CH0302 Process Instrumentation

Lecture 10 – Composition Analysis

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Introduction – Composition Analysis

- Industrial significance
- Spectroscopic analysis
- Gas analysis by thermal conductivity
- Analysis of moisture in gases
- pH ion concentration

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Introduction – Composition Analysis

- Industrial significance

Why do we need composition analysis in process industries?

Understand the BIG PICTURE

9 Phases in Process industries

Introduction – Composition Analysis

- Industrial significance
- Spectroscopic analysis
- Gas analysis by thermal conductivity
- Analysis of moisture in gases
- pH ion concentration

Introduction – Composition Analysis

- Spectroscopic Analysis

What is spectra? and Spectrum?

How it helps us in the analysis of composition of substances?

Classification of Spectroscopic Methods

Introduction – Composition Analysis

- Industrial significance
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- Gas analysis by thermal conductivity
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- pH ion concentration

Introduction – Composition Analysis

- Gas analysis by thermal conductivity
- Methods used
- Applications

Composition Analysis

- Industrial significance
- Spectroscopic analysis
- Gas analysis by thermal conductivity
- Analysis of moisture in gases
- pH ion concentration

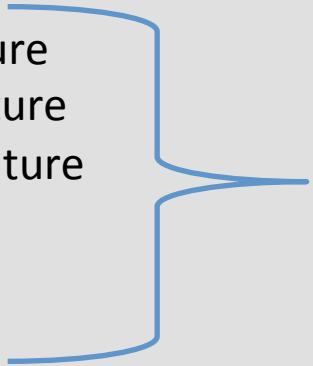
Composition Analysis – Humidity

- Analysis of moisture in gases (Humidity)
- Definitions
- Methods – Psychrometer, Hygrometer and Dew point
- Moisture measurements in Paper and Lumber

Composition Analysis- Humidity

Analysis of moisture in gas

Dry bulb temperature
Wet-bulb temperature
Dew point temperature
Humidity
Absolute humidity
Relative humidity
Relationship between
density, pressure and temperature



Psychrometer
Hygrometer
Dew Point method

Analysis of moisture in gas – Definitions

Dry bulb temperature

Air temperature measured by a thermometer, thermocouple or other conventional measuring instrument.

Wet Bulb temperature

Temperature of air measured by a thermometer covered (thermometer bulb) by wet wick.

Analysis of moisture in gas – Definitions

Dew point temperature

When a vapor is cooled slowly at constant pressure, the temperature at which the first liquid forms is the dew point temperature.

Analysis of moisture in gas – Definitions

Humidity (Air-water systems)

Refers to the amount of moisture present in air

Absolute humidity

It is the ratio of amount of water vapor to that of the dry air

$$H_a = \frac{kg \text{ of } H_2O_{(V)}}{kg \text{ Dry Air}}$$

Analysis of moisture in gas – Definitions

Humidity (Air-water systems)

For example, if the absolute humidity is 0.0150 kg H_2O/kg DA then for every kilogram of dry air there is 0.0150 kg H_2O water vapor for a total of 1.0150 kg. The mass fraction of water is 0.0150 of H_20/1.0150 kg humid air = 0.0148 kg H_20/kg

Analysis of moisture in gas – Definitions

Relative humidity

It is the ratio of partial pressure of vapor to that of vapor pressure of water

$$R_H = \frac{p\mathrm{H_2O}}{p^*\mathrm{H_2O}(T)} \times 100$$

For example, A relative humidity of 40% signifies that partial pressure of water vapor equals 4/10th of vapor pressure of water at the system temperature.

Analysis of moisture in gas – Definitions

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Analysis of moisture in gas – Definitions

Relationship between the density, temperature and pressure of an ideal gas can be obtained by relating the specific molar volume (volume/mole) to density

$$\bar{V}\left(\frac{litres}{mole}\right) = \frac{\bar{M}(g/mol)}{\rho(g/lit)} \qquad \text{----------} \qquad (1)$$

