

# Chapter one

## Introduction

### 1.1 General

Soil is a thin layer on the earth's crust on which depends all life on the land. It is made up of mineral particles, water, organic matter, air and many of organisms and it differs from a few centimeters in depth to several meters. Soils support critical processes such as hydrologic and biogeochemical cycling, and they contain a wide array of organisms ranging from bacteria, nematodes, fungi, cyanobacteria, etc., to earthworms, ants, termites, rodents, etc. [1, 2].

### 1.2 The clay

A production unit needs to have good quality clay to produce a strong brick that can be used in construction. Certain types of clay are not good for making fired bricks. For example, the clay used by a potter to make bowls and cups is not good for making bricks because it has a high shrinkage rate, which causes the bricks to crack during drying. To produce 1,000 bricks per day, about three cubic meter the clay is dug and the brick-molding site should not be more than 200 meters [3, 4].

Clay is a fine-grained natural rock or soil material that contains one or more clay minerals with traces of metal oxides and organic matter [5]. Clays are plastic due to their water content and become hard, brittle and non – plastic upon drying and firing. Geologic clay deposits have amounts of water trapped in the mineral structure [6, 7]. Depending on the soils content in which it is found, clay can appear in various colors from white to dull gray or brown to deep orange- red [8].

Drying and firing convert the clay into a ceramic material. Clay used for making pottery, brick are used as both decorative and construction products, wall

and floor tiles [9]. Different types of clay, when used with different minerals and firing conditions, are used to produce earthenware, stoneware, and porcelain. Prehistoric humans discovered the useful properties of clay [10, 11].

Clay is one of the oldest building materials on Earth, among other ancient, naturally – occurring geologic materials such as stone and organic materials like wood. Between one – half and two – thirds of the world’s population, in traditional societies as well as developed countries, still live or work in a building made with clay as an essential part of its load-bearing structure.

In addition, it is a primary ingredient in many natural building techniques. Clay is used to create adobe, cob, cordwood, and rammed earth structure and building elements such as wattle and daub, clay plaster, clay floors and clay paints and ceramic building material. Clay was used as a mortar in brick chimneys and stone walls where protection from water is needed [12].

### **1.3 The Brick**

A brick is building material used to make walls, pavements and other elements in building construction. Traditionally, the term brick referred to unit composed of clay, but it is now used to denote any rectangular units laid in mortar. A brick can be composed of clay – bearing soil, sand and lime, or concrete materials. Bricks are produced in numerous classes, types, materials, and sizes which vary with region and time period, and are produced in bulk quantities. Two basic categories of bricks are fired and non- fired bricks.

Bricks are a significant basic material of construction required in all spheres of constructional activities and constitute about 13 % of the total cost of building materials required for construction. It has been established that the use of clay bricks provide a superior and comfortable physical living environment than the use of other materials as far as residential construction is concerned. Despite all initiatives to introduce alternative walling materials like compressed earth block,

concrete/ stone Crete block and fly – ash brick, it is envisaged that burnt clay brick would still occupy the dominant position [13].

Also known as earth building, unfired clay brickworks is constructed using earth materials (possibly with some additives). Earth building is not “fired” like conventional bricks, but the building units are air dried after manufacture to reduce shrinkage and improve strength. In some traditional forms of earth construction (e.g. cob or rammed earth), monolithic (solid) walls are constructed, but unfired clay bricks are similar to other building systems where there the units (bricks) are bonded together with mortar and possibly covered with a finishing system (paint or render). Traditional forms of unfired clay bricks (cob blocks, adobe and mudbricks) are generally made by hand and as a result, have varying dimensions and other properties. Traditional earth building has thick wall (often over 300 mm thick) as the mortar provides low bond strength and the thick walls have sufficient mass to keep them stable against lateral loads in dwellings [14].

Fired bricks are one of the longest- lasting and strongest building materials, sometimes referred to as artificial stone. Also known as mudbricks, have a history older than fired bricks, and have an additional ingredient of a mechanical binder such as straw [15].

Thermal clay brick to be called this name must be exposed to high temperatures, so the heat is necessary for thermal clay bricks.

#### **1.4 Heat**

Heat can be defined a form of energy that causes a difference in temperature, or the perception of warmth [16].

In physics, heat is considered as a form of energy existing as the result of the random motion of molecules and is the form of energy that is transferred between bodies as a result of their temperature difference. It can also be defined as a form

of energy associated with the motion of atoms or molecules and capable of being transmitted through solid by conduction, through fluid media by convection, and through empty space by radiation [17].

In physics, heating is transfer of energy, from a hotter body to a colder one, other than by work or transfer of matter. It occurs spontaneously whenever a suitable physical pathway exists between the bodies. The pathway can be direct, as in conduction and radiation, or indirect, as in convective circulation. Heating is a dissipative process. Heat is not a state function of a system [18].

This transfer of energy usually results in an increase in the temperature of the colder body and a decrease in that of the hotter body [19].

## **1.5 Temperature**

Temperature is a numerical measure of heat and cold. Its measurement is by detection of heat radiation, particle velocity, kinetic energy, or most commonly, by the bulk behavior of a thermometric material. Thermometers may be calibrated in any of various temperature scales, Celsius, Fahrenheit, Kelvin, etc. [20].

It is a measure of the average translational kinetic energy associated with microscopic motion of atoms and molecules. The details of the relationship to molecular motion are described in kinetic theory. The temperature definition from kinetic theory is called the kinetic temperature. Temperature is not directly proportional to internal energy, since temperature measures only the kinetic energy part of the internal energy [21, 22]. Therefore, temperature is the main reason for changing weather and climate.

## **1.6 Difference between Weather and Climate**

Weather is a mixture of events that happen every day in our atmosphere including temperature, rainfall and humidity. Weather is not the same everywhere. Perhaps it is dry and sunny today where you live, but in other parts of the world,

it is cloudy, raining or even snowing. Every day, weather events are recorded and predicted by meteorologists worldwide. Weather is the condition of the atmosphere at a particular place over a short period of time [23].

The weather is just the state of atmosphere at any time; including things such as temperature, precipitation, air pressure and cloud cover. Daily changes in the weather are due to winds and storms. Seasonal changes are due to Earth revolving around the sun [24].

Climate in your place on the globe controls the weather where you live. Climate is the average weather pattern in a place over many years. Therefore, the climate of Antarctica is quite different from the climate of a tropical island.

Hot summer days are quite typical of climates in many regions of the world, even without the effects of global warming. Climate refers to the weather pattern of a place over a long period, maybe 30 years or more, long enough to yield meaningful averages [25].

The atmosphere in Sudan in general is a high temperature atmosphere, ranging between 45-50 degrees Celsius in summer, and from 35 - 40 degrees Celsius in the fall, and from 30 - 35 degrees Celsius in winter. Building in the Sudan needs material which reduces temperatures inside the buildings. From this concept the researcher needs a building material whose thermal conductivity is very low, because the decrease in thermal conductivity leads to good cooling inside buildings [26, 27].

### **1.7 The Effect on Human Life**

There are three main effects on human life:

### **1.7.1 Heat and Cold Effects on Human Life**

The human body normally regulates its own temperature very well, but can be affected in a number of ways when it suffers the effect of extreme temperature, in particular the very young or elderly are the most susceptible to the effects of heat and cold [28].

### **1.7.2 Temperature Effects on Human Life**

Natural humans at a temperature of 30 ° C starting from birth, are suspected to live longer than the human being at 36.8 ° C.

Physical structure of humans does not have the ability to withstand very low temperatures, so if the body temperature dropped to less than 30 degrees Celsius will cause the weakness of the performance of its internal devices, causing the failure of the functions of some devices, and tracked by direct death [29, 30].

### **1.7.3 Climate Effect on Human Life**

Climate change has brought about severe and possibly permanent alterations to our planets geological and ecological systems. The Intergovernmental Panel on Climate Change (IPCC) contended in 2003 that “there is new and strong evidence that most of the warming observed over the last 50 years is attributable to human activities” these changes have led to the emergence of large – scale environmental hazards to human health, such as extreme weather, ozone depletion, loss of biodiversity [31].

## **1.8 Humidity**

Physicists have long been concerned with humidity exchange through absorbent materials in the walls and roofs of buildings. Water vapor was generally regarded as a nuisance, causing condensation within walls, with consequent mold growth and corrosion of construction materials. However, the stabilization of the

interior climate by humidity- active building materials and furnishing was of great value in the world of museums and archives [32].

Humidity buffering by absorbent materials has long been used to stabilize the microclimate in show cases and transport boxes. These have a very low air exchange rate, so the efficiency of humidity exchange between the buffer material and the air in the case was not important [33, 34].

Humidity is the presence of water vapour in air (or any other gas). In normal room, air there is typically about 1% water vapour, but it is widely present in greater or less amounts. High humidity make hot days feel even hotter. Low humidity can give people a feeling of a dry throat, or sensations of “static” when touching things. Humidity is measured using a hygrometer. Humidity affects many properties of air, and on materials in contact with air. Water vapour is a key agent in both weather and climate, and it is an important atmospheric greenhouse gas. A huge variety of manufacturing, storage and testing process are humidity – critical.

Air- conditioning systems in buildings often control humidity, and significant energy may go into cooling the air to remove water vapour. Humidity measurements contribute both to achieving correct environmental conditions and to minimizing the energy cost of this [35].

## **1.9 Research Problem**

The temperatures are very high within Sudanese rooms without air conditioners and fans, humidity so the research aims to reduce these two problems.

## **1.10 Literature Review**

There are three previous studies in thermal brick, all of which are consistent with this study in some chemical compounds for clay bricks, and also agree that

the time to burn mud bricks between 24 to 48 hours, and thermal conductivity ranging from 0.02 to 0.04. The difference from this study is that all of its chemical compounds add oxygen to it and become oxides; in addition, the average temperature for burning clay bricks ranges from 700 to 780 degrees Celsius, and in this study between 900 and 950 degrees Celsius.

### **1.11 The Objective of Thesis**

How to find a kind of clay brick which makes the temperatures very low inside Sudanese rooms without air conditioners and fans, also to reduce humidity.

### **1.11 Organization of the Thesis**

This thesis is made up of four chapters other than this chapter. Chapter two deals with the Theoretical Background. Chapter three deals with the Experimental Techniques. Chapter four deals with the Results, Discussion and Conclusion.



# Chapter Two

## Theoretical Background

### 2.1 Heat

Since 1970s, the energy crisis has been listed in the five most essential worldwide problems. And the other four problems are respectively people, food, environment, and resource [36]. In this situation, energy saving becomes more important than ever. People are encouraged to contribute on sustainable development in daily life.

As a common heater, radiator is used for heating the room. It heats the environment by thermal energy, which is transferred from other forms of energy. A process of heat transfer exists when the radiator heats a room [37].

Heat transfer has been widely used nowadays. Therefore, it is important for a researcher to have related knowledge on heat transfer. At the same time, following with the boom of the computer technology, certain types of Computer Software have been introduced for the purpose of analyzing heat transfer efficiently.

#### 2.1.1 Heat Transfer

Temperature is a common phenomenon in nature. And it was used to describe the hot and cold materials. From the perspective of micro-physics, the temperature stands for the intensity of molecular motion [38]. According to Holman [39], energy transfer happens while temperature difference exists between material bodies. Heat transfer is a science used for estimating the energy transfer.

When the temperature difference exists between material bodies, heat is always transferred from the hotter object to the colder one [40]. In other words, heat never goes from a colder object to a warmer object. The transfer of the heat can be discovered from everywhere in people's daily life. For instance, the temperature

of hot water starts to drop if a piece of ice put into the cup. This is because the temperature of the water is higher than the ice so heat is transferred from the water to the ice.

Heat transfer has been widely applied in various fields, there are mainly three research fields. These three aspects are:

- 1) How to increase the heat transfer rate.
- 2) How to decrease the heat transfer rate.
- 3) How to keep the temperature in certain range.

Heat transfer has three basic transfer models: conduction, convection and radiation. Regards to the study of heat transfer; it is divided into these three parts. Accordingly, these three parts are introduced here one by one in detail.

### **2.1.2 Heat Transfer by Conduction**

Conduction is a process of heat transfer generated by molecular vibration within an object. The object has no motion of the material during the heat transfer process. The example below will explain about conduction heat transfer [41].



**Figure- 2.1: Conduction heat transfer**

If there is a metal stick see figure 2.1 [42], then using a candle to heat the left side of the stick for a while, then the right side of the stick will be found to be hot as well. It is because the energy has been transferred from the left side of the stick to the right side. This kind of heat transfer is conduction [figure-2.1].

### 2.1.3 Conduction Rate Equation

Based on the experiment experiences, for the one dimension conduction heat transfer in a plane wall, the amount of heat energy being transferred per unit time is proportional to the normal temperature gradient  $\frac{dT}{dx}$  and the cross-sectional area  $A$  [43], this can be expressed as:

$$Q = -kA \frac{dT}{dx} \quad (2.1)$$

Where  $Q$  is the heat-transfer rate in watts, (W)

$A$  is cross-sectional area in meter square, ( $m^2$ )

$k$  is the thermal conductivity of the material in watts per meter kelvin,  $W/(m.K)$

$\frac{dT}{dx}$  is the temperature gradient.

Equation (2.1) is the formula of calculation of conduction heat transfer rate; it is also known as Fourier's law of heat conduction. The minus sign means that heat is transferred in the direction of decreasing temperature. If the heat transfer rate  $Q$  is divided by the cross-sectional area  $A$ , equation (2.1) will give:

$$Q'' = -k \frac{dT}{dx} \quad (2.2)$$

Where,  $Q''$  is called conduction heat flux. The heat flux can be described as the heat transfer rate through unit cross-sectional area.

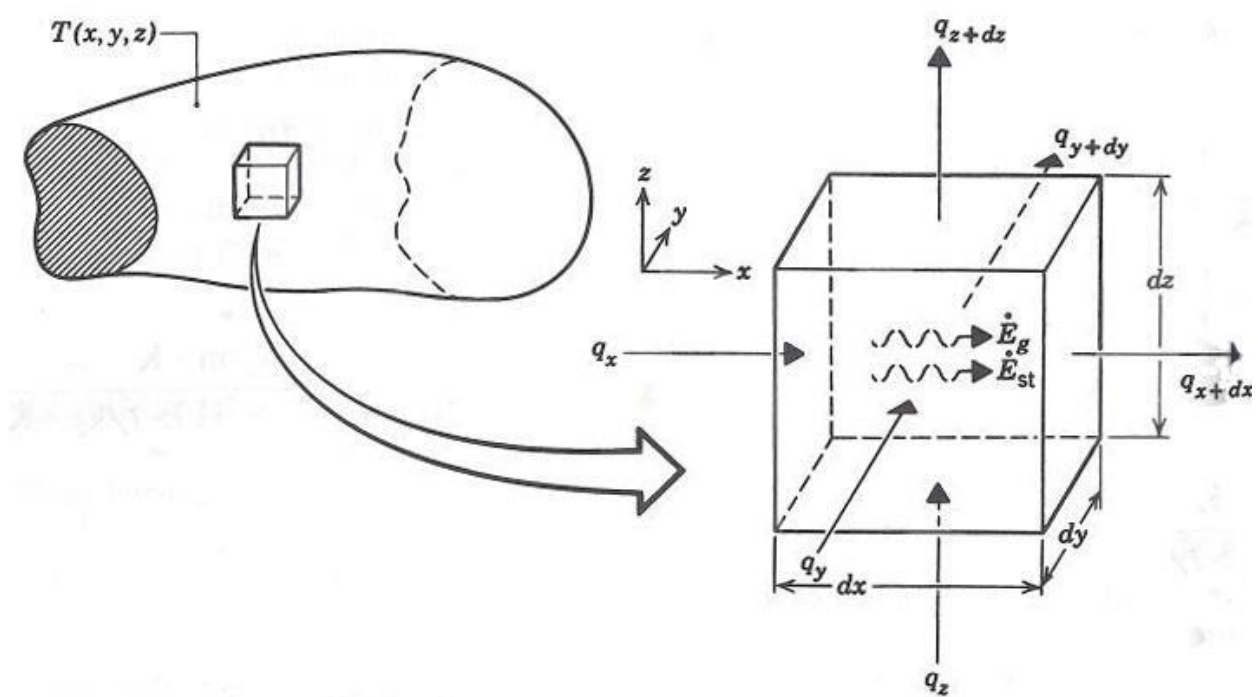
The thermal conductivity  $k$  indicates the substance's ability of transferring heat. If it is a big amount, it means the substance has high level of ability on heat transfer. The number of the thermal conductivity depends on the material; of course, it is also affected by the temperature outside. The heat transfer situation is observed by setting different thermal conductivities when simulating the heat transfer processes between room and radiator [44].

## 2.1.4 Partial Differential Equation of Heat Conduction

Refers to the research on conduction, one of the most important purposes is to know how the temperature is distributed in the medium. Once the distribution situation of the temperature is known, the heat transfer rate can be calculated.

To derive a mathematical formulation of temperature distribution, both the law of the conservation of energy and the Fourier's law should be used. On the basis of conservation of energy, the balance of heat energy for a medium is expressed as [45].

$$\begin{aligned}
 &[\text{Energy conducted from outside of the medium}] + [\text{Heat generated within medium}] = \\
 &[\text{Energy conducted to outside of the medium}] + [\text{Change in internal energy within medium}]
 \end{aligned}
 \tag{2.3}$$



**Figure- 2.2 Conduction Analysis in Cartesian Coordinates**

Based on the heat-conduction energy balance, the following equation was derived:

$$\frac{\partial}{\partial x} \left( k \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial y} \left( k \frac{\partial T}{\partial y} \right) + \frac{\partial}{\partial z} \left( k \frac{\partial T}{\partial z} \right) + q^{\bullet} = \rho c \frac{\partial T}{\partial t} \quad (2.4)$$

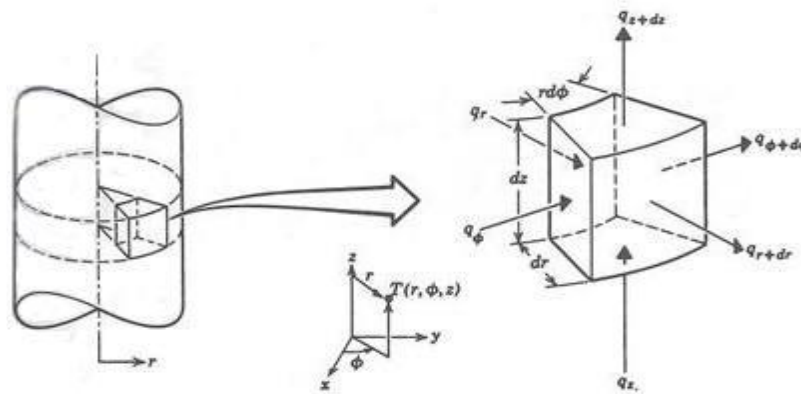
Where  $\rho$  is density in  $\text{kg/m}^3$

$c$  is the specific heat of material in  $\text{J/Kg.k}$

$q^{\bullet}$  is the Heat generated per unit volume in  $\text{W/m}^3$

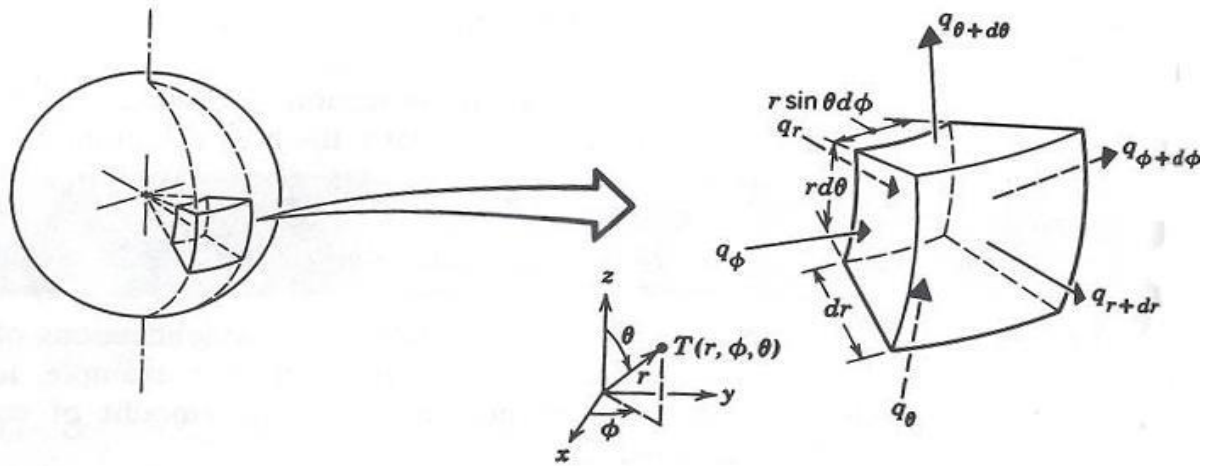
Equation (2.4) is called differential equation of heat conduction; it is also called heat diffusion equation. This equation describes the process of the general conduction heat transfer in mathematical method. When applying the equation to solve problems, equation (2.4) will be simplified in accordance with the requirement of question and boundary conditions.

The heat equation (2.4) was expressed in a Cartesian coordinates. For cylindrical coordinates and spherical coordinates, the heat conduction energy balance is shown in Figure- 2.2, Figure- 2.3. The heat diffusion equation is expressed as equation (2.4) and (2.5) [46].



