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8. MODERN SOLUTIONS IN VENTILATION AND AIR CONDITIONING SYSTEMS

8.1. Microclimate hygiene requirements

Microclimate can be defined as a set of physical and chemical properties that we observe in a relatively small enclosed space, which has influence on living beings, for instance people, animals, etc. The main parameters are air purity and chemical composition, indoor temperature, relative humidity, velocity of air, and also temperature of the surrounding areas, lighting, noise level, furniture, color of walls and air ions (ASHRE, 2004; ASHRE, 2007). All components of the microclimate can significantly influence human mood, mental and physical performance, work efficiency and health condition (Skwarczyński & Dumała, 2002). It is worthy to note that comfort of a human being can be decreased by physical, chemical and biological pollutants. In case of the physical ones, the most important are noise and vibration, while in the group of biological pollutants we can distinguish for instance dust or bacteria. Most tests of Indoor Air Quality (IAQ) examine chemical components like nitrogen dioxide, sulphur dioxide, carbon monoxide, carbon dioxide or volatile organic compounds. The standards show indoor environment classes, although they differ in names: A, B, C in EN ISO 7730 (ISO 7730:2006), 1, 2, 3, 4 in EN 13779 (PN-EN 13779:2008) or I, II, III, IV in EN-15251 (EN 15251:2007) (Table 8.1).

Table 8.1. Categories of indoor environment according to EN-15251 (Source: EN15251:2007)

Category	Characteristics
I	High quality – rooms used by people sensitive to environmental factors and prone to discomfort, for instance small children, ill elderly people, etc.
II	Normal level – rooms in new and retrofitted buildings
III	Average acceptable level – existing buildings
IV	Buildings which do not fulfill the conditions from I-III categories and could be acceptable only for a brief period.

Recommended conditions for room microclimate according to PN-78/B-03421 and PN-EN 13779:2008 standards are the following:

a) For people with a low metabolism, for example writing or taking part in meetings, lectures – the air temperature in winter should be in a range of 20-22°C, while the recommended range in summer is 23-26°C, relative humidity (RH) 40-55%, maximal air velocity 0.2 m/s in winter and 0.3 m/s in summer.
b) For people with an average metabolism, for instance performing some manual work in laboratories – the air temperature in winter should be in a range of 18-20°C and 20-23°C in summer, RH 40-60%, maximal air velocity 0.2 m/s in winter, whereas 0.4 m/s in summer.

The range of recommended air temperature for classrooms is shown in the table below (2002/91/EC). The values depend on classroom categories: A – high level of expectations, B – average level and C – low requirements (Table 8.2).

Table 8.2. The range of recommended air temperature for classrooms (Source: 2002/91/EC)

Type of room	Category	Temperature [°C]	
		Winter (good clothing insulation)	Summer (low clothing insulation)
rooms in schools	A	21.0	25.5
	B	20.0	26.0
	C	19.0	27.0

Spanish regulations (UNE-EN 13779:2008, Ministerio de Industria, Energia y Turismo 2007, Comentarios al RITE-2007) settle interior design conditions of the operating temperature and humidity depending on the metabolic activity of the people, their clothes and the PPD factor (predicted percentage of dissatisfied users), percentage of estimated dissatisfied persons for a given thermal sensation in a big group, according to the following two possibilities:

a) for people with sedentary lifestyle, metabolic activity of 1.2 met, grade of clothing 0.5 clo in summer and 1 in winter, PPD between 10 and 15%:
   - in summer – temperature 23-25°C, RH 45-60%,
   - in winter – temperature 21-23°C, RH 40-50%;
b) in cases of other metabolism, the temperature and humidity values should be taken from the UNE-EN ISO 7730:2007 standard. The range of recommended air temperature for conference and office rooms is shown in Table 8.3 for three room categories.

Another important parameter of the microclimate is CO_2 concentration. Too high a level could provoke headaches, decline in concentration, eye diseases, breathing difficulties etc.

Table 8.3. The range of recommended air temperature for conference and office rooms (Source: UNE-EN ISO 7730:2007)

Type of the room	Category	Temperature [°C]	
		Winter (good clothing insulation)	Summer (low clothing insulation)
conference rooms, offices, main hall, classrooms	A	22.0±1.0	24.5±1.0
	B	22.0±2.0	24.5±1.5
	C	22.0±3.0	24.5±2.5

More general guidelines concerning the quality of air inside facilities are contained in the PN-EN 13779:2008 standard. Table 8.4 presents a classification of indoor air quality developed on the basis of the above mentioned standard. The recommended concentration of carbon dioxide in rooms equals 1000 ppm. This minimum sanitary requirement is recommended by the European Office of WHO 2000 (Air Quality Guidelines for Europe 2000) and by ASHRAE 2004 and 2007.

