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WATER VAPOUR SORPTION AND HUMIDITY – A SURVEY ON MEASURING METHODS AND STANDARDS

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Abstract

Under environmental conditions water exists in all three classical states of matter: solid, liquid and gas. The water molecule is non-linear and therefore polar. In comparison with other liquids water has anomalous features; about 63 exceptional properties are recorded. This article starts with reviewing properties of water, typical occurrences and definitions such as relative and absolute humidity and moisture content.

Water is present everywhere in nature and engineering; it may be helpful or harmful. The survey concerns both: atmospheric hygrometry and usual measuring methods of the moisture content of solids and liquids as well as water sorption. The determination of the atmospheric humidity is among the more difficult problems in metrology. In contrast, humidity

determination of materials is simple; however the definition of the dry state is difficult. Because water is bound at and in solids and liquids in many different ways it turns out that the humidity content of materials is difficult to define and to measure accurately. We provide a survey on the measuring methods, describe the most important ones and discuss advantages and accuracy.

In the search for extraterrestrial water special remote measuring methods have been developed analysing the spectrum of electromagnetic radiation either of natural sources or produced by a probe and reflected. Spacious deposits have been detected photographically. In situ investigations are made using conventional methods.

With regard to the problems of measurements, standardisation of measuring methods and procedures is required. There exist many institutions, which are engaged in investigating the use of water and standardising measuring methods. In tabular form, we give a survey on existing standards.

1. Introduction

Water is present everywhere in nature; this could be advantageous or disadvantageous. Handling of a variety of materials includes often the use of water, as solvent or dispersant medium, adsorptive, reacting agent, cleaning agent and lubricant. For handling, storage and quality assurance of foods, pharmaceuticals, textiles, plastics, paper, wood and building materials the water content must be known. Many processes, such as corrosion protection, refrigeration, air conditioning in museums, greenhouses, saunas, laboratories and climate chambers as well as humidors for manufacturing of pure materials, require the control of the air humidity. An extreme control of humidity is required for insulating gases, such as those in transformers and power plants, as well as protecting and other pure bulk gases. Natural gas transport requires control of humidity down to a measuring range of ppm in presence of high contents of solid and liquid contaminants as well as corrosives in varying concentrations. In general, insulating liquids must be free from traces of water.

Very different applications of humidity measurements are made under very different circumstances within a wide measuring range from nearly zero up to saturation and sometimes with high sensitivity. Thus, a great variety of measuring methods is applied [1-4]. Because the term "humidity" is not well defined and because the different measuring methods deliver not always comparable results standardisation of measuring methods and procedures is required.

A humidity measurement covers two groups of measuring problems: the atmospheric humidity and the material moisture. In both groups, the phenomena and its mathematical description are very different and so are the methods and instrumentation for measurement and control. The two groups are of high importance for life and techniques and thus, a large variety of measuring instruments is available on the market.

2. Water structures

Under global environmental conditions water exists in all three classical states of matter: solid, liquid and gas. The water molecule is non-linear (Fig. 1) and therefore polar. In comparison with other liquids it has anomalous features; about 63 exceptional properties are recorded [5].

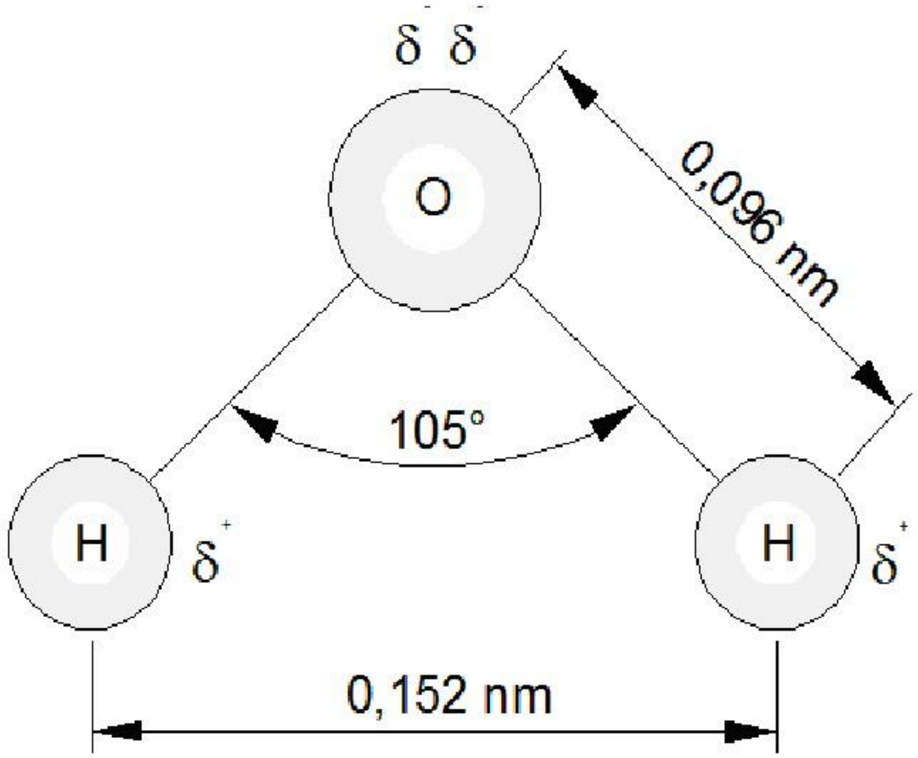


Figure 1. Schematic structure of a water molecule. WW1776b.jpg

Water in the gaseous phase

In gaseous phase water is present as a dimeric complex along with single molecules [6] (Fig. 2). Air contains always water vapour in a concentration from near zero up to the saturation value determined by temperature. In addition, liquid or solid agglomerates may be present and visible as clouds, droplets, snow or hailstones. Contaminations should be taken into account, thus, little droplets of ionic solutions are formed with salt from sea water, and dust provides nuclei for condensation.

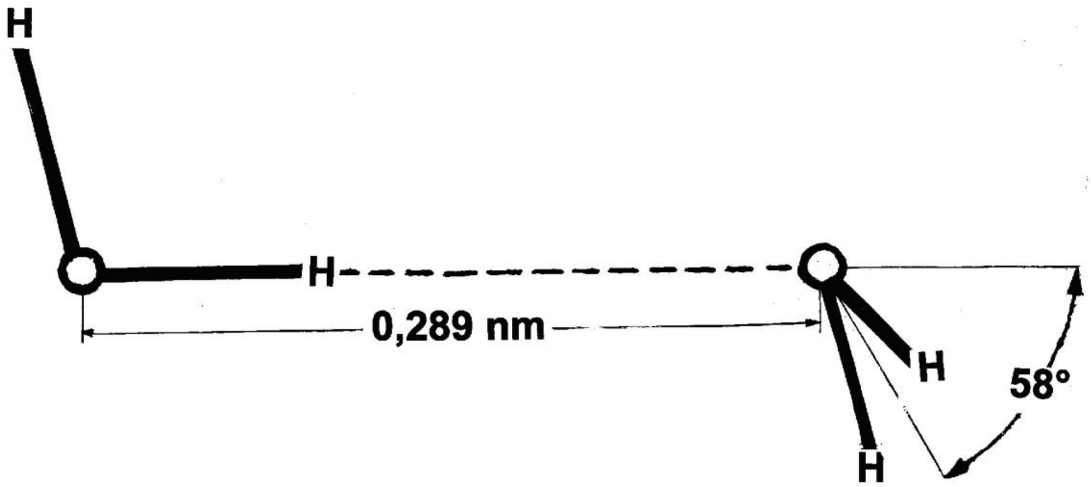


Figure 2. Structure of dimeric water molecule in vapour. WW1778.jpg

Water in liquids

Liquid water consists mostly of aggregates of several molecules (Fig. 3). In addition, water can form mixtures and solutions in liquids. Due to its high polarity, dissociation and ionization of substances can occur.

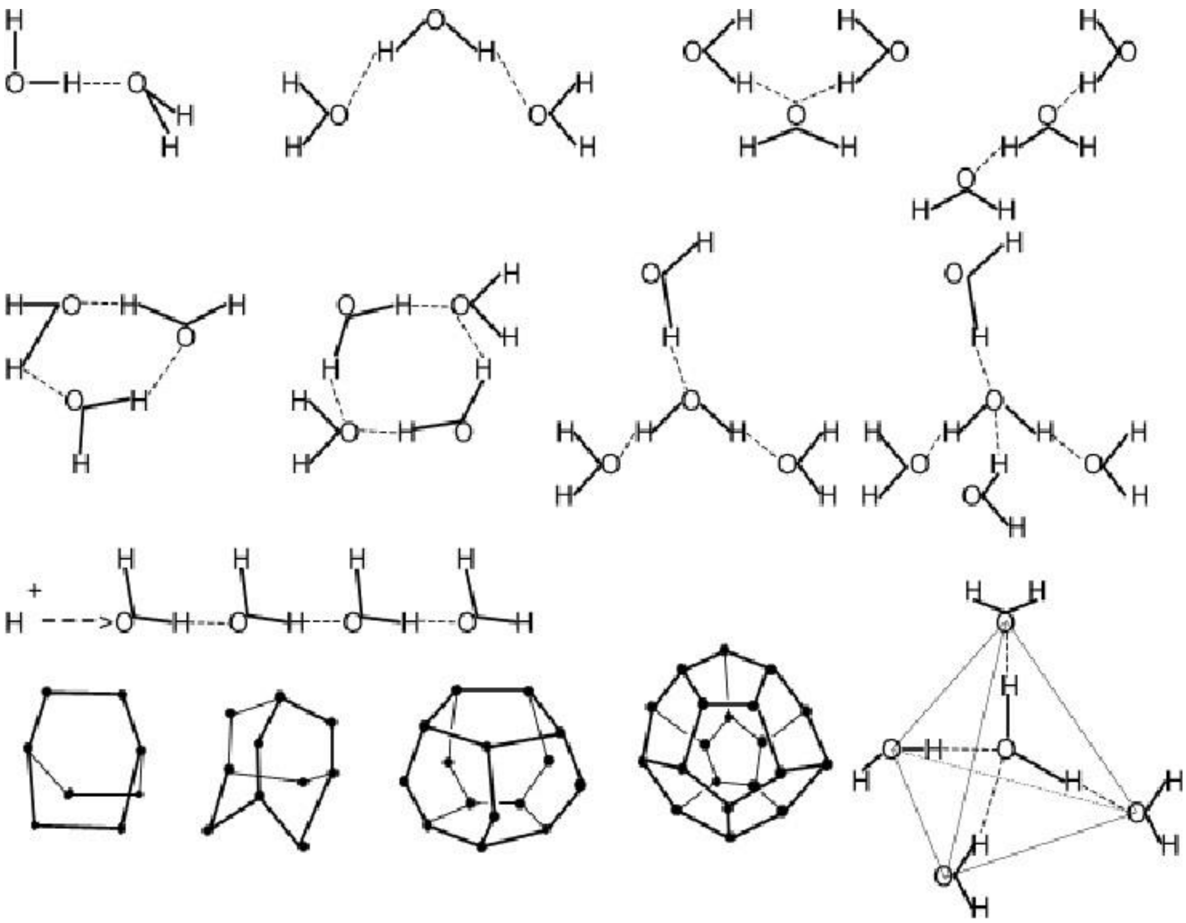


Figure 3. Possible structures of water molecules. WW1779b.jpg

Water near solid surfaces

At ambient temperatures up to about 35 °C, free bulk water consists of unstable and quickly varying aggregates of several molecules (Fig. 3); single molecules are seldom. As shown in Table 1, water is bound at a solid differently. Interpacked water filling larger pores and spaces between grains has the same structure as free bulk water. Likewise, capillary water fills capillaries (macropores) and nanopores (mesopores). Due to water uptake, the structure of some materials can store large amounts of water and/or can undergo swelling. A solid surface exposed to the atmosphere is more or less covered with physisorbed water molecules attracted by van der Waals forces (London dispersion forces). These are induced, fluctuating dipoles. Whilst their temporary mean value is zero, the binding energy per atom is of the order of 0.5 eV. Down to temperatures of -50 °C, liquid water layers have been observed in fissures of permafrost structures. About two layers of physisorbed water molecules at a solid surface or at the surface of ice behave in a quasi-liquid state down to a temperature of 33 K. Such quasi-liquid layers behave like free water; however, the surface influences the structures within about eight layers. Thus, bound water has properties different from those of free water [6]. Physisorption is reversible because the electron orbital structure is not influenced and only weak deformation of the molecular grid occurs. Parts of the adsorbate vaporise with decreasing vapour pressure or increasing temperature and a new equilibrium responds to the new ambient state. Nevertheless, to remove physisorbed water completely in a reasonable time, warming up is often required in addition to vacuum.

Binding forces at polar surfaces and induced electrostatic dipoles at metallic surfaces are much stronger; they are of the order of 0.1 kJ mol-1. Though there is still no chemical bond, and thus, such bindings should be classified as physisorption.

Chemisorption is a dissociative stoichiometric bonding at surface molecules of the solid. Binding enthalpies range between 100 and 500 kJ mol-1. Chemisorption is irreversible. Energy is required to release molecules, whereby hydroxyl groups may recombine to form water molecules.

Absorptive binding of water is associated with diffusion of water molecules, which are first physisorbed at the surface, into free molecular sites in the interior of a material.

The formation of a hydrate and binding as water of crystallisation are chemical reactions. Binding enthalpies are stronger than those of physisorption. Nevertheless such reactions may be completely reversible and may take place even at low temperatures.

Natural and technical surfaces are always contaminated. Impurities at the surface are hardly avoidable. Water may emulsify or dissolve such species by forming an ionic salt solution e.g.

A typical effect accompanying water sorption is swelling. By expanding the matrix of dry material, additional volume is available for water molecules. For example, the small specific surface area of dry clay minerals increases by water uptake to values between 10 and 2200 $m^2\ g^{-1}$ as determined by the BET method.

Table 1. Water near solid surfaces

Type of water	Formation process
Free bulk water	
- volume water	Filling of volumes
- interpacked water	Filling of macropores and interspaces between particles
Water bound physically at the solid surface	
- physisorbed water layers	Adsorption (physisorption) at the outer surface and at pore walls and micropore filling
-capillary water in mesopores	Adsorption (physisorption) and condensation in mesopores (capillary condensation)
Water bound chemically at the surface	
- chemisorbed water	Adsorption and chemisorption at the outer surface and at pore walls
Water bound in the solid bulk material	
- absorbed water	Adsorption and diffusion → absorption

3. Air and gas humidity

The following chapter is concerned with the water content of air and process gases [7]. The earliest and still widely employed application of detection of air humidity is in weather forecast because humidity is one important parameter. Weather forecast has been made most probably since the beginning of mankind. Animals and plants are equipped with humidity sensors as well, and it is believed that some animals can forecast weather.

Although living in highly developed countries and mostly in protected environments, weather is still governing our life and it influences also industrial processes. Water vapour in air causes atmospheric phenomena such as rain, snow or frost and affects solids by corrosion of metals, caking of powders and deterioration of delicate technical devices. Humidity sensors with linear, quick and reversible responses have been developed for measuring water vapour concentration in air [8].

Historical

The first record of a water vapour adsorption experiment is found in the Bible. In the Book of Judges [9] we read,

> "And Gideon said to God: If you want me to save Israel by my hand, as you said, behold, I put fresh sheared wool on the floor and if the dew falls only on the wool, and it will be dry at all the earth beside, than shall I know that you want to save Israel by my hand, as you have said. And it was so: When he got there in the early morning and wrung out the wool, he could press out the dew from the wool, a bowl full of water. After that Gideon said to God: Your anger should not flare out against me, if I speak again: Only once more I will try it with the wool: Only the wool shall be kept dry, and dew shall be upon all the ground. And God did so in the following night: The wool remained dry and the dew was on all the ground."

Already Luther remarked that the description of the experiment is unclear. Nevertheless, there are plausible explanations for the inconsistent results [10-11].

A strange volumetric device, which was in use until recently, should be mentioned: "The doctor of Cairo" (Fig. 4). These artistic bowls served for dew sampling during cool nights. The condensed water was used for medical purposes.

Figure 4. “The Doctor of Cairo” (dew sampler). WI1593e.jpg

The aim of the first gravimetric adsorption measurements was to forecast weather by determination of atmospheric humidity. The very first to describe such an instrument [12], was the German cardinal Nicolaus Cusanus (1401-1463). In his book "Idiota de Staticis Experimentis", wich was published in 1450, that means "The layman about experiments with a balance" (Fig. 5) [13], he let this ignorant person, probably his mechanic, suppose,

> "If anyone hangs on one side of a big balance with dry wool and loads of stone on the other side until equilibrium is established, at a place and in air of moderate temperature he could observe that with increasing humidity the weight of the wool increases and with increasing dryness of the air it decreases. By these differences it is possible to weigh the air and it is likely that one might perform weather forecasting."

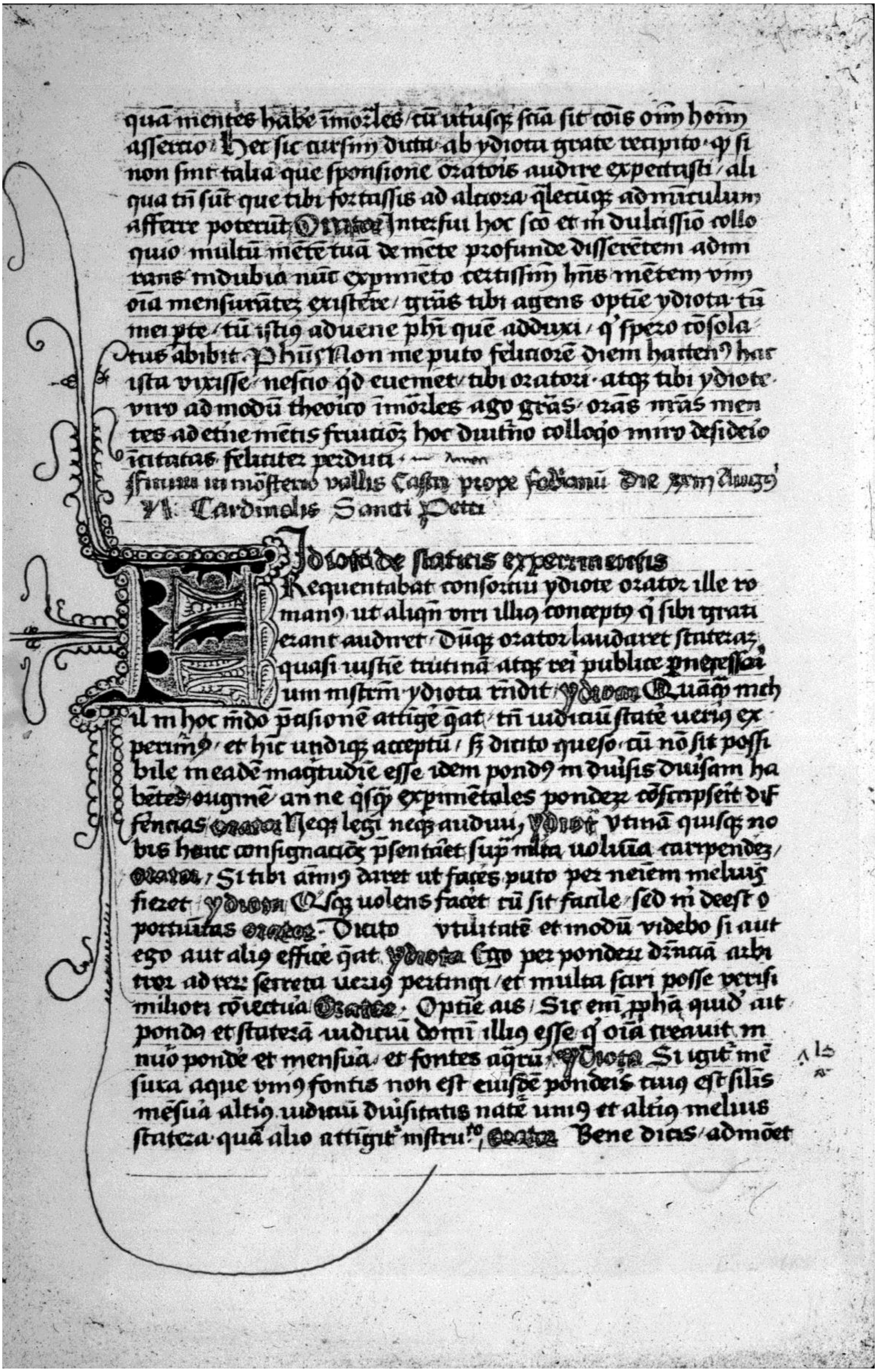


Figure 5. Nicolaus Cusanus (1401-1463). "Idiota de Staticis Experimentis" 1450. BM0126d.jpg

About 20 years later the Italian architect and painter Leo Battista Alberti (1404-1472) described a similar device,

> "We know, that a sponge becomes wet from atmospheric humidity and by this fact we make a balance with which we weigh the weight of the air and the dryness of the winds." [14].

From Leonardo da Vinci (1452-1519) we have three designs of inclination balances loaded with a sponge or with cotton (Fig. 6) [15-17]. With reflected face he added to the sketches,

> "To recognize the quality and density of the air and to forecast rain."

and

> "Means to detect, when the weather will break-up."

In the following decades a large variety of hygrometers had been developed [1-4].

