HEALTH MINISTRY OF THE REPUBLIC OF MOLDOVA
NICOLAE TESTEMITANU
STATE UNIVERSITY OF MEDICINE AND PHAMACY

GENERAL HYGIENE DEPARTAMENT

Aliona TIHON

AIR HYGIENE

CHISINAU
2017

HEALTH MINISTRY OF THE REPUBLIC OF MOLDOVA
NICOLAE TESTEMITANU
STATE UNIVERSITY OF MEDICINE AND PHAMACY

GENERAL HYGIENE DEPARTAMENT

Aliona TIHON

AIR HYGIENE

CHISINAU
CEP *Medicina*
2017

CZU 614.71(076.5)
T 59

The paper was discussed and approved at the Meeting of Central Methodic Consilium of the State University of Medicine and Pharmacy "Nicolae Testemitanu", no 1 from 6.X.2016

This recommendation was elaborated at the
Department in General Hygiene

There guidelines are intended for practical laboratory works on general hygiene. The guidelines were compiled by ***Aliona Tihon, associate professor***.

Recenzenți:

Ion Bahnarel – Dr. hab. med. university professor Department in General Hygiene State University of Medicine and Pharmacy "Nicolae Testemițanu", Republic of Moldova

Sergiu Ceban – Dr. in med. associate professor Department in Hygiene State University of Medicine and Pharmacy "Nicolae Testemițanu", Republic of Moldova

The guidelines for practical classes correspond to the syllabus of the student curricula of faculties of Medicine, Pharmacy and Dentistry.

DESCRIEREA CIP A CAMERELI NAȚIONALE A CĂRȚII
Tihon, Aliona.
Air hygiene / Aliona Tihon; "Nicolae Testemiţanu" State Univ. of Medicine and Phamacy, Gen. Hygiene Dep. – Chişinău: CEP *Medicina*, 2017. – 90 p.
Referinţe bibliogr.: p. 88. – 100 ex.
ISBN 978-9975-82-043-1.
614.71(076.5)
T 59

ISBN 978-9975-82-043-1

ABBREVIATIONS

CCA – Constsnt Current Anemometer
CTA – Constant Temperature Anemometer
CVA – Constant Votage Anemometer
EET – Equivalent Effective Temperature
ET – Effective Temperature
LDA – laser Doppler Anemometer
PWM – Pulse Width Modulation
RTDs – resistence tempeeature detectors
RT – resultant temperature
RH – relative humidity

Units of measure

°C – celsius degree
ft – feet
km – kilometer
mi – miles
°R – Reaumur degree
°F – Fahrenheit degree

AIR

Atmospheric air

The atmosphere of Earth is the layer of gases, commonly known as air that surrounds the planet Earth and is retained by Earth gravity. The atmosphere protects life on Earth by absorbing ultraviolet solar radiation, warming the surface through heat retention (greenhouse effect), and reducing temperature extremes between day and night (the diurnal temperature variations). By volume, dry air contains 78.09% of nitrogen, 20.95% of oxygen, 0.93% of argon, 0.039% of carbon dioxide, and small amounts of other gases. Air also contains a variable amount of water vapor, on average around 1% at sea level, and 0.4% over the entire atmosphere. Air content and atmospheric pressure vary at different layers, and air suitable for use in photosynthesis by terrestrial plants and breathing of terrestrial animals is found only in ytheEarth's troposphere and in artificial atmospheres. The atmosphere has a mass of about 5.15×1018 kg, three quarters of which is within about 11 km (6.8 mi; 36,000 ft) of the surface. The atmosphere becomes thinner and thinner with increasing altitude, with no definite boundary between the atmosphere and outer space. The Kármán line, at 100 km (62 mi), or 1.57% of Earth's radius, is often used as the border between the atmosphere and outer space. Atmospheric effects become noticeable during atmospheric reentry of spacecraft at an altitude of around 120 km (75 mi). Several layers can be distinguished in the atmosphere, based on characteristics such as temperature and composition.

Principal layers

In general, air pressure and density decrease with altitude in the atmosphere. However, temperature has a more complicated profile with altitude, and may remain relatively constant or even increase with altitude in some regions (see the temperature section,below). Because the general pattern of the temperature/altitude profile is constant and measurable by means of instrumented balloon soundings, the temperature behavior provides a useful metric to distinguish atmospheric layers.

In this way, Earth atmosphere can be divided (it is called atmospheric stratification) into five main layers. Excluding the exosphere, Earth has four primary layers, which are the troposphere, stratosphere, mesosphere, and thermosphere. From the highest to the lowest, the five main layers are:

- Exosphere: 700 to 10,000 km (440 to 6,200 miles)
- Thermosphere: 80 to 700 km (50 to 440 miles)
- Mesosphere: 50 to 80 km (31 to 50 miles)
- Stratosphere: 12 to 50 km (7 to 31 miles)
- Troposphere: 0 to 18 km (0 to 7 miles)

The Earth's atmosphere layers are similar to the layers in the interior of the Earth. There are four major layers of atmosphere above the Earth that are separated by temperature. Each of these layers is separated by an increasing or decreasing temperature of the gases in the layer. The tropopause, stratopause, mesopause are the areas where two atmosphere layers gradually pass from one layer into another.

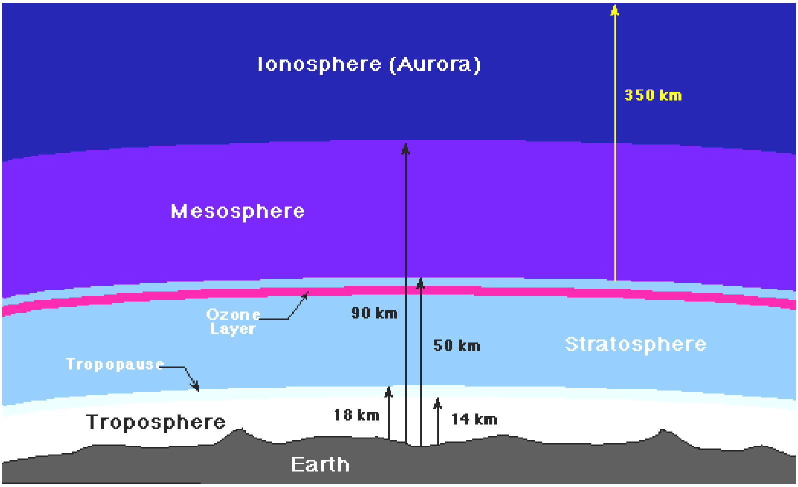


Fig. 1. Principal layers.

Atmosphere gases

The concentration of atmosphere gases varies depending on the atmosphere layers. The troposphere contains primarily nitrogen (78%) and oxygen (21%). The remaining 1% of the atmosphere is trace gases. The stratosphere contains a layer of relatively high concentrations of ozone. The lower part of the thermosphere is the ionosphere. This layer has free ions and electrons that are the result of ionization of gas molecules. As the distance increases from Earth the atmosphere becomes thinner as the molecules move further and further apart.

Troposphere

The lower boundary is the surface of the Earth. The upper boundary varies between 7 km (23,000 ft.) above the poles and 14 km (56.000 ft.) above the equator. This is the layer of the atmosphere where we live. The troposphere contains 75% of the total mass of the atmosphere. The air cools 6.5°C for each kilometer above sea level. Most of the energy from the sun travels through the atmosphere and is absorbed by the ground. The ground heats up warming the air above creating air currents. The rising of warm air and falling of cooler air creates convection currents that cause air circulation in this layer of the atmosphere.

Stratosphere

The lower boundary is the tropopause which separates the stratosphere from the troposphere. The upper boundary of the stratosphere is 50 km (32 miles; 170,000 feet). The bottom layer of the stratosphere remains constantly at approximately 60°C. Jet streams are formed here as cold air from the poles meets the warmer air rising from the equator. It is a strong eastward moving wind that blows horizontally around the Earth. The stratosphere contains the ozone layer. Ozone is created when radiation from the sun splits two-atom oxygen molecules into separate atoms. They combine with other two-atom molecules to form a three-atom molecule. The layer acts as a shield from ultraviolet radiation from the sun. The upper part of the stratosphere warms up to approximately 18°C as the ozone reacts with ultraviolet radiation giving off enough heat to warm this layer.

Mesosphere

The mesosphere is the third layer of the atmosphere. It extends from the top of the stratopause to an altitude between 80 and 85 km. The temperature begins to drop in this layer until it reaches minus 90°C. The upper region of the mesosphere is the coldest region of the Earths atmosphere layers. Water vapor is sometimes present in this layer and it can be seen from Earth as thin feathery clouds of ice crystals. Many meteors entering the atmosphere burn up in this layer. The heat causes enough friction between a meteoroid and gas particles in the mesosphere to burn them up. Shooting stars are the trail of hot glowing gases as a meteoroid burns.

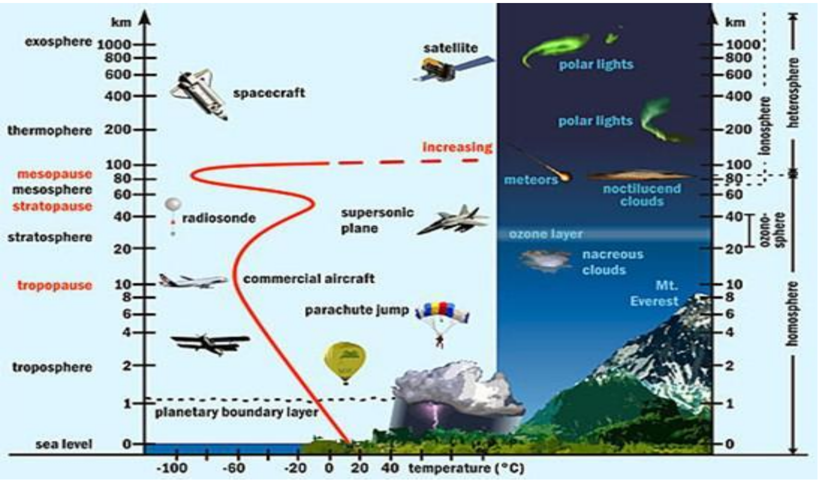


Fig. 2. Principal layers.

Thermosphere (Ionosphere and exosphere)

Location of layer above Earth: 640 kilometers (400 miles; 2.100.000 feet).The thermosphere has two layers of Earths atmosphere layers. The atmosphere is very thin in the thermosphere. The space shuttles orbit in the thermosphere. The layer has free ions and electrons that are the result of ionization of gas particles. Radio waves bounce off the ionosphere allowing communication with countries overseas. The aurora borealis, (northern lights) is formed when electrically charged particles from the sun collide with particles in the ionosphere producing multicolored lights. The temperature in this region can reach 1500°C (2.730 degrees F). The air particles are so far apart that a person would not feel warmth because of the low density of the particles. The exosphere is the highest layer of the atmosphere. It extends up to 10.000 km (6.200 miles; 33.000.000 feet.) above the Earth. Satellites orbit the Earth in the exosphere. The atmosphere in this layer is extremely thin and atoms and molecules of air are constantly escaping into the outer space. Free-moving particles move in and out of the solar wind in the exosphere.

METHODS OF DETERMINING TEMPERATURE AND HUMIDITY. THEIR HYGIENIC ASSESSMENT

Learning objectives:

1. To substantiate the hygienic significance of microclimate for different premises (residential, public/social, industrial) and to master the measurement and hygienic assessment of its following parameters: air temperature, radiant temperature, relative humidity, air velocity.
2. To master, enhance and systematize the students' knowledge about the hygienic significance of the atmospheric and indoor air movement direction and speed as the microclimate factor in residential, public and industrial premises.
3. To master the methods of determination and hygienic assessment of the air movement direction and speed.

You should know:

1. Definition of «microclimate» and factors, which influence its formation.
2. Physiological basics of human heat exchange and thermoregulation, their dependence on the microclimate: physiological reactions in the comfortable or uncomfortable (hot or cold) microclimate.
3. Hygienic significance of the atmospheric and indoor air, its role in the microclimate formation and mechanisms of the organism heat exchange.
4. Methods and devices for determination of the air movement direction and speed outdoors and indoors.

You should have the following skills:

1. To measure the indoor air temperature, radiant temperature, air humidity and to assess the temperature and humidity conditions of different premises (residential, public/social, industrial).
2. To determine the air movement direction and speed, wind strength.
3. To draw hygienic conclusions and to assess the results of outdoor and indoor air movement direction and speed.

Measurement of physical propertes of air

Air environments refer, in addition to ambient air, to the industrial, occupational air (indoor and outdoor), non-industrial occupational indoor air (household, study halls, shops, theatres, and medical facilities) and the air inside the means of transport (cars, trains, planes).

The microclimate refers to all the physical factors of air (temperature, humidyti, air currents heat radiation) which influence the heat exchange between the body and the environment. Such physical properties as atmospheric pressure, radiation and air electricity are microclimate factors but they to not determine microclimate factors, they do not have a direct influence on the human thermal sensations.

It is considered that the most favorable microclimate in the household is the one which requires a minimum activity of the thermoregulatory apparatus, both in healthy and sick persons. Small oscillations of the microclimate, within physiological limits have a positive effect by stimulating the thermoregulatory capacity. Ample oscillations have adverse effects.

Air Temperature

Air temperature affects the growth and reproduction of plants and animals, with warmer temperatures promoting biological growth. Air temperature also affects nearly all other weather parameters. For instance, air temperature affects:

- the rate of evaporation
- relative humidity
- wind speed and direction
- precipitation patterns and types, such as whether it will rain, snow, or sleet.

Medical importance

- It has themolytic influence.
- It has unfavorable effects when it drops below some limits, which are considered to be physiological, or when it exceeds some superior limits.
- It influences air pollution.
- It influences the other physical air factors (humidity, air currents, pressure).

Effects of Low Temperature on the Human Body

The local action is manifested by:

- Angioneurosis, that appears in the extremities of the body. If the local action of hypothermia is of short term, then the circulatory disturbance can be recovered by massage and gradual rewarming.
- Paralysis and partial paralysis (paresis) that occur mostly at the level of the facial nerve.
- Inflammation of nerves (neurosis), neuralgia (of trigeminal nerves).

The general action has two phases, in which the symptomatology evolves from unpleasant cold to low psychic activity and mental confusion.

The evolution dependes on the clinical from of hypothermia:

- In mild froms: total recovery.
- In severe torms: partial recovery with some permanent damage (chronically nephritis, peripheral neurosis and lesions of the mycocardium).
- In very severs forms: lethal, caused cardiac or respiratory stop.

The prognostics of disorders due to low temperature exposure depends on the following factors:

- The body temperature level: the lower the central body temperature is, the more reserved the prognostic is.
- The period of exposure to hypothemia: the exposure to a less low temperature for a longer period is more damaging than a short time exposure to a very low temperature.
- The anatomic and functional integrity of the cardiovascular and respiratory systems.

The treatment consists in a quick heating, through immersion in warm water of 34-35°C, gradually heating the water to 40-43°C, for 10 minutes; massage with a dry towel; administration of vitamin C, solutions containing glucose; oxygen therapy; resting in bed, because in some hours or days patients may have a hypothermic crisis or a quick death, due to cardiac stress.

Diseases favored by coldness

- Respiratory tract diseases: rhinitis, inflammatory process of the pharynx, tonsillitis, larynx, bronchitis, pneumonia and bronchial pneumonia.

- Cardiovascular diseases (unfavorable effects: on patients with coronary diseases, high blood pressure, obstructive and arteriosclerosis).
- Diseases of the locomotion apparatus (rheumaticdiseases).
- Digestive diseases (relapse of gastroduodenal ulcer).
- Diseases of the peripheral nervous system (relapse of neuralgia, neurosis, paralysis and partial paralysis (paresis)).

Measurement of air temperature

Instruments:

- Common thermometrs are used to determine the thermal values between - 30°C and 300°C and alcohol themometers-between - 70°C and 120°C.
- Ordinary thermometers are: room thermometer, bathroom thermometer, laboratory thermometer, etc. special thermometers are*:* medical thermometer, skin thermometer, maximum and minimum thermometer, the thermograph.
- The medical thermometer measures thermal values between 35-42°C, and the skin thermomenter between 20-40°C. The smalles changes in the themal environment are recorded by skin temperature, which is a highly sensitive physiological indicator.
- Maximum and Minimum thermometers (Six-Bellani) show the maximum and minimum temperature in a given period of time.
- The thermograph records the air temperature, the resulting diagram being called a thermogram.

Special thermometers

A thermometer is a device that measures temperature or a temperature gradient. A thermometer has two important elements: (1) a temperature sensor (e.g. the bulb of a mercury-in-glass thermometer) in which some physical change occurs with temperature, and (2) some means of converting this physical change into a numerical value (e.g. the visible scale that is marked on a mercury-in-glass thermometer). Thermometers are widely used in industry to control and regulate processes, in the study of weather, in medicine, and in scientific research.

There are various principles by which different thermometers operate. They include the thermal expansion (A.k.A.growing heat) of solids or liquids with temperature, and the change in pressure of a gas on heating or cooling. Radiation-type thermometers measure the infrared energy emitted by an object, allowing measurement of temperature without contact. Most metals are good conductors of heat and they are solids at room temperature. Mercury is the only one in liquid state at room temperature, and has high coefficient of expansion. Hence, the slightest change in temperature is notable when it's used in a thermometer. This is the reason behind mercury and alcohol being used in thermometer.

Mercury thermometers

Mercury thermometer is a common type of thermometer in everyday use. Narrow bore of capillary tube makes the thermometer more sensitive. Range: -10°C to 110 °C (or 0 °C to 100 °C).

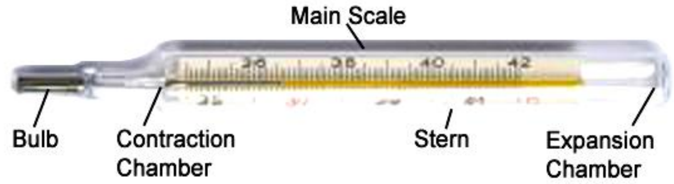


Fig. 3. Mercury thermometers.

Spirit thermometer

For temperatures below O°C,- especially below - 20°C, - a spirit thermometer is used. These are similar in construction to the ordinary mercurial thermometer but contain alcohol colored with some anilin dye, usually eosin, as the thermometric fluid.

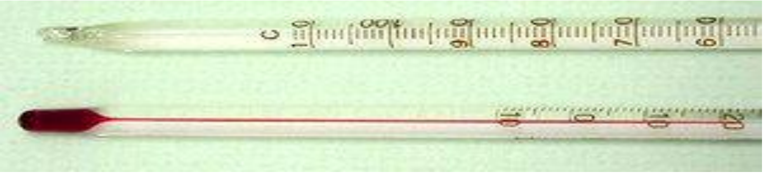


Fig. 4. Spirit thermometer.

Thermometers for high temperatures – For the observation of temperatures over 100°C, a long-stemmed mercurial themometer is used. Its scale may be lengthened so as to register up to 300°C. For temperatures ranging from 300°C to 450°C, the capillary tube of the thermometer contains nitrogen gas instead of a partial or complete vacuum.