**Figure- 2.3 Conduction Analysis in Cylindrical Coordinates**

Cylindrical Coordinates:



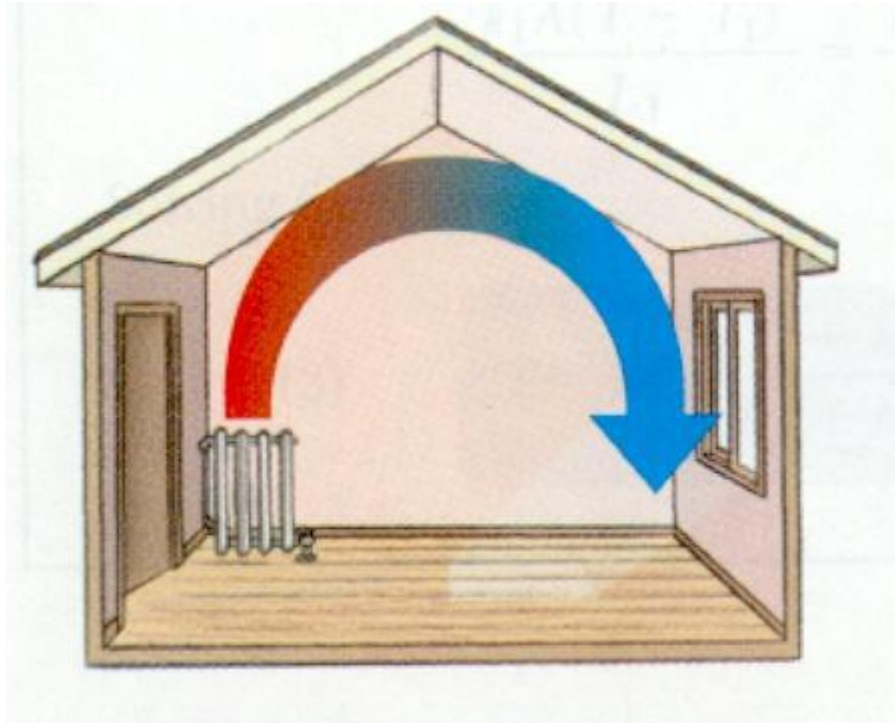
**Figure- 2.4 Conduction Analysis in Spherical Coordinates**

$$\frac{1}{r} \frac{\partial}{\partial r} \left( kr \frac{\partial T}{\partial r} \right) + \frac{1}{r^2} \frac{\partial}{\partial \phi} \left( k \frac{\partial T}{\partial \phi} \right) + \frac{\partial}{\partial \theta} \left( k \frac{\partial T}{\partial \theta} \right) + q \cdot = \rho c \frac{\partial T}{\partial t} \quad (2.5)$$

Where  $(r, \theta, \phi)$  are the Spherical (cylindrical) coordinates, and  $k$  is the constant.

### 2.1.5 Heat Transfer by Convection

Convection is the delivery of heat from a hot region to a cold region in a bulk, macroscopic movement of matter, which is opposed to the microscopic delivery of heat between atoms involved with conduction [47]. It means that convection must follow with conduction. In the system of convection heat transfer, the heat can be transferred within the fluid; it can be transferred between fluid and surface as well. The heat transfer between surface and fluid is called convective heat transfer [48].



**Figure- 2.5 Heat Transfer by Convection**

The air around the radiator is heated up by the radiator and then moves to the cold region, as shown in figure-2.5 [49].

### **2.1.5.1 Newton's Law of Cooling**

The basic formula of calculating convective heat transfer rate is the Newton's law of cooling. The Newton's law of cooling can be used to express the overall effect of convection [50]:

$$Q = h A \Delta T \quad (2.6)$$

Where Q is heat-transfer rate;

h is convection heat transfer coefficient in  $W/(m^2.k)$

A is area in  $m^2$

$\Delta T$  is temperature difference between fluid and surface in K.

As formula (2.6) shows, convection coefficient of heat transfer is one of the most important parts of the formula. The main task of investigating the convection is to solve calculate the convection coefficient of heat transfer. Once the

coefficient of heat transfer has been found, the heat transfer rate can be calculated [51].

## 2.1.6 Heat Transfer by Radiation

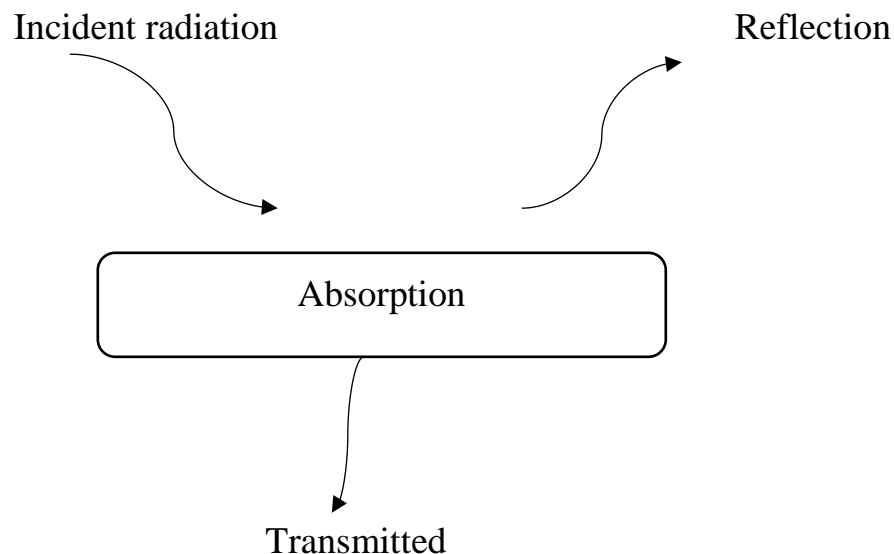
For conduction and convection heat transfer, the heat can only be transferred through a material medium. Whereas, the radiation heat transfer can exist in vacuum. Energy transfer through electromagnetic waves is called radiation. Thermal radiation is radiation that is propagated as a result of a temperature. Finally, radiation heat transfer is defined as “heat transfer by the emission of electromagnetic waves which carry energy away from the emitting object [52]”.

### 2.1.6.1 Properties of Radiation

Incident radiation energy can be reflected, a material surface absorbed and transmitted when it strikes. According to the Energy Balance Equation, the relationship between them can be expressed as:

$$\alpha + \rho + \tau = 1 \quad (2.7)$$

Where,  $\alpha$  is absorptivity,  $\rho$  is reflectivity and  $\tau$  is transmissivity see figure 2.6.



**Figure- 2.6 Effects of Incident Radiation**



If a body absorbs total incident radiation, this body is called Blackbody. Therefore, the absorptivity of blackbody is one.

### **2.1.6.2 Stefan-Boltzmann Law of Thermal Radiation**

Holman as gave a concept of the emissive power: the energy emitted by the body per unit area and per unit time, marked with E [53].

Stefan-Boltzmann law of thermal radiation describes the relationship between emissive power of a blackbody and temperature. It shows that:

$$E_b = \sigma T^4 \quad (2.8)$$

Where  $E_b$  is the energy radiated per unit time and per unit area.

$\sigma$  is the Stefan-Boltzmann constant with value of  $5.669 \times 10^{-8} \text{ W/m}^2 \text{ K}^4$

T is temperature in K.

Equation (2.8) is known as the Stefan-Boltzmann law. Based on the law, it is known that a subject's emissive power increases as soon as the subject's temperature rises.

The blackbody is an ideal body. The ratio of the emissive power between the real body and blackbody at the same temperature is called emissivity of the real body, which is [54]:

$$\varepsilon = \frac{E}{E_b} \quad (2.9)$$

Then the emissive power of a real body can be expressed as:

$$E = \varepsilon E_b = \varepsilon \sigma T^4 \quad (2.10)$$

The emissivity of a blackbody is one.

### 2.1.6.3 Radiation Energy Exchange

There are two types of Energy Exchange:

#### 2.1.6.3.1 Radiation Energy Exchange between Blackbodies

To calculate the energy exchange between two blackbodies with surfaces  $A_m$  and  $A_n$ , the following expression would be applied:

$$Q_{1-2} = E_{bm} A_m F_{mn} - E_{bn} A_n F_{mn} \quad (2.11)$$

Where  $F_{mn}$  is the fraction of energy leaving surface  $m$  which reaches surfaces  $n$ , and  $E_b$  is the blackbody emissive power.

#### 2.1.6.3.2 Radiation Energy Exchange between non-Blackbodies

Holman has given definitions for two terms in order to calculate the radiation energy exchange: Irradiation  $G$  and Radiation  $J$ . Irradiation is “the total radiation incident upon a surface per unit time and per unit area” and Radiation is “total radiation which leaves a surface per unit time and per unit area”. As a result, the Radiation on a surface can be calculated by the following formula [55], which has been mentioned by:

$$J = \varepsilon E_b + \rho G = \varepsilon \sigma T^4 + \rho G \quad (2.12)$$

Where  $\varepsilon$  is emissivity

$E_b$  is the blackbody emissive power

$\rho$  is the reflectivity

$\sigma$  is the Stefan-Boltzmann constant

Equation (2.10) can be used for calculating the radiation energy loss of an object in a large room.

$$q = \sigma A_1 \varepsilon_1 (T_1^4 - T_2^4) \quad (2.13)$$

Where  $A_1$  is the surface area of the object

$\varepsilon_1$  is the emissivity of the object

$T_1$  is the temperature of the object

$T_2$  is the temperature of the room.

$q$  is the radiation energy loss

### 2.1.7 Temperature and Pressure

The most commonly used scales for temperature are Fahrenheit and Celsius, labeled °F and °C. United States people use Fahrenheit while in other parts of the world people are familiar with Celsius. Both scales are linear and can be converted from each other by the following expressions:

$$^{\circ}F = 32 + 9/5^{\circ}C \quad (2.14)$$

$$^{\circ}C = ((^{\circ}F - 32))/ (9/5) \quad (2.15)$$

Since water vapor exist in gas mixture, it behaves in accordance with gas laws and exerts a partial pressure in the gas mixture just like any other constituents. The ideal gas law is known as

$$PV = nRT \quad (2.16)$$

Where  $P$  is absolute pressure,  $V$  is volume,  $n$  is number of moles of gas,  $T$  is absolute temperature and  $R$  is universal gas constant. Then we have Dalton's law, this law is perhaps the most important gas law applicable to humidity measurement. Dalton supposed that if we have a mixture of gases  $a$ ,  $b$ , and  $c$  to be

combined into a known volume at known temperature, then their individual contribution to the pressure could be written as, according to ideal gas law [56]:

$$P_a = \frac{n_a RT}{V}, P_b = \frac{n_b RT}{V}, P_c = \frac{n_c RT}{V} \quad (2.17)$$

These are called “partial pressure” of each gas constituent. He proposed that the total pressure should be the sum of all partial pressure constituents, hence:

$$P_{\text{total}} = P_a + P_b + P_c \quad (2.18)$$

Dalton’s law is stated as: The total pressure of a mixture of gases is equal to the sum of the pressure of the constituent gases, if each were individually to occupy that same volume, at that same temperature [57].

### 2.1.8 Specific Heat Capacity of Substance and Specific Heat

We know that when heat energy is absorbed by a substance, its temperature increases. If the same quantity of heat is given to equal masses of different substances, it is observed that the rise in temperature for each substance is different. This is due to the fact that different substances have different heat capacities.

So heat capacity of a substance is the quantity of the heat required to raise the temperature of the whole substance by one degree.

If the mass of the substance is unity then the heat capacity is called Specific heat capacity or the specific heat [58].

$$Q = C m \Delta T \quad (2.19)$$

Where (Q) is quantity of heat absorbed by a body.

(m) is mass of the body.

( $\Delta T$ ) is rise in temperature.

(C) is specific heat capacity of a substance it depends on the nature of the material of the substance. S.I unit of specific heat in  $\text{J kg}^{-1}\text{K}^{-1}$

NOTE: - Heat capacity = specific heat x mass. Its S.I unit is in  $\text{J K}^{-1}$ .

## **2.2 Clay**

Soil is one of the primary materials used for construction of traditional low cost dwellings in Sudan and is well suited to local weather conditions and occupancy patterns. Soil construction methods are used in 80% of urban buildings in Sudan while this figure exceeds 90% in rural areas. Buildings are constructed entirely, or partially of soil, depending on location, climate, available skills, cost, building use and local tradition [59].

### **2.2.1 Soils of Sudan**

In Sudan, the main soil types are identified as black cotton soils (grarh or badobe), red sand ironstone soils, and laterite and lateritic soils.

### **2.2.2 Black Cotton Soil (grarh)**

The term black cotton soil, otherwise known as (grarh or badobe), is derived from the soils dark or black in color and the fact it was originally used for growing cotton in general. In Sudan, one of the following processes forms black cotton soil or badobe: to the east of the Blue Nile, badobe is a residual soil derived from its parent rock. Between the two Niles (the Gezeria clay plain), the black cotton soil is a transported alluvial deposit from the Ethiopian mountains to the east.

The black cotton soils of Sudan have the following common characteristics [60]:

- The color ranges from dark grey to dark brown.
- Pronounced volume change upon wetting and drying. i.e extreme expansion and shrinkage properties.
- High (35%) clay content (clay is defined as soil fraction containing particle size less than 0.002mm). This clay fraction is composed mainly of the grarah.
- The liquid limit (L.L) ranges between 47% and 93%.
- The plastic limit (P.L) ranges between 26% and 50%.
- The plasticity index (P.I) ranges between 13% and 58%.

- The linear shrinkage ranges between 8% and 18%.

### **2.2.3 Red Sand-Ironstone Soils (goz)**

To the west of the main Nile and the White Nile extend the red sand – iron stone Goz soils, these soils are formed from the breakdown of the Nubian sand stone rock that underlies soils of north and western Sudan. This soil type also occupies large land area in Sudan (7%) [61]. In general, however, knowledge of the engineering properties of these soils is limited. They are mainly red or brown ironstone soils formed in dry arid conditions.

Attempts have been made to relate them to the laterite and lateritic soils of West Africa, but they possess different properties to those soils. Goz soils include wind- blown sands, silt and clays that have accumulated in depths of up to 5m, where the lower layers have become consolidated with time.

Many villagers in these areas have built dwellings from Goz soils that demonstrate greater durability properties than those buildings made from grarah soils. A possible reason for this is that Goz soils tend to have a lower clay content so they expand and shrink less on wetting and drying, making them more stable through periods of climatic fluctuation.

Clay is a fine-grained natural rock or soil material that combines one or more clay minerals with traces of metal oxides and organic matter. Clays are plastic due to their water content and become hard, brittle and non-plastic upon drying or firing.

The materials known as clays differ so greatly in composition and properties that it is impracticable to class them accurately and in detail [62].

Soil has been used in Sudan as a building material like in most developing countries. Low-income groups in the Sudan for construction of their houses use it. For construction purposes, soil has the advantage of being cheap, always available, and easy to work with and develops comfortable dwelling [63].

All clays are composed of one or more clay mineral, other minerals.

In most materials described as clays, the clay minerals are the predominant and essential constituent, and this should always be borne in mind though in some commercially useful brick-and tile-clays the total clay minerals may be only 30-35% of the whole material and in some workable clay-pastes, it is even less [64].

Geologic clay deposits are mostly composed of phyllosilicate minerals containing variable amounts of water trapped in the mineral structure [65]. Depending on the soil's content in which it is found, clay can appear in various colors from white to dull gray or brown to deep orange-red [66].

Clays exhibit plasticity when mixed with water in certain proportions. When dry, clay becomes firm and when fired in a kiln, permanent physical and chemical changes occur. These changes convert the clay into a ceramic material. Because of these properties, clay is used for making pottery, both utilitarian and decorative, and construction products, such as bricks, wall and floor tiles [67]. Different types of clay, when used with different minerals and firing conditions, are used to produce earthenware, stoneware, and porcelain. Prehistoric humans discovered the useful properties of clay [68, 69].

Clay is one of the oldest building materials on Earth, among other ancient, naturally-occurring geologic materials such as stone and organic materials like wood. Between one-half and two-thirds of the world's population, in traditional societies as well as developed countries, still live or work in a building made with clay as an essential part of its load-bearing structure. Also a primary ingredient in many natural building techniques, clay is used to create adobe, cob, cordwood, and rammed earth structures and building elements such as wattle and daub, clay plaster, clay render case, clay floors and clay paints and ceramic building material. Clay was used as a mortar in brick chimneys and stone walls where protected from water [70].

## **2.3 Brick Clay**

Human uses brick, the most important tiny piece for construction works for many years back. Its history goes back to some of the earliest times in the civilization of men. Many world famous archaeological excavations provide much information about the brick uses in different parts of the world. Many years back, bricks were made at warm places and simply placed in the Sunlight for hardening. The hand-shaped, Sun-dried, mud bricks were made and used during the Pre-Pottery Neolithic Period. The oldest examples of brick use were first found in Southern Turkey.

In the 5th century B.C., burnt bricks were used in the wall of the city of Babylon. The ancient Egyptians also used Sun dried clay bricks in their numerous world famous historic monuments.

Brick production was done by hand until about 1885. In the middle of the 19th century brick manufacturers began the development of mechanical production. Due to the development in different sectors, enormous expansion of house and demand for bricks lead to mechanized production of bricks [71].

Clay brick is the first man made artificial building material and one of the oldest building materials known. Its widespread use is mainly due to the availability of clay in most countries. Its durability and aesthetic appeal also contribute to its extensive application in both load bearing and non-load bearing structures. The properties of clay units depend on the mineralogical compositions of the clays used to manufacture the unit, the manufacturing process and the firing temperature [72].

Brick is one of the most accommodating masonry units due to its properties. The firing process could affect the physical and mechanical properties, colors and appearance of the manufactured brick. Many studies have been carried out by manipulating the firing process at different temperature, utilizing fast firing and



traditional firing but most of the research are more focusing on the physical and mechanical properties of fired clay bricks only[73, 74]. For instance, studies by Dunham et al investigated shorter firing times in the manufacturing of clay bricks while Dondi et al.[75] compared the influences of fast firing and traditional firing on physical and mechanical properties of clay bricks. Therefore, previous research contains very limited discussion on the effect of different heating rates, particularly on physical and mechanical properties of manufactured fired clay bricks incorporating different types of clay [76].

These clays depend for their value on physical properties, rather than chemical composition and frequently the permissible range of brick clay is very wide.

The basic requirements that must be fulfilled by brick clays, (physical, chemical and mineralogical) are:

- To be present as consistent deposit sufficiently extensive and accessible to warrant large-scale development.
- To be plastic enough to mold easily into shape and retain that shape in both wet and dry state. (This means there must be a proportion of clay minerals to confer all the essentials of plasticity).
- Good proportion of non- plastic minerals i.e. non-clay mineral is also essential so that the shapes do not shrink excessively on drying and firing.
- Fluxing agents, commonly the alkali elements of sodium and potassium (k) must be present, but magnesium (Mg), calcium (Ca) and ferrous (iron Fe+2) can behave as fluxes at higher temperatures [77].

### **2.3.1 Plasticity of Clays**

Plasticity of clays may be defined as the behavior of clays when mixed with water but in insufficient amounts to permit flow without external applied stresses.

Clays differ greatly in the extent and quality of their plasticity. The "fat" or "strong" clays undergo a large change in shape on the application of a small force while "lean" or "short" clays undergo a much smaller change of shape and require a greater force to make the change appreciable. Hence in comparing the plasticity of clays it is necessary to include the extent of change of shape as well as of the force necessary to produce it [78].

### **2.3.1.1 Plasticity of Clays are Affected Chiefly by**

#### 1. Water content effect:

Plasticity is exhibited by clays within a comparatively narrow range of water content. Above a certain value the clay mass becomes mud or a slip whilst dry clay is virtually devoid of plasticity i.e. practically has no plasticity. The maximum plasticity of a clay is developed at a specific water content which corresponds with a film around each particle about 2000 Å thick. For most clay, this would be in the water content range 15-25% by weight.

#### 2. Effect of size of particles:

Plasticity is attributed- by many investigators – to the fineness of the grains of the materials. It is said that even non-plastic material if very finely ground will develop small plasticity e.g. quartz and limestone when ground to pass a 200-mesh sieve when mixed with water have a slight plasticity but do not hold together on drying.

#### 3. Effect of particle size distribution:

A mass of a good packing density gives better plasticity than a similar system with higher bulk volume. Packing density is the ratio of the weight of a material to the minimum volume it can occupy. Usually well- graded materials give good packing and hence in the case of clays if they are well graded they will be plastic.

Brick-clays may contain:

25-75% silt and clay (fine < 0.06mm). 10-50% sand (2-0.06mm).

If clay is too plastic i.e containing high percentage of fines, coarser material has to added and vice versa.

#### 4. Effect of previous history:

The treatment which clay has undergone has large effect on its plasticity.

Air-dried clay when mixed with water restore its original plasticity but if clay dried by artificial heat or sometimes if exposed to tropical conditions its plasticity become low because of partial decomposition of the clay or due to partial conversion of colloidal materials into an inert material [79].

### **2.3.2 Fired Clay Brick**

A small, rectangular block made of fired clay is a simple description of clay brick, the clay brick production varies widely in composition from one place to another.

Silica (grains of sand), alumina, lime, iron, manganese, Sulphur and phosphates, with different proportions mainly compos the clays. Grinding or crushing the clay in mills and mixing it with water to make it plastic are the steps to manufacture bricks. Then, the plastic clay is molded, textured, dried and fired.

Bricks are manufactured with variety of colors, such as dark red, brown and gray base on the firing temperature of the clay during manufacturing [80]. The firing temperature for brick manufacturing varies from 900 C -1200 C. Clay brick have an average density of 2 mg/m<sup>3</sup>.

### **2.3.3 History of Clay Brick**

In the Middle East date 10,000 years ago, archaeologists have found bricks. Mud left after the rivers flood in that area makes these bricks. Scientists suggested this idea. The bricks were molded by bare hand. Then, the bricks were left under the sun in order to make it dry. Layering the bricks using mud and tar as mortar is the way to build the structure of the bricks.

During the Industrial Revolution, bricks were used extensively for building new factories and homes. Until the nineteenth century, raw materials for bricks were mined and mixed, and bricks were formed, by manual labor. The first brick making machines were steam powered, and the bricks were fired with wood or coal as fuel. Modern brick making equipment is powered by gas and electricity. Some manufacturers still produce bricks by old method, but the majorities are using the modern method [81].

### **2.3.4 Types of Brick**

There are some types of clay brick as shown in figure-2.7.