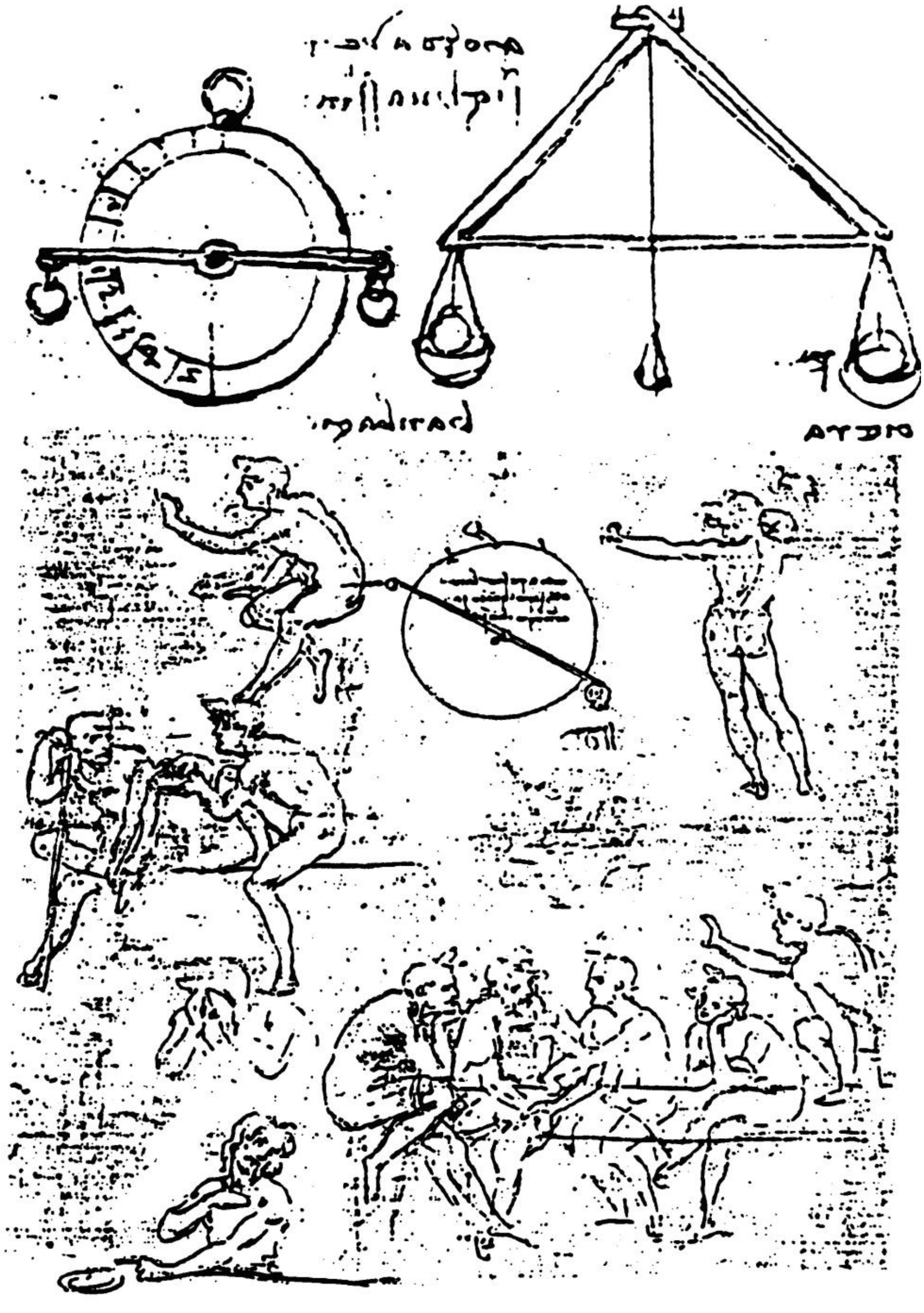


Figure 6. Sketches of gravimetric hygrometers/barometers of Leanardo da Vinci. BM0089b.jpg

Definitions

Air humidity is the amount of water vapour in the air disregarding the possible presence of liquid or solid aggregates like raindrops, fog, snow or hailstones. The parameter "air humidity", which is a function of temperature, is governed only by the availability of water and the thermal energy available for evaporation. Air humidity can be expressed in several ways [18]:

- Absolute humidity AH_{air} is defined as the mass of water vapour m_w presented in unit mass m_{air} or unit volume V_{air} of dry air.

  $$AH_{air} = \frac{m_w}{m_{air}} \Big/ \mathrm{g\ kg^{-1}} \quad (1a)$$

  or

  $$AH_{air} = \frac{m_w}{V_{air}} \Big/ \mathrm{g\ m^{-3}} \quad (1b)$$

- Relative humidity RH_{air} is the ratio of the amount of water vapour in the air m_w at a specific temperature to the maximum mass that the air could hold at this temperature $m_{w,max}$ usually expressed as a percentage.

  $$RH_{air} = \frac{m_w}{m_{w,\max}} \times 100 \Big/ \% \quad (2a)$$

  Another definition is the ratio of the partial pressure of water vapour p in a gaseous mixture of air to the saturation vapour pressure p_0 at a specific temperature temperature. The values differ slightly near the saturation point.

  $$RH_{air} = \frac{p}{p_0} \times 100 \Big/ \% \quad (2b)$$

  Relative humidity is the most frequently encountered measurement of humidity because it is regularly used in weather forecasts.

- Specific humidity SH_{air} is the ratio of water vapour to air (dry air plus water vapour) in a particular volume of air. Specific humidity ratio is expressed as a ratio of kilograms of water vapour, m_w, per kilogram of air, $m_{air} + m_w$.

  $$SH_{air} = \frac{m_w}{m_{air} + m_w} \quad (3)$$

- The dew point is associated with the relative humidity. This is the temperature at which water vapour saturates from gas into liquid or solid usually forming rain, snow, frost, or dew. At this temperature the relative humidity is 100 %. From the dew point temperature, the relative humidity can be derived by means of tables.

Measuring methods of air humidity

The peculiar characteristic of the water molecule facilitates its identification and allows the application of very different methods to determine humidity. The methods are standardised in all industrial states [19]. Water vapour is as a primary contaminant in process gases at very low-levels of particular interest to the semiconductor industry. Therefore, efforts are directed toward developing water vapour measurements and standards at the part per billion level and below for characterisation of moisture concentration. Measuring instruments and standards are normally used in industrial applications for contamination control in process gases.

Table 2. Methods for the measurement of air and gas humidity

Method	Principle of measurement
	Measuring method
Hygrometer	Measurement of parameters, like change of length, mass, electric resistance, electric capacity, sorption, dew point, that depends on humidity
Psychrometer	Measurement of evaporation coldness by temperature difference
Dew point meter	Observation of condensation at a surface (chilled mirror) in dependence of temperature
Gravimetric train	Elaborate absorption system maintained as the primary standard for humidity measurements
	Humidity sensor
Dielectric measurement	Capacitive measurement with a condenser taking the advantage of the high dielectric constant of water
Electric conductivity measurements	Electrochemical measurement of conductivity
Microwave and infrared spectroscopy	Measurement of absorption of radiation
Nuclear magnetic resonance spectroscopy	Measurement of resonance between a high-frequency electromagnetic field and ^{1}H nucleus of water of a sample, which is arranged into a strong homogeneous magnetic field
Activation analysis	Measurement of absorption of fast neutrons or γ-rays
Moisture indicator	Qualitative test observing colour change

Hygrometry

The earliest hygrometers made in the 15th century were balances loaded on one side with textile [17, 20]. Today the gravimetric method is applied as a primary standard for humidity measurements. The NIST gravimetric hygrometer has an uncertainty of 0.1 % mass fraction. Furthermore, a suitable mass sensor is the quartz crystal balance whose surface is covered by a hygroscopic film or by a microporous substance [21-22]. As the mass of the crystal changes due to adsorption of water vapour, the frequency of the oscillator changes. Ultrathin Linde Type A (LTA- type) molecular sieves grown on a quartz crystal microbalance have high sensitivity, good reversibility and long life at low humidity ranges [23].

The simplest and still widely used mechanical hygrometer is the hair hygrometer of Horace Bénédict de Saussure [24] (Fig. 7). It measures the elongation of hair with increasing humidity due to swelling of the hair cells. Hairs from humans, sheep or horses are used; today also plastic strips or fibres are used. Whereas the mass adsorbed is somewhat proportional to relative air humidity the elongation of the hair or fibre (up to ~ 2.5 %) is not linear and the scale is spread in the middle of the measuring range. The traditional folk art device known as a "weather house" works on this principle with a sensor being catgut or hair.

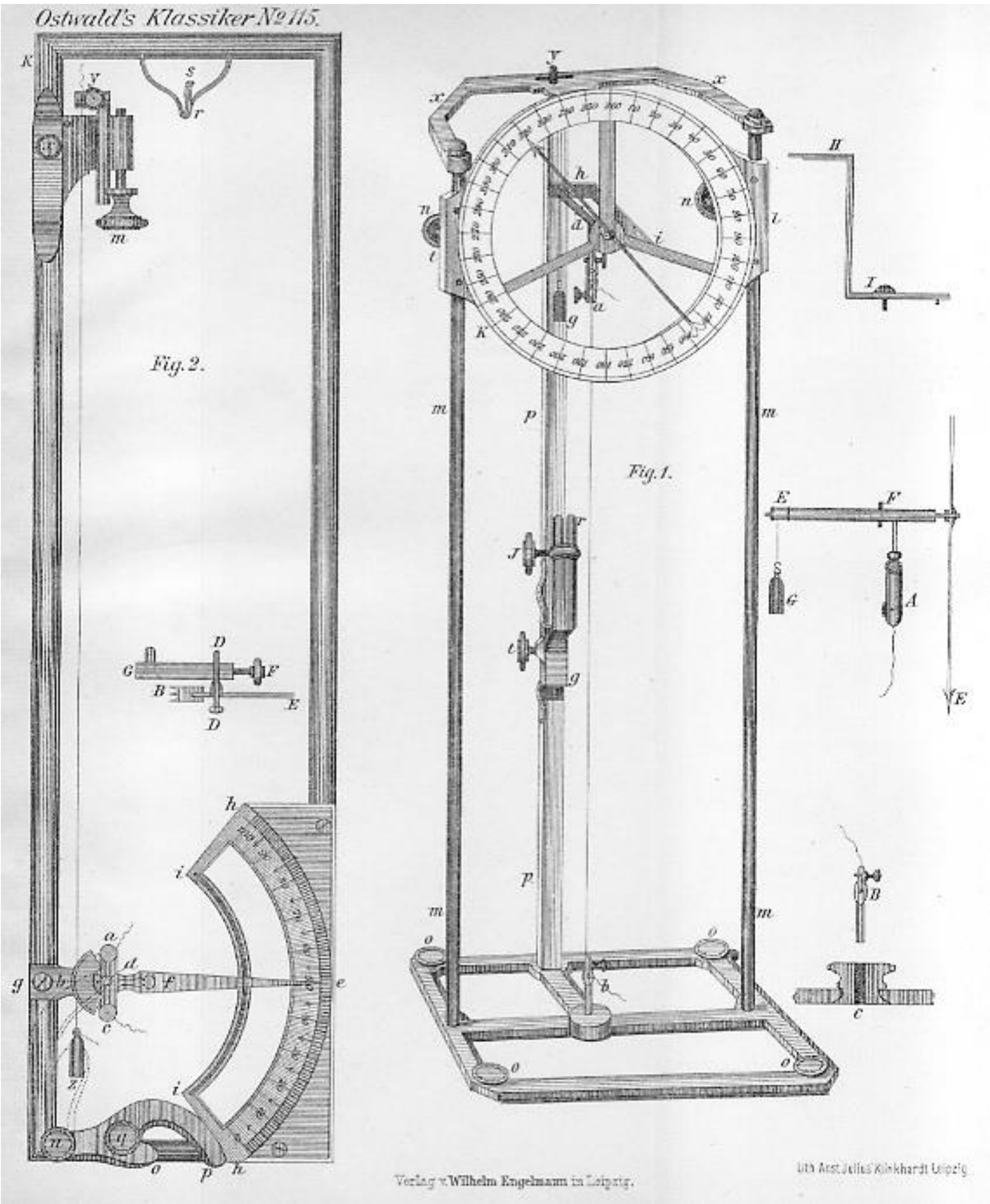


Figure 7. Hair hygrometer of Horace Bénédict de Saussure (1783). Fig. 7a: Large hygrometer. The hair is stretched between a and b. Fig.7b: Hand hygrometer. The hair is stretched between y and z. WI0129d.jpg

More accurate measurements and electronic recording of results are achieved with a coulometric hygrometer. It measures the change in the electrical impedance or resistance of a thin layer of a hygroscopic material, lithium chloride or phosphorus pentoxide e.g. (Fig. 8).

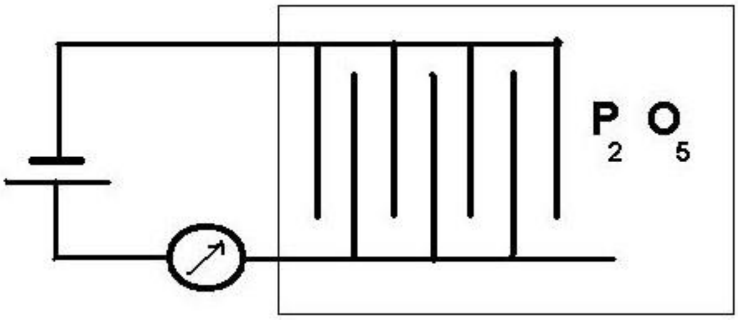


Figure 8. Coulometric hygrometer: Keidel cell (1950): platinum electrodes on a substrate covered with a thin film of P_2O_5. WI1718.jpg

Other hygrometers sense changes in electric capacity (with an electret e.g.), volume, or the transparency of various substances that respond to relative humidity. The oxide sensor is made up of an inert substrate material and two dielectric layers, one of them is sensitive to humidity. The moisture molecules pass through the pores of the surface and cause a change to a physical property of the layer beneath it. An aluminium oxide or silicon oxide sensor has two metal layers that form the electrodes of a capacitor. The number of water molecules adsorbed will cause a change capacity of this condenser due to the high dielectric constant of water.

The measurement of the electrical resistance of thin hygroscopic films or of semiconductors can be used in hygrometry and, likewise, as sensors in head space analysis in order to determine material humidity. Typical substances include lithium chloride, stearic acid and zinc stearate [25]. The relation between conductivity and relative humidity is in general not linear and may be applied only within a restricted measuring range. Highly sensitive humidity sensors based on single SnO_2 nanowires have linear response in conductivity to humid air [26]. Cells with MnO_2 clay solid electrolytes have good linearity and fast response in galvanic potential to changes in humidity [27]. Thick film and disc humidity sensors based on semiconducting hubnerite ($SnWO_4$) compositions show a maximum sensitivity factor when doped with Li^+ andW^{6+} sites in hubnerite material that contributes to hubnerite sensing mechanism [28].

A silicon oxide sensor can be an optical device that changes its refractive index when water is absorbed into the sensitive layer. A wavelength shift can also be detected on the output, which can be precisely correlated to the moisture concentration.

Optical methods include the observation of colour transition of chemical compounds when reacting with water molecules. They are widely used to control the activity of drying agents and as breakthrough indicators [29]. Test methods of qualitative water indication include redden of blue cobalt(II) chloride [26, 30]. Usually, blue cobalt(II) chloride is dispersed in silica gel. Sensors, which consist of such salts, are dispersed on different substrates, such as cellulose, cellulose acetate, polyvinyl pyrollidon, wool, calcium sulphate, silica gel, zeolites and alumina. Wool impregnated with cobalt chloride is blue in dry state and converts to yellow by moisture adsorption [31]. Humidity indicating gels, which are light blue in dry state and dark blue in moist state, are obtained by dispersing copper sulphate in silica gel. Yellow lead iodide is obtained from a mixture of potassium iodide and lead nitrate by moisture adsorption. Polymer dye systems changing colour with air humidity can also be used as humidity sensors. A high sensitive optical humidity probe has been developed by use of violet Nafion crystal films. At a wavelength of 650 nm, a reversible change in the absorbance of the films with relative humidity is linear in the range of zero to 1 % of moisture [32]. For rough control of air humidity in closed rooms, cheap colour indicators on plates are offered.

The colour indicator tube (Dräger Tube or Stain Tube) is used for a quick and rough measurement of moisture in natural gas pipelines. Each tube contains a chemical that changes its colour when the gas passes through. For use, the tube is inserted into a gas pump, used once and discarded. The error can be as high as 25 percent.

In absorption spectroscopy, light passes through a gaseous sample and the amount of light absorbed at a specific wavelength is measured. A tunable laser provides a source of narrow, variable wavelength light that can be used to analyze the small spectral features. According to the Lambert-Beer law, the amount of light absorbed by the gas is proportional to the amount of gas present in the light's path; therefore, this technique is a direct measurement of moisture.

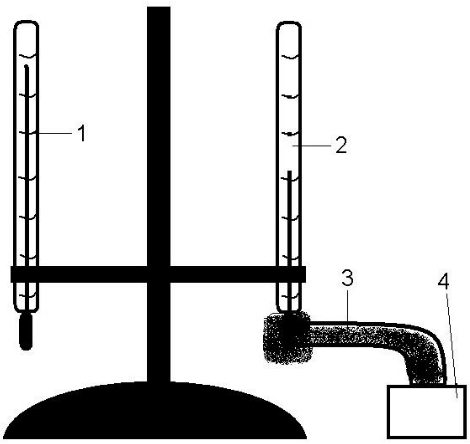
Lyman-alpha hygrometer [33] is a hygrometer based on the absorption of radiation by water vapour at the Lyman-alpha line, which is an emission line of atomic hydrogen at 121.567 nm. Lyman-alpha radiation can be generated by a glow discharge in hydrogen, and a nitric oxide ion chamber normally accomplishes detection. Two magnesium fluoride windows both at the radiation source and at the detector bound the absorption path. Lyman-alpha hygrometers are used on aircraft and on meteorological towers for high-frequency humidity measurements. Inconveniences of the method, like drift of the source intensity or contamination of the windows, are overcome by special calibration techniques or by baselining the high-frequency output to the humidity values provided by a slower, but stable, hygrometer.

Psychrometry

In 1825 August constructed the first psychrometer (Fig. 9) on a proposal of Leslie [34-35]. Richard Assmann (1845-1918) added a ventilator, and this aspiration psychrometer [36] is regarded as a standard instrument for air humidity measurements (Fig. 10). It consists of two thermometers; the bulb of one of it is kept wet usually by means of a humidified cotton envelope. Evaporation from the wet bulb lowers the temperature, so that the wet-bulb themometer shows a lower temperature T_{wet} than those of the dry-bulb thermometer T_{dry}. Evaporation is supported by an air stream, which is generated either by a ventilator or by whirling the thermometer in the air by hand (sling psychrometer). From the temperature difference, the partial pressure of water vapour in the air p_{H_20} can be determined using Sprung's formula [37].

$$p_{H_20} = p_0 - C_{psy} (T_{dry} - T_{wet}) \tag{4}$$

where p_0 stands for the saturation pressure at the temperature of the wet bulb T_{wet} and the psychrometric constant C_{psy} = 0,67 hPa K^{-1} stands for a height up to 500 m and T_{wet} > 0 °C. The relative humidity can be derived by means of graphical tables.



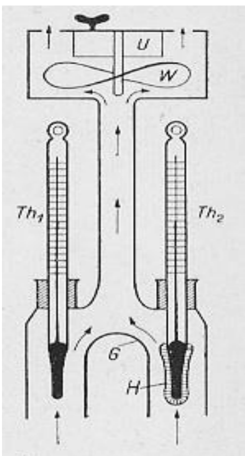


Figure 9. August psychrometer (1825). 1 dry thermometer, 2 wet thermometer, 3 cotton strip, 4 water reservoir. WI1772b.jpg

Figure 10. Friedrich Aßmann's aspiration psychrometer (1887). H cotton envelope, G air channel, Th thermometer, W ventilator, U motor. WI1773a.jpg

Dew point hygrometry

In 1820, John Frederic Daniell invented a dew point hygrometer, which came into widespread use. The Lambrecht dew point hygrometer is a metal mirror with good thermal conductivity, such as silver or copper. The mirror is properly plated with an inert metal, such as iridium, nickel or gold, to prevent tarnishing and oxidation and is polished. It is cooled by evaporation of ether until moisture just begins to condense onto it (chilled mirror, CMH) (Fig. 11). The decrease of light intensity due to scattering is observed optically. The temperature at the beginning of opaqueness of the metal is the dew point temperature.

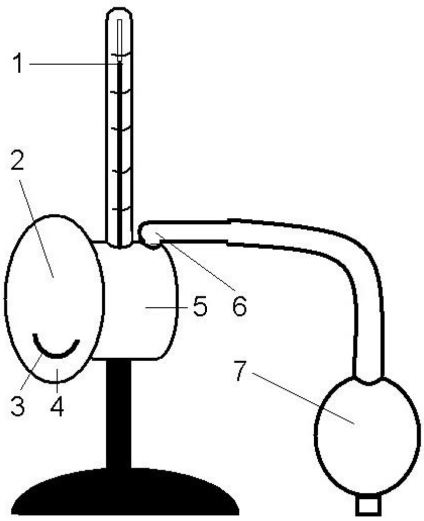


Figure 11. Lambrecht dew point hygrometer (1881). 1 thermometer, 2 metal mirror, 3 gap, 4 reference mirror, 5 container filled with ether, 6 air supply, 7 air pump. W1775a.jpg

Today the mirror is cooled using a Peltier cooler. The temperature of the mirror is controlled by electronic feedback to maintain a dynamic equilibrium between evaporation and condensation on the mirror, thus, to measure the dew point temperature closely. A beam of light, typically from a solid-state LED, is aimed at the mirror surface and a photodetector monitors the reflected light. A platinum resistance thermometer (PRT), which is properly embedded in the mirror, monitors the mirror temperature at the established dew point. Knowing the atmospheric temperature and the dew-point temperature, the relative humidity can be determined by means of a table. Among the various hygrometric techniques, the dew point method is considered as the most accurate (relative accuracy is about 1 % above 5% RH). Only the gravimetric train, which is used as a primary standard, exceeds it.

