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Mechanical ventilation system in swimming-pools.

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DESCRIPTION

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Abstract

The subject of this thesis is a good indoor climate in swimming pools. It's very important to achieve good indoor climate in swimming pool in order to swimmers and spectators don't have bad effect on their health. The long operational time of envelope constructions can also be possible only in good environment. The aim of this thesis is to define the good solution of mechanical ventilation system for swimming pool.

Good indoor climate of swimming pools is very important and discussed subject. Guidelines in the different countries have their own recommendations about significance of indoor climate parameters for achieving good indoor climate. The commonest of these (ASHRAE, National building Code of Finland D2, Russian designing and building code 31-113-2004. Swimming pools) were described in the thesis. Then the comparison between these ones was made.

In the thesis the main indoor climate problems in swimming pools were described. And the commonest of problems is moisture problem. Moisture can cause the bad impact on human health and building constructions. Ventilation systems of swimming pool have the main purpose to supply fresh air and no less important purpose of these systems is to avoid moisture problem.

Thesis bases mainly on the information of ventilation equipments (heat pumps, dehumidifiers etc.) and theoretical sources. The three of common ventilation systems (simple system, system with different types of dehumidifier or heat pumps and system with heat recovery) were investigated, described and then compared between each other. During investigation of different types of dehumidifiers (wall mounted or floor standing, channel) the comparing between these ones was made. Also the solution, about which one will be best for operation in swimming pool, was made.

Subject headings, (keywords)

Audit, condition assessment, mechanical systems, HVAC systems, air conditioning systems

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CONTENTS

1 INTRODUCTION

A swimming pool is an amazing place, where you can enjoy the fun, and swim in the middle of a cold winter. According to the ASHRAE recommendations there are three main types of swimming pools. In my thesis I will speak about the “swimming pools with no spectator’s places”. Each designer knows that the good indoor climate is important in swimming pool. To create acceptable indoor climate we should comply with the recommendations. Deviating from norms can cause a variety of problems. These problems can be related with health of swimmers and with the facility itself.

The main problem of swimming pools is the excess moisture. In my thesis I will give the details about issue. Continuously 150-250 grams of water evaporate per hour from the water surface. If we don’t do anything with this problem, the relative humidity will rise and cause the excess moisture. In this situation some things can happen, e.g. water vapor may condense on cold surfaces, windows sweat, walls and ceiling become wet, indoor surfaces get damaged, mould and unpleasant odors appear. Moisture gradually penetrates into all holes: the brick and cinder block get cracks, concrete structures weak due to corrosion. Excess moisture can also cause high concentration of pollutant in the indoor air that finally leads to a variety of human diseases. Therefore, the solution of the problem of excess moisture is one of the main tasks of the designing of the pool.

It is impossible to avoid the excess moisture at all, but it’s possible to keeping it at the required level is needed to create comfort. Measures to prevent moisture are different. This may be a simple cover pool (pool cover during the hours when it does not work), simple conditioning or ventilation system. Cover and stationary air conditioners do not give actual results themselves they can only be used as additional measures. Ventilation system for swimming pool has a big importance to ensure good indoor climate. The task of the ventilation system is not only providing the necessary supply of fresh air, but first and foremost it is the creating of an acceptable level of humidity. The objective of my thesis is to answer the question: Which method of mechanical ventilation is the most effective? An effective ventilation system is a system that has a minimum capital and operating costs, provides a comfortable indoor climate. The system should be simple to operate and repair.

The first part of my thesis gives the information about parameters of indoor climate in swimming pools. The first part gives recommendations of different guidelines and norms about good indoor climate too. A comparative analysis is provided in the same part. The second part tells about the problems, which may occur in swimming pool when we don't provide the recommended parameters of microclimate. Part three focuses on the problem of moisture, because the elimination of this problem is the main task of the ventilation system. Later in the fifth section I describe and compare three major systems of ventilation: a simple mechanical system, ventilation system with dehumidifiers, ventilation systems with heat exchanger. The conclusion provides an answer to the question: what kind of ventilation is the most effective for the swimming pool to prevent moisture? After the conclusion the seventh part makes additional general recommendations (about methods of air supply) which also have an important significance in ensuring a comfortable microclimate.

2 INDOOR CLIMATE REQUIREMENTS FOR SWIMMING POOLS

In order to achieve acceptable and healthy indoor climate in swimming pool the designer has to know necessary parameters of indoor climate. Values of these parameters are presented in different kind of standards and regulations. In this chapter it has been investigated and compared recommendations given by standards in America (ASHRAE), Finland (D2) and Russia (Building code 31-113-2004).

2.1 ASHRAE

The following chapter is based on ASHRAE standard 62-2001 “Ventilation for acceptable indoor air quality” /1/ and ASHRAE standard 55-2004 “Thermal environmental conditions for human occupancy” /2/.
ASHRAE Standard 62-2001 “Ventilation for Acceptable Indoor Air Quality” defines ventilation requirements and specifies indoor air quality (chemical, physical and biological contaminants) and air flow rates for required acceptable indoor climate for human occupants. Requirements for thermal comfort are not included in this standard.
Recommended supply air flow rates are given in table 1 in cfm/ft² (l/s*m²). The contamination produced is not presumed to be proportion to the number of persons.

Table1. Supply air flow rate for ventilation /1, p.9/.

Application	Outdoor air requirements		Comments
	cfm/ft²	l/s*m²	
Swimming pools (pool and deck area)	0,50	2,50	Higher values may be required for humidity control

Because of excess relative humidity and temperature in swimming pool heat load of heating system or dehumidifying system will be increased. If we have about +29 °C of indoor temperature in swimming pool and intake air flow with temperature less than +29 °C, this cold flow reduces indoor temperature and increase heat load of the heating equipment. But if relative humidity of outdoor air is less than this one of indoor air, it helps to reduce the humidity.

The 1989 ASHRAE Handbook Applications Fundamentals /3, p.4.7/ specifies relative humidity significant for swimming pools and cites a deck-level relative humidity of 50-60% to fulfil the requirements of acceptable indoor climate. Another important parameter for acceptable indoor climate is air change rate, which should be 4-6 according to the 1989 ASHRAE Handbook Applications /3, p.4.8/.

ASHRAE standard 55-2004 “Thermal environmental conditions for human occupancy” specifies parameters for acceptable thermal environment for all occupants. This standard describes the methods that may be used to determine operative temperature for occupied zone using giving values of humidity, metabolic rate, air speed and clothing insulation. Guidelines about air speed are the following: “The required air speed may not be higher than 0,8 m/s..... the elevated air speed must be under the direct control of the affected occupants and adjustable in steps no greater than 0,15 m/s “/2, p.6/. But this standard doesn’t give any information specifically for swimming pools. Acceptable concentration of air contaminants is given in table B-1 of ASHRAE 62-2001 and they are the same as for other type of buildings.
/1, p.6,9 /, /2, p. 4-6/, /3, p.4.7/

2.2 Finnish national building code D2. Regulation and guidelines

The following chapter is based on D2 Regulations and guidelines 2003 “Indoor climate and ventilation of building” /4/, which gives information concerning designing acceptable indoor climate in the existing or new building.

Except the general recommendation about the acceptable indoor climate this standard gives some information concerning swimming pool area. Indoor climate of swimming pool area has to be designed and calculated in such a way that air movement, surface temperatures and other indoor factors don’t cause discomfort to the visitors. At the same time there shouldn’t be such internal conditions which can cause damage of building construction. The guideline values for the design of ventilation for swimming pool are presented in table 2.

Table 2. The guideline values of ventilation for swimming pool /4, p.35/.

Space type	Outdoor air flow (dm³/s)/m2	Sound level $L_{A,eq,T}$/ $L_{A,max}$, dB	Air velocity (winter/summer) m/s	Note!
Swimming pool area	2	38/43	0,40	*
*Moisture removal is a design factor. To be calculated separately in each case.				

As you can see in swimming pool there is not sufficient basis for designing air flow rates according to the number of occupants. In this case the design should be based on the surface areas in question. Also these guidelines don't give the exactly recommendations about the acceptable moisture level in swimming pools. There is only said that moisture removal should be calculated in each case individually. /4, p. 30-35/

2.3 Russian designing and building code 31-113-2004. Swimming pools

The following chapter is based on designing and building code 31-113-2004 /5/.
According to the designing and building code 31-113-2004 heating, ventilation and air conditioning systems have to provide the following parameters of indoor climate for swimming pools.

Table3. Indoor air requirement for swimming pools /5, p.40/.

Premise	Designing **indoor temperature**, ^{0}C	**Air flow rate**
Swimming pool halls (with spectator's places and without)	On 1-2 degrees more than designing water temperature*****	Not less than 80 m³/h of outdoor air for a swimmer or not less than 20 m³/h for a spectator

*Designing water temperature for improving swimming pool is +26 - +29 ^{0}C
The accepted relative humidity for swimming pool should be between 50 and 65 % levels. The lower limit of this acceptable range of relative humidity is specified for cold weather period.

The solution of air exchange rate for swimming pool should prevent the formation of stagnant zones (prevalence of an extract air over a supply air flow rate is not more than 0,5-times exchange rate).

The indoor temperature is given for working period in cold seasons. During warm seasons the designed indoor temperature must not exceed the outdoor temperature by more than 3 degrees according to the requirements of Russian Building rules and norms 41-01. The velocity of air must not exceed 0,2 m/s in swimmer's zones.

In addition to the given parameters of indoor climate "Sanitary and epidemiological rules and norms 2.1.2.1188-03. Swimming pools" says that the free chlorine concentration in the air above the water surface have to be not more than 0,1 mg/m³, ozone concentration – not more than 0,16 mg/m³. The noise level in swimming pool must not exceed 60 dB(A) /5, p. 35-43/.

2.4 Comparison

All recommendations that are given in guidelines are needed to achieve the acceptable indoor climate in swimming pools (to avoid health hazard effect or damage of building envelope). Values of parameters are almost equal, but some deviations can be between different guidelines. In table 4 you can see the most important parameters.

Table4. Indoor air requirement for swimming pools.

Parameter of indoor climate	ASHRAE (America)	D2 (Finland)	Designing and building code
Supply air flow rate (l/sec)	2,5*	2,0*	80/3,6=22,2**
Relative humidity (%)	50-60	-	50-65
Air change rate (1/h)	4-6	-	0,5
Indoor temperature (^{0}C)	calculated	-	28-31
Air velocity (m/s)	0,8	0,4	0,2
Pollution concentration	-	as for other building type	clorine-0,1mg/m³; ozone-0,16mg/m³
* for m² of area			
** for one swimmer			

We can say that ASHRAE standard 62-2001 cites that outdoor air flow rate should be at least 2.5 l/s per one square meter and at the same time D2 regulations say that this meaning should be 2,0 l/s and Russian Code 31-113-2004 – not less than 80 m^3/h for swimmers.

None of regulation or standards gives exact recommendation about indoor temperature. Every time it should be calculated according to the given values of humidity, temperature of water and others. But every time values of acceptable indoor temperature for swimming pool have a magnitude 27-29 ^0C. For example Russian Code 31-113-2004 says that indoor temperature should be on 1-2 degrees more than water temperature, hence from +28 to +31 °C.

The levels of relative humidity, which are the most important for me because of the aim of my thesis, also have the lower differences. ASHRAE Handbook Applications 1989 recommends the magnitude between 50% and 60%. D2 regulation doesn't say anything about reasonable relative humidity for swimming pool. And finally Russian Code 31-113-2004 cites that relative humidity for swimming pool should be from 50% and 65%.