#### **2.3.4.1 Common Brick**

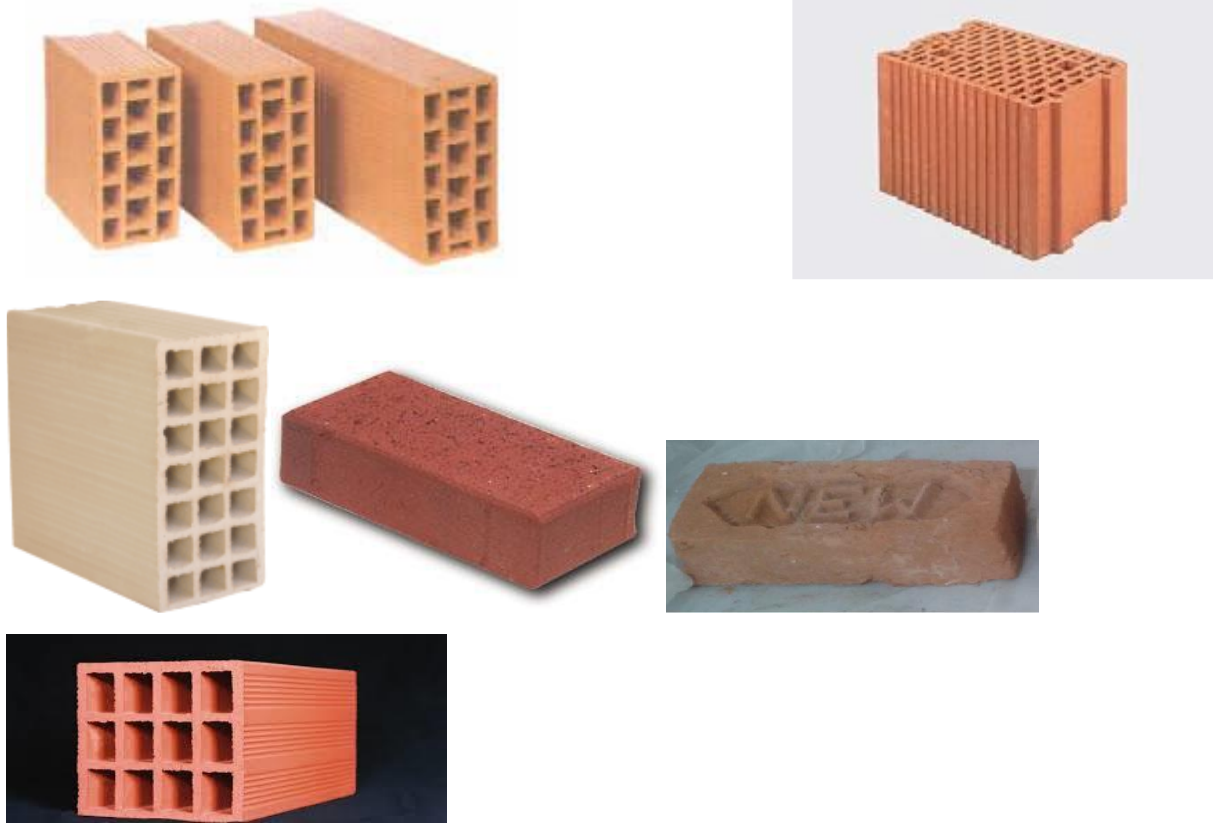
This type of brick does not have a specific amount on the surface, and is usually used for the walls that will be covered with a layer of plaster, or for other uses where the appearance of the surface is not so important [82].

#### **2.3.4.2 Face Brick**

Either this type of brick has a finishing on the surface, smooth or sandy texture, the color is uniform or colorful. Bricks are used to make the surface of the wall to look pretty and be strong nature of the weather.

#### **2.3.4.3 Engineering Brick**

Engineering brick is a solid brick construction, which is used for retaining wall, resistant to burning, bridge foundation, sewerage, wall form, and erosion. Figure- 2.6 shows the typical types of brick [83].



**Figure- 2.7 Typical Types of Clay Brick**

### **2.3.5 Properties of Bricks**

The properties of clay bricks affect appearance and quality of masonry construction. In order to achieve the designated of durability, quality and strength, emphasis on the properties of units such as dry shrinkage, dry density, initial rate of suction (IRS) and compressive strengths (CS) have to be calculated [84].

### **2.4 Humidity**

Water vapor measurements are closely related to temperature and pressure, water vapor is a form of gas, so it also follows the laws of gas.

Humidity is the amount of water vapor present in the air. Water vapor is the gaseous state of water and is invisible to the human eye. Humidity indicates the

likelihood of precipitation, dew, or fog. Higher humidity reduces the effectiveness of sweating in cooling the body by reducing the rate of evaporation of moisture from the skin. The amount of water vapor that is needed to achieve saturation increases as the temperature increases [85].

Humidity is the presence of water vapour in air (or any other gas). In normal room air there is typically about 1 % water vapour, but it is widely present in greater or less amounts. High humidity makes hot days feel even hotter. Low humidity can give people a feeling of a dry throat, or sensations of “static” when touching things. Humidity is measured using a hygrometer [86].

#### **2.4.1 Measurements of Humidity**

There are three main measurements of humidity: absolute, relative and specific. Absolute humidity is the water content of air expressed in gram per cubic meter. Relative humidity, expressed as a percent, measures the current absolute humidity relative to the maximum (highest point) for that temperature. Specific humidity is the ratio of the mass of water vapor to the total mass of the moist air parcel [87].

Humidity is a qualitative concept referring to the presence of water vapour in a gas. It is quantified with various physical quantities such as mixing ratio  $r$ , amount fraction  $x_w$ , water vapour pressure  $e_w$ , dew-point temperature  $T_d$  and relative humidity. The mixing ratio is the ratio between masses of water vapour  $m_w$  and dry gas  $m_g$  [88] in a sample as shown in Equation (2.20):

$$r = \frac{m_w}{m_g} \quad (2.20)$$

The amount fraction of water vapour in humid air is the amount (in moles) of water vapour  $n_w$  divided by the total amount of gas components  $n_w+n_g$  in a gas

sample. It can be expressed using  $r$  in Equation (2.20) with the molar masses of dry gas ( $M_g$ ) and water vapour ( $M_w$ ) in the following way:

$$x_w = \frac{n_w}{n_w + n_g} = \frac{r}{\frac{M_w}{M_g} + r} \quad (2.21)$$

The molar masses can be obtained from the literature e.g. from [89]. According to the Dalton's law partial pressure of water vapour in a gas mixture equals to the amount fraction of water vapour multiplied by the total pressure ( $p$ ) of a gas mixture. However, Dalton's law is valid only for ideal gases and thus a water vapour enhancement factor ( $fe_w$ ) is introduced:

$$fe_w = x_w p \quad (2.22)$$

For humid air the enhancement factor can be calculated e.g. according to Hardy [90].

In order to convert water vapour pressure to dew-point temperature or to relative humidity an equation for saturation water vapour pressure ( $e_{ws}$ ) is needed. The metrological community often uses equations by Hyland and Wexler [91] or Sonntag [92] due to their applicability to a wide temperature range. The knowledge of saturation water vapour pressure the relative humidity can be calculated as

$$RH = \frac{x_w P}{f(P, T) e_{ws}(T)} \bullet 100\% rh \quad (2.23)$$

When carrying out humidity calculations it is important to be aware of whether the saturation water vapour pressure is with respect to water or ice. Typically within metrological community at temperatures below 0 °C the saturation pressure is expressed with respect to ice [93].

### 2.4.2 Absolute Humidity

Absolute humidity is the total mass of water vapour present in a given volume or mass of air. Absolute humidity in the atmosphere ranges from near zero to roughly 30 grams per cubic meter when the air is saturated at 30 °C (86 °F).

Absolute humidity (AH) is the mass of the water vapour ( $m_{H_2O}$ ), divided by the volume of the air and water vapor mixture ( $V_{net}$ ), which can be expressed as:

$$AH = \frac{m_{H_2O}}{V_{net}} \quad (2.24)$$

It forms a part of the total atmospheric pressure. The amount of atmospheric moisture is proportional to the partial pressure of the water vapor, which allows a measurement of the absolute humidity in the air [94, 95].

Absolute humidity is expressed in g/m<sup>3</sup>, which is in fact the measure of the vapor density of water [96].

Also absolute humidity is defined as water vapor density and is expressed as water mass per unit volume of dry air, it can be expressed as:

$$AH = \frac{216.7e}{T_a + 273.16} \quad (2.25)$$

Where  $e$  is the vapor pressure and  $T_a$  is ambient temperature.

If ideal gas behavior is assumed the absolute humidity (AH) can be calculated using the formula:

$$AH = C \cdot P_w/T \quad (2.26)$$

Where C is Constant 2.16679 in gK/J,  $P_w$  is Vapour pressure in Pa, and T is Temperature in K



### 2.4.3 Relative Humidity

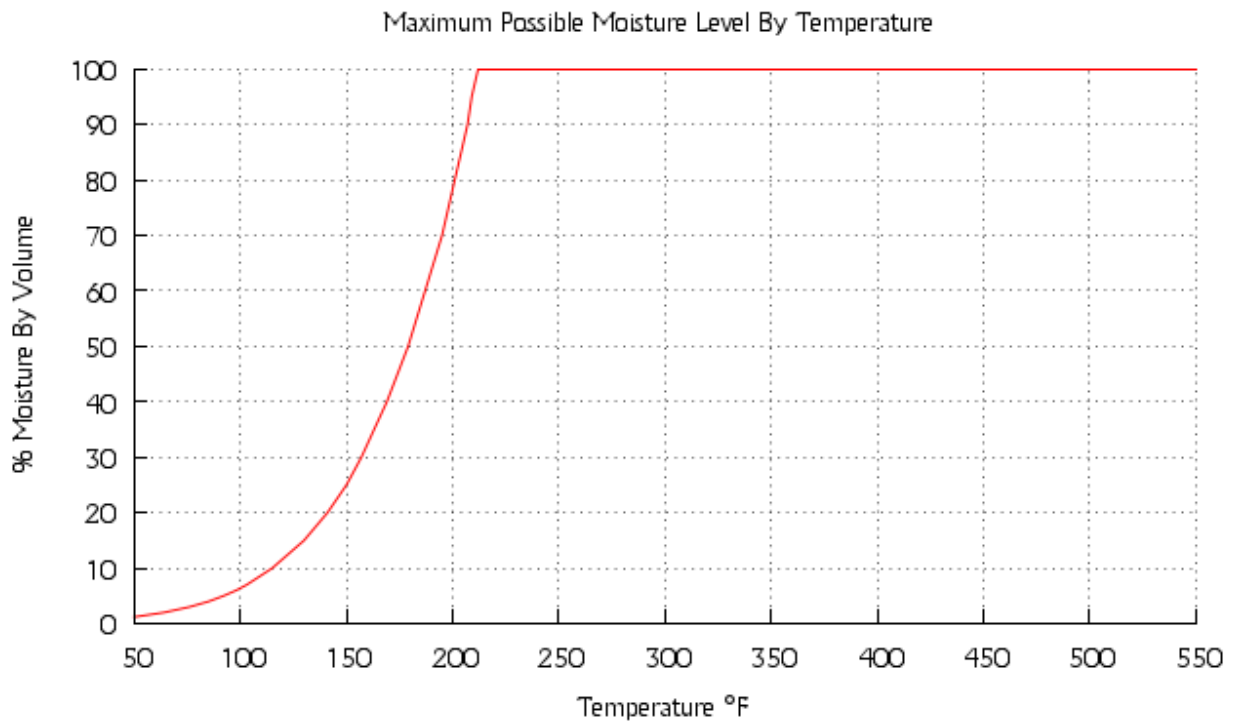
Relative humidity – how saturated a gas (or a space) is with water vapour. This is the most commonly used measure of humidity. Usually expressed as a percentage, with the symbol “% RH”, for example “The humidity is 51 % RH”. Interaction of water vapour with materials is often in proportion to relative humidity [97].

The relative humidity (RH or  $\phi$ ) of an air-water mixture is defined as the ratio of the partial pressure of water vapor ( $P_{H_2O}$ ) in the mixture to the equilibrium vapor pressure of water ( $P_{H_2O}^*$ ) over a flat surface of pure water at a given temperature. A higher percentage means that the air-water mixture is more humid.

$$\Phi = \frac{P_{H_2O}}{P_{H_2O}^*} \quad (2.27)$$

Relative humidity is an important metric used in weather forecasts and reports, as it is an indicator of the likelihood of precipitation, dew, or fog. In hot summer weather, a rise in relative humidity increases the apparent temperature to humans (and other animals) by hindering the evaporation of perspiration from the skin [98].

Relative humidity is familiar to most of us because of its everyday usage with regard to the weather. Unfortunately the amount of moisture the air can hold depends on the temperature of the air. The following graph shows the maximum percentage of water vapor that the air can hold at a given temperature [99].



**Figure- 2.8 Maximum possible moisture by temperature**

The graph shows that the higher the temperature (up to 212°F) the higher the amount of water vapor the air can hold. At 212°F and above it is possible for the air to be totally water vapor (steam) and the % moisture by volume can reach 100%.

Relative humidity is the ratio of vapor pressure to the saturation water vapor pressure at a given temperature:

$$\text{Relative humidity} = \text{water vapor pressure} / \text{saturation water vapor pressure} \quad (2.28)$$

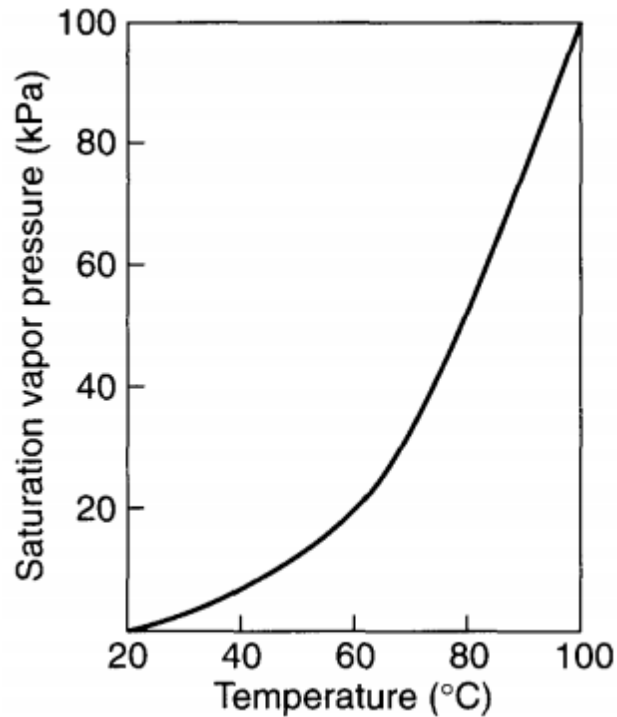
As the temperature increases, saturation vapor pressure increases. Consequently, the relative humidity decreases with increasing temperature if the absolute humidity in the air is kept constant [100].

Most people are familiar with relative humidity, because they hear it on weather forecast all the time. For the relative humidity, it is the ratio of the amount

of moisture in the air at a specific temperature to the maximum amount that the air could hold at that temperature, expressed as a percentage. More accurate definition of relative humidity is that it is the ratio of the actual partial vapor pressure to the saturation vapor pressure of the gas, multiplied with 100% at the prevailing ambient temperature [101]. For an actual vapor pressure  $e$ , and saturation vapor pressure  $e_s$  [102],

$$\text{Relative Humidity (RH)} = \frac{e}{e_s} \times 100\% \quad (2.29)$$

The following figure-2.9 shows water vapor pressure versus temperature:



**Figure- 2.9 Saturation Vapor Pressure vs Temperature**

Relative humidity is at all temperatures and pressures defined as the ratio of the water vapour pressure to the saturation water vapour pressure (over water) at the gas temperature:

$$RH = \frac{P_w}{P_{w_s}} \times 100\% \quad (2.30)$$

On the other hand, as the ratio of the actual water vapor dry mass mixing ratio ( $w$ ) to the equilibrium (or saturation) mixing ratio ( $w_s$ ) at the ambient temperature and pressure:

$$RH = 100 \frac{w}{w_s} \quad (2.31)$$

The two definitions are related by  $w = \epsilon e(P - e)^{-1}$  and  $w_s = \epsilon e_s (P - e)^{-1}$  where ( $\epsilon$ ) is the ratio of the molecular weights of water and dry air, and  $P$  is the ambient air pressure.

Normally the definition is expressed implicitly in terms of the vapor pressure:

$$e_s (T_d) = e(T) \quad (2.32)$$

To express ( $T_d$ ) in terms of RH, an expression for the dependence of ( $e$ ) on  $t$  is needed [103].

Moreover, rearranging to solve for  $T_d$  gives:

$$T_d = T_c \left[ 1 - \frac{T \ln \left( \frac{RH}{100} \right)}{\frac{L}{R_w}} \right]^{-1} \quad (2.33)$$

Where  $T$  is the temperature in Kelvin ( $T = T_c + 273.15$ ),  $T_c$  is temperature in centigrade,  $R_w$  is the gas constant for water vapor ( $461.5 \text{ J K}^{-1} \text{ kg}^{-1}$ ), and  $L$  is the enthalpy of vaporization, which varies between  $L = 2.501 \times 10^6 \text{ J kg}^{-1}$  at  $T = 273.15 \text{ K}$  and  $L = 2.257 \times 10^6 \text{ J kg}^{-1}$  at  $T = 373.15 \text{ K}$ .

#### 2.4.4 Specific Humidity

Specific humidity (or moisture content) is the ratio of the mass of water vapor to the total mass of the moist air parcel. Specific humidity is approximately equal

to the "mixing ratio", which is defined as the ratio of the mass of water vapor in an air parcel to the mass of dry air for the same parcel.

As temperature decreases, the amount of water vapor needed to reach saturation also decreases. As the temperature of a parcel of air becomes lower it will eventually reach the point of saturation without adding or losing water mas.

Specific humidity is the ratio of the mass of water vapor to the total mass of the mixture of water vapor and dry air. The specific humidity (q) can be calculated if the % moisture by volume (%MV) is known.

$$\text{Specific Humidity} = q = 0.622 \times \%MV / [(100 - \%MV) + 0.622 \times \%MV] \quad (2.34)$$

The factor 0.622 is for normal air only. It must be corrected if the average molecular weight of the gases is different than air.

Specific humidity and mixing ratio are two other ways of expressing the amount of humidity in the air. Specific humidity is the ratio of the weight of water vapor to the unit weight of air containing it.

$$\text{Specific humidity} = \text{mass of water vapor} / \text{total mass of air} \quad (2.35)$$

### **2.4.5 Dew Point**

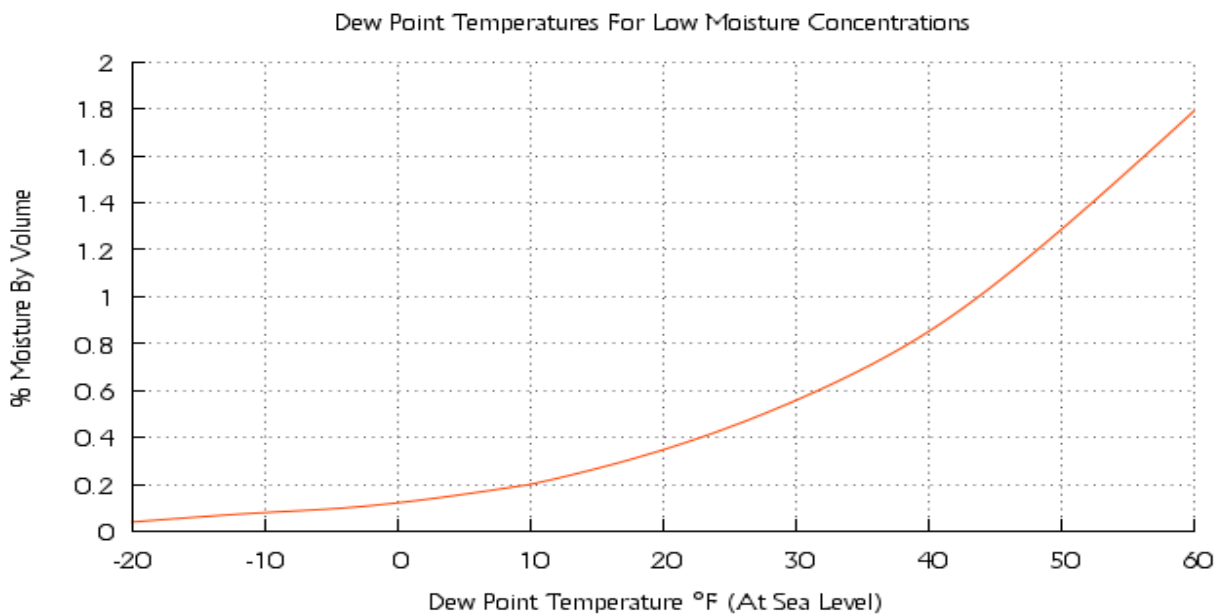
Dew point (or dew-point temperature) - the temperature at which condensation (dew) would occur if a gas was cooled. Dew point is a useful measure for two reasons:

- The dew point tells us what temperature to keep a gas, to prevent condensation
- Dew point is an absolute measure of the gas humidity (at any temperature) and relates directly to the amount of water vapour present (partial pressure of water vapour) [104].



**Figure- 2.10 Photo of Dew, or Condensation**

The dew point as shown in figure-2.11 is the temperature at which the relative humidity reaches 100%. The RH cannot exceed 100%, so if we continue to cool air it will give up moisture in the form of condensation [105].



**Figure- 2.11 Gives the dew/frost point temperatures for low concentrations of moisture in the air**

Dew-point temperature is another humidity related parameter, which is defined as the temperature to which the air should be cooled to reach saturation,

when the moisture content is constant. The dew point temperature gives a measure of the absolute humidity in the air, and it corresponds to the saturation vapor density at that temperature [106].

A volume of gas must be cooled such that it becomes saturated with respect to liquid water to the temperature. This is the temperature at a particular vapor pressure when  $e = e_s$  at total pressure  $P$  [107]. The definition of frost point is very similar; it is the temperature to which a volume of gas must be cooled, such that it becomes saturated with respect to ice. From the definition, we know the units for dew and frost point are the same with temperature, but relative humidity have no unit, it is just a percentage.

Actually relative humidity only tells you how full the air is of moisture, it doesn't tell you how much moisture is in the air, nor does it tell you if there is large amount of humidity. While people find dew point to be confusing, it is a very important variable and it is the indicator as to how much moisture is in the air. High dew points (greater than  $15^{\circ}\text{C}$ ) means that it is "sticky", low dew points (less than  $-5^{\circ}\text{C}$ ) means it is really dry. A relative humidity of 100% is an indication of dew/frost and fog, it often occurs during periods of rain. So at a very low dew point, even if the relative humidity is nearly 100%, people still feels very dry, those concepts are quite confusing. It is also important to note that the current dew point will never be higher than the current temperature and if the temperature is at the dew point and the temperature falls [108].

## 2.4.6 The Relationship between Relative Humidity and the Dew Point

The relative humidity (RH) and the dew point temperature ( $T_d$ ) in figure-2.12 are two widely used indicators of the amount of humidity in air. However, there is a very simple rule of thumb that have to be quite useful for approximating the conversion for moist air ( $RH > 50\%$ ), which does not appear to be widely known by the meteorological community:

$T_d$  decreases by about  $1^\circ\text{C}$  for every 5% decrease in RH (starting at  $T_d = T_C$ , the dry-bulb temperature, when  $RH = 100\%$ ):

$$T_d \approx T_C - \left( \frac{100 - RH}{5} \right) \quad (2.36)$$

Or

$$RH \approx 100 - 5(T_C - T_d) \quad (2.37)$$

Where  $T_C$  and  $T_d$  are in degrees Celsius and RH is in percent [109].



