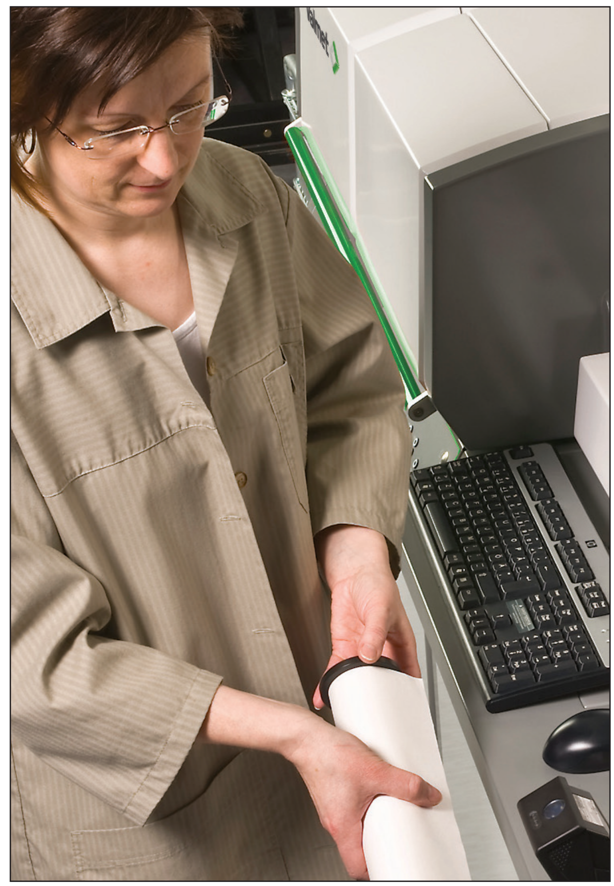
Valmet Paper Lab

Measurement of paper and board moisture content in laboratory conditions

Both wood fibers and the paper made from them are hygroscopic: they attempt to reach a moisture content equilibrium with the surrounding air. A rise in the ambient relative humidity increases the moisture content of paper, and conversely, a lower ambient relative humidity level results in a decrease of paper moisture content.



The hygroscopic nature of paper is due to the fact that the components of wood fibers – such as hemicellulose and cellulose – attempt to bind water molecules to their hydroxyl groups via hydrogen bonding. When water molecules bind themselves to the wood fiber, the fiber swells. The fibers in paper are interconnected as a fiber network, and thus any changes taking place in the individual fibers also cause changes in the network as a whole, in other words in the paper itself.

In addition to swelling, fibers binding with moisture also become more flexible and lose their stiffness. This has a significant effect on many paper properties. Water molecules bind themselves to the surfaces of the crystalline cellulose and amorphous components in fibers. During the adsorption process water molecules penetrate into the fiber cell wall, and hydrogen bonds between the chain molecules in the amorphous component of cellulose open and form new hydrogen bonds between water molecules and the hydroxyl groups of the released chain molecules. Upon drying, hydrogen bonds between chain molecules and water molecules are once again replaced by hydrogen bonds between chain molecules.

It is to be noted that when a dried fiber is remoistened, some of the hydrogen bonds between the hydroxyl groups of the chain molecules resist becoming replaced by hydrogen bonds with water molecules. As a consequence, at a given relative humidity the equilibrium moisture content of previously dried pulp remains lower than that of undried pulp. The water content of fiber, pulp or paper therefore depends not only on the relative humidity of the surrounding air, but also on the drying history of the fiber.

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When conditioning paper and board samples at 50% relative humidity in a laboratory, one cannot be sure of the drying history of the paper or board. As can be seen from figure 1, the moisture content of a paper sample at 50% relative humidity may vary greatly depending on its drying history. In order to ensure that the measurement results of samples are comparable with each other, their drying history should first be harmonized by pre-conditioning the samples at a relative humidity of under 35% for 1–5 hours, depending on the paper or board quality. This ensures that the samples will reach their equilibrium moisture content at a relative humidity of 50%, according to the lower curve in figure 1.

In laboratory conditions the moisture content of paper is usually 6–7%. As a rule of thumb, we can say that if the relative humidity of the surrounding air changes by 10% (20–60 % RH), the total change in moisture content of paper will be about 1%. This result is dependent on the type of fiber used, and on any non-fibrous materials contained in the paper. For example fillers decrease the moisture content of paper because they do not absorb water to the extent that fibers do.