Pyrometer – is a type of remote-sensing thermometer used to measure the temperature of a surface. Various forms of pyrometers have historically existed. In the modern usage, it is a device that from a distance determines the temperature of a surface from the spectrum of the thermal radiation it emits, a process known as pyrometry and sometimes radiometry.

The word pyrometer comes from the Greek word for fire, "πυρ" (*pyro*), and *meter*, meaning to measure. The word pyrometer was originally coined to denote a device capable of measuring the temperature of an object by its incandescence, visible light emitted by a body which is at least red-hot. Modern pyrometers or infrared thermometers also measure the temperature of cooler objects, down to room temperature, by detecting their infrared radiation flux.

A modern pyrometer has an optical system and a detector. The optical system focuses the thermal radiation onto the detector. The output signal of the detector (temperature T) is related to the thermal radiation or irradiance j^* of the target object through the Stefan–Boltzmann law, the constant of proportionality σ, called the Stefan-Boltzmann constant and the emissivity ε of the object.

$$j^* = \varepsilon \delta T^4$$

This output is used to infer the object's temperature from a distance, with no need for the pyrometer to be in thermal contact with the object; most other thermometers (e.g. thermocouples and resistance temperature detectors (RTDs)) are placed in thermal contact with the object, and allowed to reach thermal equilibrium.

They may be classified, according to the principles on which they act into:

1. pyrometers using the expansion of solids as a means of measuring high temperatures; Darnell's pyrometers are of this type (*fig. 5, fig. 5.1*);
2. pyrometers using the contraction of baked clay, as Wedgwood';
3. pyrometers employing the expansion of air, as Pouillet's, Regnault's, and Jolly's pyrometers (*fig. 6, fig. 6.1*);
4. pyrometers using the known melting points of solids;
5. pyrometers depending on the chemical decomposition of solids, as Lamy's pyrometers;

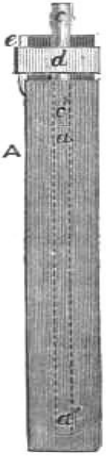


Fig. 5. Daniell's Pyrometer, Register.

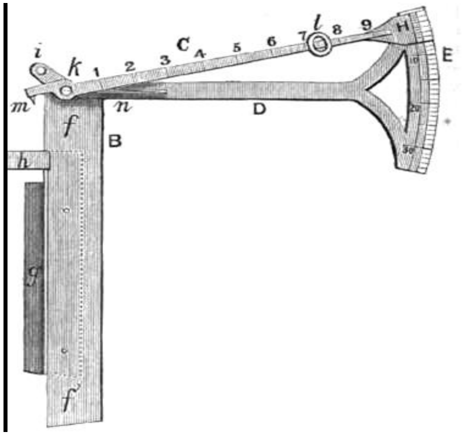


Fig. 5.1. Daniell's Pyrometer, Scale.

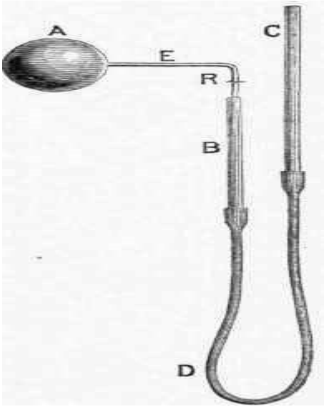


Fig. 6. Jolly's Air Thermometer.

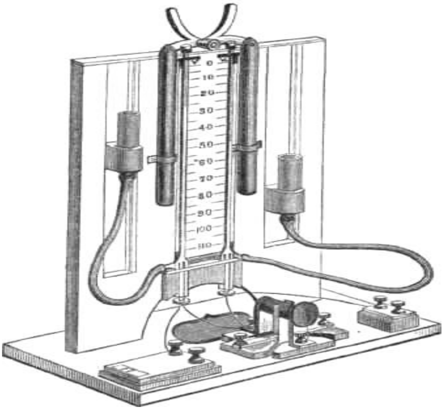


Fig. 6.1. Siemens's Pyrometer, Resistance Measurer.

6. pyrometers measuring temperatures by heating a known weight of water, by allowing to cool in it a known weight of platinumor other metal, which has been heated to the temperature of the space or of the body to be tested, as Pouillet's pyrometers;
7. pyrometers which determine temperatures ty measuring the strength of thermo-electric currents produced by heating the junction of two different metals, as Bec-querel's pyrometers;

8. pyrometers which determine temperatures by the measurement of changes, produced by heat, in the electrical resistance of a length of platinum wire, as Siemens's pyrometers (*fig.7, fig.7.1*);
9. pyrometers which use the expansion of the wave length of a sound, which traverses a tube placed in the furnace to measure its temperature as Mayer's pyrometer does.

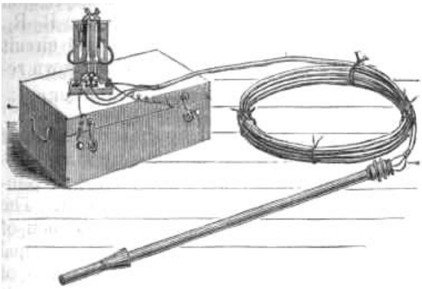


Fig. 7. Siemens's Pyrometer, General View.

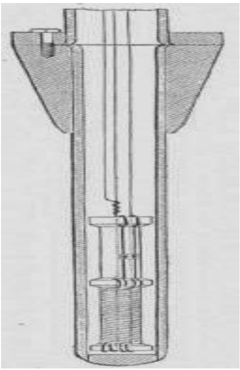


Fig. 7.1. Siemens's Pyrometer, Coil Tube.

Thermograph – the variations in the temperature curve, indicated by the pointer of the pyrometer, are recorded by means of mechanical or electrical devices on a revolving chart spowing different degrees of temperature and definite periods of time, as a day, a week, or a month. By means of a pen or small piece of graphite attached to the tip of the pointer, a permanent record of its to and fro movements under the influence of fluctuations in the temperature, is produced.

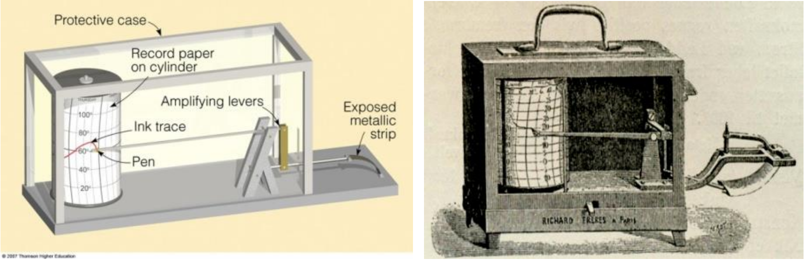


Fig. 8. Thermograph.

Maximum-minimum thermometer – these instruments record both the highest and the lowest points reached by the tempeeature during a definite period of time within, as twenty- four hours. It is a six-shaped thermometer registering thermometer which can record the maximum and minimum temperatures reached over a period of time, for example 24 hours. It is used to record the extremes of temperature at a location, for instance in meteorology and horticulture. It was invented by Englishman James Six in 1780; the same basic design remains in use.), consisting of an U-shaped, capillary glass tube, the upper portions of both arms being of somewhat larger caliber than the body of the tube. The thermometer scale is attached to each arm of the tube, the one arm forming the maximum, the other the minimum thermometer. The upper portion of the arm corresponding to the maximum, of the thermometer is expanded into a small, pointed bulb and contains a little of alcohol and vapor of alcohol. The lower portion or body of the tube contains mercury. In addition to this each arm contains an index consisting of a small, barbed bar of steel, one end of which rests on the surface of the column of mercury forming the two thermometprs. The thermometric substance of this instrument is the alcohol in the upper arm of the tube, while the mercury in the body of the tube is the propeller of the indices. Both indices are carried upward by the contraction of the mercurial column on the one hand, and the expansion on the other, as the result of a fall or risc in the temperature, and each of them is arrested at the point corresponding to the lowest temperature reached during the period of time under obsevation in the one arm, and at the point corresponding to the highest temperature reached during the same time on the other arm, thus recording the two extremes in temperature for that period of time. The indices are prevented from falling due to the dividing column of mercury. After reading the themometer the indices are again brought in contacct with the surface of the mercurial column by drawing a small horseshoe magnet downward along the side of each arm of the instrument.

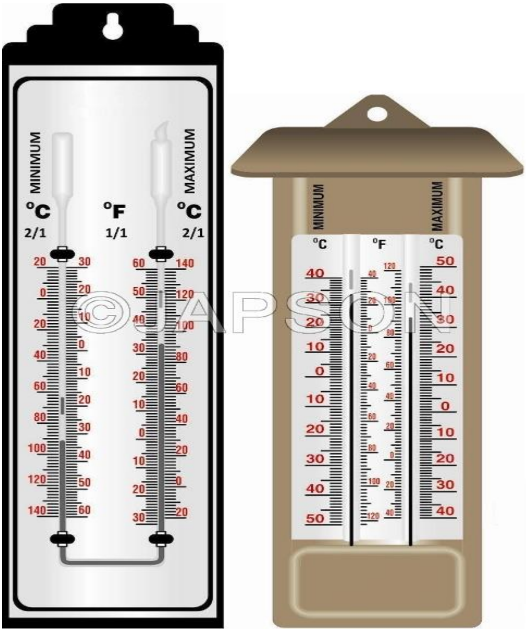


Fig. 9. Maximum-minimum thermometer.

Measuring Maximum and Minimum temperature

Sanitary regulations

The optimum average value is 18°C to 22°C, in the summer not exceeding 26°C. Horizontally, the differences must not exceed 2–3°C and vertically, 1,5–2°C. Temperature variations within 24 hours should not be more than 4–6°C for heating stoves and 2–3°C for central heating. The comfort temperature is higher in hospitals (20–22°C), especially in certain wards, operating rooms. On the other hand, it is lower when hard labor is involved (10–12°C).

Temperature measurement – must be made in several points and levels, to calculate a mean value, and to track variations in space and time. Also, it is indicated to repeat the measurement during the day.The outside air temperature is measured in the shade. The thermometer is placed at least 4 m from the walls and at 2 m above the ground.

If possible it is best to record the daily maximum and minimum temperature as well as that which you record at a specific moment in time when you make your observations. You can simply use your normal thermometer. With this you need to record temperatures at about 14:00 where the daily maximum usually occurs, or very early in the morning when the temperature is similar to the overnight minimum. These are good times to take your am/pm measurements.

Study of the temperature condition of the indoor air

The temperature is measured in 6 or more points to characterize fully the temperature conditions of premises.

Thermometers (mercurial, alcohol, electric or psychrometer dry thermometers) are placed onto support racks at three points ata distance of 0.5 meter above the floor, at three points at a distance of 1.5 meters above the floor level (points t_2, t_4, t_6 and t_1, t_3, t_5 respectively) and at a distance of 20 cm from the wall along the diagonal section of the laboratory.

The thermometer data are recorded after 10 minutes of the exposition at the point of measurement.

Air temperature parameters in premises are calculated using the following formulas:

a) the average temperature in the premises:

$$t_{\text{aver.}} = \frac{t_1 + t_2 + t_3 + t_4 + t_5 + t_6}{6},$$

b) the vertical variation of the air temperature:

$$D\tau_{\tau\rho\varepsilon\varpi.} = \frac{t_1 + t_3 + t_5}{3} - \frac{t_2 + t_4 + t_6}{3},$$

c) the horizontal variation of the air temperature:

$$D\tau_{\rho o \eta.} = \frac{t_5 + t_6}{2} - \frac{t_1 + t_2}{2}.$$

Diagrams and calculations are written down into the protocol, the hygienic assessment is made. It is necessary to consider the following data: the optimal air temperature must be from +18 to +21°C in residential and class-room premises, wards for somatic patients; the vertical temperature variation must be not more than 1.5-2.0°C, the horizontal one - not more than 2.0-3.0°C. Daily temperature variations are determined using the thermogram, made in the laboratory using the thermograph. The daily temperature variation must be not more than 6°C.

The allowable and optimal standards of the temperature presented in table 1 are the hygienic assessment criteria for residential and public premises.

Table 1

Temperature standards for residential, public and administrative premises

Season	***Temperature***	
	Optimal	**Allowable**
Warm	20-22°C 23-25°C	No more than 3°C higher than the measured outdoor air temperature*
Cold and transitional	20-22°C	18 – 22°C**

Note:

- the allowable temperature is not more than 28°C for public and administrative premises, which are permanently inhabited, for regions with the estimated outdoor air temperature of 25°C and above – not more than 33°C.
- the allowable temperature is 14°C for public and administrative premises where the inhabitants are wearing their street clothes.

The standards were established for people that are continuously staying in the premises for 2 hours or more.

The temperature standards for the workplace air of industrial areas are set in the State Standard #12.1.005-88 “General sanitary and hygienic requirements for the workplace air”, depending on the season (cold, warm) and work category (easy, moderate and hard).

The optimal temperature standards for the cold season are set from 21 to 24°C during the physically easy work and from 16 to 19°C during hard physical work. These temperature ranges between to 22-25°C and 18-22°C during the warm season. The allowable maximum temperature is not more than 30°C for the warm season, the allowable minimum temperature for the cold season is 13°C.

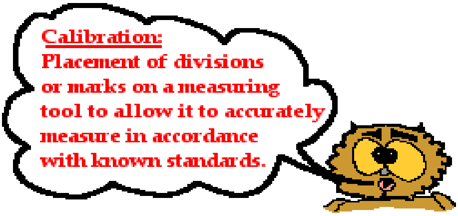
Thermometers and the Celsius Temperature Scale

A temperature is an objective comparative measurement of hot or cold. It is measured by a thermometer. Several scales and units exist for measuring temperature, the most common being Celsius (denoted °C;

formerly called centigrade), Fahrenheit (denoted °F), and, especially in science, Kelvin (denoted K).

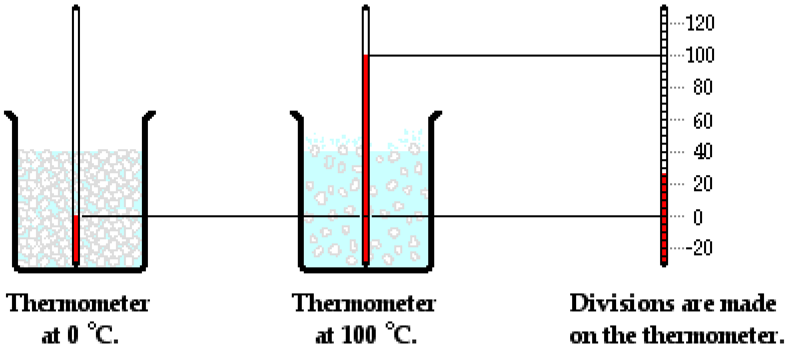
Today, there are a variety of types of thermometers. The type that most of us are familiar with from science class is the type that consists of a liquid encased in a narrow glass column. Older thermometers of this type used liquid mercury. In response to our understanding of the health concerns associated with mercury exposure, these types of thermometers usually use some type of liquid alcohol. These liquid thermometers are based on the principal of thermal expansion. When a substance gets hotter, it expands to a greater volume. Nearly all substances exhibit this behavior of thermal expansion. It is the basis of the design and operation of thermometers.

As the temperature of the liquid in a thermometer increases, its volume increases. The liquid is enclosed in a tall, narrow glass (or plastic) column with a constant cross-sectional area. The increase in volume is thus due to a change in height of the liquid within the column. The increase in volume, and thus in the height of the liquid column, is proportional to the increase in temperature. Suppose that a 10-degree increase in temperature causes a 1-cm increase in the column's height. Then a 20-degree increase in temperature will cause a 2-cm increase in the column's height. And a 30-degree increase in temperature will cause s 3-cm increase in the column's height. The relationship between the temperature and the column's height is linear over the small temperature range for which the thermometer is used. This linear relationship makes the calibration of a thermometer a relatively easy task.

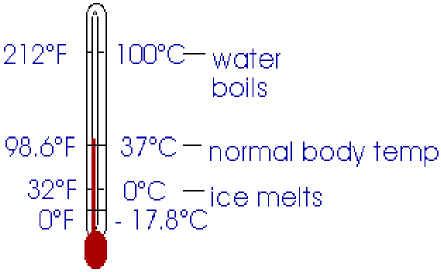


The calibration of any measuring tool involves the placement of divisions or marks upon the tool to measure a quantity accurately in comparison to known standards. Any measuring tool - even a meter stick - must be calibrated. The tool needs divisions or markings; for instance, a meter stick typically has markings every 1-cm apart or every 1-mm apart. These markings must be accurately placed and the accuracy of their placement can only be judged when comparing it to another object that is precisely known to have a certain length.

A thermometer is calibrated by using two objects of known temperatures. The typical process involves using the freezing point and the boiling point of pure water. Water is known to freeze at 0°C and to boil at 100°C at an atmospheric pressure of 1 atm. By placing a thermometer in mixture of ice water and allowing the thermometer liquid to reach a stable height, the 0-degree mark can be placed upon the thermometer. Similarly, by placing the thermometer in boiling water (at 1 atm of pressure) and allowing the liquid level to reach a stable height, the 100-degree mark can be placed upon the thermometer. With these two markings placed upon the thermometer, 100 equally spaced divisions can be placed between them to represent the 1-degree marks. Since there is a linear relationship between the temperature and the height of the liquid, the divisions between 0 degree and 100 degree can be equally spaced. With a calibrated thermometer, accurate measurements can be made of the temperature of any object within the temperature range for which it has been calibrated.


Calibrating a Celsius Thermometer

In the United States, it is still common to use the Fahrenheit scale. On the Fahrenheit scale, water freezes at 32°F (0°C) and water boils at 212°F (100°C). It, too, may have been a "centigrade" scale with 0°F the lowest temperature Fahrenheit could obtain with water, ice, and **salt** and 100°F his not-quite-right measure of human body temperature.



Units

The tempeature measuring unit is the degree, which has different values depending on the used thermometric scale. Each thermometric scale has two constant points: the melting poing of ice, and the boiling poing of distilled water, at an atmospheric pressure of 760 mm Hg. The Celsius scale (°C) is divided into 100 degrees. In France, the Reaumur (°R) scale, divided into 80 degrees is used, and in the United Kingdom, the United States and other and other Anglophone countries the Fahrenheit scale (°F) divided into 180 degrees is used.

Thermometer scales

1. The centigrade scale - is the most commonly used in scientific investigations. It has for its zero-point the melting-point of ice, while 100° is the boiling-point of water with the barometer at 760 mm.

2. The Fahrenheit scale – on this scale the zero-point is 32° below the melting- point of ice, and the boiling-point of water is 212° with the barometer at 29.905 inches in the latitude of London. This is the standard scale in the United States, but for obvious reasons, the centigrade scale is preferable to it. Traditionally slow to adopt the metric system and other accepted units of measurements, the United States more commonly uses the **Fahrenheit temperature scale**. A thermometer can be calibrated using the Fahrenheit scale in a similar manner as was described above. The difference is that the normal freezing point of water is designated as 32 degrees and the normal boiling point of water is designated as 212 degrees in the Fahrenheit scale. As such, there are 180 divisions or intervals between these two temperatures when using the Fahrenheit scale. The Fahrenheit scale is named in honor of German physicist Daniel Fahrenheit. A temperature of 76 degree Fahrenheit is abbreviated as 76°F. In most countries throughout the world, the Fahrenheit scale has been replaced by the use of the Celsius scale.