$\bar{M}$ = Average molecular weigth of gas

$\bar{V}$ = molar volume

Analysis of moisture in gas – Definitions

Substituting equation 1 in ideal gas equation we can have density of the gas

$$P\bar{V} = RT \qquad \bar{V} = \frac{v}{n} \text{ (Specific molar volume)}$$

$$P\left(\frac{\bar{M}}{\rho}\right) = RT$$

$$\rho = \frac{\bar{M}}{RT}$$

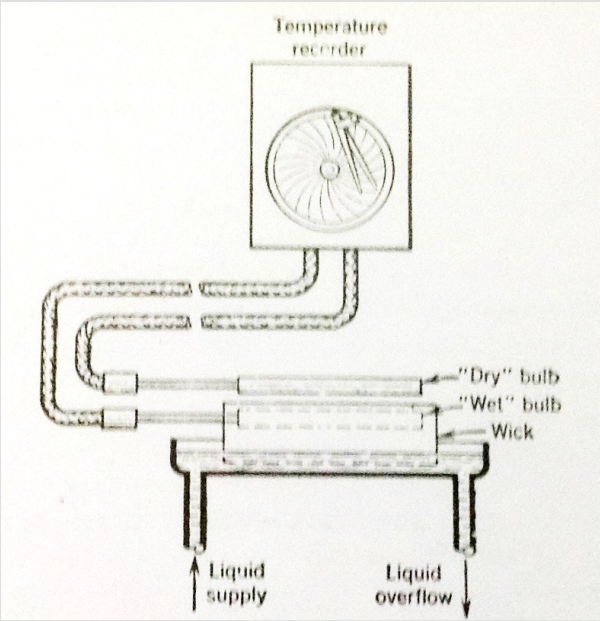
Moisture Measurement Technique

Psychrometer – (Wet and Dry bulb Method)

Hygrometer – (Mechanical and Electrical)

Dew Point method

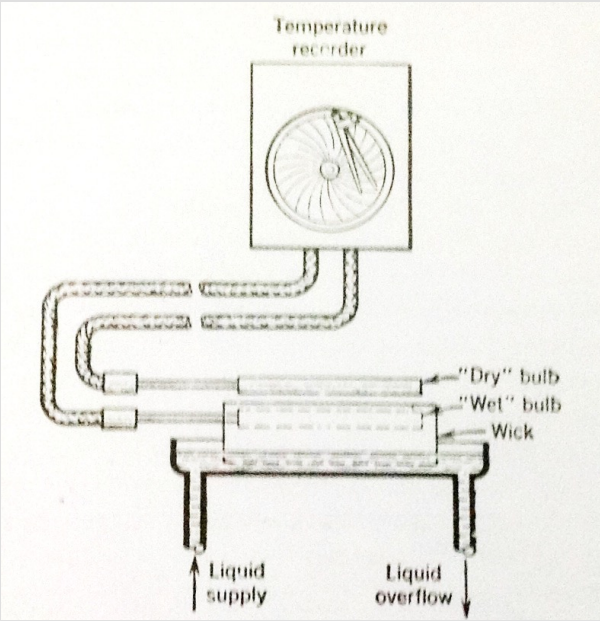
Moisture Measurement Technique – Psychrometer (wet-dry-bulb temperature)



- It has been a popular method for monitoring humidity, primarily due to its simplicity and inherent low cost.

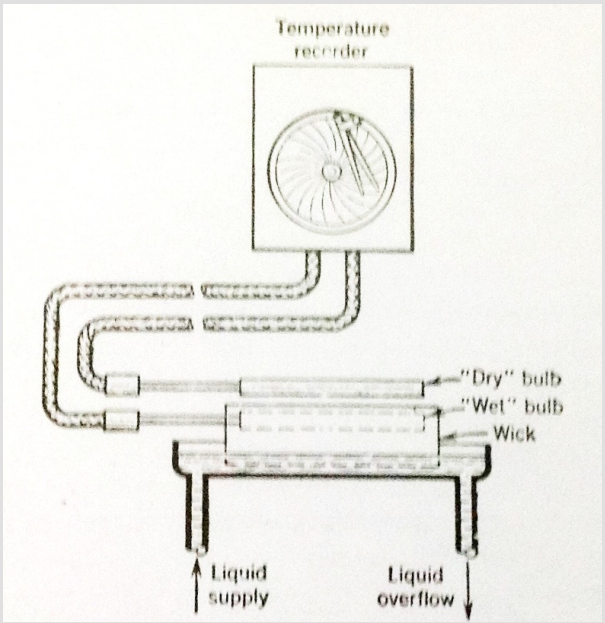
- A typical industrial psychrometer consists of a pair of electrical or pressure spring type thermometers is shown in the figure

Moisture Measurement Technique – Psychrometer (wet-dry-bulb temperature)



- Air is passed over both the thermometers.
- The resultant evaporating cooling produces a wet bulb temperature approximately equal to the thermodynamic wet bulb temperature.
- The difference between dry-bulb temperature and wet-bulb temperature is called wet bub depression which determines the humidity level.