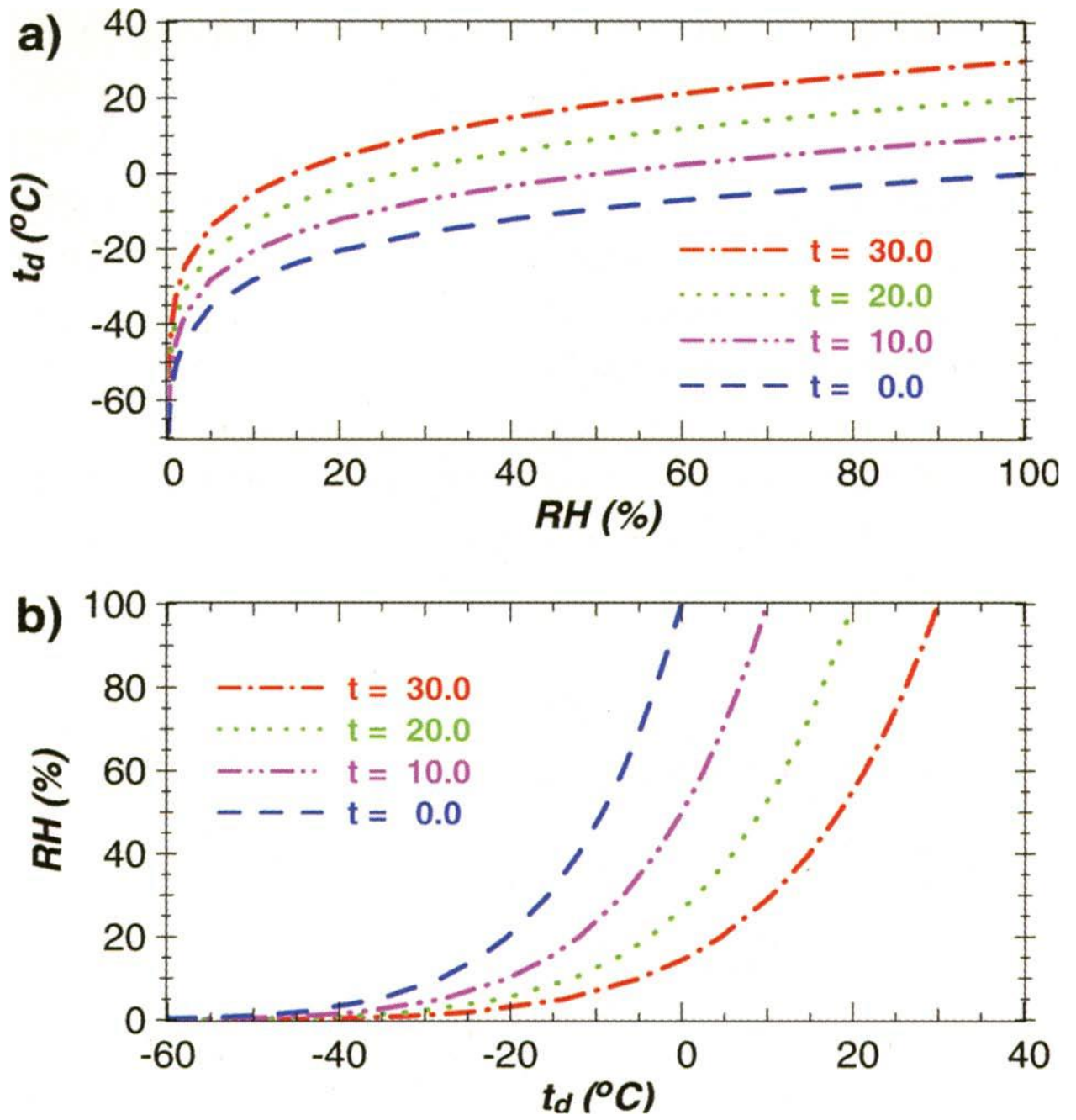


Figure- 2.12 Relationship between dew point temperature and relative humidity

# Chapter 3

## Experimental Techniques

### 3.1 Measurement of Concentration

There are some of the components about Measurement of Concentration:

#### 3.1.1 The Device of Series Canberra 35 Plus

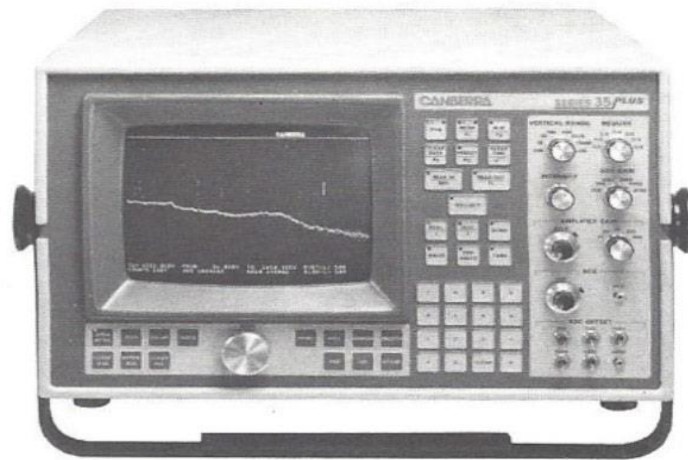
The function of the core Canberra is to analyze the raw material (Clay bricks) after being poured in the form of powder into chemical elements see figuer-3.1. The chemical elements of clay bricks are found to be (K, Ca, Ti, Mn, Fe, Cu, Zn, Pb, Sr, Y, Zr), and the following is automatically calculated for each chemical element [the Kinetic energy (E), Intensity (INT), Standard deviation (S), Time waiting (T), Concentrations (CONC), and Errors].



**Figure - 3.1 Brick clay powder**

By the early 1980s the Series-40 was replaced by the Series 35, which was basically a re-packaged S-40. It had a toggle-switch cursor control like earlier Canberra MCAs. The Tracor-Northern counterpart soon came out with a neat little wheel control that made it much easier to move the cursor faster or slower. Mike Charland designed a similar controller for Canberra and this was enough to

warrant a new model number, the S-35 Plus in figure-3.2, which became a very popular instrument, maybe the best-selling MCA from Canberra of all time.



**Figure - 3.2 Canberra 35 Plus device**

### **3.1.2 Multi-Channel Analyzer (MCA)**

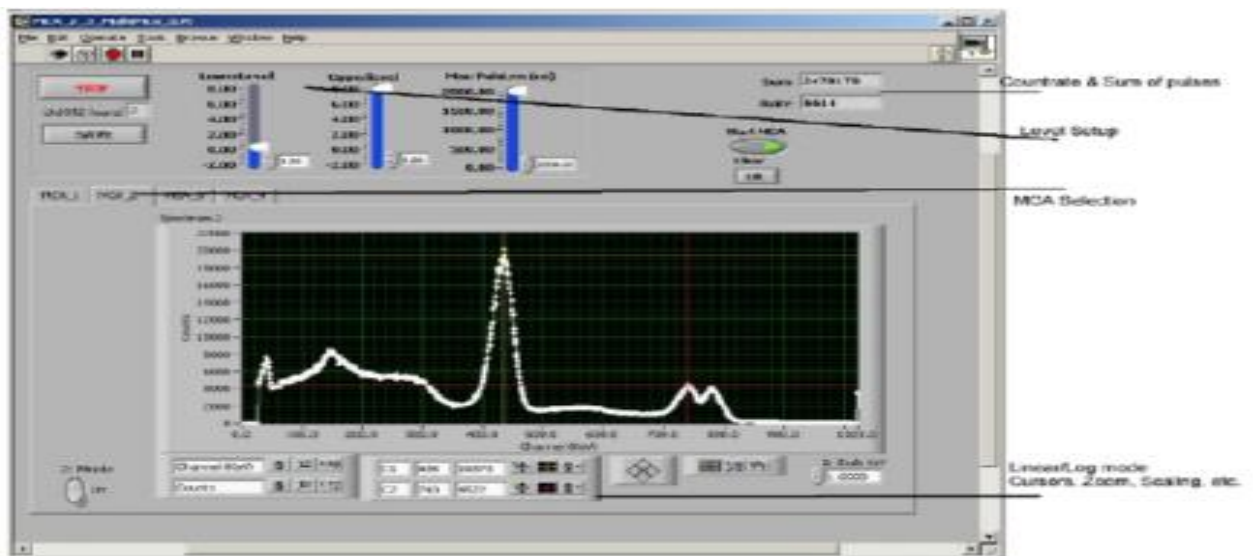
There are various methods of measuring amplitude of pulses depending of the application, but single channel analysis (SCA) and multi-channel analysis (MCA) methods are mostly used.

Single Channel Analyzer (SCA) is used for counting the number of incoming radiation at selected energy range, with two adjustable levels. Only pulses with amplitude falling in between the two levels are counted. Input pulses are observed by two discriminators set at LL (Lower Level) and UL (Upper Level) respectively. MCA method has to be used to have the distribution of pulse heights.

Due to the rapid advancement of large integrated circuits, FPGAs (Field Programmable Gate Array) are utilized in many applications to control or to process signals and are used in nuclear instruments. FPGAs are semiconductor devices containing programmable logic and programmable interconnects.

The firmware application code for the ezUSB controller board was developed with Keil C-compiler. The host PC software was designed in the sense that there is a central control for the 4 MCA channel for setting the threshold levels, starting, stopping, clearing the MCA, etc.

Configured UNIO52 boards are assembled in a small 19” Rack, together with fiveVolt power supply. The USB cables are fed via a USB hub as one single connection to the PC. BNC cables connect the two analog inputs. In the background, the nuclear test pulser and a detector system can be seen.



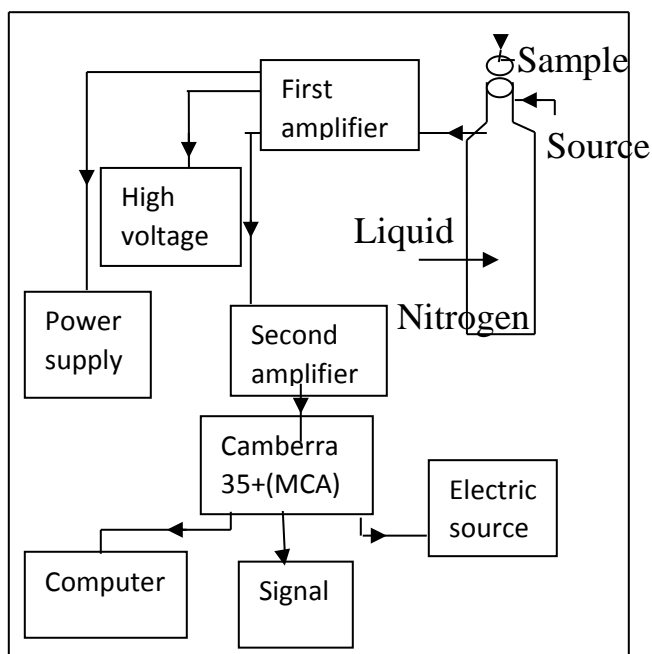
**Figure- 3.3 The Multi-Inputs MCA and collected spectrum of  $^{60}\text{Co}$  and  $^{137}\text{Cs}$  point sources**

By clicking on the “MCA Selection” in figure-3.3 one of the 4 tabs are selected to show the spectra of the according MCA channel. The MCA’s have a resolution of 1024 channels which were tested with a nuclear pulser. Collected data can be stored to hard disc and can be read by other computing or visualization software such as Matlab and Excel.



**Figure- 3.4 The System used to Analyze the Concentration of Elements by Canberra 35+ Device**

The calculation of the concentration of samples was performed by using Canberra 35+ device. A semiconductor detector in the form of Crystal materials Lethem, silicon, and cadmium was used. Energy was 30 ml Korean and the software used in the computer was Excel program, as in (Fig 3.5).



**Figure- 3.5 Flowchart of the System used to Analyze the Concentration of Elements by Canberra 35+ Device**

### 3.1.3 Composition of the Measuring Path

The composition of the measuring path (figure 3.5) includes:

1. Lead shield – protection: which Provides an increase in the sensitivity of the spectrometer by reducing the level of the external gamma background recorded in the detection unit (the outer side of the "house" is made of lead with a wall thickness of 100 mm, and the inside part is made of sheet lead and sheet cadmium);
2. Semiconductor detector of a coaxial type of extremely pure germanium produced by Canberra. The range of detectable detector energies from 50 keV to 10 MeV. The effectiveness of registration is 35%. Resolution on the line  $^{60}\text{Co}$  (1.33 MeV) is 1.8 keV;
  - Spectrometric preamplifier;
  - spectrometric device;

- Multichannel analyzer «InSpector-2000» (Figure 3.6).
- Computer Pentium-II with Windows-98 system and software for gamma spectrometry "Genie-2000" of Canberra;
- Printer;
- Measured sample in a vessel of the required geometry (vessel type "Denta").



**Figure- 3.6 Multichannel analyzer «InSpector-2000»**

Gamma quanta emitted during the decay of uranium nuclei partially (Compton scattering) or completely (photoabsorption), falling into the detector, lose their energy in the detector material. The lost energy is then emitted in the form of light quanta, which are converted into electric pulses by means of a photoelectric multiplier.

The amplitude of the pulses is proportional to the absorbed energy of gamma quanta. Calculation of the U238 content by gamma spectrometric method is

carried out using Th<sup>234</sup> radionuclide. In the decay chain, it is in a state of equilibrium with U<sup>238</sup>. For calculation, we use 63.4 keV energy lines (gamma-ray yield 3.8%) and 92 keV (total gamma-quantum yield 5.4%).

A gamma spectrum appears on the analyzer screen, in which along with the Compton momentum distribution, there are photopics corresponding to the total energy loss of gamma quanta in the crystal of the detector. The area of the photopack is proportional to the activity of the radionuclide, and its location (after calibration of the facility for energy) corresponds to the energy of gamma rays emitted by the radionuclide. These data are used to determine the activity of uranium.

The energy calibration of the spectrometer is performed in order to establish the connection between the gamma-ray energy and the position of the total absorption peaks in the experimental spectrum.

Before the direct measurement of the activity of the soil sample, the activity of a bulk reference sample was measured for calibrating the spectrometer by energy, energy resolution and registration efficiency [110].

### **3.1.4 Important Safety Considerations**

There are three potential hazards in the use and handling of Canberra detectors that must be recognized and properly dealt with to avoid the risk of personal injury.

#### **3.1.4.1 High Voltage**

Canberra detectors may operate at bias voltages of 5000 V dc or more. Always be sure that detectors are properly grounded. In addition, use extreme caution when adjusting internal preamplifier controls to avoid contact with the high voltage circuit.



### **3.1.4.2 Liquid Nitrogen**

LN<sub>2</sub> can cause frostbite if not handled properly. Avoid skin contact with LN<sub>2</sub> or with surfaces cooled by LN<sub>2</sub>.

### **3.1.4.3 Vacuum Failure – Over pressurization**

When a cryostat exhibits signs of catastrophic vacuum failure, such as heavy moisture or ice formation on the surfaces, extremely high LN<sub>2</sub> loss rate, and so forth, the adsorber, which normally maintains vacuum, may be virtually saturated.

When allowed to warm up, the adsorber will outgas and the pressure in the cryostat will rise. Canberra cryostats and Dewars sold by Canberra have a pressure relieving seal-off valve, which designed to prevent dangerous levels of pressurization.

Canberra makes a wide variety of detector types. Figure 5 illustrates detector that are available from Canberra, and the energy range they cover.

### **3.1.5 Cryostat Canberra**

The cryostat consists of a vacuum chamber, which houses the detector element plus a Dewar (double wall vacuum-insulated vessel) for the liquid nitrogen cryogen. In some cases, the detector chamber and Dewar are permanently connected. These are called “integral” cryostats. “Dipstick” cryostats have a detector vacuum chamber with a dipstick- like cold finger, which is inserted into the neck of the Dewar.



**Figure- 3.7 Cryostat Canberra filled with Liquid Nitrogen (LN<sub>2</sub>)**

The detector element is held in place by a holder, which is electrically isolated from but thermally connected to a copper cold finger. The cold finger transfers heat from the detector assembly to the liquid nitrogen reservoir. The detector holder is held in place by an anti-microphonic stabilizer. The detector holder as well as the outer vacuum jacket or “end-cap” are thin to avoid attenuation of low energy photons. The holder is generally made of aluminum and is typically 1 mm thick.

The end-cap is also generally made of aluminum. It is typically 1.5 mm thick. The detector element face is located typically 5 mm from the end-cap.

### **3.1.6 Temperature Range**

The environmental temperature range for LN<sub>2</sub> cooled detectors is 5 °C to 40 °C. Electrically cooled detectors may be subject to other limits.

### **3.1.7 Setup and Test**

The significant specifications of Ge detectors are few in number, and detectors are not complex instruments, so it is possible to verify the performance of a detector with relative ease – if the proper equipment is available and correct procedures are used.

The equipment used in conjunction with a Ge detector must be of the right type and in good working order to ensure good system performance. Likewise, the procedures must reflect the standards of the manufacturer or there will be unexplained differences in performance between tests in the factory and in the field.

### **3.1.8 Equipment Required**

The Setup and Test section assumes that the test equipment listed here is available. For efficiency measurements, the  $^{60}\text{Co}$  source should be calibrated to NIST standards.

- Ge Detector, Cryostat, and Preamplifier
- NIM Bin and Power Supply – Model 2000 or Equivalent
- Amplifier – Model 2026 or Equivalent
- MCA – with 8192 ADC Range, 4096 Memory, and Digital Readout
- Detector Bias Supply – Model 3106D, or Equivalent or Model 3102D for bias of 2000 volts or less.
- Voltmeter (Analog or 3-1/2 digit)
- Oscilloscope – 50 MHz bandwidth, 5 mV/div.
- Sources as in Table- 3.1.

**Table- 3.1 Test Sources of Detector**

Detector Type	60Co	57Co	55Fe	109Cd
Coaxial	P	S		
REGe	P	S		S
XtRa	P	S		S
LEGe		S	P	
Ultra-LEGe		S	P	
Well	P	S		
BEGe	S	P		

Where P = Primary source and S = Secondary source

### 3.1.9 Manufacturing Process of Brick

Clay is one of the most abundant natural mineral materials on earth. For brick manufacturing, clay must possess some specific properties and characteristics. Such clays must have plasticity, which permits them to be shaped or molded when mixed with water; they must have sufficient wet and air-dried strength to maintain their shape after forming. In addition, when subjected to appropriate temperatures, the clay particles must fuse together.

#### 3.1.9.1 Type of Clay

Clays occur in three principal forms, all of which have similar chemical compositions but different physical characteristics.

**Surface Clays:** Surface clays may be the up thrusts of older deposits or of more recent sedimentary formations. As the name implies, they are found near the surface of the earth.

**Shales:** Shales are clays that have been subjected to high pressures until they have nearly hardened into slate.

### **3.1.9.2 Fire Clays**

Fire clays usually mined at deeper levels than other clays and have refractory qualities.

Surface and fire clays have a different physical structure from shales but are similar in chemical composition. All three types of clay are composed of silica and alumina with varying amounts of metallic oxides. Metallic oxides act as fluxes promoting fusion of the particles at lower temperatures. Metallic oxides (particularly those of iron, magnesium and calcium) influence the color of the fired brick.

The manufacturer minimizes variations in chemical composition and physical properties by mixing clays from different sources and different locations in the pit. Chemical composition varies within the pit, and the differences compensated for by varying manufacturing processes. As a result, brick from the same manufacturer will have slightly different properties in subsequent production runs. Further, brick from different manufacturers that have the same appearance may differ in other properties [111].

### **3.1.9.3 Manufacturing**

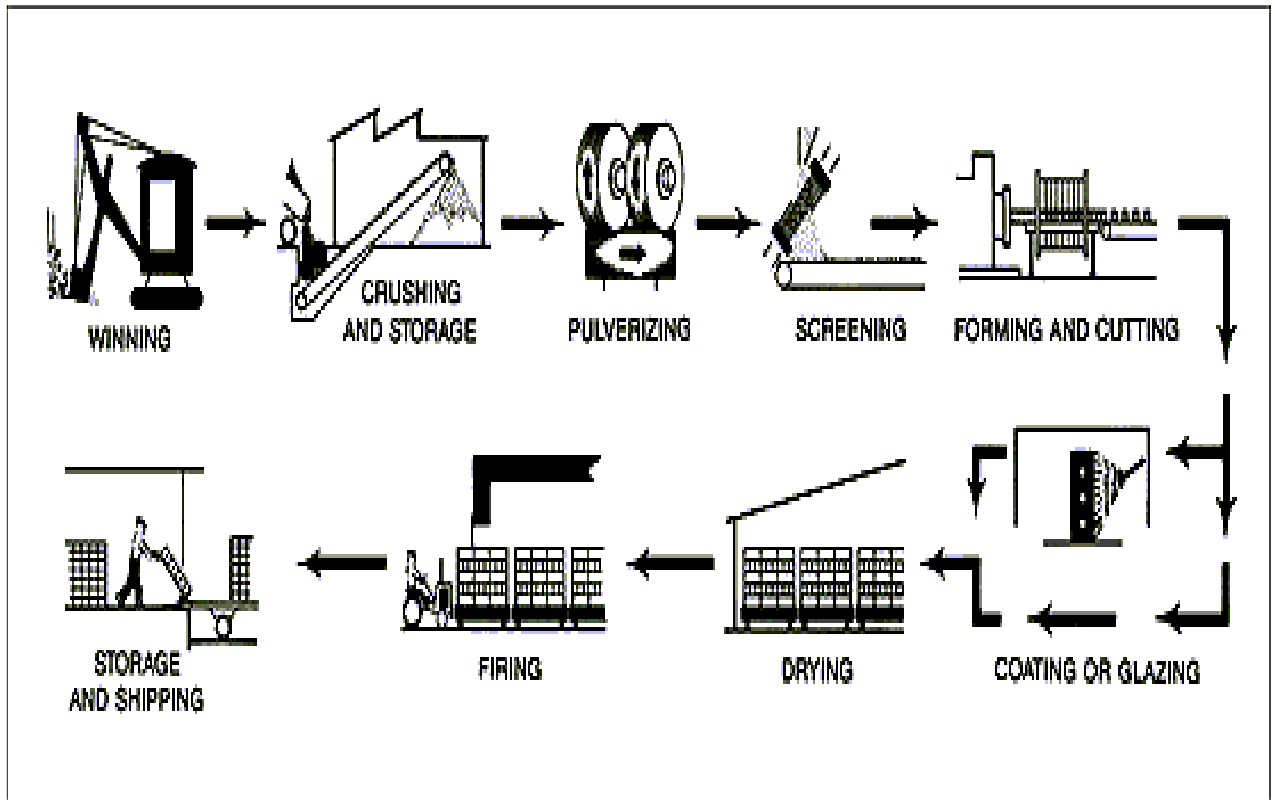
Although the basic principles of manufacture are uniform, individual manufacturing plants tailor their production to fit their particular raw materials and operation. Essentially, brick produced by mixing ground clay with water, forming the clay into the desired shape, and drying and firing.