Temperatures expressed by the Fahrenheit scale can be converted to the Celsius scale equivalent using the equation below:

$$°C = (°F - 32°)/1.8$$

Similarly, temperatures expressed by the Celsius scale can be converted to the Fahrenheit scale equivalent using the equation below:

$$°F = 1.8°C + 32°$$

3. The Reaumur scale – on this scale the melting-point of ice also corresponds to the zero-point, while the boiling-point of water is at 80°. This scale has never been used very extensively and is now falling into disuse.

4. Relative values of the degrees on the three scales

$$5°C = 9°F = 4°R$$

$$1°C = \frac{9}{5}°F = \frac{4}{5}°R$$

$$1°C = \frac{5}{9}°F = \frac{4}{9}°R$$

$$1°C = \frac{5}{4}°F = \frac{9}{4}°R$$

To convert centigrade degrees into Fahrenheit degrees, miltiply by $\frac{9}{5}$ and add 32.

$$(C \times \frac{9}{5}) + 32 = F$$

To convert centigrade degrees into Reaumur degrees, multiply by $\frac{4}{5}$,

$$C \times \frac{5}{4} = R$$

To convert Fahrenheit degrees into centrigrade degrees, subtract 32 and multiply by $\frac{5}{9}$,

$$(F - 32) \times \frac{5}{9} = C$$

To convert Fahrenheit degrees into Reaumur degrees, subtract 32 and multiply by $\frac{4}{9}$,

$$(F - 32)\times \frac{4}{9} = R$$

To convert Reaumur degrees into centigrade degrees, multiply by $\frac{5}{4}$,

$$R \times \frac{5}{4} = C$$

To convert Reaumur degrees into Reaumur degrees, multiply by $\frac{9}{4}$

$$(R \times \frac{9}{4}) - 32 = F$$

An instrument called thermometer ascertains this:

Name of thermometer	Boiling point	Freezing point
Fahrenheit	32	212
Centigrade (Calcius)	0	100
Reaumur	0	80

5. The Kelvin temperature scale While the Celsius and Fahrenheit scales are the most widely used temperature scales, there are several other scales that have been used throughout history. For example, there is the Rankine scale, the Newton scale and the Romer scale, all of which are rarely used. Finally, there is the **Kelvin temperature scale**, which is the standard metric system of temperature measurement and perhaps the most widely used temperature scale among scientists. The Kelvin temperature scale is similar to the Celsius temperature scale in the sense that there are 100 equal degree increments between the normal freezing point and the normal boiling point of water. However, the zero-degree mark on the Kelvin temperature scale is 273.15 units cooler than it is on the Celsius scale. So a temperature of 0 Kelvin is equivalent to a temperature of -273.15 °C. Observe that the degree symbol is not used with this system. So a temperature of 300 units above 0 Kelvin is referred to as 300 Kelvin and not 300 degree Kelvin; such a temperature is abbreviated as 300 K. Conversions between Celsius temperatures and Kelvin temperatures (and vice versa) can be performed using one of the two equations below.

°C = K - 273.15°
K = °C + 273.15

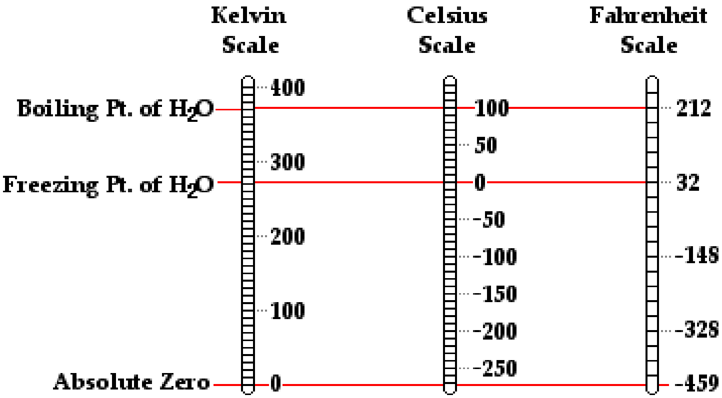
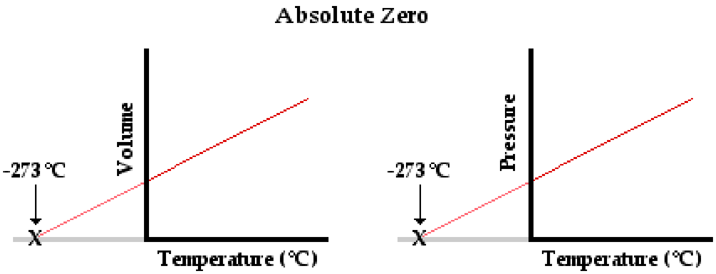


Fig. 10. Thermometer scales

The zero point on the Kelvin scale is known as **absolute zero**. It is the lowest temperature that can be achieved. The concept of an absolute temperature minimum was promoted by Scottish physicist William Thomson (a.k.a. Lord Kelvin) in 1848. Thomson theorized based on thermodynamic principles that the lowest temperature which could be achieved was -273°C. Prior to Thomson, experimentalists such as Robert Boyle (late 17th century) were well aware of the observation that the volume (and even the pressure) of a sample of gas was dependent upon its temperature. Measurements of the variations of pressure and volume with changes in the temperature could be made and plotted. Plots of volume vs. temperature (at constant pressure) and pressure vs. temperature (at constant volume) reflected the same conclusion - the volume and the pressure of a gas reduces to zero at a temperature of -273°C. Since these are the lowest values of volume and pressure that are possible, it is reasonable to conclude that -273°C was the lowest temperature that was possible.

Thomson referred to this minimum lowest temperature as *absolute zero* and argued that a temperature scale be adopted that had absolute zero as the lowest value on the scale. Today, that temperature scale bears his name. Scientists and engineers have been able to cool matter down to temperatures close to -273.15°C, but never below it. In the process of cooling matter to temperatures close to absolute zero, a variety of unusual properties have been observed. These properties include superconductivity, superfluidity and a state of matter known as a Bose-Einstein condensate.



A volume vs. temperature and a pressure vs. temperature plot will each have an x-intercept of -273 C. The volume and the pressure of a gas seem to reduce to 0 at a very specific temperature (assuming the gas remains as a gas).

Measurement of the air temperature in a class-room:

1. Devices which are used for the measurement
2. The place for the measurement
3. Points and readings of the measurements along the horizontal and vertical lines

t_1(h=1.5m) = ________°C

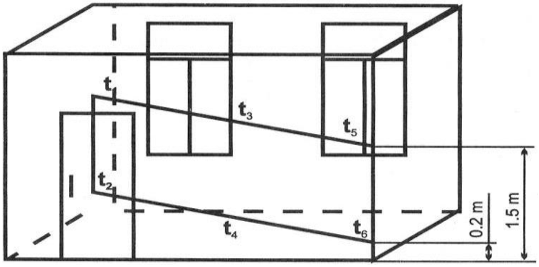
t_2(h=0.2m) = ________°C

t_3(h=1.5m) = ________°C

t_4(h=0.2m) = ________°C

t_5(h=1.5m) = ________°C

t_6(h=0.2m) = ________°C



1.4. Calculation of the average temperature:

Total t6 =□

$$t_{av} = \frac{\sum tb}{n},$$

1.5. Calculation of the temperature differences

– on the vertical line

$$t_v = \frac{t_1 + t_3 + t_5}{3} - \frac{t_2 + t_4 + t_6}{3} =$$

– on the horizontal line

$$t_h = \frac{t_5 + t_6}{2} - \frac{t_1 + t_2}{2} =$$

Two temperatures are to be measured; i.e. the temperature of the sample gas, which is called the dry bulb or ambient temperature, and the temperature of a thermometer covered with a porous substance (wick) which is saturated with pure water and is in equilibrium with the sample gas which is passed over it at an adequate velocity. The depression of temperature of the wet-bulb versus the dry-bulb can be correlated with water vapor pressure using the equation:

$$e\ e_w - 66\times10^{-5}P(T_a - T_w) \times (1+115\times10^{-5}T_w)$$

where:

e – is the vapor pressure of water in the sampled gas
e_w – is the saturation vapor pressure if water at temperature t_w
P – is the atmospheric pressure
T_a – dry bulb temperature in °C
T_w – wet bulb tempereture, in °C

This equation is valid only if the thermometers are in a gas strem of sufficient velocity (about 200 meters/min.or 650 ft/min) at low velocities, errors in measurement could easily occur.

Advantages:

The psychrometer does have certain inherent advantages,i.e.:

- The psychrometer can be used at ambient temperatures above 100°C (212°F), and the wet-bulb measurement is usable up to a few degrees below the boiling poin.
- It is a fundamental measurement service.
- Its cost is low

Disadvantages:

Major shortcomings of the psychometer are:

- As the relative humidity drops to values below about 15% RH, the problem of cooling the wet-bulb to its full depression becomes difficult. The resul could be impaired accuracy below 15%RH, and few psychrometers work well below 5% to 10%RH.

- Wet-bulb measurements at temperatures below 0°C (32°F) are difficult to obtain with a high degree of confidence. Automatic water feeds are not feasible due to freeze-up.
- Most physical sources of error, such as dirt, oil or contamination on the wick, insufficient water flow, etc., tend to increase the apparent wet-bulb temperature. This results in the derived relative humidity being higher than the actual relative humidity.
- Errors in psychrometric practice and derived %RH.

Methods of equivalent-effective and resultant temperatures determination

Equivalent-effective temperature (EET) is a contingent-numeral determination of human subjective heat feeling (“comfortable”, “warm”, “cold” ect.) under different ratios of temperature, humidity, air movement, and the *resultant temperature (RT)* – also the radiant temperature. These standard units of EET and RT correspond to the temperature of still (0 m/s) 100 % water saturated air. The feeling of heat or cold results from different variations of these EET and RT standard units.

The EET and RT were elaborated in special box conditions with different ratio of microclimate characteristics and drawn up in tables and nomograms.

First, temperature, humidity, air movements are measured for the EET determination in the certain room. The value of EET is determined in accordance to these data (see table 4) and an appropriate conclusion is drawn. The use of this table is simple: The EET is determined at the intersection of air temperature value (the first and last columns), air movement and humidity (at the top of the table).

The equivalent-effective temperature is determined at the intersection of the dry-bulb (at the left) and wet-bulb (at the right) thermometers of the psychrometer and the air movement (m/min on the curved lines) on a nomogram (*fig. 11*).

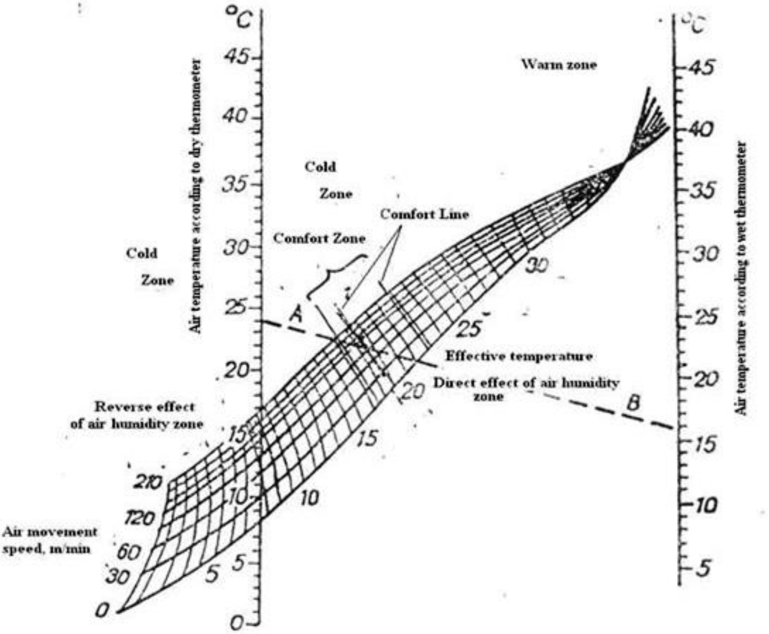
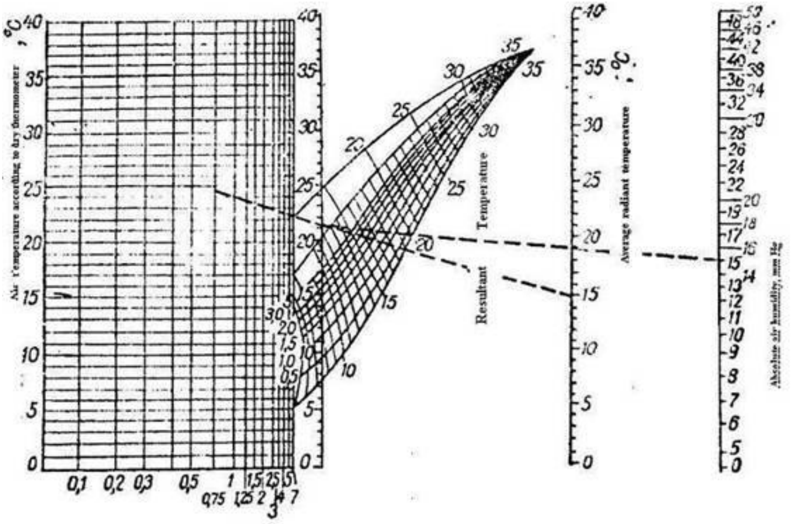


Fig. 11. Nomogram of the effective temperature determination.



air movement, m/s

a

The following actions should be done to find out the resultant temperature from the nomogram (*fig.12*). First, the point, where the air movement corresponds to the air temperature (by dry thermometer) is found. Then, a line starting from that point to the radiant temperature value is drawn, and from the point, where this line and the temperature scale intersect to the right, another line is drawn – to the value of the absolute air humidity (the right scale). The resulting temperature value will be at the intersection of the last line and the nomogram curves.

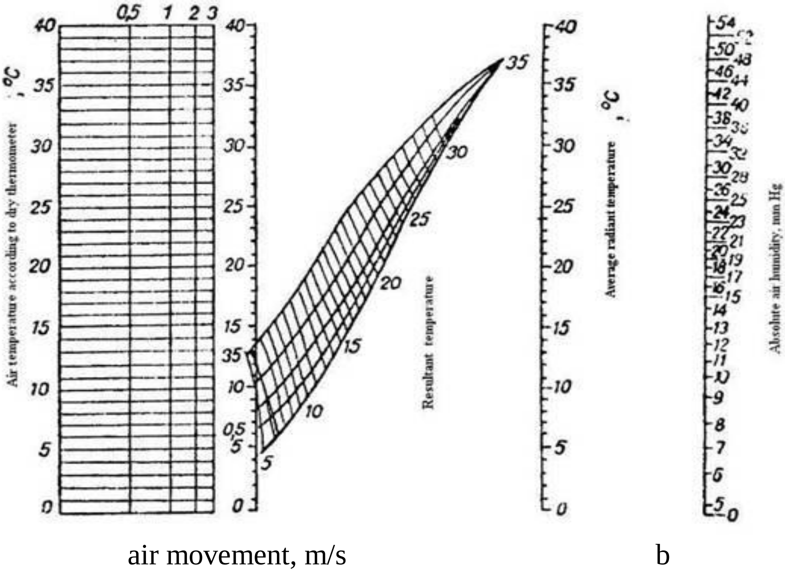


Fig. 12. Nomogram of the resultant temperature determination (*a* – during light work; *b* – during hard work).

Effective temperature

Effective temperature is a relative value, obtained by the assesment of the heat sensation produced by the combined effect of temperature, humidity and air currents on the body effective temperature is marked with ET and is expressed in effective temperature degrees (ET°). The comfort zone is between 17.2 – 21.7° ET, and the comfort line is 18.1 – 18.9° ET.

AIR HUMIDITY

Medical importace of air humidity

- It influences the regulation of body temperature (thermolysis by evaporation).
- It influences air pollution.
- It determines the climate.

Effects of air humidity variation on the human body

Indirect effect:

- Air humidity interferes in outbalancing big differences of air temperature.

Direct ieffect:

- Relative humidity under 10-15% makes the mucosa dry out, bleed and split, producing thirst sensation.
- Relative humidity under 30% makes the respiratory mucosa dry out, creating a favorabile environment for the development of pathological germs.
- Relative humidity over 70-80% has a negative influence effect thermic regulation through the evaporation of perspiration (if the air temperature is high) and it increases thermal losses of the body (if the air temperature is low).

Diseases favored by the changes of the relative humidity:

- Catarrh inflammation of the mucous membranes of the respiratory tract due to the action of some viruses.
- Influenza (it looks like the influenza virus is destroyed by high air humidity).
- Scarlet fever (streptococcus is not resistant to high air humidity).
- Acute bronchitis and the decline of the symptomology of cronic bronchitis (in the periods with high air humidity associated with low air temperature).

In case of high air humidity, air pollution with sulfur dioxide produces sulfuric acid, which can enter the respiratory system with vapor and then it irritates the mucosa.

- Asthma-bronchitis (it appears that this disease is not influenced by high air humidity, not even in periods with fog).
- Rheumatism (there is no a direst connection between high air humidity and the frequency of rheumatism pain).
- Tuberculosis (in cold seasons with low air temperature, high air humidity and fog the frequency of hemoptysis grows).

Generally the rise of air humidiity favors the growth of Gram negative bacteria and the decrease of air humidity facilitates the growth of Gram positive bacteria.

At different temperatures air is capable of taking up variable amounts of moisture, there being a saturation point for cach degree of temperature. The point of saturationr rises with the elevation of temperature of the air, so that when the air is saturated at a high temperature and then is cooled, there is a precipitation of moisture in the form of rain or dew, or in the form of sleet, snow, or hail.

- **Dew-point** – the point of saturation at a certain degree of temperature is known as the dew-point.
- **Absolute humidity** – absolute humidity is the total mass of water presentin a given volume of air. The absolute humidity varies with the temperature, increasing in amount with the increase of the temperature of the air.
- **Maximum of saturation** – the maximum saturation of air is the maximum amount of moisture, in grams, which 1 cubic meter of air is capable of holding at a certain temperature.
- **Deficiency of saturation** – deficiency of saturation is the amount of moisture in grams, which 1 cubic meter of air, at a certain temperature, is capable of taking up, in addition to that which it already contains, to become fully saturated. It is the difference between the maximum saturation for that degree of temperature and the absolute humidity.
- **Relative humidity** – relative humidity is the quantity of moisture contained in the air, at a certain temperature, expressed in per cent, or the quantity of moisture that can be taken up at that temperature, or the absolute humidity expressed in per cent, of the maximum of saturation. It is the greatest near the surface of

the earth during the night when the temperature approaches the dew-point, and it is least during the middle of the day when the heat is the greatest.

Air humidity

Humidity is moisture content of the atmosphere. The atmosphere always contains some moisture in water vapor. Its maximum amount depends on the temperature. The amount of vapor that the air will saturate increases with temperature rise. At 4.4° C (40° F), 454 kg (1000 lb) of moist air contain maximum 2 kg of water vapor; at 37.8° C (100° F), the same amount of moist air contains maximum 18 kg of water vapor. When the atmosphere is saturated with water, the level of discomfort is high because the evaporation of perspiration with its attendant cooling effect is impossible.