3 PROBLEMS CAUSED BY DEVIATIONS FROM THE NORMS

To achieve the acceptable indoor climate for the swimming pools the parameters of indoor climate should comply with the norms. These parameters have been discussed in the previous chapter. If air conditioning system cannot provide appropriate air parameters the following problems may occur in swimming pool halls.

3.1 Excess or low relative humidity

According to the R. H. Howell and H. J. Sauer /6/ the low relative humidity (especially in winter time, when outdoor air contains small amount of moisture) can cause the drying of the skin and hair. Some medical advisers think that it also may leads to mucous membrane drying and as a result respiratory complaints and increase the possibility of occurrence of cold diseases. But for the present there are not any documents which can evidence the direct link between low relative humidity and serious health hazards. Also low level of relative humidity can cause the excess evaporation from water surface. So it can lead to the additional load on the conditioning system. /6, p. 112/

Kappler /7/ pays attention that the high relative humidity level in swimming pool hall decreases condensation through the skin and reduces the regulation possibility of human organism (about temperature maintenance on defined level). The sensation of stuffiness may occur. /7, p 48-50/

The high level of relative humidity (or in other words – moisture content) is not only harmful to the health of occupants of swimming pool but it also seriously affects structures of swimming pool hall (particularly on building scope, surfaces, windows). And I'm going to tell more about this problem which occurs in the swimming pools. Solution of that problem will be the main target of my thesis.

3.2 Low temperature of surfaces

If the surfaces of swimming pool halls have temperature lower than specified in norms, the person (swimmer) loses more heat as a result of radiation. And even without air moving the sensation of draught appears in swimming pool hall. The low surface temperatures may get cold. The specified surface temperature is achieved by proper thermal insulation, surface heating or application of thermal coverings.

3.3 High air velocity

Kappler /7/ also claims that the too high air velocity level may increase the amount of heat transferred from human body as a result of convection. Generally heat emissions from human body decrease and the overheat zones appear along with the cold zones. These overheat zones cause the sensation of draught. /7, p. 48/

3.4 Air impurities

In addition to maintaining a constant humidity level, the engineer must think about the air quality. We know that different kind of chemicals are added into water to ensure health and hygiene requirements by neutralization of various organic substances and microorganisms that remain from the swimmers. These chemicals can cause air pollution and various irritations in swimmers. Therefore to support acceptable indoor air quality in swimming pool the air-conditioning system is needed, which ensure assimilations of chemical emissions from water surface in addition to common metabolic human emissions.

4 MOISTURE IN SWIMMING POOL

4.1 Sources of moisture

The excess relative humidity of air in swimming pool may lead to unacceptable conditions, such as moisture, condensation on cool surfaces, mould and etc. The main source of moisture production is the water surface, because of evaporation of water. F. Asdrubali cites in his article /8, p. 311-319/ that water evaporation from free surfaces is a function of many parameters, such as water temperature, surface area of the pool, the indoor air temperature and relative humidity, the amount of air movement over the pool surface. The water evaporation rate can be calculated using equation given in ASHRAE Handbook Application: $E = (0{,}089 + 0{,}40782 \cdot V_a)A_p \cdot \Delta p / Y$; where V_a is the velocity of air parallel to the water surface (m/s) and Y is the latent heat of evaporation of water (kJ/Kg). Also some measurements (Table 5) have been done to investigate process of evaporation. Water and air temperatures, relative humidity, air velocity values were then set.

Table5. Water evaporation measurements: investigated environmental conditions/8, p.314/.

T_w (°C)	20	21	22	23	24	25	26	27	28	29	30
T_a (°C)	22	23	24	25	26	27	28	29	30	31	32
Φ (%)	50	50	50	50	50	50	50	50	50	50	50
	60	60	60	60	60	60	60	60	60	60	60
	70	70	70	70	70	70	70	70	70	70	70
V_a (m/s)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	0.08	0.08	0.08	0.08	008	0.08	0.08	0.08	0.08	0.08	0.08
	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

.

All the measurements have been repeated at least two times and the results show that as expected evaporated mass flow increases and relative humidity decreases during raise of water temperature as it show in figure 1.

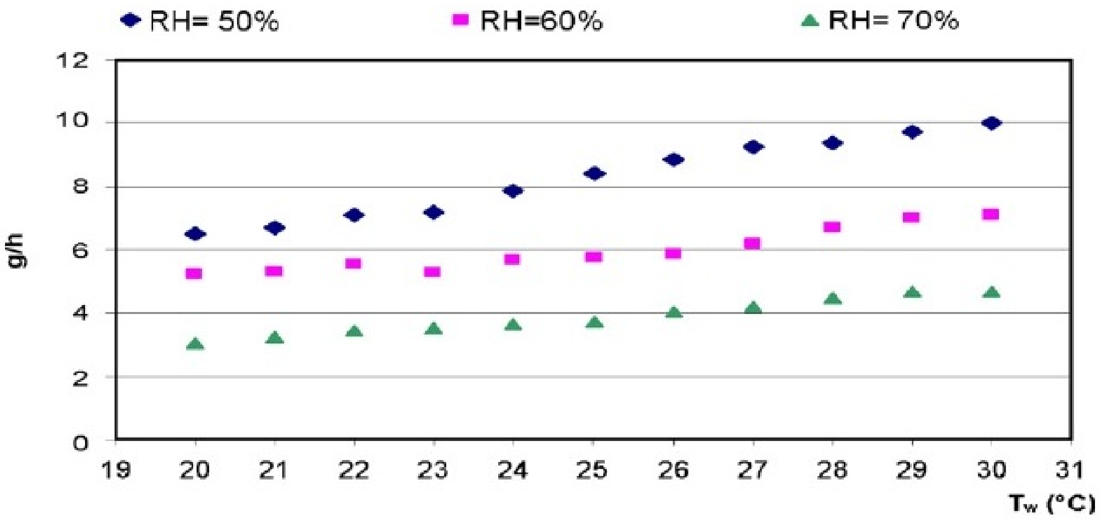


Figure1. Evaporated water from pool surface (g/h), as a function of water temperature, for different values of relative humidity (Va=0,05 m/s) /8, p. 314/.

The higher the internal temperature in comparison with the water temperature, the lower is the evaporation.

/8, p. 311-314/

4.2 Moisture-related problems

The moisture problems are serious issue. They can cause health hazards, problems in the building envelope. According to Olli Seppanen and Jarek Kurnitski /9/ the most common moisture-related problems are:

- during warm seasons infiltration of warm, moist outside air through cracks and holes in the enclosure and as a result condensation on the cold surfaces inside the swimming pool hall;

- during cold seasons exfiltration of warm, moist indoor air through crack and holes and as a result condensation on outside walls and ceiling;

- water leaking into the enclosure, resulting in mould growth, peeling paint, wood decay or corrosion;

- water seeping through porous building materials from moisture source to the material that doesn't tolerate moisture /9, p. 36-37/;

- very high relative humidity is associated with increased growth of microorganisms such as mould and bacteria /9, p. 33/;

- indoor humidity greater than about 50% increases indoor dust mite levels. Low ventilation rates may thus increase the prevalence or intensity of allergic and other symptoms /9, p. 33/

4.3 Measures to control moisture

The following chapter is also based on the article by Olli Seppanen and Jarek Kurnitski /9, p. 58-60/. The effectiveness of a measure to control moisture depends on the air-conditioning system, heating system, building construction and other factors. The effectiveness and cost of measures to control moisture depends on the type of building, is it new or existing. When we talk about moisture control in a new building, we should pay attention on relation between measure of moisture control and construction and operational costs of a building. Most of the good and modern measures are energy-saving. So they reduce the operational costs, but in the same time they elevate the construction costs. Moisture problems appearing in the existing building means bad designed or mounted ventilation or air-conditioning system; insulation of building enclosure lost its talent heat; swimming pool isn’t operated properly.

Measures against moistures damages are given in the Table 6. The first group says that building construction should be designed, constructed and maintenance properly. So there is no any condensation that can cause damage of building envelope. The second group covers ventilation and how it can influence on the moisture level. And the last third group is about heating. Because of temperature affects level of relative humidity, as it was written previously.

Table6. Methods for controlling moisture in new building /9, p. 59-60/.

Method	Effect on construction costs	Effect on energy consumption and cost
Building construction		
Improve thermal properties of windows	increase	Decrease
Design structure to resist the moisture load of local climate	negligible	none or small decrease
Ventilate walls and other building components to prevent condensation	negligible	none or small decrease
Improve thermal insulation of building envelope	increase	Decrease
Design and install material for minimum leakage of plumbing	negligible	None
Ventilation		
Provide adequate, controllable natural ventilation	slight increase	may increase or decrease
Provide possibility for ventilation on demand	slight increase	Decrease
Use mechanical exhaust ventilation in warm and moderate climate	slight increase	decrease due to reduced air leakage
Use mechanical and exhaust ventilation with heat recovery to reduce relative humidity indoors	slight increase	Decrease
Heating		
Use central heating in cold and moderate climates	slight increase	slight increase
Do not use unvented open-flame heaters	none	None
Control temperature with thermostats	slight increase	Decrease
Encourage use of district heating	negligible	decreases use of primary energy
Require chimneys for all heating boilers and furnaces	slight increase	Decrease

5 MECHANICAL VENTILATION SYSTEM FOR SWIMMING POOL

The ventilation of a swimming pool requires special approach because of high extract of moisture and different odors characterized for swimming pools. Indoor swimming pool requires constant ventilation and drying of air unlike other premises without a big water surface.

The big capital costs needed to build swimming pool can be paid off the parameters required for good indoor climate temperature, humidity and air velocity. It is also necessary to remove harmful odors and fumes. For the design of ventilation systems in the swimming pool special attention should be paid to evaporation.

5.1 Simple ventilation systems

The simplest methods to create acceptable indoor climate in the swimming pool is separate supply and exhaust air systems, which work simultaneously (simple mechanical ventilation system). It can be said according to /10/ that by using these systems the needed amount of fresh outdoor air is supply and then exhaust from swimming pool hall to support designed temperature, volume flow and relative humidity level.

These systems for swimming pools are similar to the same air-conditioning system for residential buildings. The main difference is the control method, particularly for swimming pools this method is based not only on temperature control, but on the relative humidity control too. Also more powerful air-conditioning equipment is used in the swimming pool.

The system is appropriate to apply for small swimming pools with water surface 40 m² provided that the moisture content of outdoor air in the warm season is less than the moisture content of indoor air for comfort. In other words, this system is not recommended for use in the warm season in the coastal zone, because it is impossible to provide conditions of comfort even at high air exchange.

System described in this chapter consists of two separate systems as it shows in figure 2. Supply system includes air intake unit (with damper to prevent the leakage of cold air during winter when the fan is turned off); outdoor air filter (to cleaning); supply air fan; heater (to heat outdoor air during cold seasons); control module (to regulate air flow and temperature). Exhaust system is carried out by exhaust fan which is mounted in the special prepare air ducts /10/.