The raw material components also affect how quickly the paper or board reaches an equilibrium moisture content with the ambient conditions. With thinner papers this may take place in about 15 minutes, whereas thicker boards or papers containing large amounts of sizing agents may take up to 24–48 hours to reach their equilibrium moisture content.

In practice, however, paper samples are tested as soon as they arrive at the laboratory because the paper/board machine operators need the measurement results with minimum delay after preparing the machine reel. Thus the moisture content of the samples may vary greatly during testing, as it continually conditions with the ambient air. Any changes in sample moisture content have a direct effect on measurement results.

Effect of moisture on paper properties

When paper attempts to reach its equilibrium moisture content with the surrounding air, its grammage increases in line with rising ambient relative humidity, and correspondingly decreases as ambient humidity drops. For example, if the moisture content of 80 g/m^2 copy paper increases from 4% to 5 %, a 0.8 g/m^2 change in grammage is obtained. However, changes will also take place in terms of paper size, in which case the increase in grammage is likely to be less.

The effect of moisture on grammage is of little importance in comparison to the effect it has on other paper properties. Often an attempt is made at the paper mill to attain a moisture content equivalent to the level required by the printing house, so that the changes in paper size, surface and strength properties caused by the change in moisture content remain as small as possible.

When a fiber absorbs moisture, it becomes more flexible and its stiffness decreases. Bonding with moisture also weakens interfiber hydrogen bonding, as some of these bonds are replaced with hydrogen bonds between the fiber hydroxyl groups and water molecules.

For these reasons the strength properties of paper change and deteriorate as the paper is moistened. Figure 2 illustrates the effect of moisture on strength properties.

The tensile strength of paper declines and stretch at break increases as the paper moisture content rises (figure 3). When examining the tensile strength of paper exposed to increasing ambient relative humidity,

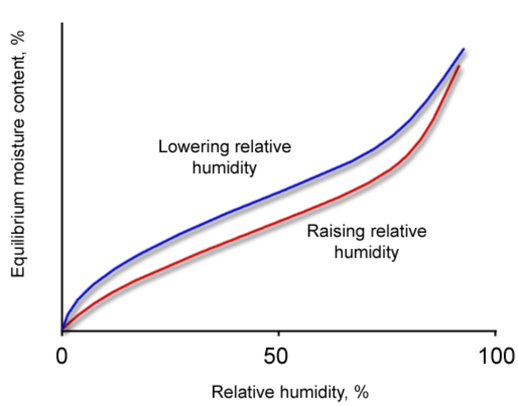

Figure 1 – Dependence of the equilirium moisture content of pulp on the relative humidity of the surrounding air.

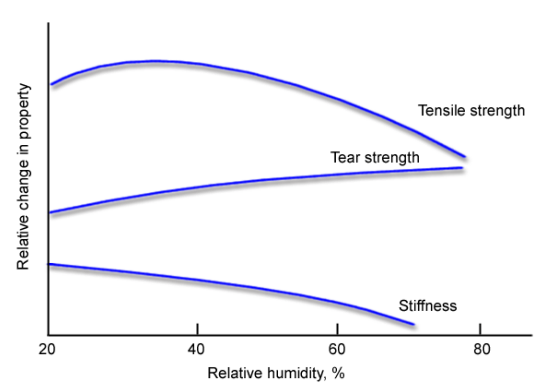

Figure 2 – The effect of moisture on the strength properties of paper.

it is evident that tensile strength increases at first but then falls relatively rapidly as the relative humidity of the surrounding air increases.

The tearing resistance of paper appears to increase as the ambient relative humidity increases. However, when the relative humidity is sufficiently high the tearing resistance of paper is reduced, because the strength of the individual fibers decreases. The rise in tearing resistance is believed to be due to the increased stretch at break: this makes the paper more plastic so that the tear load is divided across a larger surface area and the paper can withstand a greater level of stress before tearing.

Paper stiffness also declines as it gets moister because fiber flexibility increases. Softness, which is inversely proportional to moisture, increases as the moisture content increases. This is why chemicals that increase the moisture content of paper are sometimes used with certain paper grades.

