Air conditioning

MODULE 14

In this module we will be covering the problems related to indoor air quality, problems that become the most urgent to address when designing air conditioning systems, since they are the primary index of environmental **comfort**. The sensation of well-being cannot be standardized, but depends on the individual's perception. To put it simply, everybody produces, through his or her **metabolism**, a certain amount of energy that is different from person to person, and that is exchanged with the environment. As a consequence, everyone's body reacts differently to variations in the environmental conditions by activating a thermoregulation system, whose working mechanism is the same for everyone, but whose exact reaction is different from person to person. When considering these conditions for environmental comfort, we cannot fail to mention the importance of air **purity**, since the concentration of oxygen – which is constantly consumed during breathing – is of vital importance for the human body. At the end of the module, we will be analyzing the instruments used for measuring the parameters that can make an environment comfortable, i.e. moisture and temperature.

PREREQUISITES

- Knowing the functions carried out by some parts of the human body
- Knowing how to carry out simple mathematical equations
- Knowing how to use tables and charts

OBJECTIVES

- Knowing what are the climatic parameters that are index of well-being
- Knowing how energy is produced and dissipated in the human body
- Knowing the methods for assessing well-being conditions
- Being familiar with measuring instruments
- Knowing how to make the most suitable choices in order to ensure comfort conditions

UNIT 24

Thermohygrometric well-being

24.1 Generalities and microclimate

Man lives well in environments in which there is thermal comfort, i.e. where the climatic conditions do not require the intervention of systems aimed at regulating body temperature, i.e. environments in which people neither sweat nor shiver with cold. "Hot" or "cold" microclimatic conditions, along with exposition time, the type of activity (light, moderate, heavy, very heavy) and clothing, can cause exposed people to experience thermal stress by heat or cold and, in extreme situations, even serious health damage. A "hot" microclimate may cause a worker to experience discomfort, leading up to thermal stress (strong rise in body temperature).

"Cold" conditions, in addition to discomfort, may also cause an increase in the so-called cold-related illnesses (common cold, bronchitis, articular pain).

The technological development in the construction field, together with a wide range of design-related issues, have made it essential to settle the matter of air change in order to remove a significant amount of pollutants from living spaces. Human beings spend 70-80% of their time in closed environments.

Both in the working and in the family environment, pollutants can be found in the form of:

- gas pollutants: CO_2, CO, SO_2, NH_3 and others;
- microbes and in particular bacteria;
- smoke;
- particulates;
- humidity.

The presence of these substances depends both on human presence (smoke, cooking, clothing) and also on external factors (degradation of surrounding structures). In addition to that, not all of these substances can be perceived by human sense of smell. Others, such as humidity, although not polluting per se, are to be contained within certain limits in order not to cause neither discomfort nor annoyance. These annoyances may increase in case of a sudden transition from a "hot" to a "cold" environment or vice versa.

The term **microclimate** means

> the set of the environmental parameters which affect the thermal exchanges between the subject and the environment within enclosed spaces, and which determine the so-called **thermal comfort**.

The fundamental quantities that contribute to determining the thermal comfort of the human body are: air temperature, relative humidity, ventilation, radiant heat, energy expenditure, the thermal resistance of clothing.

In fact, the human body tends to maintain its thermal equilibrium, so that its temperature stabilizes at optimal values. In order to achieve this equilibrium it is essential that the hygienic conditions of the environment are suitable. It would suffice to think that the presence of people determines, because of breathing, a decrease in the quantity of oxygen contained in the surrounding air, with the consequent increase of carbon dioxide. This, as well as becoming unbearable when it reaches a concentration of 5-6%, causes loss of consciousness when it reaches a concentration of approximately 10%. Therefore, it is necessary to replace the so-called *foul* air with clean air; an additional reason for doing this is because of perspiration, which causes unpleasant smells.

Checking simultaneously the temperature, humidity, purity and distribution of the air in the environment is the process called **air conditioning**. Depending on the modalities through which this process is implemented, an environment can be said to be *conditioned*, *air-conditioned*, or *ventilated*.

Air conditioning systems are those used in civil environments such as offices, schools, apartments, shops, hospitals, theaters etc., and have the purpose of keeping, both during summer and winter, the thermal-hygrometric conditions that are more appropriate for people's well-being. The plant, in addition to controlling the temperature and specific humidity, must also ensure a proper ambient air movement, filter it, and ensure that is appropriately replaced. Carrying out these operations means interacting with the external environment in the sense that, depending on the thermal characteristics of the outdoor air, those of the indoor air are modified so as to maintain constantly an ideal climate.