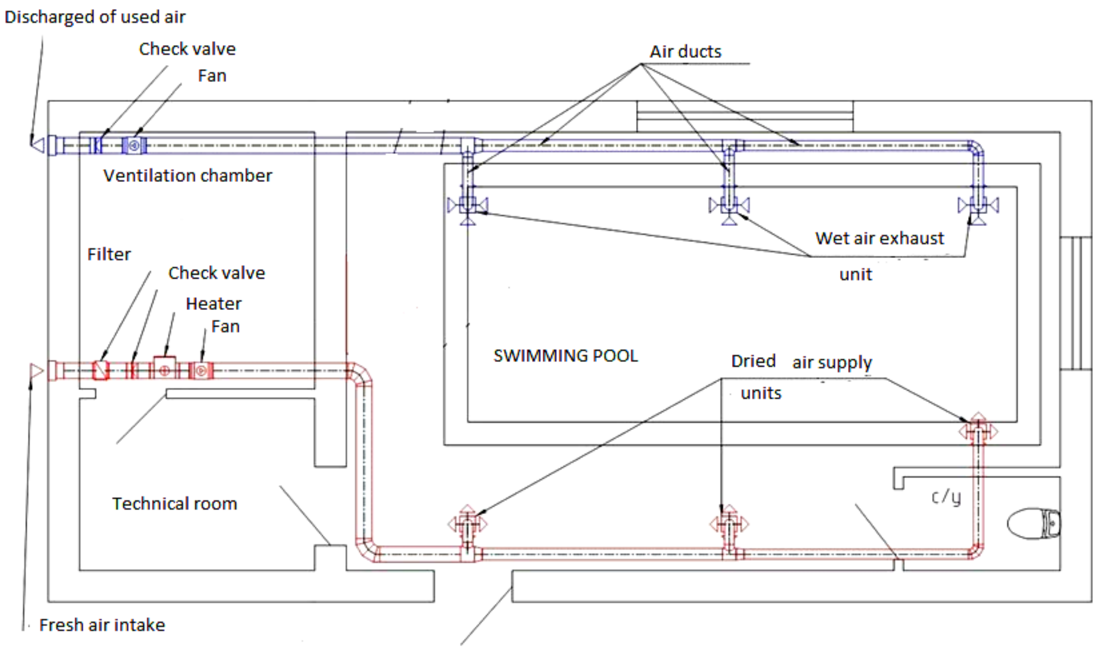


Figure 2. Simple ventilation system /10/.

5.2 Ventilation system with dehumidifier

Another one kind of ventilation system for swimming pool which allows decreased energy consumption is a system using dehumidifiers. Because in this case fans deliver the amount of air strictly required to provide good indoor climate. Norris company site /11/ gives useful information about dehumidifiers and their types. The main characteristic of dehumidifier is its performance. It shows how many gallons of water per unit time can be extracted from the air using device at certain temperature and humidity in the room. Performance is measured in liters per day. Maximum values can be reached by dehumidifiers only at 30 ° C and 80% humidity. Closely related value can be detected only in the swimming pool: air temperature 28-30 ° C, water temperature 25-28 ° C, relative humidity 60-90%.

Ventilation systems with dehumidifier can be different according to the applied dehumidifier. Dehumidifier can be visibly mounted (floor standing or wall mounted) and concealed in the building structures (channel, single-unit or with remote compressor), which are installed in separate premises. Another classification of dehumidifiers is based on the principle of dehumidification process. Two common types are condensation dehumidifier and adsorption one.

In adsorption dehumidifier exhaust of air mass is carried out by adsorbent. This type of device is operated at low temperatures and for “deep” drainage. It effective works at temperature range from -20°C to +30°C and humidity range from 2% to 100%. The big advantage of this dehumidifier is possibility to dry without cooling and to work at zero temperature. The operational principle of adsorption dehumidifier is shown in figure 3.

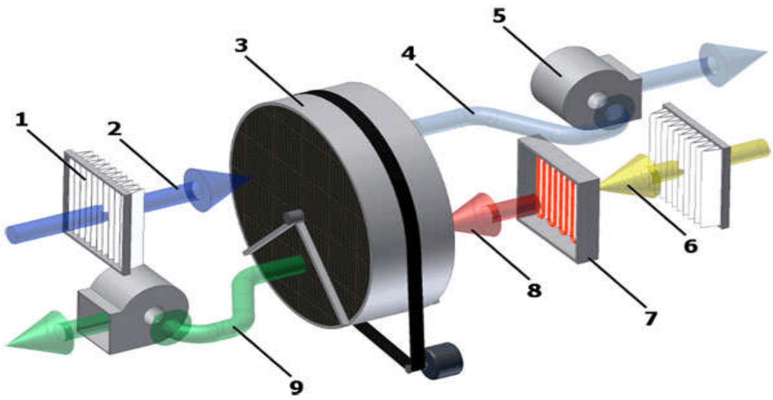


Figure3. Principles of operation of adsorption dehumidifier /11/.
1 – filter; 2 – wet air; 3 - rotor; 4 – dry air; 5 – fan; 6 – regenerative air; 7 - heater; 8 – hot regenerative air; 9 – wet regenerative air.

Air mass is discharged by fan from premises and then it goes into the drying camera, where adsorbent (adsorption rotor) is situated. Here absorbent of moisture is carried out by adsorption material like fiberglass. Construction of rotor allows work by two parallel air flows at the same time. One air flow goes back into the premises and moisture is removed from adsorbent by additional hot air flow (t=100…140°C). To allow non-stop drying of air and regeneration of adsorbent rotor rotates continuously. Adsorption dehumidifiers are well operated for technological drying and in storage areas.

The principle of the condensation dehumidifier (dryer) is quite simple - the wet air passes through the dryer and goes back into the room with low moisture content, as it shows in figure 4. The air goes across a refrigerated coil and rapidly cooled below its dew point. Then the cooled air passes across the condenser where it is heated again and returned to the served area, but already with low relative humidity. Condensate formed during dehumidification process is assigned to the drainage system to drain.

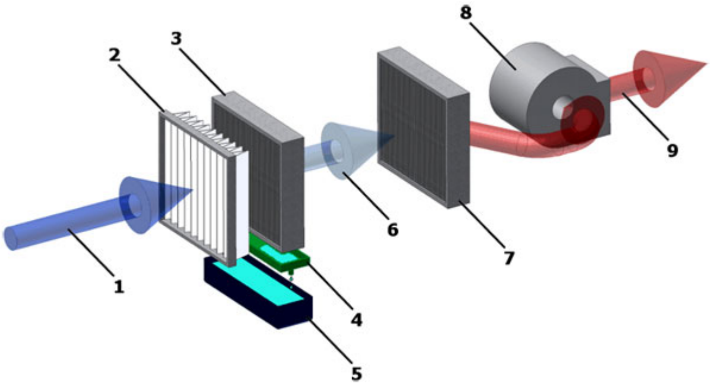


Figure4. Principles of operation of condensation dehumidifier /11/.

1 – wet air; 2 - filter; 3 - evaporator; 4 – tray for drainage; 5 – container for drainage; 6 – dry and cool air; 7 - condenser; 8 - fan; 9 – dry and heated air.

A characteristic of this method is the fact that the energy transitions are carried out within the closed circuit in the serviced area where is an air exchange. The individual component of the heat balance is the energy recovery. There the following processes occur: transition of latent heat in sensible heat during condensation and conversion of mechanical energy of fans and compressors in the sensible heat. As a result, the amount of heat discharged in the condenser exceeds the amount of heat extracted at the evaporator. Because of this, the heating of air takes place in the process drying of the air. The temperature difference at the inlet and outlet of the dryer is in the range 3-5 ° C (as we can show in figure 5).

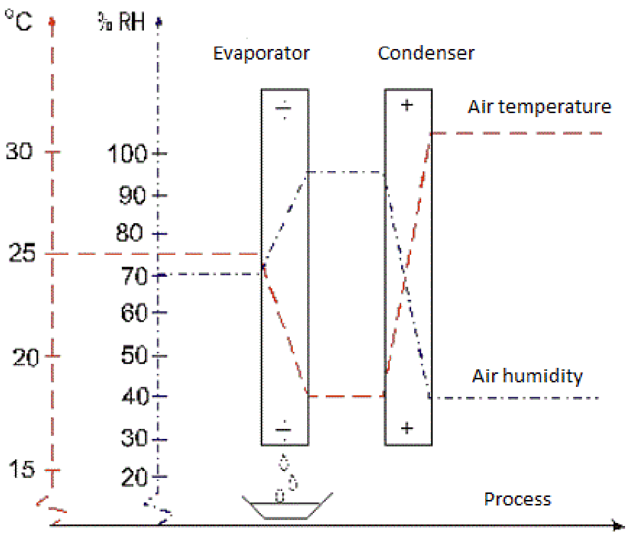


Figure5. Changing of temperature and humidity in condensation dehumidifier /12/.

Performance of this type of dehumidifier largely depends on the initial temperature of processed air. The warmer the air the more water vapour can be contained in this air. When the air temperature decreases the moisture content in the air rapidly decreases too. That can reduce the performance of the equipment. Condensation dehumidifier can be effectively operated in swimming pool and other building where evaporation of water occurs and ineffective operated in building with low temperature. In the discussion below I will talk about condensation dehumidifier.

Dehumidifier, as a separate system, is not able to provide good ventilation for swimming pool by themselves. It doesn't carry out supplying the fresh air and works on 100% as a recirculation unit. Dehumidifier can't prevent the odors in the swimming pool and doesn't supply air to breathe. Supplying of fresh air for breathe is carried out by separate supply-exhaust ventilation system. /11/

5.2.1 Ventilation system with wall-mounted or floor-standing dehumidifiers

This type of dehumidifiers are usually operated in medium-sized swimming pools with water surface from 20 to 40 square meters and its performance from 30 to 110 liters per hour. The main scheme of this type of ventilation system for swimming pool you can see in Figure 6. Using only the wall dehumidifiers to provide a comfortable indoor climate of the pool is absolutely not effective. Wall dehumidifiers help maintain the necessary moisture, but do not provide ventilation in the room. Also, for the complete removal of moisture even in a small pool, usually it's necessary to install more than one unit, and this is not economically effective and takes a lot of space. Wall-mounted dryers are best used in conjunction with the system of supply and exhaust ventilation.

Further I would like to say some words about three of the most common manufactures of wall-mounted and floor-standing dehumidifier: Dantherm, Calorex and Aerial. After familiarizing with their main operational principles I will have the possibility to say which one is the most effective.

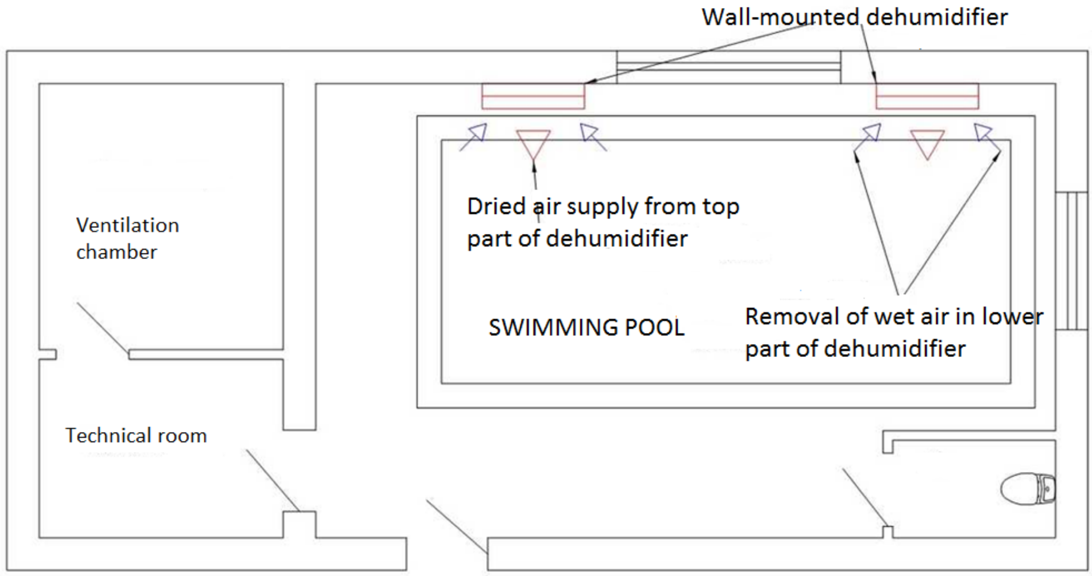


Figure6. Ventilation system with wall-mounted dehumidifier /10/.