#### **3.1.9.3.1 Manufacturing of Brick**

The manufacturing process has six general phases: mining and storage of raw materials, preparing raw materials, forming the brick, drying, firing, cooling, de-hacking, and storing finished products (see Figure- 3.9).

- Preparation of Raw Material (excavated & ground)
- Forming or shaping (mixing with water to a plastic condition to obtain the desired shape) –Stiff-mud, Soft-mud, Dry press processes

- Setting and drying
- Glazing → provides a thin & smooth coat on the surface. Firing or burning → in kilns above 950°C
- Cooling → rate of cooling affects brittleness, color & shape.



**Figure- 3.8 Diagrammatic Representation of Manufacturing Process**

### 3.1.9.3.2 Mining and Storage

Surface clays and some fire clays are mined in open pits with power equipment. Then the clay or shale mixtures are transported to storage areas (see Photo 3.8).



**Figure- 3.9 The Clay Crushed and Transported to Storage Area**

Continuous brick production regardless of weather conditions ensured by storing sufficient quantities of raw materials required for many days of plant operation. Normally, several storage areas (one for each source) used to facilitate blending of the clays. Blending produces more uniform raw materials, helps control color and allows raw material control for manufacturing a certain brick body.

### **3.1.9.3.3 Preparation**

To break up large clay lumps and stones, the material processed through size-reduction machines before mixing the raw material. Usually the material processed through inclined vibrating screens to control particle size [112].

### **3.1.9.3.4 Forming**

Tempering, the first step in the forming process, produces a homogeneous, plastic clay mass. Usually, this achieved by adding water to the clay in a pug mill (see Fig. 3.10), a mixing chamber with one or more revolving shafts with blade extensions. After pugging, the plastic clay mass is ready for forming. There are three principal processes for forming brick: stiff-mud, soft-mud and dry-press.



**Figure- 3.10 Clay is Thoroughly Mixed with Water in Pug Mill before Extrusion**

#### **3.1.9.3.5 Stiff-Mud Process (Extrusion)**

- The clay is mixed with just enough water to produce plasticity (~ 12 - 15% water by weight)
- The clay is extruded through a "die" producing a horizontal column of clay which passes through an automatic cutter
- Cutter-wire spaces and die sizes should be precisely calculated to compensate for shrinkage during drying and firing
- As the clay column leaves the die, textures or surface coatings may be applied
- The green bricks (not solidified yet!) are then stacked with care to allow sufficient airspace between them to create even coloring and uniform strength during drying and firing.

Next, the clay extruded through a die to produce a column of clay. As the clay column leaves the die, textures or surface coatings may be applied an automatic



cutter then slices through the clay column to create the individual brick. Cutter spacing and die sizes must carefully be calculated to compensate for normal shrinkage that occurs during drying and firing



**Figure- 3.11 Stiff-mud process**



Extrusion Die

Brick column left the die

Bricks are cut with wires



Individual bricks are separated and stacked

Final Product

**Figure- 3.12 Extrusion Process**

### 3.1.9.3.6 Soft-Mud Process (Forming)

- In this process, the clay contains too much water to be extruded (~ 20 - 30% water by weight)
- Instead of extrusion, individual molds (often wood) are utilized, and are lubricated with either oil, water or sand to prevent the clay from sticking to the mold

–If sand is used, grains with a maximum diameter of .5mm sprinkled on the mold surfaces after immersed in water

–If oil is used, it will be absorbed by the brick and burned during firing

- The soft-mud process is carried out by hand or by machine.



**Figure- 3.13 Soft-Mud Process**

### 3.1.9.3.7 Dry-Press Process

- ❖ This process is adaptable for clays of very low plasticity (< 10% water by weight)
- ❖ Instead of wooden molds, the clay is formed with steel molds and is put under high pressure to create a very compact, dense brick
- ❖ Hydraulic or compressed air-rams generate pressures ranging from 3.5-10 MPa (Mega Pascal).

### **3.1.9.3.8 Drying**

- ✓ After molding the brick unit through either extrusion or soft mud process, bricks go through the setting and drying stage. Before they enter the kiln to be fired, the green bricks must be correctly dried. (40-200 °C at 24-48 hrs)
- ✓ The moisture must be minimized to prevent certain defects and shrinkage from happening when fired at extreme heat in the kiln. Shrinkage can cause the bricks to crack.

### **3.1.9.3.9 Firing**

- Firing, one of the most specialized steps in the manufacture of brick, requires from 40 to 150 hr., depending upon kiln type and other variables.
- The two general types of kilns are tunnel and periodic kilns.
- A periodic kiln is one that is loaded, fired, allowed to cool and unloaded, after which the same processes are repeated.
- In a tunnel kiln, units are similarly loaded on special cars, which pass through various temperature zones as they travel through the tunnel. The heat conditions in each zone are carefully controlled and the kiln operates continuously.



**Figure- 3.14 Brick Enter furnace for Firing**

The fusibility of clay causes it to become hard, solid and of relatively low absorption when properly fired. Firing consists of:

- Water smoking  $\sim 200^{\circ}\text{C}$   $\rightarrow$  evaporation of free water
- Dehydration  $\sim 450^{\circ}\text{C}$ - $750^{\circ}\text{C}$   $\rightarrow$  evaporation of chemically bound water
- Oxidation  $\sim 450^{\circ}\text{C}$ - $950^{\circ}\text{C}$   $\rightarrow$  oxides are formed
- Vitrification  $\sim 950^{\circ}\text{C}$ - $1200^{\circ}\text{C}$   $\rightarrow$  low melting components liquefy and fill the pores

#### **3.1.9.3.10 Fusing Takes Place in Three Stages**

- ❖ Incipient fusion, that point when the clay particles become sufficiently soft that the mass sticks together;
- ❖ Vitrification, when there is extensive fluxing and the mass becomes tight, solid and non-absorbent; and
- ❖ Viscous fusion, the point at which the clay mass breaks down and tends to become molten.

The key to the firing process is to control the temperature in the kiln so that incipient fusion and partial vitrification are complete but viscous fusion avoided.

### **3.1.9.3.11 Cooling**

- After the temperature has reached the maximum and maintained for a prescribed time, the cooling process begins. 48 to 72 hr. are required for proper cooling in periodic kilns; but in tunnel kilns, the cooling period seldom exceeds 48 hr.
- Because the rate of cooling has a direct effect on color and because excessively rapid cooling will cause cracking, cooling is an important stage in the firing process.

### **3.1.9.4 Defects in Bricks**

- Defects are sometimes formed because of:
  - Unsuitable chemical composition
  - Improper mixing of clay, sand & water
  - Improper shaping
  - Improper burning
  - Laminations: Occurs on the extruded sections of some hollow bricks
  - Cracks: - Composition
  - Improper drying before burning
  - Rapid cooling
  - Too much sand →lack of cohesion

### **3.1.9.5 Properties of Bricks**

- ❖ All properties of brick affected by composition of the raw materials and the manufacturing processes. It is for this reason that most manufacturers blend clays to reduce the possibility of impurities from one clay source affecting the overall quality of the finished product.
- ❖ The properties that most concern the users of brick are durability, color, texture, size variation, compressive strength and absorption.

- ❖ Porosity and Absorption is affected by chemical composition, proper mixing and shaping and the degree of burning
- ❖ Porosity affects the strength and durability of the brick. Higher porosity (or higher absorption) leads to lower strength and lower durability.

$$\text{Absorption\%} = \frac{\text{Weight of water absorbed}}{\text{Weight of dry clay product}} \times 100\% \quad (3.1)$$

### 3.1.9.6 Classification of Bricks

There are some Classification of Bricks as shown in figure 3.16

#### 1- X-Section

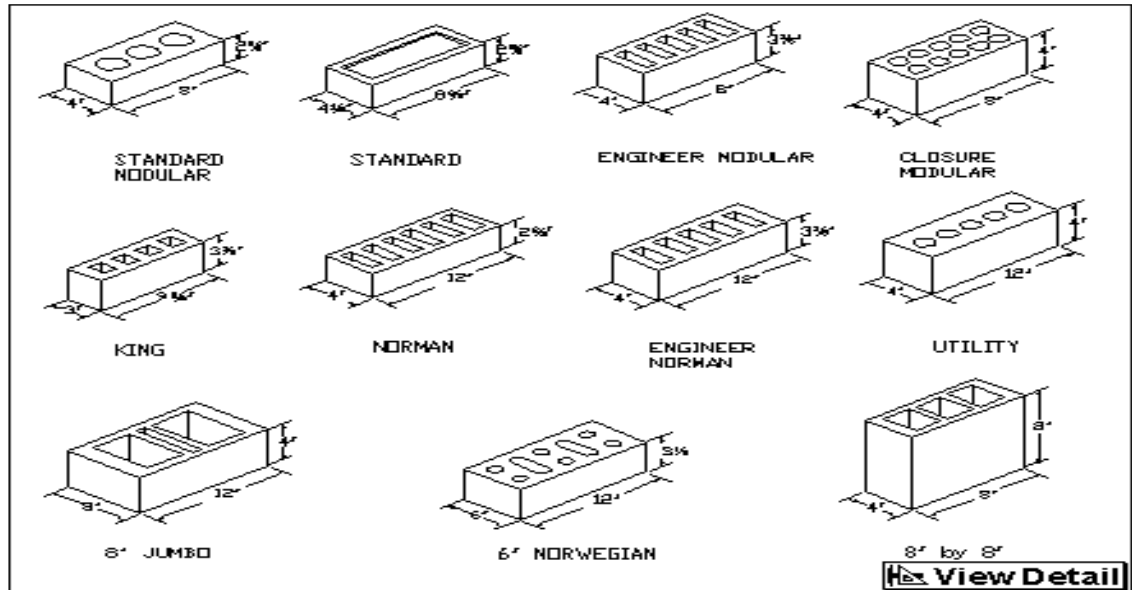
- Solid
- Vertically perforated
- Horizontally perforated

#### 2- Size

- Standard (190x90x50) cm
- Modular (190x90x85) cm
- Block (larger)

#### 3- Use

- Facing
- Paving
- Sewer
- Fire



**Figure- 3.15 Classification of Bricks**

### 3.2 Preparation of Sample

A basic clay mixture was prepared from two type of raw materials (the yellow and gray clays), taken from different areas of the industrial partner’s mine. In addition, three different types of pore-forming materials (sawdust, rice-peel and seed-shell) added to the raw clay mixtures during the preparation of the brick samples.

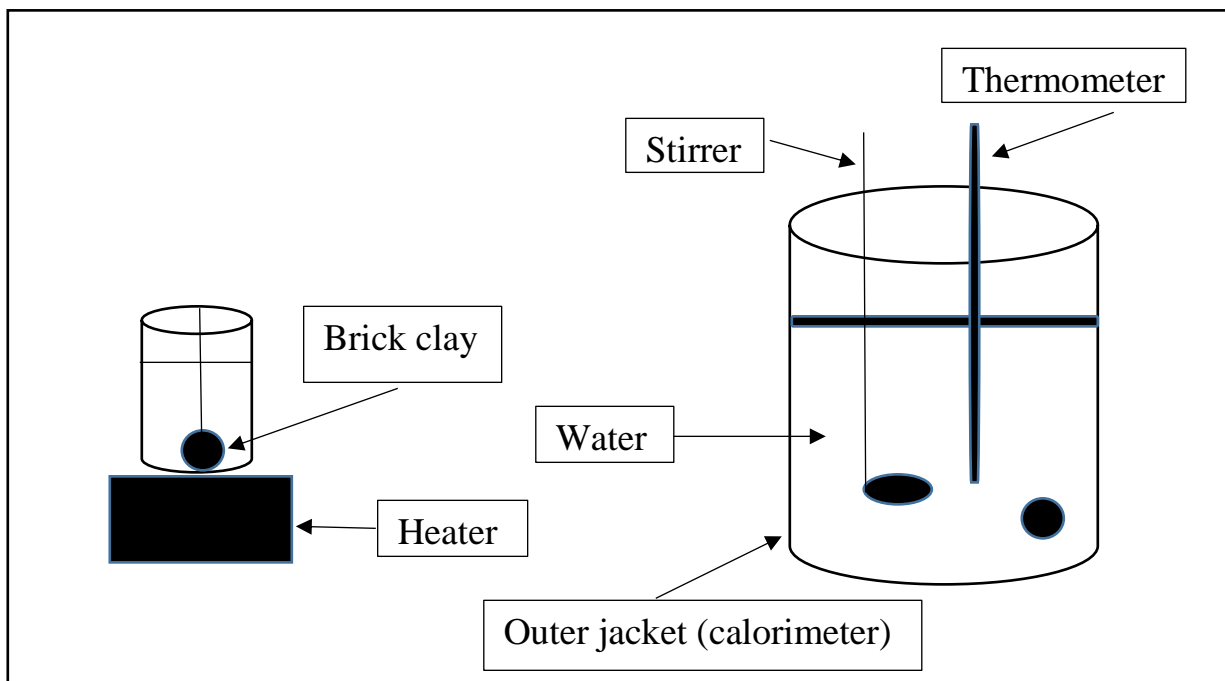
The phase composition of the yellow and gray clays, were determined by using X-ray diffraction apparatus (XRD, Bruker D8).

The brick samples were prepared from the mixture of the yellow and gray clay in the ratio of 4:1.

### 3.3 Measurement of Specific Heat Capacity by the Method of Mixtures

Specific heat capacity is a measure of the amount of heat energy required to change the temperature of 1 kg of a material by 1 K. Hence, it is important, as it will give an indication of how much energy will be required to heat or cool an object of a given mass by a given amount. Molar heat capacity is a measure of the amount of heat necessary to raise the temperature of one mole of a pure substance by one degree K.

When a high temperature object is placed in contact with a low temperature object, then energy will flow from the high temperature object to the lower temperature object, and they will approach an equilibrium temperature.



**Figure- 3.16 Experimental Setup for Determining the Specific Heat Capacity of the Brick Clay**

### 3.3.1 Experiment Tools

- Solid (e.g. Brick clay) of reasonable size
- Calorimeter with an insulated outer jacket and stirrer
- Thermometer (reading up to  $0.1^{\circ}\text{C}$ )
- Heater
- Thread
- Sensitive balance
- Beaker



### 3.3.2 Aim

Clays are basic raw materials used in large quantities for the manufacture of tiles, bricks, fire clay refractories and white wares; it is possible to calculate the specific heat of the brick clay (solid) by method of mixture.

### 3.3.3 Theory

From the principle of conservation of heat energy:

Heat lost by the brick clay = heat gained by the water and the calorimeter.

Then,

$$M_b C_b (\theta_2 - \theta) = M_w C_w (\theta - \theta_1) + M_C C_C (\theta - \theta_1)$$

$$M_b C_b (\theta_2 - \theta) = (M_w C_w + M_C C_C) (\theta - \theta_1)$$

$$C_b = \frac{(M_w C_w + M_C C_C)(\theta - \theta_1)}{M_b(\theta_2 - \theta)} \text{ J/kg } ^\circ\text{C} \quad (3.2)$$

### 3.3.4 Method

By the Balance was measured the brick clay mass ( $M_b$ ), the mass of the calorimeter and stirrer ( $M_C$ ) were measured when empty and also were measured when filled with cold water to about three – quarters of its height, and the mass of water ( $M_w$ ). The temperature was taken to give temperature  $\theta_1$ . The brick was put into the water inside the peaker, and then heated until boiling and the temperature ( $\theta_2$ ) was measured.

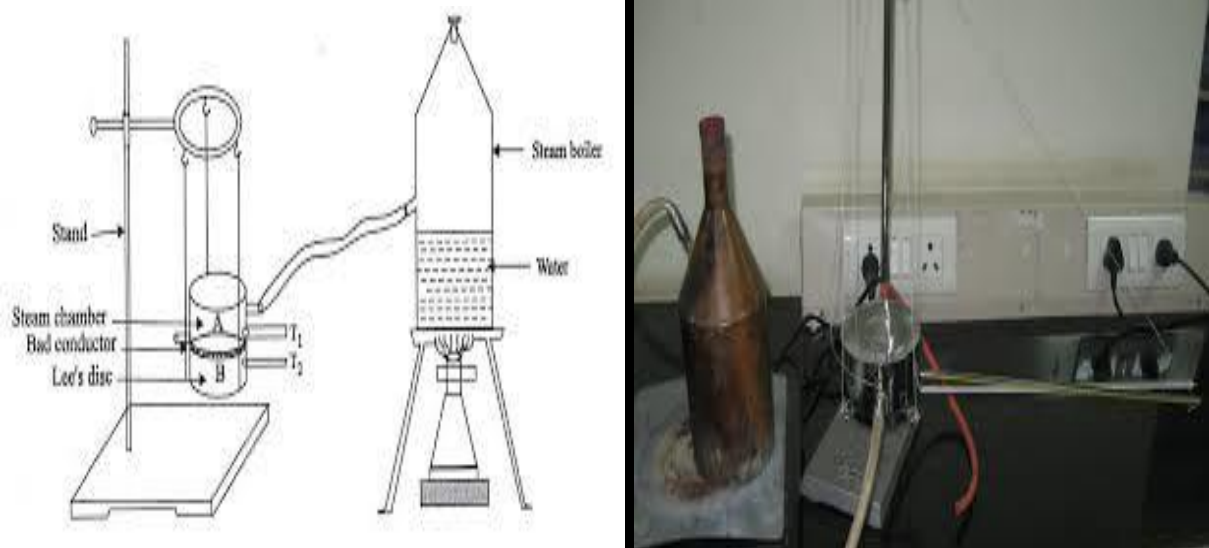
The hot brick was transferred into the cold water in the calorimeter and the temperature  $\theta$  was measured. The used specific heat capacity of the calorimeter was 897 J/Kg  $^\circ\text{C}$  and the specific heat capacity of the water was 4180 J/Kg  $^\circ\text{C}$ . The experiment was repeated three times and the average specific heat capacity of the brick clay was calculated.

### 3.3.5 Notes

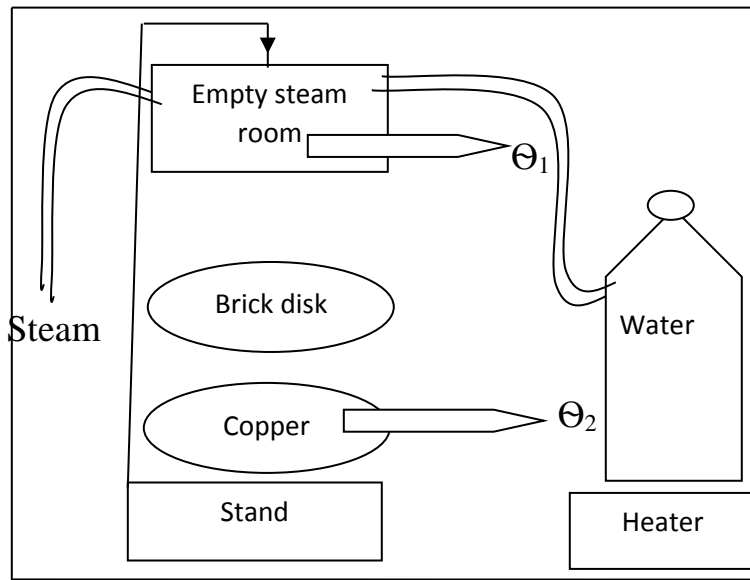
- 1- Heat capacity is the quantity of heat required to change the temperature of a body by one degree. It is expressed in joule per kelvin (J/K) in S I units.
- 2- It is important to transfer the hot brick clay quickly into the calorimeter because to minimize heat loss to the environment.
- 3- It is necessary to hold the brick clay briefly in the steam above the boiling water:
  - To allow the water on the brick clay to drop and
  - To maintain constant temperature with the steam.
- 4- The mode of heat transfer which took place in this experiment was mainly by conduction.

### 3.4 Measurement of Thermal Conductivity

Thermal conductivity was measured by a low temperature RAPID-K type heat conductivity measuring system designed for accurate steady state experiment by Lee method, as (Fig. 3.17).



**Figure- 3.17(a) Thermal Conductivity Measurement Device**



**Figure- 3.17(b) Diagram of the Thermal Conductivity Measurement System**

### 3.4.1 Theory

In the case of heat stability and thermal equilibrium together, the amount of heat transmitted per second  $H_1$  is equal to the amount of heat lost  $H_2$

$$H_1 = k \left( \frac{\pi D^2}{4} \right) \left( \frac{\theta_1 - \theta_2}{d} \right) \quad (3.7)$$

$$H_2 = ms \frac{d\theta}{dt} \quad (3.8)$$

Equating equation (3.7) and (3.8), one obtains

$$k = \frac{4ms \left( \frac{d\theta}{dt} \right) d}{\pi D^2 (\theta_1 - \theta_2)} \text{ J / mC}^\circ \quad (3.9)$$

Where (k) is the coefficient of thermal conductivity, (m) is mass of the metal disk; (s) is Specific heat capacity of the material of metal disk. (dθ/dt) is gradient from a graph of thermal conductivity; (d) is thickness of brick clay. (D) is diameter

of brick clay, ( $\theta_1$ ) is temperature at the upper surface of brick clay, ( $\theta_2$ ) is temperature at the lower surface of brick clay.

The Coefficient of thermal conductivity is directly proportional to the thermal conductivity and the cross sectional area and inversely with the length of the sample

$$\lambda = \frac{kL}{A} \quad (3.10)$$

Where (L) is length of the sample of brick clay, (A) is cross sectional area of brick clay, ( $\lambda$ ) is thermal conductivity of the brick clay.

### 3.4.2 Method

In the beginning of the experiment, the sample was heated for 20 minutes to produce equilibrium of thermal conductivity. The temperature of the empty steam room ( $\theta_1$ ) was recorded, and the temperature of bricks disk ( $\theta_2$ ) measured. The steam room was lifted, the temperature change for the time rate ( $d\theta/dt$ ) was calculated, and then the brick disc and steam room were put down on a piece of fixed copper chip. The copper chip was directly heated. Waited until the temperature of copper chip was raised by 5 degrees Celsius. The steam room was lifted; the temperatures of the brick and the fixed copper chip were lowered by 5 degrees Celsius. The temperature ( $\theta_2$ ) was recorded each minute.

