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Instrumentation of the Rain Gauge For Rainfal Measurement

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ABSTRACT: *Rain gauge is the standard instrument for measurement of rainfall. Instrumentation and measurement with regards to the rain gauge is vital to ascertain rainfall readings. These rainfall readings are used for different purposes (Scientific, engineering, agricultural, e.t.c.) depending on the user. Thus, in the course of this work, Instrumentation processes and guidelines including dimensional principles and properties for the rain gauge in question was outline practically. Three (3) months practical measurement was carried out in the study area with tips on maintaining quality measurement and presentation of these data on the rainfall chart. Classes and types of rain gauge, factors that may affect measurement of rainfall, rainfall formation processes, and rainfall distribution pattern for the area were also outlined.*

KEYWORDS: *Instrumentation and Measurement, The Rain gauge, Rainfall chart, Rainfall Distribution Pattern,*

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I. INTRODUCTION

Instrumentation refers to the calibration of equipments and instruments through scientific and engineering methods. Instrumentation Engineering is the synergistic combination of mechanical engineering, electronic engineering, control engineering, systems design engineering and computer engineering to achieve measurements and control (Council of Scientific and Industrial research, 2012). Agricultural engineers have deployed this mechanism towards increasing output in agricultural fields. This is otherwise known as agro technology instrumentation. The term agrionics has been coined recently to imply agri electronic instrumentation (Council of Scientific and Industrial research, 2012). Instruments have types, makes or models. The choice of the type and make of gauge to use depends on a number of factors, including performance, cost, reliability, maintenance requirements, organizational standards and level and quality of vendor support (Sene, 2013).The uses of instrumentation are vast. Instrumentation is used for commercial product, testing, and for basic research (George, 2008). Instrumentation of the rain gauge is for research of rainfall properties, basically the rainfall amount.

Measurement involves the use of instruments to determine variables and quantities thereby enabling man describe different phenomena in quantitative terms. Rainfall began to be measured in the scientific sense in seventeenth – century Europe, the age of Enlightenment ushering in a time in which reason and logic started to replace superstition and religious dogma, and 'experiment' replaced Aristotles's methods of just thinking and arguing about things (Royal Meteorological Society, 2010). The use of rain-gauge is the standard way of measuring rainfall. Most rain-gauges generally measure the rainfall in millimeters. The level of rainfall is sometimes reported in centimeters or inches and rain-gauge amounts are sometimes read either manually or by automatic weather station, depending on the requirements of the collecting agency. Rain-gauges should be placed in an open area where there are no obstacles such as buildings or trees to block the rain for accurate readings. Despite recent advances in the use of remote sensing, rain gauge observations are still required for operational and calibration purposes (Emad, Witold, Krajewski, and Anton, 2001).

The main objective of the work is to provide appropriate rainfall measuring equipment suitable for our environment.

The specific objectives are

1.To provide the insight and guide for instrumentation of rain gauge using practical steps.

2. To provide solution to rainfall measurement using the standard rain gauge

Rain gauge is a scientific instrument used by meteorologist and hydrologist to measure the amount of liquid precipitation over a set period of time at a specified place. Several types of rain gauges have been developed such as weighing gauges, capacitance gauges, tipping – bucket (TB) gauges, optical gauges, disdrometers, underwater acoustic sensors, and others Emad *et al*.(2001). Generally types of rain gauges are classified into recording and non – recording rain gauges. Recording rain gauges are those that take reading automatically during rainfall event. Examples are;

i. Weighing Rain-gauge: This consists of a storage bin, which is weighed to record the mass. The weighing rain gauge (WRG for short) operates on the principle of weighing the rainwater collected by the buckets (Liu, Gao, and Liu, 2013). The mass is measured using a pen on a rotating drum or by using a vibrating wire attached to a data logger. Mechanical weighing rain gauges operate by recording the weight of precipitation as it accumulates in a container, by suspending the container on a spring or the arm of a balance, the movement being magnified by levers to move a pen (Royal Meteorological Society, 2010). The electronic weighing rain gauge operates by recording the weight of water container placed on the load cell by the operator. The basic advantage is its ability to measure other forms of precipitation, like rain, hail and snow. These gauges are expensive and require more maintenance than tipping bucket gauge.