CALOREX DEHUMIDIFIERS (Germany)

Information about Calorex dehumidifiers is found on /13, p.2-7/. Wall-mounted dehumidifiers DH 33 and DH 55 and floor standing ones DH 75 and DH 110 are intended for drying of air in middle swimming pools and other building having higher relative humidity. Their characteristic is high performance, low energy consumption and modern appearance. Removing humidity from air Calorex dehumidifiers absorb latent heat and return it to the pool. So its heat pump technology converts 2,5 kW to air heating for every 1 kW of electricity consumed. These dehumidifiers provide effective removal of excess relative humidity from air by cooling to dew-point temperature and further heating.

Dehumidifiers are compact and impervious to corrosion cover, built-in filter cleans the air passing through the device. Self-contained dehumidifier requires minimal installation. Each unit has a specially barrel type discharge that allows air to be directed in an 80°C range between horizontal and vertical, so the installation is allowed at high or low level.

Calorex produces the following type of dehumidifiers:

- the highest moisture extracting wall-mounted dehumidifier for lowest power consumption of its type (its specialties are easy to clean composite cover; zero ozone depletion refrigerant; low operation pressures; long operation time; air outlet adjustable to horizontal or vertical);

- the most quiet dehumidifier available that can be wall-mounted (its specialties are high moisture extraction; corrosion free; super quiet; low operational pressures, flexible mounting; adjustable air outlet);
- floor standing high performance dehumidifiers with additional air heating options (its specialties are high moisture extraction; corrosion free; zero ozone depletion refrigerant; two speed fan; adjustable air outlet).

Condensation can be minimized by using adjustable controlling relative humidity (in the range of 55-65%) and by selecting the most appropriate installation. The possible schemes of installation are showed in figure 7/13, p.2-7/.

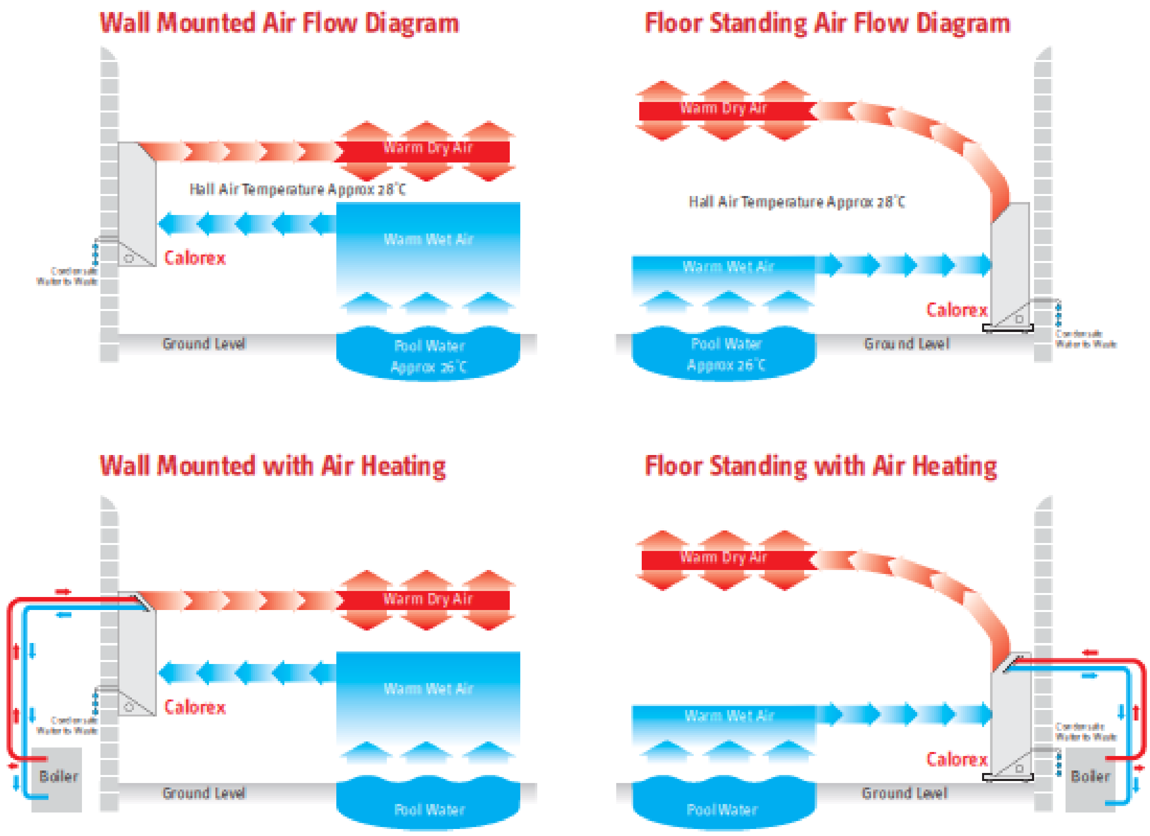
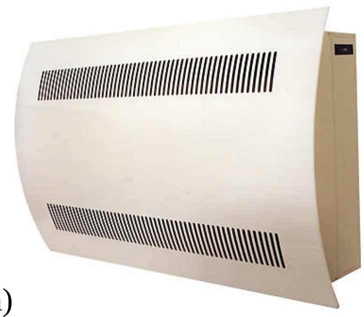


Figure7. Schemes of operational installations of wall-mounted and floor standing Calorex dehumidifiers /13, p.8/.

DANTHERM DEHUMIDIFIERS (Denmark)

Dantherm company produces wall-mounted and floor-standing dehumidifiers. This range of dehumidifiers called CDR. In this chapter the specialties of CDP units have been discussed using the information which are given from guidelines /14, p. 1-6/. If we want to protect small swimming pool (when water surface is below 40 square meters) from excess humidity, we should apply smaller CDP 35/45/65. All units you can see in the figure 8.


a)


b)

Figure8. CDP Dantherm dehumidifiers: a) CDP 35/45/65; b) CDP 35T/45T/65T; /14, p.4/.

All CDP units are flexible for installation and be installed as the swimming pool premises as the adjacent premises (in this case supplying and extracted of air is carried out through aluminum gratings connected with dehumidifier by short air duct in the wall). These schemes you can see in figure 9 /14, p.2-3/.

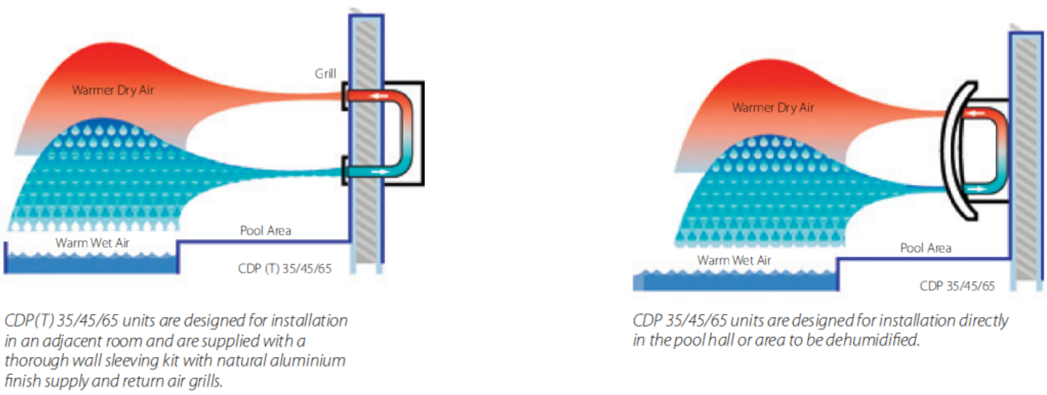


Figure9. Schemes of operational installation of CDP Dantherm dehumidifiers /14, p.2-3/.

CDP dehumidifiers can be equipped with a water-cooled condenser, so we can use excess latent heat for water heating purposes. Units have construction which allows discharge the supply air from the top or from side opposite the air inlet. The working principle of CDP unit is the same which condensation dehumidifiers have. The operation of CDP unit is fully automatically and can be controlled by remote hydrostat.

AERIAL DEHUMIDIFIERS (Germany)

Aerial guidelines /15/ says that Aerial dehumidifier is designed to work in swimming pools, saunas and recreation complexes. Unit can be operated as a wall mounted and as floor standing equipment. Dehumidifier has a modern design. Face cover can be easily removed and provide access to all internal parts. Dehumidifier works according to condensation principle, so temperature after unit is larger than before according to the principle of heating pump. It allows save energy in 2-5 times. In addition, the Aerial dehumidifier has such advantages as filter which mounted in entrance of wet air, plastic cover provides the good protection against corrosion of internal part, integrated energy saving hydrostatic compressor, working process is almost silent. Product range is represented by two types of units: AP 50 and AP 70 with certain performance depending on designed indoor parameters (temperature and relative humidity).

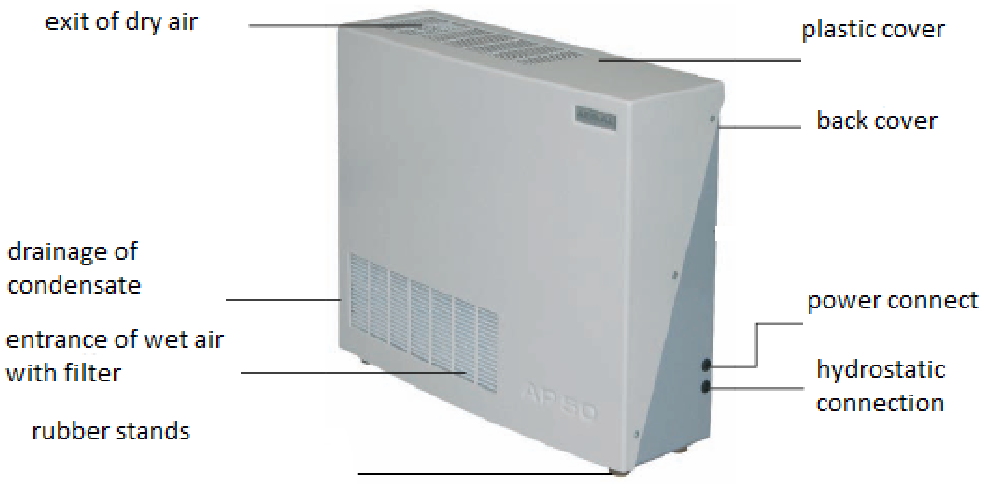


Figure10. AERIAL dehumidifier /15, p.4/.

Comparison between dehumidifiers of different manufactures.

Above we familiarized with three of the most common and famous manufactures of wall-mounted and floor-standing dehumidifiers. In this chapter I'm going to compare their technical specialities, dimensions and other parameters to make a decision: "What's the most effective dehumidifier to operate?" In this case effective means that in the same conditions the operation of that dehumidifier will have less energy consumption and will be more comfortable to use than another ones.

