Rakett 21

TAL TECH

Indoor climate and technical systems of buildings
1. Task - Finding the thermal conductivity of the boundary layer

Theory:
In a closed system, bodies with different temperatures are equalized by heat exchange: heat moves from a body with a higher temperature to a body with a lower temperature.

In the Estonian climate, walls are designed for winter situations where it is warm in the room and cold outside, so the heat moves from the room to the outside. The thermal transmittance of load-bearing structures is generally high, so thermal insulation is added to them to reduce heat loss, mainly mineral wool or some foam (EPS, XPS).

Thermal transmittance can be found from the reciprocal of thermal resistance (formula 3). So first we find the thermal resistance of the structure (formula 2). The thermal resistance of a single-layer material is found with formula 1:

$$\text{Thermal resistance: } R = d/\lambda \text{ unit } (m2 * K)/W \tag{1}$$

d – material diameter, m (NB! in meters)
λ - specific thermal conductivity of the material, unit (m2 * K)/W

Specific thermal conductivity of the material expresses the heat flow in watts that passes through 1 m thick and 1 m2 size of a material if the temperature difference between the opposite surfaces is 1K.

Finding the total thermal resistance of the boundary layer from thermally homogeneous layers

$$RT = Rsi + R1 + R2 + \ldots + Rn + Rse \tag{2}$$

Rsi – thermal resistance of the inner boundary layer, depends on the direction of the heat flow, for the wall 0.13 (m2 * K)/W

*R*1,*R*2 – calculated thermal resistance of each material layer

Rse – thermal resistance of the outer boundary layer, 0.04 (m2 * K)/W

$$\text{Thermal transmittance: } U = 1/RT \text{ , unit } W/(m2 * K) \tag{3}$$

Example exercise 1:

Task: Check whether the thermal transmittance of the wall (150mm aerated concrete + 100mm EPS) given by the architect, i.e. U-number = 0.15 W/(m2 ∗ K) corresponds to reality.

$\lambda_{concrete}$ = 0.09 (m*K)/W

λ_{EPS} = 0.032(m*K)/W

$d_{concrete}$ = 150 mm

d_{EPS} = 100 mm

First we find the thermal resistance of the entire wall:

$$Rt = Rsi + Rconcrete + R_{EPS} + Rse = 0{,}13\,\frac{W}{m^2K} + \frac{0{,}15\ m}{0{,}09\frac{W}{mK}} + \frac{0{,}10\ m}{0{,}032\frac{W}{mK}} + 0{,}04\,\frac{W}{m^2K} = 4{,}96\,\frac{W}{m^2K}$$

Then we find the the thermal transmittance which is the reciprocal of thermal resistance:

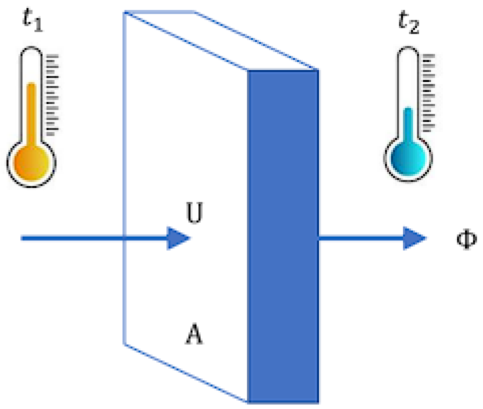
$$U = \frac{1}{R} = \frac{1}{4{,}96\,\frac{W}{m^2K}} = 0{,}20\,\frac{m^2K}{W}$$

Answer: The U number given by the architect does not correspond to reality, the actual U number is 0.20 (m2*K)/W.

2. Finding the building's heat losses, the heat flow of buildings

Theory

Buildings are made of materials that allow heat, air and moisture to pass through. In order to find the building heat losses, it is necessary to calculate how much heat escapes (heat loss) through structures, for example through walls, the floor, ceiling, doors and windows etc. Heat flow Φ is the amount of heat transferred in one unit of time through the observed body, for example through the wall of a building.