In order to increase the accuracy of this type of hygrometer, surface acoustic wave (SAW) devices are very useful because of their dual ability to detect the dew deposition and to measure the temperature with great accuracy [38]. Rayleigh wave properties were investigated in order to study the influence of dew deposition. The experimental device is cooled by means of a Peltier element until dew deposition. Because of polarization of the Rayleigh wave, the dew position induces a substantial attenuation of the wave amplitude and a shift in the wave velocity (mass-loading effect). In order to combine the influence of the temperature and the dew deposition, a thermocouple is deposited on an LST-cut quartz plate. The frequency versus temperature response is used for the dew point detection.

The application of paint and other coatings is very sensitive to humidity and dew point. Condensed water can disturb the operation and can even damage the electronic and micromechanical devices of camcorders and similar apparatus e.g., which are therefore equipped with a dew warning (dew check). Usually, this is an electric sensor whose resistance increases when moisture is present.

Quartz crystal resonator (QCM) dew/frost point sensors operating in the range -90 °C to 15 °C have a fast response time, high sensitivity and accuracy. It was possible to distinguish between supercooled dew and frost from a single scan of quartz crystal resonator [39-40].

Radiometry and LIDAR hygrometry

LIDAR (light detection and ranging) is an optical remote sensing technology that measures properties of scattered light to find information of a distant target [41-42]. By means of laser pulses and by measuring the time delay between transmission of a pulse and detection of the reflected signal, the distance to an object can be determined. Whereas radar uses radio waves, LIDAR uses much shorter wavelengths of the electromagnetic spectrum, typically, in the ultraviolet, visible, or near infrared region. In general, it is possible to image a feature or object only about the same size as or larger than the wavelength. Thus, LIDAR is highly sensitive to aerosols and cloud particles. An object has to produce a dielectric discontinuity in order to reflect the transmitted wave. Different types of scattering are used for different LIDAR applications, most common are Rayleigh scattering, Mie scattering and Raman scattering as well as fluorescence. The wavelengths are ideal for measurements of smoke and other airborne particles (aerosols), clouds, and air molecules. Since the deployment of the GPS (Global Positioning System) in the 1980s precision positioning has become possible. Airborne LIDAR systems monitor glaciers and have the ability to detect subtle amounts or growth or decline. In atmospheric physics, LIDAR is used as a remote detection instrument to measure densities and movement of certain constituents of the middle and upper atmosphere, such as clouds. Inelastic scattering is observed with Raman spectroscopy. Since the energy change in this case is quantified, the spectrum is characteristic for the target molecule. Water molecules scatter predominantly green light, Nd:YAG laser light with a wavelength of 532 nm is reflected with 660 nm wavelength. This process is applied to determine the relation of a water vapour mixture in the atmosphere.

Radiometers operating in the millimetre or submilimetre range of wavelength have an enhanced sensitivity to low water vapour and liquid contents in comparison to conventional microwave radiometers operating below 30 GZ (1 cm). The temperature and humidity profile up to 5 km above ground is determined in the arctic by using ground-based millimeter wave radiometry and variational retrieval technique [43].

4. Humidity of liquids

In liquids, traces of water often deteriorate electrically insulating properties or cause corrosion. Humidity can be determined by means of some types of hygrometers described above. For example, an electrical resistance hygrometer with aluminium an aluminium oxide moisture sensor can express the absolute humidity of gases and liquids in dew point temperature, parts per million by volume (PPMv) or parts per million by mass (PPMw). Any gas hygrometer can be used in head space gas analysis or after thermal evaporation. Likewise, some moisture measuring methods designed for solid materials can be applied, in particular thermogravimetry.

5. Moisture of solid materials

Historical

The earliest report on a dehydration process is found in Vitruvius (about 70 to 10 BC) "*Books on Architecture"* [44-45]. He describes conscientiously the process of calcination of limestone,

> "The reason why lime makes a solid structure on being combined with water and sand seems to be this: that rocks, like all other bodies, are composed of the four elements. Those which contain a larger proportion of air, are soft; of water, are tough from the moisture; earth, hard; and of fire, more brittle. Therefore, if limestone, without being burned, is merely pounded up small and then mixed with sand and so put into the work, the mass does not solidify nor can it hold together. But if the stone is first

> thrown into the kiln, it loses its former property of solidity by exposure to the great heat of the fire, and so with its strength burned out and set free, and only a residuum of heat being left lying in it, if the stone is then immersed in water, the moisture, before the water can feel the influence of the fire, makes its ways into the open pores; then the stone begins to get hot, and finally, after it cools off, the heat is rejected from the body of the lime.
> Consequently, limestone when taken out of the kiln cannot be as heavy as when it was thrown in, but on being weighed, though its bulk remains the same as before, it is found to have lost about a third of its weight owing to the boiling out of the water. Therefore, its pores being thus opened and its texture rendered loose, it mixes readily with sand, and hence the two materials cohere as they dry, unite with the rubble, and make a solid structure."

Thermogravimetry begun with Talabot, who equipped a laboratory with 39 balances for humidity control of silk, which was imported from China by ship, at Lyon in 1833 (Fig. 12) [46-47]. The whole equipment including the lovely enamel-work, which shields the ovens, seems to be lost. In 1915 Honda appears to be the very first to use the expression "thermobalance" for his instrument (Fig. 13) [48-49]. Soon afterwards such instruments were used to investigate the metabolism of plants (Fig. 14).

Figure 12. Désiccateurs Talabot 1833. Conditioning apparatus at Lyon for the measurement of the humidity of silk. BT0069a.jpg

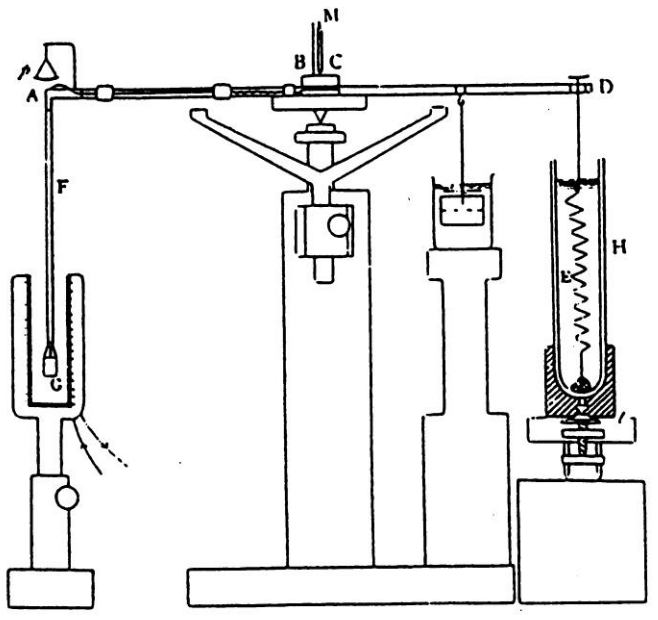


Figure 13. Honda's thermobalance. BT0145b.jpg

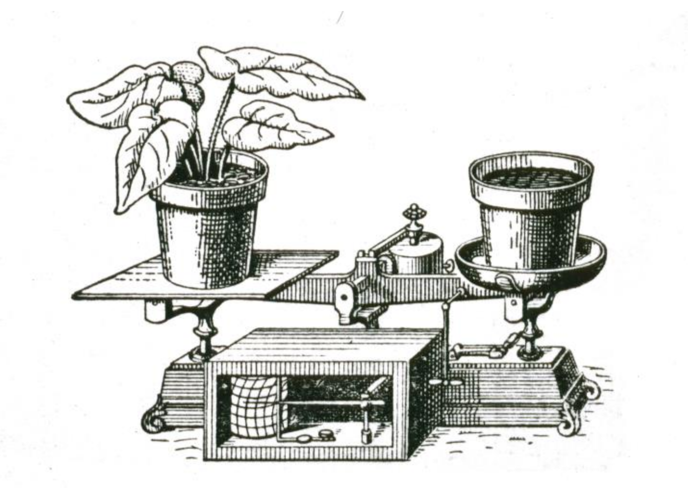


Figure 14. Gravimetric instruments for the investigation of the metabolism of plants. BT0143.jpg

In 1877 Hannay [50] described a gravimetric method to determine dehydration isotherms of salts. He conveyed water vapour, which was released from a heated sample into a cylinder that was filled with an ad- or absorbent, by means of a carrier gas. The cylinder was weighed periodically. Warming up samples in a heating chamber and sequential measurements of the decreasing sample mass in order to determine the desorption isotherm is still widely used [2-3].

In 1886 Warburg und Ihmori [51] built a beam microbalance for adsorption measurements. The first vacuum microbalances with electromagnetic compensation were made by Emich [52-53] and Urbain [54] in 1912. Today a variety of electrodynamic compensating vacuum microbalances is available on the market [55-56]. Several apparatus equipped with such balances for automatic measurement of adsorption isotherms are offered also. The first one has been built in 1962 [57] (Fig. 15). Many of those microbalances were used first to measure water adsorption from the atmosphere. Today the measurement of humidity is facilitated by so called drying or moisture balances, which are laboratory scales equipped with an infrared or microwave heater (Fig. 16) [7].

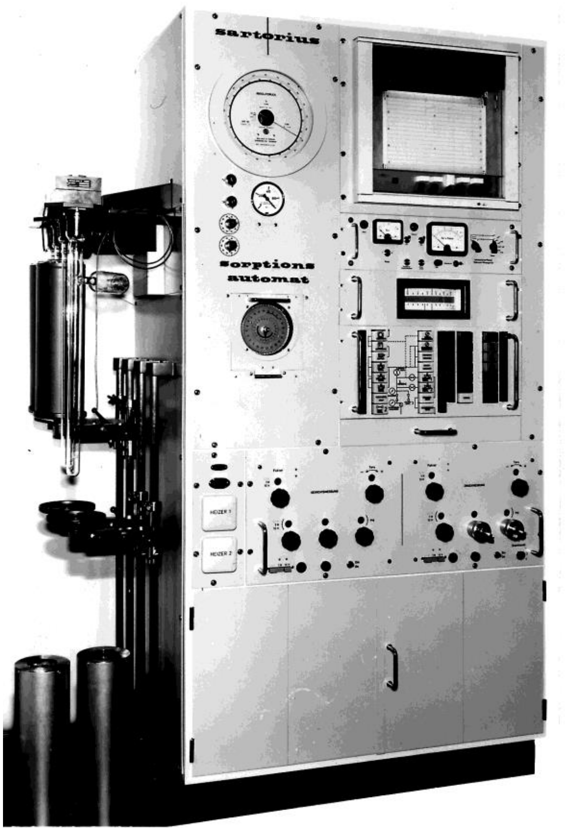


Figure 15. Sartorius 'Sorptomat' of Sandstede and Robens. Apparatus for the automatic measurement of adsorption isotherms. On the left a Gast vacuum microbalance sticks out. BT1382b.jpg

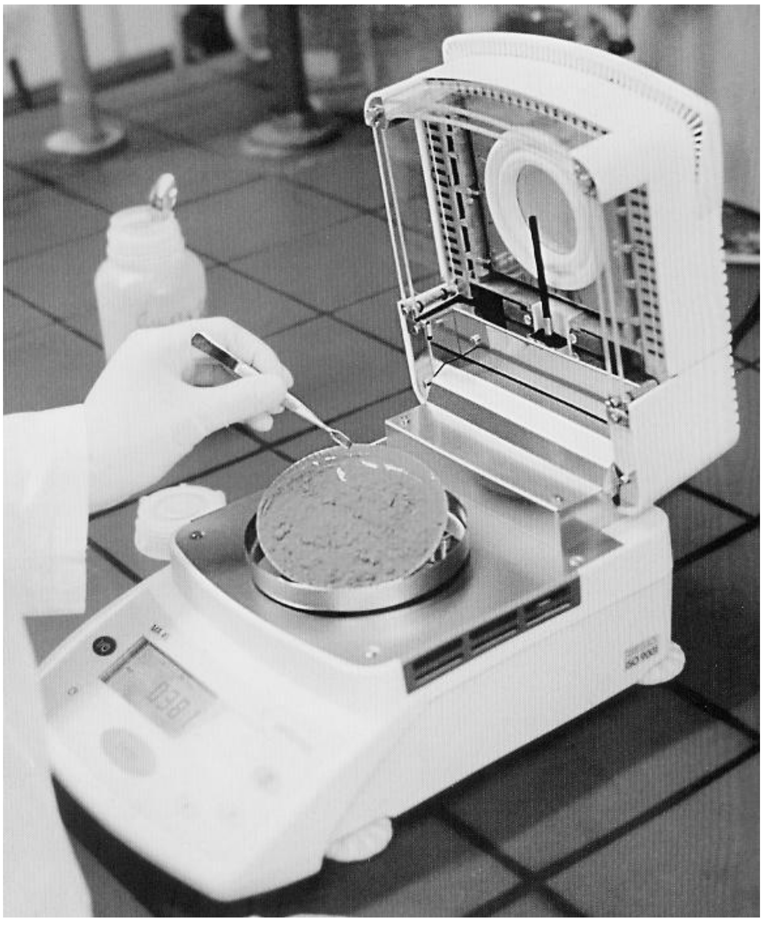


Figure 16. Drying or moisture balance Sartorius, with halogen infrared heater. WI1720.jpg

Material moisture measuring methods

There are indeed two types of humidity: Air humidity, which is independent from the other components of the air, and the humidity of materials, which is influenced or even dependent on the material in question that may be a solid, a liquid or a gas. The common term humidity also comprises liquid contents other than water, solvents e.g. [58]. In the following, we restrict ourselves to the content of water (moisture) generally expressed as the amount of water in relation to unit mass or unit volume of the sample.

The peculiar characteristic of the water molecule and its anomalous features facilitates its identification and allows the application of very different methods to determine water content and humidity depending on the ambient conditions. However, only a few methods provide reliable values [59] of the water content of solids and enable to distinguish between free bulk water, adsorbed vicinal water, absorbed and chemisorbed water. Furthermore, just the gravimetric methods measure the sum of volatile substances within a solid, whereas, in general, the task is to determine the water content only. Mostly applied methods used as routine tests are summarised in Table 3.

Table 3. Methods for the measurement of moisture content

Method	Principle of measurement
Oven-drying Moisture balance	Thermal activation of the sample and gravimetric measurement of mass loss
Thermogravimetry	Mass loss under controlled temperature programme
Sorption measurement Desiccator method	Variation of (partial) water vapour pressure and measurement of mass change
Standard contact porometry	Contact with standard of defined humidity, measurement of mass change
Dielectric measurement	Capacitive measurement with a condenser taking the advantage of the high dielectric constant of water
Electric conductivity measurements	Electrochemical measurement of conductivity
Microwave and infrared spectroscopy	Measurement of absorption of radiation
Nuclear magnetic resonance spectroscopy	Measurement of resonance between a high-frequency electromagnetic field and ^{1}H nucleus of water of a sample, which is arranged into a strong homogeneous magnetic field
Activation analysis	Measurement of absorption of fast neutrons or γ-rays
Calorimetric method	Measurement of heat capacity and conversion heat
Karl Fischer	Titration using Karl Fischer reagent
Phosphorus pentoxide	Thermal activation of the sample, absorption of water
Moisture indicator	Qualitative test observing colour change

Drying methods

The classic laboratory method of a moisture measurement of solids is the determination of the loss on drying (LOD). On the other hand, drying of the sample is necessary in order to adjust definite starting conditions for adsorption experiments. In both cases careful methods, which avoid damage of the sample, should be applied. The following methods have proved to be useful.

Drying at elevated temperature. A temperature as high as possible at which the sample is not damaged is determined by pilot tests using thermogravimetry. The drying process can be controlled thermogravimetrically as well.

Vacuum drying. Vacuum is applied at a pressure below saturation pressure of water at ambient or elevated temperature. The degree of dryness may be assessed by observing the pressure increase after locking of the connection valve to the vacuum pump.

Drying by means of desiccants. The sample is placed in a desiccator equipped with a desiccant, usually silica gel with moisture indicator, phosphorous pentoxide (p-drying), magnesium perchlorate or concentrated sulphuric acid.

Cold trap drying. At ambient temperature, the sample vessel is connected to a cold trap, which is cooled by means of a mixture of dry ice with alcohol (d-drying) or a refrigerator. In addition a vacuum pump may be connected to the cold trap.

Gas flow drying. An inert gas is passed above the sample usually at elevated temperature. The procedure is time consuming.

Freeze drying, lyophilization. Usually, the material is placed in a freeze-drying flask that rotates in a bath called a shell freezer, which is cooled below the triple point of water by mechanical refrigeration, a dry ice and methanol mixture (193 K) or liquid nitrogen (77 K). Then the frozen water in the material sublimes directly from the solid phase to the gas phase by reducing the surrounding pressure with a vacuum pump and adding enough heat. To avoid recrystallisation, sensible materials are frozen very fast.

Solvent exchange. The water included in the material is replaced stepwise by other solvents, methanol, ethanol, isopropanol, alcohol solutions in increasing concentrations 30 %, 50 %, 60 %, 70 %, 80 %, 90 % 96 % DMSO or diethlyether e.g. The final solvent is vaporised at elevated temperature. The last solvent should be volatile and should have a low surface tension. This complicated and slow method avoids damage by crystallization particularly of biological materials.

Supercritical drying is a process to remove liquid in a precisely controlled and gentle way. It is useful for the production of aerogels and for the preparation of biological materials. When a substance crosses the boundary from liquid to gas the substance volatilises and so the volume of the liquid decreases. Sensible structures like cell walls collapse because of the surface tension at the solid-liquid interface. To avoid this, the sample can be brought from the liquid phase to the gas phase without crossing the liquid-gas boundary on the phase diagram by passing through the supercritical region at high temperature and pressure above the critical point. Densities of the liquid phase and vapour phase become equal at the critical point of drying. Fluids suitable for supercritical drying include carbon dioxide (critical point 304.25 K at 7.39 MPa) and freon (about 300 K at 3.5-4 MPa). Nitrous oxide has a similar physical behaviour to carbon dioxide, but is a powerful oxidizer in its supercritical state. Supercritical water is also a powerful oxidizer partly because its critical point occurs at a very high temperature and pressure (647 K and 22.064 MPa).

Gravimetric measurement of material moisture

Gravimetric measurements to determine the humidity or dry mass of a solid material are based on the removal of water by reducing the partial pressure of water vapour of the gaseous phase above the sample. This may be done with a vacuum pump, by a condensation process within a desiccator or by means of a dry gas flow. Controlled heating of the sample shortens the measuring time. In addition to physisorbed water, chemically bound water may also be removed. The mass decrease of the solid sample is measured gravimetrically or the water mass removed is weighed.

Gravitational balances measure not the mass but the sum of mass plus buoyancy of the sample. The buoyancy of the adsorbate must also be taken into account in case water is predominant in spongy structures in comparison to the skeleton. Measurements are disturbed by convection and, at low pressures, by thermal gas flow. During the drying of large samples shrinkage of porous materials or agglomeration of fine materials result in encrustation. This obstructs evaporation from interior and distorts the drying process.

Oven-drying is a widely used method. Here the sample is dried at a constant temperature. Humidity is removed by circulating air. The sample is weighed after reaching mass constancy. Such measurements give reliable "true" results of the moisture content only in case of well known drying characteristics of the material. Weighing at intermediate times and deriving a kinetic curve may obtain more information. However, very different results may also be obtained by this method due to the different binding types of water (Fig. 17).

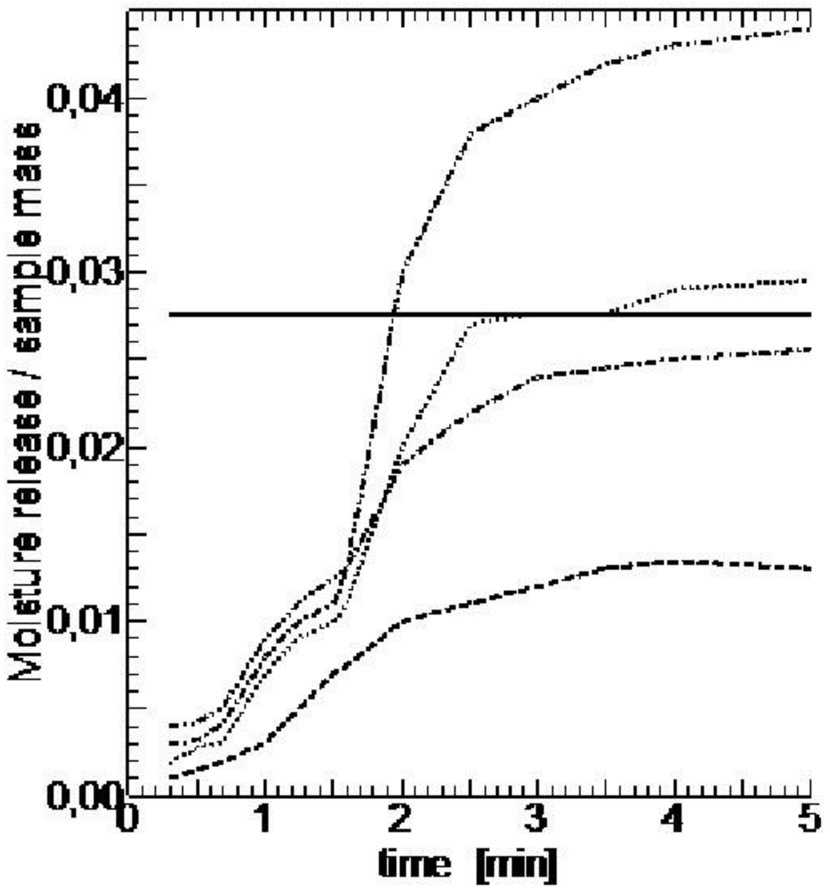


Figure 17. Infrared drying of candies at ---- 90°C, -·-·- 95°C, ····· 100°C, -···-···- 110°C, and water content measured using the Karl Fischer method ———, © Isengard. MS1408a.jpg

Because the manual laboratory method is relatively slow, automated moisture analysers that can reduce the time necessary for a test from a couple hours to just a few minutes have been developed. Electronic moisture balances are equipped with an infrared or microwave heater and a device to remove the moistened air. The moisture balance (Fig. 16) is a simplified model of a thermogravimetric apparatus, also known as conditioning apparatus.