Humidity is the amount of water vapor in the air. Water vapor is the gaseous state of water and is invisible. Humidity indicates the likelihood of precipitation, dew, or fog. Higher humidity reduces the effectiveness of sweating in cooling the body by reducing the rate of evaporation of moisture from the skin. This effect is calculated in a heat index table or humidex. The amount of water vapor that is needed to achieve saturation increases as the temperature increases. As the temperature of a parcel of air becomes lower it will eventually reach the point of saturation without adding or losing water mass. The differences in the amount of water vapor in a parcel of air can be quite large, for example; A parcel of air that is near saturation may contain 28 grams of water per cubic meter of air at 30 °C, but only 8 grams of water per cubic meter of air at 8 °C.

Humidity is specified in several different ways. The weight of water vapor contained in a volume of air is known as the absolute humidity and is expressed in grams of water vapor per cubic meter. Relative humidity, given in weather forecasts, is the ratio between the actual content of the air vapor and the content of the air vapor at the same temperature saturated with water vapor.

There are three main measurements of humidity: absolute, relative and specific. **Absolute humidity** is the water content of air at a given temperature expressed in gram per cubic meter. **Relative humidity**, expressed as a per cent, measures the current absolute humidity *relative* to the maximum (highest point) for that temperature. **Specific humidity** is a ratio of the water vapor content of the mixture to the total air content on a mass basis.

Relative humidity is a relation of absolute humidity to the maximum humidity at a given temperature, expresses in percentage, that is:

$$R=A / F \times 100,$$

Where: R - relative humidity;
A - absolute humidity;
F - maximum humidity.

Absolute humidity

Absolute humidity is the total mass of water vapor present in a given volume of air. Absolute humidity in the atmosphere ranges from near zero to roughly 30 grams per cubic meter when the air is saturated at 30°C. Absolute humidity is the mass of the water vapor (mH_2O), divided by the volume of the air and water vapor mixture (V_{net}), which can be expressed as:

$$AH = \frac{mH_2O}{Vnet}$$

Relative humidity. The relative humidity **(RH orφ)** of an air-water mixture is defined as the ratio of the partial pressure of water vapor **(pH_2O)** in the mixture to the equilibrium vapor pressure of water* **(pH_2O)** over a flat surface of pure water at a given temperature:

$$\phi = \frac{pH_2O}{*pH_2O}$$

Relative humidity is normally expressed as a percentage; a higher percentage means that the air-water mixture is more humid.

Relative humidity is an important metric used in weather forecasts and reports, as it is an indicator of the likelihood of precipitation, dew, or fog. In hot summer weather, a rise in relative humidity increases the apparent temperature to humans (and other animals) by hindering the evaporation of perspiration from the skin. For example, according to the Heat Index, a relative humidity of 75% at air temperature of 80.0 °F (26.7 °C) would feel like 83.6 °F ±1.3 °F (28.7 °C ±0.7 °C).

The most commonly used measure of humidity is **relative humidity**. Relative humidity can be simply defined as the amount of water in the air relative to the saturation amount the air can hold at a given temperature multiplied by 100. The air with a relative humidity of 50% contains a half of the water vapor it can hold at a particular temperature.

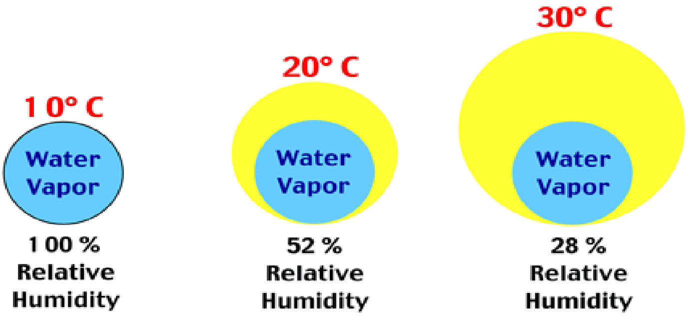


Fig. 13. Illustrates the concept of relative humidity.

The following illustration describes how relative humidity changes in a bag of air with an increase of air temperature. At 10° Celsius, a bag of dry air weighing one kilogram can hold a maximum of 7.76 grams of water vapor.

Specific humidity

Specific humidity (or moisture content) is the ratio of water vapor mass (*mv*) to the air parcel's *total* (i.e., including dry) mass (*ma*) and is sometimes referred to as the humidity ratio. Specific humidity is approximately equal to the "mixing ratio", which is defined as the ratio of the mass of water vapor in an air parcel to the mass of *dry* air for the same parcel.As temperature decreases, the amount of water vapor needed to reach saturation also decreases. As the temperature of a parcel of air becomes lower it will eventually reach the point of saturation without adding or losing water mass. The differences in the amount of water vapor in a parcel of air can be quite large, for example; A parcel of air that is near saturation may contain 28 grams of water per cubic meter of air at −1 °C, but only 8 grams of water per cubic meter of air at −12 °C.

Specific Humidity is defined as:

$$SH = \frac{m_v}{m_a}$$

$$SH = \frac{0,622 \times pH_2O}{p(dry/air)}$$

$$0,622 = \frac{MM_{H_2O}}{MM(dry/air)}$$

or

$$SH = \frac{0.622 \times p_{H_2O}}{p - 0,378 \times p_{H_2O}}$$

$$\phi = \frac{SH \times p}{(0,622 + 0,378 \times SH) * p_{H_2O}}$$

However, specific humidity is also defined as the ratio of water vapor to the total mass of the system (dry air plus water vapor)

There are various devices used to measure and regulate humidity. A device used to measure humidity is called a psychrometer or hygrometer. A humidistat is a humidity-triggered switch, often used to control a dehumidifier.

Humidity is also measured on a global scale using remotely placed satellites. These satellites are able to detect the concentration of water in the troposphere at altitudes between 4 and 12 kilometers. Satellites that can measure water vapor have sensors that are sensitive to infrared radiation. Water vapor specifically absorbs and re-radiates radiation in this spectral band. Satellite water vapor imagery plays an important role in monitoring climate conditions (like the formation of thunderstorms) and in the development of weather forecasts.

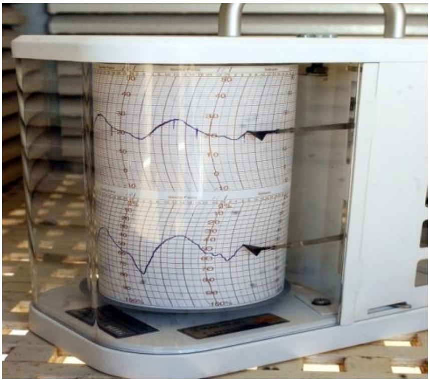


Fig. 14. Hydrometer.

Physiological relative humidity

Hygiene uses also the concept of physiological relative humidity. It is a relation of the absolute humidity at a given temperature of air to the maximum humidity at 36.5°C expressed in percentage. Physiological relative humidity characterizes the capability of air to absorb the humidity that evaporates at the body temperature. It enables to evaluate more precisely the effect of moist air.

Air humidity can be described as a deficit of saturation. The deficit of saturation is the difference between the maximum and absolute humidities at the same temperature.

There is also a concept of physiological deficit of saturation. It is the difference the between the maximum at humidity the human body temperature person 36.5°C and the absolute humidity of air. The physiological deficit of saturation lets us define how many grams of water the person can spend by evaporation in given conditions.

Air humidity is a very relevant hygienic factor because it influences the thermoexchange of the person. At low temperatures in moist air the feeling of cold is stronger than in dry air at the same temperature.

The human body permanently loses moisture with sweat, urine, saliva, etc. It is established that in quietat rest at room temperature the person loses approximately 20% of moisture with sweat, 15 % - with saliva and the remaining part – with urine and feces. Therefore, in these conditions approximately 35% of water is lost by evaporation and 65% - in liquid with feces and urine. In case of activity and heat of air – on the contrary: 60% of water is lost by the evaporation from the skin and much less by - urine and feces.

The normal relative air humidity in living quarters is 30-60%. A great range of normal air humidity is explained by the fact that its influence on the organism depends on a number of conditions. When the air temperature is 16-20^{0}C with a light air motion the optimum humidity at rest will be 40 - 60%. During physical work when the air temperature is above 20^{0}C or below 15^{0}C the air humidity must not be more than 30-40%, and when the temperature is above 25 ^{0}C it is desirable to decrease the relative humidity to 20%.

Measurement methods. Hygrometric method

Direct hygrometers – there are three types of direct hygrometer, all working on the same principle: (a) Daniell's, (b) Regnauit's, an improved type of Daniell's instrument and (c) Dinnes's hygrometers.

a) Daniell's hygrometer (*fig.15*) consists of a bent glass tube terminating in two bulbs, one covered with muslin, and the other of black glass, and containing ether and a thermometer. Ether being poured on the muslin, the black ball, cooled by the evaporation of the ether within, is soon covered with dew; at this moment, the inclosed thermometer gives the dew-point, and this, compared with the reading of one in the air, determines the humidity.

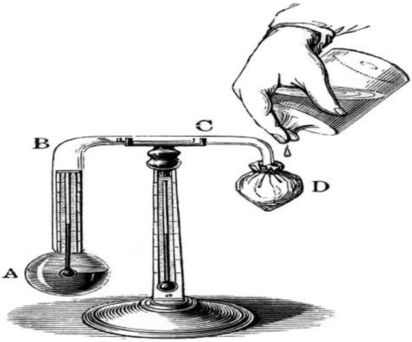


Fig.15. Daniell's hygrometer.

b) Regnault's hygrometer (*fig. 16*)

Regnault's hygrometer consists of a brightly polished thimble of very thin layer of silver, forming the continuation of a short glass tube to which the silver thimble is attached by plaster of paris or some other cement not acted upon by ether.

Fig. 16. Regnault's hygrometer.

Regnault's hygrometer:

- also called a dewpoint hygrometer it is a more accurate instrument for measuring humidity
- consists of a silver tube which contains diethyl ether o the temperature of the ether is monitored with a thermometer

- silver has a high thermal conductivity so the temperature immediately adjacent to the outside of the tube is the same as the temperature on the inside in the ether
- a gas flow over the top of the tube leads to continued evaporation of the ether causing cooling
- the temperature of the silver tube continues to drop as the ether continues to evaporate
- finally a dew appears on the outside of the tube o the temperature at which this dew first appears is the dewpoint
- at this dewpoint the air layer on the outside of the tube has just become fully saturated with water vapour and dew now forms
- relative humidity may be deduced from the dew point as follows:

$$\mathrm{Re\,lative/humidity} = \frac{\mathrm{actual/vapor/pressue}}{\mathrm{SVP/at/that/temp}} \equiv \frac{\mathrm{SVP/dew/point}}{\mathrm{SVPat/ambient/temperature}}$$

- from a knowledge of the dew point and the saturated vapour pressures, which can be obtained from tables, both the relative and absolute humidites can be calculated at the temperature required
- absolute humidity can also be measured by transducers, which are of two main types depending on the change either in electrical resistance or capacitance of a substance when it absorbs water vapour from the atmosphere
- humidity can also be measured by a mass spectrometer or by a light absorption technique using ultraviolet light

The passage of air is continued until a deposit of dew is seen on the silver, which shows that the temperature of the silver is below the dew-point. The thermometer is then read, and the temperature of the apparatus allowed to rise until the deposit of moisture has completely disappeared, when the thermometer is again read. The temperature is now above that of the dew-point, and the mean of the two readings so obtained may be taken as the temperature of the dew-point, provided that there is no more difference than two or three tenths of a degree centigrade between them.

Dines hygrometer (*fig. 17*)

Dines Hygrometer is an instrument for directly determining the dew-point, i.e. the temperature at which the air in the neighbourhood of the instrument is completely saturated with aqueous vapour. It consists of a thermometer placed horizontally, so that its stem is visible while its bulb is enclosed in a box of thin copper through which cold water can be passed from a reservoir attached to the instrument by turning the tap at the back. The tap is shut on when the side marked "o" is upward, and shut off when that marked "s" is upward. The bulb of the thermometer is placed close to the top of the box which encloses it, and the top of the box is formed of a plate of blackened glass, ground very thin indeed, in order, as far as possible, to avoid any difference of temperature between the upper and under surfaces, and so to ensure that the temperature of the thermometer shall be the same as that of the upper surface of the glass.

Fig. 17. Dines's hygrometer.

Indirect hygrometer – there are two pincipal kinds of indirect hygrometer: (a) hair hygrometer, and (b) wet-and dry-blub thermometer.

Hair hygrometer (*fig. 18*), is used to indicate the relative humidity by means of changes in length a hair undergoes with changes in atmospheric humidity. It is easier to use than the psychrometer, though it is less accurate.

It consists of a long hair degreased with ether, kept in tension by a pair of tweezers at the top of the instrument. Tweezers can be raised or lowered by means of a screw, placed above the tweezers. In this way the hair is not knotted to the suspension, otherwise a twist would be introduced making irregular the elongation.

The lower end of the hair is wound on one of the two grooves of a pulley at the base of the instrument and in the second groove is wrapped a silk wire. The latter is connected to a counterweight that keeps the hair under tension. The metal plate and the pulley are bolted to a sturdy metal frame, which can be suspended with its top ring, or can be attached to a heavy wooden or metal base.To the axle of the pulley is fastened a light needle, which ends along a graduated scale. With increasing moisture the hair elongates and the needle drops. When humidity decreases the hair shortens, the pulley turns in the opposite direction and the needle rises. The intervening space is divided into eighty – five equal parts, each of which denotes a "degre of relative humidity".

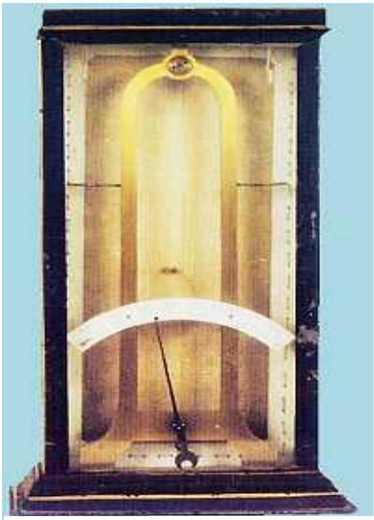


Fig. 18. Hair hygrometer.

Wet-and dry-bulb thermometer, or psychrometer (*fig. 19*) – this consists of two ordinary mercurial thermometers, as nearly alike as possible, and registering tenths of a degree centgrade, which are attached to a small frame or to a strip of wood. The bulb of one of the thermometers is covered with a jacket of cotton threads which extend into a small cup of water attached to the bottom of the frame of the device, thus keeping the bulb continuously moist through capillary attraction. This is known as the “wet-bulb” and the other- as the “dry-bulb” thermometer.

As long as the atmosphere is not saturated, moisture continues to evaporate from the wet-bulb and, in consequence, the mercury cools and contracts and shows a lower temperature than the dry-bulb thermometer, which registers the temperature of the surroundig atmosphere. The difference between the temperature registered by the two thermometers is the greatest when the atmosphere contains the least moisture, and when it is saturated they show the same temperature, since there is no evaporation from the wet bulb. When the temperature is below freezing the capillary actoin ceases and the readings of the wet-bulb themometer are unreliable.

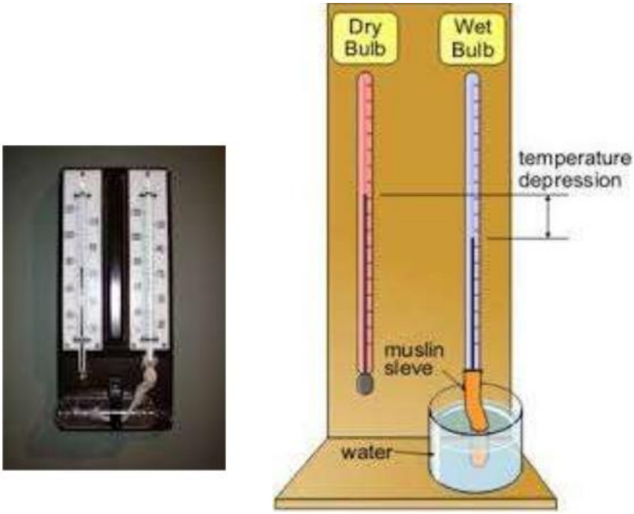


Fig. 19. Wet-and dry-bulb thermometer, or psychrometer.

The most common type of this device is the “sling” psychrometer. The two thermoneters are fastened on opposite sides of a small strip of wood, having a handle attached to its upper end by means of which the device can be made to revolve. The wet-bulb thermometer projects three or four (cm), beyond the lower end of the wooden support, and the jacket surrounding it is thoroughly moistened with distilled water whenever an observation is to be made.

Information obtained from hygrometer observations.

The important items of information to be obtained from hygrometer observations are: (a) the dew-point, (b) the tension of aqueons vapor, or the absolute humidity, and (c) the relative humidity of the atmosphere. Each of these may be calculated from the difference between the temperature of the wet-and dry-bulb thermometers, either by a formula, or from tables. The dew-point of the atmosphere is determined directly by means of one of the three types of direct hygrometers.

Absolute humidity can be calculated from the readings of the wet-and-dry-bulb thermometers according to the formula:

$$m = M - cd,$$

where:

m – the absolute humidity of the air at the temperature indicated by the dry-bulb thermometer.

t and *M* – the maximum of saturation at the thermometer.

f – is found by reference to Flugge's table.

c – a convered, usually 0,65, in the winter, when the bulb is covered with ice, 0,56.

d – the difference between the wet-and dry-bulb thermometer readins.

Relative Humidity

Hygrometric method The amount of water vapor in the air at any given time is usually less than that required to saturate the air. The relative humidity is the per cent of saturation humidity, generally calculated in relation to saturated vapor density.