Moisture Measurement Technique – Psychrometer (wet-dry-bulb temperature)



- The depression of temperature of the wet bulb versus the dry bulb can be correlated with water vapor pressure using the equation

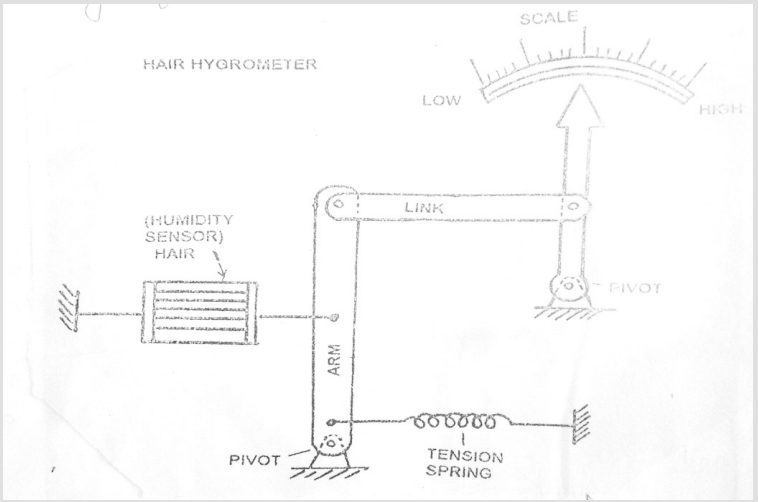
$$e = e_w - 66\times10^{-5} P(T_a - T_w)(1+115\times10^{-5} T_w)$$

e	= vapor pressure of water in gas (air)
e_w	= saturation vapor pressure of water at temperature t_w
P	= atmospheric pressure
T_a	= Dry bulb temperature
T_w	= wet bulb temperature

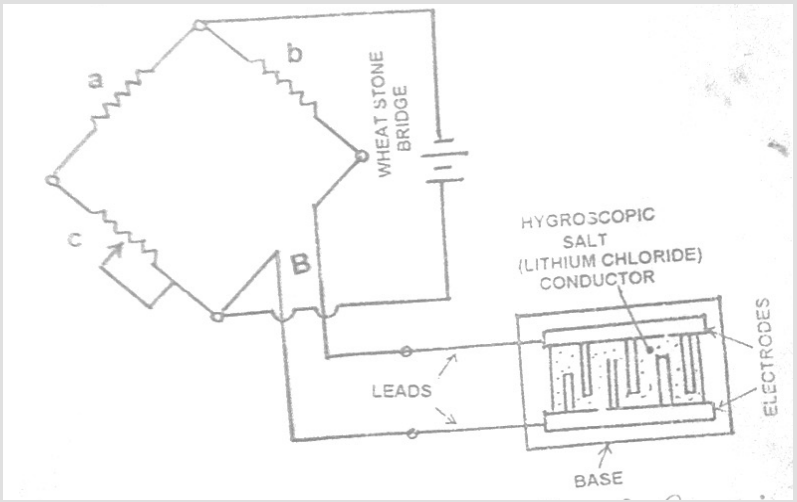
This equation is valid if the thermometers are in gas stream of sufficient velocity say 200 meters per minute