Minimum indoor sanitary conditions, i.e. minimum amount of ventilation air for a person in an hour's time ensuring the feeling of comfort during the stay in each room vary between countries, and they are defined differently by various standards. The minimum sanitary requirement in Germany according to DIN 1946-2 equals 50 m^3/h, whereas in case of WHO 2000 and CR EU 17520 for A category buildings, the air inflow stream is equal to 36 m^3/h, and similarly, 35 m^3/h in accordance with ASHRAE, 2007. The still applicable Polish standard of 1983 (PN-83/B-03430) defines the minimum stream at 20 m^3/h, but another Polish standard of 2008 (EN 13779:2008) recommends the values between 22 and 54 m^3/h. Swedish standards, for that matter, recommend the value of as low as 9 m^3/h, while the British ones opt for 25 m^3/h (Recknagel et al., 2006).

Table 8.4. Classification of indoor air quality (Source: PN-EN 13779:2008)

Category	Description	Increase of CO_2 concentration above the CO_2 concentration in the outdoor air	Max indoor CO_2 concentration while the outdoor level is 400 ppm	Outdoor air stream volume per 1 person
		ppm	ppm	m^3/h per 1 person
IDA 1	High indoor air quality	below 400	below 800	above 54
IDA 2	Medium indoor air quality	400-600	800-1000	36-54
IDA 3	Moderate indoor air quality	600-1000	1000-1400	22-36
IDA 4	Low indoor air quality	above 1000	above 1400	below 22

The Indoor Air Quality (IAQ), interpreted broadly, refers to the environmental characteristics inside buildings that may affect human health and comfort. IAQ characteristics include the concentrations of pollutants in the indoor air, as well as the air temperature and humidity. According to STR1 (2005) the air may be classified as:

- outdoor – the air entering the system or directly the room from the building environment;
- supplied – the treated air with the inflow into the room or system of air;
- indoor – the air in the room;
- overflow – the air that gets from one room to another through the openings or is supplied by ventilation systems;
- extracted – the air getting out of the room;
- removed – the air getting out into atmosphere;
- recirculating – the air supplied to the air treatment equipment.

The air quality categories (STR1, 2005):

- the removed air – referring to air pollutants getting out into the atmosphere;
- the exhaust air – referring to air pollutants being extracted from the indoor air:
- the indoor air – referring to air cleanliness in the room.

The same document (STR1, 2005) shows characteristics of the air flow into the operation zone:

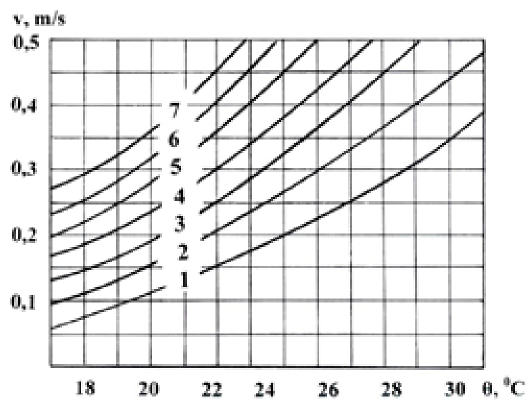

Fig. 8.1. The operation zone air flow characteristics, where: v – maximal air velocity, m/s; Te – the air temperature at the measuring point, 1-7 – air characteristics (Source: STR1, 2005)

The microclimate and air quality parameters are determined by the category of the environmental quality in the room that can be: high (A), average (B) or low (C). These values are different in summer and winter seasons (STR1, 2005). The parameters of the microclimate in the air conditioned rooms must be within the limits of thermal comfort conditions. In some cases and in production premises, they may be within the limits of thermal environmental conditions (STR1, 2005).

The hygiene norms for Lithuania (HN 69:2003) provide indoor air normative values and requirements. The thermal comfort and environmental requirements are set to the working area (operating zone), and are divided into categories for two year seasons (winter and summer). There are three categories of work regarding the degree of difficulty: easy work (Ia, Ib) (Table 8.5), medium difficulty (IIa, IIb) and hard physical work (III).

Table 8.5. Thermal comfort conditions for easy work in Lithuania (Source: HN 69:2003)

Season	Easy work categories	Air temperature, °C	Relative humidity, %	Maximal air velocity, m/s
Winter	Ia	22-24	40-60	≤ 0,1
	Ib	21-23		
Summer	Ia	23-25	40-60	≤ 0,1
	Ib	22-24		≤ 0,2

Depending on the force that determines air circulation, indoor air circulation could be (Šarupičius, 2012; Juodis 2009): flowing, thermal (prevails in places where there are powerful heating sources and the air circulation is determined by convective flows that come from hot devices), filling (fresh air is supplied by the whole surface of ceilings or walls) while pushing the polluted air through the floor, or the openings, located in the lower areas of a room or on the opposite wall), or mixed (in case of the flowing circulation the air is supplied by a single or several flows that move and mix the indoor air) (Šarupičius, 2012; Juodis, 2009).

The rates of air flow per unit of floor area are given in Table 8.6 (STR1, 2005).

Table 8.6. Indoor air flow for different rooms in schools (Source: STR1, 2005)

Type of rooms	Classrooms, laboratories	Conference hall, meeting rooms	Library, reading rooms	Gym, sports activities rooms
Design value of air m^3/h per unit of floor area $1m^2$	10.8	21.6	7.2	7.2
Design value of air m^3/h for person	21.6	28.8	14.4	43,2

Thermal comfort defines such thermal climate conditions in which a person feels contented. The person may be dissatisfied by factors that affect everyone – cold, heat or discomfort (Lapinskienė & Laukys, 2011; Juodis, 2009). It is impossible to determine the ideal thermal conditions or warm environment that would satisfy everyone.