Conditioning systems are those intended for industrial environments and their purpose is conditioning temperature, humidity, purity, and distribution of air, so as to facilitate or improve a specific industrial process. The conditions thus obtained, that vary depending on the type of process, are maintained constant throughout the year. This type of process does not interact with the outside, in the sense that the outdoor temperature and humidity conditions do not affect the indoor ones.

Ventilation systems are used in almost all fields of application, and their purpose is introducing systematically, in the unit of time, a certain amount of replacement air, enough to ensure appropriate microclimatic conditions. In this type of process, some thermohygrometric parameters such as air purity are not meant to be controlled. Depending on whether the introduction of the air is carried out though mechanical means or not, ventilation can be categorized as *mechanical* or *natural*.

Regardless of the process to be implemented, however, it is important to ensure that no air can escape unless new air can be entered by means of openings or channels (fan or fanless).

24.2 Metabolism

In designing an air conditioning system, it is necessary to lay down the conditions that make the occupants perceive the environment as comfortable. It is therefore necessary to analyze what constitutes thermal well-being so as to identify and define the parameters that influence it. **Thermal well-being** is not a standardized concept but is linked both to human perceptions – and, consequently, varies from person to person – and to factors of no less importance, such as speed and humidity of the air, the average temperature of the radiating surfaces, the type of physical activity being performed and the thermal insulation characteristics of the clothing being worn.

The human body performs a complex series of transformations through which thermal energy is obtained from the chemical energy contained in food and eventually, through muscular activity, mechanical energy. This series of transformations is called **metabolism**. The increase of thermal energy in the human body causes its temperature to rise until it reaches a balance when the amount of heat produced equals the amount of heat exchanged with the outside environment. This balance is achieved when the internal temperature stabilizes around 36.7 °C. Since there is a relationship between energies, the principle of the conservation of energy applies, for which:

$$E_{\text{input}} = E_{\text{output}}$$

When you make every term explicit, the equation becomes:

$$M = \pm C \pm R + E \pm I + L \tag{24.1}$$

Let us examine each term.

- **M** is the **energy produced by metabolism**, it is always positive and its unit of measurement is the *met*, which is defined as the energy expenditure of a relaxed seated person. The energy relation between met and kcal is:

  $$1 \text{ met} = 50 \text{ kcal (h body-m}^2)^{-1} = 58.2 \text{ W m}^{-2}$$

  In order to calculate the metabolic power as a function of a specific activity see Table 24.1. The basal metabolic rate refers to the minimum heat resulting from the fundamental physiological activity of a lying individual, in a state of complete muscular rest, lightly dressed, and measured 12 hours after meals, in an environment at a temperature of 25 °C in still air conditions. This value is approximately 72 kcal h^{-1}, corresponding to 81 W for a man with a body surface area of 1.8 m^2. The value of the metabolism is subject to variations, to be more precise it increases both because of the ingestion of food and when muscular work is performed, moving from the value of 90 kcal h^{-1} for individuals involved in sedentary or very light work to the value of 600 kcal h^{-1} for individuals engaged in heavy activity.

Table 24.1 • Metabolic power

Type of activity performed	Met	W m^{-2}
Rest		
Sleeping	0,3	41
Lying	0,8	47
Sitting	1,0	58
Standing	1,2	70
Sedentary work		
Home, school, office, etc.	1,2	70
Light standing work		
Shops, malls, labs, etc...	1,6	93
Medium standing work		
Machine tools, salesperson, chores...	2,0	116
Heavy work		
Complex machine tools, auto repair, gym, assembly work	3,0	175

- **± *C*** is the **thermal power exchanged by convection**; it depends on the temperature of the air, its speed, and the type of clothing the individual is wearing. The thermal resistance is measured in *clo*; its relationship with the units of the International System is:

$$1 \text{ clo} = 0.155 \text{ m}^2 \text{ K W}^{-1}$$

Table 24.2 • Thermal resistance of clothing

Clothing	Clo
None	0,0
Short pants	0,1
Tropical outfit: underpants, open-collared shirt or t-shirt, short pants, light socks, sandals	0,3
Light summer outfit: underpants, light pants, open-collared shirt and t-shirt, socks and shoes	0,5
Light work outfit: light underwear, long sleeve cotton work shirt, work pants, wool socks, shoes	0,7
Typical winter indoor outfit: underwear, long sleeve shirt, pants, long sleeve sweater, warm socks, shoes	1,0
Typical European winter work outfit: warm underwear, shirt, outfit consisting of pants, jacket and waistcoat, wool socks, heavy shoes	1,5

The individual's resistance is equal to 0 clo if naked, and the resistance is equal to 1.8 clo if wearing a winter outdoor outfit. The thermal resistance of clothing is shown in Table 24.2. The thermal power is positive if the heat is transferred from the individual to the ambient air, negative otherwise.