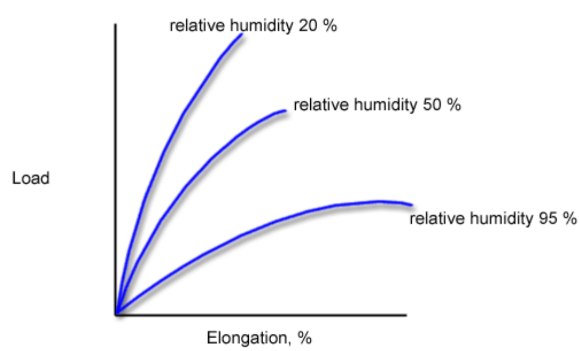

Figure 3 – The effect of moisture on tensile strength and stretch.

Moisture measurement

Generally, the measurement of moisture content is based on either IR (infrared) technology or microwave technology. Other measurement methods are also used, such as resistive measurement and capacitive methods, but today the IR measurement is by far the most common moisture content measurement method used for paper products. Microwave measurement is used for thicker products such as boards, and in chemical pulp drying as well as for products containing a lot of materials impermeable to infrared light. The microwave method is also well suited to thinner paper grades.

IR measurement can be typically used in the grammage range 15–300 g/m^2, and in some cases up to 500 g/m^2. The upper limit depends on the structure of the board: is the board manufactured using virgin or recycled fiber, and what types of filler and color have been used. In addition, any printing ink residue in the pulp can strongly affect measurement results.

The microwave measurement technique is based on the dielectric permittivity of the measured material. Dielectric permittivity describes the absorption of energy caused by molecular rotation, which changes in line with the level of moisture content. In order to perform an analysis of dielectric permittivity, resonance changes in the paper or board web are measured. When measuring water content, a frequency of 22.2 GHz is typically used. This wavelength is sensitive to water but is not absorbed into the fibers or fillers.

A typical microwave moisture content measurement gauge operates at the dry end for heavy paper grades which contain non-deinked recycled fiber. The carbon components in the web do not interfere with the measurements for pH change, material composition or changes in bulk. Microwaves are used to measure the moisture content of large grammages because they are able to penetrate into a considerably thicker medium than infrared radiation. Due to extensive permeability the measurement process is not affected by the different moisture levels existing within board layers.

Paper Lab moisture content module

The Paper Lab moisture content module uses microwave technology, which makes possible a reliable measurement of the moisture content of both papers and different boards. Figure 4 illustrates the structure of the Paper Lab moisture content module.

The module determines the moisture content of paper as a percentage. In order to calculate the moisture percentage, a grammage figure is required from the basis weight module. The moisture measurement method is grade-dependent, because the moisture behavior of paper is largely dependent on its structure, the manufacturing methods and the raw materials used. Moisture behavior is controlled using calibration. Grade-specific calibration on-site is always carried out during Paper Lab start-up, using as reference the specific moisture measurements performed by the mill in question. These typically include either a standard device or the traditional dry content determination in the heating chamber.

The moisture content module can be used for example to monitor the moisture profile, to determine the dry solids content, or for more extreme actions such as readjusting the strength values of paper or board. However, the user should keep in mind the tendency of paper and board to absorp or desorp moisture when changes take place in the in surrounding air conditions. If the sample does not air-condition in line with set standards before testing, no adjustments should be made for example to the strength properties, unless the moisture of the surrounding air significantly deviates from standard conditions.

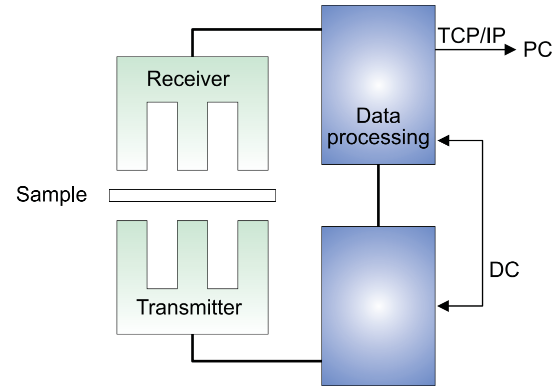

Figure 4 – Structure of Paper Lab moisture content module.