By setting the values for a sufficient amount of thermal climate, it is agreed that these value are satisfactory for 80% of people, whereas 20% may be dissatisfied. The thermal environment could be: comfortable (less than 5% are dissatisfied), moderate and unacceptable (more than 20% people are dissatisfied) (Juodis, 2009; Bilinskienė, 2017).

8.2. Outdoor air parameters

Outdoor air parameters (STR1, 2005; Bilinskienė et al., 2012) can be divided into:
1) Group A – the calculated and installed microclimate systems will not be able to operate in the microclimate conditions for up to 10% of their annual operating time;
2) Group B – the calculated and installed microclimate systems will not be able to operate in the microclimate conditions for up to 2% of their annual operating time.

In winter season, if there are no specific construction or technological requirements, the heating, mechanical ventilation and air conditioning systems function/ operate in accordance with the parameters of the outdoor air of group B (STR1, 2005; Bilinskienė et al., 2012). The outdoor air temperature is 5˚C for natural ventilation systems.

Tables 8.7 and 8.8 present the design outdoor air parameters for evaluation of energy performance of a building (STR2, 2016).

Table 8.7. Average wind speed per month in Lithuania (Source: STR2, 2016)

Month number												
v_{wind}	1	2	3	4	5	6	7	8	9	10	11	12
	4,1	3,8	3,8	3,5	3,2	3,0	2,9	2,7	3,2	3,6	4,0	3,9

Table 8.8. Term tm days per month and average outdoor air temperature per month in Lithuania (Source: STR2, 2016)

Month number												
t_m, days	1	2	3	4	5	6	7	8	9	10	11	12
	31	28	31	30	31	30	31	31	30	31	30	31
$\theta_{e,m}$, °C	–5,1	–4,4	–0,7	5,5	11,9	15,4	16,7	16,2	11,9	7,2	2	–2,4

Design outdoor temperature for heat loss calculation (Bilinskienė et al., 2012) in Vilnius is –23°C. It is normal for Lithuanian climate zone, thermal comfort and climate have to be ensured in buildings when the outdoor temperature is –24°C.

In case of Poland and Spain, several climatic zones are selected and in each one the design outdoor temperature and average monthly temperature are established at different level.

8.3. Ventilation and air conditioning

Ventilation is a system which exhausts the air from a room replacing it with the fresh air (Šarupičius, 2012; Bilinskienė, 2017). Ventilation and air-conditioning systems must be selected according to the purpose of the building and the use of special features, to guarantee the normative indoor climate and clean air under normal use and outdoor weather conditions (STR1, 2005). Natural ventilation is used in cases where the supply or exhaust air is not clean, and the user, without harming others, can provide microclimate and clean air directly regulating the amount of air entering the room, or when the outdoor air is infiltrated into the room (STR1, 2005). Mechanical ventilation is used in cases where there is no natural ventilation or it is not possible to keep normative air parameters in a room. The mechanical and natural ventilation can work together (STR1, 2005). There are strict building energy efficiency requirements for a building ventilation system (STR2, 2016):

1) In the design of mechanical ventilation systems, priority should be given to ventilation system equipment with a maximum efficiency, the lower value of non-renewable primary energy factor used by the ventilating unit and the higher value of the renewable primary energy factor.
2) If the building is equipped with a system for mechanical ventilation with recuperation, the value of the energy efficiency class of the building (or its part) and the energy consumed by the recuperator fans shall comply with the requirements of Regulation (STR2, 2016).

All ventilation systems can be divided into several groups according to the following features (Šarupičius, 2012; Juodis, 2009):

1) depending on the source of pressure and the mode of air transferring, it can be natural or forced ventilation;
2) depending on the area of usage, it can be exhaustion or indraft ventilation;
3) depending on the size and number of rooms served, it can be local or closed circulation ventilation;
4) depending on the construction, it can be channel or non-channel ventilation.

Heating, ventilation and air conditioning systems are combined with one another (STR1, 2005):
1) Air supply systems can be used as heating air systems.
2) In some cases, air conditioning systems may be used as heating systems.
3) When the room is air-conditioned, it must not be naturally ventilated.

If a ventilation system is installed professionally and qualitatively, it helps to preserve the equipment in production premises, protects the construction of the building and prolongs the exploitation period of many materials. The used air must be discharged in the best way which does not endanger human health, nature and structures (STR1, 2005). Fig. 8.2 presents supplied and exhaust air categories EHA1-4.