- **± *R*** is the **thermal power exchanged by radiation** between the body surface and the surrounding surfaces; it is positive if the average temperature of the surfaces delimiting the environment is less than the surface temperature of the individual, negative otherwise.

- ***E*** is the **amount of heat dissipated by surface evaporation**; it is always positive, therefor it is always transferred to the environment. This dissipative process is related to the fact that the liquid contained in the epidermis, evaporating, subtracts heat from the surface itself. In the human body, evaporation occurs through two mechanisms:
  – *perspiration*;
  – *transpiration*.

The first is defined as a process of evaporation, undetectable to the senses, of water at skin level, i.e. the phenomenon, which is slow but continuous, does not depend either on the senses or on muscular work or on the external temperature, and it is not influenced by the regulation system of the human body, either. Typical examples are having a shiny forehead or damp hands.
The second is one of the primary means of thermoregulation; when the temperature exceeds 36 °C, sweat glands are stimulated and begin to secrete sweat. The evaporation of sweat allows to dissipate a considerable quantity of heat (in the order of 500 kcal kg^{-1}), maintaining a practically constant skin temperature.

- **± *I*** is the **amount of heat due to the temperature variation of the body itself**. If the heat is stored, then the value is positive, if transferred it is negative. One thing to keep in mind is that the variation range of the temperature of the human body is very narrow relatively to the optimal value of 36.7 °C; in fact, small negative (35 °C) or positive (39 °C) variations give rise to a significant reduction of reactive capabilities; further decreases (down to 28 °C) or increases (up to 43 °C) are life-threatening; lastly, values such as 25 °C and 50 °C are deadly.

- ***L*** is the **heat equivalent of the work performed by the individual on the external environment**, it depends on muscle activity and is always positive. This work represents a small percentage of the energy balance of the metabolism, more or less about 10-20%. This means that, if we think of the human as a motor and the work is its efficiency, it is a low-yield machine.

24.3 Thermoregulation of the human body

A person in an environment at 25 °C, in still, non-saturated air conditions, at rest, lightly dressed, has no need for any regulating action in order to balance the heat produced by his or her metabolism and the heat exchanged with the environment; i.e. the person is neither hot, a sensation that occurs with perspiration, nor cold, whose manifestations include shivering or trembling and the so-called *goose bumps*. As soon as the balance conditions change, the human body reacts by trying to adapt to the new conditions and restore the energy balance given by (24.1). The center of the thermoregulation system of the body is in a nervous structure called *hypothalamus*, even thought there are other structures than concur, in different measure, in restoring this balance. If the ambient temperature gets lower or the speed of air increases, the amount of heat transferred from the human body tends to increase. The first thermoregulating action carried out by the body is limiting the increase of thermal dispersion, and this is achieved by restricting the blood vessels of the skin in such a way as to decrease blood flow, lowering the pressure and, consequently, the surface temperature. In doing so, the temperature difference between the skin and the environment is lowered, and the amount of heat dispersed as well. If the temperature gets even lower, even the deeper tissues of the organism can be affected, and the body would tend to cool down since the dispersion would be too intense with respect to the heat produced; in this case, the body reacts by increasing muscular work, which is typically accompanied by a greater heat production (obtained, for example, by tapping your feet or rubbing your hands): you have chills or voluntary muscle movements. At this point, it is necessary to protect yourself by increasing the thermal resistance of your clothing or by modifying artificially the thermal conditions of the environment.

In the opposite situation, i.e. when the temperature of the environment increases, the first thermoregulation reaction of the organism, aimed at reducing thermal dispersion, is again acting on the blood vessels of the skin, expanding them so as to increase the pressure and consequently the surface temperature, in order to restore the necessary condition for the heat exchange. In addition to that, if the temperature of the environment increases further, the second thermoregulating reaction of the organism consists in activating the sweat glands, in order to increase heat loss; in fact, by evaporating from the skin, sweat subtracts evaporation heat from the body. Surface evaporation is easier when the air is in motion, and especially when its relative humidity is low. The ideal condition of sweat evaporation is when the temperature of the skin is greater than the dew temperature of the environment, that is the temperature at which ambient air becomes saturated with water vapor. If, at high temperature, the air is almost motionless, the skin is covered with a thin layer of sweat that cannot evaporate easily; the body can no longer dissipate the heat produced by its metabolism and its temperature increases with life-threatening consequences and effects. In these cases, it is necessary to decrease the resistance of clothing or, as before, artificially change the thermal conditions of the environment.