Moisture Measurement Technique – Hygroscopic

Mechanical

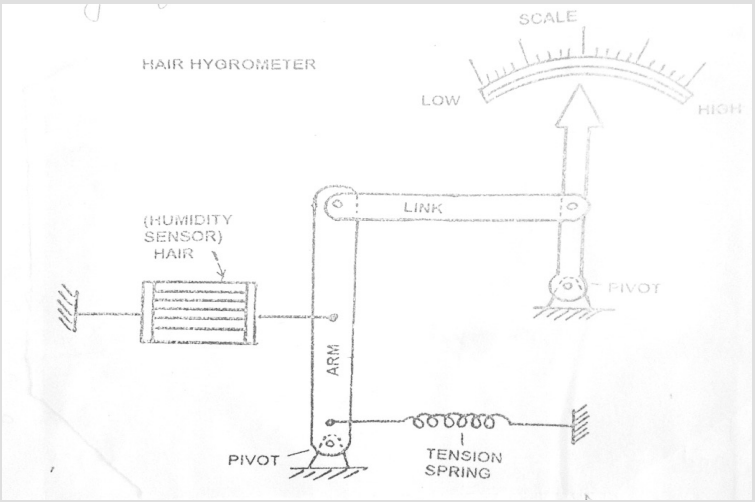


Electrical



Moisture Measurement Technique – Hygroscopic

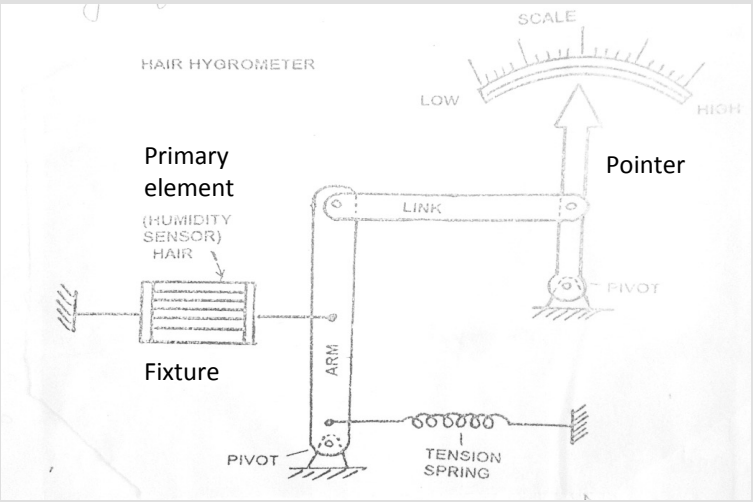
Mechanical



- This method employs linear contraction and expansion of a hygroscopic material like hair, wood, animal membrane or paper.
- The most commonly used element are the hair element and the wood element.
- A typical hygrometer which uses hair as the primary element is shown in the picture.

Moisture Measurement Technique – Hygroscopic

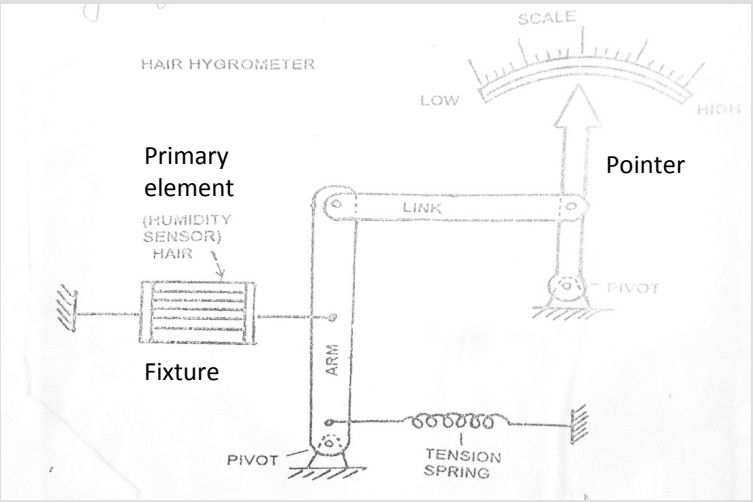
Mechanical



- The hair element is made from a bundle of human hairs set in a fixture with one end fixed
- The other end is arranged to operate directly the pointer of the instrument
- The element is maintained under light tension by a spring

Moisture Measurement Technique – Hygroscopic

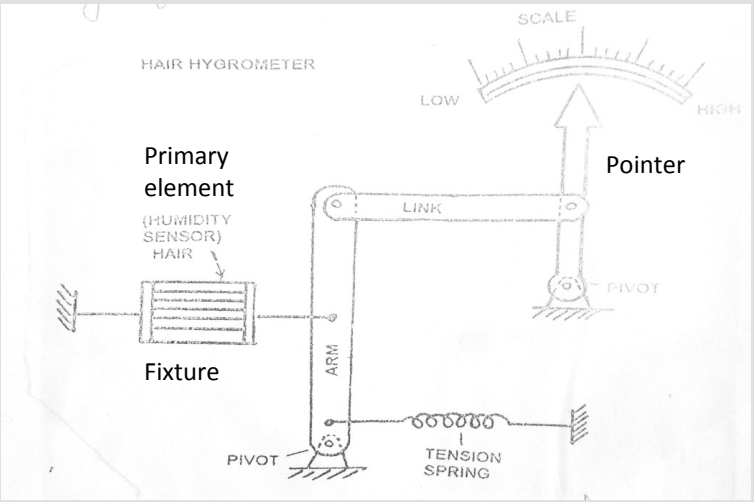
Mechanical



- The movement made by the free end of the spring operates the instrument pointer.

Moisture Measurement Technique – Hygroscopic

Mechanical



Advantages

The mechanical type hygrometers are most satisfactory for measuring relative humidity of air when dry bulb temperature does not vary widely.