Another way is to record the time needed for the loss of one degree Celsius [114].

### 3.5 Classical Humidity Measurement Methods

There are various types of classical humidity measuring instruments, using several different measurement methods such as psychrometers, dew-point hygrometers, and hygrometers using hygroscopic materials.

All methods have their own advantages and drawbacks, and a proper measurement method selected depending on the application.

### 3.5.1 Hygrometer

An instrument used for measuring the amount of humidity and water vapor in the atmosphere, in soil, or in confined spaces. Humidity measurement instruments usually rely on measurements of some other quantity such as temperature, pressure, mass or a mechanical or electrical change in a substance as moisture is absorbed.

By calibration and calculation, these measured quantities can lead to a measurement of humidity. Modern electronic devices use temperature of condensation (the dew point), or changes in electrical capacitance or resistance to measure humidity differences. The Italian Renaissance polymath Leonardo da Vinci invented the first crude hygrometer in 1480 and Swiss polymath Johann Heinrich Lambert created a more modern version in 1755.

The maximum amount of water vapor that is held in a given volume of air (saturation) varies greatly by temperature; cold air can hold less mass of water per unit volume than hot air. Most instruments respond to (or are calibrated to read) relative humidity (RH) [115].

### 3.5.2 Psychrometer

Psychrometry is one of the oldest methods used in humidity measurements. A psychrometer mainly consists of two thermometers one in ambient air and the other in contact with water. At temperatures above the freezing point of water, evaporation of water from the wick lowers the temperature, so that the wet-bulb thermometer usually shows a lower temperature than that of the dry-bulb thermometer. When the air temperature is below freezing, however, the wet-bulb is covered with a thin coating of ice and may be warmer than the dry bulb.

The measurement is based on the calculation of the actual vapor pressure  $P_w$  using the difference between wet and dry bulb temperatures according to the following empirical formula.

$$P_w = P_s - P_{tot} A (T_d - T_w) \quad (3.11)$$

Where  $T_d$  is the dry bulb temperature,  $T_w$  is the wet bulb temperature,  $P_s$  and  $P_{tot}$  are the saturation pressure and the pressure of the ambient air, respectively, and  $A$  is the psychrometer constant, which is a function of geometry and airflow.

The wet bulb temperature is the temperature reached after cooling due to evaporation from a moist surface. The amount of heat taken by the water for evaporation is equal to the heat loss of air. In addition, the amount of cooling due to the evaporation is a function of the ambient relative humidity. As a result, psychrometers allow the relative humidity estimation based on dry and wet-bulb temperature measurements. The most important advantage of psychrometers is that they do not require calibration. Main drawbacks are the requirement of the regular replacement of distilled water and the requirement of airflow with a high flow rate.



**Figure- 3.18 A sling Psychrometer for Outdoor Use**

### **3.5.3 The Dew-Point Hygrometer**

Water vapor density of the air is determined by the measurement of the dew-point temperature. The dew-point temperature is measured by a dew-point hygrometer, which consists of a thermometer, a cooler, and a detector. Dew formation is detected using a light source and a photodetector.

In the dew-point hygrometer, a light source is directed on a mirror and the reflected light intensity is measured by a photodetector. The mirror is cooled down using a cooler, controlled by an electronic circuit. When the mirror temperature reaches the dew point temperature, water condenses on the surface of the mirror, and the light intensity detected by the photodetector changes. The temperature at this instant gives the dew-point temperature.

This measurement method has a wide dynamic range, and it is very accurate. Major disadvantages are the expensive setup, high power consumption, and difficult maintenance of the system, such as the requirement of regular cleaning of the mirror surface.

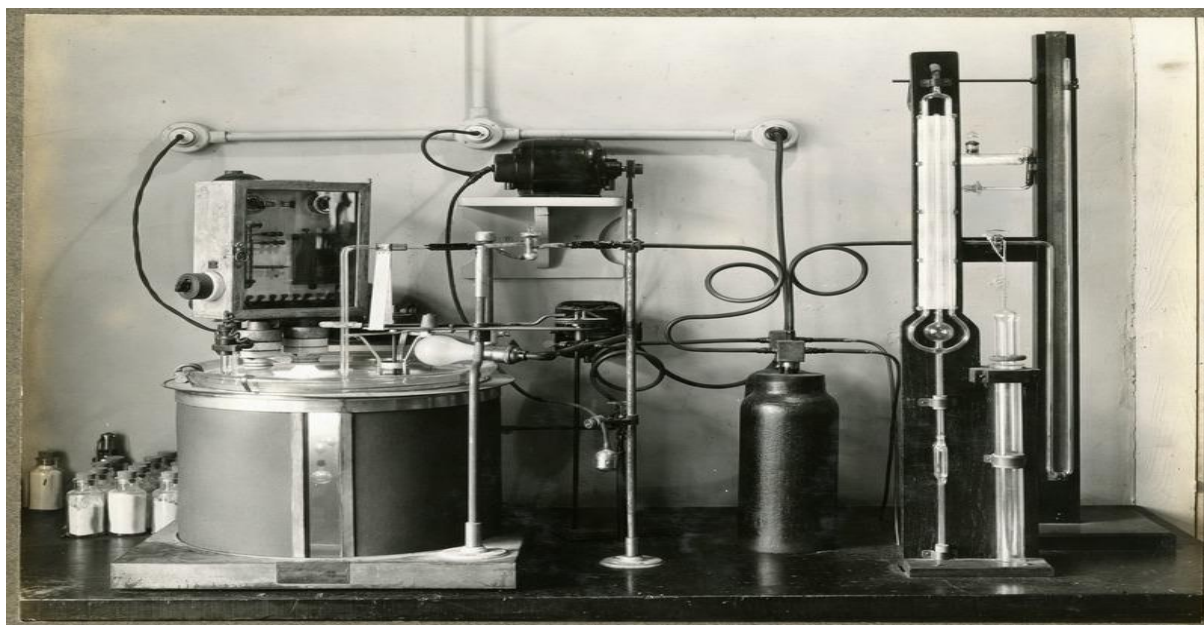


**Figure- 3.19 A hair Tension Dial Hygrometer with A nonlinear Scale**

### 3.5.4 Hygrometers Using Hygroscopic Materials

Another fundamental method of humidity measurement is making use of the hygroscopic materials (honey, glycerin, ethanol, methanol, concentrated sulfuric acid, and concentrated sodium hydroxide (lye)). There is a wide variety of different materials, showing different hygroscopic properties. Hygrometers of this type divided into two groups as mechanical and electrical types.

In a mechanical hygrometer, the change in the physical dimensions of the hygroscopic material is used. This material can be a human hair, a paper strip, or a polymer fiber. The mechanical hygrometer has a scale to which the hygroscopic material is attached. The length of this material changes when exposed to humidity, so the scale of the hygrometer deflects, showing a value depending on the amount of humidity. The mechanical hygrometer has the major advantage that it does not require any power supply. The other advantages include being simple and inexpensive. However, it has nonlinear output characteristics, and shows hysteresis.



**Figure- 3.20 Apparatus for the Determination of the Hygroscopicity of Fertilizer, Fixed Nitrogen**



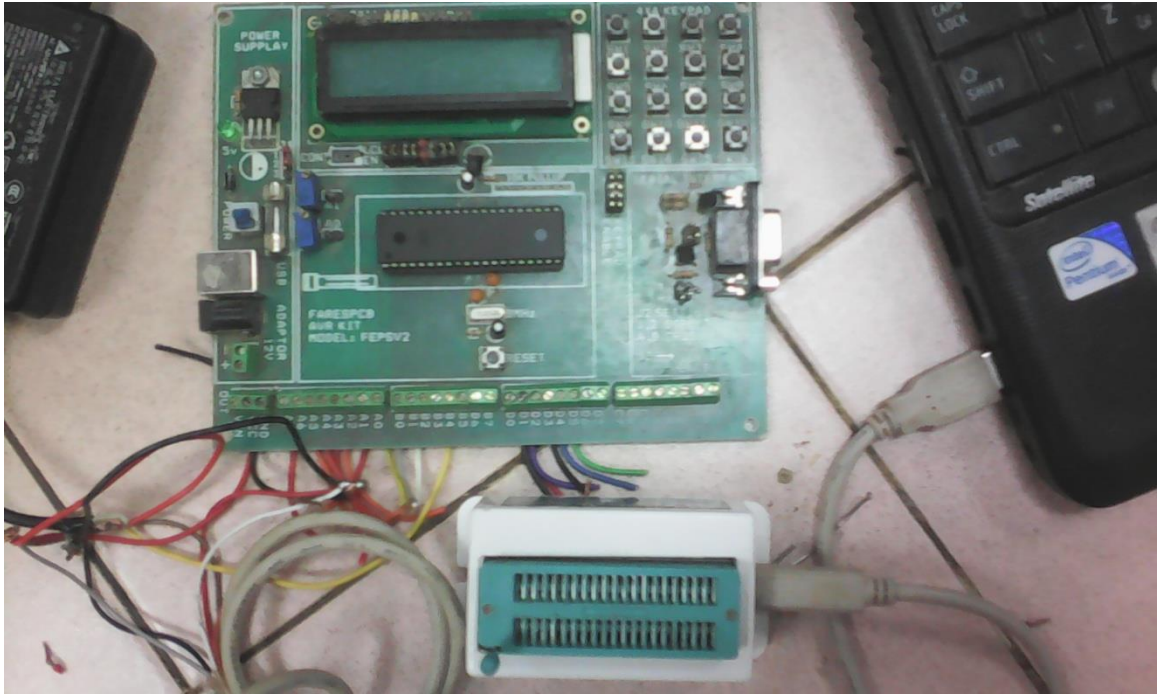
### **3.6 Miniaturized Humidity Sensors**

Developments in the micromachining technology have encouraged the development of miniaturized humidity sensors. Miniaturized humidity sensors have the advantage of small size, low cost, low power consumption, and high performance when compared to the classical measurement methods. Various types of miniaturized humidity sensors were designed, they use materials having different humidity dependent parameters. Major techniques of measurement methods used in miniaturized humidity sensors are listed as resistive, capacitive, mechanical, gravimetric, and optical techniques. In addition to these widely used techniques, there are some different techniques based on electromagnetic and thermal humidity sensing methods. Miniaturized humidity sensors also have been used in complex micro systems where they are integrated with other types of transducers and electronic circuitries. Following subsections shortly describe the humidity sensors based on micromachining techniques.

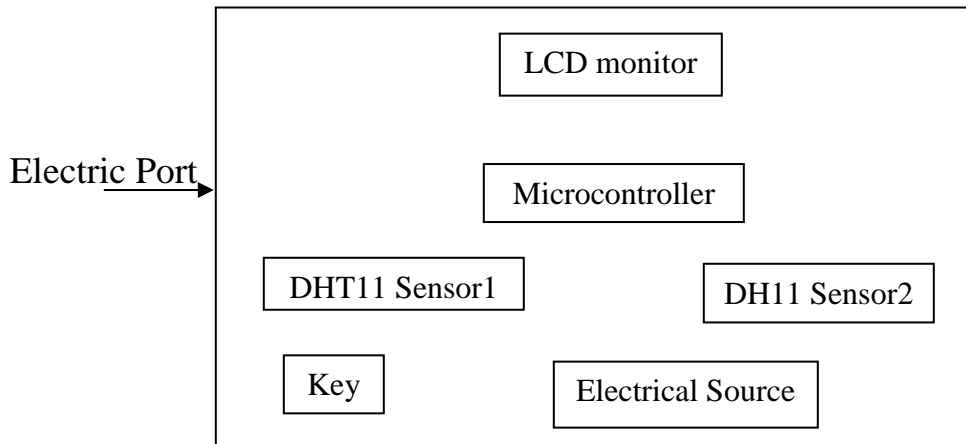
#### **3.6.1 DHT11 - Humidity and Temperature Sensor**

The DHT11 is a basic, low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). It is simple to use, but requires careful timing to grab data. The only real downside of this sensor is that you can only get new data from it once every 2 seconds.

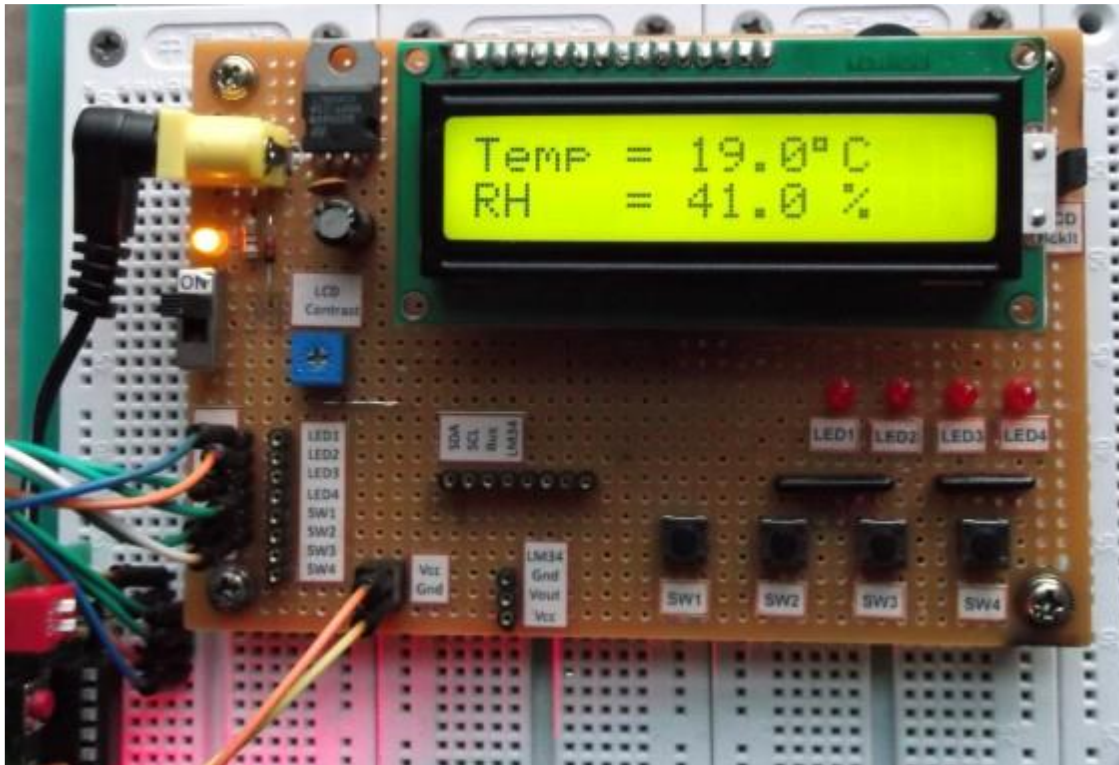
The measurement of the humidity of samples was performed by using circuit of humidity device which was collected by the researcher, as shown in figure-3.21 and figure-3.23. The flowchart of the above device is shown in Fig.3.22.



**Figure- 3.21 The Circuit of Humidity Device Collected by Researcher**



**Figure- 3.22 Flow Chart Circuit of the Humidity Device Collected by Researcher**



**Figure- 3.23 The Circuit of Humidity Device**

### **3.6.1.1 Features**

The features of humidity device which was collected by researcher are:

- 1- Full range temperature compensated
- 2- Relative humidity and temperature measurement
- 3- Calibrated digital signal
- 4- Outstanding long-term stability
- 5- Extra components are not needed
- 6- Long transmission distance
- 7- Low power consumption
- 8- 4 pins packaged and interchangeable

### **3.6.1.2 Details**

This sensor includes a resistive-type humidity measurement component and temperature measurement component, and is connected to a high-performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness. Each DHT11 element is strictly calibrated in the laboratory and is extremely accurate on humidity calibration. The calibration coefficients are stored as programmers in the memory, which are used by the sensors internal signal detecting process.

The single-wire serial interface makes system integration quick and easy. Its small size, low power consumption and up-to-20 meter signal transmission makes it the best choice for various applications, including those most demanding ones. The component is 4-pin single row pin package.

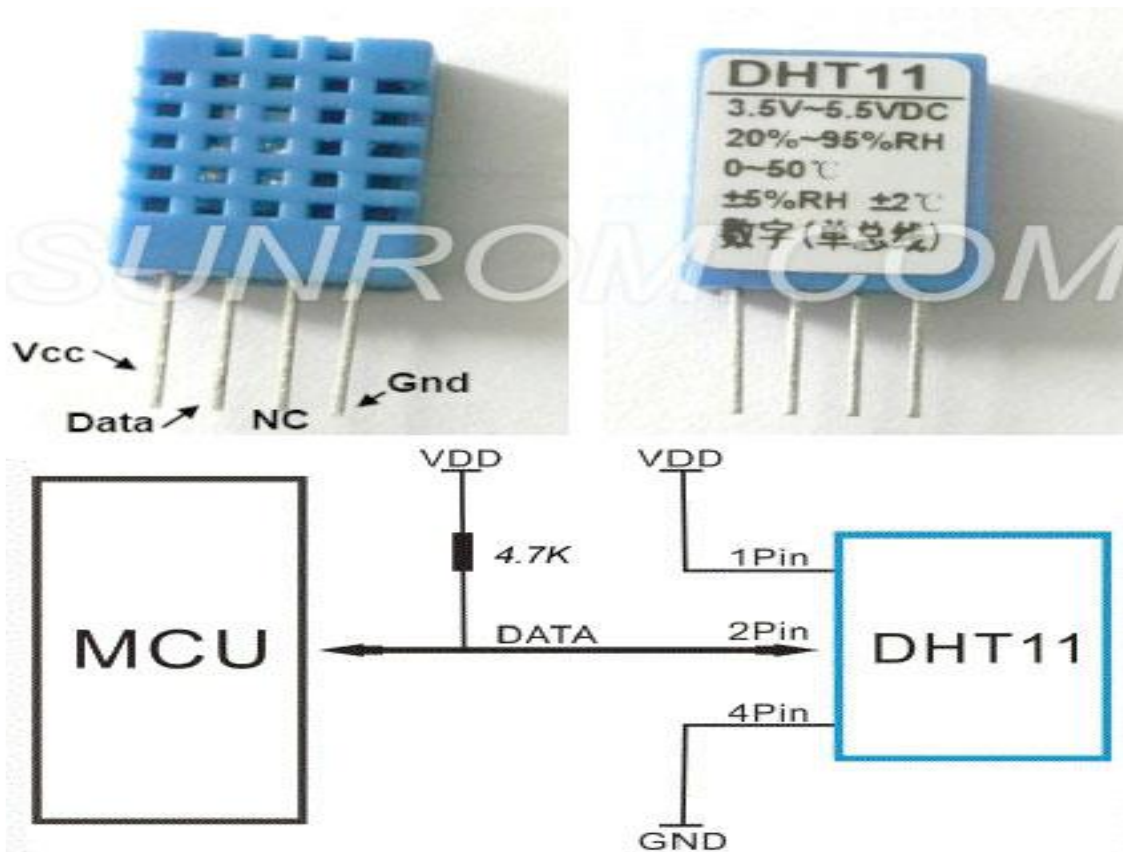
**Table- 3.2 The Specifications of DHT11 Sensor of Humidity**

Item	Measurement Range	Humidity Accuracy	Temperature Accuracy	Resolution	Package
DHT11	20-90%RH 0-50 °C	±5%RH	±2°C	1	4 Pin Single Row

Parameters	Conditions	Minimum	Typical	Maximum
<b>Humidity</b>				
Resolution		1%RH	1%RH	1%RH
			8 Bit	
Repeatability			± 1%RH	
Accuracy	25°C		± 4%RH	
	0-50°C			± 5%RH
Interchangeability	Fully Interchangeable			
Measurement Range	0°C	30%RH		90%RH
	25°C	20%RH		90%RH
	50°C	20%RH		80%RH
Response Time (Seconds)	1/e(63%)25°C, 1m/s Air	6 S	10 S	15 S
Hysteresis			± 1%RH	
Long-Term Stability	Typical		± 1%RH/year	
<b>Temperature</b>				
Resolution		1°C	1°C	1°C
			8 Bit	8 Bit
Repeatability			± 1°C	
Accuracy		± 1°C		± 2°C
Measurement Range		0°C		50°C
Response Time (Seconds)	1/e(63%)	6 S		30 S

Item	Condition	Min	Typical	Max	Unit
Power supply	DC	3	5	5.5	V
Current supply	Measuring	0.5		2.5	mA
	Stand-by	100	Null	150	uA
	Average	0.2	Null	1	mA

DHT11's power supply is 3-5.5V DC, as shown in figure-3.24. When power supplied to the sensor, do not send any instruction to the sensor in within one second in order to pass the unstable status. One capacitor valued 100nF can be added between VDD and GND for power filtering.



**Figure- 3.24 Typical Application of DHT11 Sensor**

### 3.6.1.3 Communication Process: Serial Interface (Single-Wire Two-Way)

The interesting thing in this module is the protocol that is used to transfer data. All the sensor readings are sent using a single wire bus, which reduces the cost and extends the distance. In order to send data over a bus you have to describe the way the data is transferred, so that transmitter and receiver can understand what to say to each other. This is what a protocol does. It describes the way the data is transmitted. On DHT-11, the 1-wire data bus is pulled up with a resistor to VCC. Therefore, if nothing occurred the voltage on the bus is equal to VCC.

### 3.6.1.4 Communication Format

Communication Format Separated into Three Stages:

- 1) Request: To make the DHT-11 send you the sensor readings you have to send it a request. The request is, to pull down the bus for more than  $18\mu\text{s}$  in order to give DHT time to understand it and then pull it up for  $40\mu\text{s}$ .
- 2) Response: What comes after the request is the DHT-11 response. This is an automatic reply from DHT, which indicates that DHT received your request. The response is  $\sim 54\mu\text{s}$  low and  $80\mu\text{s}$  high.
- 3) Data Reading: What will come after the response is the sensor data. The data is packed in a packet of five segments of 8-bits each. Totally  $5 \times 8 = 40\text{bits}$ .

The DHT11 elements are calibrated strictly for humidity calibration in extreme laboratory conditions, which focuses on humidity calibration. The general internal sensor detection process is done by the OTP memory, used for storing the calibration coefficients by storing the programs for it. The integration is made quite easy by the use of single wire serial interface. Low power consumption and long distance signal transmission, which can be up to 20 meter are maintained. The component consists of the 4-pin single row pin package.