Summing up, we can say that air conditioning is a technical problem that is more critical in summer than in winter. Not only because providing heat to an environment is easier than subtracting it, but also because the greatest difficulty is maintaining the air humidity conditions at optimal values, and this is easier to do in winter than in summer. In fact, in winter, when the air temperature is increased by any heating body, humidity tends to remain at low values; there is the need, therefore, to introduce in the environment a certain quantity of water vapor in order to restore the humidity levels necessary for well-being; there are easy ways to do it, for example by hanging a crock pot full of water to the radiators. In summer, on the contrary, lowering the temperature by using artificial means automatically increase humidity levels, that is returned to the conditions necessary for well-being by using dehumidifying means, which consist in placing in contact with the air to be treated cold surfaces, which are to be the colder the larger is the amount of water vapor to be removed.

24.4 Criteria for the evaluation of well-being

To analyze the well-being conditions, conditions for which there is no thermoregulation intervention by the organism and under which the person's activity can be carried out with greater ease maximizing its efficiency, it is necessary to consider some parameters related to:

- the type of physical activity performed;
- the thermal insulation characteristics of the clothing being worn;
- the microclimatic parameters of the environment external to the individual, such as air temperature, relative humidity, air velocity, and mean radiant temperature.

There are no scientific criteria for the evaluation of well-being; experimental methods, still in the analysis phase, have been the subject of study, especially by the **ASHRAE**, to define an evaluation index that would allow to connect the objective environmental parameters with a person's subjective ones, and would allow to define their priority from the microclimatic point of view. The experimental study has led to draw some graphics, for example that of Figure 24.1. From the analysis of the graph it can be noted that, given a well-being state with a set of three values of temperature, relative humidity and air speed, the same condition can be obtained with a different combination of values, increasing temperature and speed but reducing humidity.

Given that the sensitivity to thermal parameters varies from person to person, the point is finding the highest percentage of people that, the clothing and type of activity being the same, perceive as comfortable a series of environmental microclimatic conditions.

For example, a statistic analysis found that, as far as the speed v of air is concerned, the majority agrees in finding annoying a speed higher than $v = 2.5$ m s^{-1} in summer and at $v = 0.15$ m s^{-1} in winter.