Figure 2: Weighing rain gauge (Liu, Gao, and Liu., 2013).

ii. Tipping Bucket Rain-gauge: This consists of a funnel that collects and channel precipitation into a see-saw-like container. After a pre-set amount of precipitation falls, the lever tips, dumping the collected water and sending an electrical signal. It has a chart which is measured every 10 minutes period and it rotates once in every 24 hours. This is not as accurate as the standard rain-gauge since the rainfall may stop before the lever tips and when next rainfall period begins, it may take not more than one or two drops to tip the lever. A counter records the number of tips (AU Bureau of Met, 2007). Major users according to sales report are listed below;

S/N	Organization	Qtyin Service
1	Australian Bureau of Meteorology	520
2	Campbell Scientific (USA, Canada, Brazil, Australia	1,400
3	Hydro – meteorological Programs, Brazil	147
4	San Benadino, Riverside, Ventura, Santa Barbara, San Diego, San Luis Obispo, CA – USA	403
5	Department of Agriculture, Western Australia	80
6	Department of Lands, Planning & Environment, Northern Territory – Australia	180
7	Department of Meteorology Thailand/ Royal Irrigation Department of Thailand	2,000
8	Department of Water Resources South Australia	170
9	Department of Irrigation & Drainage – East Malaysia	820
10	Department of Water Resources – China	160
11	Central Water Commission, India	274
12	Changjiang Water Commission, China	125
13	Environment Canada	440
14	Government of Fiji	90
15	Government of Turkey	110
16	Hydro Tasmania – Australia	80
17	Government of Indonesia Public Works	620
18	Locher Environmental – Florida – USA	273

19	Malaysia Irrigation and Drainage Department (JPS) / Government of Malaysia	2,460
20	Manly Hydraulics Laboratory, New South Wales – Australia	110
21	Mekong River Commission – Cambodia	340
22	Mekong River Commission – Laos	250
23	New Zealand Regional Councils	500
24	National Oceanic & Atmospheric Administration, Climate Reference Network – USA	155
25	Papua New Guinea	140
26	Queensland Department of Natural Resources – Australia	450
27	South African Weather Service	415
28	South Florida/ St. Johns River Water Management Districts – USA	426
29	Stevens Water Monitoring – USA	260
30	Sydney Catchment Authority & Sydney Water Board, NSW – Australia	300
31	Theiss Environmental Service, Victoria – Australia	180
32	Tyco Environmental – England	310

Table 1: TB3 Sales Report of Major Users (Hydrological Services America, 2013)

Figure 3: The tipping bucket Rain gauge (John, 2011)

iii. Optical Rain Gauge: This type of gauge is a high technology gauge that allows the reader view and obtains rainfall data from flashes of light from its photo detectors that transmit raindrop falling through its laser beam path. These flashes are detected by the gauge sensor placed at right angle to the laser diode. Optical rain gauges are a spin – off from visibility instruments, falling rain drops being detected by their effect on horizontal beam of light (Royal Meteorological Society, 2010). This type of rain gauge is shown below;

Figure 4: Optical Rain Gauge (Liu, Gao, and Liu., 2013)

Iv. The Disdrometer: This uses underwater sound effect to calculate rainfall data like drop size distribution of rain drops falling on its water surface. The sensor transforms the mechanical impact of each drop into an electrical pulse (ARM, 2016). It thus, converts them to rainfall rate and other rainfall data. With calibration, the size of each pulse is interpreted as the diameter of the observed drop (ARM, 2016). This type of rain gauge is shown in the figure below;

Figure 5: The Disdrometer (Liu, Gao, and Liu., 2013)

Non Recording Rain Gauges: Non recording rain gaugesare manned operated gauges (manual gauges). Example is the standard rain gauge (SRG).

i. **Standard Rain-gauge:** This was developed in the 20th century and is being used for over 100 years by many weather stations. it consists of a funnel emptying into a graduated cylinder of 2cm diameter which fits into a large container of 20cm diameter and 50cm tall. The larger outer container catches the rain water that overflows the inner cylinder and when measuring, height of water in the small cylinder is recorded while the over flow in large container is poured into another cylinder (measurably up to 250mm) to be recorded as total rainfall. This is also used in snow areas. In the winter, the small tube is taken out, and snow falls directly into the large tube (Jenifer, 2003). The collected snow is melted and measured to obtain the rainfall amount.

Figure 6: Standard rain gauge (Olive centre, 2012)

II. MATERIALS AND METHODOLOGY

Materials: The materials used for this work are;

The Study Area: The study area is Enugu Town, the capital city of Enugu state of Nigeria. Located in Western Africa, the Federal Republic of Nigeria (named for the Niger River) is the most populous country of Africa (World Atlas, 2017). The needs of the country in the areas of agriculture, science, engineering, e.t.c., call for scientific and environmental measures as well as documentation. Enugu state of Nigeria is located in the figure below;

Figure 1: Map of Nigeria West Africa with location of Enugu (World Atlas, 2017).