A thermogravimetric apparatus (Fig. 18) consists of a balance and a heating unit to adjust the sample temperature at a constant value or to control the defined temperature increase [60]. Measurements are made either in air, an inert gas flow or vacuum [61]. To investigate the water content, measurements are performed at low temperatures. Physisorbed water and condensed pore water vaporise mainly up to 100 °C. Chemisorbed components and crystal water are liberated at higher temperatures. Quasi isothermal thermograms (QTGA) are measured at slow temperature increase whereby the sample is held under saturation vapour pressure using special sample containers (Fig. 19). QTGA can be evaluated for binding parameters and for pore size distribution.

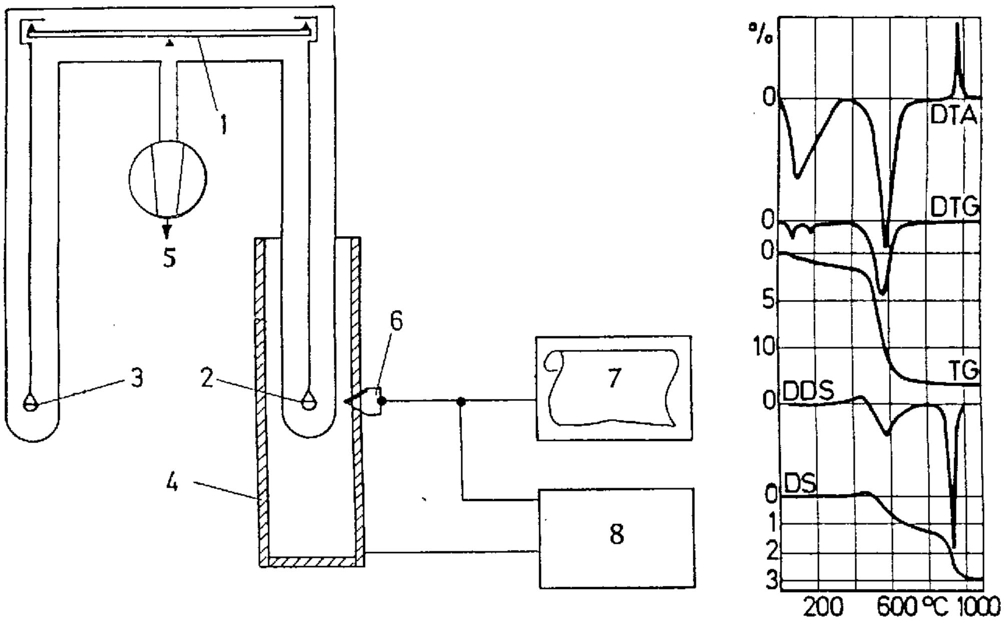


Figure 18. Diagrammatic view of a thermogravimetric apparatus with vacuum thermobalance (MOM Derivatograph). 1 balance beam, 2 sample, 3 counterweight, 4 oven, 5 vacuum pump, 6 temperature sensor, 7 recorder, 8 temperature program control. The records for thermogravimetric analysis (TGA): DTA differential thermal analysis, DTG differential thermogravimetry, TG thermogravimetry, DDT differential thermal dilatometry, thermal dilatometry. BT0999d.jpg

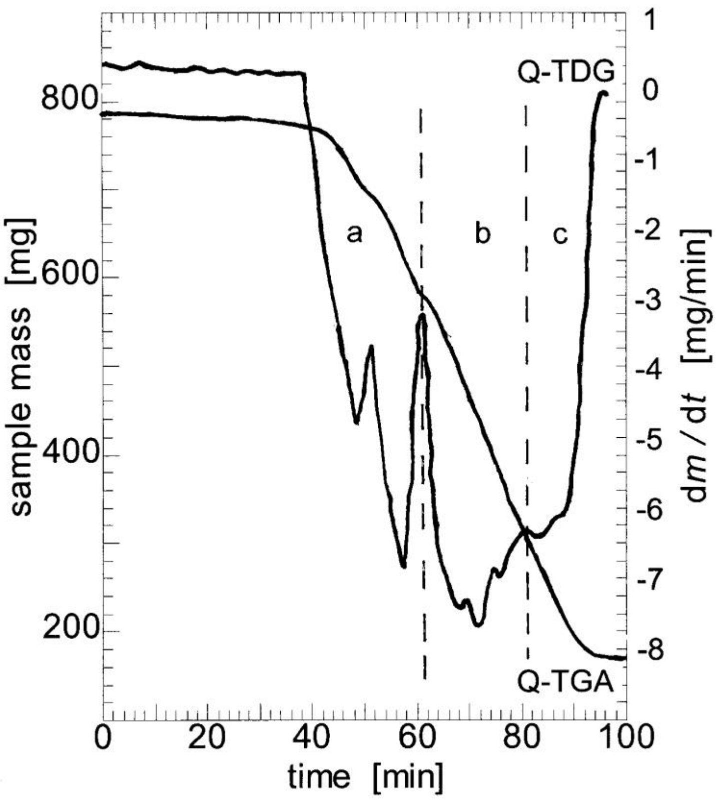


Figure 19. Quasi-isothermal water desorption from activated carbon (Merck) according to Staszczuk. Mass loss (Q-TGA) and its time derivative (Q-DTG) are plotted. © Stasczuck. MS1781b.jpg

Measurement of water sorption isotherms

To measure adsorption isotherms of water vapour, the mass adsorbed is usually determined gravimetrically as a function of stepwise varied pressure at constant temperature [62]. Alternatively, the mass adsorbed may be determined from volume, pressure and temperature in the sample vessel using the equation of state. Adsorption measurements are started from a dry sample state in vacuum or dry atmosphere as well as from a defined humidity. Desorption is started from a defined humidity, from saturation pressure if possible.

Sorption isotherms may be measured simply by placing the samples in a desiccator at constant temperature. Different humidities are adjusted by means of salt solutions [63]. One sample is exposed to a defined single humidity by the integral sorption method whereas the humidity around one sample is stepwise varied by the interval method. Intermediate evacuation or movement of the gas atmosphere can speed up measurements.

An apparatus of gravimetric water sorption consists of a microbalance and a thermostat. Water vapour pressure is adjusted and varied by means of a carrier gas flow loaded with water vapour (Fig. 20a). Alternatively, using a vacuum balance, either portions of water vapour are added or the pressure is adjusted by means of a thermostated water reservoir (Fig. 20b).

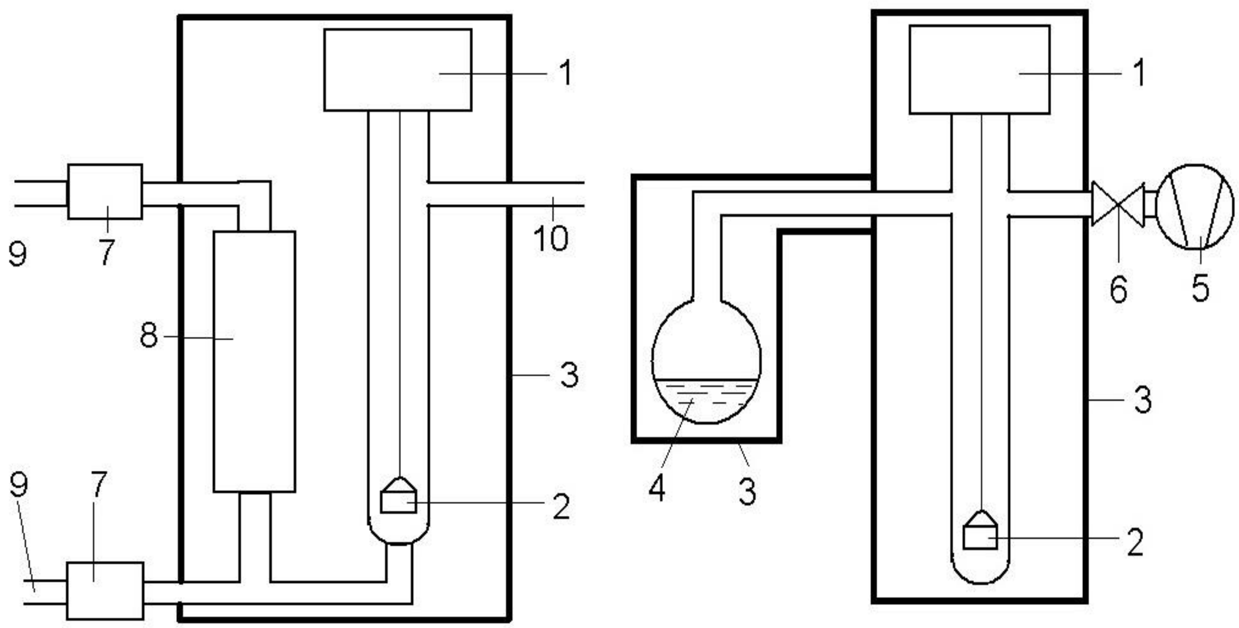


Figure 20. Apparatus of gravimetric water sorption consisting of a microbalance and a thermostat. 1 vacuum balance, 2 sample, 3 thermostated case, 4 water, 5 vacuum pump, 6 valve, 7 flow control, 8 humidifyer. 9 gas inlet, 10 gas outlet.
Figure 20a. Water vapour pressure is adjusted and varied by means of a carrier gas flow loaded with water vapour. BT1788a.jpg
Figure 20b. Alternatively, using a vacuum balance, either portions of water vapor are added or pressure is adjusted by means of a thermostated water reservoir. BT1788c.jpg

Modified volumetric apparatus as widely used for the measurement of adsorption of permanent gases may also be applied for the measurement of water sorption isotherms. Here, condensation in the manifold must be avoided. Drying processes can be easily observed by stepwise pumping of the water vapour, which is developed from a sample, in a calibrated volume.

The standard contact porometry was developed by Volfkovich, Bagotzky, Sosenkin and Shkolnikov [64]. Here, the sample is brought into contact with a porous standard sample with defined water content (Fig. 21). In thermodynamic equilibrium, the liquid into the whole pore system has an identical chemical potential. The humidity of the sample can be derived from the equilibrium water mass in the standard. A set of standards allows the determination of an isotherm even near saturation pressure.

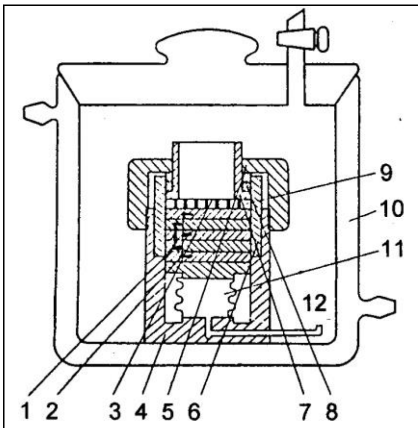


Figure 21. Conditioning equipment for Standard Contact Porometry according to Volfkovich, Bagotzky, Sosenkin and Shkolnikov. 1 sample layer, 2 standard layer, 3 diaphragm, 4 vessel, 5 screw flange, 6 centring tube, 7, 12 vapour inlet, 8, 9 O-rings, 10 thermostat, 11 bellows. BT1782.jpg

In water adsorption isotherms, the specific adsorbed amount n_a is plotted as a function of the relative vapour pressure p/p_0.

$$n_a = n_a\left(\frac{p}{p_0}\right)_T \tag{5}$$

This corresponds to eq. (2b) applied in hygrometry [18]. The specific adsorbed amount n_a is derived from the gravimetrically or volumetrically measured data using

$$n_a = \frac{m_a}{m_s \cdot M_a} = \frac{p_n}{R \cdot T_n} \cdot V_a \tag{6}$$

where m_a is the mass adsorbed, m_s the sample mass, M_a is the mole mass of the adsorbate water, p_n is the standard pressure, R is the universal gas constant, T_n is the standard temperature, V_a is the specific adsorbed gas volume.

With hydrophilic surfaces, isotherms of types I, II, IV and VI according to IUPAC classification (Fig. 22) [6, 65] are observed. The hysteresis may be voluminous and may cover the whole region of relative pressure [32, 66]. On hydrophobic materials, adsorption starts only at elevated pressures; that means there is hardly adsorption at the surface but condensation in pores and isotherms correspond to type II and V. However, often water sorption isotherms cannot be assigned to any type of the IUPAC classification as demonstrated in Figure 23.

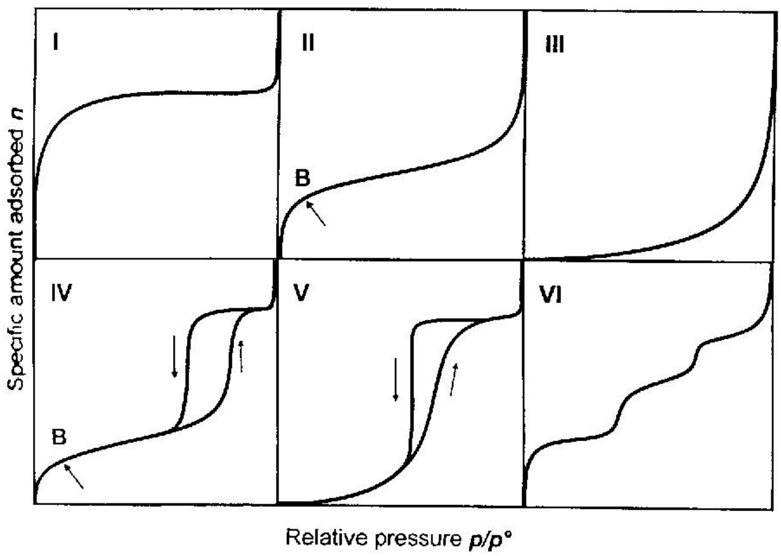


Figure 22. IUPAC classification of gas adsorption isotherms. MS1005e.jpg

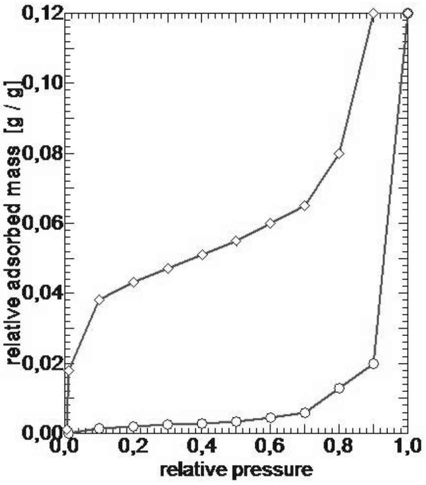


Figure 23. Water vapour isotherm at 298 K on a hardened cement paste (Dyckerhoff white).
O adsorption, ◊ desorption. MS1415.jpg

From type I, II and IV isotherms, the specific surface area [67-68] can be calculated by the method of Brunauer, Emmet and Teller (BET) [69] . Type I may be described by the Langmuir equation and the horizontal plateau results from a monolayer covering the surface (monolayer capacity n_m). The monolayer capacity n_m is calculated using the BET equation:

$$\frac{\frac{p}{p_0}}{n_a\left(1-\frac{p}{p_0}\right)} = \frac{1}{n_m\,C} + \frac{C-1}{n_m\,C}\cdot\frac{p}{p_0} \qquad (7)$$

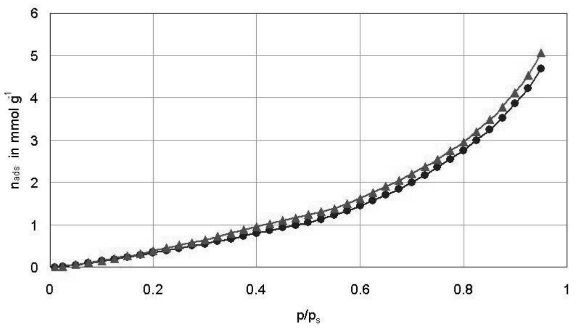
The specific surface area a_s is calculated using

$$a_\mathrm{s} = n_\mathrm{m}\; a_\mathrm{m}\; N_\mathrm{A} \qquad (8)$$

where N_A is Avogadro's number and a_m is the molecular cross sectional area occupied by an adsorbed molecule in a complete monolayer. For water a value of a_m = 0.125 nm^2 is recommended.

The ESW theory by Adolphs [70-72] provides a modeless way of calculating surface energies and specific surfaces areas directly from sorption isotherms. Thermodynamically, the excess surface work (ESW) is the sum of the surface free energy and the isobaric isothermal work of sorption. The measured isotherms are transformed into ESW isotherms by plotting the product of the adsorbed amount and the change in chemical potential versus the adsorbed amount. The ESW isotherms show at least one minimum that yields a sorption energy, which corresponds approximately to the loss of degrees of freedom of the sorptive. Thus, the binding strength of the adsorption layer can be estimated. From the mass adsorbed in the first minimum a specific surface area similar to the BET surface area can be obtained.

Figure 24a shows the water vapour isotherms on polyurethane and silica/polyurethane nanocomposite [73-74]. These are type III isotherms that are characteristic for hydrophobic materials. According to the classical models of BET and BJH, further evaluation of the isotherms is not possible. The transformation into ESW isotherms shows Figure 24b. The minimum of the ESW isotherms corresponds to a loss of degrees of freedom, which describe a medium strong physisorption of the water molecules on the surface. However, the deeper and sharper ESW minimum of the nanocomposite shows that the nanocomposite better adsorbs the water because of the silica additive slightly reduces the hydrophobic characteristics. Further evaluation of ESW isotherm yields a specific surface area of about 6 m² g^{-1}.



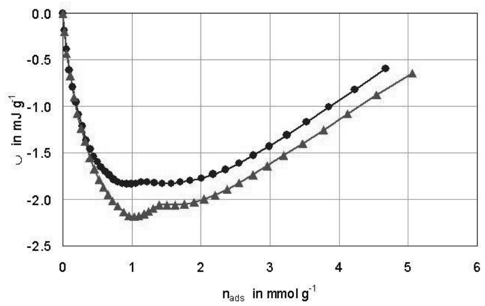


Figure 24a. Water vapour isotherms type III on hydrophobic materials (polyurethane • and silica/polyurethane nanocomposite ▲) MS1418a.jpg

Figure 24b. Transformation of water vapour isotherms in Figure 24a into ESW isotherms. The minimum of the ESW isotherms corresponds to a loss of degrees of freedom of -1.6 RT/2 for polyurethane • and -1.8 RT/2 for silica/polyurethane nanocomposite ▲. The calculated specific surface areas are 5.9 m² g^{-1} (polyurethane) and 6.6 m² g^{-1} (nanocomposite), respectively. MS1419a.jpg

Furthermore from types II and IV isotherms, the pore size distribution can be determined according to the method of Barrett, Joyner and Halenda (BJH) [75] e.g. and various parameters of pore systems can be derived.

Figure 25 shows the water vapour isotherm and the nitrogen isotherm on activated carbon [67]. The whole isotherms as well as the calculated specific surface areas and the pore size distributions are different. However using the adsorbed volume as ordinate, the nitrogen and water sorption curves meet each other at the saturation point in accordance to Gurwitsch's rule [76]. This demonstrates that parameters obtained by using inert gases can only be applied with restrictions to predict adsorption of water. If a material should be used in a humid environment water sorption measurement are unavoidable.

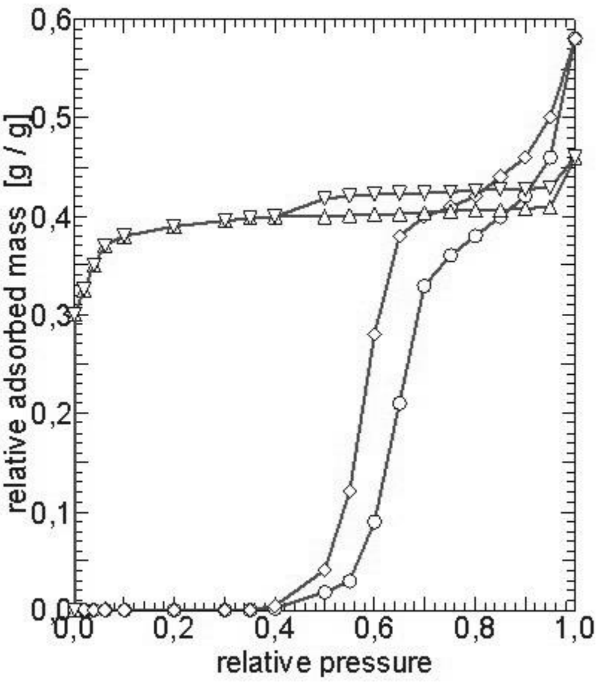


Figure 25. Nitrogen adsorption Δ and desorption ∇ isotherm at 77 K and water vapour adsorption O and desorption ◊ isotherm at 298 K on activated carbon according to Juhola. Note: Using the adsorbed volume as ordinate the nitrogen and water sorption curves meet each other at the saturation point in accordance to Gurwitsch's rule. MS1783b.jpg

Measuring the adsorbed water mass in a material can give the relative humidity of the air with which the material is in equilibrium. For example, the adsorption isotherm of water vapour on wool in Figure 26 can be used for air humidity measurement at 15 °C and 25 °C [30].