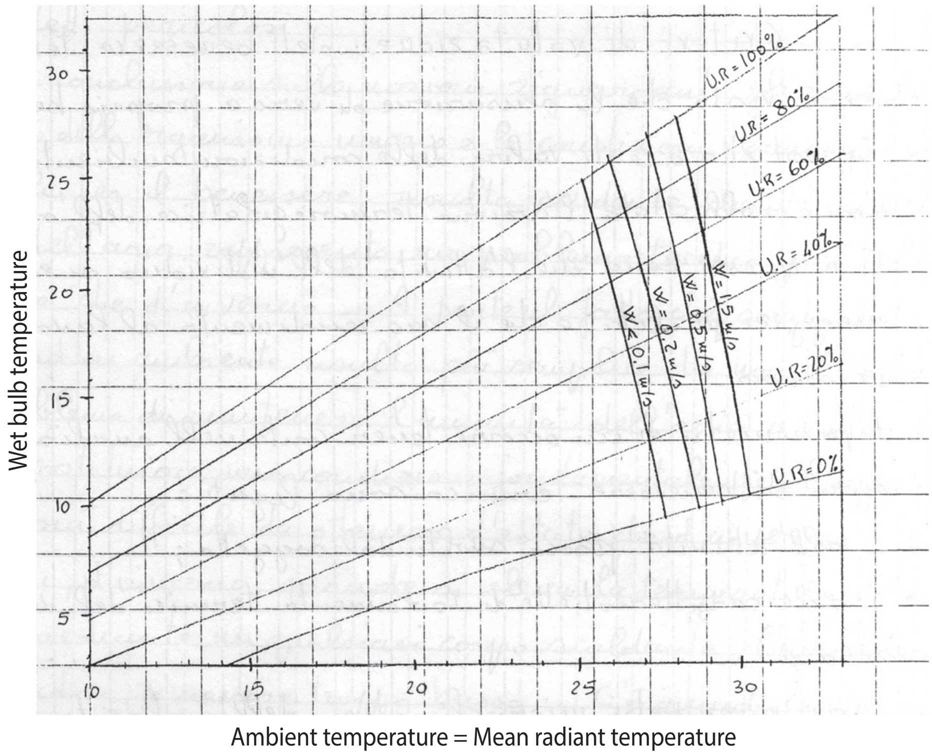


Figure 24.1

On the other hand, especially in the summer, a slight ventilation, with speeds in the order of $v = 0.1 \div 0.15$ m s^{-1}, is appreciated both for the pleasant effect it produces, and because it avoids the creation of zones where hot and humid air stagnates around people. As for humidity, values lower than 30% are to be excluded in any season since they cause excessive evaporation with consequent drying of the mucous membranes of the respiratory system. Values higher than 70% are to be excluded as well since, especially in the winter, they promote the condensation of water vapor on cold walls, and in particular on glass windows, where the dew temperature of air can be quickly reached while, in the summer, they can cause an accentuated perception of smells, with unpleasant effects, especially in crowded spaces.

The values of temperature, therefore, fall within a well defined range reported in a graph, within which we can distinguish two zones of thermal comfort, a summer one and a winter one. The graphs are drawn as a function of the type of activity being performed and the two areas relate to two different types of clothing appropriate to the season analyzed: 1 clo for the winter season and 0.5 clo for the summer. The graphs are valid if the mean radiant temperature does not differ much from the dry bulb temperature. To summarize, we can say that, narrowing the fields, the optimal values are, for winter, between 20 °C and 22 °C and, for summer, between 24 and 26 °C, with a relative humidity around 50%.

24.5 Internal thermal-hygrometric conditions of a project

Determining the **internal conditions of a project**, in the air conditioning field of, is easy as far as the winter mode is concerned, since they are determined under Law 10/91, expanded upon by the current Legislative Decree 192/05, modified in the Legislative Decree 311/06 and confirmed by the current legislation, Law 90/2013, setting as highest permissible temperature 20 °C with a tolerance of ± 2 °C, and as relative humidity values ranging between 50 and 60%.

On then other hand, it is quite difficult to determine the internal conditions of the project in the summer mode, because there is no law regulating these values, and various factors that can influence the choice are involved: the type of room, the activity performed in it, how long people are supposed to stay in the room, and the manufacturing cost of the plant.

More in detail, when choosing the most appropriate temperature it should be kept in mind that the optimal values refer to a situation where people stay in an environment long enough to acclimatize (offices, houses, department stores etc.); obviously, the situation is different when we deal with premises where permanence time is short (bars, tobacconists etc.). In fact, a person that, in winter, moves from a cold external environment to a well heated room has a pleasant feeling even if the temperature jump is between 20 and 30 °C; in summer, if one moves from a hot and damp external environment to a properly cooled room, he or she may feel uncomfortable because of the sudden temperature jump even if it is only 3-4 °C. Keeping in mind that the optimal relative humidity is about 50%, good sense suggests to keep a temperature difference of 7-10 °C for the premises where a long stay is expected and a temperature difference of 3-4 °C for short-stay premises.

The experience also suggests that in the environments in which latent loads are not relevant it is cheaper to have a plant that creates a higher dry-bulb temperature with a lower relative humidity. Inversely, in environments with high latent loads, it is cheaper to have a plant that creates a lower dry-bulb temperature with a higher relative humidity.

24.6 Importance of air renewal

Controlling temperature, humidity, and air speed, however, is not enough to ensure the conditions of environmental comfort. It is also necessary to evaluate the purity of the air in relation to the effects caused by the biological activity of the people staying in a closed environment, which causes variations in the chemical-physical composition of the air.

The minimum air renewal to be introduced into the environment must be based primarily on the respiratory needs of the occupants, which require the replacement of the consumed oxygen and the dilution of the produced carbon dioxide. During breathing, a certain amount of air is inhaled, and then exhaled. The human organism uses the oxygen (O_2) contained in the air breathed in to vitalize the blood, and exhales air which contains a percentage of carbon dioxide (CO_2) greater than that of oxygen.

The exhaled carbon dioxide, whose amount can be estimated mainly as a function of the activities being carried out and of the diet, makes the surrounding air saturated and unbreathable. Moreover, both human body and clothing emit volatile organic substances, perceived as mostly unpleasant smells.