Other materials are; Zink sheets, plastics, molding machine (molder), measuring tape, and welding machine.

Methodology: Methods used are grouped into instrumentation and measurement as below;

Instrumentation: The Zink sheet was calibrated to a cylindrical container (forming the outer cylindrical storage) using the welding machine. Plastic upon heating was used to form the inner cylindrical tube using the molding machine. Design parameters for the three main parts of the standard rain gaugeare shown below;

i. The measuring tube: This is located inside the outer cylinder and is the major part that is used for taking the reading. The values of the parameters shown in figure below are; Circumference, C = 11cm, Full vertical length, L = 21.2cm, vertical sectional length (gauging tube capacity), L_2 = 20cm, Top diameter of tube (water entrance diameter), d = 3.3cm, and bottom diameter (base), D = 11cm.

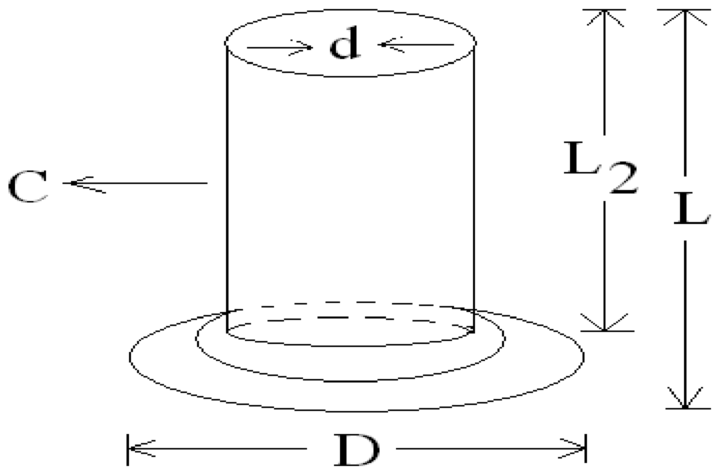

Figure 7: Dimensional properties of the measuring tube for standard rain gauge

ii. The over flow (outer) cylinder: This is the part of the standard rain gauge that stores the rain water when the measuring tube is filled up during periods of high rainfall occurrence. It is also referred as the outer storage. The values of the parameter shown below are; Vertical length of the cylinder, L = 26.6cm, Circumference of the cylinder, C = 32cm, Top Diameter of the cylinder, d = 12cm, Bottom diameter (base), D = 12.2cm

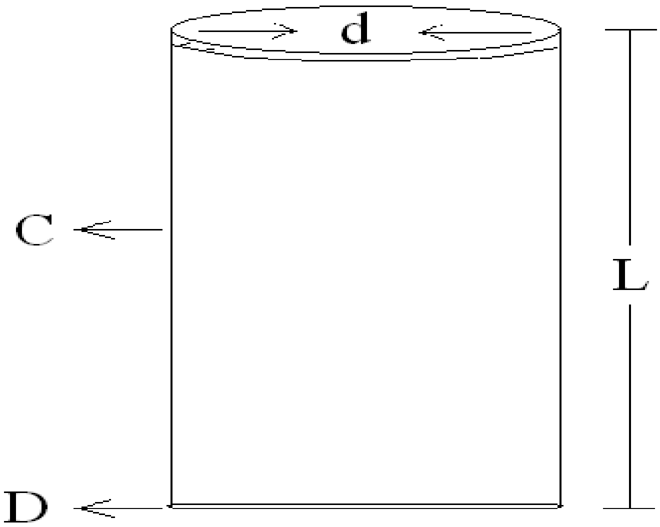

Figure 8: Dimensional properties of the outer cylinder for standard rain gauge

iii. The Funnel: This is the part of the standard rain gauge that is designed as an attachment to the overflow cylinder but in such a way that it empties into the measuring tube. This is possible by making the funnel outflow circumference smaller than the inflow circumference. The values of design parameters shown in figure below are; Total vertical length of material, L = 14cm, Length of funnel cap (cylinder lid), L_2 = 4.2cm Length of funnel base, L_3 = 6.4cm, Circumference of the upper part of funnel, C = 12cm, Circumference of the lower part of funnel (base), c = 3.3cm