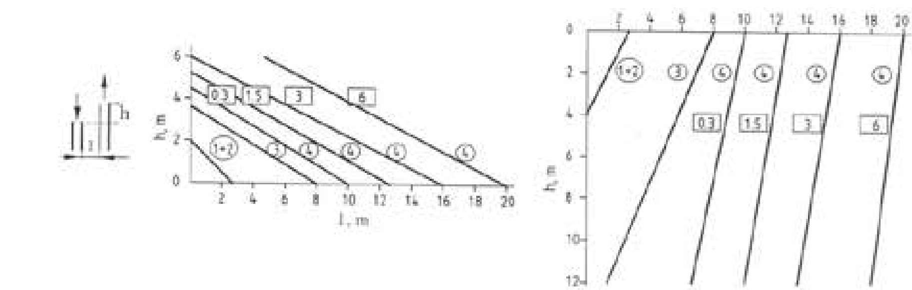

Fig. 8.2. Supplied and exhaust air categories EHA1-4 (Source: STR1, 2005)

The treatment efficiency of the exhaust air, its location and method of discharging shall be chosen so that at the specific points the air pollution does not exceed the permissible concentration (STR1, 2005).

8.4. Natural ventilation system

The natural ventilation (Fig. 8.3A) is the simplest method to ventilate buildings, when the air comes in through the building cracks, windows, vents, micro-ventilation cavities of new type windows, doors or special openings. The air is extracted by vertical draught ducts in natural mode when heated indoor air rises up. They are usually installed in toilets, bathrooms and kitchens (STR1, 2005; Šarupičius, 2012). Natural ventilation can be divided into (Šarupičius, 2012; Bilinskienė, 2017):
1) organized natural ventilation, when special elements are designed for the air to get in and out, the measurement and location of these elements are known;
2) disorganized natural ventilation, when the air penetrates through cracks and gaps, the size and location of which are unknown.

The disadvantages of natural ventilation are (Šarupičius, 2012; Juodis, 2009):
1) The incoming air is not heated when it is cold outside, for instance, during winter, the ventilation may cause a cold draught which might influence people's health.
2) The air is not cleaned and filtered, it may bring in insects, dust and other dirt.
3) Dust is common in buildings situated close to busy streets. Besides, the street noise is common through the natural ventilation of such buildings.
4) It is difficult to control the volume of incoming air and rooms can be ventilated too much or too little.
5) In summertime, when the outdoor and indoor temperature is almost equal, the air almost stops circulating.
6) Huge heat losses cause high heating prices.

The air in natural ventilation system is usually removed through the ventilation pipes on the roof.

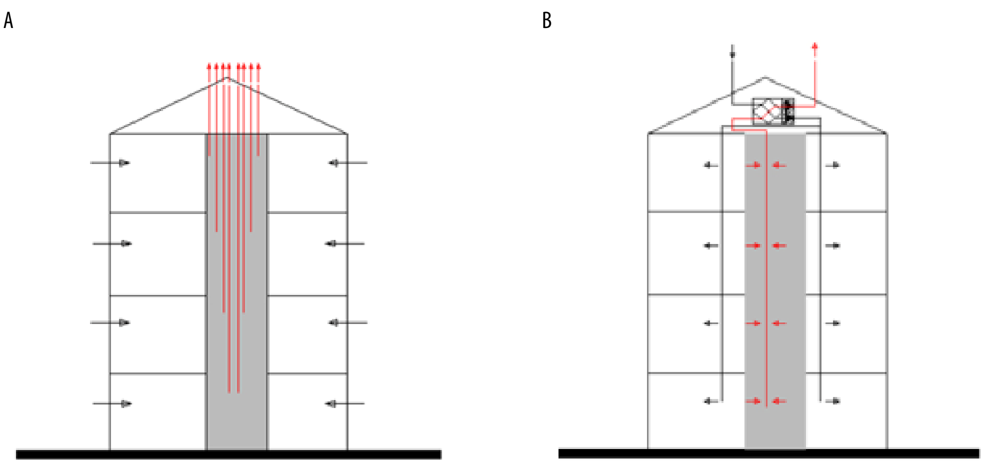

Fig. 8.3. Principal plan and scheme of ventilation system pipelines: A) the natural ventilation system, B) the mechanical ventilation system (Source: STR1, 2005; Šarupičius, 2012; Bilinskienė, 2017)

8.5. Mechanical ventilation system

The building must be ventilated and heated in such a way so as to maintain the standard air quality by using energy efficiently (STR1, 2005; STR2, 2016). The mechanical ventilation system (Fig. 8.3B) can be divided into (Šarupičius, 2012; Juodis, 2009):
1) depending on the purpose: extractive – that extracts the used air, and supplying – that supplies the fresh air;

2) depending on the use of fresh and used air: straight flow, with partial circulation, and re-circulative;
3) depending on the air circulation channel ventilation – branched or collector systems, and non- channel ventilation systems.

The advantages of mechanical systems are: while operating, a required volume of air is supplied regardless of the air temperature outside; system operating process and ventilation intensity could be controlled according to the preferences; the supplied air is heated or cooled to the temperature required, it is filtered (Bilinskienė, 2017; Juodis 2009). The disadvantages of the mechanical system are: the installation of this system is rather expensive, while operating, mechanical systems are quite noisy, electricity is continuously used. A specified volume of clean air must be supplied to the room in accordance with the requirements of health regulations. The amount of clean outdoor and recirculated air supplied to the room must be set at a level that does not exceed the air pollution in the Hygiene Norms (HN) (STR1, 2005). The air delivered to the room and coming in from other rooms must be cleaner than the air removed from the room. In order to determine the degree of air pollution emitted by public or industrial buildings (STR3, 2017), it is necessary to estimate the amount of emissions during the production process, the amount of pollutants from the internal equipment, people, etc. (STR1, 2005).