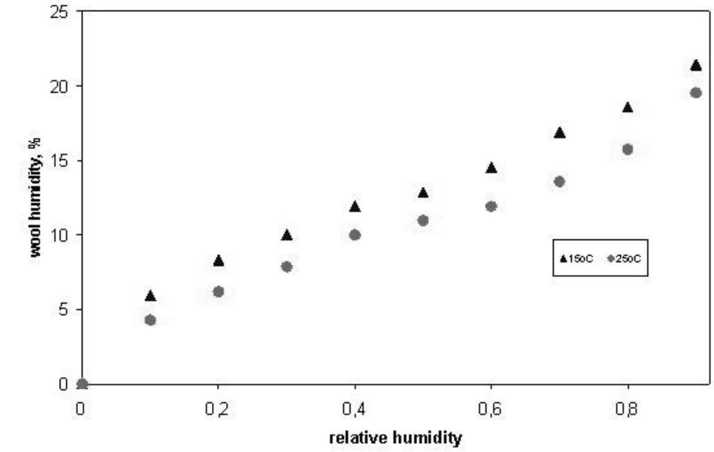


Figure 26. Adsorption isotherm of water vapour on wool at 298 K O and at 288 K Δ. MS1784a.jpg

Calorimetrical measurements

Using microcalorimeters, the heat capacity of moist and dry samples can be compared and the conversion heat during drying or water adsorption can be observed. Such measurements allow the determination of adsorption isotherms and their evaluation is discussed above.

Thermoporometry [77] makes use of the triple point depression of a liquid in contact with the solid phase within a porous matrix. This effect also depends on the curvature of the interface and, thus, of the pore radius. The sample is immersed in water or benzene and the amount of the frozen liquid is measured as a function of decreasing temperature at ambient pressure by means of a high sensitive calorimeter. From this freezing thermogram, the pore size distribution and the specific surface area can be calculated.

Chemical methods for determination of water content

Spot analysis for the detection of water include the reddening of blue cobalt(II) chloride or production of yellow lead iodide from a mixture of potassium iodide and lead nitrate (see Chap. "Hygrometry").

The most important method to determine the complete water content is Karl Fischer titration [78-82]. Water is titrated using Karl Fischer's reagent, which consists of iodine, sulphur dioxide, a basic buffer and a solvent. The original composition was modified and adapted to the matter to be investigated. An alcohol, mostly methanol, is usually used as solvent. It is esterified by means of SO_2. To obtain a quantitative reaction the ester is preferbly neutralised by imidazole to yield alkyl sulphite. In a second step, alkyl sulphite is oxidised by iodine to form alkyl sulphate in a reaction that requires water. Simplified the reaction can be written as

$$SO_2 + I_2 + 2\ H_2O \rightarrow H_2SO_4 + 2\ HI \qquad (9)$$

The consumption of iodine is measured either coulometrically or volumetrically. In the coulometric procedure, iodine is formed from iodide by anodic oxidation. In the volumetric procedure, an iodine solution is added and different techniques are used for titration. The indication of the endpoint is based on an electrochemical effect in both cases: Two platinum electrodes placed into the working medium are polarised either by a constant current or a constant voltage.

Karl Fischer titration requires water to be in direct contact with the reagent. For insoluble or hardly soluble samples a special treatment is necessary; the water has to be released from the matrix first. Some materials may cause erroneous effects by side reactions.

Because many gases include amounts of water of only few $\mu g\ dm^{-3}$, the admission of the gas sample should be made carefully in order to avoid contamination or adsorption of water by the tubing system [83]. Subsequently, the determination of humidity is made according to ISO 10101 [84-86].

Water vaporised from the sample by controlled increasing temperature can be analysed coulometrically. Parallel arranged electrodes, which are coated with thin layer of phosphorus pentoxide, might be used. Hydrogen ions are neutralised and hydrogen is set free at the cathode whereas the reaction

$$P_4O_{12}^{4-} \rightarrow P_4O_{10} + O_2 + 4e^- \qquad (10)$$

takes place at the anode. The current is measured. The resolution of a commercially offered apparatus is 100 ng. The results should be comparable to those of thermogravimetric measurements. In contrast, exclusively the water release is indicated. A typical device is the Keidel cell [7, 87-88], which is a coulometric sensor with platinum electrodes on a substrate covered with a thin film of phosphorus pentoxide [7].

Capacitance measurements

Electrical capacitance tomography (ECT) is applied for online measurement of solid moisture content of fluidised beds [89]. A twin plane ECT sensor with eight electrodes in each plane was mounted in the bottom of a glass fluidisation chamber. From the adjacent electrode pairs, the water content of the solids was estimated on the basis of the correlation between the moisture content and the permittivity value. To reduce measurement errors, the effect of the temperature on the moisture measurement was compensated.

Measurement of material moisture via the gas phase

The material moisture can be measured by evaporation or condensation of sample water and by determination of the vapour pressure and the relative humidity, respectively, within the sample vessel or in a confined volume. This may be performed also stepwise in order to obtain a desorption isotherm. Such a procedure is applied in the phosphorus pentoxide method. Likewise, other air humidity sensors can be used as described in Chapter 3 [7].

Shortening of the measuring time

In statically drying or adsorption measurements, the temperature is held constant and the water vapour pressure is changed stepwise to zero or to a given value. Drying and adsorption at constant temperature are generally slow processes. In particular, water adsorption, absorption and drying occur very slowly and the equilibrium or the dry state cannot be reached in a reasonable time. Therefore, often the measuring procedure is shortened without waiting for equilibrium conditions. To speed up measurements and, nevertheless, avoiding errors, an extrapolation method as described by Jäntti in ref. [90-92] should be preferred .

In many cases, the kinetic drying curve follows approximately a simple exponential law:

$$m_a(t) = m_{as}\left(1 - e^{-t/\tau}\right) \tag{11}$$

where $m(t)$ is the sample mass as a function of time t, m_{as} is the asymptotical equilibrium value and τ is the so-called characteristic time of the system solid/water [91, 93]. Establishing the function

$$J(t) = m_a - \frac{(dm_a/dt)^2}{d^2m_a/dt^2} \tag{12}$$

and differentiation reveals a constant value.

$$J(t) = const. = m_{as} \tag{13}$$

For its practical application, three values of the initial ad- or desorption curve in equidistant time intervals are measured and $J(t)$ is determined using

$$J(t) = \frac{m_{a2}^2 - m_{a1}m_{a3}}{2m_{a2} - m_{a1} - m_{a3}} \tag{14}$$

Indeed, the experimental Jäntti-function is not constant, but it approximates the asymptotical equilibrium value much faster than the measured adsorbed mass (Fig. 27). If the function approximates not quickly a constant value this method is not applicable and it is a definite indication that a complex drying or sorption process occurs, including swelling or encrustation e.g.

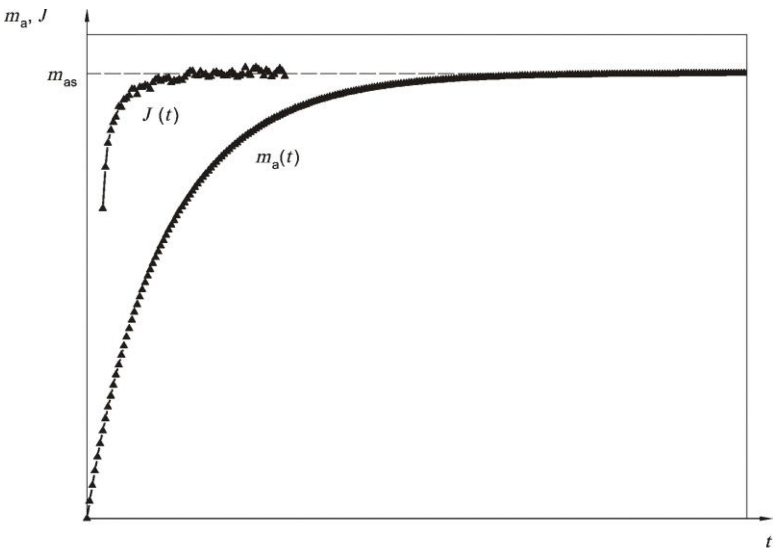


Figure 27. The Jäntti-function $J(t)$ is not constant but approximates the asymptotical equilibrium value much faster then the measured adsorbed mass $m_a(t)$. MS1407.jpg

6. Extraterrestrial water

The universe is cold. Celestial bodies, like planets, moons and asteroids, far from their star are usually covered with frozen volatiles, water ice and organics. Dwarf planets Ceres, Haumea and Orcus are covered with water ice. It is believed that comets consist of blocks of refractory material, regolith and frozen volatiles, mostly water [94-95]. Most probably, liquid water can only exist on a celestial body, which is situated in a comparatively narrow zone in vicinity of a star. In that "habitable" zone, a brisk exchange of water takes place between the body and space, well comparable with technical sorption and drying processes discussed in this paper. In our solar system, today such conditions are found on Earth, Moon, Mars and some other objects, in particular on the Jupiter moon Europa and the Saturn moon Enceladus.

A celestial body was developed from molten material, which initially included no water, but was and still is supplied with water by the following mechanisms:

- The molten basic material contains the components hydrogen and oxygen for the synthesis of water. This process can be observed in volcanic eruptions, in which always water vapour is set free.
- The solidified surface is supplied with water when hit by spatial bodies. Likewise, cosmic dust particles are often covered with ice.
- By its magnetic field, Earth is protected from solar wind, but not the Moon. Solar wind contains mainly electrons and protons. The rocks and regolith that make up the lunar surface consist of about 45 percent oxygen combined with other elements, such as mostly silicate minerals. Protons join with electrons of the surface material to become hydrogen atoms [96]. Some fractions of protons, which are travelling with one-third the speed of light, have enough force to break apart oxygen bonds in soil materials to form water.
- The opposite process is the evaporation of hydrogen, oxygen and water vapour from the body, which is hindered by gravitation and by atmospheric conditions as the recombination of water molecules to denser aggregates e.g.

Search for extraterrestrial water as well as determination of water inventory and soil moisture is based on remote measurements and analysing the spectrum of electromagnetic radiation either of natural sources or produced by a transmitter and reflected. Spacious deposits have been detected photographically. Robots make in situ investigations and, in addition, soil samples of the Moon are analysed using conventional methods.

Moon

The Moon remains drier than any desert on Earth. Nevertheless, water exists on the Moon:

- Frozen pockets of water ice remnants of water-rich comet impacts are embedded unmelted in the permanently shadowed regions near the poles [97]. Due to the very slight tilt of the Moon's axis, only 1.5°, some of these deep craters never receive any light from the Sun; they are permanently shadowed. Estimations amount to from about 6×10^9 up to 10^{12} kg of water ice in total. At least 0.6×10^{12} kg could be entombed in North Pole craters.
- Volatiles vaporise quickly into the tenuous atmosphere (10^{-10} Pa), influenced by solar radiation and daily surface temperatures up to 130 °C, and vanishes into space due to weak gravity. However, during night the temperature decreases down to -160 °C and some of the imported water is adsorbed. Weakly bound physisorbed water may comprise up to two molecular layers at the surface. Water condensed in pores is bound stronger. Some mineral surfaces hydratise and water is chemisorbed. If such a surface is hidden from solar radiation some of those stronger bound water may be hold for long time. It is estimated (optimistically) that one tonne = 10^3 kg of the top layer of the lunar surface would hold about 1 kg of water.
- Some of the vaporised water may drift to the poles and be stored in craters, which act as cold traps with temperatures down to -230 °C.

First photographic results of the Clementine mission and Lunar Prospector [96] suggested that water is on the Moon. Neutron radiation was observed as a response to the bombardment of cosmic radiation on the surface. Fast neutrons are slowed down by hydrogen and then ice can be detected with a content of 0.1 per mille in the surface material down to a depth of about 0.5 m. The distribution of the neutron radiation gave evidence for the presence of water distributed on the entire surface, but with higher concentrations at the poles. Similar effects are produced by structured surfaces of dry stones and, thus, comparative measurements had been necessary for corrections. The Deep Impact spacecraft made infrared detections of water and hydroxyl groups as part of calibration exercises in 2010.

After termination of its mission, in 1999 the Lunar Explorer and in 2006 the Smart-1 were navigated into such craters, but no water was detected. However, NASA's Lcross sattelite kicked up at least 95 litres of ice and vapour from a South Pole crater.

A NASA radar aboard India's Chandrayaan-I lunar orbiter found 40 craters ranging in size from 1 to 15 km across with pockets of ice. The radar called the Mini-SAR sends pulses of left polarised radio waves out to measure the surface roughness of the moon. While smooth surfaces send back a reversed right polarised wave, rough areas return left polarised waves. Ice, which is transparent to radio waves, also sends back left polarised waves. The Mini-SAR measures the ratio of left to right circular polarised power sent back, or the circular polarised ratio (CPR). However, a high CPR alone can not distinguish between rough patches and regions with ice. The North Pole craters had a high CPR on the inside with a low CPR on the edges. This result suggests that a material enclosed in the craters rather than surface roughness caused the high CPR signal. According to NASA, the ice should be relatively pure and at least a meter thick to give such signature.

Regolith samples of the Moon covering, which were transported to Earth by several Apollo missions, had been investigated thoroughly in laboratories using conventional methods [98-99]. Gas adsorption isotherms revealed small specific surface areas below 1 $m^2\ g^{-1}$. A water vapour isotherm is depicted in Fig. 29. The material is rather hydrophobic with small surface area and can hardly store water.

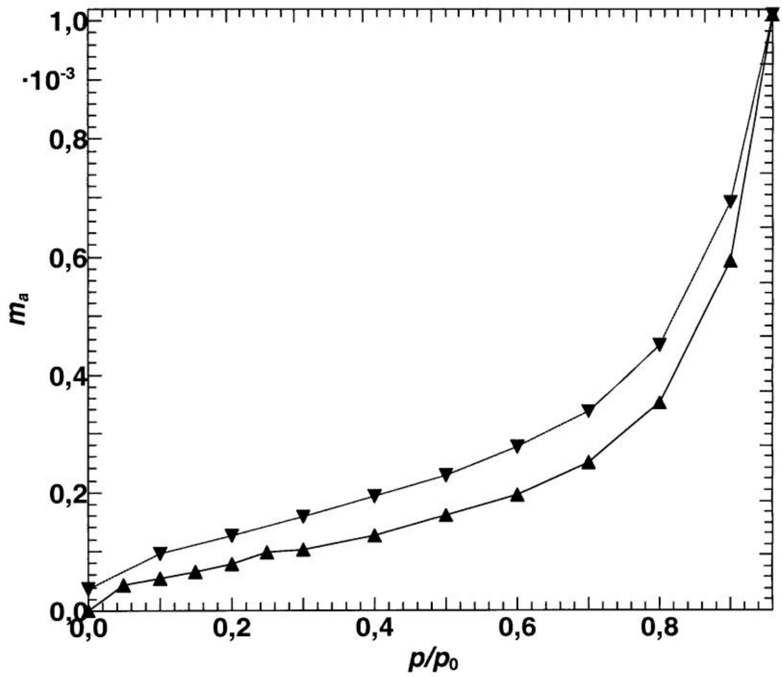


Figure 28. Water vapour adsorption and desorption isotherm at 24,9 C at Lunar regolith sample 12001.922 from the Apollo 12 mission. ▲ adsorption, ▼ desorption. UL1843b.jpg

By means of mass spectrometry, traces of water were found in the interior of volcanic pearls from the Moon, which had been brought to Earth by Apollo 15 [96, 100]. Assuming that 95 % of the water introduced vaporised immediately, the content within Moon's magma is estimated to about 750 ppm. On the other hand, the comparatively large occurrence of the element chlorine suggest, that it is really dry on Moon.

Mars

Most of the water is locked as permafrost in soil and as polar caps together with carbon dioxide ice [101]. Though the temperatures at the Mars fluctuate between -55 and 27 °C, there are no bodies of liquid water, which could create a hydrosphere. Occasionally, droplets at stones have been observed, most probably solutions of perchlorate. Only a small amount of water vapour is in the atmosphere. Water from the poles generates cirrus clouds by sublimation and fog is observed in some valleys in the morning. During summer the northern region of the North Pole is covered with a mixture of water ice and carbon dioxide ice that is 1000 km in diameter and about 5 km thick. In the south-polar region, layered deposits, which are 350 km in diameter and 1.5 km thick, with large amounts of water ice could be identified. Below these caps, deposits in soil, which could cover -when melted- the planet with an 11 m thick water layer, have been detected. For comparison, on Earth a similar coverage would be 3 km thick. In addition, deposits in the soil in the form of ice stocks or permafrost are confirmed for each region of Mars

The water occurrence on Mars was investigated during several satellite missions, first by the Odyssey mission in 2002 [102-103]. Galactic cosmic ray particles react with matter of the planets surface, and they are slowed by loss of energy. The spectra of the re-emitted neutron and gamma rays are evaluated with regard to hydrogen and oxygen peaks, which can be attributed to water at the surface down to some depth. The south polar deposits have been detected by lowered radar echo.

7. Standardization

Scientific problems concerning weather and climate are handled by the World Meteorological Organization (WMO), which is an intergovernmental organization and became the specialised agency of the United Nations for meteorology, operational hydrology and related geophysical sciences. The WMO has its headquarters in Geneva, Switzerland. There exist also national administrations and scientific societies in most countries.

The commonly used term "humidity" includes also liquid contents other than water, solvents e.g. [58]. Indeed, gravimetric methods merely measure the sum of volatile substances within a solid whereas, in general, the task is often to determine the water content only. Therefore, standardisation of measuring methods and procedures is required [2, 7, 19]. Several working groups of national and international standardisation committees develop standards of humidity measurements and related items. One reason is that new measuring instruments, which are in competition to standardised but obsolete methods, are offered. Because water adsorption largely depends on the solid partner, measuring procedures are often specialised. More than 200 standards exist for the investigation of about 70 different materials, like building materials, soil, paint, ceramics, coal, ores, plastics, food, leather, stones, paper and paperboard. More than 50 standards are already harmonised in international ISO standards. In addition, manufacturers as well as vocational and scientific societies have developed special testing specifications [26-27, 104-108]. A working committee of the German standardisation organisation DIN has just released a basic standard on gravimetric humidity measurements [109]. Certified methods of the measurement of air humidity are compiled in a vade-mecum in Germany [110]. The principle of thermal analysis is described in DIN 51006/7 [111-112].

Calibration of instruments is made by Services' in the USAPhysikalisch-Technische Bundesanstalt' and 'Deutscher Kalibrierdienst' , by 'National Physical Laboratory' and 'United Kingdom Accreditation Service' in the UK e.g. A Gravimetric Hygrometer is considered to be a primary source for calibration. National standards have been developed in US, UK, EU and Japan.

Two thermometers can be compared by immersing them both in an insulated vessel of water and stirring vigorously to minimize temperature variations. If handled with care a high-quality liquid-in-glass thermometer should remain stable for some years. Hygrometers must be calibrated in air, which is a much less effective heat transfer medium than water, and many types are subject to drift and need regular recalibration. A further difficulty is that most hygrometers sense relative humidity rather than the absolute amount of water present. But the relative humidity is a function of temperature and absolute moisture content, so that small temperature variations within the air of a test chamber are translated into relative humidity variations.

Standards for the measurement of the water content are listed in Table 4. A list of national identifiers for standards and the assigned standardisation bodies are shown in Table 5. Symbols used are reported in Table 6.

Table 4. Standards for the measurement of water content, dry mass or water sorption

ASTM		**ASTM International** (former American Society for Testing and Materials**)**, 100 Barr Harbor Drive, West Conshohocken, PA, USA
C 70	06	Test method for surface moisture in fine aggregate.
C 121	09	Test method for water absorption of slate.
C 156	09	Test method for water loss [from a mortar specimen] through liquid membrane-forming curing compounds for concrete.
C 272	91	Test method for water absorption of core materials for structural sandwich constructions.
C 324	01	Test method for free moisture in ceramic whiteware clays.
C 370	88	Test method for moisture expansion of fired whiteware products.
C 373	88	Test method for water absorption, bulk density, apparent porosity, and apparent specific gravity of fired whiteware products.
C 562	91	Test method for moisture in a graphite sample.
C 566	97	Test method for total evaporable moisture content of aggregate by drying.
C 1104	00	Test method for determining the water vapor sorption of unfaced mineral fiber insulation.
C 1258	08	Test method for elevated temperature and humidity resistance of vapor retarders for insulation.
C 1616	07	Test method for determining the moisture content of organic and inorganic insulation materials by weight.
C 1699	09	Test method for moisture retention curves of porous building materials using pressure plates.
D 280	01	Test methods for hygroscopic moisture (and other matter volatile under the test conditions) in pigments.
D 425	88	Test method for centrifuge moisture equivalent of soils.