Heat flow through the wall

Generally, the air temperature in buildings fluctuates, but for energy calculations we can take the air temperature as a fixed value. In order to maintain a constant temperature in the building we must add to the building, i.e. heat the building with the same amount of energy that escapes through the structure. The heat flow can be found using formula 4:

$$\Phi = U * A * (t1 - t2) \text{ , unit W} \quad (4)$$

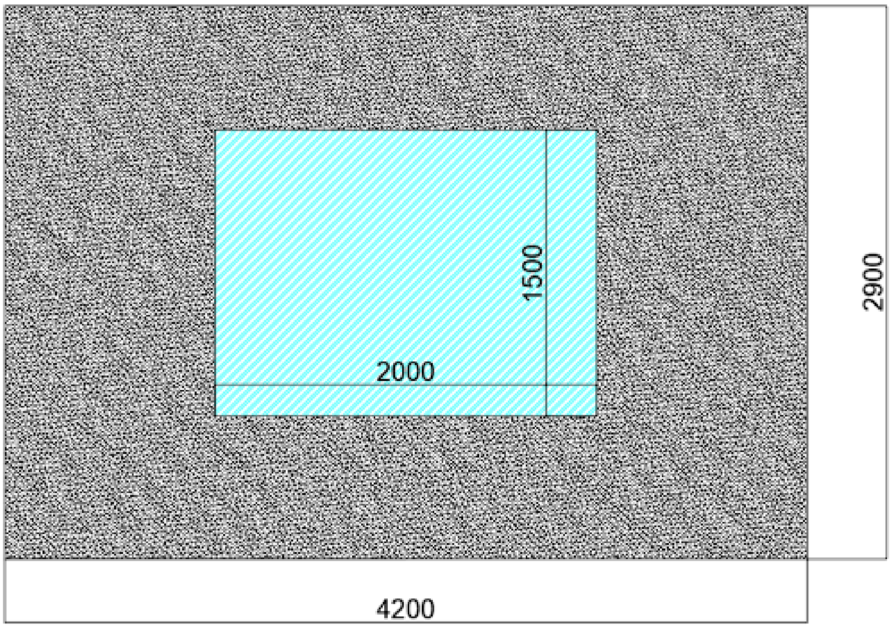
U – Thermal transmittance of the body, W/(m2*K)

A – Body surface area, m2

Δt – temperature difference on one side and on the other side of the observed body, in the given task the difference of temperatures between indoor and outdoor air.

Example exercise 2:

Task: Find the heat loss of a room with one exterior wall. The width of the outer wall is 4.2m and the height is 2.9m and there is one window in the wall with an area of 3m2. Use the U number found in the previous task as the wall U number and take the U value of the window as 0.85 W/(m2*K). The indoor air temperature is +23°C and outside temperature is -22°C.



We find the heat flow through the wall and through the window and add them together:

$$\Phi = \Phi\text{wall} + \Phi\text{window} = 0{,}2\,\frac{W}{m^2K} * 9{,}18m^2 * 45\text{K} + 0{,}85\frac{W}{m^2K} * 3m^2 * 45\text{K} = 197{,}4\text{ W}$$

3. Determining the ventilation unit's heat recovery ratio or efficiency and calculating the heat recovery capacity.

Theory

It is often asked why a ventilation device should be installed in a building at all. In older buildings, natural ventilation may once have been enough, but new and renovated buildings are often very airtight, so natural ventilation is insufficient, and mechanical or forced ventilation must be used to ensure sufficient fresh air in the room.

The working principle of ventilation is very simple in itself, a certain amount of clean outside air is blown into the room, and generally the same amount of "dirty" air is removed from the room. The amount of air flow that is blown into and extracted from the building could be equal to avoid excess or underpressure in the building.