The air containing them is commonly referred to as "foul". At this point, it is necessary to replace it with other air, oxygen-rich and poor in carbon dioxide. In normal conditions, outdoor air contains 0.03% of CO_2; the tolerable concentration of CO_2 in a closed environment can be up to 0.5% and depends on the activity being performed. The diagram of Figure 24.2 connects the air renewal per person, expressed in $l\ s^{-1}$, necessary to get an acceptable level of CO_2 concentration, with the type of activity, expressed in met.

Empirical studies have established that, entering a room occupied by people, the perceived smell is acceptable when the flow rate of air renewal reaches the value of 7.5 l s^{-1} (which corresponds to 27 m^3) per person. All this entails a reduction of CO_2 to the value of 0.1%, in perfect agreement with the recommendations of the World Health Organization. Therefore, it is necessary to include, among the factors to take into consideration when dealing with air conditioning systems, the need to purify air by introducing a certain amount of fresh air that compensates the foul one, that has to be expelled. Among the parameters that affect the optimum value of air renewal there are: crowd density (measured per square meter of floor), the function of the room, the type of activity, the presence of smokers or other sources of contamination. The recommended values are in Table 24.3.

Table 24.3 • Recommended values of air renewal

FUNCTION	MAXIMUM EXPECTED CROWD DENSITY (people/100 m^2)	AIR FLOW (m^3 h^{-1} per person)
Auditoriums	100	29
Bars / cafes	100	54
Restaurants	70	36
Hotel rooms	–	29 (per room)
Offices	7	36
School rooms	50	29
Smoking rooms	70	108
Waiting rooms	100	29
Houses	–	29

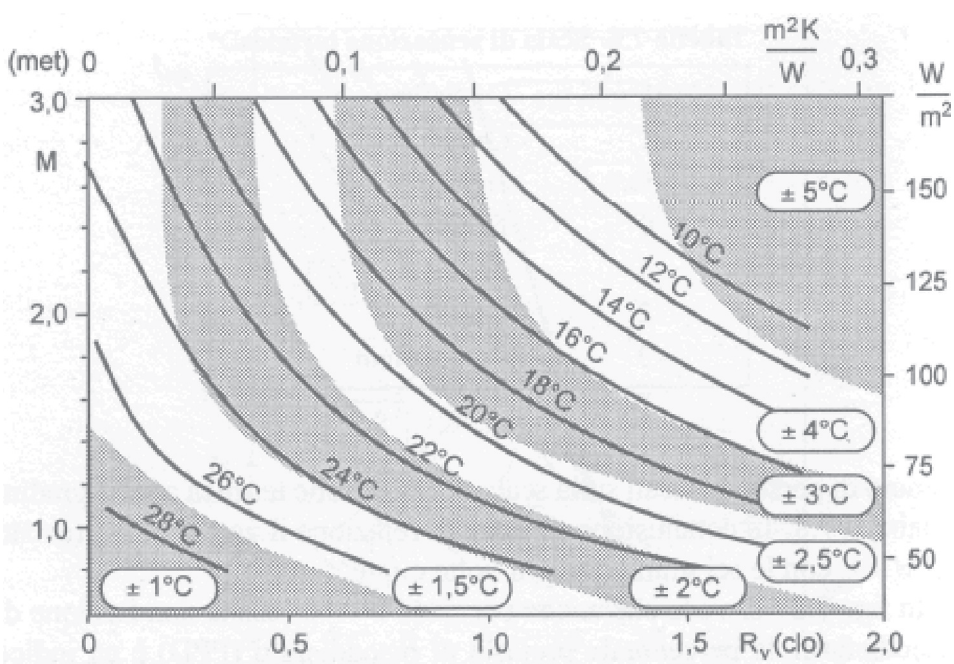


Figure 24.2

24.7 Measuring humidity

One of the simplest instruments to measure the humidity is the **hair tension hygrometer** (Figure 24.3). Invented around 1760 by Horace-Bénédict de Saussure, it consists of a hair degreased with alcohol or ether, with a small weight attached to one end. Its working principle is based on the properties of hair to lengthen and shorten depending on whether the air is dry or damp: by measuring how long the hair gets, it is possible to determine the humidity level.