D 558	04	Test methods for moisture-density (unit weight) relations of soil-cement mixtures.
D 570	95	Test method for water absorption of plastics.
D 644	99	Test method for moisture content of paper and paperboard by oven drying.
D 890	98	Test method for water in liquid naval stores.
D 1123	99	Test methods for water in engine coolant concentrate by the Karl Fischer reagent method.
D 1151	00	Practice for effect of moisture and temperature on adhesive bonds.
D 1193	06	Specification for reagent water.
D 1348	94	Test methods for moisture in cellulose.
D 1364	02	Test method for water in volatile solvents (Karl Fischer reagent titration method).
D 1412	07	Test method for equilibrium moisture of coal at 96 to 97 % relative humidity and 30 °C.
D 1461	85	Test method for moisture or volatile distillates in bituminous paving mixtures.
D 1533	00	Test method for water in insulating liquids by coulometric Karl Fischer titration.
D 1558	99	Test method for moisture content penetration resistance relationships fine-grained soils.
D 1576	90	Test method for moisture in wool by oven-drying.
D 1631	10	Test method for water in phenol and related materials by the iodine reagent method.
D 1640	06	Test methods for drying, curing, or film formation of organic coatings at room temperature.
D 1815	00	Test method for water absorption (static) of vegetable tanned leather.
D 1860	95	Test method for moisture and creosote-type preservative in wood.
D 1864	89	Test method for moisture in mineral aggregate used on built-up roofs.
D 1909	04	Table of commercial moisture regains for textile fibres.
D 2118	05	Practice for assigning a standard commercial moisture content for wool and it's products.
D 2132	03	Test method for dust-and-fog tracking and erosion resistance of electrical insulating materials.
D 2216	05	Test method for laboratory determination of water (moisture) content of soil and rock by mass.
D 2247	02	Practice for testing water resistance of coatings in 100 % relative humidity.
D 2462	90	Test method for moisture in wool by distillation with toulene.
D 2495	07	Test method for moisture in cotton by oven-drying.
D 2525	90	Practice for sampling wool for moisture.
D 2713	07	Test method for dryness of propane (valve-freeze method).
D 2842	06	Test method for water absorption of rigid cellular plastics.
D 2867	09	Test methods for moisture in activated carbon.
D 2944	71	Test methods of sampling processed peat materials.
D 2961	02	Test method for single-stage total moisture less than 15 % in coal reduced to 2.36 mm (No. 8 sieve) topsize.
D 2974	07	Test methods for moisture, ash, and organic matter of peat and other organic soils.
D 2980	04	Test method for volume mass, moisture-holding capacity, and porosity of saturated peat materials.
D 2987	88	Test method for moisture content of asbestos fiber.
D 3173	03	Test method for moisture in the analysis sample of coal and coke.
D 3175	07	Test method for volatile matter in the analysis sample of coal and coke.
D 3201	08	Test method for hygroscopic properties of fire-retardant wood and wood-based products.
D 3285	93	Test method for water absorptiveness of nonbibulous paper and paperboard (Cobb test).
D 3302	10	Test method for total moisture in coal.
D 3401	97	Test methods for water in halogenated organic solvents and their admixtures.
D 3790	79	Test method for volatile matter (moisture) of leather by oven drying.
D 3816	93	Test method for water penetration rate of pressure-sensitive tapes.
D 4017	02	Test method for water in paints and paint materials by Karl Fischer method.
D 4230	02	Test method of measuring humidity with cooled-surface condensation (dew-point) hygrometer.
D 4263	83	Standard test method for indicating moisture in concrete by the plastic sheet method
D 4377	00	Test method for water in crude oils by potentiometric Karl Fischer titration.
D 4442	07	Test methods for direct moisture content measurement of wood and wood-base materials.
D 4444	08	Test method for laboratory standardization and calibration of hand-held moisture meters.
D 4502	92	Test method for heat and moisture resistance of wood-adhesive joints.
D 4643	08	Test method for determination of water (moisture) content of soil by microwave oven heating.
D 4672	00	Test methods for polyurethane raw materials: Determination of water content of polyols.
D 4772	09	Test method for surface water absorption of terry fabrics (water flow).
D 4902	99	Test method for evaporation and drying of analytical solutions.
D 4928	00	Test methods for water in crude oils by coulometric Karl Fischer titration.
D 4931	06	Test method for gross moisture in green petroleum coke.
D 4933	99	Guide for moisture conditioning of wood and wood-base materials.
D 4942	89	Test methods for water pickup of lithographic printing inks and vehicles in a laboratory mixer.
D 4944	04	Test method for field determination of water (moisture) content of soil by the calcium carbide gas pressure tester.
D 4959	07	Test method for determination of water (moisture) content of soil by direct heating.
D 5032	97	Practice for maintaining constant relative humidity by means of aqueous glycerin solutions.
D 5229	92	Test method for moisture absorption properties and equilibrium conditioning of polymer matrix composite materials.
D 5348	95	Test method for determination of the moisture content of sulfonated and sulfated oils by distillation with xylene.
D 5349	95	Test method for determination of the moisture and volatile content of sulfonated and sulfated oils by hot-plate method.

D 5454	04	Test method for water vapor content of gaseous fuels using electronic moisture analyzers.
D 5455	93	Test method for short-term liquid sorption into paper (Bristow test).
D 5556	95	Test method for determination of the moisture and other volatile matter contained in fats and oils used in fat liquors and softening compounds.
D 5460	02	Test method for rubber compounding materials - Water in rubber additives.
D 5530	94	Test method for total moisture of hazardous waste fuel by Karl Fischer titrimetry.
D 5637	05	Test method for moisture resistance of electrical insulating varnishes.
D 5744	07	Test method for laboratory weathering of solid materials using a humidity cell.
D 5895	08	Test methods for evaluating drying or curing during film formation of organic coatings using mechanical recorders.
D 6031	96	Test method for logging in situ moisture content and density of soil and rock by the nuclear method in horizontal, slanted, and vertical access tubes.
D 6304	07	Test method for determination of water in petroleum products, lubricating oils, and additives by coulometric Karl Fisher titration.
D 6403	99	Test method for determining moisture in raw and spent materials.
D 6489	99	Test method for determining the water absorption of hardened concrete treated with a water repellent coating.
D 6565	00	Test method for determination of water (moisture) content of soil by the time-domain reflectometry (TDR) method.
D 6642	01	Guide for comparison of techniques to quantify the soil-water (moisture) flux.
D 6658	01	Test method for volatile matter (moisture) of wet blue by oven drying.
D 6782	05	Test methods for standardization and calibration of in-line dry lumber moisture meters.
D 6869	03	Test method for coulometric and volumetric determination of moisture in plastics using the Karl Fischer reaction (the reaction of iodine with water).
D 6980	09	Test method for determination of moisture in plastics by loss in weight.
D 7013	04	Guide for nuclear surface moisture and density gauge calibration facility setup.
D 7191	10	Test method for determination of moisture in plastics by relative humidity sensor.
D 7404	07	Test method for determination of emulsified asphalt residue by moisture analyzer.
D 7438	08	Practice for field calibration and application of hand-held moisture meters.
D 7546	09	Test method for determination of moisture in new and in-service lubricating oils and additives by relative humidity sensor.
E 104	02	Practice for maintaining constant relative humidity by means of aqueous solutions.
E 203	08	Test method for water using volumetric Karl Fischer titration.
E 337	02	Test method for measuring humidity with a psychrometer (the measurement of wet- and dry-bulb temperatures).
E 398	03	Test method for water vapor transmission rate of sheet materials using dynamic relative humidity measurement.
E 410	08	Test method for moisture and residue in liquid chlorine.
E 790	08	Test method for residual moisture in a refuse-derived fuel analysis sample.
E 871	82	Test method for moisture analysis of particulate wood fuels.
E 949	88	Test method for total moisture in a refuse-derived fuel laboratory sample.
E 1064	08	Test method for water in organic liquids by coulometric Karl Fischer titration.
E 1358	97	Test method for determination of moisture content of particulate wood fuels using a microwave oven.
E 1868	09	Test method for loss-on-drying by thermogravimetry.
E 255	07	Test method for humidity calibration (or conformation) of humidity generators for use with thermogravimetric analyzers.
F 1397	93	Test method for determination of moisture contribution by gas distribution system components.
F 1869	10	Test method for measuring moisture vapor emission rate of concrete subfloor using anhydrous calcium chloride.
F 2170	09	Test method for determining relative humidity in concrete floor slabs using in situ probes.
F 2420	05	Test method for determining relative humidity on the surface of concrete floor slabs using relative humidity probe measurement and insulated hood.
F 2298	03	Test methods for water vapor diffusion resistance and air flow resistance of clothing materials using the dynamic moisture permeation cell.
G 60	01	Practice for conducting cyclic humidity tests.
BS		**BSI British Standards Institution,** 389 Chiswick High Road, London, W4 4AL, U.K.
BS 1016-104.1	99	Method for analysis and testing of coal and coke - Proximate analysis - Determination of moisture content of the general analysis test sample.
1377-2	90	Methods of test for soils for civil engineering purposes - Classification tests.
1377-4	90	Methods of test for soils for civil engineering purposes - Part 4: Compaction-related tests.
1881-128	97	Testing concrete – Part 128. Methods for analysis of fresh concrete
1924-1	90	Stabilized materials for civil engineering purposes - General requirements, sampling, sample preparation and tests on materials before stabilization.
1924-2	90	Stabilized materials for civil engineering purposes - Methods of test for cement-stabilized and limestabilized materials.
2782-11.1103C	98	≡ EN 12118: Plastics piping systems - Determination of moisture content in thermoplastics by coulometry.

2880	91	Methods of testing cellulose acetate flake.
2975	04	Sampling and analysis of glass-making sands - Part 1: Methods for sampling and physical testing of glassmaking sands.
3482-2	91	Methods of test for desiccants - Determination of moisture content.
3823	90	Grading of ash and hickory wood handles for hand tools.
3958-1	82	Thermal insulating materials - Magnesia preformed insulation.
3958-2	82	Thermal insulating materials - Calcium silicate preformed insulation.
3958-3	85	Thermal insulating materials - Metal mesh faced manmade mineral fibre mattresses.
3958-4	82	Thermal insulating materials - Bonded preformed manmade mineral fibre pipe sections.
3986-1	98	Methods of test for drying performance of agricultural grain dryers - General procedures and limited requirements for wheat.
3986-2	98	Methods of test for drying performance of agricultural grain dryers - Additional procedures and crop specific requirements.
4317-15	91	Methods of test for cereals and pulses - Determination of moisture content of maize (milled and whole).
4317-2	87	Methods of test for cereals and pulses - Determination of moisture content of cereals and cereal products (Reference method).
4317-22	89	Methods of test for cereals and pulses - Determination of water absorption of flour and rheological properties of doughs using a valorigraph.
4317-25	90	Methods of test for cereals and pulses – determination of wet gluten content in wheat flour by mechanical means.
4401-3	97	Methods of test for meat and meat products - determination of moisture content (Reference method).
4585-2	82	Methods of test for spices and condiments - Determination of moisture content (Entrainment method).
4993-5	80	Methods of test for aluminium fluoride for industrial use - Determination of moisture content (Karl Fischer method).
4993-6	80	Methods of test for aluminium fluoride for industrial use - Determination of moisture content (Gravimetric method).
5050-9(	80	Methods of test for cryolite - Determination of moisture content (Karl Fischer method).
5050-10	80	Methods of test for cryolite - Determination of moisture content (Gravimetric method).
5072-2	74	Methods of test for sodium fluoride for industrial use - deTermination of moisture content.
5268-2	02	Structural use of timber - Part 2: Code of practice for permissible stress design, materials and workmanship.
5309-2	76	Methods for sampling chemical products - Sampling of gases.
5350-C5	02	Methods of test for adhesives - Determination of bond strength in longitudinal shear for rigid adherends.
5752-1	79	Methods of test for coffee and coffee products – Green coffee - Determination of moisture content (Basic reference method).
5752-2	84	Methods of test for coffee and coffee products – Green coffee: determination of moisture content (Routine method).
5752-13	95	Methods of test for coffee and coffee products – Roasted ground coffee - Determination of moisture content - Karl Fischer method (Reference method).
5752-14	95	Methods of test for coffee and coffee products – Roasted ground coffee - Determination of moisture content (loss in mass at 103 °C, routine method).
6091-2	87	Vulcanized fibre for electrical purposes - Methods of test.
6986-3	90	Analysis of instant tea - Method for determination of moisture content (loss in mass at 103 °C).
7312	90	Methods of test for magnetite for use in coal preparation.
7319-2	90	Analysis of sodium chloride for industrial use – Method for determination of moisture content.
7970	05	Electric cables - Metallic wire and foil sheath constructions of power cables having XPLE insulation for voltage from 66 kV (U[M] = 72.5 kV) to 132 kV (U[M] = 145 kV).
BVL		**Bundesamt für Verbraucherschutz und Lebensmittelsicherheit,** Bundesallee 50, 38116 Braunschweig (Germany)
57.20.19-1(EG)	82	Determination of the drying loss of sodium nitrite (E250).
DIN		**Deutsches Institut für Normung e.V**., Burggrafenstraße 6, D-10772 Berlin, Germany
4051	02	Sewer clinkers - requirements, testing, quality control.
8063-5	99	Pipe joints and components of unplasticized poly(vinyl chloride) (PVC-U) for pipes under pressure - Part 5: General quality requirements, testing.
8949	00	Refrigerant filter driers – Testing.
1048-1	91	Testing methods for concrete; fresh concrete
1948-5	91	Testing methods for concrete; hardened concret, specially prepared specimens
10236	01	Analysis of spices and condiments - Determination of loss in mass of capsicum and allium species and of dried vegetables by vacuum oven drying.
10304-2	69	Determination of moisture content and dry substance of glucose syrup; Vacuum oven method.
10304-3	71	Determination of moisture content and dry matter content of glucose syrup; Refractive index method.
10321	80	Determination of the water content of dried milk.
10360	72	Fruit and vegetables - Determination of dry matter content of deep-frozen or heat-preserved spinach.
10453	83	Determination of water content of caseins and caseinates - reference method.
18132	95	Soil, testing procedures and testing equipment - Determination of water absorption.
18180	89	Gypsum plasterboards - Types and requirements.

19682-5	07	Soil quality - Field tests - Part 5: Determination of soil moisture.
19747	09	Investigation of solids - Pre-treatment, preparation and processing of samples for chemical, biological and physical investigations.
29597	95	Aerospace - Application of liquid coating materials.
43903	87	Electrical switch gear and control gear; Humidity of compressed air; Physical relationships, methods of measuring.
45922-1	84	≡ CECC 41000 Harmonized system of quality assessment for electronic components; Generic specification: Potentiometers.
46449	70	Insulating varnishes and insulating resin materials for electrical purposes; Finishing varnishes, Test methods.
51078	02	Testing of ceramic raw materials and materials - Preparation of samples for the determination of change of mass during drying and for chemical analysis.
52251-2	87	Indirect methods of determining the frost resistance of roofing tiles; Determination of water absorption.
52251-3	87	Indirect methods of determining the frost resistance of roofing tiles; Determination of coefficient of impregnation.
52331	95	Testing of glass; Crushing and drying of samples for chemical analysis.
52459	81	Testing of building sealants; Determination of the water absorption of backfill material; Retentive capacity.
53129	01	Testing of solid fibre board - Water absorption and swelling - Water immersion.
53814	74	Testing of textiles; Determination of the water retention power of fibres and yarn cuttings.
53923	78	Testing of textiles; Determination of water absorption of textile fabrics.
54540-9	07	Testing of hygiene products - Tissue and nonwoven - Part 9: Determination of moisture content.
57291-2	79	≡ VDE 0291-2 Compounds for use in cable accessories; Casting resinous compounds before cure and in the cured state.
65046-2	98	Aerospace - Methods of test for surface protective coatings; paints, varnishes - Part 2: Specimens, preparation of specimens, drying.
66138	08	Isothermal measurement of the sorption of vapours at solids.
DIN V		**Deutsches Institut für Normung e.V**., Burggrafenstraße 6, D-10772 Berlin, Germany
52049	98	Testing of bitumen - Determination of water content of bituminous emulsions - Drying test.
EN		**Comité Européenne de Normalisation - CEN**, Rue de Stassart 36, B-1050 Bruxelles, Belgium **Note:** Once adopted, EN standards can only be purchased in the form of national adoptions. A list of national identifiers for standards and the assigned standardization bodies is given at the end of this table.
3-7	04	Portable fire extinguishers - Part 7: Characteristics, performance requirements and test methods. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
62	77	Glass reinforced plastics - Standard atmospheres for conditioning & testing. [national adoption from EN: UNI]
121	91	Extruded ceramic tiles with low water absorption (E <= 3%) - Group A1. [national adoptions from EN: I.S. SN]
159	91	Dust-pressed ceramic tiles with water absorption E > 10% - Group B3. [national adoptions from EN: I.S. SN]
176	92	Dust-pressed ceramic tiles with a low water absorption (E <= 3%) - Group B1. [national adoptions from EN: I.S. ÖNORM SN]
177	91	Dust-pressed ceramic tiles with a water absorption of 3% < E <= 6% - Group B2A. [national adoptions from EN: I.S. SN]
178	91	Dust-pressed ceramic tiles with a water absorption of 6% < E <= 10% - Group B2B. [national adoptions from EN: I.S. ÖNORM SN]
186-1	91	Extruded ceramic tiles with a water absorption of 3% < E <= 6% (Group A2A); Part 1. [national adoptions from EN: I.S. SN]
186-2	91	Extruded ceramic tiles with a water absorption of 3% < E <= 6% (Group A2A) - Part 2. [national adoptions from EN: I.S. PN SN]
187-1	91	Ceramic tiles - Extruded ceramic tiles with a water absorption of 6% < E <= 10% (Group A2B) - Part 1. [national adoptions from EN: I.S. SN]
187-2	91	Ceramic tiles - Extruded ceramic tiles with a water absorption of 6% < E <= 10% (Group A2B) - Part 2. [national adoptions from EN: I.S. ÖNORM SN]
188	91	Ceramic tiles - Extruded ceramic tiles with a water absorption of E > 10% (Group A3). [national adoptions from EN: I.S. SN]
212	03	≡ UNE 56424: Wood preservatives - General guidance on sampling and preparation for analysis of wood preservatives and treated timber. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
322	93	Wood-based panels - Determination of moisture content. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
382-1	94	Fibreboards - Determination of surface absorption - Part 1: Test method for dry process fibreboards. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
382-2	94	Fibreboards - Determination of surface absorption - Part 2: Test methods for hardboards. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]

480-5	05	Admixtures for concrete, mortar and grout - Test methods - Part 5: Determination of capillary absorption. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
771-1	03	Specification for masonry units – Part 1: Clay masonry units. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
771-2	03	Specification for masonry units – Part 2: Calcium silicate masonry units. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
771-3	03	Specification for masonry units – Part 3: Aggregate concrete masonry units (dense and light-weight aggregates). [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
771-4	03	Specification for masonry units – Part 4: Autoclaved aerated concrete masonry units. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
771-5	03	Specification for masonry units – Part 5: Manufactured stone masonry units. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
771-6	05	Specification for masonry units - Part 6: Natural stone masonry units. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
772-7	98	Methods of test for masonry units - Part 7: Determination of water absorption of clay masonry damp proof course units by boiling in water. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN UNE UNI]
772-10	99	Methods of test for masonry units - Part 10: Determination of moisture content of calcium silicate and autoclaved aerated concrete units. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN UNE UNI]
772-11	00	Methods of test for masonry units - Part 11: Determination of water absorption of aggregate concrete, manufactured stone and natural stone masonry units due to capillary action and the initial rate of water absorption of clay masonry units. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
844-4	97	Round and sawn timber - Terminology - Part 4: Terms relating to moisture content. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
993-1	95	Methods of test for dense shaped refractory products - Part 1: Determination of bulk density, apparent porosity and true porosity. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
1015-10	99	Methods of test for mortar for masonry - Part 10: Determination of dry bulk density of hardened mortar. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
1015-18	02	Methods of test for mortar for masonry - Part 18: Determination of water absorption coefficient due to capillary action of hardened mortar. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
1015-19	98	Methods of test for mortar for masonry - Part 19: Determination of water vapour permeability of hardened rendering and plastering mortars. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
1097-6	00	Tests for mechanical and physical properties of aggregates - Part 6: Determination of particle density and water absorption. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
1097-10	99	Tests for mechanical and physical properties of aggregates - Determination of water suction height. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
1161	96	Feather and down - Test methods - Determination of moisture content. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
1170-6	97	Precast concrete products - Test method for glass-fibre reinforced cement - Part 6: Determination of the absorption of water by immersion and determination of the dry density. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
1217	98	Materials and articles in contact with foodstuffs - Test methods for absorption of ceramic articles. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNI]
1348	07	Adhesives for tiles - Determination of tensile adhesion strength for cementitious adhesives. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
1353	96	Determination of moisture content of autoclaved aerated concrete. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
1402-3	03	Unshaped refractory products - Part 3: Characterization as received. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
1609	96	Thermal insulating products for building applications - Determination of short term water absorption by partial immersion. [national adoptions from EN: BS DIN GOST R I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
1860-2	05	Appliances, solid fuels and firelighters for barbecueing - Part 2: Barbecue charcoal and barbecue charcoal briquettes - Requirements and test methods. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
1925	99	Natural stone test methods - Determination of water absorption coefficient by capillarity. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
2155-2	93	Test methods for transparent materials for aircraft glazing - Determination of water absorption. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SNV DIN SS UNE UNI]
2155-13	93	Test methods for transparent materials for aircraft glazing - Part 13: Determination of temperature at

		deflection under load. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SNV DIN SS UNE UNI]
2378	95	Aerospace series - Fibre reinforced plastics - Determination of water absorption by immersion. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SNV DIN SS UNE UNI]
2667-6	01	Aerospace series - Non-metallic materials - Foaming structural adhesives - Test methods - Part 6: Determination of water absorption. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNI]
12048	96	Solid fertilizers and liming materials - Determination of moisture content - Gravimetric method by drying at (105 ± 2)°C. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
12049	96	Solid fertilizers and liming materials - Determination of moisture content - Gravimetric method by drying under reduced pressure. [national adoptions from EN: BS DIN I.S. NBN NEN NF ÖNORM SN SS UNE UNI]
12087	97	Thermal insulating products for building applications - Determination of long term water absorption by immersion. [national adoptions from EN: BS DIN GOST R I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
12088	97	Thermal insulating products for building applications - Determination of long term water absorption by diffusion. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
12105	98	Resilient floor coverings - Determination of moisture content of agglomerated composition cork. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
12118	97	Plastics piping systems - Determination of moisture content in thermoplastics by coulometry. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
12390-8	09	Testing hardened concrete - Part 8: Depth of penetration of water under pressure. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
12429	98	Thermal insulating products for building applications - Conditioning to moisture equilibrium under specified temperature and humidity conditions. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
12509	01	Timber poles for overhead lines - Test methods - Determination of modulus of elasticity, bending strength, density and moisture content. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
12746	00	Footwear - Test methods for insoles and insocks - Water absorption and desorption. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
13040	07	Soil improvers and growing media - Sample preparation for chemical and physical tests, determination of dry matter content, moisture content and laboratory compacted bulk density. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
13183-1	02	Moisture content of a piece of sawn timber - Determination by oven dry method. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
13183-2	02	Moisture content of a piece of sawn timber - Estimation by electrical resistance method. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
13183-3	05	Moisture content of a piece of sawn timber - Part 3: Estimation by capacitance method. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
13407	06	Wall-hung urinals - Functional requirements and test methods. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
13579	02	Products and systems for the protection and repair of concrete structures - Test methods - Drying test for hydrophobic impregnation. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
13748-1	04	Terrazzo tiles - Part 1: Terrazzo tiles for internal use. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
13748-2	04	Terrazzo tiles - Part 2: Terrazzo tiles for external use. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
13755	02	Natural stone test methods - Determination of water absorption at atmospheric pressure. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
13815	06	Fibrous gypsum plaster casts - Definitions, requirements and test methods. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNI]
14251	03	Structural round timber - Test methods. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
14298	04	Sawn timber - Assessment of drying quality. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
14411	06	Ceramic tiles - Definitions, classification, characteristics and marking. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
14774-1	09	Solid biofuels - Determination of moisture content - Oven dry method - Part 1: Total moisture - Reference method. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNI]
14774-2	09	Solid biofuels - Determination of moisture content - Oven dry method - Part 2: Total moisture - Simplified method.

