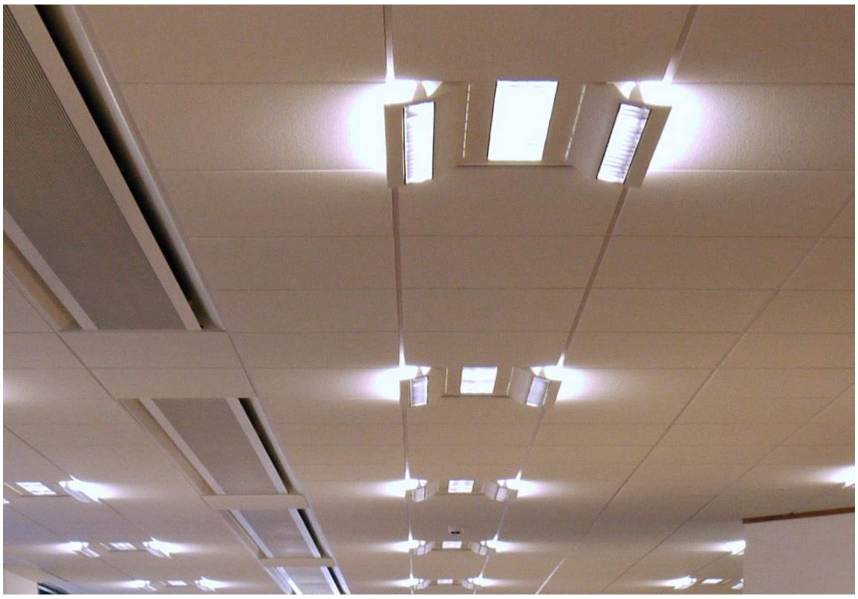


Image of lighting and mechanical services coordination

Chilled beams

In order to gain the benefit of not running fans constantly within fan coil units, and to take advantage of the natural cycle created by falling cool air, the chilled beam concept is becoming more popular in office developments.

Essentially, a chilled beam is a cooling coil that is stretched into a linear section of flow and return pipework, each with a series of radiating fins attached. Because the cooling surface is spread over a much greater area, uniformity in the cooling effect can be achieved without the need to use energy in the running of the fans. However, the risk of condensation on the cool pipework still exists. To ensure that condensation doesn't form, the cooling medium cannot run at temperatures as low as those used in fan coil units.

In addition, the humidity within the space has to be carefully controlled to make sure that any potential water source that could go on to form condensation is limited.

Integrated services

In much the same way as lighting has to be carefully placed in a ceiling to optimise the use of luminaires, components that are associated with the supply and extract of air from a space also require careful placement. This can often lead to the preferred location of luminaires and supply diffusers being in the same place.

When additional services, such as fire alarm smoke detectors, public address speakers, sprinkler heads and movement detectors are added into the equation, it is easy to see how a ceiling can become congested with the inevitable need for compromise.

The need for mechanical services and luminaires to be in the same locations within ceilings to ensure that they achieve their optimal functionality, along with the architectural preference for minimal ceiling congestion, has led to the development of integrated cooling and lighting solutions.

Air handling luminaires

Where cool air is provided from an FCU, it is sometimes possible for the air to return through a recessed modular luminaire. Combining the extract point and the luminaire has the advantage of reducing ceiling congestion and means that both luminaire and extract point can be placed at preferred positions, as discussed.

Care should be taken, however, when selecting such luminaires. Poor design can lead to lamps running below their optimum temperatures when air flows across them and consequently consideration should be given to a number of factors:

- the type of lamp used and its operating temperature: T5 lamps, for example, operate efficiently at a higher temperature than T8 lamps. LED drivers operate more efficiently at lower temperatures.
- the air path through the luminaire: air should ideally pass through the sides of the luminaire and not over the lamps.

Image of integrated chilled beams being installed

Integrated chilled beams

The nature of chilled beams means that such beams occupy a large proportion of ceiling space and so integrating lighting into them is sometimes the only option.

