Hoval

Calculating the supply air flow with the help of the load calculation. What you need to know.

The purpose of a hall ventilation system is to distribute supply air by means of a controlled and therefore calculable indoor air flow in order to dissipate heat loads and pollutant loads. There are various types of air guidance system which can perform this task. A design procedure is therefore required which makes it possible to assess the potential air guidance systems and select the best one for the requirements in question.

Stationary and transient examination of the load calculation

The load calculation procedures calculate the supply air and extract air flows based on the head loads and substance loads to be dissipated, taking into account the load magnitudes. The inclusion of the load factors makes it possible to assess which air guidance system would be most effective for the application in question. The release of heat and substances into the hall can be examined from both a stationary and transient perspective. The transient examination produces differential equations for the substance and heat loads. In the case of the heat loads, the solution is “simplified” insofar as there is no analytical solution. In the case of the substance loads, the differential equation approach shows the pollutant concentration as a function of time. In practice, both representations are of limited use, as the conditions in live production are stationary in the majority of cases. If we assume stationary conditions, the calculations are much simpler. The laws can then be deduced from balance equations for heat and substance flows. The relationships for the heat and substance load factors, which are themselves derived from balance analyses, are particularly suitable for this purpose.

The calculations are carried out separately for heat and substance loads. Once the values have been calculated for the supply air and extract air flows, the higher value is used as the basis for the design. In both cases, information about the collected air flows is required – they must be available in advance as a result of the air flow design process. This only takes into account the collection devices which take their air from the work area. This results in conditional equations for the supply and/or extract air flows as a function of the load factors, the values of which can be determined analytically or taken from VDI 2262 sheet 3, depending on which air guidance system has been selected.

Heat load calculation in comparison

The approach used for the load calculations differs from that used for the other calculations. It is therefore to be expected that the results will differ as well, and it is important to consider how these differences will be evaluated. In manufacturing halls, the air guidance system options are based on two principles: mixing and stratifying. The equations for the heat load calculation include the heat load factor. If the mixing ventilation value is used for this factor – by definition, the value 1 – the heat load calculation turns into the calculation equation for mixing ventilation, whereby the results will be identical. Using the heat load factor from the stratification air guidance system produces the supply or extract air flow of a stratification ventilation system. However, the result will not be equivalent to the result obtained via the method of determining the thermal flows. A key process in stratified ventilation is the replacement of the thermal flows and the specified layer height which is established in the process. This is not taken into account in the load calculation. The supply air flow in this case will generally not match the flow required to replace the thermal flows for a particular layer height. If it is lower, this will result in the undesirable consequence of the air flows returning to the work area; if it is higher, the function will be ensured but with an unnecessarily high air flow. This must be checked in order to provide clarity. This means that a stratified ventilation calculation based on the magnitude of the thermal flows is required. The stratified ventilation calculation that determines the heat dissipation is therefore always carried out by determining the thermal flows and not via the load calculation.

Convective component of the heat flow

Ventilation technology can only dissipate the convective component of the heat loads. The heat load values that are to be used include both the convective component and the radiated component. It is therefore necessary to determine the corresponding components. It is possible to calculate the radiated component analytically, but it is not particularly suitable for a manual calculation procedure. Alternatively, the convective and radiated components can be estimated by analogy with the operative room temperature t_R in accordance with DIN EN 7730, for which the following relationships are established with the air temperature t_L, the radiation temperature of the (visible) enveloping surfaces t_U and the air speed w_L in the work area:

$$t_R = 0.5 t_L + 0.5 t_U \quad for \; w_L < 0.2 \; m/s$$
$$t_R = 0.6 t_L + 0.4 t_U \quad for \; 0.2 \; m/s \le w_L < 0.6 \; m/s$$

Based on the coefficient of the air temperature t_L, the convective components can be assumed to be 50% or 60%, depending on the air speed in the work area. As expected, the value also depends on the surface temperature of the heat sources and can, for example, be slightly above 60% in processing centres with small temperature differences of around 3 K between the surface and the environment, and slightly below 50% in the case of higher surface temperatures.