Here is brief information about the main advantages of each manufacture's wall-mounted and floor-standing dehumidifier. The key benefits of a Calorex dehumidifier are flexible design for simple use and installation; energy efficient; low temperature operation; available with air heating option; automatic operation; quality construction; optional features; simple installation; heat recovery to air /13, p.3/. The benefits of Dantherm unit are comfortable installation and maintenance (only annual cleaning of evaporator, condenser and filter), low sound level and ecology safety (R407 refrig.) /14, p.2/. The advantages of Aerial dehumidifiers are simple maintenance, durable and light cover, small size, ecological safe refrigerant R407, sealed compressor /15, p. 4/.

Table7. Comparative analysis of dehumidifiers of diff-t manufactures /13, 14, 15/.

Specifications	Calorex DH 33	Dantherm CDP 35	Aerial AP50
Operating tem-re range (°C)	15-35	10-36	3-35
Dehumidification (l/hr)	1,25	1,21	1,21
Heat recovered to air (kW)	1,9	-	-
Air flow (m^3/h)	440	250	1070
Sound pressure level (dB(A))	48	47	52
Electrical data supply (V/Hz)	230/50	230/50	230/50
Power consumption (kW)	0,75	0,75	0,715
Width (mm)	780	950	802
Depth (mm)	255	315	251
Height (mm)	653	800	678
Weight (kg)	37	60	54
Type of refrigerant	R407	R407	R407c
Cost (euro)	2500	2340	2300

According to the table 7, where we assumed all specifications of different dehumidifiers, we can make some conclusions. We compared three dehumidifiers with average performance 1,21 l/hr. All of them use the same refrigerator R407 and have equal electrical supply values 230/50 V/Hz, their sizes and costs are almost identical. First of all pay attention on dehumidifiers with high performance. As we told previously the main characteristic of dehumidifier is performance (how many gallons of water per unit time can be extract from the air). Calorex dehumidifier has the biggest performance – 1,25 l/h without requiring big air flow rate (only 440 m³/h). But Aerial dehumidifier requires 1070 m³/h of operated air providing only 1,21 l/h dehumidification. In addition, Aerial dehumidifier has other disadvantages: high noise level and rather big weight. Dantherm unit has dehumidification ability of 1,21 l/h having the smallest air flow rate. So according to the table 7
I can say that CAlorex dehumidifier has the biggest amount of advantages, he is the easiest, the most compact, the most silent, has needed operational temperature range and provides the needed dehumidification ability consuming the same amount of energy (as another smaller dehumidifiers). So the Calorex dehumidifier is more economical effective.

5.2.2 Ventilation system with channel dehumidifiers

Channel dehumidifiers are intended usually for swimming pools with medium or large size and in that cases when installation of wall mounted or floor standing dehumidifier is impossible. /10/ Dehumidifiers are mounted in special room, which can be used for water treatment equipment (this room should have the same wall with swimming pool). But models with high pressure fans can be installed far from swimming pool, because the static pressure of fan is up to 250 Pa (it allows to overcome aerodynamic resistance of long air ducts (up to 50m). The dehumidifier is connected with swimming pool by two ducts (one delivers the supply dried air, another delivers exhaust wet air). The channel dehumidifiers also have the possibility to mix supply air with fresh outdoor air. But it is not enough for comfort conditions. The main scheme of ventilation system with channel dehumidifier is intended in figure 11 /10/.

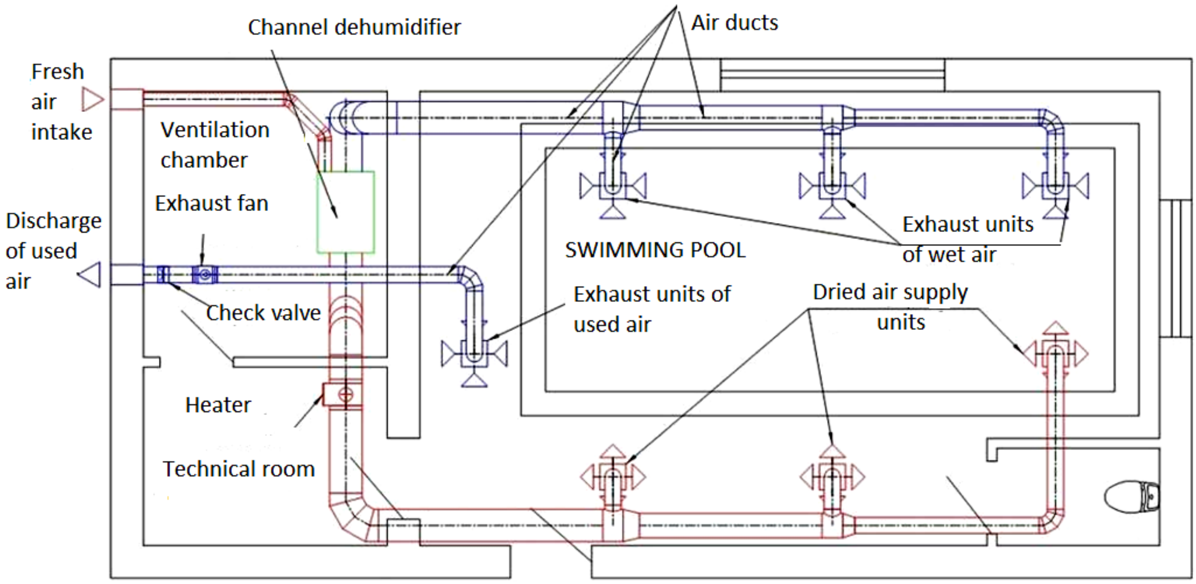


Figure11. Ventilation system with channel dehumidifier /10/.

CALOREX DEHUMIDIFIERS (Germany)

Guidelines Calorex /16, p.1-2/ tells us about the range of channel dehumidifiers (or with another words – induct style dehumidifiers). I'm going to tell about Calorex dehumidifier AA300 VH that presented in figure 12 /16/. This unit is ideal for swimming pools with large or medium size. They have from 0 to 1300 m³/h variable speed fan with two external static pressure settings. These dehumidifiers are designed to connect to the air ducts and provide the maximum air supplying. The units are installed in special technical room (e.g. there are equipments for water treatment and etc.), in an attic or basement. The heat that produced during condensation is used for water heating or air heating depending on the configuration. Each unit has optional control panel kit, which can be mounted up to 20 meters away (where it will be comfortable to maintenance) or directly on the unit. Also everyone has the switch to change operating range of ventilation system working and fresh air introduction point. Changing operating parameters of dehumidifier we can control the parameters of indoor air such as temperature and relative humidity. All duct flanges are flexible.

Figure12. Calorex channel dehumidifier /16, p.1/.

DANTHERM DEHUMIDIFIERS (Denmark)

As the Dantherm guidelines /14, p.5/ say, the range CDP75, 125, 165 of ducted Dantherm dehumidifiers has been specially intended for dehumidification in larger swimming pools (commercial or private) and any other aggressive environment where high capacities are required to control the humidity. Dehumidifier works according to principle of water condensation. The wet air from the water surface passes through a dehumidifier, leaving the supply air drier and several degrees warmer. The compact CDP units are highly flexible regarding installation; each unit has wall-mounting kit. They are designed for installation in plant rooms, with ducted supply and return air. Ducts carrying supply and return air and their grids should be selected so that sum of pressure losses isn’t be more than value specified in equipment passport (e.g. for CDP75 max pressure losses are 170 Pa). Otherwise, dehumidifier may turn off due to tripping of high pressure as a result of too low air flow through the dryer. Exit of wet air is provided on the side of the device, as you can see in figure 13 /14, p.5/. Changing the location of the fan can provide supply of dry air from the side or from the top. The maximum value of fresh air from outside should not be more than values specified in equipment passport (e.g. for CDP75 is 225 m^3/h). Too much amount of fresh air, especially in winter period, can cause the frosting of condenser. The operation of the CDP units is fully automatic and can electronically be controlled via a separated remote hygrostat. Hydrostat, on the evidence of which is controlled ambient air humidity, can be installed in the supply air or indoors. A range of options and versions are available for each model to meet individual requirements.

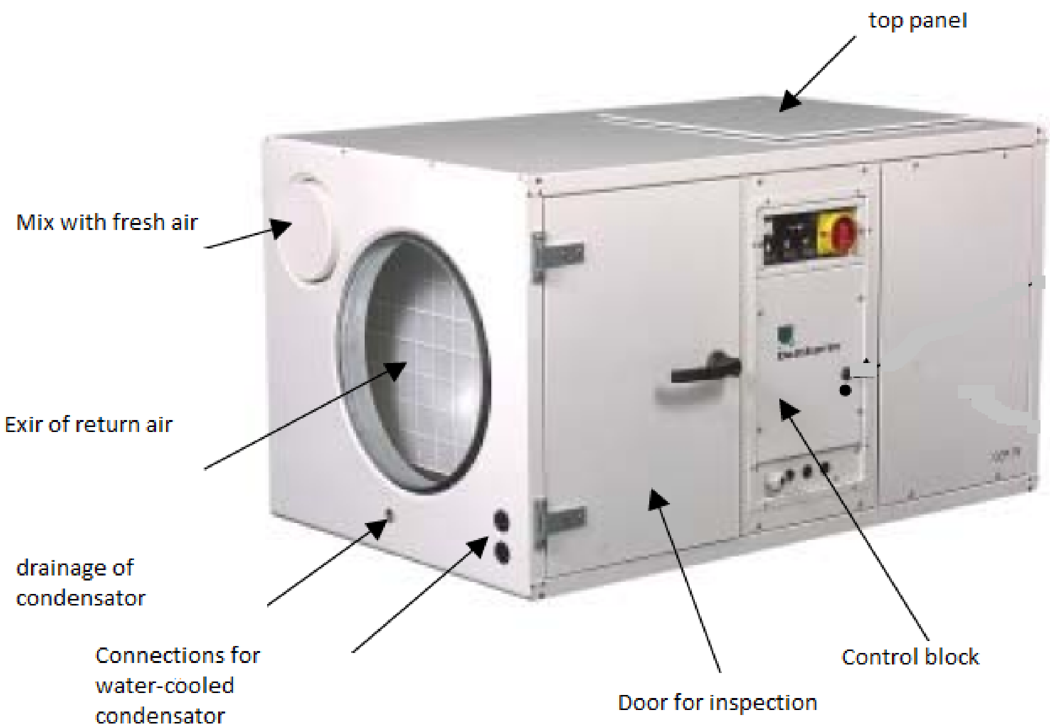


Figure13. Dantherm dehumidifier CDP 75 /14, p.5/.

If the swimming pool has large area of window, it will be better to deliver dried and warm air through pipes under the floor and blown out by the window. In this way condensing can be avoided.

AERIAL DEHUMIDIFIERS (Germany)

The range AP H (100, 120, 160, 200) of Aerial dehumidifiers are intended for swimming pools, as Aerial guidelines says /15, p.5/ and are installed in special technical room. Units are intended to connect to air ducts system and work according to the principle of water condensation. Due to the heat discharged during condensation process air passed through dehumidifier is warmer than before. It allows save energy – heat, which can be used for water heating. And manufactures deliver all necessary connectors required for this.

Plastic cover of dehumidifier is easily removed to allow access to the all internal parts and protect again the corrosion effect. Each unit has hermetic piston compressor, condenser and evaporator maid of copper. The fan of dehumidifier with regulate speed has from 180 to 200 Pa pressure. Work of each dehumidifier can be regulated by control block.