		[national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNI]
14774-3	09	Solid biofuels - Determination of moisture content - Oven dry method - Part 3: Moisture in general analysis sample. [national adoptions from EN: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNI]
20535	94	≡ ISO 535: Paper and boards - Determination of water absorptiveness - Cobb method. [national adoptions from EN: BS DIN I.S. NBN NF ÖNORM PN SN SS UNE UNI]
29865	93	≡ ISO 9865: Textiles - Determination of water repellency of fabrics by the Bundesmann rain-shower test. [national adoptions from EN: BS DIN I.S. NBN NF ÖNORM PN SN SS UNE UNI]
60749-7	02	Semiconductor devices - Mechanical and climatic test methods - Part 7: Internal moisture content measurement and the analysis of other residual gases. [national adoptions from EN: BS CEI DIN IEC I.S. NBN NEN NF ÖNORM PN SS UNE]
60749-7	06	Semiconductor devices - Mechanical and climatic test methods - Part 39: Measurement of moisture diffusivity and water solubility in organic materials used for semiconductor components. [national adoptions from EN: BS CEI DIN IEC I.S. NBN NEN NF ÖNORM PN SS]
60811-1-3	95	≡ IEC 60811-1-3 ≡ VDE 0473-811-1-3: Insulating and sheathing materials of electric cables - Common test methods - Part 1: General application; Section 3: Methods for determining the density - Water absorption tests - Shrinkage test. [national adoptions from EN: BS CEI DIN I.S. NBN NEN NF ÖNORM PN SN SS UNE]
60893-1	04	≡ IEC 60893-1 ≡ VDE 0318-1: Insulating materials - Industrial rigid laminated sheets based on thermosetting resins for electrical purposes - Part 1: Definitions, designations and general requirements. [national adoptions from EN: BS CEI DIN I.S. NBN NEN NF ÖNORM PN SN SS UNE]
EN ISO		**Comité Européenne de Normalisation - CEN**, Rue de Stassart 36, B-1050 Bruxelles, Belgium
62		≡ ISO 62: Plastics - Determination of water absorption. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
287	09	≡ ISO 287: Paper and board - Determination of moisture content of a lot - Oven-drying method. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
291	08	≡ ISO 291: Plastics - Standard atmospheres for conditioning and testing. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
585	99	≡ ISO 585: Plastics - Unplasticized cellulose acetate - Determination of moisture content. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
638	08	≡ ISO 638: Paper, board and pulps - Determination of dry matter content - Oven-drying method. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS PN SN SS UNE UNI]
665	00	≡ ISO 665: Oilseeds - Determination of moisture and volatile matter content. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
712	09	≡ ISO 712: Cereals and cereal products - Determination of moisture content - Reference method. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
1517	95	≡ ISO 1517 (superseded by EN ISO 9117-3): Paints and varnishes - Surface-drying test - Ballotini method. [national adoptions from EN ISO: DIN NBN NF NS ÖNORM SN]
1666	97	≡ ISO 1666: Starch - Determination of moisture content - Oven-drying method. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
1741	94	≡ ISO 1741: Dextrose - Determination of loss in mass on drying - Vacuum oven method. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
2417	02	≡ ISO 2417: Leather - Physical and mechanical tests - Determination of the static absorption of water. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
3251		≡ BS 3900-B18(2003) ≡ ISO 3251: Paints, varnishes and plastics - Determination of non-volatile-matter content. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
3344	97	≡ ISO 3344: Reinforcement products - Determination of moisture content. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
3727-1	01	≡ ISO 3727-1: Butter - Determination of moisture, non-fat solids and fat contents - Part 1: Determination of moisture content (reference method). [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
5404	02	≡ ISO 5404: Leather - Physical and mechanical tests - Determination of the water resistance of heavy leathers. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
5537	04	≡ ISO 5537: Dried milk - Determination of moisture content (reference method). [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
6330	00	≡ ISO 6330: Textiles - Domestic washing and drying procedures for textile testing. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
6540	10	≡ ISO 6540: Maize - Determination of moisture content (on milled grains and on whole grains). [national adoption from EN ISO: I.S.]
9117-1	09	≡ ISO 9117-1: Paints and varnishes - Drying tests - Part 1: Determination of through-dry state and through-dry time. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS PN SN SS UNE UNI]

9117-2	10	Paints and varnishes - Drying tests - Part 2: Pressure test for stackability. [national adoptions from EN ISO: BS I.S. NEN PN SS UNI]
9117-3	10	≡ ISO 9665: Paints and varnishes - Drying tests - Part 3: Surface-drying test using ballotini. [national adoptions from EN ISO: BS I.S. NEN NF PN SS UNI]
9665	00	Adhesives - Animal glues - Methods for sampling and testing. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
10545-3	97	≡ ISO10545-3: Ceramic tiles - Part 3: Determination of water absorption, apparent porosity, apparent relative density and bulk density. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
10565	98	≡ ISO 10565: ≡ BS 4289-11(1998): Oilseeds - Simultaneous determination of oil and water contents - Method using pulsed nuclear magnetic resonance spectrometry. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
11125-7	97	≡ ISO 11125-7: Preparation of steel substrates before application of paints and related products - Test methods for metallic blast-cleaning abrasives - Part 7: Determination of moisture. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
11127-5	97	≡ ISO 11127-5: Preparation of steel substrates before application of paints and related products - Test methods for non-metallic blast-cleaning abrasives - Part 5: Determination of moisture. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
12570	00	≡ ISO 12570: Hygrothermal performance of building materials and products - Determination of moisture content by drying at elevated temperature. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
12571	00	≡ ISO 12571: Hygrothermal performance of building materials and products - determination of hygroscopic sorption properties. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
13758	96	≡ ISO 13758: Methods of test for petroleum and its products - Liquefied petroleum gases - Assessment of the dryness of propane - Valve freeze method. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
15148	02	≡ ISO 15148: Hygrothermal performance of building materials and products - Determination of water absorption coefficient by partial immersion. [national adoptions from EN ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
60811-1-3	95	≡ IEC 60811-1-3 ≡ VDE 0473-811-1-3: Insulating and sheathing materials of electric cables - Common test methods - Part 1: General application; Section 3: Methods for determining the density - Water absorption tests - Shrinkage test.
60893-1	04	≡ IEC 60893-1 ≡ VDE 0318-1: Insulating materials - Industrial rigid laminated sheets based on thermosetting resins for electrical purposes - Part 1: Definitions, designations and general requirements. [national adoptions from EN ISO: BS CEI DIN I.S. NBN NEN NF ÖNORM PN SN SS UNE]
prEN		**Comité Européenne de Normalisation - CEN**, Rue de Stassart 36, B-1050 Bruxelles, Belgium
3615	99	≡ DIN EN 3615 ≡ NFL 17 457: Aerospace series - Fibre reinforced plastics - Determination of the conditions of exposure to humid atmosphere and of moisture absorption.
15414-3	09	Solid recovered fuels - Determination of moisture content using the oven dry method - Part 3: Moisture in general analysis sample.
GOST		**Committee of the Russian Federation for Standardization, Metrology and Certification**, Leninsky Prospekt 9, Moskva 117049, Russia
2409	95	Refractories - Method for determination of bulk density apparent and true porosity, water absorption.
12730.0	78	Concretes - General requirements to methods of determination of density, porosity, moisture content, water absorptions and water tightness.
IEC		**International Electrotechnical Commission**, 3 rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland
60811-1-3	01	≡ EN 60811-1-3 ≡ GOST R IEC 60811-1-3 ≡ JIS C3660-1-3 ≡ NFC 32 026 Common test methods for insulating and sheathing materials of electric cables - Methods for general application - Methods for determining the density - Water absorption tests - Shrinkage test.
ISO		**International Organization for Standardization**, Central Secretariat, 1 rue de Varembé, BP 56, CH-1211 Geneva 20, Switzerland
62	08	Plastics - Determination of water absorption. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 62)]
287	09	≡ JIS P8127: Paper and board - Determination of moisture content of a lot - Oven-drying method. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 287)]
291	08	Plastics - Standard atmospheres for conditioning and testing. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 291)]
310	92	Manganese ores and concentrates - Determination of hygroscopic moisture content in analytical samples - Gravimetric method. [direct adoption from ISO: PN]

535	91	≡ EN 20535 ≡ JIS P8140: Paper and board - Determination of water absorption - Cobb method. [direct adoptions from ISO: NBR NM NS]
585	90	Plastics - Non plasticized cellulose acetate - Determination of moisture content. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 585)]
589	08	≡ SANS 589: Hard coal - Determination of total moisture. [direct adoption from ISO: NEN]
638	08	≡ JIS P8203: Paper, board and pulps - Determination of dry matter content - Oven-drying method. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 638)]
665	00	≡ EN ISO 665: Oilseeds - Determination of moisture and volatile matter content. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 665)]
672	78	≡ BS 1715-2.6(1989): Soaps - Determination of moisture and volatile matter content - Oven method. [direct adoptions from ISO: NBN NEN PN UNE]
711	85	≡ DIN 10350 ≡ NFV 03 706 ≡ PN 93/A-74012 ≡ UNE 34068-2: Cereals and cereal products - Determination of moisture content (Basic reference method). [direct adoptions from ISO: NF UNI]
712	09	Cereals and cereal products - Determination of moisture content - Reference method. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 712)]
771	77	≡ DIN 10268: Oilseed residues - Determination of moisture and volatile matter content. [direct adoption from ISO: PN]
802	76	≡ NBN T 03 401 ≡ SIS 11 77 90: Aluminium oxide primarily used for the production of aluminium - Preparation and storage of test samples. [direct adoption from ISO: SS]
939	80	≡ UNE 34096-7 ≡ : NFV 03 402: Spices and condiments - Determination of moisture content - Entrainment method. [direct adoptions from ISO: DIN PN]
1026	82	Fruit and vegetable products - Determination of dry matter content by drying under reduced pressure and of water content by azeotropic distillation. [direct adoption from ISO: PN]
1442	97	≡ ÖNORM N 4004 ≡ UNE 34552-2: Meat and meat products - determination of moisture content (Reference method). [national adoptions from ISO: NEN PN UNI]
1609	96	≡ EN 1609: Thermal insulating products for building applications - Determination of short term water absorption by partial immersion.
1666	96	Starch - Determination of moisture content - Oven-drying method. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 1666)]
1741	94	≡ NFV 03 621: Dextrose - Determination of loss in mass on drying - Vacuum oven method. [direct adoption from ISO: EN (national EN adoptions see under EN ISO 1741)]
2066	04	Resilient floor coverings - Determination of moisture content of agglomerated composition cork.
2190	98	≡ UNE 56917: Cork - granulated cork - determination of moisture content. [direct adoption from ISO: NF]
2291	80	Cocoa beans - Determination of moisture content (Routine method).
2386	98	Corkwood in planks, virgin cork, ramassage, gleanings, corkwood refuse and corkwaste - determination of moisture content. [direct adoption from ISO: NF]
2417	02	≡ UNE 59006: Leather - Physical and mechanical tests - Determination of the static absorption of water. [direct adoption from ISO: SANS, EN (national adoptions from EN see under EN ISO 1741)]
2462	73	≡ NBN T 03 152: Sodium chlorate for industrial use - Determination of moisture content - Gravimetric method.
2483	73	≡ NBN T 03 165 ≡ UNE 34203: Sodium chloride for industrial use - Determination of the loss of mass at 110 °C.
2596	06	Iron ores - determination of hygroscopic moisture in analytical samples - Gravimetric, Karl Fischer and mass-loss methods. [direct adoptions from ISO: BN NEN SS]
2696	76	Fibre building boards - Hard and medium boards for general purposes - Quality specifications - Water absorption and swelling in thickness.
2832	73	≡ NBN T 03 462 ≡ NFT 20 151: Sodium fluoride for industrial use - Determination of moisture content. [direct adoption from ISO: PN]
2896	87	Rigid cellular plastics - Determination of water absorption. [direct adoptions from ISO: NEN SS]
3082	09	Iron ores - Sampling and sample preparation procedures. [direct adoptions from ISO: BS NEN]
3087	98	Iron ores - Determination of the moisture content of a lot. [direct adoptions from ISO: BS NBR PN UNI]
3130	75	≡ DIN 52183: Wood - Determination of moisture content for physical and mechanical tests. [direct adoptions from ISO: NBN ÖNORM UNI]
3251	08	≡ BS 3900-B18(2003): Paints, varnishes and plastics - Determination of non-volatile-matter content. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 3251)]

3344	97	Reinforcement products - Determination of moisture content. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 3344]
3393	76	≡ NBN T 03 444 ≡ NFT 20 161: Cryolite, natural and artificial, and aluminium fluoride for industrial use determination of moisture content - Gravimetric method. [direct adoption from ISO: SS]
3727-1	01	Butter - Determination of moisture, non-fat solids and Fat contents - Part 1: Determination of moisture content (Reference method). [direct adoption from ISO: EN (national EN adoptions see under EN ISO 3727-1)]
4299	89	Manganese ores - Determination of moisture content.
4470	81	Sawn timber - determination of the average moisture content of a lot. [direct adoption from ISO: ÖNORM]
5068-1	07	Brown coals and lignites - Determination of moisture content - Part 1: Indirect gravimetric method for total moisture. [direct adoptions from ISO: BS NEN]
5068-2	07	Brown coals and lignites - Determination of moisture content - Part 2: Indirect gravimetric method for moisture in the analysis sample. [direct adoptions from ISO: BS NEN]
5069-1	83	Brown coals and lignites - Principles of sampling - Part 1: Sampling for determination of moisture content and for general analysis. [direct adoption from ISO: PN]
5069-2		Brown coals and lignites - Principles of sampling - Part 2: Sample preparation for determination of moisture content and for general analysis. [direct adoption from ISO: PN]
5404	02	≡ UNE 59007: Leather - Physical and mechanical tests - Determination of the water resistance of heavy leathers. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 5404]
5530-1	97	≡ BIS IS 12516-1: Wheat flour - Physical characteristics of doughs - Part 1: Determination of water absorption and rheological properties using a farinograph. [direct adoption from ISO: NEN NF PN]
5530-3	88	Wheat flour - Physical characteristics of doughs - Part 3: Determination of water absorption and rheological properties using a valorigraph.
5537	04	≡ BIS IS 11623 ≡ SANS 5537: Dried milk - Determination of moisture content (Reference method). [direct adoption from ISO: BS DIN I.S. NBN NEN NF NS ÖNORM PN SN SS UNE UNI]
5550	06	Caseins and caseinates - Determination of moisture content (reference method). [direct adoptions from ISO: BS NEN NF]
5635	78	≡ PN 92/P-50158 ≡ UNE 57049: Paper - Measurement of dimensional change after immersion in water.
5637	89	≡ AS/NZS 1301.442S ≡ PN 92/P-50159 ≡ UNE 57112: Paper and board - Determination of water absorption and increase in thickness after immersion in water.
6129	81	Chromium ores - Determination of hygroscopic moisture content in analytical samples - Gravimetric method.
6330	00	≡ AS 2001.5.4 ≡ BIS IS 15370 ≡ EN 26330: Textiles - Domestic washing and drying procedures for textile testing. [direct adoptions from ISO: EN GOST-R (national adoptions from EN see under EN ISO 6330)]
6540	80	Maize - Determination of moisture content (on milled grains and on whole grains). [direct adoptions from ISO: DIN EN I.S. PN (national adoptions from EN see under EN ISO 6540)]
6783	82	≡ DIN 52102 ≡ SS 13 21 25 ≡ UNE 83134: Coarse aggregates for concrete - Determination of particle density and water absorption hydrostatic balance method.
7033	87	Fine and coarse aggregates for concrete - Determination of the particle mass-per-volume and water absorption - Pycnometer method.
7513	90	≡ BIS IS 13859: Instant tea in solid form - Determination of moisture content (loss in mass at 103 °C) [direct adoptions from ISO: NF PN]
7700-1	08	Food products - checking the performance of moisture meters in use - Part 1: Moisture meters for cereals. [direct adoptions from ISO: BS NF]
7700-2	87	Check of the calibration of moisture meters - Part 2: Moisture meters for oilseeds.
8361-2	91	Thermoplastics pipes and fittings - Water absorption - Test conditions for unplasticized poly vinyl chloride (PVC-U) pipes and fittings. [direct adoptions from ISO: NEN PN]
8361-3	91	≡ DIN 16890: Thermoplastics pipes and fittings - Water absorption - Test conditions for acrylonitrile butadiene styrene (ABS) pipes and fittings. [direct adoption from ISO: PN]
8375	09	Timber structures - Glued laminated timber – Test methods for determination of physical and mechanical properties.
8557	85	Aluminium ores - Determination of hygroscopic moisture in analytical samples - Gravimetric method.
8756	94	Air quality - Handling of temperature, pressure and humidity data. [direct adoptions from ISO: DIN GOST R PN SS]
8787	86	≡ JIS P8141 ≡ UNE 57044: Paper and board - Determination of capillary rise - Klemm method. [direct adoptions from ISO: DIN EN NBR NM NEN NF PN UNI]

8851-1	04	Butter - Determination of moisture, non-fat solids and fat contents (routine methods) - Part 1: Determination of moisture content. [direct adoptions from ISO: NEN NF]
9033	89	≡ AS 2932.2: Aluminium ores - Determination of the moisture content of bulk material.
9117-1	09	≡ EN ISO 9117-1: Paints and varnishes - Drying tests - Part 1: Determination of through-dry state and through-dry time. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 9117-1]
9117-2	10	Paints and varnishes - Drying tests - Part 2: Pressure test for stackability. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 9117-2]
9117-3	10	Paints and varnishes - Drying tests - Part 3: Surface-drying test using ballotini. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 9117-3]
9665	98	≡ BS 647(1993): Adhesives - Animal glues - Methods for sampling and testing. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 9665]
9865	93	≡ EN 29865: Textiles - Determination of water repellency of fabrics by the Bundesmann rain-shower test. [direct adoptions from ISO: NEN NS]
10251	06	≡ AS 2863: Copper, lead, zinc and nickel concentrates - Determination of mass loss of bulk material on drying. [direct adoption from ISO: BS]
10545-3	97	≡ SAC GB/T 3810.3 ≡ SIA 248.078: Ceramic tiles - Part 3: Determination of water absorption, apparent porosity, apparent relative density and bulk density. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 10545-3]
10565	98	Oilseeds - Simultaneous determination of oil and water contents - Method using pulsed nuclear magnetic resonance spectrometry. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 10565]
11093-3	94	≡ UNE 57163-3: Paper and board - Testing of cores - Part 3: Determination of moisture content using the oven drying method. [direct adoptions from ISO: BS DIN NF]
11125-7	93	≡ JIS Z0311 ≡ NFT 35 507-7: Preparation of steel substrates before application of paints and related products - Test methods for metallic blast-cleaning abrasives - Part 7: Determination of moisture. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 11125-7]
11127-5	93	≡ JIS Z0312: Preparation of steel substrates before application of paints and related products - Test methods for non-metallic blast-cleaning abrasives - Part 5: Determination of moisture. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 9117-3]
11294	94	Roasted ground coffee - Determination of moisture content - Method by determination of loss in mass at 103 °C (Routine method). [direct adoptions from ISO: NF PN]
11461	01	Soil quality - Determination of soil water content as a volume fraction using coring sleeves - Gravimetric method. [direct adoptions from ISO: BS DIN NF PN SS UNE]
11464	06	Soil quality - Pretreatment of samples for physico-chemical analyses. [direct adoptions from ISO: BS DIN NF SS]
11465	93	≡ BIS IS 15106: Soil quality - Determination of dry matter and water content on a mass basis - Gravimetric method. [direct adoptions from ISO: DIN NEN NF PN SS]
11520-2	01	Agricultural grain driers - Determination of drying performance - Part 2: Additional procedures and crop-specific requirements. [direct adoptions from ISO: BS NEN SS]
11722	99	≡ DIN 51718 ≡ JIS M8812 ≡ SANS 11722: Solid mineral fuels - Hard coal - Determination of moisture in the general analysis test sample by drying in nitrogen. [direct adoptions from ISO: NEN PN]
11817	94	≡ DIN 10772-1: Roasted ground coffee - Determination of moisture content - Karl Fischer method (Reference method). [direct adoptions from ISO: NF PN]
12570	00	≡ SIA 180.214: Hygrothermal performance of building materials and products - Determination of moisture content by drying at elevated temperature. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 12570]
12571	00	Hygrothermal performance of building materials and products - Determination of hygroscopic sorption properties. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 12571]
12572	01	Hygrothermal performance of building materials and products – determination of water vapour transmission properties
12743	06	≡ AS 2862.1: Copper, lead, zinc and nickel concentrates – Sampling procedures for determination of metal and moisture content. [direct adoption from ISO: BS]
13758	96	≡ IP 395: Methods of test for petroleum and its products - Liquefied petroleum gases - Assessment of the dryness of propane - Valve freeze method. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 13758]