In comparison, the calculation procedures for designing a stratified ventilation system based on the thermal flows have the advantage that the components of the heat loads that can be dissipated convectively are part of the calculations and result in an optimum supply air flow that is as low as possible with the relevant specifications.

Reference values will only help in the short term

The heat load values should be established by means of calculations or measurements. In the case of heat loads in production facilities, this can often be difficult and time-consuming. Using reference values from the electrical connection ratings is certainly quicker and easier, but involves a significant amount of imprecision. For this reason, it is not recommended. These values come from specific applications with conditions which are generally not known and are therefore irreproducible and undifferentiated.

released into the hall	convectively active	can be dissipated convectively
in the automotive industry 40 %	50 %	20 %
in mechanical engineering 25 %	n/a	25 %

Table 1, Reference values for heat loads from connection values according to regulations

VDI 3802 and VDI 2262 provide data for mechanical production in the automotive industry (see Table 1), but without any indication of whether the value includes direct chip removal and/or external cutting fluid cooling. The same sources state that, when these measures are taken into account, the values can be 30% and 70% lower respectively. This means that supply air flows calculated in this way can deviate by over 100%. Another value that is still commonly used is taken from a directive that has now been withdrawn (DIN VDE 0100-300) for unspecified applications in mechanical engineering (with no information about the convective component). These applications could include machining production, injection moulding machines or presses. The high connection ratings of presses, for example, are only used for very short periods, which results in low levels of heat release. It stands to reason that a standard value for all of these applications will provide correspondingly imprecise results. Using reference values results in a large variation in the magnitude of the supply air flows and is therefore not suitable for a reliable design. If need be, however, they can be used – with reservations – at the start of a project to provide a rough estimate.

Minimum magnitude of the extract air flow

If, theoretically, we take the extract air flow as zero, the supply air flow is only dissipated by the collection devices. This necessarily means that the thermal flows are returned completely to the work area. However, this situation must be avoided. This can only be achieved if the magnitude of the extract air flow and the positions of the extract air openings (at the highest point of the hall) are such that the air still flows well through the top area of the hall despite the collection devices. The basic principle is: extract air must not consist entirely of collected air. For stratified ventilation, the extract air flow is governed by the condition $\dot{m}_{EXT} \geq 0.3 \cdot \dot{m}_{SUP}$

Substance load calculation in comparison

In a similar way to the heat load calculations, the equations for the substance load calculation include the substance load factor. If the mixing ventilation value is used for this factor – by definition, the value 1 again – the substance load calculation turns into the calculation equations for the pollutant mass flow in the room/in the extract air. These equations assume an even distribution of the pollutant in the relevant flow area of the hall, but this is guaranteed with a substance load factor of 1.

Choosing a substance load factor from the stratification air guidance system produces the supply air quantity of a stratification ventilation system. But as with the heat loads, it is also the case here that the supply air flow calculated in this way is not necessarily the flow that is required to replace the thermal flows. In order to clarify this matter, a stratified ventilation system must be designed based on the magnitude of the thermal flows. However, the algorithm does not take into account the pollutant load. The only requirement is the combined release of pollutant and heat load so that the thermal flows can dissipate the substances. It is therefore possible that a lower supply air flow will be determined to replace the thermal flows at the specified layer height than in the load calculation. In this case, the higher value from the load calculation is used for the design, as the magnitude of the supply air flow in this case ensures that a specified pollutant concentration is observed in the work area.

This article shows that load calculations can be used to determine the supply air flow for different types of air guidance system by means of the load factors. In the case of heat load dissipation, the calculation based on the thermal flows is used for the stratification air guidance system. When dissipating pollutants, the supply air flow calculated using the thermal flows must be at least as large as the flow from the load calculation.