Figure13. Aerial dehumidifier AP H100- AP H120 /15, p.5/.

Comparison between channel dehumidifiers of different manufactures

Now we should compare operational parameters of different manufacture's channel dehumidifiers to say which one is the most effective. For this aim we look at three dehumidifiers which have almost the same dehumidification performance. In or case it is 3,5 l/h. Only Dantherm manufacture doesn't have unit with this value of performance, only 2,7 l/h and the following with 5,17 l/h. So we have to take into account this circumstance.

Below it has been briefly said about the main advantages of each channel dehumidifier. The main benefits of Calorex AA300 VH are: integration with water and air heating system, fan with high pressure, air filters with good efficiency, soundproof panels, stainless steel frame, the ability to change working regimes. Aerial dehumidifier AP H160 has the following advantages: cover is built from several modules, modern view, hermetic compressor, all junctions are easily to connect-disconnect, control block, air filter can be changed without any disconnecting from duct. And finally benefits of Dantherm CDP75 dehumidifier are low energy consumption, close to silent operation, easy to operate and control, room thermostat, wall-mounting kit, failure monitoring kit.

Table8. Comparative analysis of dehumidifiers of diff-t manufactures /14, 15, 16/.

Specifications	Calorex AA300VH	Dantherm CDP 75	Aerial AP H160
Operating tem-re range (°C)	15-36	20-38	10-36
Dehumidification (l/hr)	3,6	2,7	3,52
Heat recovered to air (kW)	9,8	-	-
Air flow (m^3/h)	1300	1500	1400
Sound pressure level (dB(A))	61	58	63
Electrical data supply (V/Hz)	230/50	230/50	400/50
Power consumption (kW)	2	1,85	2
Width (mm)	730	1155	800
Depth (mm)	1025	725	570
Height (mm)	850	650	1750
Weight (kg)	111	130	159
Type of refrigerant	R407	R407	R407
Cost (euro)	7290	5000	6100

Table 8 is constituted on the basis of information about dehumidifiers provided in the manufacture's guidelines. According to this table I can say that all three dehumidifiers have equal operating temperature ranges and equal power consumption. All other parameters are different. During studying the table 8 we should remember that have to take into account Dantherm dehumidifier which has another performance range (not about 3,5-3,6 l/h, but 2,7 l/h).

From all dehumidifiers Aerial unit has the biggest weight, the largest sizes, creates the biggest amount of noise. In addition, this dehumidifier requires a big voltage. Because of this the operation will be expensive because of big size and weight and uncomfortable because of high voltage requirement. Dantherm dehumidifier (even taking into account its performance) requires bigger amount of air than Calorex one and has bigger weight (more than about 20kg). Calorex unit is the most expensive when we talk about capital cost. But after comparative analysis I can say that Calorex dehumidifier is the most effective, because it has the biggest performance and doesn't require big amount of air volume and creates a little amount of noise. So Calorex dehumidifier allows compensate the big capital costs by rather small operative costs.

5.2.3 Ventilation system with heat pumps

In some swimming pool heat pumps are used to dehumidify indoor air and to heating purposes. Compared with the heat exchanger the evaporator of heat pump uses the exhaust air as a cold source, whereas the condenser contributes to the pool water and supply air heating. The operating principle of heat pump is the same as for compression dehumidifier and it’s described by Johansson L. with Westerlund L. /17, p. 285-287/. Air from the swimming pool is passed through the unit and cooled and water vapour is condenser. According to manufactures information about 20% of indoor air is cooled in evaporator. Figure 14 shows the ventilation process when the heat pump is installed.

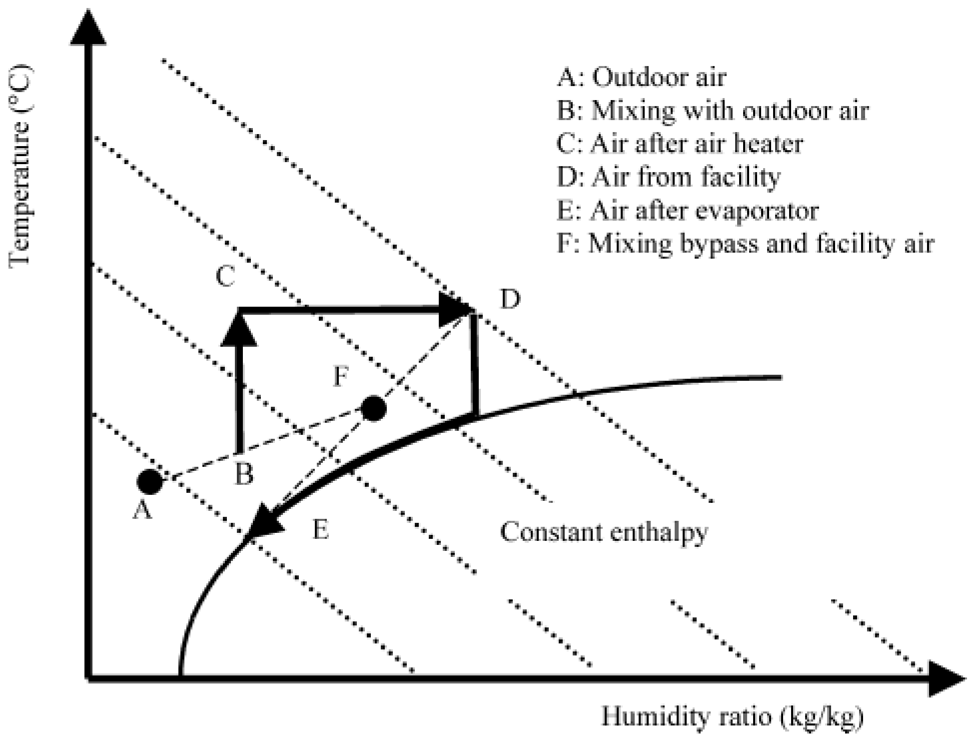


Figure14. Pathways in a Mollier diagram using heat pump /17, p.286/.

Heat pump is always operated at maximum load, because the efficiency of heat pump working decreases at part load. The equipment is automatically shut off when the relative humidity isn’t so high, so the operation of heat pump is not needed.

5.3 VENTILATION SYSTEM WITH HEAT RECOVERY

The next type of mechanical ventilation system is supply-exhaust ventilation with heat-recovery unit, which allows to use the heat energy of exhaust air to preheat the fresh incoming air. To find out the operating principle of heat recovery working we can ask Johansson L. and Westerlund L. /17, p.283-285/ for help. How does it work? Supply and exhaust air flow pass through a heat exchanger, where they exchange their heat without mixing. As a result, the supply air, when coming to the main heater, already has almost optimal temperature. It allows to decrease energy demands. So only small heat-up is carried out in the main heater and it allows to reduce energy consumption (electricity or warm water). The outdoor air flow and other air flow can be regulated with dampers. When the relative humidity in a swimming pool rises we can increase outdoor air flow (by opening damper) and vice versa. On figure 15 we can see the pathways in a Mollier diagram for the heat recovery. Points from A to D are different stages of ventilation process. In stages A we have outdoor air with its parameters and then the temperature and humidity of outdoor air increase in the point B. Vice versa the temperature of exhaust air from swimming pool hall is reduced. So required parameters of operated air are achieved (after the addition heating). The heat needed to the evaporation is taken from water, so the evaporation pathway C-D is almost horizontal.

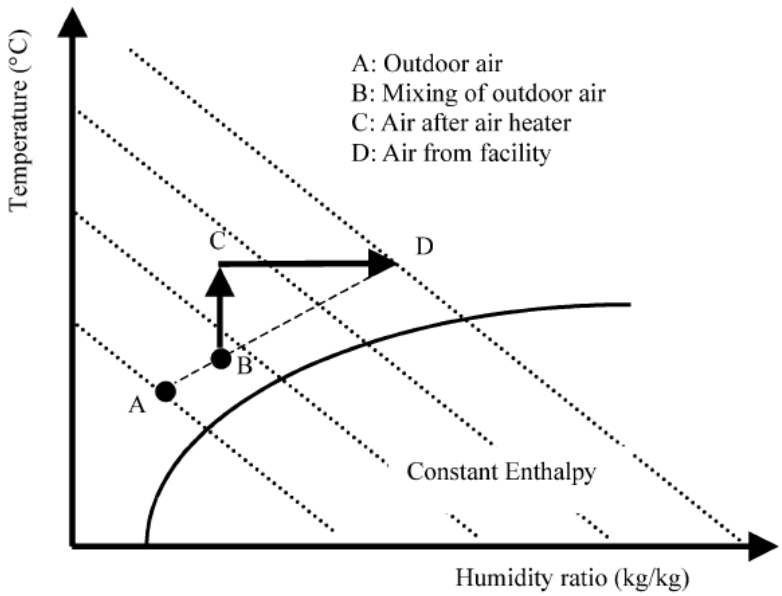


Figure15. Pathways in a Mollier diagram for the heat recovery /17, p.284/.

Supply-exhaust air system (figure 16) in one block with heat recovery consists of the following equipments:

- supply and exhaust fan;
- outdoor air filter (to clean supply air);
- double-damper to prevent the leakage of cold air during winter when the fan is turned off;
- heat recovery unit (to reduce energy consumption);
- heater (water or electricity) (to heat-up of outdoor air), used after heat recovery;
- moisture, temperature, air flow control

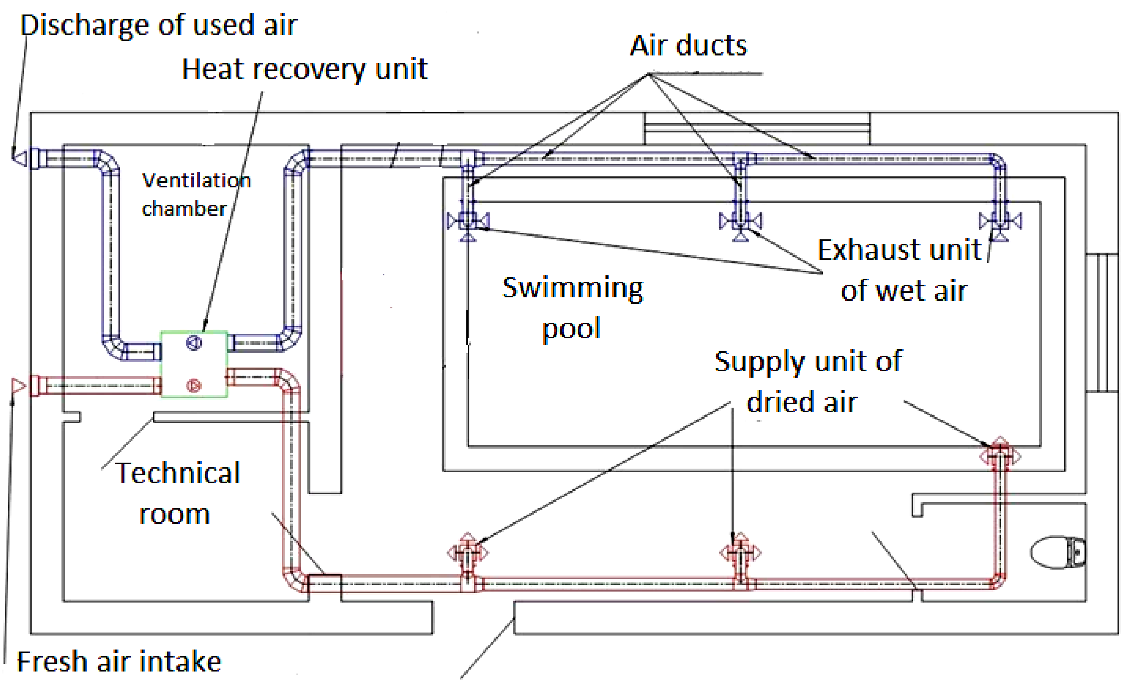


Figure16. Ventilation system with heat recovery /10/

For air conditioning purposes in swimming pool usually the following supply-exhaust system are installed: with plate, liquid-coupled and rotary heat exchanger /18/. Ventilation systems equipped with heat exchanger of different type have the different costs and actual efficiency of their heat exchangers. The biggest actual efficiency belongs to a rotary heat exchanger. It reaches almost 85%. Liquid-coupled exchanger has about 50% of efficiency, plate exchanger – 60%. Significant of each heat exchanger depends on many factors. E.g. depending on the ratio of air flow rates and the parameters of supply and exhaust air ventilation system, significant the actual efficiency varies from 10 to 70%

Ventilation system with rotary heat exchanger has big capital costs (bigger than for systems with plate and liquid-coupled exchangers). The second disadvantage of rotary heat exchanger is the mixing of air flows. So except the transmission of heat from outdoor air to supply air, the transmission of moisture can occur. This can cause the additional load on the air conditioning and dehumidification system. The plate heat exchanger is more acceptable for swimming pool ventilation system, because there is no mixing of air flows in plate exchanger. This avoids the possible transfer of moisture from outdoor air. Therefore use of plate heat exchanger in swimming pool ventilation systems is more effective than use of rotor one.