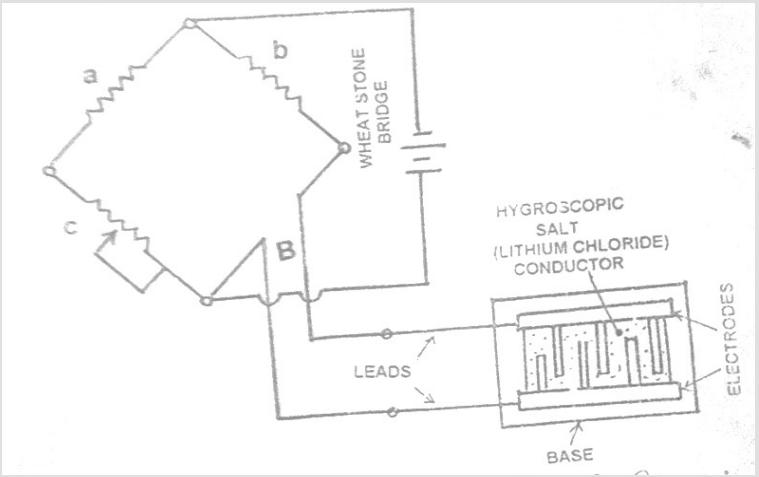
Disadvantage

The accuracy of the mechanical hygrometer is not very high since hair and wood element are temperature sensitive

Moisture Measurement Technique – Hygroscopic

Electrical

Lithium chloride is used as the primary element (hygroscopic) and gains moisture until it is in equilibrium with the partial pressure of the liquid vapor in the gas surrounding the element.

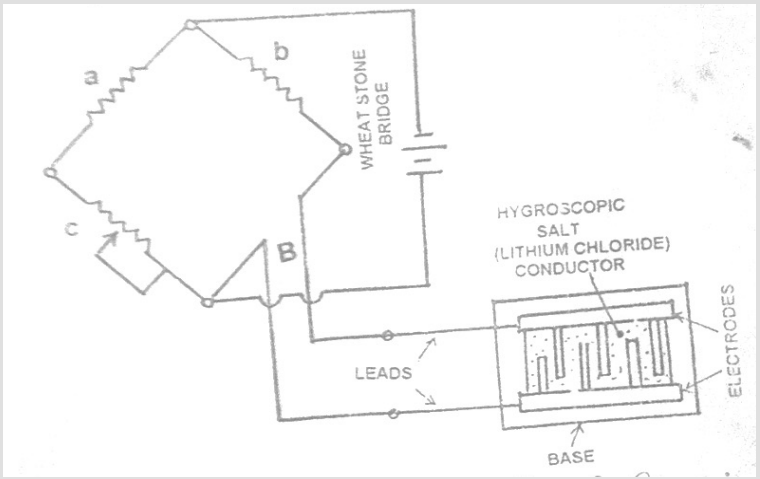


Moisture Measurement Technique – Hygroscopic

The electric conductivity between the wires depends on the moisture content of the film.

By measuring the electrical resistance of the element (Lithium electrode conductor) with a form of wheat stone bridge. The relative humidity can be indicated.