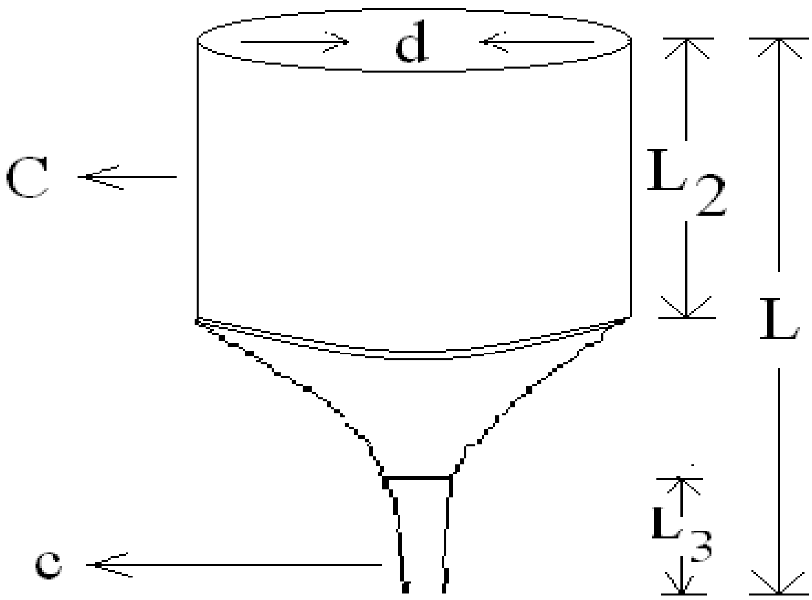

Figure 9: Dimensional properties of the funnel for standard rain gauge.

Measurement: The instrument was mounted in an open field, appropriately. Rainfall amount was read daily (7.00 am) using the measuring device on the inner cylindrical tube. The data obtained was record in the work book and presented in the rainfall chart. The placement of the three parts of the standard rain gauge is presented below;

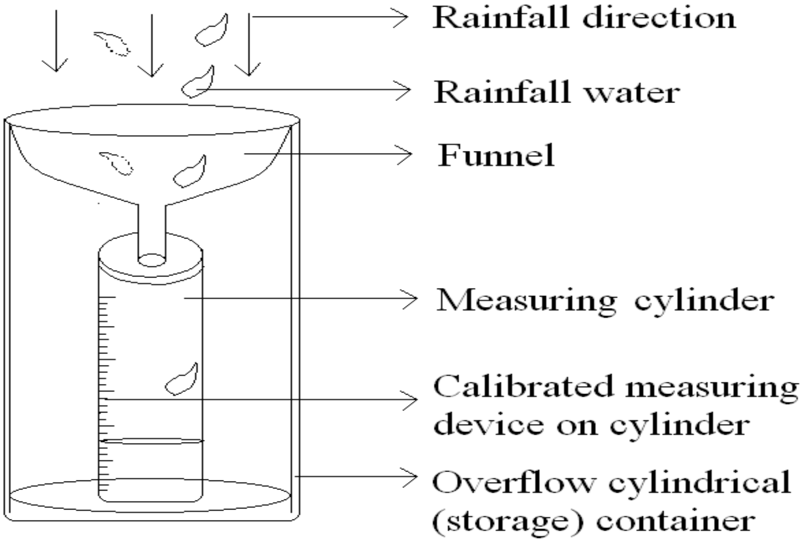

Figure 10: Placement of the standard rain gauge parts for rainfall collection

III. RESULTS AND DISCUSSIONS

Results:

The result of the instrument produced is presented below;

Figure 11: Three major parts of the standard raingauge

Note: In the figure 6 above, the measuring tube is the white plastic by the left, outer cylinder at the center and the funnel at right.

The results from the measurements are thus presented below;

Day	Amount of rainfall in The Rain Gauge
1	-
2	-
3	-
4	-
5	-
6	-
7	-
8	-
9	-
10	-
11	-
12	-
13	-
14	-
15	-
16	-
17	-
18	-
19	-