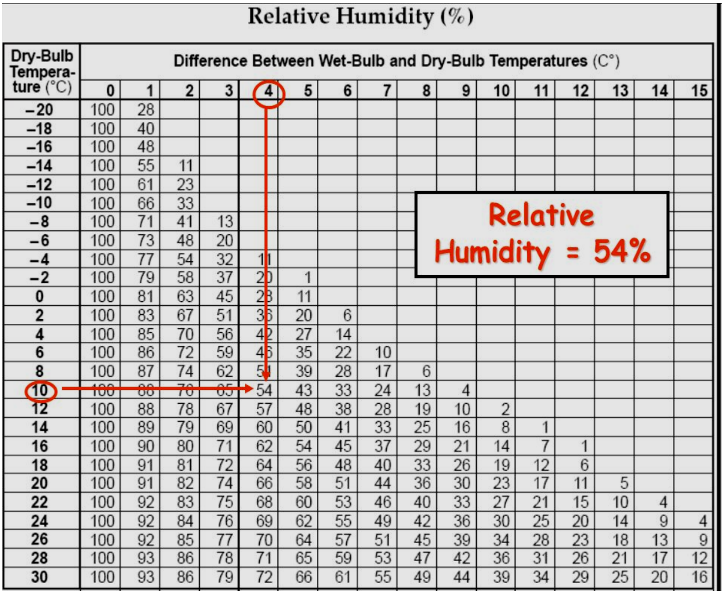
$$\text{Relative Humidity} = \frac{\text{actual vapor density}}{\text{saturation vapor density}} \times 100\%$$

The most common units for vapor density are gm/m^3. For example, if the actual vapor density is 10 g/m^3 at 20°C compared to the saturation vapor density of 17.3 g/m^3 at that temperature, then the relative humidity is:

$$\text{R.H.} = \frac{10\,\text{g}/\text{m}^3}{17{,}3\,\text{g}/\text{m}^3} \times 100\% = 57{,}8\%$$

Table 2

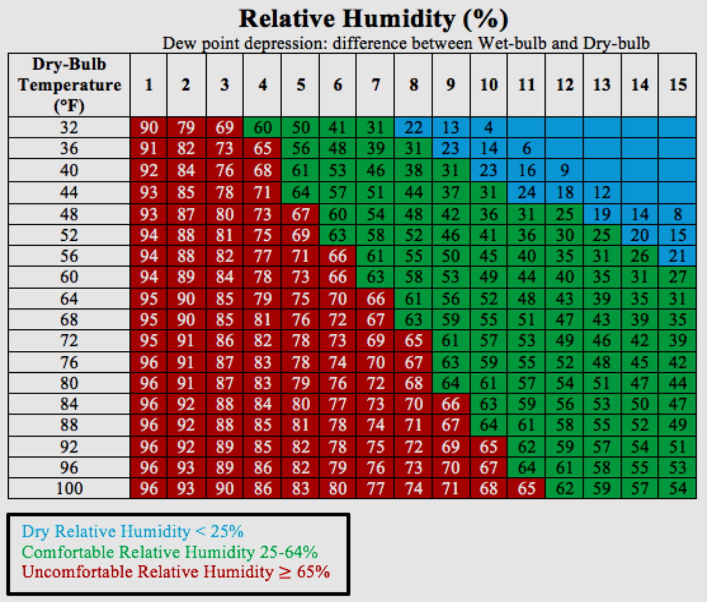
Relative humidity



Relative Humidity (%)

Dry-Bulb Temperature (°C)	Difference Between Wet-Bulb and Dry-Bulb Temperatures (C°)															
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
–20	100	28														
–18	100	40														
–16	100	48														
–14	100	55	11													
–12	100	61	23													
–10	100	66	33													
–8	100	71	41	13												
–6	100	73	48	20												
–4	100	77	54	32	11											
–2	100	79	58	37	20	1										
0	100	81	63	45	28	11										
2	100	83	67	51	36	20	6									
4	100	85	70	56	42	27	14									
6	100	86	72	59	46	35	22	10								
8	100	87	74	62	51	39	28	17	6							
10	100	88	76	65	54	43	33	24	13	4						
12	100	88	78	67	57	48	38	28	19	10	2					
14	100	89	79	69	60	50	41	33	25	16	8	1				
16	100	90	80	71	62	54	45	37	29	21	14	7	1			
18	100	91	81	72	64	56	48	40	33	26	19	12	6			
20	100	91	82	74	66	58	51	44	36	30	23	17	11	5		
22	100	92	83	75	68	60	53	46	40	33	27	21	15	10	4	
24	100	92	84	76	69	62	55	49	42	36	30	25	20	14	9	4
26	100	92	85	77	70	64	57	51	45	39	34	28	23	18	13	9
28	100	93	86	78	71	65	59	53	47	42	36	31	26	21	17	12
30	100	93	86	79	72	66	61	55	49	44	39	34	29	25	20	16

Relative Humidity = 54%



Relative Humidity (%)

Dew point depression: difference between Wet-bulb and Dry-bulb

Dry-Bulb Temperature (°F)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
32	90	79	69	60	50	41	31	22	13	4					
36	91	82	73	65	56	48	39	31	23	14	6				
40	92	84	76	68	61	53	46	38	31	23	16	9			
44	93	85	78	71	64	57	51	44	37	31	24	18	12		
48	93	87	80	73	67	60	54	48	42	36	31	25	19	14	8
52	94	88	81	75	69	63	58	52	46	41	36	30	25	20	15
56	94	88	82	77	71	66	61	55	50	45	40	35	31	26	21
60	94	89	84	78	73	66	63	58	53	49	44	40	35	31	27
64	95	90	85	79	75	70	66	61	56	52	48	43	39	35	31
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42
80	96	91	87	83	79	76	72	68	64	61	57	54	51	47	44
84	96	92	88	84	80	77	73	70	66	63	59	56	53	50	47
88	96	92	88	85	81	78	74	71	67	64	61	58	55	52	49
92	96	92	89	85	82	78	75	72	69	65	62	59	57	54	51
96	96	93	89	86	82	79	76	73	70	67	64	61	58	55	53
100	96	93	90	86	83	80	77	74	71	68	65	62	59	57	54

Dry Relative Humidity < 25%
Comfortable Relative Humidity 25-64%
Uncomfortable Relative Humidity ≥ 65%

Psychrometer

Humidity is determined by psychrometes and hygrometers. Hygrographs determine humidity fluctuations for a day or a week. Absolute air humidity is determined by psychrometes (from Greek psychros - cold). Psychrometes are of August and Assman types.

The psychrometer (from the Greek "psykhrós" = cold + "métron" = measure) is an instrument for measuring the humidity, or the amount of water vapor in the air.It is made of two identical thermometers, one of which -- surrounded by a moistened wick,gauze or muslin sleeve is always kept wet, and consequently is cooler than the air, dueto water evaporation. The drier the air around is, the faster the water evaporates and thegreater the temperature difference between the two thermometers.

This difference is used to determine through a "psychrometric table" (Table 3 next) -the humidity of the air. For example, the instrument shown in fig.indicates a dry bulbtemperature of 22.5ºC and a wet bulb temperature of 20.0ºC, i.e., a difference of 2.5ºC. The psychrometric table indicates a corresponding relative humidity of 80% (see the highlighted cells in *Table 3*).

Table 3

Psychrometric table Relative Humidity (%) - sea level
Dry Bulb Dry bulb minus Wet bulb (ºC)

°C	1	2	3	4	5	6	7	8	9	10
10	88	77	66	55	44	34	24	15	6	
11	89	78	67	56	46	36	27	18	9	
12	89	78	68	58	48	39	29	21	12	
13	89	79	69	59	50	41	32	22	15	7
14	90	79	70	60	51	42	34	25	18	10
15	90	81	71	61	53	44	36	27	20	13
16	90	81	71	63	54	46	38	30	23	15
17	90	81	72	64	55	47	40	32	25	18
18	91	82	73	65	57	49	41	34	27	20
19	91	82	74	65	58	50	43	36	29	22
20	91	83	74	67	59	53	46	39	32	26
21	91	83	75	67	60	53	46	39	32	26
22	91	83	76	68	61	54	47	40	34	28
23	92	84	76	69	62	55	48	42	36	30
24	92	84	77	69	62	56	49	43	37	31
25	92	84	77	70	63	57	50	44	39	33

The psychrometer was invented in 1825 by the German meteorologist Ernst FerdinandAugust. In 1892, another German meteorologist, Richard Assman, introduced the "Aspirated Psychrometer", an enhancement over the August model. In the Assman psychrometer, the air is forced to pass through the wet bulb, thus increasing the evaporation rate and making the measurement more precise (*Fig. 2*). Another variant is the "Sling Psychrometer", in which ventilation is achieved by whirling it in the air before taking a reading.

The August psychrometer has the following characteristics:

- *Practicity*: easy to use, fast results (in a few minutes).
- *Simplicity*: only two thermometers and a wet gauze.
- *Durability*: practically unlimited useful life.
- *Maintenance*: no moving parts, no electricity.
- *Accuracy*: around 5% when ventilated.
- *Long term stability*: practically does not change with time.
- *Reference*: may be used to check the accuracy of other humidity meters.

An alternative to the psychrometer is the Capacitive Hygrometer, a solid state device which indicates digitally the humidity, by measuring the dielectric constant of the moist air, by means of an electronic capacitor. It does not use any wet materials, but needs electricity to work. Its long term stability is fair, needing recalibration from time to time, and it does not work well in high relative humidity environments - when condensation may occur.

August psychrometer consists of two identical mercury thermometers fixed on a support. By temperature difference on dry and humid thermometers we can define absolute air humidity using a table or formula.

Psychrometer – a device that is used to determine the relative humidity, **psychrometer in August** (*Fig. 21*) consist of two equal thermometers, the bulb of one of which, i. e., the so-called "wet thermometer", is covered with a thin piece of muslin that is to be moistened, whilst the bulb of the second, the "dry thermometer", remains without covering. The dry thermometer indicates true temperature, while the wet thermometer, due to coldness of evaporation, indicates the lower a value, the drier the ambient air is. The two readings make possible accurate determination of relative and absolute humidity of the air, vapour pressure, and the dew point, either by calculation or by means of psychrometric tables. The difference between both temperatures, i.e., the "psychrometric difference", is, additionally, depending upon the speed, with which the air flows past the wet thermometer. Only above 2 m/sec further increase of speed will no longer be noticeable. The relevant equations for compensation and the psychrometric tables in use are based on a speed of ventilation of, at least, 2 m/sec. In the case of psychrometers with artificial ventilation, one is to take care therefore that this speed is guaranteed during measurement.

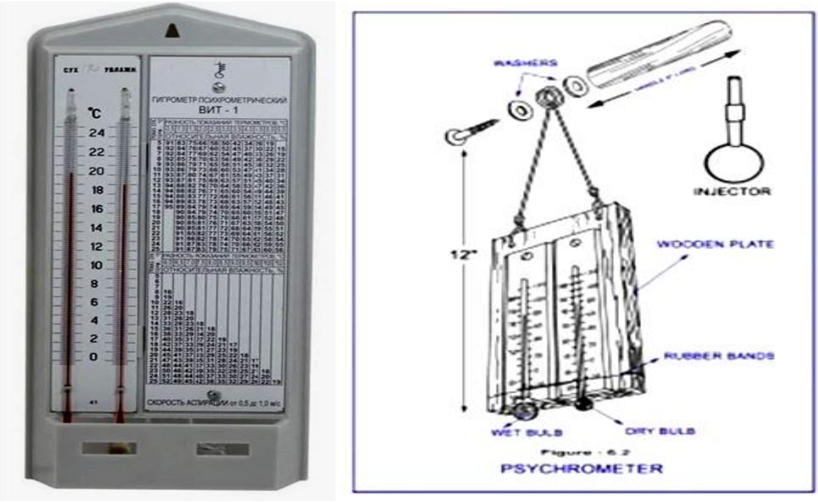


Fig. 21. August psychrometer.

Absolute humidity is calculated using the Regnault formula:

$$A = f - a \cdot (t - t_1) \cdot B,$$

where: A – the air absolute humidity at the current temperature in Hg mm;

f – maximum pressure of water vapour on the wet thermometer temperature (see the table of saturated water vapours, table 3);

a – psychrometric coefficient is 0.0011 for enclosed spaces;

t – temperature of the dry thermometer;

t_1 – temperature of the wet thermometer;

B – barometric pressure during the humidity determination, Hg mm.

The relative humidity is calculated using the following formula:

$$P = \frac{A \times 100\%}{F}$$

where: P – the value of relative humidity to be found, %;

A – absolute humidity, Hg mm;

F – maximum pressure of water vapour on the dry thermometer temperature, Hg mm (see the table of saturated water vapours, table 1).

Table 4

Maximum pressure of the air water vapour of premises

Air temperature, ºC	**Water vapourpres sure, Hg mm**	**Air temperature, ºC**	**Water vapourpres sure, Hg mm**
-20	0.94	17	14.590
-15	1.44	18	15.477
-10	2.15	19	16.477
-5	3.16	20	17.735
-3	3.67	21	18.630
-1	4.256	22	19.827
0	4.579	23	21.068
1	4.926	24	22.377
2	5.294	25	23.756
4	6.101	26	25.209
6	7.103	27	26.739
8	8.045	30	31.843
10	9.209	32	35.663
11	9.844	35	42.175
12	10.518	37	47.067
13	11.231	40	53.324
14	11.987	45	71.83
15	12.788	55	118.04
16	13.634	100	760.0

Psychrometric tables for the August psychrometer are used for the relative humidity (RH) determination (if the air velocity is 0.2 m/sec.). The value of RH is found at the point of the dry and wet thermometers data intersection, table 2.

The psychrometer operation is based on the fact that the rate of the water evaporation from the surface of the dampened psychrometer reservoir is proportional to the air dryness. The drier the air – the lower the wet thermometer result is in comparison with the dry thermometer due to the latent evaporation.

Assman psychrometer (*fig. 22*) The aspirator psychrometer by Assmann serves for measuring the air temperature and the humidity. Two parallel mounted, equal mercury thermometers are used. The bulb of one thermometer (wet bulb thermometer) is covered by a wick, which must be moistened for a measurement. The bulb of the other thermometer remains without wick. Both bulbs are encased by two radiation tubes. In order to achieve an effective radiation shield the surface of the instrument is polished. Depending on the amount of water vapour in the ambient air the water evaporates more or less from the wick of the wet bulb thermometer. The evaporative cooling causes the mercury column of the wet bulb thermometer to drop. The dry bulb thermometer is indicating the true air temperature. From the difference in temperature of both thermometers results the psychrometric depresssion. From this the relative humidity, the dew point temperature and the vapour pressure of the air may be computed or determined from tables. Both thermometer bulbs are ventilated during measurements by fan. The ventilating speed at the bulbs averages 3 m/s.

This type has been acknowledged as the meteorological standard instrument for decades. It obtains the greatest possible accuracy at the measurement of temperature and humidity of the atmosphere and, therefore, is suited also for control of other hygrometers. An aspirator ventilates both thermometers during the measurement. This eliminates errors which, in the case of one-sided aspiration, may be caused by the difference in the individual lags of the two thermometers. In the open air the device is used on the side sheltered from the wind or is held so that aspiration is not diminished (suction openings turned into the wind). The thermometers are protected against the influence of radiation by means of two, each, highly polished concentric enveloping tubes, which are thermically insulated against one another and against the body of the device, and which, likewise, are ventilated by the aspirator. This double protection against radiation enables on accurate measurement, even under the most powerful insolation of the device.

The psychrometric method principle consists in the water evaporation from a substrate. The humidity is deduced by determining the difference between the psychrometer's two thermometers because the evaporation and cooling of the water found on the surface of the thermometer's wet and tank depends on the humidity. This psychrometer has long been used as the standard wet and dry bulb psychrometer capable of highly accurate humidity measuring. The humidity of air can be precisely measured by this instrument. Two thermometers of insulated type, as (wet and dry bulbs), are located.

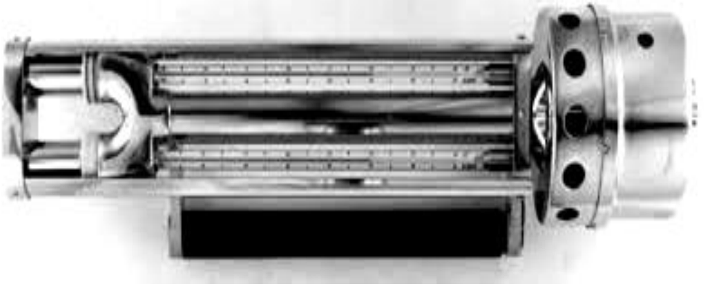


Fig. 22. Assman psychrometer.

Fig. 22.1. Assman psychrometer.

Determination of air humidity using the Assmann aspiration psychrometer

The significant disadvantage of August psychrometer is its dependence on the air velocity. The air velocity influences the evaporation intensity and wet thermometer cooling.

This disadvantage has been eliminated in Assmann psychrometer due to the usage of the ventilator. The ventilator produces the constant air movement ata speed of 4 m/sec near thermometer reservoirs. As a result data do not depend on the air velocity inside or outside of the premises. Furthermore, thermometer reservoirs of this psychrometer are protected by reflecting cylinders around psychrometer reservoirs from the radiant heat.

The cambric of Assmann aspiration psychrometer wet thermometer is dampened using the pipette, a spring of the aspiration device is set or the psychrometer with electrical ventilator is plugged in. After these procedures the psychrometer is hung up onto the support at the determination point. The data of wet and dry thermometers are taken 8-10 minutes later.

Absolute air humidity is calculated using the sprung formula:

$$A = t - 0{,}5 \times (t_1 - t_2) \times \frac{B}{755},$$

where: A – absolute air humidity in mm/Hg;

t – maximum pressure of water vapour on the wet thermometer temperature;

0.5 – constant psychometric coefficient;

t – temperature of the dry thermometer;

t_1 – temperature of the wet thermometer;

B – barometric pressure at the determination moment in mm/Hg.

Relative humidity is determined using the following formula:

$$P = A \times \frac{100\%}{F},$$

where: P – the value of relative humidity to be found, %;

A – absolute humidity, mm/Hg;

F – maximum humidity at the dry thermometer temperature, mm/Hg.

Relative humidity is determined using the psychrometric tables for aspiration psychrometers. The value of the relative humidity is found at the intersection point of the dry and wet thermometer data (see table 3).

Hair or membrane hygrometers are used for the determination of the relative humidity of the air. These devices measure the relative humidity directly. The hygrometer operation is based on the facts, that the degreased hair lengthens, and the membrane/diaphragm weakens when it is damp, and vice-versa when they are dry.

Table 5

Relative humidity standards for residential, public and administrative premises (abstract from Building Norms and Rules 2.04.05-86)

Season	**Relative humidity, %**	
	Optimal	**Allowable**
Warm	30-60	65*
Cold and transitional	30-45	65

Note:* Allowable humidity is 75% for regions with the estimated outdoor air relative humidity more than 75%. The standards are set for people who stay continuously in premises for more than 2 hours.

Table 6

Determining the temperature

Height from the floor, m	**temperature on the diagonal, °C**			**temperature difference on the horizontal °C**
	the inner wall	**the center of the room**	**the outer wall**	
0.1				
1.0				
1.5				
temperature difference on the vertical				

The first measurement of temperature is done at a height of 10 cm from the floor and characterizes the air at the foot level.

The second measurement is done at a height of 1.5 meter from the floor – in the respiration zone of a man.

The third measurement is done at a height of 50 cm from the ceiling and characterizes convection in the room. In hospital the second measurement is done at the level of bed. Measuring of temperature in horizontal line is done in three points: from the external angle to the internal angle at a height of 20 cm. The change of temperature in time is measured by thermograph. It is done in three places at a height of 1.5 cm from the floor.

The first measurement of temperature is done at a height of 10 cm from the floor and characterizes the air at the foot level.

The second measurement is done at a height of do on 1.5 meter from the floor – in the respiration zone of a man.

Table 7

Table of tangents

tg α	**< α°**	**tg α**	**< α°**	**tg α**	**< α°**	**tg α**	**< α°**
0.0175	1	0.2867	16	0.6009	31	1.0355	46
0.0349	2	0.3056	17	0.6249	32	1.1106	47
0.0524	3	0.3249	18	0.6494	33	1.1918	48
0.0699	4	0.3443	19	0.6745	34	1.2799	49
0.0875	5	0.3640	20	0.7002	35	1.3764	50
0.1051	6	0.3839	21	0.7265	36	1.4826	51
0.1228	7	0.4040	22	0.7536	37	1.6003	52
0.1405	8	0.4245	23	0.7813	38	1.732	53
0.1584	9	0.4452	24	0.8098	39	1.881	54
0.1763	10	0.4663	25	0.8391	40	2.050	5
0.1944	11	0.4877	26	0.8693	41	2.246	56
0.2126	12	0.5095	27	0.9004	42	2.475	57
0,2309	13	0.5317	28	0.9325	43	2.747	58
0.2493	14	0.5543	29	0.9657	44	3.078	59
0.2679	15	0.5774	30	1.0000	45	3.487	60

See annex. Determination of the relative humidity based on the Assmann psychrometer data (%).