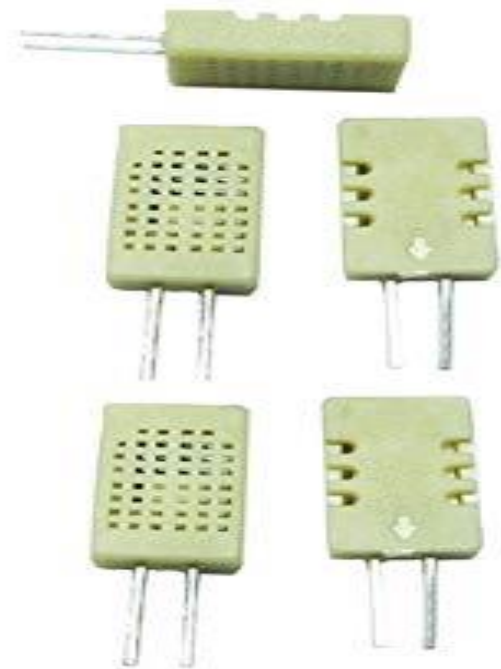
**Table- 3.3 Specifications of DHT11 Sensor**

Item	Measurement Range	Humidity Accuracy	Temperature Accuracy	Resolution	Package
DHT11	20-90%RH 0-50 °C	$\pm 5\%RH$	$\pm 2^\circ\text{C}$	1	4Pin Single Row

### 3.6.2 Resistive Humidity Sensors

Resistive humidity sensors as shown in figure-3.25 are transducers that convert the humidity change into resistance change. Ceramics, polymers and

electrolytes are the main groups of materials that have been used and reported for resistive humidity measurement. These materials have humidity induced resistance characteristics, which allow the humidity measurement by the measurement of resistance.

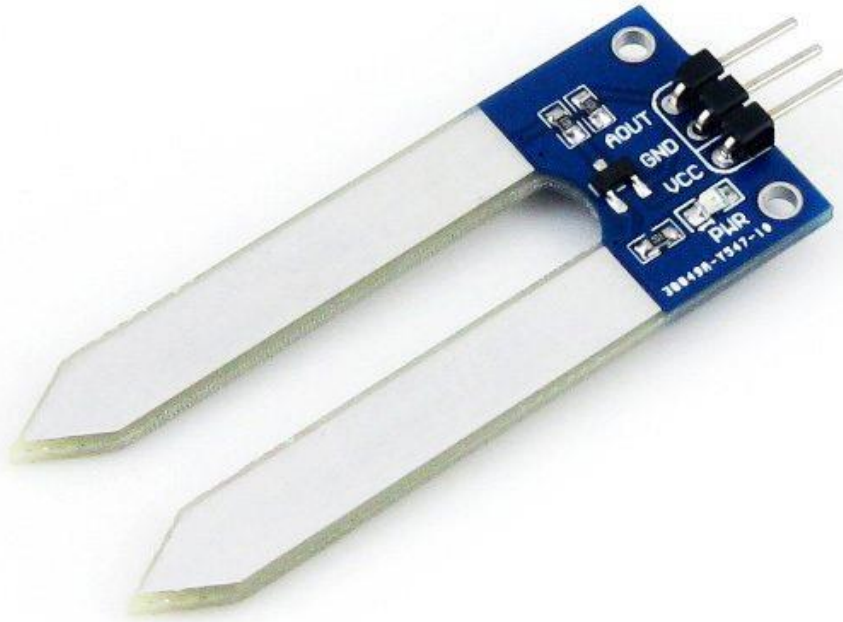


**Figure- 3.25 Resistive Humidity Sensors**

### **3.6.3 Hygrometric Humidity Sensors**

One of the very well-known mechanical transduction techniques is the usage of piezoresistivity. Piezoresistivity is simply defined as the resistance change of a material with respect to a change in mechanical stress. In order to use this property in humidity sensor applications as shown in figure-3.26, a humidity dependent mechanical stress is obtained. Humidity sensitivity of mechanical properties of polyimide films has been investigated. It was reported that humidity-induced extension of polyimide films is quiet linear in a wide range of humidity. However, the material behavior strongly depends on the conditions of the polyimide fabrication process.





**Figure- 3.26 Hygrometer Humidity Sensors**

### **3.6.4 Gravimetric Humidity Sensors**

Gravimetric humidity sensors as shown in figure-3.27 were developed on the fact that the mass of a hygroscopic material changes by humidity absorption. In this measurement method, a resonator structure fabricated with a hygroscopic material deposited on it. Assuming that the absorbed water vapor behaves like a rigid mass, the change in frequency approximated with the equation as follows:

$$\Delta f = -2 \frac{1}{A} \frac{f_0^2}{\sqrt{\mu\rho}} \Delta m \quad (3.12)$$

Where A is the surface area,  $f_0$  is the nominal frequency,  $\mu$  is the shear modulus,  $\rho$  is the density and  $\Delta m$  is the change of mass caused by absorption.

Test results have shown that the resonance frequency of the resonators increase with the increasing relative humidity of the environment. Resonators provide very high sensitivity and low response time, but the frequency change with respect to relative humidity demonstrates exponential characteristics.



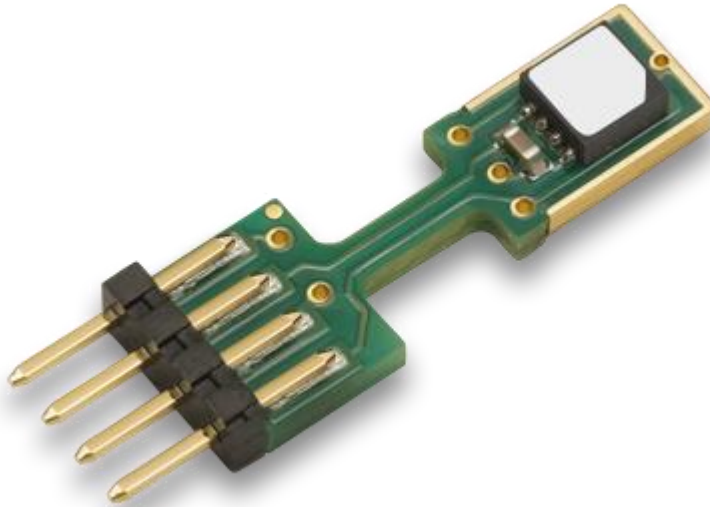
**Figure- 3.27 Gravimetric Humidity Sensors**

### **3.6.5 Optical Humidity Sensors**

Optical methods also have been developed for humidity sensing applications as shown in figure-3.28. The optical humidity measurements based on the humidity dependence of the amplitude, the polarization, and the frequency of an optical signal. Humidity dependence of these parameters arises from the humidity induced dielectric constant change of the medium where the signal propagation takes place.

An example of this type of humidity sensors is the optical fiber humidity sensor fabricated using a hydrophilic gel deposited on the thinner zone of a biconically tapered single mode optical fiber. The sensing mechanism relies on the refractive index with respect to the relative humidity. A variation of 6.5dB of

the transmitted optical power has obtained within the 30% to 80% relative humidity range. The sensor material shows a good reproducibility and low hysteresis.



**Figure- 3.28 Optical Humidity Sensor**

### **3.6.6 Thermal Humidity Sensors**

Thermal humidity sensors as shown in figure-3.29 have developed by making use of the difference in the thermal conductivity of air and that of water vapor. An absolute humidity sensor has demonstrated using a single micro air bridge heater. The micro heater sensing region is heated up to a low temperature level at which the thermal conductivity of the air and the water vapor is almost the same. Then, same region heated up to a temperature level where thermal conductivity difference between the air and water vapor becomes significant. Heating achieved by applying double pulse currents.

The resistance of the micro heater changes due to the temperature coefficient of resistance (TCR) property. As a result, the difference of the voltages in two cycles becomes a function of the absolute humidity in the air [116].



**Figure- 3.29 Thermal Humidity Sensor**

# Chapter Four

## Results, Discussion and Conclusion

### 4.1 Results of Analysis of Concentration by Means of Canberra Device

Analysis results showed that composition of the three samples differed mainly in three elements calcium, manganese, and lead. Whereas it was approximately constant for the other elements. This shows that increasing the ratio of kaolin clay to garirh clay in the mixture increases calcium and manganese ratios and decreases the lead and vice versa was performed by the Canberra device See tables-4.1, 4.2, and 4.3 did this analysis.

The clay mud dimensions (length x width × height) were (200 × 200 × 200) mm<sup>3</sup>. After molding the brick unit through either extrusion or soft mud process, the green bricks must be correctly dried at (40-200 °C for 24-48 hrs). Firing, one of the most specialized steps in the manufacture of brick, 900 – 950 C, requires from 40 to 150 hr. depending upon furnace type and other variables. After the temperature has reached the maximum value and was maintained for a prescribed time, the cooling process begins, 48 to 72 hr. are required for proper cooling.

Chemical composition tests using X-ray fluorescence (XRF) technique and mineralogical examination based on X-ray diffraction (XRD) were carried out to study the composition of soil brick samples. The chemical composition, presented in Tables (4.1, 4.2, &4.3) showed that the soil brick contained a significant amount of iron (Fe), and contained very small of amount of Lead (Pb). In addition, it was found that the element of high intensity is the element of iron (Fe), and the least powerful element is the element of potassium (K).

The elements (K, Ca,Ti, Mn, Fe, Cu, Zn, Pb, Rb, Sr, Y, Zr) have been detected in the chemical analysis of the clay brick sample

**Table- 4.1 Analysis Results for Sample 1: (75% garirh, 25% kaolin), [ EL ( elements), E ( kinetic energy), INT (intensity), s (standard deviation), T ( time waiting ), CONC ( concentrations).**

**Sample 1: Analysis Results:**

EL	E[KEV]	INT [C/S]	S	T	CONC [FRAC]	ERROR
K	3.312	0.051	1.51E+03	0.0129	1.62E-02	5.22E-03
Ca	3.690	0.580	2.46E+03	0.0162	4.61E-02	1.10E-02
Ti	4.508	0.590	4.46E+03	0.0224	2.28E-02	4.50E-03
Mn	5.895	0.198	1.03E+04	0.0413	1.12E-03	5.10E-04
Fe	6.400	20.532	1.26E+04	0.0509	1.63E-01	3.04E-02
Cu	8.041	0.182	2.35E+04	0.0475	7.81E-04	1.84E-04
Zn	8.631	0.094	2.48E+04	0.0567	3.20E-04	9.06E-05
Pb	10.540	0.070	3.73E+04	0.0911	9.86E-05	2.70E-05
Rb	13.375	0.300	6.11E+04	0.1524	1.54E-04	3.27E-05
Sr	14.142	2.078	6.32E+04	0.1699	9.27E-04	1.76E-04
Y	14.933	0.334	6.72E+04	0.1878	1.27E-04	2.72E-05
Zr	15.746	2.752	7.92E+04	0.2058	8.09E-04	1.53E-04

**Table- 4.2 Analysis Results for Sample 2: (70% garirh, 30% kaolin)****Sample 2: Analysis Results:**

EL	E[KEV]	INT [C/S]	S	T	CONC [FRAC]	ERROR
K	3.312	0.051	1.51E+03	0.0129	1.63E-02	5.22E-03
Ca	3.690	0.580	2.46E+03	0.0162	5.57E-02	1.10E-02
Ti	4.508	0.590	4.46E+03	0.0224	2.31E-02	4.50E-03
Mn	5.895	0.198	1.03E+04	0.0413	2.18E-03	5.10E-04
Fe	6.400	19.532	1.26E+04	0.0509	1.70E-01	3.04E-02
Cu	8.041	0.182	2.35E+04	0.0475	7.91E-04	1.84E-04
Zn	8.631	0.094	2.48E+04	0.0567	3.32E-04	9.06E-05
Pb	10.540	0.070	3.73E+04	0.0911	9.09E-05	2.70E-05
Rb	13.375	0.300	6.11E+04	0.1524	1.52E-04	3.27E-05
Sr	14.142	2.078	6.32E+04	0.1699	9.40E-04	1.76E-04
Y	14.933	0.334	6.72E+04	0.1878	1.32E-04	2.72E-05
Zr	15.746	2.752	7.92E+04	0.2058	8.05E-04	1.53E-04

**Table- 4.3 Analysis Results for Sample 3: (80% garirh, 20% kaolin)**

**Sample 3: Analysis Results:**

EL	E[KEV]	INT [C/S]	S	T	CONC [FRAC]	ERROR
K	3.312	0.051	1.51E+03	0.0129	1.64E-02	5.22E-03
Ca	3.690	0.580	2.46E+03	0.0162	5.80E-02	1.10E-02
Ti	4.508	0.590	4.46E+03	0.0224	2.30E-02	4.50E-03
Mn	5.895	0.198	1.03E+04	0.0413	2.248E-03	5.10E-04
Fe	6.400	21.532	1.26E+04	0.0509	1.69E-01	3.04E-02
Cu	8.041	0.182	2.35E+04	0.0475	7.85E-04	1.84E-04
Zn	8.631	0.094	2.48E+04	0.0567	3.26E-04	9.06E-05
Pb	10.540	0.070	3.73E+04	0.0911	8.95E-05	2.70E-05
Rb	13.375	0.300	6.11E+04	0.1524	1.53E-04	3.27E-05
Sr	14.142	2.078	6.32E+04	0.1699	9.32E-04	1.76E-04
Y	14.933	0.334	6.72E+04	0.1878	1.30E-04	2.72E-05
Zr	15.746	2.752	7.92E+04	0.2058	8.07E-04	1.53E-04

The highest concentration in the thermal clay brick of the three samples was due to the iron element and the lowest concentration was that of the lead element.

The concentration ratio in the iron element was low in the sample-1 and the mean ratio in the sample-3, the highest in the sample-2. Concentration of the lead element was very low in the sample-3 and slightly increased at the sample-2 and highest concentration at the sample-1.



## 4.2 Results and Discussion of Specific Heat Capacity of the Three Samples

In order to calculate the thermal conductivity of the samples, the specific heat capacity have to be known.

**Table- 4.4 The Specific Heat Capacity of the Three Types of Brick Clay, at Room Temperature 23C°**

M / Kg	$\theta$ / C° (sample-1)	$\theta$ / C° (sample -2)	$\theta$ / C° (sample -3)
$M_c=0.049$	$\theta_2 = 100$	$\theta_2 = 100$	$\theta_2 = 100$
$M_w=0.139$	$\theta_1 = 22$	$\theta_1 = 24$	$\theta_1 = 23$
$M_b=0.139$	$\theta = 25$	$\theta = 27$	$\theta = 26$
C / J/Kg C°	$C_{s1} = 806.42$	$C_{s2} = 828.51$	$C_{s3} = 822.44$

The temperature of the room was measured at 23 ° C. The temperature of the clay bricks differed through the three samples. The temperature ( $\theta_1$ ) of sample -1 becomes less by one degree of room temperature, and in sample 2 it increases by one degree of room temperature, while sample-3 is equal to room temperature.

When the heat transferred from high-temperature materials to low-temperature materials to be stable, the experiment showed that the lowest temperature in terms of thermal stability ( $\theta$ ) and specific heat ( $C_s$ ) was in sample -1, followed by sample -3 and highest in sample-2.

## 4.3 Results of Thermal Conductivity

The thermal conductivity measurement was performed for all the previously prepared brick samples. Fig. 4.1 represents the results and shows that the temperature significantly decreases with the time in the three samples. The coefficient of thermal conductivity and the thermal conductivity were calculated using  $(d\theta/dt)$  from the chart below.

The following table shows the values of thermal conductivity coefficient and the thermal conductivity for the three samples of bricks. These values were calculated from the drawing in fig.4.1.

**Table- 4.5 Values of Thermal Conductivity Coefficient (k) and Thermal Conductivity ( $\lambda$ ) of the Brick Clay for the Three Samples.**

The samples	Sample 1	Sample 2	Sample 3
coefficient of thermal conductivity (k)	1.5352J/m.C°	1.74 J/m.C°	1.199J/m.C°
thermal conductivity of the brick clay ( $\lambda$ )	0.023028W/m.k	0.0261W/m.k	0.01799W/m.k

The following chart shows the relationship between the temperatures in degrees Celsius versus time in seconds for the three samples.

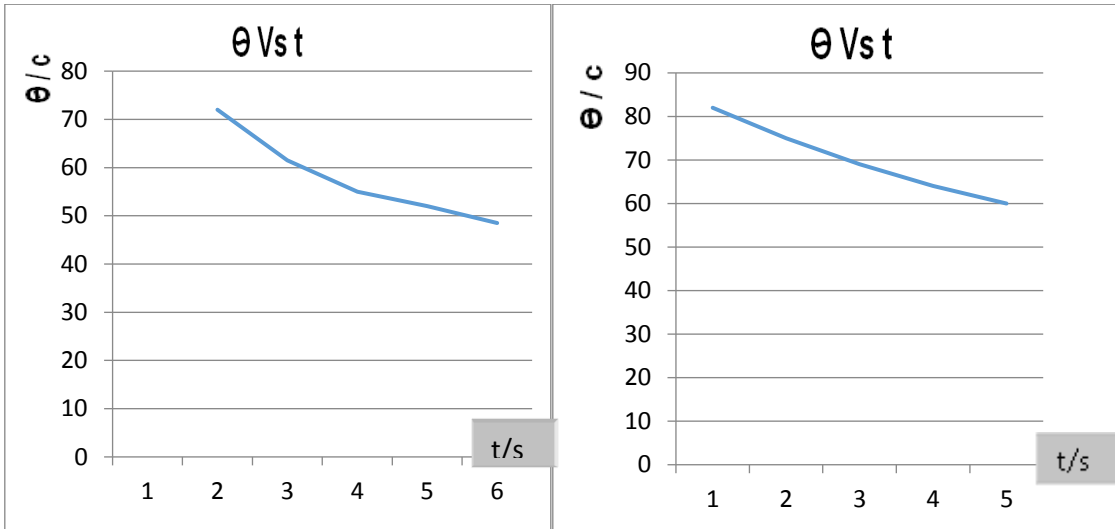


Figure (a)

Figure (b)

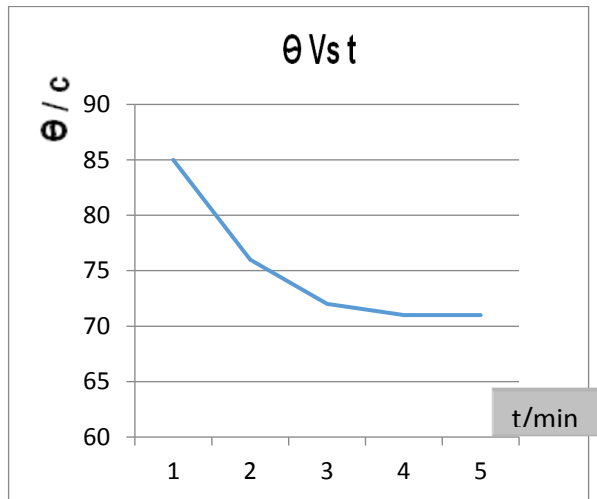


Figure (c)

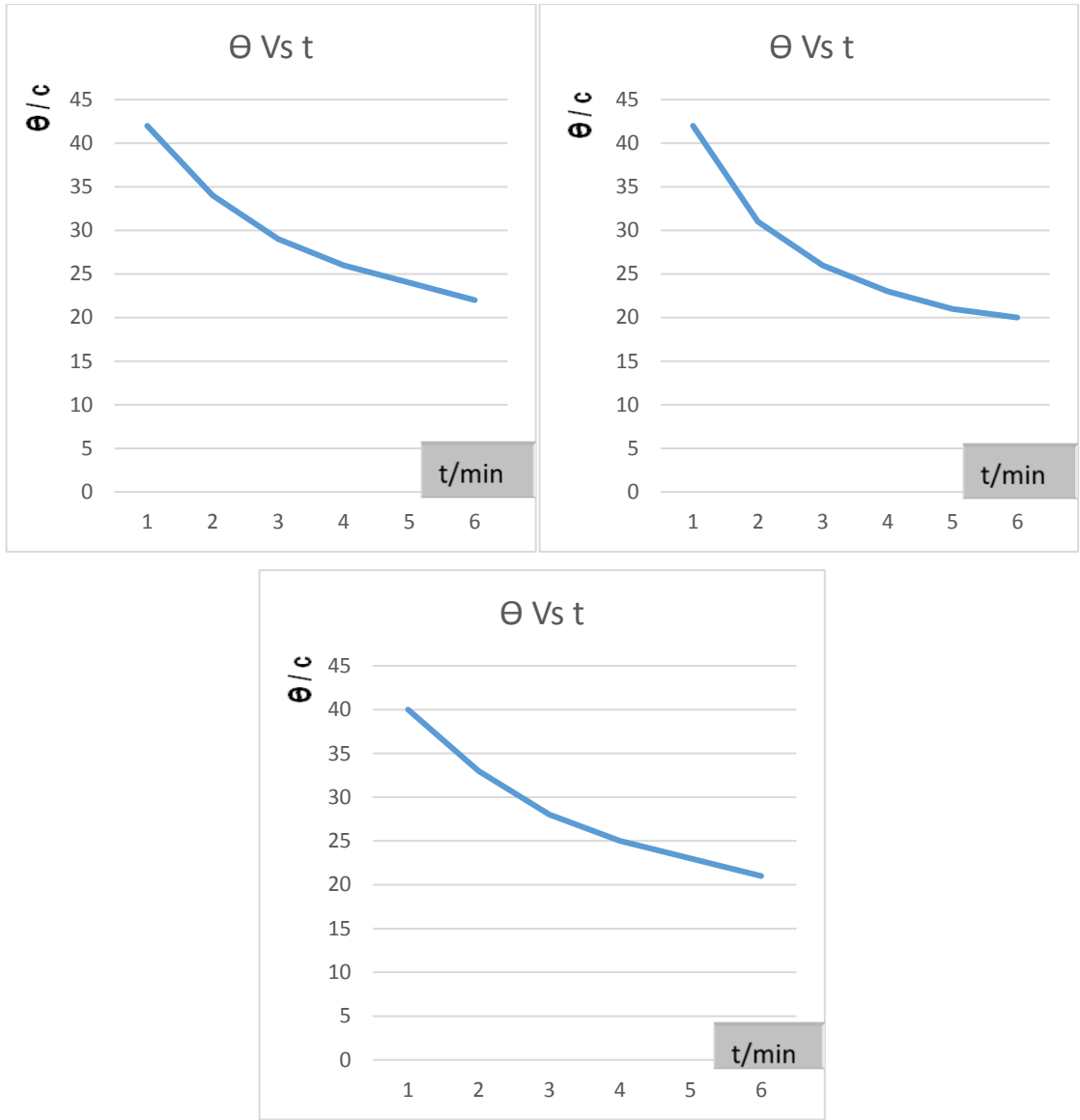
**Figure- 4.1 Shows the Relation between Time shown in the x- axis Versus Temperature on the y- axis for the three samples. Temperature decreases as time passes. Fig (a) shows sample 1, Fig (b) shows sample2, Fig (c) shows sample3.**

The following table shows the highest and lowest temperature of the three samples resulting from external heat transfer as shown in the figure- 4.1 above.