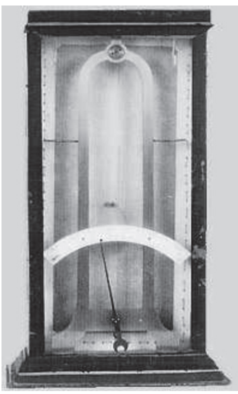


Figure 24.3

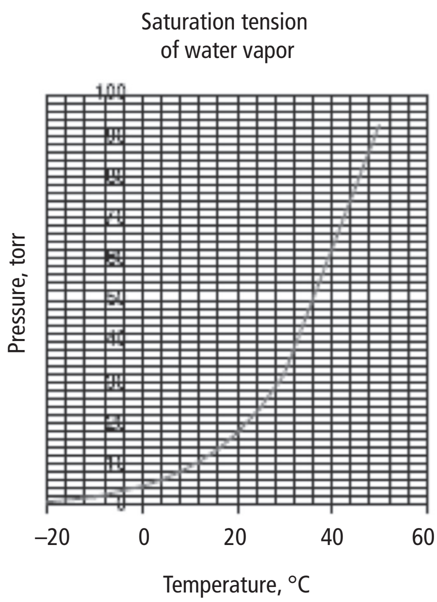
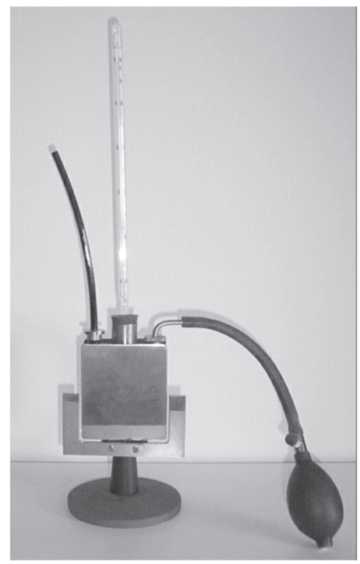


Figure 24.4



x = 10 cm; y = 10 cm; z =32 cm; m = 1020 g

Another type of instrument for measuring humidity is the **Chitoni condensation hygrometer** (Figure 24.4). It is made up by a metal box with mirror walls supported by a thermally insulating substrate. A mirror metal plate partially surrounds the box. On the top there are three holes: one for housing a rubber stopper with a hole which allows the insertion of a thermometer, one for introducing air by means of a suitable rubber pump, and one for expelling ether vapors. In the original instrument there were no thermometer, pump and fitting, which were added later. It works by introducing sulfuric ether in the box, while air is made to bubble through it by means of the pump; the evaporation of ether causes the temperature to lower.

Observing the moment when the mirror surface of the box fogs up (by comparing the surface of the box with the one of the juxtaposed plate) and reading the thermometer we can obtain the **dew point t_r**, i.e. the temperature at which the ambient air is saturated with water vapor. Knowing the ambient temperature t_0, we can read on the Regnault tables both the vapor tension f_0 corresponding to t_0 and the f_r value corresponding to t_r.

The relative humidity UR is obtained by the ratio:

$$UR = f_r/f_0$$

The *psychrometer* (Figure 24.5) is a simple and quite widely used tool for measuring humidity.

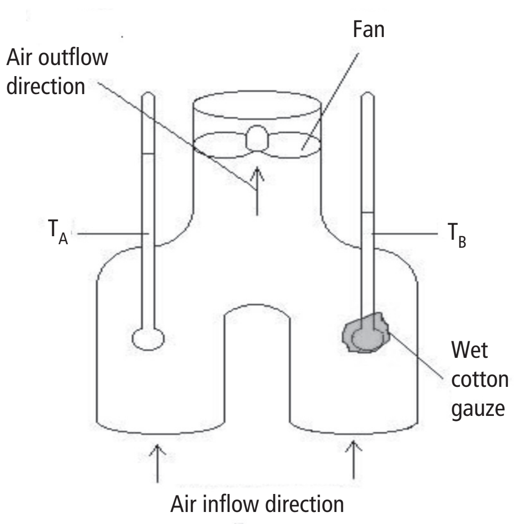


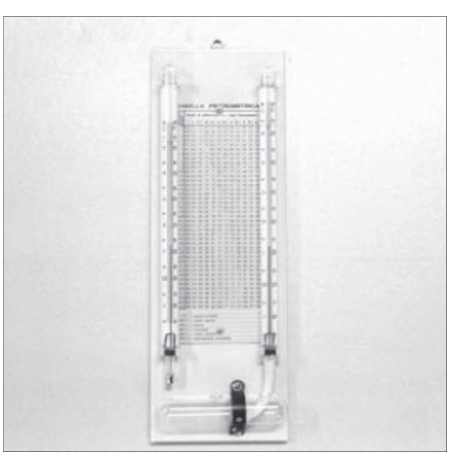
Figure 24.5

It consists of two thermometers: one, called *dry-bulb thermometer*, simply measures the temperature of the air; the other, called *wet-bulb thermometer*, has its bulb wrapped in cotton gauze soaked in distilled water, and therefore measures the temperature of the water in contact with the air, which is lower because of the heat required for evaporation.