13765-6	04	Refractory mortars - Part 6: Determination of moisture content of ready-mixed mortars. [direct adoptions from ISO: BS NEN]
15148	02	Hygrothermal performance of building materials and products - Determination of water absorption coefficient by partial immersion. [direct adoption from ISO: EN (national adoptions from EN see under EN ISO 15148]
15968	00	Direct reduced iron - Determination of apparent density and water absorption of hot briquetted iron (HBI).
16586	03	Soil quality - Determination of soil water content as a volume fraction on the basis of known dry bulk density - Gravimetric method. [direct adoptions from ISO: DIN NF PN UNE]
17190-4	01	Urine-absorbing aids for incontinence - Test methods for characterizing polymer-based absorbent materials -Part 4: Determination of moisture content by mass loss upon heating. [direct adoption from ISO: NEN]
18775	08	Veneers - Terms and definitions, determination of physical characteristics and tolerances. [direct adoption from ISO: NF]
20983	08	Instant coffee - determination of moisture content -Karl Fischer method (Reference method). [direct adoptions from ISO: BS NEN]
23391	06	Dried rosehips - Specification and test methods.
23394	06	Dried oleaster - Specification and test methods.
24557	09	Pulses - Determination of moisture content - Air-oven method. [direct adoptions from ISO: BS NEN]
JIS		**Japanese Standards Association (JSA)** 1-24 Akasaka 4-Chome Minato-ku, Tokyo 107, Japan
A 1111	07	Method of test for surface moisture in fine aggregate.
A 1125	07	Methods of test for moisture content of aggregate and surface moisture in aggregate by drying.
A 1437	92	Test methods for moisture resistance of boards for interior system of building.
A 1470-1	08	Determination of water vapour adsorption/desorption properties for building materials - Part 1: Response to humidity variation.
A 1470-2	08	Determination of water vapour adsorption/desorption properties for building materials - Part 2: Response to temperature variation.
A 1475	04	Method of test for hygroscopic sorption properties of building material.
A 1476	06	Measuring method for moisture content of building materials by drying at elevated temperature.
A 1802	09	Methods of test for production control of concrete - Method of test for surface moisture in fine aggregate by centrifugal force.
A 1803	09	Methods of test for production control of concrete - Method of test for surface moisture in coarse aggregate.
A 6930	97	Plastic films vapour barrier for residential use.
B 8392-3	01	Compressed air - Part 3: Test methods for measurement of humidity.
C 9730-2-13	10	Automatic electrical controls for household and similar use - Part 2-13: Particular requirements for humidity sensing controls.
C 60068-2-38	88	Basic environmental testing procedures - Part 2: Tests, Test Z/AD: Composite temperature/humidity cyclic test
C 60068-3-6	08	Environmental testing - Part 3-6: Supporting documentation and guidance - Confirmation of the performance of temperature/humidity chambers.
C 60721-2-1	95	Classification of environmental conditions - Part 2: Environmental conditions appearing in nature temperature and humidity.
C 60721-3-4	97	Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Section 4: Stationary use at non-weatherprotected locations.
C 61300-2-48	10	Fiber optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-48: Tests - Temperature - humidity cycling
D 0203	94	Method of moisture, rain and spray test for automobile parts.
D 4414-1	98	Automotive parts - Brake linings and disc brake pads - Part 1: Test procedure of seizure to ferrous mating surface due to corrosion (moisture adsorption method).
E 3017	07	Parts for railway signalling - Waterproof test method.
E 4034	94	Railway rolling stock parts - Test methods of resistibility for moisture and rainfall.
G 2403	03	Methods for sampling, preparation and determination of moisture content of aluminium dross.
K 0225	02	Testing methods for determination of trace components in diluent gas and zero gas.
K 1468-1	99	Acid-grade fluorspar - Method for chemical analysis - Part 1: Determination of moisture content of a lot.
K 2301	08	Fuel gases and natural gas - Methods for chemical analysis and testing.
K 6857	73	Testing methods for resistance of adhesive bonds to water or moisture.
K 5600-3-2	99	≡ ISO 1517: Testing methods for paints - Part 3: Film formability - Section 2: Surface-drying test (Ballotini method).
K 5600-3-3	99	≡ ISO 9117: Testing methods for paints - Part 3: Film formability - Section 3: Through-dry.
K 5600-7-2	99	Testing methods for paints - Part 7: Long-period performance of film - Section 2: Resistance to humidity (continuous condensation).
K 5600-7-3	99	Testing methods for paints - Part 7: Long-period performance of film - Section 3: Resistance to humidity (intermittent condensation).

K 5600-7-4	99	Testing methods for paints - Part 7: Long-period performance of film - Section 4: Humidity and cool-heat cycling test.
K 5600-7-9	06	Testing methods for paints - Part 7: Determination of resistance to cyclic corrosion conditions - Section 9: Salt fog/dry/humidity
K 7129	08	Plastics - Film and sheeting - Determination of water vapour transmission rate - Instrumental method.
K 7225	05	Rigid cellular plastics - Determination of water vapour transmission properties.
L 1915	98	Test methods of humidity transfer characteristics of futon.
M 8082	99	Method of sampling and methods of determination of copper content and moisture of copper scraps for smelting.
M 8100	92	Particulate materials - General rules for methods of sampling.
M 8101	88	Methods for sampling, preparation and determination of moisture content of non-ferrous metal bearing ores.
M 8102	93	Methods for sampling and determination of moisture content of blister copper.
M 8108	08	Chromium, manganese and ferruginous manganese ores - Sampling, sample preparation and determination of moisture content and size distribution.
M 8109	96	Method for sampling and method of determination of moisture content of garnierite nickel ores.
M 8705	06	Iron ores - Determination of the moisture content of a lot.
M 8803	93	Methods for test of equilibrium moisture of coal at 96 to 97 % relative humidity and 30 °C
M 8811	00	Methods for sampling and determination of total moisture and adherent moisture of coal and coke.
M 8820	00	Coal and coke - Determination of total moisture content of a lot.
P 8127	10	Paper and board - Determination of moisture content of a lot - Oven-drying method.
P 8153	06	Paper and board - Measurement of hygroexpansivity - Part 1: Hygroexpansivity up to a maximum relative humidity of 68 %.
P 8154-3	08	Paper and board - Accelerated ageing - Part 3: Moist heat treatment at 80 °C and 65 % relative humidity.
P 8202	98	Method of testing water content of lot of paper pulp.
P 8203	10	≡ ISO 638: Paper, board and pulps - Determination of dry matter content - Oven-drying method.
R 1703-1	07	Fine ceramics (advanced ceramics, advanced technical ceramics) - Test method for self-cleaning performance of photocatalytic materials - Part 1: Measurement of water contact angle.
R 3913	00	Reinforcement products - Determination of moisture content.
W 0814	02	Aircraft equipment - Environmental and operating conditions for airborne equipment - Humidity, temperature and pressure tests.
Z 0208	76	Testing methods for determination of the water vapour transmission rate of moisture-proof packaging materials (dish method).
Z 0222	59	Method of permeability test for moisture proof packing case.
Z 0301	89	Method of moisture-proof packaging.
Z 7302-3	99	Densified refuse derived fuel - Part 3: Test method for moisture.
Z 8806	01	Humidity - Measurement methods.
JLPGA		**Japanese Liquefied Petroleum Gas Association**
S-03	81	LP Gas evaporation residue test method (Mass method)
LN		**Luftfahrt-Norm, Deutsches Institut für Normung e.V**., Burggrafenstraße 6, D-10772 Berlin, Germany
29820	77	Polydiallylphthalate (PDAP) moulding compounds with glass-fibre filler; Technical specification.
65336	73	Sheets, tubes and rods of laminates on phenol-formaldehyde resin base - Technical specification.
SFS		**Suomen Standardisoimisliitlo r.y.** NT Build 361, Nordtest, Espoo
	91	Nordtest method, Concrete, Hardened: Water-cement ratio,
SIA		**Schweizerischer Ingenieur- und Architektenverein,** Selnaustrasse 16, CH-8001 Zürich
262.175	05	≡ SN EN 480-5: Admixtures for concrete, mortar and grout - Test methods - Part 5: Determination of capillary absorption.
164.504	97	≡ SN EN 844-4: Round and sawn timber - Terminology - Part 4: Terms relating to moisture content.
266.016	05	≡ SN EN 771-6: Specification for masonry units - Part 6: Natural stone masonry units.
177.107	98	≡ SN EN 772-7: Methods of test for masonry units - Part 7: Determination of water absorption of clay masonry damp proof course units by boiling in water.
177.111	00	≡ SN EN 772-11 Methods of test for masonry units - Part 11: Determination of water absorption of aggregate concrete, manufactured stone and natural stone masonry units due to capillary action and the initial rate of water absorption of clay masonry units.
177.160	99	≡ SN EN 1015-10 Methods of test for mortar for masonry - Part 10: Determination of dry bulk density of hardened mortar.
180.214	00	≡ SN EN ISO 12570 ≡ ISO 12570: Hygrothermal performance of building materials and products - Determination of moisture content by drying at elevated temperature.
246.201	99	≡ SN EN 1925: Natural stone test methods - Determination of water absorption coefficient by capillarity.
246.211	08	≡ SN EN 13755: Natural stone test methods - Determination of water absorption at atmospheric pressure.
248.078	97	≡ SN EN ISO 10545-3: Ceramic tiles - Part 3: Determination of water absorption, apparent porosity, apparent relative density and bulk density.
253.049	98	≡ SN EN 12105: Resilient floor coverings - Determination of moisture content of agglomerated composition cork.

279.074	96	≡ SN EN 1609: Thermal insulating products for building applications - Determination of short term water absorption by partial immersion.
279.077	97	≡ SN EN 12087: Thermal insulating products for building applications - Determination of long term water absorption by immersion.
279.078	97	≡ SN EN 12088: Thermal insulating products for building applications - Determination of long term water absorption by diffusion.
VDE		**Verband der Elektrotechnik Elektronik Informationstechnik e.V.**, Stresemannallee 15, D-60596 Frankfurt am Main
0291-2	79	≡ DIN 57291-2: Compounds for use in cable accessories - Casting resinous compounds before cure and in the cured state.
0318-1	76	≡ EN 60893-1: Insulating materials - Industrial rigid laminated sheets based on thermosetting resins for electrical purposes - Part 1: Definitions, designations and general requirements.
0318-2	76	≡ EN 60893-2: Insulating materials - Industrial rigid laminated sheets based on thermosetting resins for electrical purposes - Part 2: Methods of test.
VDMA		**Verband Deutscher Maschinen- und Anlagenbau e.V.**, Postfach 71 08 64, D-60498 Frankfurt am Main
24351	99	Drying technology - General terms.

Table 5. List of national identifiers for standards and the assigned standardization bodies

AS	**Standards Australia,** GPO Box 476, Sydney NSW 2001, Australia
ASTM	**ASTM International** (former American Society for Testing and Materials**)**, 100 Barr Harbor Drive, West Conshohocken, PA, USA
BS	**BSI British Standards Institution,** 389 Chiswick High Road, London, W4 4AL, U.K.
BVL	**Bundesamt für Verbraucherschutz und Lebensmittelsicherheit,** Bundesallee 50, 38116 Braunschweig, Germany
CEI	**Comitato Elettrotecnico,** Sede di Milano, Via Saccardo 9, 20134 Milano, Italy
DIN	**Deutsches Institut für Normung e.V**., Burggrafenstraße 6, D-10772 Berlin, Germany
EN	**Comité Européenne de Normalisation - CEN,** Rue de Stassart 36, B-1050 Bruxelles, Belgium
GOST or **GOST R**	**Committee of the Russian Federation for Standardization, Metrology and Certification**, Leninsky Prospekt 9, Moskva 117049, Russia
IEC	**International Electrotechnical Commission**, 3 rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland
I.S.	**NSAI: National Standards Authority of Ireland,** Glasnevin, Dublin 9, Ireland
ISO	**International Organization for Standardization**, Central Secretariat, 1 rue de Varembé, BP 56, CH-1211 Geneva 20, Switzerland
JIS	**Japanese Standards Association (JSA)** 1-24 Akasaka 4-Chome Minato-ku, Tokyo 107, Japan
JLPGA	**Japanese Liquefied Petroleum Gas Association**
NBN	**Bureau de Normalisation,** Rue de Birmingham, 131, B-1070 Bruxelles Belgium
NBR or **NBR NM**	**Associacao Brasileira de Normas Tecnicas**, Avenida 13 de Maio 13/28 Andar CEP 20003-900, Rio de Janeiro RJ, Brazil
NEN	**Nederlands Normalisatie-Instituut**, Postbus 5059, 2600 GB, Delft, The Netherlands
NF or **NFV**	**AFNOR Assoc. Francaise de Normalisation,** 11 Avenue Francis de Pressense, 93571 St Denis la Plaine CEDEX, France
NS	**Standards Norway,** P.O. Box 242, NO-1326 Lysaker, Norway
ÖNORM	**Austrian Standards Institute (ASI)**, Heinestrasse 38, Postfach 130, A-1021 Wien, Austria
PN	**PKN Polish Committee for Standardization,** Swietokrzyska 1400-050 Warszawa, Poland
SAC	**Standardization Administration of China,** No. 9 Madian East Road, Haidian District, Beijing 100088 China
SEV	**Verband für Elektro-, Energie- und Informationstechnik,** Seefeldstrasse 301, CH-8034 Zürich, Switzerland
SFS	**Suomen Standardisoimisliitlo r.y.** NT Build 361, Nordtest, Espoo
SIA	**Schweizerischer Ingenieur- und Architektenverein,** Selnaustrasse 16, CH-8001 Zürich, Switzerland
SN	**SNV Swiss Association for Standardization,** Buerglistr. 29, CH-8400 Winterthur, Switzerland
SS	**Standardiserings-Kommissionen i Sverige,** SE-118 80 Stockholm, Sweden
UNE	**AENOR: Asociacion Espanola de Normalizacion Certificacion,** Fernandez De La Hoz, 52 28010 Madrid, Espana
UNI	**Ente Nazionale Italiano di Unificazione,** Via Sannio, 2, 20135 Milano, Italy
VDE	**Verband der Elektrotechnik Elektronik Informationstechnik e.V.**, Stresemannallee 15, D-60596 Frankfurt am Main, Germany
VDMA	**Verband Deutscher Maschinen- und Anlagenbau e.V.,** Postfach 71 08 64, D-60498 Frankfurt am Main, Germany

Table 6. Symbols used.

Symbol	Significance	Usual unit	SI unit
AH_{air}	Absolute humidity	g kg^{-1}	1
AH_{air}	Absolute humidity	g m^{-3}	kg m^{-3}
a_m	Molecular cross sectional area, occupied by an adsorbed molecule in a complete monolayer	nm^2	m^2
C	BET parameter		1
C_{psy}	Psychrometric constant = 0,67 hPa K^{-1} for height up to 500 m and T_{wet} > 0 °C	hPa K^{-1}	Pa K^{-1}
m	Sample mass		kg
m_a	Adsorbed mass		kg
M_a	Mol mass of adsorbate		kg mol^{-1}
m_s	Sample mass		kg
m_a/m_s	Specific mass adsorbed		1 = kg kg^{-1}
m_{Air}	Mass of dry air		kg
m_{as}	Asymptotic equilibrium value of mass adsorbed		kg
m_w	Mass of water vapour		kg
$m_{w,max}$	Maximum mass of water vapour that the air could hold at the given temperature		kg
n_a	Specific adsorbed amount		mol kg^{-1}
N_A	Avogadro constant = 6.022 x 10^{23}		mol^{-1}
p	Pressure		Pa
p_0	Saturation pressure	hPa	Pa
p_n	Standard pressure (= 101 325)		Pa
P_{H2O}	Water vapour pressure in air	hPa	Pa
R	Universal gas constant (= 8.314)		J K^{-1} mol^{-1}
RH_{air}	Relative humidity	%	1
SH_{air}	Specific humidity		1
t	time		s
T	Temperature	°C	K
T_n	Standard temperature (= 273.15)		K
T_{dry}	Temperature of dry air	°C	K
T_{wet}	Temperature of the wet surface of the thermometer	°C	K
V_a	Specific adsorbed gas volume		m^3 kg^{-1}
V_{air}	Volume of dry air		m^{-3}
τ	Characteristic time of the adsorption process		s

8. Conclusion

For the determination of atmospheric humidity the methods developed in the 18th and 19th centuries are still predominant. Psychrometry is regarded as a standard method. Increasingly, the measurement is converted to an electrical signal allowing for transmission of results and control of processes. Efforts are directed toward developing water vapour measurements and standards at the part per billion levels and below.

The survey demonstrates that different measuring methods must be applied due to the very different tasks of humidity measurements and due to the great number of materials to be tested. With regard to the disturbances, which are specific to each method, the measurements should be compared to standardised procedures. In many cases, it is necessary to determine water within a mixture of different volatiles. In such cases, water should be identified by chemical methods as a reference. Today Karl Fischer titration is preferred as a reference method. If equilibrium cannot be achieved within reasonable time mathematical extrapolation methods should be applied.

Search for extraterrestrial water is based on remote measurements by analysing the spectrum of electromagnetic radiation either of natural sources or produced by a probe and reflected. Spacious deposits had been detected photographically. In situ investigations are made using conventional methods.

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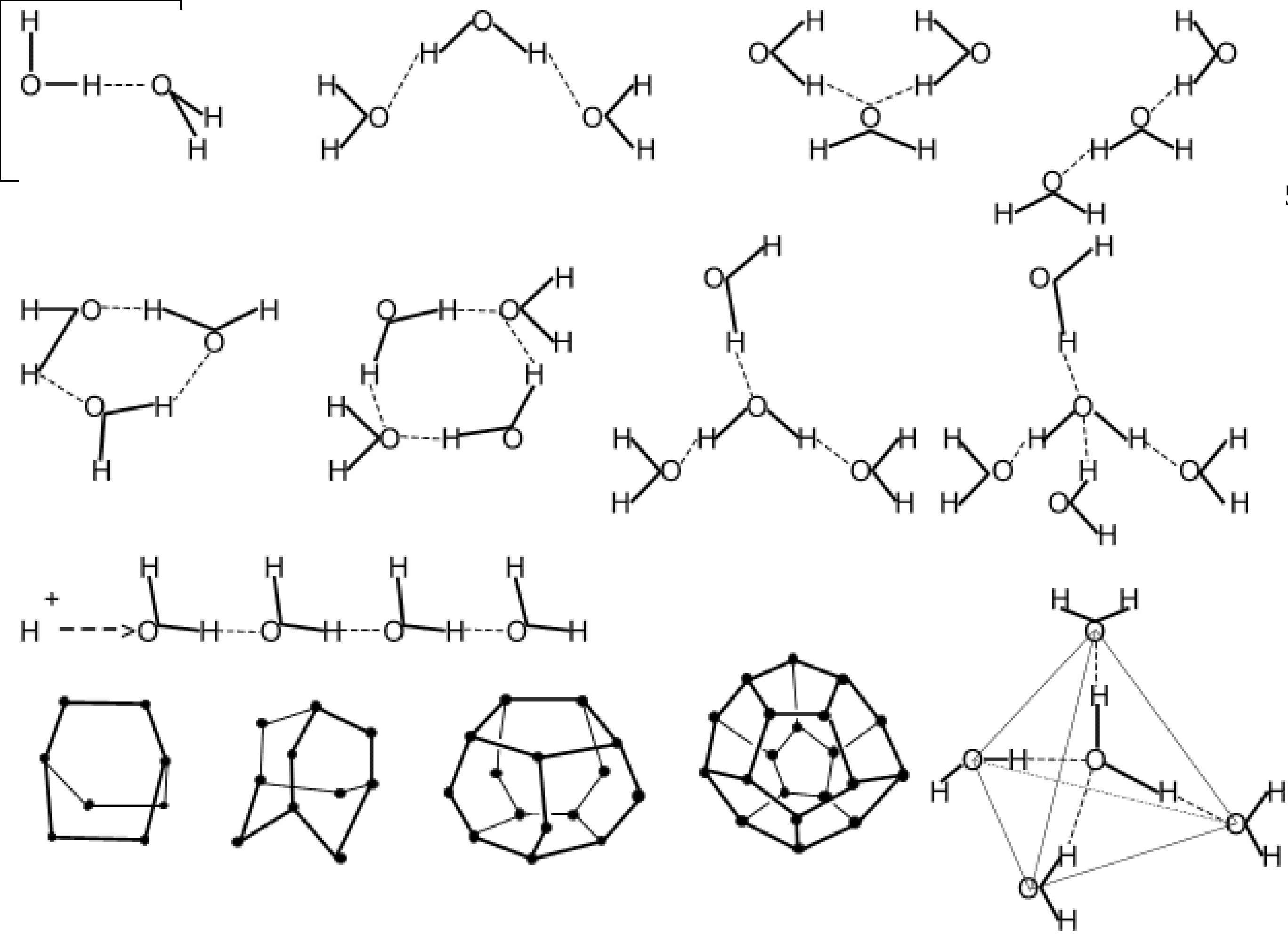

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