Electrical

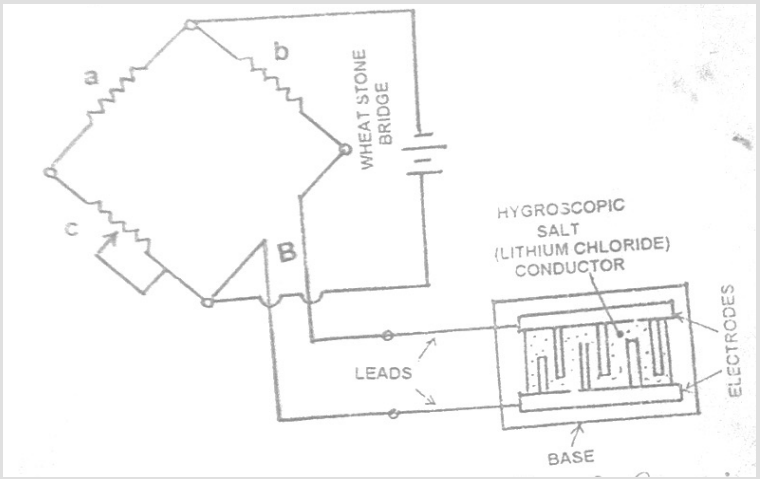


Moisture Measurement Technique – Hygroscopic

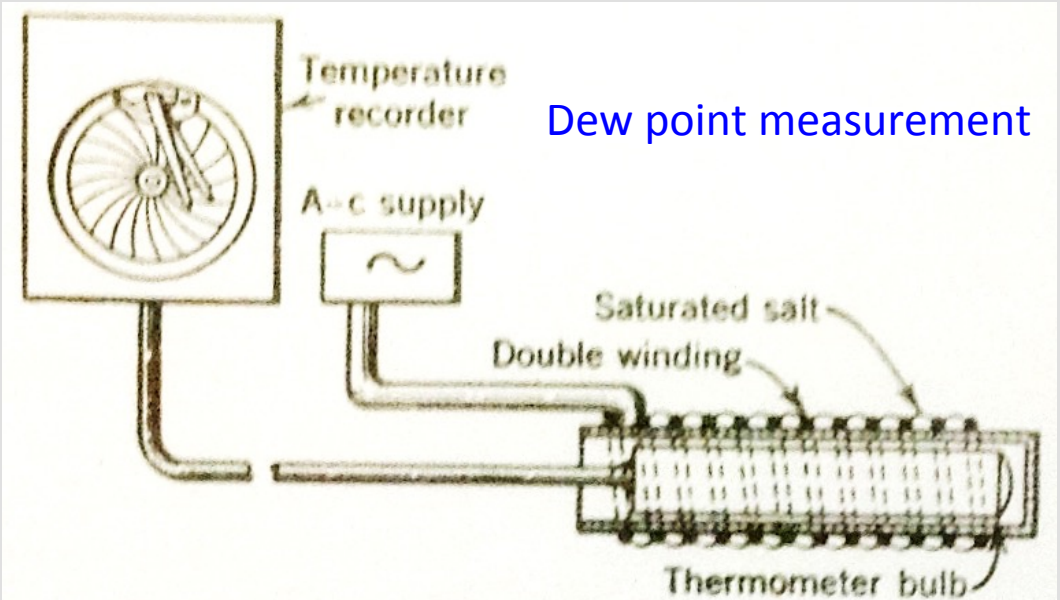
Advantages

- It is fast in response
- The moisture equilibrium between the salt film on the element and the surrounding gas is reached quickly.