Humidity deficit (the difference between the maximum and absolute air humidity) is determined using the table of saturated water vapours. The absolute air humidity, calculated using Regnault or Sprung formulas is subtracted from the value of the maximum air humidity according to the dry psychrometer thermometer.

Physiological humidity deficit (the difference between the maximum air humidity at 36.5°C body temperature and absolute air humidity) is determined using the same table of saturated water vapours (*see table 2*).

Dew point (the temperature when the absolute air humidity is maximum) is determined using the same table of saturated water vapours (*see table 3)* in reverse direction. When the absolute air humidity is equivalent to the maximum the temperature is found using the value of absolute humidity.

The scheme shows, that the rise of temperature provokes the maximum humidity increase in geometric progression, the absolute humidity – in arithmetical progression.When the air temperature rises, the relative humidity decreases. As a result the amount of water in the air (absolute humidity) is essentially lower in cold seasons than in summer, but it is closely related to saturation (maximum humidity). That is why the relative humidity is high in cold seasons and low in summer usually.

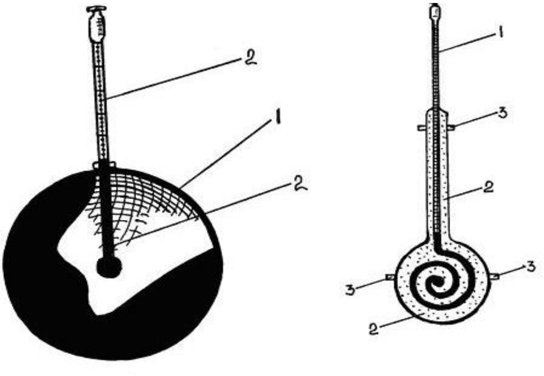
Daily temperature, air humidity and atmospheric pressure variation are determined using the thermograph, hygrograph and barograph respectively.

Sanitary regulations

Air humidity is dependent on the external humidity, the degree of overcrowding in the house, the type of activities in the household. The optimum relative humidity is between 35-65%, with an average of 50%. Humidity should be lower as the temperature increases to maintain a state of thermal comfort. Relative humidity should not be below 20-25% as it causes dryness of the mucosa. If the humidity is above 70-75%, it is considered that the air is damp.

Radiant temperature and wall temperature determination

Spherical thermometers are used for the radiant temperature determination in premises, wall thermometers – for the wall temperature determination (*see fig. 23 a, b*)



a *b*

Fig. 23. Thermometers for the radiant temperature determination
a – the section of the spherical black thermometer (1 – 15 cm diameter sphere covered with dull black paint; 2 – thermometer with the reservoir at the center of the sphere);
b – Wall thermometer with the flat turbinal reservoir (1 – thermometer; 2 – base cover (foam-rubber); 3 – sticky tape)

Spherical thermometer consists of the thermometer located inside the hollow sphere 10-15 cm in diameter and covered with porous polyurethane foam layer. This material has similar coefficients of the infrared radiation adsorption as the human skin.

Radiant temperature is also determined at a height of 0.2 and 1.5 meters above the floor.

The inertia the device is considerable (up to 15 min.), that is why the thermometer data must not be taken before that time.

At a height of 0.2 and 1.5 m the spherical thermometer data must not vary by more that 3ºC in comfortable microclimate conditions.

The values of the radiant temperature below are recommended for different premises.

Table 8

Standard values of radiant temperature for different premises

Type of premises	Radiant temperature, ºC
Residential premises	20
Classrooms, laboratories	18
Lecture-rooms. halls	16-17
Gymnasiums	12
Bathrooms, swimming pools	21-22
Hospital wards	20-22
Doctors' consulting rooms	22-24
Operating room	25-30

Special thermometers with the flat turbinal reservoir are used for the wall temperature determination. These thermometers are attached to the wall with special putty (wax with colophony addition) or alabaster. The wall temperature is also determined at a height of 0.2 and 1.5 meters above the floor. In some cases it is necessary to determine the temperature of the coldest parts of the wall.

The high levels of infrared irradiation in especially hot manufacture areas are measured using actinometers (solar radiation instrument) and are expressed in mcal/(cm^2×min).

The assessment of thermal areas – Hill katathermometry

When the physical factors of the microclimate do not affect the thermoregulatory system, the body is in a state of thermal balance expressed in a state of comfort. The body's thermal comfort or discomfort can be assessed either by determining the microclimate physical factor complex (by katathermometric method), or by exploring the physiological reactions of the body under the influence of these factors.

Hill katathermometry

This method is used to determine the air cooling capacity, which depends on the combined and simultaneous action of temperature, humidity and its movement. The Hill katathermometer is a specific thermometer with colored alcohol. Knowing the katafactor (F) and the time of descent (t), the air cooling power (H), called the katavalue is obtained. It can be calculated with a simple formula:

$$H = F/t$$

According to the katavalue, we can assess thermal areas. In the comfort zone, the dry katavalue should be between 4–6, and the wet katavalue - between 12 -18.

Table 9

Assessment of thermal areas

	Dry katavalue	**Wet katavalue**
Warm zone	<4	<12
Comfort zone	4 - 6	12 – 18
Cold zone	>6	>18

The Hill katathermometer, of dry type, is also used to determine lower velocities of air currents.

Measurement of the air velocity outdoors

What is necessary to measure air velocity outdoors?

1. The devices for the measurement.
2. The place of carrying out the measurements.
3. The course of the work.
4. Indices of anemometer:
   - before the measurement
   - after the measurement
   - the time of the measurement
5. Calculation the anemometer rotations number per second.

Measurement of the air movement velocity indoors

What is necessary to measure air velocity outdoors?

1. The devices for the measurement.
2. The place of carrying out the measurement.

3. The course of the work this the time when the alcohol falls down from 38° to 35° C.
   - F is the factor of catathermometer
   - Q1 is the average temperature of catathermometer
   - Q2 is the air temperature in the room
   - H is cooling ability of air

$$H = \frac{F}{t} =,$$

$$Q = Q1 - Q2 =$$

4. Determination of the velocity of air movement V by:

   4.1. the table

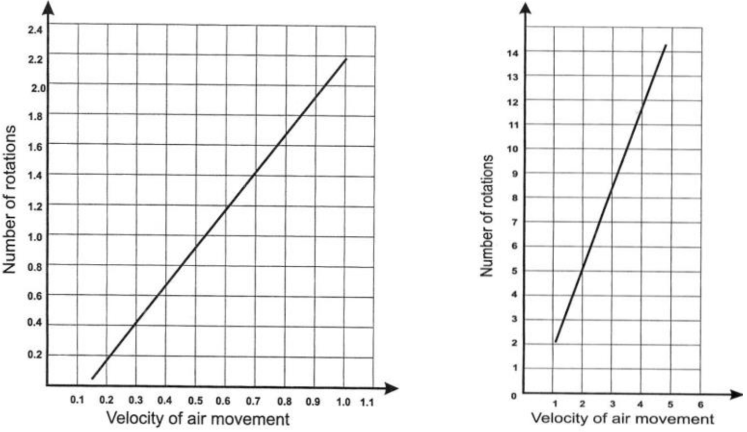
$$\frac{H}{Q}\_\_\_\_\_\_, \qquad V = \_\_\_\_\_\_\_\_\_\_$$

   4.2. the formula

$$V = \left(\frac{\frac{H}{Q} - 0{,}20}{0{,}40} \right)^2 = \_\_\_\_\_\_$$ for the air movement less than l m/s

$$V = \left(\frac{\frac{H}{Q} - 0{,}13}{0{,}47} \right)^2 =$$ for the air movement more than l m/s

Graph for determining the air movement velocity

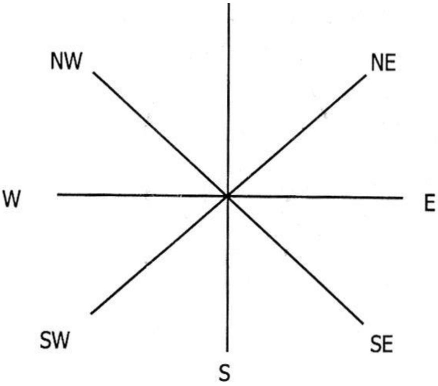


from 0.3 to 1 m/s

from 1 to 5 m/s

Hygienic assessment of the air movement direction

Case problem



In the given place the wind blows over the year:

1. The north wind was blowing for 90 days, North-West wind was blowing for 45 days,
2. The west wind was blowing for 30 days,
3. The south-West wind was blowing for 40 days,
4. The south wind was blowing for 30 days,
5. The south -East wind was blowing for 30 days,
6. The east wind was blowing for 30 days,
7. The north-East wind was blowing for 45 days,
8. The days without wind - 25.

Draw the "windrose" S: l cm corresponds to 20 days

Answer the following questions:

1. What wind direction prevails in this place?
2. Where must a living zone be built?
3. Where must industrial enterprises be built?

Methods of the assessment of human heat balance by calculation of heat emission

The assessment of human feeling of the heat/cold is done by comparing the heat production and heat emission during work. The heat emission is calculated as the sum of radiation, conduction and water evaporation.

The basic data are:

1. at rest the human heat production accounts to 0.8 – 1.5 kcal (3.34 – 6.27 kg) per 1 kg body weight per 1 hour, during hard work – 7-9 kcal/kg×h;
2. the body surface of the "average" human (170 cm of height and 65 kg of body weight) is approximately 1.8 m^2 (see table 10);
3. 100% of the body surface takes part in heat emission by conduction and sweat evaporation;
4. 80% of the body surface takes part in heat emission by radiation (see table 10). 40 % of the body surface takes part in heat emission by radiation relating to the one-sided heat radiation source.

Table 10

Dependence of the human body surface on body weight

Body weight, kg	Body surface, m^2	
	100 %	**80 %**
40	1.323	1.058
45	1.482	1.186
50	1.535	1.228
55	1.635	1.308
60	1.729	1.383
65	1.830	1.464
70	1.922	1.538
75	2.008	1.606
80	2.098	1.678
85	2.188	1.750
90	2.263	1.810
95	2.338	1.870
100	2.413	1.930

1. heat emission by radiation (radiation) can be calculated using the following formula:

$$q_{irr.} = 4.5\times(t_1 - t_2)\ s \qquad (1)$$

where:

q – heat emitted by radiation, kcal/h;
t_1 – body temperature, °C;
t_2 – internal wall surface temperature, °C;
s – body surface area, m^2.

2. Heat emission by conduction can be calculated using the following formula:

$$q_{con} = 6(t_1 - t_2) \times (0.5 + \sqrt{v})\ s \qquad (2.1)$$

$$q_{con} = 7.2\ (t_1 - t_2) \times (0.27 + \sqrt{v})s \qquad (2.2)$$

where :

q – heat emitted by conduction, kcal/h;
6; 0.5 – constant coefficients if air movement is less than 0.6 m/s;
t_1 – body temperature, °c;
t_2 – air temperature, °c;
7.2; 0.27 – constant coefficients if air movement is higher than 0.6 m/s;
v – air movement, m/s;
s – body surface area, m^2.

3. The maximum amount of water evaporated from the body surface can be calculated using the following formula:

$$p_{evap} = 15(f_{max} - f_{abs})\ X\ (0.5 + \sqrt{v})s \qquad (3.1)$$

where:

p_{evap} – water. evaporated from the body surface under this conditions, ml/h;
15 – constant coefficient;
f_{max} – maximum humidity at the temperature of the bodysrin;
f_{abs} – absolute humidity at the currant air temperature.
“f_{abs}” – can be calculated using the following formula:

$$f_{abs} = \frac{f_{rel} \times f_{\max}}{100\%}, \qquad (3.2)$$

where:

f_{max}– maximum humidity at the air temperature, hg mm. ;
$f_{rel.}$– relative humidity at the current air temperature, %;
($f_{max} - f_{abs}$) – physiological humidity deficit, hg mm.;
v – air movement, m/s;
s – body surface area, m^2.

Quantity of emitted heat may be calculated by multiplication of the result by 0.6 (calorie evaporating coefficient of 1 gr/ml water), or by putting the coefficient “9” in formula instead of “15” (0.6×15 = 9). It is necessary to remember that an adequate heat self-feeling remains stable if sweat evaporation is not more than 250 ml (it takes 150 kcal).

Example of calculation of emitted heat:

A “standard man” (body surface is 1.8 m^2, height – 170 cm, body weight – 65 kg) in light clothing with body temperature of 36°C works physically hard (570 kcal/h) in a room. Microclimate characteristics of the room are: air temperature 32ºC, average radiant temperature 22ºC, air movement 0.7 m/sec., relative humidity 70%. Evaluate the feeling of this man calculate the heat emission by radiation (heat emission from 80% of body surface) and conduction using the formula (1)

$$q_{irr} = 4.5(36-22)\times1.8\times0.8 = 90.72 \text{ kcal/h}$$

$$q_{cond} = 7.2\times(36-22)\times(0.27 + 0.83)\times1.46 = 160 \text{ kcal/h}$$

For the calculation of the maximum amount of water evaporated from the body surface, the maximum humidity at 36°C is determined according to the table the “maximum pressure of water vapour at different temperatures”. The maximum humidity is 42.2 mm/Hg according to this table.

Absolute humidity at the air temperature of 32°C is determined using the formula (3.2):

$$f_{abs} = \frac{70\% \times 42{,}2 \text{Hg mm}}{100\%} = 29{,}5 \text{ mm/Hg},$$

insert the calculation results into the formula (3.1):

$$p_{evap} = 15\times (42.2 - 29.5)\times(0.5 = 0.83)\times1.8 = 456 \text{ ml/h}.$$

the heat emission by evaporation under this condition is:

$$456\times0.6 = 273.6 \text{ kcal/h}.$$

calculate the total heat emission:

$$q = 90.\,72 + 160.0 + 273.6 = 524.32 \text{ kcal}.$$

Comparing the heat emission and heat production (570 kcal/h) in the assessment of the feelings of the human, we can conclude that the heat production exceeds the heat emission, and thus the microclimate of this room causes the “heating” effect.

Comment: these calculations ignore heat emission by breathing, i.e. inhaled air heating and water evaporation from the lung surface. This amount is near 15% of total heat emission in comfortable conditions. We inhale the air of certain temperature and humidity. The exhaled air is heated to the body temperature and is saturated to the 100% humidity.

Case problems

Case problem 1

The indoor air temperature is 25°C according to the dry thermometer and 19°C according to the wet thermometer of the Assman`s psychrometer, the indoor air movement is 1 m/sec. Determine the indoor equivalent-effective temperature and make a conclusion about the body heat balance.

Case problem 2

The indoor air temperature is 30°C according to the dry thermometer of the Assman`s psychrometer, indoor air movement is 0.8 m/sec, the absolute humidity is 12 mm/Hg, the average radiant temperature is 25°C. A man works physically hard. Determine the indoor resultant temperature and make a conclusion about the body heat balance.

Case problem 3

Calculate the hygienic microclimate in a class-room: - the average temperature is 22°C; the difference of the vertical temperature is 5.5°C; that of the horizontal temperature is 2°C, reading of the dry thermometer of the psychrometer is 21°C; the reading of the wet thermometer is 18°C; the period of time when the alcohol in the catathermometer falls from 38°C to 35°C is 128 seconds; the factor of the catathermometer (F) is 615.

Case problem 4

Calculate the hygienic microclimate in a secondary school gym: the average temperature is 19°C; the difference of the vertical temperature is 2°C; the difference of the horizontal teperature is 3.5°C; the reading of the dry thermometer of the psychrometer is 20°C, the reading of the wet thermometer is 12°C; the period of time when alcohol in the catathermometer falls from 38°C to 35°C is l min 42sec, the factor of the catathermometer (F) is 615.

Case problem 5

Calculate the hygienic microclimate in a therapeutic ward for adults. It is characterized by the following parameters: the average temperature is 24°C, the vertical temperature difference is 3°C; the horizontal temperature difference is 1.5°C; the reading of the dry thermometer of the Assman's psychrometer is 24°C, the reading of the wet thermometer is 17°C; the period of time when alcohol falls down in a catathermometer falls from 38°C to 35°C is 133 seconds, the factor of the catathermometer (F) is 615.

SPEED MOVEMENT OF AIR

Anemometer is a device used for measuring wind speed, and is a common weather station instrument. The term is derived from the Greek word *anemos*, which means "wind", and is used to describe any wind speed measurement instrument used in meteorology. The first known description of an anemometer was given by Leon Battista Alberti in 1450.

Cup anemometers. A simple type of anemometer was invented by Dr. John Thomas Romney Robinson of Armagh Observatory in 1845. It consisted of four hemispherical cups mounted on horizontal arms, which were fixed on a vertical shaft. The air flow past the cups in any horizontal direction, turned the shaft at a rate that was proportional to the wind speed. The refore, the number of the turns of the shaft within a certain periode of time produced a value proportional to the average wind speed for a wide range of speeds

When Robinson first designed his anemometer, he asserted that the cups moved one-third of the speed of the wind, irrespective of by the cup size or arm length. This was apparently confirmed by some early independent experiments, but it was incorrect. Instead, the ratio of the speed of the wind and that of the cups, the anemometer factor, depends on the dimensions of the cups and arms, and may have a value between two and a little over three. Every previous experiment involving an anemometer had to be repeated.

The three-cup anemometer developed by Canadian John Patterson in 1926 and subsequent cup improvements by Brevoort and Joiner (USA) in 1935 led to a cupwheel design which was linear and had an error of less than 3% up to 60 mph (97 km/h). Patterson found that each cup produced the maximum torque when it was at 45° to the wind flow. The three-cup anemometer also had a more constant torque and reacted more quickly to gusts than the four-cup anemometer.

The three-cup anemometer was further modified by Australian Dr Derek Weston in 1991 to measure both wind direction and wind speed. Weston added a tag to one cup, which caused the cupwheel speed to increase and decrease as the tag moved alternately with and against the wind. Wind direction is calculated based on these cyclical changes in cupwheel speed, while the wind speed is determined from the average cupwheel speed.Three-cup anemometers are currently used as the industry standard for wind resource assessment studies and practice.

Fig. 24. Cup anemometer type.

Three four types of cup anemometer:
1) Windmill anemometers
2) Hot Wire / Film Anemometer
3) Laser Doppler anemometers
4) Sonic anemometers

Vane anemometers. The other form of mechanical velocity anemometer is the *vane anemometer*. It may be described as a windmill or a propeller anemometer. Unlike the Robinson anemometer whose axis of rotation is vertical, the axis on the vane anemometer must be parallel to the direction of the wind and therefore horizontal. Furthermore, since the wind varies in direction and the axis has to follow its changes, a wind vane or some other contrivance to fulfill the same purpose must be employed.

Vane anemometer thus combines a propeller and a tail on the same axis to obtain accurate and precise wind speed and direction measurements by the same instrument. The speed of the fan is measured by a tachometer and converted to a windspeed by an electronic chip. Hence, volumetric flowrate may be calculated if the cross-sectional area is known.