8.6. Air conditioning systems

Air conditioning is used where it is necessary to maintain a constant temperature and relative humidity indoors, or cool the air supplied, or when there are special air purity requirements (in medical institutions, clean rooms and etc.). The process of creation and maintenance of the artificial climate within rooms or buildings is called air conditioning (STR1, 2005). The air is conditioned when natural and mechanical ventilation systems are not capable of ensuring the level of indoor air temperature, relative humidity, circulation and cleanness regulated by the Hygiene norms (HN). The air conditioning systems (Juodis, 2009; Bilinskienė, 2017) can be:

1) Variable air volume systems. These systems are used in buildings which require cooling, but where some spaces need different amounts of cooling or where cooling load changes during a day. Individual control of room temperatures is achieved in this system. The most popular is the system with extracted air recirculation.
2) Constant volume systems: these are systems with an air handling unit, which supplies air only at fixed temperature. The advantage of the constant volume system is lower cost, the disadvantage – that it is not energy effective.

3) Dual duct systems: this type of air conditioning system requires separate heated and cooled air streams in individual ducting systems. This is the main reason why two pipe systems with separate heated and cooled air ducts are not popular in Lithuania.

The air conditioning system may be divided into: comfort, technological or comfort-technological. The purpose of the comfort air conditioning system is to create optimal hygienic work and living conditions, whereas technological systems are designed to create the best air conditions for technological process (Juodis, 2009; Šarupičius, 2012). The air conditioning system includes a cooling coil, humidifier or dehumidification equipment.

8.7. Ventilation and air conditioning equipment

The ventilation and air conditioning solutions are adopted according to the features of the building, technology, microclimate, energy supply and operating conditions (STR1, 2005). The building ventilation and air conditioning as well as the architectural building solutions are combined with one another throughout all stages of projecting (STR1, 2005; Juodis, 2009). Ventilation equipment is comprised of air supply and exhaust devices, silencers, air distribution and extraction devices (Šarupičius, 2012a; Bilinskienė, 2017).

Fig. 8.4. AHU construction (Source: R. Bilinskienė's private archive; WEB-1,3)

The basic functions of a central air handling unit (AHU) are (Fig. 8.4):
1) to deliver fresh air into the distribution system and the room space;
2) to filter out any solid pollutants;

3) to extract polluted air from the room space;
4) to heat the air to the required temperature.

The main air handling unit (Fig. 8.4) components: fans, filters, heating coil, heat recovery unit, etc.

Fig. 8.5. Location of the AHU: A-B) in the basement, C-D) on the roof (Source: photos by T.J. Teleszewski)

A general view of the air handling unit located in the basement is shown in Fig. 8.5A-B, while Fig. 8.5C-D shows the air handling unit installed on the roof.

The air ducts (Fig. 8.6) are used in ventilation and air conditioning systems to supply and extract air. Air ducts could be installed with thermal or sound insulation. With reference to their cross section, air ducts are divided into two main groups: round and rectangular. The fans are (Šarupičius, 2012; Bilinskienė, 2017) designed to cause air circulation inside the room and air ducts (Fig. 8.6). Fans are the main source of noise and vibration in ventilation systems (HN 33:2007).

Fig. 8.6. Air duct types (Source: Bilinskienė, 2017; WEB-1,2; R. Bilinskienė's private archive; T.J. Teleszewski's private archive)

Depending on the principle of operation fans can be divided into:
1) axial fans (the air flows parallel to the shaft, Figs. 8.7A-D),
2) centrifugal or radial fans (the air flows in a radial direction relative to the shaft, Fig. 8.7E),
3) mixed flow fans (the air flows in both axial and radial direction relative to the shaft),
4) cross flow fans (the air flows in an inward direction and then in an outward radial direction, Fig. 8.7F).

Fig. 8.7. Examples of fan constructions: A), B) an axial fan for installation in the ventilation duct and on the roof, C), D) axial fans installed on the roof, E) a centrifugal fan, F) a cross flow fan installed in the AHU unit (Source: Bilinskienė, 2017; WEB-1; R. Bilinskienė's private archive; photos by T.J. Teleszewski)

Fig. 8.8A-D show the following types of fan impellers: axial impellers (Fig. 8.8A-B), a centrifugal impeller (Fig. 8.8C) and a cross flow fan impeller (Fig. 8.8D). Due to the way the fan impeller is connected to the motor shaft, the fans can be divided into:

1) direct drive fans (the impeller is directly connected to the motor shaft, Figs. 8.7A-E).