**Table- 4.6 Represents the Value of Difference Temperature of Three Samples outside the Brick Clay**

Samples	Highest temperature	Lower temperature	Difference temperature
Sample-1	75	45	30
sample-2	85	60	25
Sample-3	85	72	13

We conclude from the table above that the least external heat loss is in sample-3, therefore, this sample represents the best sample for the use of external construction.



**Figure- 4.2 Shows the Relation between Temperature versus Time for Difference Temperature inside the Brick Clay**

**Table- 4.7 Represents the Values of Difference Temperature of Three Samples inside the Brick Clay**

Samples	Highest temperature	Lower temperature	Difference Temperature
Sample-1	42	20	22
sample-2	42	22	20
Sample-3	40	21	19

We conclude from the table above that the least difference temperature inside the thermal clay brick buildings of the sample-3, therefore, this sample represents the best sample for use in the building until the buildings become cool without industrial air conditioners and cooling fans.

#### **4.4 Discussion of Thermal Conductivity**

Figure (4.1c), shows that the thermal conductivity coefficient was approximately 1.195 J/m.C, giving the lowest thermal conductivity, which was 0.016024 W/m.k. It was better than the other two samples, because the thermal conductivity of sample 1 was 0.021024 W/m.k, and sample 2 was 0.024024 W/m.k, this calculation from equation (3.8).

The researcher concluded that the best sample of the refractory bricks samples is sample-3 consisting of (70 % garirh, 30 % kaolin). Because its internal and external difference temperature and thermal conductivity were very low, compared to other samples. Followed by the worst sample-2 which consists of (80 % garirh, 20 % kaolin), and sample-1 is worse it consists of (75 % garirh, 25 % kaolin). Because the proportion of heat transfer was very low compared to other samples as shown in the comparison tables between the states of the Jazeera and Khartoum.

## **4.5 Results of Humidity**

The results of measuring the humidity in air and inside the room shows that the humidity is high in the morning and very low at noon and rises again during evening, tables- 4.8 and 4.9 show the measurements performed in Khartoum and the Jazeera States.

The Reading of humidity for the Jazeera state for about three days, Saturday 16 \ 9 to Monday 18 \ 9\2017, from 6 am until 10 pm.

The humidity measurement was performed for all the previously prepared brick samples.

**Table- 4.8 The Air and Room Humidity for the Three Samples which was Measured in the Jazeera State.**

Time	Sample 1		Sample2		Sample3	
	Air humidity %	Room humidity %	Air humidity %	Room humidity %	Air humidity %	Room humidity %
1	45	70	50	75	47	73
2	42	69	46	74	45	72
3	40	67	42	70	41	70
4	38	58	39	62	39	61
5	35	41	36	51	37	50
6	33	39	35	42	36	41
7	32	39	35	38	35	39
8	32	39	35	38	35	38
9	33	40	35	38	35	38
10	34	40	35	39	36	40
11	36	41	36	40	38	41
12	38	43	37	42	39	45
13	41	45	39	46	42	47
14	44	47	42	48	45	50
15	46	50	45	55	48	54
16	46	58	50	65	50	63

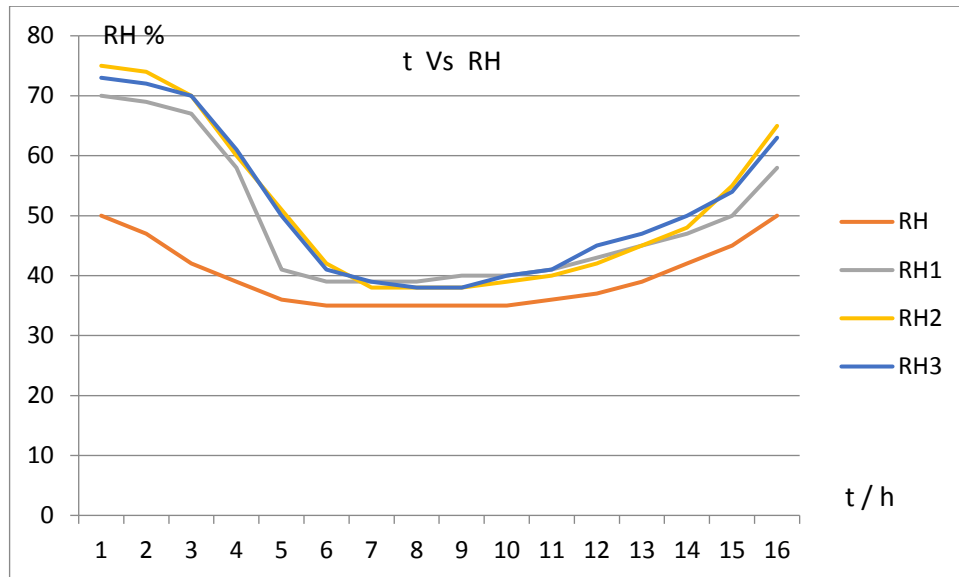
The Reading of humidity for the Khartoum state for three days, Wednesday 20 \ 9 to Friday 22 \ 9\2017, from 6 am until 10 pm.



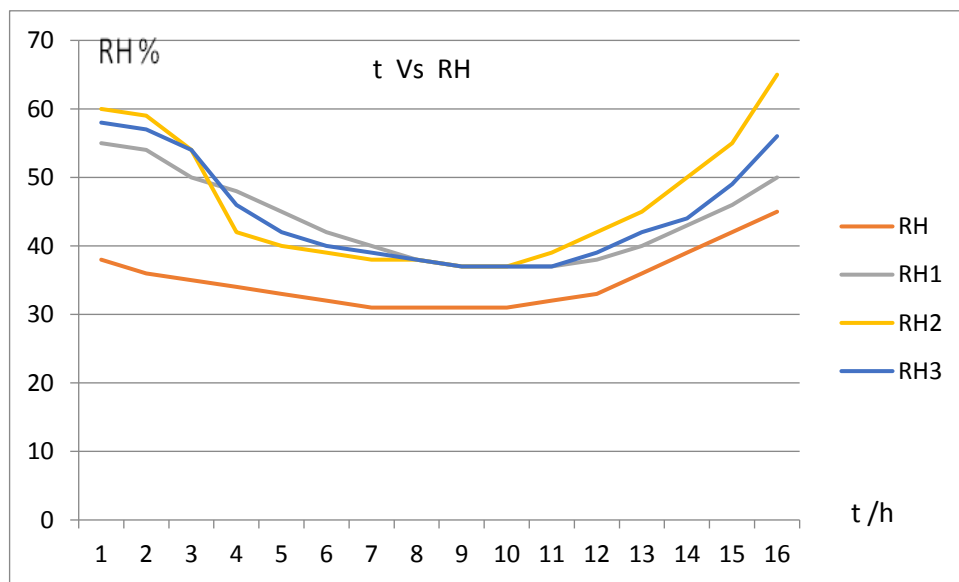
**Table- 4.9 The Air and Room Humidity for the Three Samples which was Measured in the Khartoum State.**

Time	Sample 1		Sample2		Sample3	
	Air humidity %	Room humidity %	Air humidity %	Room humidity %	Air humidity %	Room humidity %
1	38	55	42	60	40	58
2	36	54	39	59	38	57
3	35	50	38	58	37	54
4	34	48	36	42	36	46
5	33	45	34	40	34	42
6	32	42	33	39	33	40
7	31	40	32	38	32	39
8	31	38	32	38	31	38
9	31	37	31	37	31	37
10	31	37	31	37	31	37
11	32	37	33	40	31	37
12	33	38	35	42	33	39
13	36	40	37	45	35	42
14	39	43	38	50	38	44
15	42	46	40	55	41	49
16	45	50	43	65	44	56

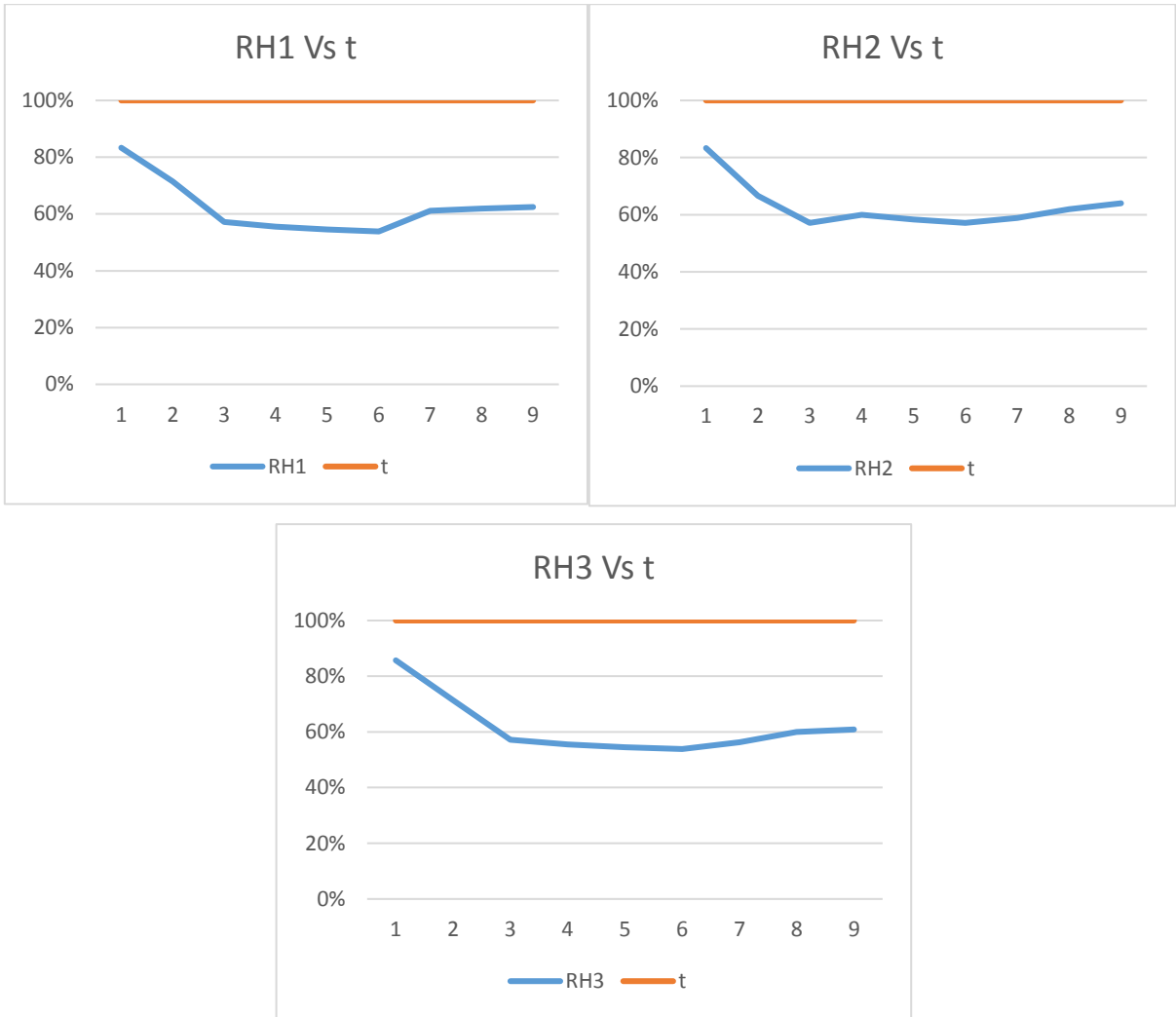
The following chart figure (4.3) illustrates the relationship between the humidity in percentage against the time in hour for the three samples, RH air humidity, RH1 Room humidity of sample 1, RH2 Room humidity of sample 2, and RH3 Room humidity of sample 3.



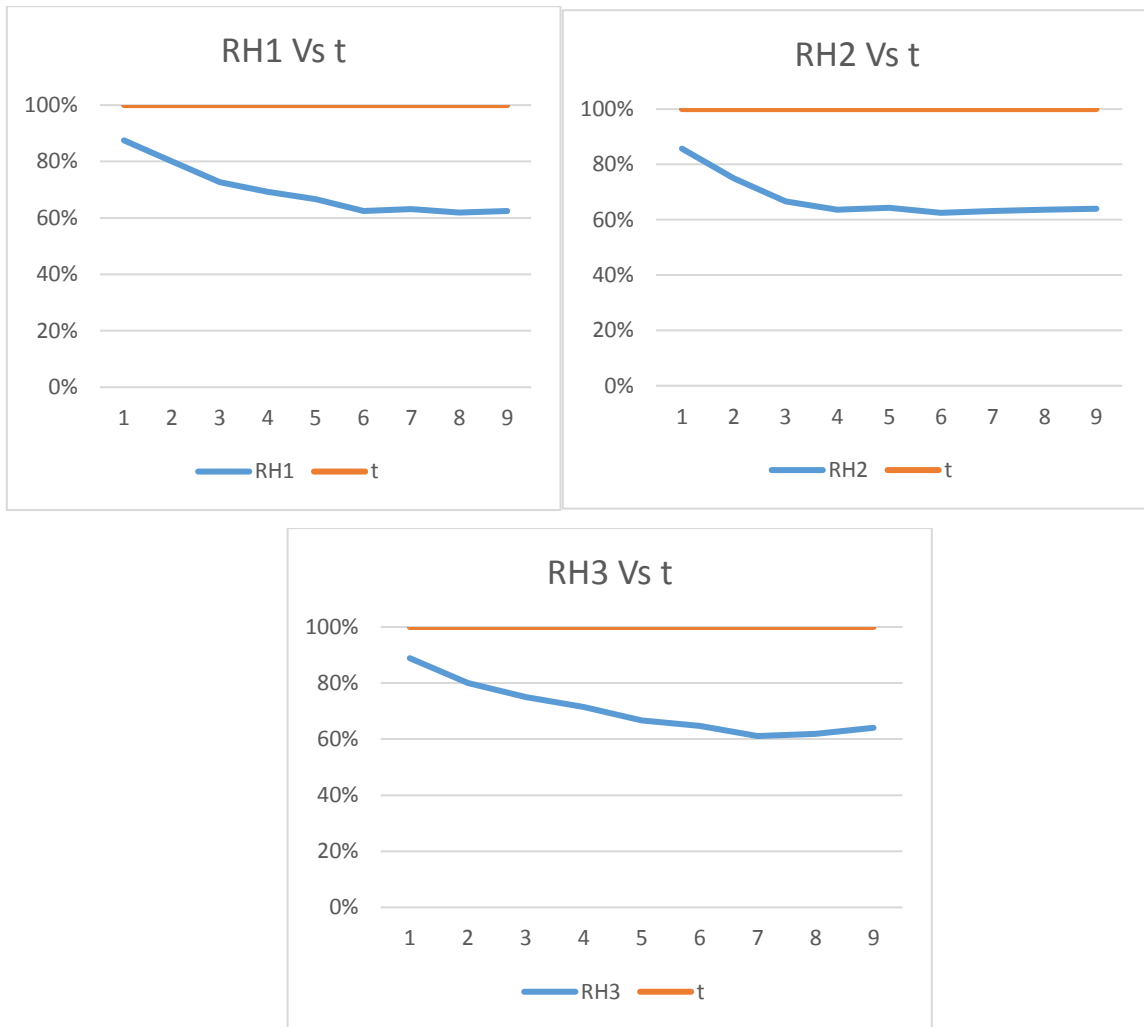
**Figure- 4.3 The Relation between Humidity Versus Time in the Three Samples, Measurements were Performed in the Jazeera State.**



**Figure- 4.4 The Relation between Humidity Versus Time in the Three Samples, Measurements were Performed in the Khartoum State.**



**Figure-4.5 Reading of Humidity Performed in the Jazeera State by Psychrometer Device**



**Figure-4.6 Reading of Humidity Performed in the Khartoum State by Psychrometer Device**

These results in figure-4.5 and 4.6 were measured using a conventional Psychrometer device and were similar to the results calculated by the modern humidity device (DHT-11 Sensor) collected by the researcher. This means that the results are correct relative to the measured results of the Sensor device.

#### 4.6 Discussion of Humidity

The following table shows the comparison of the values of humidity for the three samples of bricks. These values were calculated from the drawing in fig.4.3 and 4.4.

**Table- 4.10 Comparison of Air and Room Humidity for the Three Samples Measured in the Jazeera State.**

The best sample	Sample1		Sample3		Sample2	
	Air humidity %	Room humidity %	Air humidity %	Room humidity %	Air humidity %	Room humidity %
At morning	45	70	45	72	45	73
At evening	39	44	39	45	39	46
At evening	42	46	42	47	42	48

**Table- 4.11 Compared to Air and Room Humidity for the Three Samples Measured in the Khartoum State.**

The best sample	Sample1		Sample3		Sample2	
	Air humidity %	Room humidity %	Air humidity %	Room humidity %	Air humidity %	Room humidity %
At mornin g	38	55	38	57	38	58
At evenin g	33	38	33	39	33	40
At evenin g	38	42	38	44	38	50

These results were selected according to air humidity stability compared to the three samples in the states of Al Jazeera and Khartoum. The air humidity was equal in the three samples at one time in the morning and twice in the evening. The result was that the lowest humidity was found in the room of thermal clay bricks in sample-1 and the highest in the sample-3, and the average of in sample-2.

In addition, the lowest percentage of humidity in the state of the Al Jazeera was 44% and the highest was 73%, while in the state of Khartoum, the lowest percentage of humidity was 38% and the highest was 58%. This study shows that

the humidity is very low in the state of Khartoum compared to the state of the Al Jazeera.

After calculating the humidity of the three samples of refractory bricks, it was noticed that the best sample was sample-1. It comprises 75% garirh and 25% kaolin. The reason, the sample was the best, was because it is reading of humidity is lower than the other two samples. The study recommends that the refractory bricks are best in humidity installed by 75% garirh and 25% kaolin.

#### **4.7 Discussion and Comparison with Previous Studies**

In this study, the clay mud dimensions (length x width × height) were (200 × 200 × 200) mm<sup>3</sup>. After molding the brick unit through either extrusion or soft mud process, the green bricks must be correctly dried. (40-200 °C at 24-48 hrs). Firing, one of the most specialized steps in the manufacture of brick, 900 – 950 C, requires from 40 to 150 hr. depending upon furnace type and other variables. After the temperature has reached the maximum and maintained for a prescribed time, the cooling process begins. 48 to 72 hr. are required for proper cooling in periodic kiln. The chemical composition of the brick clay samples are (K, Ca,Ti, Mn, Fe, Cu, Zn, Pb, Rb, Sr, Y, Zr).

In the study of : Graziela Girardi [117], the clay mud dimensions (length x width × height) were (300 x 300 x 300) mm<sup>3</sup>, found that the specific heat capacity was 545 J / kg K, thermal conductivity was range to be from 0.02 to 0.05 W/mK,, and brick materials have high humidity (-90%). Mineral wool is a common insulation used at temperatures below 700°C for 24 hours.

Concerning the dynamic thermal characteristics, the calculated values showed that the thickness of the material has a significant effect on decrement factor and on thermal lag. Thus, the brick with a 300 mm thickness has a decrement factor equal to 0.02 and a thermal lag of only 2.51 h. This means that indoor temperature fluctuations will be great, as temperature peaks will be rapidly transmitted to the

interior of the building. The chemical composition of soil samples are ( $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{K}_2\text{O}$ ,  $\text{MgO}$ ,  $\text{CaO}$ ,  $\text{Na}_2\text{O}$ ,  $\text{TiO}_2$ ,  $\text{LOI}$ ).

In the study of N. Laaroussi, A. Cherki, M. Garoum, A. Khabbazi, A. Feiz [118], the clay mud dimensions (length x width x height) were ( $100 \times 100 \times 26$ )  $\text{mm}^3$ , found that the specific heat capacity was  $1500 \text{ J / kg K}$ , thermal conductivity was  $0.04 \text{ W / m K}$ . The bricks are burnt with flame at a temperature of  $780^\circ\text{C}$  for 24 hours.

The chemical composition of soil samples are ( $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{K}_2\text{O}$ ,  $\text{MgO}$ ,  $\text{CaO}$ ,  $\text{TiO}_2$ ,  $\text{P}_2\text{O}_5$ ).

In the study of Pusit Lertwattanakul and Jarunsri Choksiriwanna [119], the clay mud dimensions (length x width x height) were ( $100 \times 100 \times 100$ )  $\text{mm}^3$ . Found that the specific heat capacity about four samples was  $740 \text{ J / kg K}$ . Thermal conductivity was the range of the thermal conductivity was  $0.024\text{-}0.028 \text{ W/m.K}$ , and the humidity at temperature  $30 - 35^\circ\text{C}$  was  $70 - 80 \%$ . The bricks are burnt with flame at a temperature of  $800^\circ\text{C}$  for 24 hours.



## 4.8 Conclusions

The specific heat capacity of the three samples and the thermal conductivity were calculated. The three samples were analyzed, and a Canberra 35+ device obtained the concentrations. The results of the thermal conductivities of the brick sample products were found to decrease from 0.0261 (W/m K) to 0.01799(W/m K) (i.e. ~32%), for the sample 80% garirh, 20% kaolin. Increment of garirh did not decrease the standard mechanical properties below the levels required for construction materials. After calculating the humidity of the three samples of refractory bricks, it was noticed that the best sample was sample 1. It comprises 75% garirh and 25% kaolin. The reason, the sample was the best, was because its proportion of humidity very lower than the other two samples. The study recommends that the refractory bricks are best in humidity installed by 75% garirh and 25% kaolin.

New digital humidity sensor was converted to humidity meter by assembling sensor with programmed microcontroller and display unit, this is calibrated with ordinary one.

The researcher concluded that in a hot area, the best sample of the refractory bricks samples is the sample-3 consisting of (70 % garirh, 30 % kaolin). Because its internal and external difference temperature and thermal conductivity were very low, compared to other samples. Followed by sample-2, which consists of (80 % garirh, 20 % kaolin), were as sample-1, which is the worst and consists of (75 % garirh, 25 % kaolin). Where as in the humidity area, the best sample was sample 1. It comprises (75% garirh and 25% kaolin). The reason, the sample was the best, was because its proportion of humidity is lower than the other two samples.

## **4.9 Recommendation**

We recommend:

- 1- To add rubber to each sample and perform calculations.
- 2- To further change the percentage of the materials or change the materials.
- 3- To develop the humidity meter.

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