20	26
21	-
22	-
23	-
24	-
25	-
26	-
27	-
28	-
29	-
30	198
31	-
Total	224

Table 2: March, 2017 Rainfall measurement in Enugu capital, Nigeria West Africa

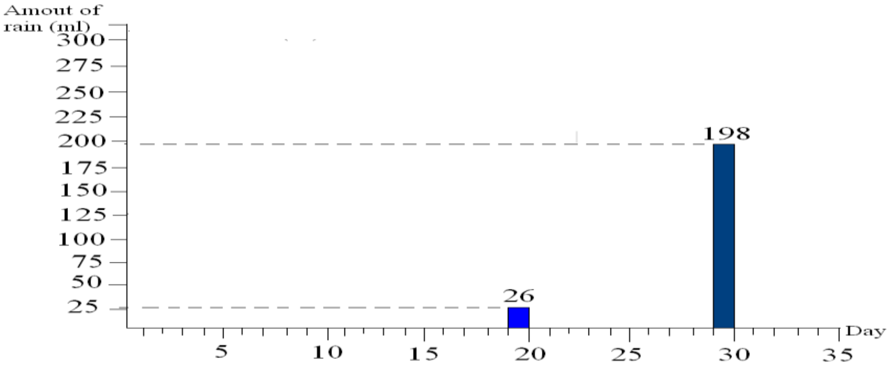

Figure 12: Rainfall chart of the region for the Month of March 2017.

Rainfall result from the measurements in the month of April 2017 is tabulated below;

Day	Amount of rainfall in The Rain Gauge
1	-
2	-
3	-
4	-
5	-
6	364
7	-
8	-
9	245
10	-
11	-
12	-
13	-
14	-
15	-
16	-
17	672
18	-
19	-
20	371
21	-
22	-
23	-
24	-
25	71
26	40
27	-
28	291
29	-
30	-
Total	2054

Table 3: April, 2017 Rainfall measurement in Enugu capital, Nigeria West Africa

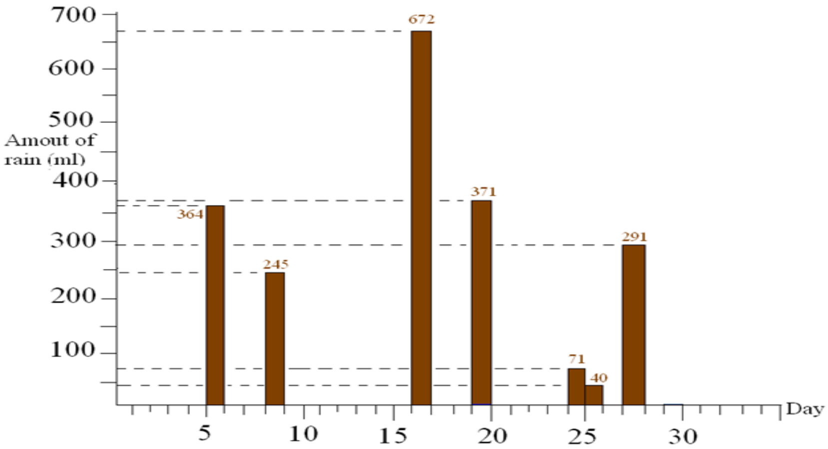

Figure 13: Rainfall Chart of the Region for the month of April 2017.

Rainfall result from measurements in the month of May 2017 is presented in the table below;

Day	Amount of rainfall in The Rain Gauge
1	180
2	119
3	-
4	-
5	-
6	-
7	-
8	-
9	90
10	-
11	-
12	412
13	-
14	-
15	-
16	72
17	-
18	-
19	-
20	-
21	-
22	-
23	-
24	-
25	316
26	-
27	-
28	-
29	-
30	109
31	-
Total	1298

Table 4: May, 2017 Rainfall measurement in Enugu capital, Nigeria West Africa

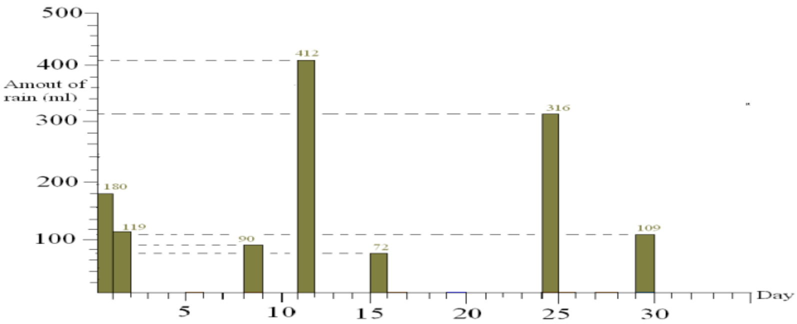

Figure 14: Rainfall Chart of the Region for the Month of May 2017.