In cases when the direction of the air motion is always the same, as in ventilating shafts of mines and buildings, wind vanes known as air meters are employed, and give satisfactory results.

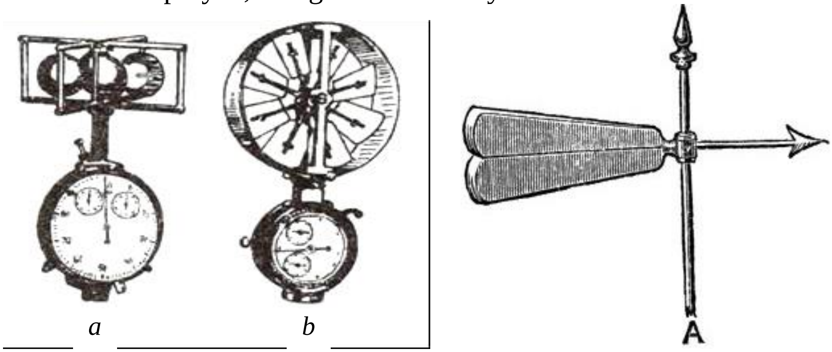


Fig. 24.1. b) cup anemometers, c) vane anemometers.

Hot Wire anemometers – for this, a very thin and electrically heated wire is used, which is cooled as wind flows past. This type of anemometer allows experts to obtain a relationship between the flow speed and resistance of the wire. Classifications of hot wire anemometers include Constasnt Current Anemometer (CCA), Constant Votage Anemometer (CVA), and Constant Temperature Anemometer (CTA). In some cases, Pulse Width Modulation (PWM) anemometers are also used.

*Fig. 2*5. Hot Wire anemometers.

Laser Doppler anemometers – The Laser Doppler Anemometer, or LDA, is a widely accepted tool for fluid dynamic investigations in gases and liquids and has been used as such for more than three decades. It is a well-established technique that gives information about flow velocity. Its non-intrusive principle and directional sensitivity make it very suitable for applications with reversing flow, chemically reacting or high-temperature media and rotating machinery, where physical sensors are difficult or impossible to use. It requires tracer particles in the flow. The method's particular advantages are: non-intrusive measurement, high spatial and temporal resolution, no need for calibration and the ability to measure in reversing flows.

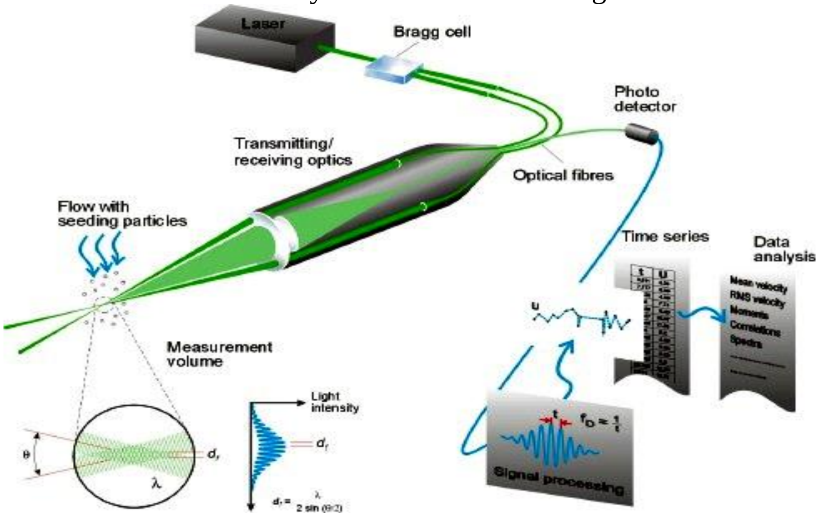


Fig. 26. Laser Doppler Anemometer.

LDA principle.

Principles

The basic configuration of an LDA consists of:

- A continuous wave laser
- Transmitting optics, including a beam splitter and a focusing lens
- Receiving optics, comprising a focusing lens, an interference filtre and a photodetector
- A signal conditioner and a signal processor.

Advanced systems may include traverse systems and angular encoders. A Bragg cell is often used as the beam splitter. It is a glass crystal with a vibrating piezo crystal attached. The vibration generates acoustical waves acting like an optical grid.

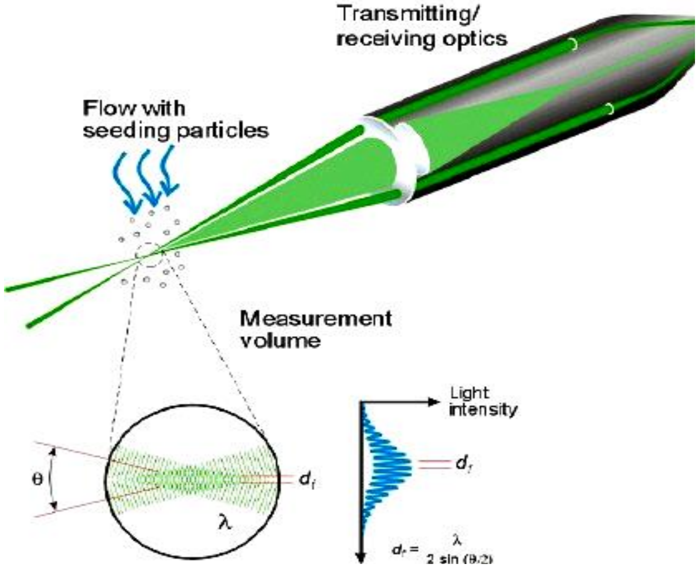
Fig. 27. Bragg cel.

The Bragg cell used as a beam splitter.

The output of the Bragg cell is two beams of equal intensity with frequencies f0 and fshift. These are focused into optical fibres bringing them to a probe.

In the probe, the parallel exit beams from the fibres are focused by a lens to intersect in the probe volume.

The probe volume



The probe and the probe volume.

The probe volume is typically a few millimeters long. The light intensity is modulated due to interference between the laser beams. This produces parallel planes of high light intensity, so called fringes. The fringe distance df is defined by the wavelength of the laser light and the angle between the beams:

$$d_r = \frac{\lambda}{2\sin(\theta/2)}.$$

Each particle passage scatters light proportional to the local light intensity. Flow velocity information comes from light scattered by tiny "seeding" particles carried in the fluid as they move through the probe volume. The scattered light contains a Doppler shift, the Doppler frequency fD, which is proportional to the velocity component perpendicular to the bisector of the two laser beams, which corresponds to the x axis shown in the probe volume. The scattered light is collected by a receiver lens and focused on a photo-detector. An interference filtre mounted before the photo-detector passes only the required wavelength to the photo-detector. This removes noise from ambient light and from other wavelengths.

Signal processing

The photo-detector converts the fluctuating light intensity to an electrical signal, the Doppler burst, which is sinusoidal with a Gaussian envelope due to the intensity profile of the laser beams. The Doppler bursts are filtered and amplified in the signal processor, which determines fD for each particle, often by frequency analysis using the robust Fast Fourier Transform algorithm. The fringe spacing, df provides information about the distance travelled by the particle The Doppler frequency fD provides information about the time:

$$t = 1/fD$$

Since velocity equals distance divided by time, the expression for velocity thus becomes: Velocity

$$V = df \times fD$$

Determination of the sign of the flow direction

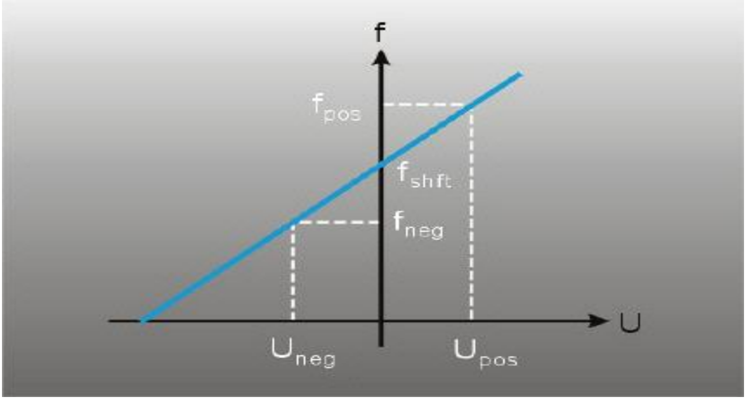


Fig. 28. Signal processing.

Doppler frequency to velocity transfer function for a frequency shifted LDA system.

The frequency shift obtained by the Bragg cell makes the fringe pattern move at a constant velocity. Particles which are not moving will generate a signal of the shift frequency fshift. The velocities Vpos and Vneg will generate signal frequencies fpos and fneg , respectively. LDA systems without frequency shift cannot distinguish between positive and negative flow direction or measure 0 velocity. LDA systems with frequency shift can distinguish the flow direction and measure 0 velocity.

Two- and three-component measurements

To measure two velocity components, two extra beams can be added to the optics in a plane perpendicular to the first beams. All three velocity components can be measured by two separate probes measuring two and one components, with all the beams intersecting in a common volume as shown below. Different wavelengths are used to separate the measured components. Three photo-detectors with appropriate interference filtres are used to detect scattered light of the three wavelengths.

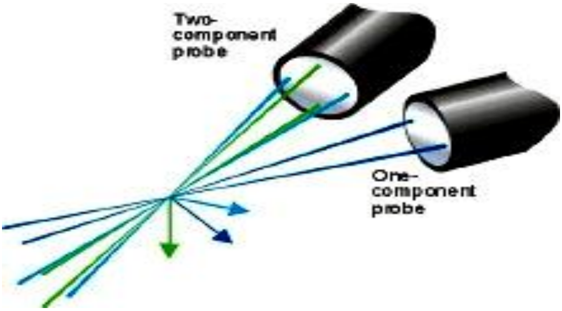


Fig. 29. LDA optics for measuring three velocity components.

Modern LDA systems employ a compact transmitter unit comprising the Bragg cell and colour beam splitters to generate up to 6 beams: unshifted and frequency shifted beams of three different colours. These beams are passed to the probes via optical fibres.

Seeding particles

Liquids often contain sufficient natural seeding, whereas gases must be seeded in most cases. Ideally, the particles should be small enough to follow the flow, yet large enough to scatter sufficient light to obtain a good signal-to-noise ratio at the photo-detector output. Typically the size range of particles is between 1 µm and 10 µm. The particle material can be solid (powder) or liquid (droplets).

Sonic anemometers – anemometers of the type use ultrasonic sound waves to help measure the velocity of wind. Based on the time of flight that sonic pulses take between pairs of transducers, wind speed is measured. Sonic anemometers provide fast and accurate measurements of three dimensional wind speed and are widely used by the Centre for Atmospheric Science to make both routine wind and detailed turbulence measurements. These instruments are able to make wind speed measurements over the range 0 – 60 m/s, with a resolution of 1 cm/s at rates up to 100Hz. This speed and resolution allows turbulent structure on scales of a few cm to be resolved.Sonic anemometers operate by measuring the time taken for a pulse of sound to travel between a pair of transducers. This time depends on the distance between the transducers, the speed of sound and the air speed along the axis of the transducers as follows:

$$T = L/(c+v)$$

Where:

T is time,
L is the distance between transducers,
c is the speed of sound,
v is the air speed along the transducer axis.

The speed of sound in air is dependant on temperature, pressure and suspended contaminants such as dust and fog. In order to obtain the air speed between the transducers, each transducer alternates as transmitter and receiver so that pulses travel in both directions between them. The air speed is calculated from the pulse times in each direction as follows:

$$v = 0.5L(1/t1-1/t2)$$

The speed of sound, from which an estimate of air temperature may be derived may be calculated from the pulse times as follows:

$$c = 0.5L(1/t1+1/t2)$$

By arranging three pairs of transducers on three different axis, three dimensional wind speed and hence direction and wind angle is obtained. Due to the high sensitivity of sonic anemometer measurements, measurements will be affected by small flow distortions caused by the airflow past the transducers and their supporting struts. There are various designs of anemometer head which attempt to minimise such flow distortions. Additionally most manufacturers perform careful wind tunnel calibrations and automatically implement a direction dependant correction for any distortion which does occur. Sonic anemometers are able to operate in most conditions experienced in the atmosphere, however heavy rain affects data quality from some models as water droplets on the transducers significantly effect pulse times. This problem is generally minimised by checking the signal quality of received sonic pulses and rejecting those with poor signal quality. Additionally if ice builds up on the transducers measurements are similarly affected. In order to overcome this problem some models are fitted with anti-ice heating.

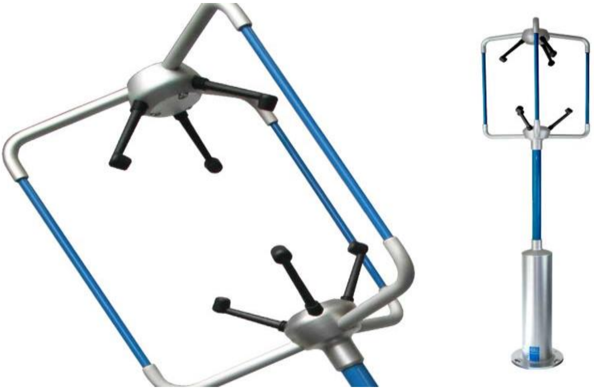


Fig. 30. Sonic anemometers.

ATMOSPHERIC PRESSURE

Air is a tangible material substance and as a result has **mass**. Any object with mass is influenced by the universal force known as **gravity**. Newton's Law of Universal Gravitation states: any two objects separated in space are attracted to each other by a force proportional to the product of their masses and inversely proportional to the square of the distance between them. On the Earth, gravity can also be expressed as a **force of acceleration** of about 9.8 meters per second per second. As a result of this force, the speed of any object falling towards the surface of the Earth accelerates (1st second – 9.8 meters per second, 2nd second – 19.6 meters per second, 3rd second – 29.4 meters per second, and so on.) until **terminal velocity** is attained.

The surface of the earth is at the bottom of an atmospheric sea. The standard atmospheric pressure is measured in various units:

1 atmosphere = 760 mmHg = 29.92 inHg = 14.7 lb/in2 = 101.3 KPa

The fundamental SI unit of pressure is the Pascal (Pa), but it is a small unit so kPa is the most common direct pressure unit for atmospheric pressure. Since the static fluid pressureis dependent only upon density and depth, choosing a liquid of standard density like mercury or water allows you to express the pressure in units of height or depth, e.g., mmHg or inches of water. The mercury barometer is the standard instrument for atmospheric pressure measurement in weather reporting. The decrease in atmospheric pressure with height can be predicted from the barometric formula. The unit mmHg is often called torr, particularly in vacuum applications: 760 mmHg = 760 torr. For weather applications, the standard atmospheric pressure is often called 1 bar or 1000 millibars. This has been found to be convenient for recording the relatively small deviations from standard atmospheric pressure with normal weather patterns. The standard atmosphere (symbol: atm) is a unit of pressure defined as 101325 Pa (1.01325 bar), equivalent to 760 mm/Hg (torr), 29.92 mm/Hg and 14.696 psi.

Thus the standard consists of a tabulation of values at various altitudes, plus some formulas by which those values were derived. For example, at mean sea level the standard gives a pressure of 101,325 pascals (14.6959 psi) (1 atm), a temperature of 15 °C (59 °F), a temperature lapse rate of −6.5 °C (20.3 °F) per km (roughly −2 °C (-3.6 °F) per 1,000 ft), and a density of 1.2250 kilograms per cubic meter (0.07647 lb/cu ft). The tropospheric tabulation continues to 11,000 meters (36,089 ft), where the pressure has fallen to 22,632 pascals (3.2825 psi), the temperature to −56.5 °C (−69.7 °F), and the density to 0.3639 kilograms per cubic meter (0.02272 lb/cu ft). Between 11 km and 20 km, the temperature remains constant.

Atmospheric pressure, sometimes also called barometric pressure, is the pressure exerted by the weight of air in the atmosphere of Earth (or that of another planet). In most circumstances atmospheric pressure is closely approximated by the hydrostatic pressure caused by the weight of air above the measurement point. Low-pressure areas have less atmospheric mass above their location, whereas high-pressure areas have more atmospheric mass above their location. Likewise, as elevation increases, there is less overlying atmospheric mass, so that atmospheric pressure decreases with increasing elevation. On average, a column of air one square centimetre [cm^2] (0.16 sq in) in cross-section, measured from the sea level to the top of the atmosphere, has the mass of about 1.03 kilograms (2.3 lb) and weight of about 10.1 newtons (2.3 lb_f). That force (across one square centimeter) is the pressure of 10.1 N/cm^2 or 101,000 N/m^2. A column 1 square inch (6.5 cm^2) in cross-section would have the weight of about 14.7 lb (6.7 kg) or about 65.4 N.

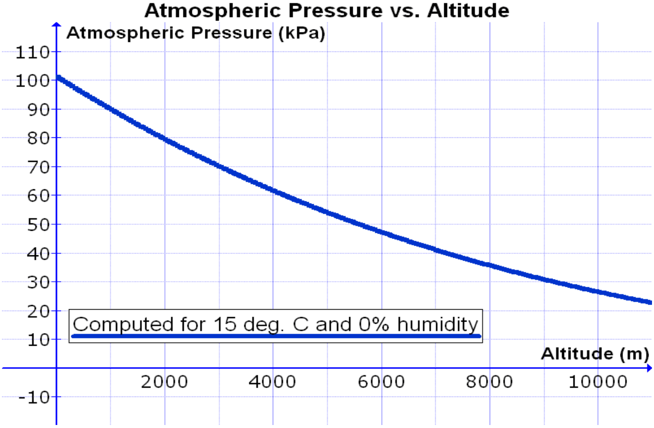
Altitude variation. Pressure varies smoothly from the Earth's surface to the top of the mesosphere. As altitude increases, atmospheric pressure decreases. One can calculate the atmospheric pressure at a given altitude. Temperature and humidity also affect the atmospheric pressure, and it is necessary to know these to compute an accurate figure. The graph was developed for the temperature of 15 °C and the relative humidity of 0%.

Variation in atmospheric pressure with altitude, computed for 15 °C and 0% relative humidity.