Electrical

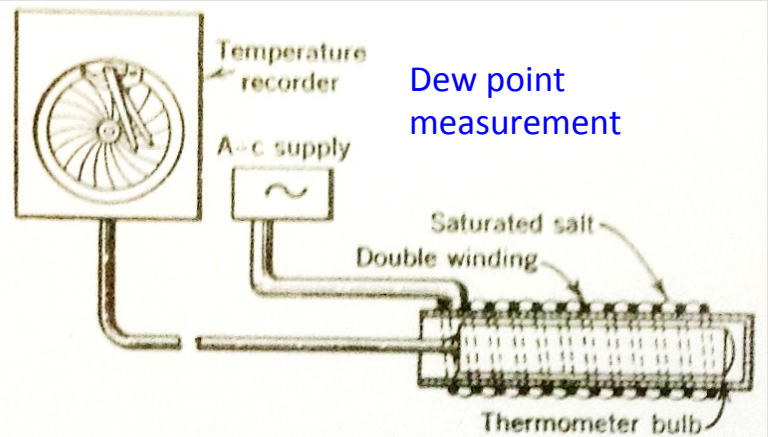


Moisture Measurement Technique



Dew point measurement

Moisture Measurement Technique

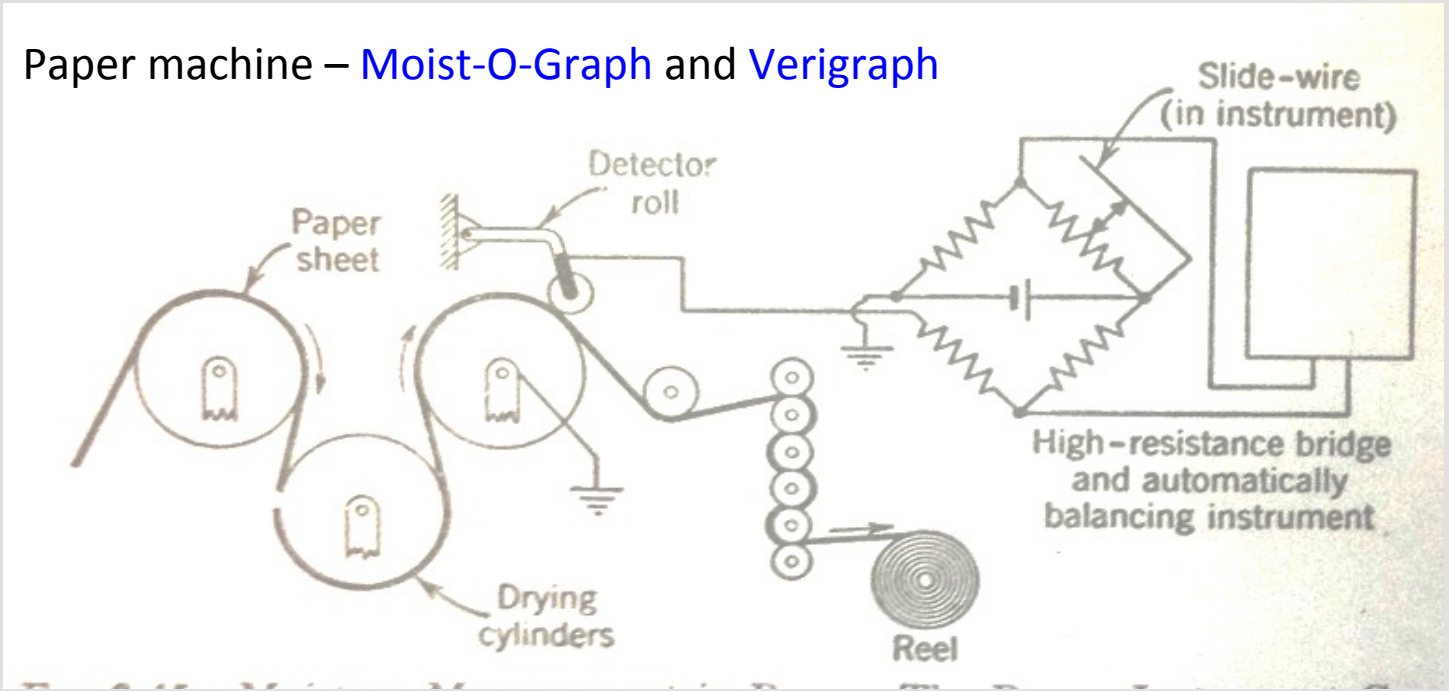


This method is used to measure absolute humidity, partial pressure of vapor and dew point.

The electrical conductivity between the wires is directly proportional to the moisture in the salt taken from the surrounding gas.

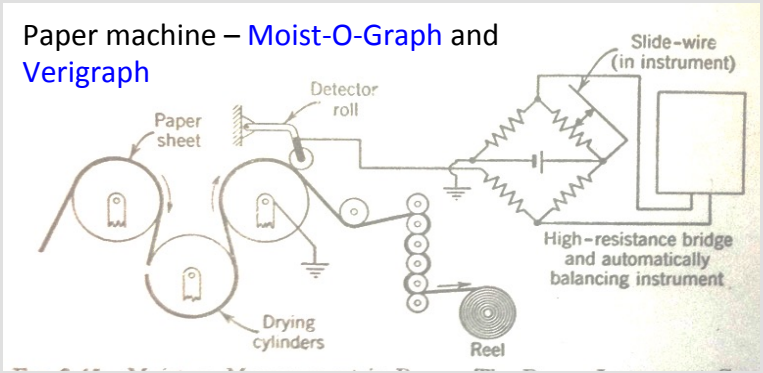
Moisture analysis in paper and lumber

Paper machine – Moist-O-Graph and Verigraph



Moisture analysis in paper – Moist–O–graph

Paper machine – Moist-O-Graph and Verigraph



The moisture problem in paper and textile industries is obtaining a uniform moisture in the finished product.

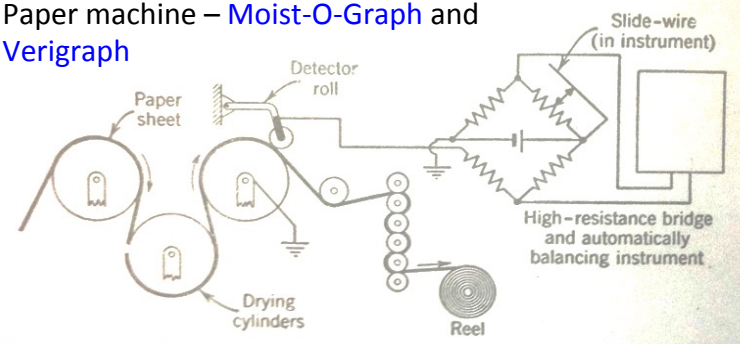
The amount of moisture determines the weight and quality of the product

Two methods are commonly used to detect the moisture in paper industries to meet the finished product specifications:

(1) Moist-O-Graph and (2) Verigraph

Moisture analysis in paper – Moist–O–graph

Paper machine – Moist-O-Graph and Verigraph



Moist-O-Graph operates by measuring the electrical resistance through the paper

A detecting roll is placed against the paper on the drying cylinder.