Monthly rainfall data from March to May 2017 is presented below;

S/N	Month	Rainfall Amount
1	March	224
2	April	2054
3	May	1298
4	Average	1192

Table 5: Monthly rainfall amount for the area

No rainfall event occurred in the months of January and February. Thus, rainfall records of Enugu for March, April and May are presented in rainfall chart below;

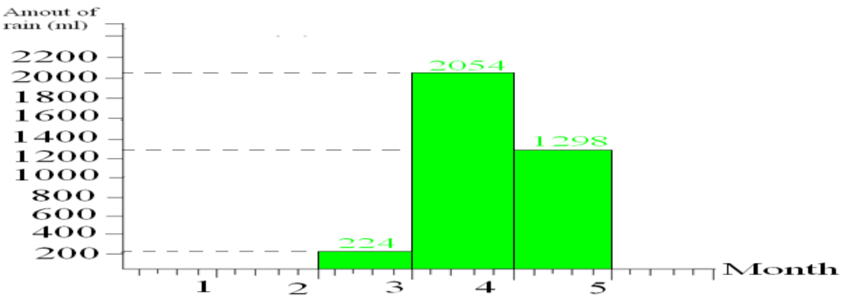

Figure 15: Monthly rainfall Chart from January to May

IV. DISCUSSIONS

Instrumentation of the Standard Rain Gauge: Instrumentation of the standard rain gauge can be done using plastics, glass or metal or combination of different materials but the design settings for the parts remains the same. If made with metal, it may be coated with oil paints of desired colour to serve as additional anti – rusting agent.

Measurement of Rainfall: The rainfall data collected is recordable as rainfall amount of that particular rain storm by a Meteorologist who empties the gauge container and replaces it for another rainfall collection and reading. The reading is done every 24 hours interval and recorded as daily rainfall which should be repeated to get monthly and annual rainfall. These measurements help farmers make decisions about planting, crop irrigation and harvesting, they also aid engineers to design effective bridges, storm drains, and other structures.
Placement of these gauges should be well calculated to avoid obstruction of rainfall and addition of splashed rainfall. The World Meteorological Organization (WMO) recommends for installation: Distance = min. height of the next obstacle x 4 (NIVUS GMBH, 2016). The funnel is design to prevent animals from drinking or gaining access to the collected rain. You should have at least one deputy to record the rainfall when you are away or ill (Met Office, 2013). The equipment is mounted on a stand to avoid addition of splashed water from the ground surface. This is shown in the figure below;

Figure 16: Assembled and mounted rain gauge for data collection

Rainfall Distribution:

Rains are tiny droplets of water that have condensed from atmospheric water vapor that becomes heavy enough to fall under gravity. Smaller drops are called cloud droplets and their shape is spherical (Okolotu, Oluka, Eze, 2017).These smaller drops thus grow until they also become unstable and break up thus producing raindrop growth by chain reaction (United States Meteorological Survey; 2009). Most moisture responsible for the formation of cloud and rain evaporates from water surface over the earth, basically open water surfaces like oceans seas rivers lakes and streams. Solar radiation (sunlight) supplies the necessary energy for evaporation of water vapor. The largest sources of water vapor are tropical and semi-tropical oceans (they require less sunlight for evaporation to occur compared to temperate region where the oceans are cooler or in ice state).Thus high rainfall is expected in such areas.

Rainfall distribution is an aspect of rain effectiveness which concerns how rainfall is distributed through a year. Biomodal distribution of rainfall is rainfall distribution pattern where the rainy season is divided into two parts with a dry period between. A single rainy season is described as a unimodal distribution. These rainfall distribution patterns give annual guidance to the data collectors on when to obtain their readings.

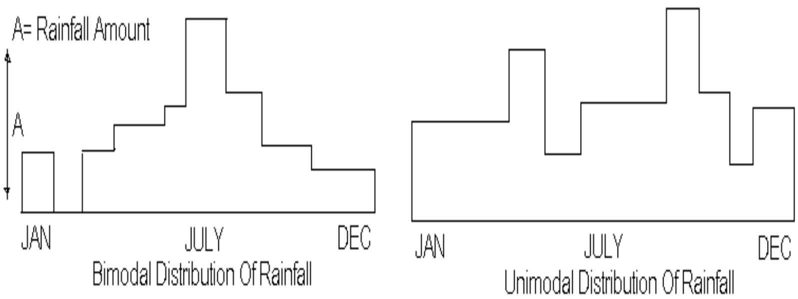

Figure 17: Patterns of Annual Rainfall Distribution (Hudson, 1971)

V. CONCLUSION

This work is worthwhile as it provides guidelines to the+ instrumentation and measurement of the rain gauge.

VI. RECOMMENDATION

More work should be done on design of this instrument's improvement, enabling it to take record of other rainfall data and also available at affordable price.

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