2) belt drive fans (a transmission system using a flexible belt to transfer power, Fig. 8.7F)

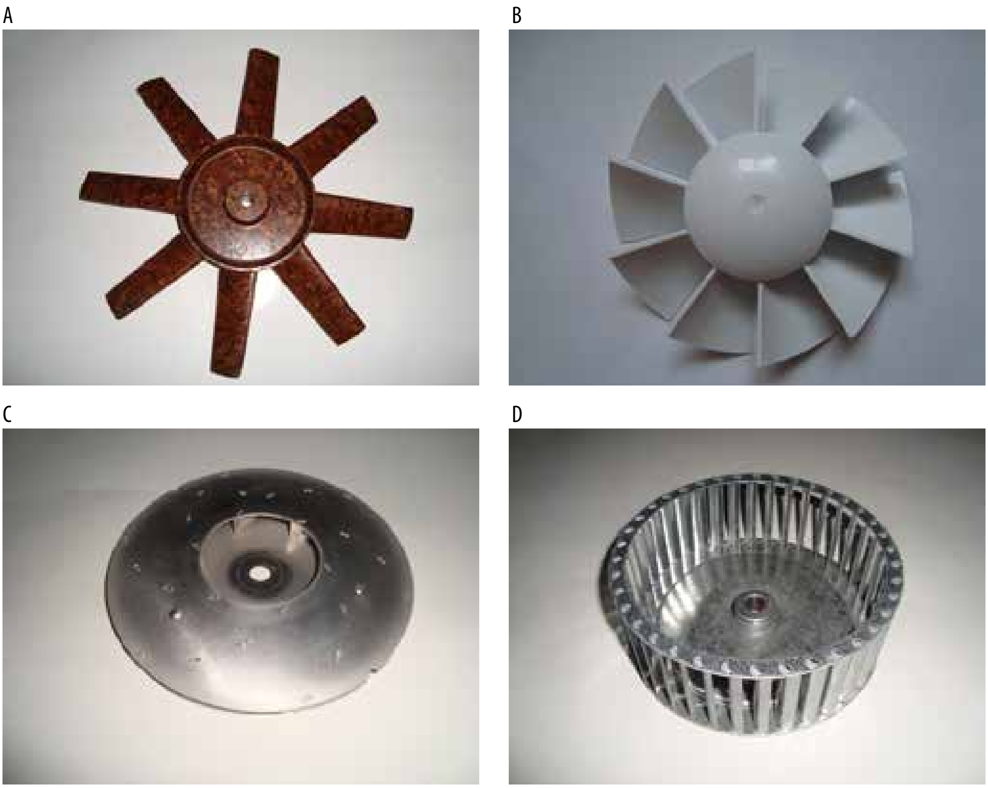

Fig. 8.8. Examples of fan rotor designs: A), B) axial fan impellers, C) a centrifugal impeller, D) a cross flow fan impeller (Source: photos by T.J. Teleszewski)

Depending on the purpose of usage, fans can be produced of various materials: steel, plastic, stainless steel, etc.

The basic technical parameters of the fan selection are the flow rate of the fan V and the pressure p. In the case of typical ventilation, the required flow rate V [m^3/h] is determined on the basis of the volume of the ventilated room V_p [m^3] and the assumed number of air changes per hour k [1/h]:

$$V = V_p k\,, \tag{8.1}$$

To determine the required pressure, Bernoulli equation (Fig. 8.9) can be used:

$$\frac{p_1}{\rho g} + z_1 + \frac{v_1^2}{2g} = \frac{p_2}{\rho g} + z_2 + \frac{v_2^2}{2g} + \Delta p_s, \tag{8.2}$$

where

v_1, v_2 – velocity in sections 1 and 2 (m/s)
p_1, p_2 – pressure in cross-sections 1 and 2 (Pa)
z_1, z_2 – height of the cross-section of the channel in relation to any chosen reference level (m),
ρ – air density (kg/m³),
g – gravity (m/s²).

Hydraulic losses Δp_s are divided into major losses Δp_l and minor losses Δp_m:

$$\Delta p_l = \frac{l \lambda v^2 \rho}{8 R_h}, \tag{8.3}$$

where

l – length of the channel (m)
R_h – hydraulic radius (m)
λ – Darcy-Weisbach friction factor.

The hydraulic radius is equal to the ratio of the cross-sectional area of channel A to its circumference P:

$$R_h = \frac{A}{P}, \tag{8.4}$$

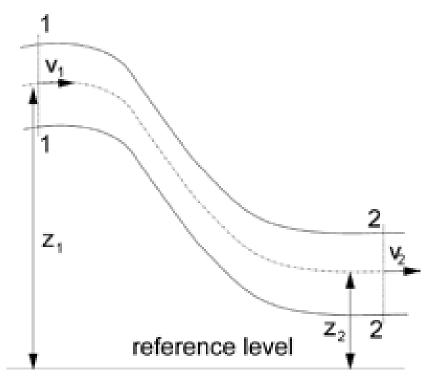

Fig. 8.9. Auxiliary drawing for the Bernoulli equation (Source: own elaboration)

Minor losses are expressed in the function of dynamic pressure:

$$\Delta p_m = \zeta \frac{\rho v^2}{2}, \tag{8.5}$$

where

ζ – minor loss coefficient (–).

The intersection of the system characteristics with the characteristics of the fan is the fan work point (Fig. 8.10). The fan duty point should correspond to the maximum fan efficiency (Fig. 8.10).