In the other hand, during cold seasons (when outdoor temperature below zero) operation of ventilation system with plate heat exchanger without additional heating of air becomes almost impossible, because the heat exchanger freezes at - 7°C outdoor temperature. The freezing point of the rotary heat exchanger is much lower (about -27 ° C), and the liquid-coupled heat exchanger almost never freezes, even in conditions of high humidity. Therefore, the liquid-coupled heat exchanger is often used in ventilation systems for swimming pools./18/

6 COMPARISION BETWEEN DIFFERENT TYPES OF VENTILATION SYSTEMS FOR SWIMMING POOL AND DISCUSSION

In this chapter I am going to compare the three main types of mechanical ventilation system for swimming pools and the basic of my comparative analysis is investigation of R.M.Lazzarin and G.A.Longo /19, p.565-570/. Comparison was made with ventilation systems under the same conditions, the systems considered are the following: simple ventilation system, system with dehumidifier (heat pump) and ventilation system with heat recovery unit.

Before comparing we should tell some words about indoor and outdoor operative parameters to analyze the performance of ventilation system. The considered air temperature is about 27-28 °C that warmer than water temperature on 1-2°C. Designed relative humidity is 50% in according to the standards. The outdoor air has the temperature 0°C and humidity ratio of 3 g/kg. The sensible heat is 50 kW, latent heat is 75kW. Ventilation rate is 10 000 m^3/h.

First I would like to tell some words about features of each system (advantages or disadvantages). The simple ventilation system (when supply and exhaust systems are separate) requires a bid amount of energy because the dehumidification process is occurred out due to a big change rate. We need to heat big amount of outdoor air almost during all year. Especially it's rather expensive during cold seasons (from -20°C to +28°C). And if it's raining during the summer the wet warm outdoor air is supplied in the premises. So it further increases the moisture problem in swimming pool. And in this time we discharge warm return air outside that means a great amount of heat losses.

Ventilation system with wall-mounted or floor-standing dehumidifiers has the following disadvantages: an appearance of equipment is not always combined with interior design and considerable noise from the fan and compressor. But the advantage is that dehumidifiers can be mounted after installation of all ventilation system. Thus, if the swimming pool is designed or constructed with deviations from the guidelines and the necessary relative humidity is not supported, this problem can be corrected.

Ventilation system with heat recovery has the several advantages. All equipment that needed to provide good indoor comfort conditions doesn't require a lot of space. The built-in heat recovery allows save 50-70% of heat because supply air is warmed up in heat exchanger by exhaust air (in this conditions the supply and exhaust air flow rate are not mix). This economy allow reduce the power of heater in ventilation plant in 2-2,5 times. Although this type of ventilation system has higher capital cost but the operational costs are rather lower.

Table 9 tells us about thermal power (of the fuel) consumption of the different heating systems considered. And result can be easily appreciated if we take as a reference system the system with heat recovery, for simple ventilation system needs a 40% higher energy supply, and at the same time system with heat pump save 13% of energy. So the ventilation system with heat pump is the most energy saving system and in this time simple ventilation requires the biggest amount of energy.

Table9. Thermal power consumption of the different heating systems /19, p.564/.

System	Simple ventilation	Ventilation with dehumidifier (heat pump)	Ventilation with heat recovery
Power (kW)	239,5	147,4	170,6
Comparison	140%	87%	100%

But these systems are different not only in energy requirement; they have quite different distribution of this energy. Each examined system has such common heat losses as sensible (heat transmission through the building envelope), the sensible and latent (evaporation from the water surface) losses of exhaust air and exhaust losses through chimney. Distribution of energy flow for the simple ventilation system is presented in figure17 /19, p.565/. As we can see, the great amount of losses in this system is exhaust losses.

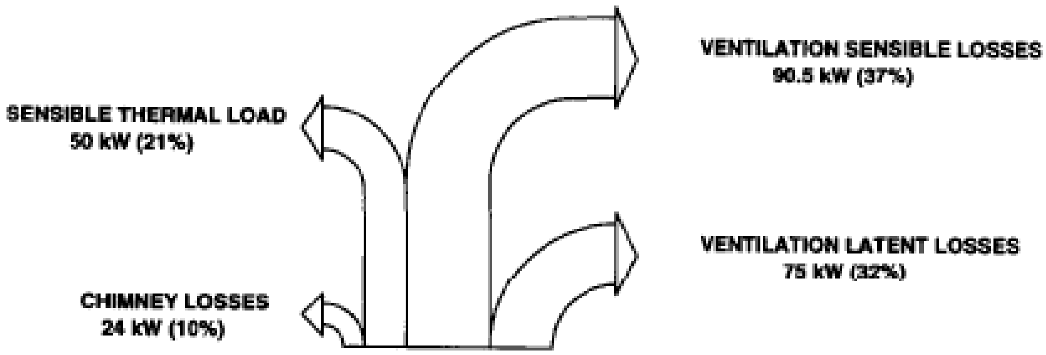


Figure17. Energy flow diagram for the simple ventilation system /19, p.565/.

Diagram for system with heat recovery, which showed in figure 18 /19, p.566/, presents that this system can reduce exhaust losses and hence, the sensible losses from the swimming pool room have more relative importance.

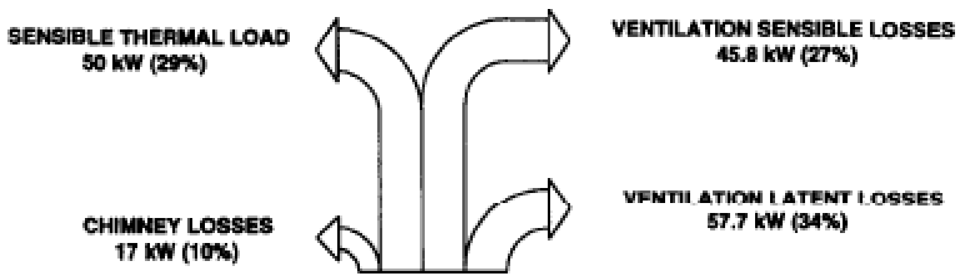


Figure18. Energy flow diagram for the vent. system with heat recovery/19, p.566/

The last one type of ventilation system uses a large amount of the enthalpy in the exhaust air. And energy flow diagram in figure 19 /19, p.567/ shows a percentage increase in the sensible losses of the swimming pool.

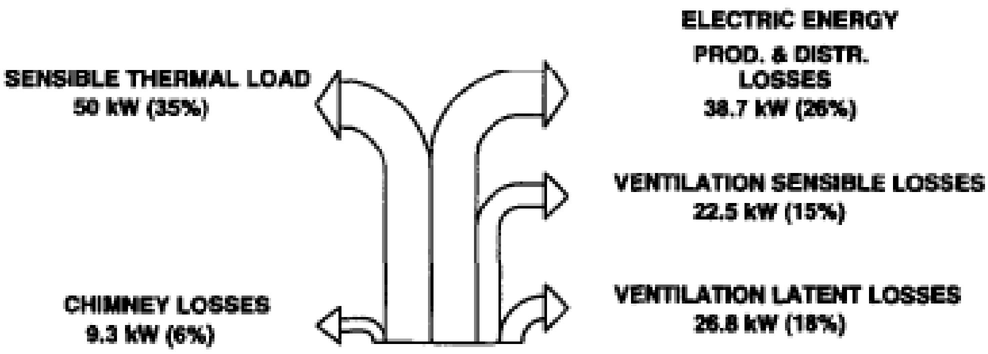


Figure19. Energy flow diagram for the ventilation system with dehumidifier (heat pump) /19, p.567/.

The comparison has been carried out under nominal conditions, but results can be modified for different outside and inside conditions. A higher relative humidity reduces the pool evaporation. “In the example was considered, an increase of the inside relative humidity from 50 to 70% almost allows a halving of the evaporation loads (from 75 to 40 kW). At the same time ventilation rate is reduced from 10 000 m³/h to only 3500”/19, p.568/. Figure 20 shows how thermal power consumption of different ventilation systems depends on the relative humidity of indoor air.

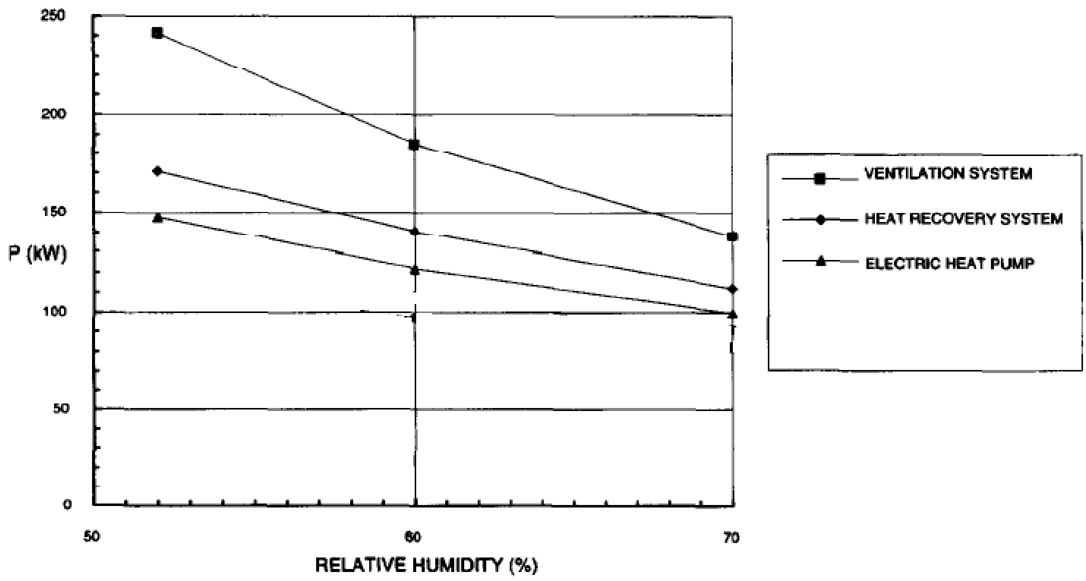


Figure20. Thermal power consumption of ventilation systems as a function of relative humidity in the swimming pool /19, p.568/.