At low altitudes above the sea level, the pressure decreases by about 1.2 kPa for every 100 meters. For higher altitudes within the tropospheric, the following equation (thebarometric formula) relates atmospheric pressure *p* to altitude *h*

$$p \approx p_0 \times \left(1 - \frac{L \times h}{T_0}\right)\frac{gM}{RL} \approx p_0 \times \left(1 - \frac{g \times h}{c_p - T_0}\right)\frac{C_p M}{R}$$

$$p \approx p_0 \times \exp\left(\frac{g \times M \times H}{R \times T_0}\right)$$



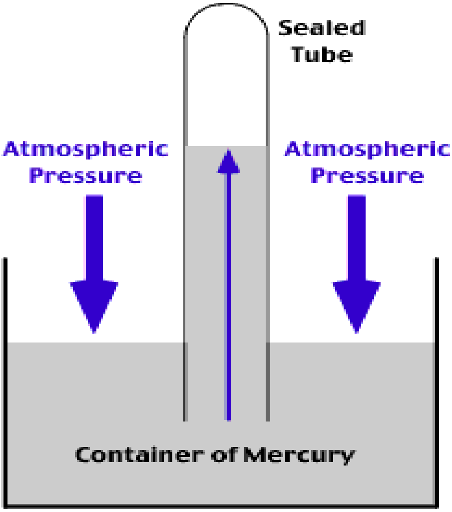
Where the constant parameters are as described below:

Parameter	Description	Value
p_0	sea level standard atmospheric pressure	101325 Pa
L	temperature lapse rate = g/c_p for dry air	0.0065 K/m
c_p	constant pressure specific heat	~ 1007 J/(kg·K)
T_0	sea level standard temperature	288.15 K
g	Earth-surface gravitational acceleration	9.80665 m/s^2
M	molar mass of dry air	0.0289644 kg/mol
R	universal gas constant	8.31447 J/(mol·K)

The atmosphere having weight exerts, therefore, a constant but variable amount of pressure upon the earth's surface. The amount of pressure exerted by the atmosphere is dependent upon the quantity of moisture it is hholding and upon its temperature. The degree of pressure which it exerts is subject to constant fluctuations through the incessant movements occurring between its higher and lower strata, as will as through its movements from one point to another over the earth’s surface, the latter movements giving rise to what are known as winds.The movements of the atmosphere are produced by an increase or a decrease in the amount of moisture at one point of the earth’s surface as compared with other surrounding points, such increase or decrease in the amount of moisture being brought about through precipitation from the clouds, or through evaporation of moisture from the earth’s surface. On the other hand, movements of the atmosphere are also brought about by an increase or decrease in its temperature as a result of a greater amount of heat radiation at one point than at another, but more particularly through the confluence of the high temperature of the torrid zone and the influnce of the low temperature of the polar regions.

Measuring Atmospheric Pressure

Any instrument that measures air pressure is called a **barometer**. The first measurement of atmospheric pressure began with a simple experiment performed by ***Evangelista Torricelli*** in 1643. In his experiment, Torricelli immersed a tube, sealed at one end, into a container of mercury (*see Fig. 31 below*). Atmospheric pressure then forced the



Torricelli's Barometer

Fig. 31. Diagram showing the construction of Torricelli's barometer.

mercury up into the tube to a level that was considerably higher than the mercury in the container. Torricelli determined from this experiment that the pressure of the atmosphere is approximately 30 inches or 76 centimeters (one centimeter of mercury is equal to 13.3 **millibars**). He also noticed that height of the mercury varied with changes in outside weather conditions.

The most common type of barometers used in homes is the aneroid barometer (*Fig. 32*). Inside this instrument is a small, flexible metal capsule called an aneroid cell. In the construction of the device, a partial vacuum is created inside the capsule so that small changes in outside air pressure cause the capsule to expand or contract. The size of the aneroid cell is then calibrated and any change in its volume is transmitted by springs and levers to an indicating arm that points to the corresponding atmospheric pressure.

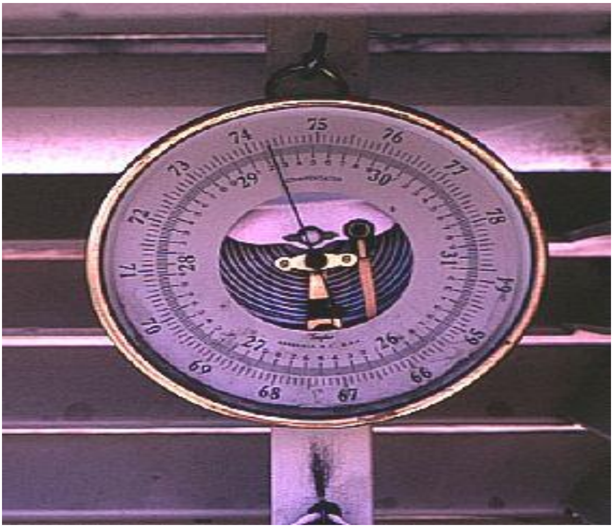


Fig. 32. Aneroid barometer.

For climatological and meteorological purposes, **standard sea-level pressure** is said to be 76.0 cm or 29.92 inches or 1013.2 millibars Scientists often use the **kilopascal** (kPa) as their preferred unit for measuring pressure. 1 kilopascal is equal to 10 millibars. Another unit of force sometimes used by scientists to measure atmospheric pressure is the **newton**. One millibar equals 100 newtons per square meter (N/m^2).

Barometer (from Gr. βάρος, pressure, and μέτρον, measure), an instrument by which the weight or pressure of the atmosphere is measured. The ordinary or mercurial barometer consists of a tube about 36 in. long, hermetically closed at the upper end and containing mercury. In the "cistern barometer" the tube is placed with its open end in a basin of mercury, and the atmospheric pressure is measured by the difference of the heights of the mercury in the tube and the cistern. In the "siphon barometer" the cistern is dispensed with, the tube being bent round upon itself at its lower end; the reading is taken of the difference in the levels of the mercury in the two limbs. The "aneroid" barometer (from the Gr. α- privative, and νηρός, wet) employs no liquid, but depends upon the changes in volume experienced by an exhausted metallic chamber under varying pressures. "Baroscopes" simply indicate variations in the atmospheric pressure, without supplying quantitative data. "Barographs" are barometers which automatically record any variations in pressure.

Mercurial barometer

Barometer is a scientific instrument used in meteorology to measure atmospheric pressure. Pressure tendency can forecast short term changes in the weather. Numerous measurements of air pressure are used within surface weather analysis to help find surface troughs, high pressure systems and frontal boundaries.

Barometers and pressure altimeters (the most basic and common type of altimeter) are essentially the same instrument, but used for different purposes. An altimeter is intended to be transported from place to place matching the atmospheric pressure to the corresponding altitude, while a barometer is kept stationary and measures subtle pressure changes caused by weather. The main exception to this is ships at sea, which can use a barometer because their elevation does not change. Due to the presence of weather systems, aircraft altimeters may need to be adjusted as they fly between regions of varying normalized atmospheric pressure.

The **Siphon barometer** consists of a tube bent in the form of a siphon, and is of the same diameter throughout. A graduated scale passes along the whole length of the tube, and the height of the barometer is ascertained by taking the difference of the readings of the upper and lower limbs respectively. This instrument may also be read by bringing the zero-point of the graduated scale to the level of the surface of the lower limb by means of a screw, and reading off the height at once from the surface of the upper limb. This barometer requires no correction for errors of capillarity or capacity. Since, however, impurities are contracted by the mercury in the lower limb, which is usually in open contact with the air, the satisfactory working of the instrument comes soon to be seriously interfered with.

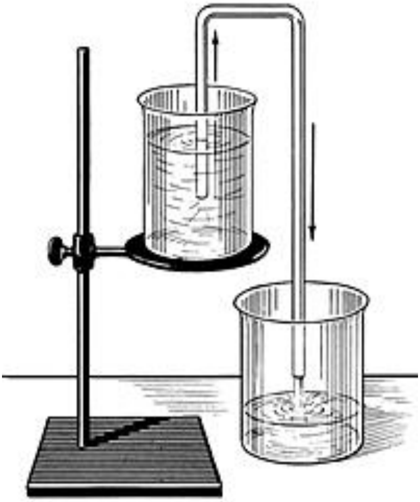


Fig. 33. Siphon barometer.

Cistern barometer – This barometer is subject to two kinds of error, the one arising from capillarity, and the other from changes in the level of the surface of the cistern as the mercury rises and falls in the tube, the latter being technically called the *error of capacity*. If a glass tube of small bore be plunged into a vessel containing mercury, it will be observed that the level of the mercury in the tube is not in the line of that of the mercury in the vessel, but somewhat below it, and that the surface is convex. The capillary depression is inversely proportional to the diameter of the tube. In standard barometers, the tube is about an inch in diameter, and the error due to capillarity is less than .001 of an inch. Since capillarity depresses the height of the column, cistern barometers require an addition to be made to the observed height, in order to give the true pressure, the amount depending, of course, on the diameter of the tube.

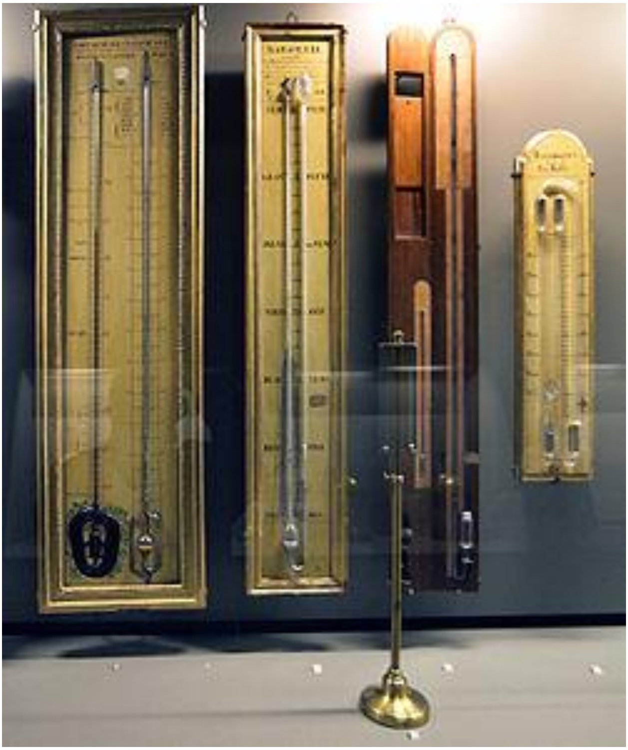


Fig. 34. Cistern barometer.

The error of capacity arises in this way. The height of the barometer is the perpendicular distance between the surface of the mercury in the cistern and the upper surface of the mercurial column. Now, when the barometer falls from 30 to 29 inches, an inch of mercury must flow out of the tube and pass into the cistern, thus raising the cistern level; and, on the other hand, when the barometer rises, mercury must flow out of the cistern into the tube, thus lowering the level of the mercury in the cistern. Since the scales of barometers are usually engraved on their brass cases, which are fixed (and, consequently, the zero-point from which the scale is graduated is also fixed), it follows that, from the incessant changes in the level of the cistern, the readings would be sometimes too high and sometimes too low, if no provision were made against this source of error.

Barometer scale – the metric scale is most commonly employed for scientific observations. On this scale the standard pressure at sea-level is taken as 760 mmHg, at the temperature O°C. In the standards of the United States and Great Britain measurement is made in inches, tenths, and hundredths, at the temperature 32°F. The standrd pressure at sea level is 30 inches.

The vernier – in order to facilitate the accurarte reading of the barometer, a small movable scale, called a “vernier,” is attached to the side of the fixed scale, and is moved upward and downward by means of a rack and pinion arrangement. This allows the reading of the fractional parts of the millimeter.

To read the fractional parts of a millimeter of the pressure recorded by the barometer, the zero-point of the vernier is brought on a level with the top of the meniscus of the point at which it cuts off the light passing between it and the top of the meniscus. The line on the vernier scale that is on a level with, or nearest to, one of the lines on the fixed scale indicates the number of tenths of a millimeter to be added to the reading of the fixed scale; *e,g.,*the reading of the fixed scale is 764 mm., and the line on the vernier scale that is on the same level with, or nearest to, one of the lines on the fixed scale is the eighth, then the correct reading of the barometer is 764.8 mm.

Temperature on the barometer – a small mercurial thermometer attached to the metal case surrounding the barometer tube records the temperature on the barometer. The reading of this thermometer should always be taken before the reading of the barometer itself, otherwise the breath of the observer and the heat given off from his body might change its reading, and this affects the accuracy of his observations.

Method and place of barometer installation – barometers should be installed in a room protected from direct sunlight and removed from marked temperature fluctuations.

Barometer readings – the first point to be observed in reading the barometer is to note and record the temperature on the thermometer attached to it. The next point to observe is whether the instrument is properly suspended, after which the zero-point of the scale is adjusted by bringing the surface of the mercury in the cistern to the “fiducial point,”by either raising or lowering the bottom of the cistern, as may be required, by means of the screw attached beneath it. The vernier is now raised above the top of the column of the mercury in the tube and then carefully brought down on the level with the top of the meniscus. In regulating the vernier it is very essential that the eye of the observer should also be on the a level with the top of the meniscus. The number of pressure in millimeters is shown on the fixed scale and the tenths of a millimeter-on the vernier scale.

Corrections of barometric readings – to obtain accurate results, as well as for purposes of comparison, several corrections of barometer readings are necessary: (*a*) for variations in the meniscus according to the diameter of the barometer tube. For a tube of 12 mm. diameter the correction in so small that it has but little influence on the results and may be ignored. For the same reasons (*b*) variations in the barometer scale, as well as (*c*) variations in the glass tube under different conditions, may be ignored. The only important influence on the barometric reading for which correction must be made is that which is due to the expansion and contraction of the mercury at different degrees of temperatures. With an increase of 1°C, of temperature, mercury expands at the rate of 0.00018 times of its volume, consequently the influence of varying degrees of heat on the height of the column of mercury in the barometer tube must be eliminated after every observation. Correction of the barometric temperature reading is made according to the formula:

$$b/0 = \frac{\frac{b}{t}}{1+a_t},$$

reducing the reading to 0°C temperature.

Where:

b/0 – the barometer reduced to 0°C,
b/t – the barometer as it is read,
a – the constant, 0.00018 the coefficient of expansion of mercury for each degree of temperature.
t – temperature on the barometer.

Example – the barometer stands at 768.4 mmHg., and the temperature at 18.3°C.

$$b/0 = \frac{768{,}4}{1 + 0{,}00018 \times 18{,}3}$$

With the temperature below 0°C the formula is

$$b/0 = \frac{\frac{b}{t}}{1 - a_t},$$

Stationary barometer – in the stationary barometer the bottom of the cistern is fixed and zero-point of the scale cannot be adjusted at each reading as in the cistern barometer. The sacle is also fixed, but it is arranged in such a manner, however, that its zero-point indicates a barometric pressure of 760 mm Hg

Differential barometer

This type of barometer consists of a glass tube of the same diameter throughout its length, and which is bent in the from of the letter S.

It is scaled at its upper end, but the lower arm of the tube , which is U- shaped, is open to the air. The tube is somewhat constricted at the middle whereby the movement of the mercury is impeded, to a slight degree. The upper portion of the tube contains vacuum, hence the contraction and expansion of the mercury lowers and raises the level of the column in both arms of the tube. The scale is either fixed or movable, the method of the barometer reading depending on this point. The distance between the upper and lower levels of the mercury is the height of the mercurial column. This type of barometer is used principally in determining degrees of altitde and the height of mountains.

Fig. 35. Stationary barometer.

Aneroid barometer

Aneroid barometer consists of a thin-walled, metallic chamber which has been nearly released of of air, its sides being held apart by a strong spring. The pressure of the atmosphere on the sides of the chamber is indicated by means of a pointer which is attached to the spring and moves over a dial. Aneroid barometers are constructed so to be self- recording- like a thermograph.

Fig. 36. Aneroid barometer.

Correction of readings – three corrections of aneroid barometer are necessary:

a) for temperature,
b) for the divisions on the dial,
c) for the altitude of the place of observation.

TEST

1. *Measures used for the determination of the microclimate factors action on the organism are*:
    a) physical
    b) chemical
    c) bacteriologic
    d) physiological
    e) psychological

2. *Catathermometer is used for the determination of:*
    a) air cool ability
    b) air speed
    c) air temperature
    d) relative air humidity
    e) action of the microclimate factors

3. *The effective temperature shows the:*
    a) air temperature
    b) caloric effect produced by the climatic factors
    c) humidity and air motion
    d) sum action of the microclimate factors
    e) selective action of the air temperature

4. *Which of the following elements determines the resultant temperature*
    a) air temperature
    b) air humidity
    c) air speed
    d) atmospheric pressure
    e) caloric radiation

5. *Which of the following statements about ultraviolet is false*:
    a) ultraviolet causes cell lesions
    b) ultraviolet has stimulating effect
    c) ultraviolet increases the organism resistance

    d) ultraviolet increases the metabolism
    e) ultraviolet poduces the melanin pigment

6. *Which of the following statements about air viciation assessment is true:*
    a) air viciation is done only in closed areas
    b) air viciation is done only in the atmospheric air
    c) air viciation is a result of the physiologic process
    d) air viciation is the result of some economic and social activities
    e) air viciation is done in occupation areas

7. *Artificial sources of air pollution are*
    a) air and ground transport
    b) soil erosion
    c) industrial process
    d) burning process
    e) volcano eruption

8. *Natural sources of air pollution are:*
    a) air and ground transport
    b) soil erosion
    c) industrial process
    d) burning process
    e) volcano eruption

9. *Indirect action on the air pollution are:*
    a) decreased sun radiation
    b) vegetation damage
    c) cancer appearance
    d) illness aggravation
    e) metal corrosion

10. *Direct action on the air pollution are:*
    a) decreased sun radiation
    b) vegetation damage
    c) cancer appearance
    d) illness aggravation
    e) metal corrosion

Response to the test

1. a,d,e
2. a,b,e
3. b,d
4. a,b,c,e
5. b,c
6. a,c
7. a,c,d
8. b,e
9. a,b,e
10. c,d

REFERENCES

1. Ahrens, C. Donald. Essentials of Meteorology. Published by Thomson Brooks/Cole, 2005.
2. Bailyn, M. (1994). A Survey of Thermodynamics, American Institute of Physics Press, New York, ISBN 0-88318-797-3, page 24.
3. Chang, Hasok (2004). Inventing Temperature: Measurement and Scientific Progress. Oxford: Oxford University Press. ISBN 978-0-19-517127-3.
4. Dines, William Henry. Anemometer. *1911 Encyclopӕdia Britannica*.
5. Invention of the Meteorological Instruments, W.E. Knowles Middleton, The Johns Hopkins Press, Baltimore.
6. Instrumentation: Pitot Tube Static Anemometer, Part 1". Mt. Washington Observatory. Retrieved 14 July 2014.
7. Joe Buchdahl. "Atmosphere, Climate & Environment Information Programme". Ace.mmu.ac.uk. Retrieved 2012-04-18.
8. Jump up^Journal of the Atmospheric Sciences (1993). "stratopause". Retrieved2013-10-18.
9. Jump up^ Drake, Stillman (1970). "Berti, Gasparo". Dictionary of Scientific Biography. 2. New York: Charles Scribner's Sons.. ISBN 0-684-10114-9.
10. Jump up^ "History of the Barometer". Barometerfair.com. Retrieved 2010-02-04.
11. Kittel, Charles; Kroemer, Herbert (1980). Thermal Physics (2nd ed.). W. H. Freeman Company. pp. Appendix E. ISBN 0-7167-1088-9.
12. Meteorological Instruments, W.E. Knowles Middleton and Athelstan F. Spilhaus, Third Edition revised, University of Toronto Press, Toronto, 1953
13. Zimmer, Carl (3 October 2013). "Earth's Oxygen: A Mystery Easy to Take for Granted". New York Times. Retrieved 3 October 2013.

External links

1. http://www.nasa.gov/mission_pages/sunearth/science/mos-upper-atmosphere.html#.VHg5AzHF8vY
2. Collection of historical anemometer (http:// www. geag. de/ txt_sammlung. htm)
3. Website about different Anemometers (http:/ / www. anemometertypes. com/)

CONTENTS