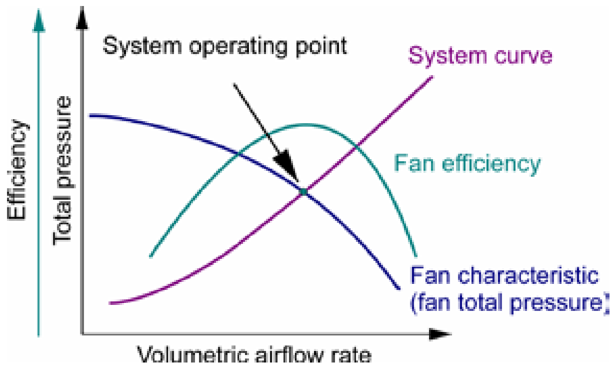

Fig. 8.10. Fan work point (Source: own elaboration)

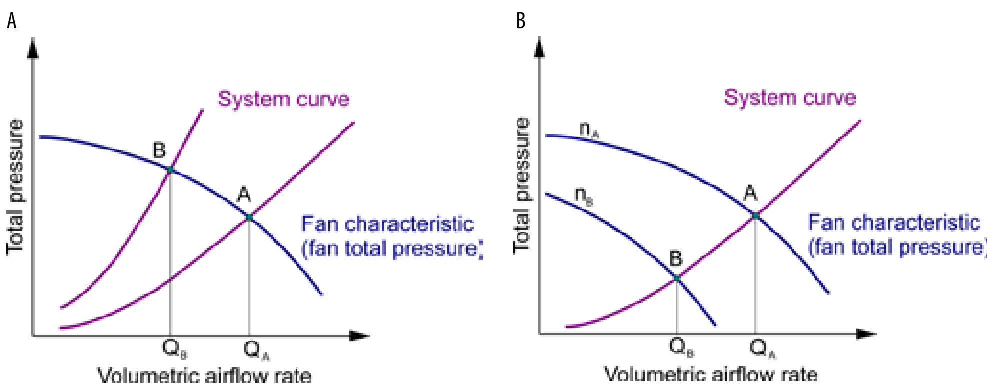

Fig. 8.11. Fan flow rate control: A) regulation by throttling, B) regulation by changing the rotational speed of the fan impeller (Source: own elaboration)

The flow rate of the fans can be regulated by throttling or by changing the rotational speed of the fan impeller. Fig. 8.11A shows an exemplary throttle regulation of the fan output from point A to point B through the operation of the air damper. The reduction in airflow rate from Q_A to Q_B has resulted in additional hydraulic losses, which is why the regulation is unfavourable in terms of energy. Fig. 8.11B shows an example of the operation of the regulation by changing the rotational speed of the fan impeller. In the case of this adjustment, the reduction of the output from Q_A to Q_B was achieved by reducing the rotational speed from n_A to n_B. The rotational speed change of the fan impeller in this case also involves a reduction in fan power, which is beneficial from the energy point of view of the fan. The rotational speed control of the fan impeller is implemented by using frequency converters (Fig. 8.12), which are additionally connected by automatic control systems.

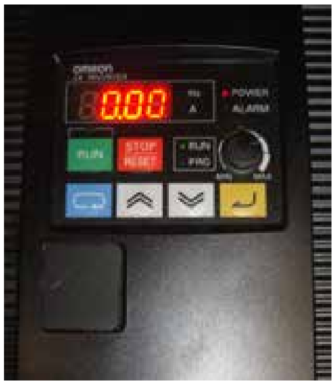

Fig. 8.12. A frequency converter control panel (Source: T.J. Teleszewski's private archive)

Fig. 8.13. An example of application of a throttle regulation: 1 – an air damper. 2 – an electric actuator, 3 – a fan, 4 – a ventilation duct (Source: T.J. Teleszewski's private archive)

Photo 8.13 presents an exemplary application of throttling regulation, while Fig. 8.14A-B present exemplary construction for air dampers for round ducts (Fig. 8.14A) and for rectangular ducts (Fig. 8.14B).

A B

Fig. 8.14. An air damper for a circular duct (A) and for a rectangular duct (B) (Source: T.J. Teleszewski's private archive)

Sources of noise in ventilation system can be: a fan, air circulation during duct and local obstacles (elbows, valves) (Šarupičius, 2012a; Bilinskienė, 2017). Noise silencers used in ventilation systems are divided into tubular and laminar.

Fig. 8.15. Noise silencer types (Source: Bilinskienė, 2017; R. Bilinskienė's private archive; WEB-1)

A noise silencer (Fig. 8.15) consists of a perforated inner canal, for the air flow, a noise absorbing material and an external shell.

Air distribution in ventilation systems (Juodis, 2009; Bilinskienė, 2017):

1) Chilled beams – they are used for ventilation and cooling systems where required for individual regulation of the temperature.
2) Displacement diffusers – the air is supplied into the customer area and extracted from the upper zone of the room. Diffusers give for customer comfort, good air quality and high ventilation efficiency.
3) The another equipment.

The air in ventilation, conditioning or air heating systems is warmed up by heaters. Heaters (Fig. 8.16) could be classified as (Juodis, 1998; Bilinskienė, 2017): water, stream and electric.

Fig. 8.16. Types of heaters (Source: Bilinskienė, 2017; WEB-2,3; T.J. Teleszewski's private archive)

Coiled heating elements for an electric heater and hot water coils are shown in Fig. 8.17A and 8.17B-C, respectively.