By means of the bridge circuit the resistance across the paper is measured and indicated in the recorder. The temperature at the point of measurement is maintained constant since it may affect the resistance.

Composition Analysis- Humidity

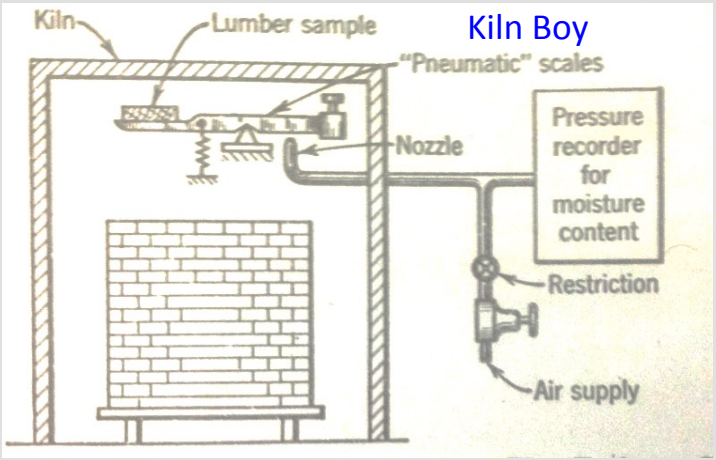
Moisture analysis in Lumber

One of the simplest means of determining the moisture contents in the substances is to weigh a known volume of material during drying operation.

Naturally this method is best for materials being dried in batch operations in ovens or kilns.

One method of this type measurement is the Kilnboy of the FOXBRO Company.

Moisture analysis in lumber

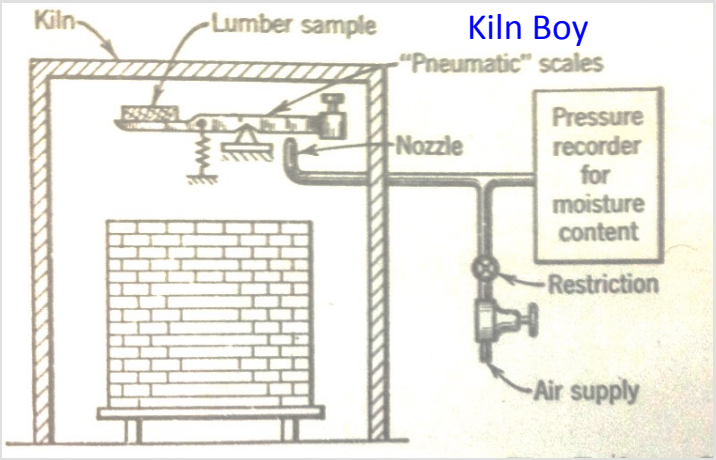


This method is used for measuring the moisture content of kiln dried lumber.

A simple beam scale is installed as shown in figure.

The scale holds a sample of lumber to be dried. The deflection of beam as the lumber loses moisture is detected by the simple pneumatic-nozzle system.

Moisture analysis in lumber



The resulting air pressure is indicated by the simple pneumatic nozzle system, and the resulting pressure is indicated at the receiver.

The receiver is calibrated in terms of weight of the sample (show moisture content).

pH Measurements – Working principle

The measurement of pH or (acid or basic) characteristics of liquids is necessary in many of the chemical production process.

- Improves yield
- Finds application in condensate systems to check on corrosion
- In the food manufacture reduce spoilage and improve taste
- In mining industries – Flotation process
- Paper industry – Alkaline/Acidity nature of cooking chemicals

pH Measurements – Working Principle

The most common industrial method of measuring pH is by glass cell and calomel cell electrodes with potentiometer.

- In brief, these methods requires that an electrode be immersed in the solution.
- An electrical potential is produced at the electrode which forms an electrolytic half-cell.
- This is called the measuring cell.

pH Measurements – Working Principle

- A second electrode is required to provide a standard potential to the complete cell. This is called reference cell.
- Therefore the algebraic sum of the potentials of two half-cells is proportional to the concentration of hydrogen ions in the solution.
- More details are found in the following weblink.
  https://www.youtube.com/watch?v=P1wRXTl2L3I

References

1. Donald P. Eckman, (2004) *Industrial Instrumentation*, CBS Publishers, Pp. 1- 27.
2. Pieter R. Wiederhold, *Water Vapor Measurement and Instrumentation*
3. www.wikipedia.com

Thank You