In fact, if the environment in which the thermometer is located is not saturated, the water evaporates by absorbing heat from its surroundings, the bulb cools down and the thermometer marks a temperature lower than the room temperature. If the environment, instead, is saturated, there is no evaporation on the wet bulb, and the two thermometers will mark the same temperature.

By reading simultaneously the two thermometers it is also possible to derive the relative humidity and dew point. The psychrometer, however, does not directly provide the required values, which can derived from a psychrometric table (Table 24.4) or from a psychrometric diagram. One of the most widely used is the *Asmann psychrometer* (Figure 24.6 and Figure 24.7).

Figure 24.6



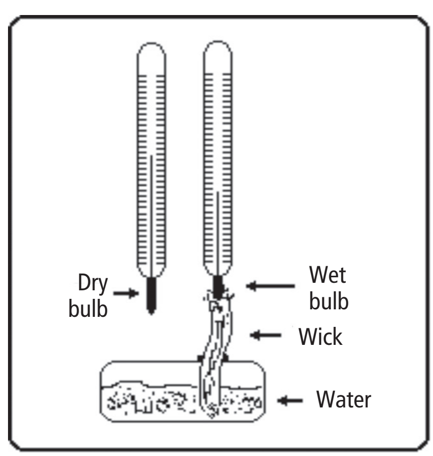


Figure 24.7

Table 24.4 • Psychrometric table

T° of the bulb	Temperature difference between the two wet bulbs										
	1/2	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6
2	90	83	75	67	61	54	47	42	36	31	26	23
3	90	83	76	69	63	56	49	44	39	34	29	26
4	91	84	77	70	64	57	51	46	41	36	32	28
5	91	85	78	71	65	59	54	48	43	39	34	30
6	92	85	78	72	66	61	56	50	45	41	35	33
7	92	86	79	73	67	62	57	52	47	43	39	35
8	92	86	80	74	68	63	58	54	49	45	41	37
9	93	86	81	75	70	65	60	55	51	47	43	39
10	94	87	82	76	71	66	61	57	53	48	45	41
11	94	88	82	77	72	67	62	58	55	50	47	43
12	94	88	82	78	73	68	63	59	56	52	48	44
13	94	89	83	78	73	69	64	61	57	53	50	46
14	94	89	83	79	74	70	66	62	58	54	51	47
15	94	89	84	80	75	71	67	63	59	55	52	49
16	95	90	84	80	75	72	67	64	60	57	53	50
17	95	90	84	81	76	73	68	65	61	58	54	52
18	95	90	85	81	76	74	69	66	62	59	56	53
19	95	91	85	82	77	74	70	66	63	60	57	54
20	95	91	86	82	78	75	71	66	64	61	58	55
21	95	91	86	83	79	75	71	68	65	62	59	56
22	95	91	87	83	79	76	72	69	65	63	60	57
23	96	91	87	83	80	76	72	69	66	63	61	58
24	96	92	88	84	80	77	73	70	67	64	62	59
25	96	92	88	84	81	77	74	70	68	65	63	59
26	96	92	88	84	81	77	74	71	68	65	63	59
27	96	92	88	84	81	77	74	71	68	65	63	59
28	96	92	88	84	81	77	74	71	68	65	63	60
29	96	92	88	84	81	77	74	72	69	66	63	60
30	97	93	89	85	82	78	75	72	69	66	64	60
31	97	93	89	85	82	78	75	72	69	66	64	61
32	97	93	89	85	82	78	75	72	70	67	64	61
33	97	93	89	85	82	78	75	72	70	67	64	62
34	97	93	89	85	82	78	75	72	70	67	65	62
35	97	93	89	85	82	78	75	72	70	67	65	62
36	98	94	90	86	83	79	76	73	71	68	65	63
37	98	94	90	86	83	79	76	73	71	68	66	63
38	98	94	90	86	83	79	76	73	71	68	66	63
39	98	94	90	87	83	80	77	74	72	69	67	64
40	98	95	90	87	83	80	77	74	72	69	67	64