A number of manufacturers offer chilled beams with integrated lighting and presence/absence control.

The issues with beams with integrated lighting are similar to those of air handling luminaires, the difference being that lamps may be subject to cold air falling from the chilled pipework within the beam rather than the returning cold air.

Impact on lighting

Light sources, be they fluorescent, LED or any of the high-pressure lamp types are designed to operate optimally within a specific temperature range. Moving outside of these ranges will affect the efficiency of the lamp, resulting in a lower output and a change in the colour temperature of light emitted.

The effect of temperature on lamps is well known and provision can be made at the installation design stage, provided that the interaction of the various design elements is understood.

Differences in ambient temperature across a ceiling can be caused by either a pre-determined control of mechanical systems, or by unplanned interaction, such as unbalanced extract from an office space.

Where a number of luminaires are installed in a common space and are subject to overall control, drifts in colour temperature and output will not be readily noticeable. However with the advent of better and more precise control of heating and cooling systems, particularly in large open-plan spaces, the effect on lighting can be quite pronounced.

Integrated chilled beams are usually controlled independently of each other, which allows the temperature around any integrated lamps to differ depending on whether the chilled beam is operating or not. Because the lamps are so close to the chilled water circuit within the beams and may be subject to falling cold air passing over them, they are likely to suffer a change in colour temperature.

In relatively small spaces, this may not be noticeable, however in large open-plan spaces, particularly where several beams can be viewed simultaneously, differences in colour temperature will be noticeable.

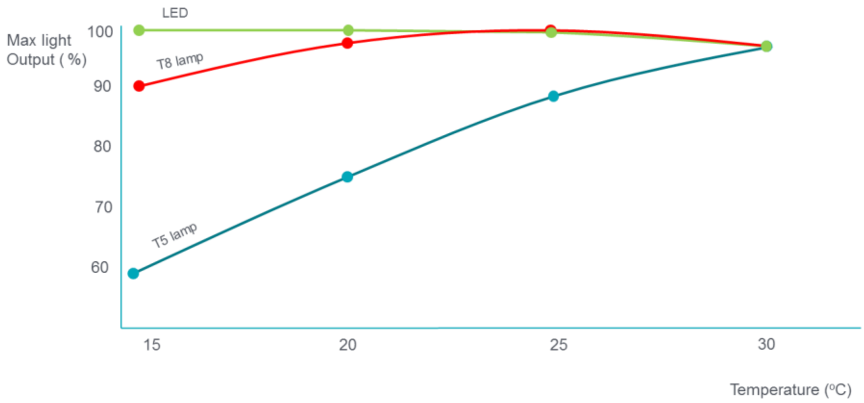
When designing or advising on the use or installation of systems that integrate lighting with mechanical chilled services, the location of lamps within the air-handling luminaire or chilled beam and the air path should be carefully considered.

Whilst not directly related to lighting design, the control of the mechanical systems should be clarified and, where fluctuations in the temperature of adjacent chilled beams is likely to occur, careful selection of integrated chilled beams should be made.

Typical operating temperatures	
Fan coil unit air supply	Typically 6^{o} C to 8^{0} C below the ambient temperature in the space to be cooled.
Chilled beam surface temperature	Typically 14^{o} C to 18^{o} C
T5 lamp optimum operating temperature	Typically 35^{o} C around the lamp
T8 lamp optimum operating temperature	Typically 25^{o} C around the lamp
LED optimum operating temperature	Typically 25^{o} C

Typical performance curves for T8, T5 and LED drivers.

The graph below shows the typical performance curves for T5 and T8 linear fluorescent plus LED drivers over the ambient temperature range that is likely to be encountered in a cooled office space.



It can be seen that the output of the T5 lamps is affected to a greater extent than T8 or LED when the temperature around the lamp falls. If integrated cooling/lighting solutions are not properly designed, there could be a noticeable difference in illumination levels depending on whether the mechanical systems are cooling the space at any given time.

For detailed information and specific lamps characteristics, consultation with the lamp manufacturer should be made.