For the simple ventilation system the reduction is quite considerable: from 240 kW on 52% r.h. to 140 kW on 70%, so the reduction is quite considerable. System with heat recovery and system with heat pump have almost equal energy savings – about 50 kW (when system operates at a r.h. of 70% instead of 50%). But at the same time we should appreciate that a modification of the inside conditions can influence the energy needs as much as a more complicated plant.

7 ADDITIONAL GENERAL RECOMMENDATIONS. METHODS OF AIR SUPPLY

According to the recommendations of the 1989 ASHRAE Handbook Applications /3, p.4.8/ the optimal air change rate is from 4 to 6. So wide range of recommended values is due to differences in the intensity of the pool, its attendance and the type of equipment installed. Numerous examples of exploited swimming pools show that the used air distribution scheme is more important than air exchange ratio.

At first glance, it’s easier to take more outdoor air than to design effective systems for air distribution. But this way may cause high operating costs for the owner, because of unnecessary energy consumption.

It’s important that conditioned air is delivered where it’s really needed. The main places where the fresh air should be delivered are places for spectators (if they are in the swimming pool) and surfaces which should be cool. There should be also the limited mobility of air above the water surface.

The main target of air distribution designing is to achieve the effective reduction of relative humidity and acceptable indoor air quality. Simple increasing of volume flow rate through the equipment to reduce the moisture can’t solve the problem of condensation and formation of stagnant zones, which will accumulate a "bad" air. Here are some recommendations given by Lan Xie and Kenneth Cooper /20, p. 16-27/ that enable to ensure the correct air distribution in the swimming pool.

7.1 Water surface

The air flow above water surface should be kept on the minimum level to avoid excess air mobility in the swimming area. In addition, that allows reduce evaporation, which increases with increasing air velocity. In that case the velocity of air shouldn’t be zero. If there is not weak, steady air flow above water surface, various gases evolved from the water will accumulate above the surface. Because of this swimmers may have same problems such as irritation of eyes and breathing problems. Complaints about the uncomfortable conditions in the water may be caused by poor air distribution and the fact that chloramines are not removed from the water surface. Formation of necessary air flow rate above the water surface can be prevented by the location of supply units (too high level above water surface – 4,5-9 meters). The correct placed exhaust units can help to solve this problem. /20, p.16-27/

7.2 Supply and exhaust air unit

Usually ceilings in swimming pools are higher than in offices. The supply diffusers located on the ceiling often can’t carry out fresh air to floor and water surface. To avoid difficult adjustments of air distribution air supplying is carried out on floor level (in this case flow covers the coldest surfaces). This scheme is most frequently applied where heating is required due to the cold climate. But wherever air supply diffusers were located, it is necessary to take care of air grids for the flow direction on the desired surface.

At first glance, the simplest solution is to place exhaust unit at the same level as supply unit. This mistake may lead to the fact that a short-circuiting of air flow takes place when the supply air enters into the exhaust unit. It can occur when supply and exhaust unit have incorrect position and air flow from supply unit is incorrect distributed. Supply air should be discharged below along windows and walls around of perimeter of swimming pool hall. If the supply air is being heated, the supply grills may be close to the ground - otherwise, discharge height should be at least eight feet. And wet exhaust air should be extracted from higher lever on the opposite side. The insufficient size of holes of exhaust unit is often added to the wrong location. As they are noisy and unattractive look, so the designers try to make it less. But as a result, air flow goes through the small holes with higher speed and noisy becomes stronger.

The properly designed size of exhaust units can eliminate this noise and reduce pressure losses in the air ducts. If the designed project is properly calculated, so you have enough places to accommodate the exhaust units with the “right” size.

When we talk about rather big swimming pools it is important that there are big vertical air temperature differences inside building caused by significant heat load. As a result, mass of superheated air are collected under the ceiling, which create a big temperature contrast on the surface of the ceiling during cold seasons. It can lead to additional heat losses and extra mechanical stress bearing structures. To prevent this problem in a high swimming pool we should use AIR injection type, creating a turbulent swirling jet. Jet with a strong injection of the root often have more range and can deliver air vertically down from a height of 20 m. Regulation of air throw is based on the effect of tightening the flow and by turning the guide vanes. Injection diffusers provide a temperature gradient on the height of the building within 0,1 ° C / m (maximum - 0,15 ° C / m). Thus, at an altitude ceiling of the order of 18-20 m overheated air from the ceiling does not exceed 3 °C. /20, p.16-27/

7.3 Air duct

Correct distribution of air straight depends on the quality of installation of air ducts, which should be mounted so that the condensate doesn’t form there. All joints of supply and exhaust air ducts should be properly airproofed, including their connection with supply units, fans and exhaust unit. The special attention should be paid to an under pressure air ducts. When the holes are formed in these ducts, the air is started to swamp there from the unconditioned rooms. As a result the condensation appears and the equipment to reduce moisture level became to work improperly. If the ducts are laid outside the conditioned room, they should be placed in the thermal insulation. The air ducts for swimming pool are made of the material resistant to the corrosion caused by chlorides and the joints between different parts of air ducts should be good airproofed and covered with mastic. /20, p.16-27/

7.4 Places for spectators and changing rooms.

Spectators should also feel comfortable in swimming pool /20/. But to maintain comfort of spectators, environmental conditions should not be so warm. Designers don't have possibility to maintain different temperatures without separation barrier in the area of swimming and the area for the spectators. The special equipment should be installed to create additional air flow in the area for the spectators (when there are lots of people). Special attention should be given to the choice of installation supply air units. For example, you can direct the flow of dry air directly on the spectators, setting the extract grilles behind the sitting places.

Changing rooms should not be connected to the system which provides the dehumidification of swimming pool. For ventilation purposes of changing rooms the individual supply and exhaust systems are required. To prevent the overflow of high humidity and the smell of chloramines from the swimming pool to other areas in the basin is necessary to maintain negative pressure relative to adjoining premises and the outer atmosphere. /20, p.16-27/

8 CONCLUSION

A designer has a difficult task to ensure comfort for swimmers and good operating of swimming pool facilities. This means a huge responsibility because of the high importance of the technical solutions when selecting materials, building construction and design of engineering systems. The decisions influence the capacity, efficiency, safety and resource of building. The parameters of microclimate such as humidity, air mobility in the area serviced and uniform temperature distribution along the height of the building are the most important for designing. Customers and owners of swimming pools should remember that installation of the simple air conditioners is not energy effective, so pay attention to the more expensive and thus more functional specialized equipment. Service systems to ensure optimum air conditions, taking into account the complex and often hostile work environment requires highly professional and thorough compliance with service regulations.

According to the results of my analysis the most effective solution to remove excess moisture, ventilation and dehumidification is a swimming pool supply and exhaust ventilation system with one or two dehumidifiers to reduce the relative humidity to the required level. This usually happens in summer when dehumidifying performance of supply-exhaust ventilation system is not using the pool when the drying capacity of the ventilation system is insufficient. Joint application of ventilation and dehumidifiers can maintain relative humidity at a low level, which excludes the discomfort and condensation on windows, walls and steel structures. This combination allows solve complex optimization problems to achieve minimum energy consumption with additional restrictions as to the design stage and during operation.

BIBLIOGRAPHY

1. ASHRAE Standard 62-2001. Ventilation for acceptable indoor air quality. American society of heating, refrigerating and air-conditioning engineers. 2001.
2. ASHRAE Standard 55-2004. Thermal environmental conditions for human occupancy. American society of heating, refrigerating and air-conditioning engineers. 2004.
3. ASHRAE Handbook. Applications. American society of heating, refrigerating and air-conditioning engineers. 1989.
4. The D2 Regulations and guidelines 2003 “Indoor climate and ventilation of building”
5. Russian designing and building code 31-113-2004. Swimming pools.
6. Howell R.H., Sauer H.J. Environmental control principles. A textbook Supplement to the ASHRAE handbook. American society of heating, refrigerating and air-conditioning engineers. University of Missouri. 1985.
7. Kappler H.P. Private pool. Stroyisdat. Moscow. 1993
8. F. Asdrubali. 2009. A scale model to evaluate water evaporation from indoor swimming pools. Department of industrial engineering. Energy and building. Italy. p-s 311-319.
9. Olli Seppanen and Jasek Kurnitsk. 2009. Moisture control and ventilation. Dampers and Mould. Health care organization. WHO Regional Office for Europe. p-s 31-62.

10. Swimming pool ventilation. http://alterair.com.ua/reshenija/130-ventiljacija-basseina (read 01.11.2010)
11. Kind of dehumidifiers and moisture problems. http://www.norris.ru/nrsn/ng5.html. Read 09.11.2010.
12. Dehumidification methods. http://www.wozduh.ru/index.php?p=faq&faq_id=18&area=1 .Read 09.11.2010
13. Calorex guidelines. Dehumidifiers. For indoor pools and spas. Humidity and condensation control the Calorex way. UK. (can be found http://www.calorex.com/pool-heating/indoor-swimming-pools/documents/Dehumswimmingpoolv.1_001.pdf). P-s 1-8.
14. Dantherm guidelines. CDP. Pool dehumidification for comfort and wellness. Denmark. (can be founded http://www.dantherm-air-handling.com/Documentation/Brochures/Dehumidifiers.aspx).
15. Aerial guidelines. Product catalog. (can be founded http://www.aerial.ru/dehumidifiers/AP-H.shtml).
16. Calorex guidelines. An induct style dehumidifier. (can be founded http://www.calorex.com/pool-heating/indoor-swimming-pools/DH75-110.htm).
17. Johansson L., Westerlund L. Energy savings in indoor swimming-pools; comparison between different heat-recovery systems. Elsevier. Applied energy. 2001. p-s 281-303
18. http://www.tria-komm.ru/airing/country-house.htm Read 12.12.2010.
19. Renato M., Lazzarin and Giovanni A. Longo. Comparison of heat recovery systems in public indoor swimming pools. Pergamon. Applied Thermal Engineering. UK. 1996. p-s 565-570.
20. Lan Xie and Kenneth Cooper. 2006. Natatoriums. The inside story. ASHRAE journal. USA. p-s 16-25.

APPENDIX 1.

Appendix on one page

List of symbols and abbreviations used.

A	Surface of evaporation area	m^2
G	Mass flow rate	Kg/s, g/h
I	Water latent heat of evaporation	kJ/kg
t	time	S
T	temperature	^0C
V	velocity	m/s
Y	Latent heat of evaporation	kJ/kg
W	Specific humidity	Kg of moisture/kg of dry air
r.h.	Relative humidity	%

List of definitions.

Room temperature is the air temperature that prevails in the occupied zone.

Ventilation is the maintaining and providing indoor air quality by changing indoor air.

Air change rate is the outdoor air flow that flows into or from the room during one hour per the volume of air in the room $(m^3/h)/m^3 = 1/h$.

Air-conditioning is the control of the air purity, temperature, humidity and movement of indoor air by processing the supply air or the secondary air.

Exhaust air is the extract air that is discharged from the building.

Mechanical supply air and exhaust air ventilation system is the system in which filtered heated or cooled air is supplied and polluter air extracted from the building by fans.

Occupied premises is a room occupied for long period of time.

Supply air is the air that is introduced into the room.