The filters (Fig. 8.18) for dust and air-blast dry filters must be installed in front of the fan in mechanical ventilation systems (STR1, 2005).

Heating, ventilation and air conditioning equipment should be arranged so as to minimize the risk of fire or fire explosion (STR1, 2005). Central heating and ventilation pipes that pass through the walls should be protected against the spread of fire to the adjacent rooms. Fig. 8.19 shows the protection of a pipe with an intumescent pipe collar which prevents the spread of fire and smoke to the neighbouring fire zones.

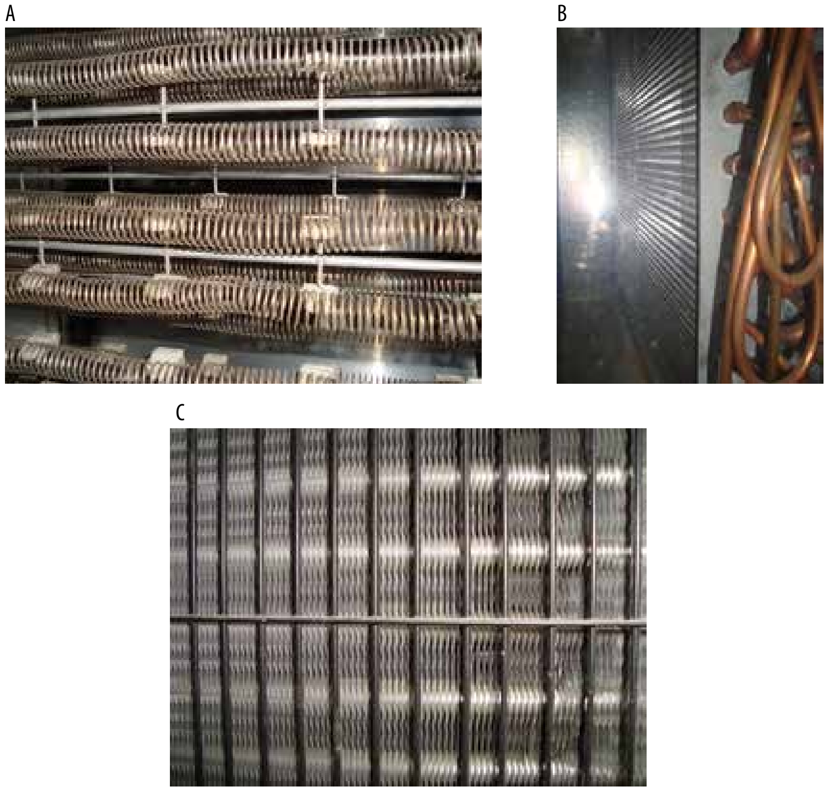

Fig. 8.17. Elements of the air heating section: A) coiled heating elements for an electric heater, B-C) hot water coils (Source: T.J. Teleszewski's private archive)

Fig. 8.18. Types of filters (Source: Bilinskienė, 2017; WEB-1,2,3)

Fig. 8.19. Intumescent pipe collars (Source: photo by T.J. Teleszewski)

8.8. Heat recovery ventilation

Heat recovery ventilation (HRV), also known as mechanical ventilation heat re-covery (MVHR), is an installation that reduces heat loss caused by building ventilation. Heat recovery ventilation makes it possible to significantly reduce the energy needed to heat the air blown into the building. It is therefore a must in an energy-saving construction. Heat recovery ventilation is used both in public buildings and in private homes. The main element of the heat recovery installation is air-to-air heat exchanger which employs a cross-flow or counter-flow heat exchanger between the inbound and outbound air flow. The recovery of warm air from the used air stream as the main assumption of the HRV is possible thanks to the thin walls of the HRV unit, which separate the two streams, at the same time allowing for the transfer of energy without mutual mixing. It is a process subject to control and regulation. Air purification is carried out by appropriate filters that also capture allergens, which is why this type of ventilation is especially recommended for asthmatics and allergy sufferers. A favourable microclimate in a house results from constant air circulation and from heating the air streams flowing into the house by the HRV filtration. The HRV eliminates the need for additional airing of the apartment or unsealing of windows or doors.

The HRV operation is as follows (Fig. 8.20): the air intake sucks clean air from the outside. Then, through ventilation ducts, it passes to a ventilation unit with a heat exchanger, where after passing through the inlet channel, it flows through filters responsible for catching dust and pollen. At the same time, the used (contaminated) air is extracted from the bathroom, toilet, wardrobe and kitchen rooms through the ventilation ducts attached to the heat exchanger.. The streams of used air passing in the adjacent channels in the device give off the heat to the incoming streams, which means that it goes back to the building. The exhausted and cooled air is thrown out through the launcher. The distribution of clean and heated air is carried out inside the building. The amount of supply and exhaust air is the same. The view of a heat exchanger is shown in Fig. 8.21.

Fig. 8.20. An example of using HRV in a single-family home (Source: own elaboration)

A

B

Fig. 8.21. An air heat exchanger (Source: photo by T.J. Teleszewski)

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