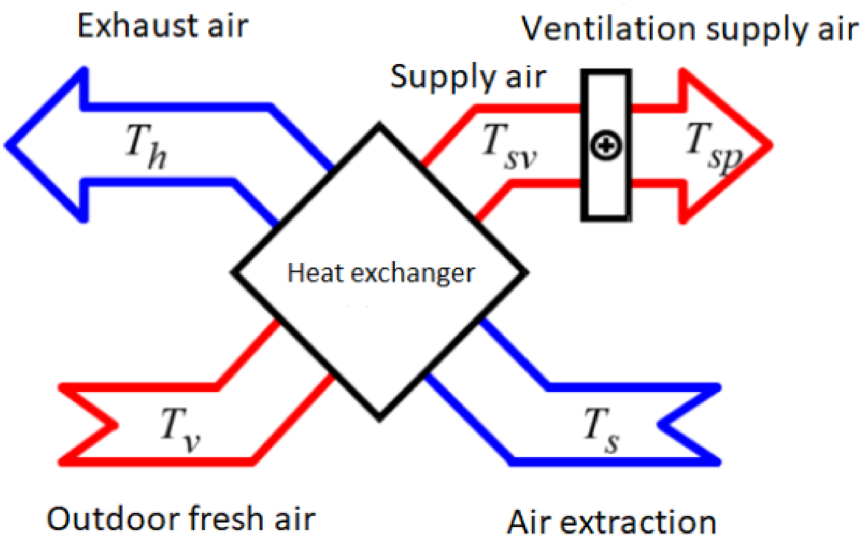
However, blowing cold outdoor air directly into the room in winter would be very uncomfortable for the occupants of the room, and heating costs would also increase. Therefore, the air blown into the room must be heated first. One good way to do this is to remove the heat from the outgoing air and transfer it to the incoming air, using heat recovery ventilation units.

The most common types of heat exchangers are rotor heat exchangers, plate heat exchangers and intermediate heat carrier-heat exchangers.

The savings achieved with a heat exchanger are expressed by its efficiency. The efficiency of the rotor heat exchanger is the highest, usually >80%, the efficiency of the plate heat exchanger is between 60-80%. The plate heat exchanger justifies itself better where air mixing is not allowed (e.g. toilets, rooms with high humidity, dusty work rooms, etc.). In the case of a plate heat exchanger, the exhaust and intake air flows do not mix much. Intermediate heat carrier-heat exchangers are used in ventilation systems where the mixing of intake and exhaust air must be completely excluded, for example in hospitals.

Only the heat exchanger may not be enough to ensure a sufficiently high temperature of the blown-in air, therefore it may be necessary to reheat the blown-in air, which is done with a reheating calorifier.

Calculation of heat recovery efficiency



Scheme No. 2. The working principle of a heat recovery unit with a post-heating calorifier

$$\eta = \frac{Tsupply\ air - Toutside\ air}{Texhaust\ air - Toutside\ air}$$ **no unit**

η - heat recovery ratio or efficiency.

$T_{supply\ air}$ - outside air that has passed through the heat exchanger, warmed up and is then fed into the room, temperature °C

$T_{exhaust\ air}$ – the temperature of the air extracted from the room in °C

$T_{outside\ air}$ – outdoor air temperature. °C

Calculation of heat exchanger capacity

The capacity of the heat exchanger shows how much energy the heat exchanger takes from the air extracted from the room and gives it to the air taken from outside and blown into the room during a certain time unit. Watts are generally used as the unit of power, although for larger airflows it makes more sense to use kW.

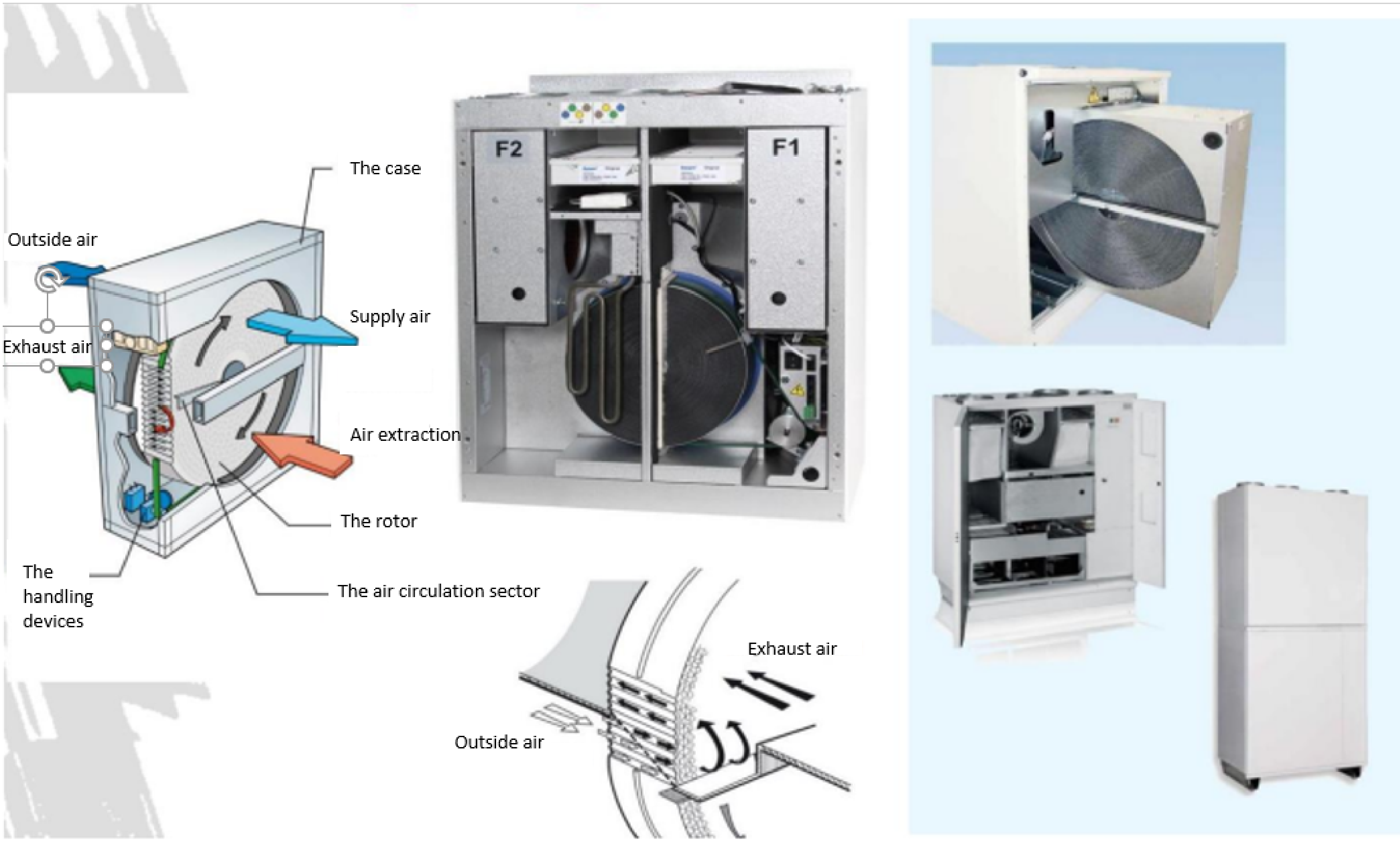
$\Phi = L * \rho\ air * c\ air * \Delta t$ unit W

L – air flow rate m3/s

ρ air – air density, 1.2 kg/m3

c air - specific heat of air, 1000 J/(kg·°C)

Δt – air temperature difference before and after passing through the heat exchanger in °C



Example exercise 3:

Find the ratio of the temperature of the rotor heat exchanger if the outside air temperature is -22°C, the temperature of the air extracted from the room is +23°C, and the temperature of the air blown into the room after the heat exchanger is +16°C. Calculate the power of the given heat exchanger, i.e. the amount of energy that the outside air can get in one second passing through the heat exchanger before the air is blown into the room, if the ventilation air flow rate is 100 l/s.

Efficiency of heat recovery

$$\eta = \frac{T_{\text{Supply air}} - T_{\text{Outside air}}}{T_{\text{Exhaust air}} - T_{\text{Outside air}}} = \frac{16-(-22)}{23-(-22)} = \frac{38}{45} = 0,84 = 84\%$$

Heat exchanger capacity

$$\Phi = 0,1\frac{\text{m}^3}{\text{s}} * 1,2\frac{\text{kg}}{\text{m}^3} * 1000\frac{\text{J}}{\text{KgK}} * (16-(-22)) = 4560\text{W} = 4,56\text{kW}$$