# Development of Portable Rain Calibrator Prototype using Submersible Pump

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**Abstract.** During the rainy season, floods in Indonesia increase rapidly, so that rainfall data is needed that is valid and accurate. Rainfall equipment in Indonesia must be calibrated every year. However, to calibrate all equipment installed in almost all of Indonesia requires portable calibrator equipment. Lipi has made portable rainfall using a peristaltic pump, while BMKG has a calibrator equipment called Rainfall is still manual. In this research, a rainfall calibrator prototype was made that is able to measure rainfall intensity using a microcontroller that is used to regulate the speed of submersible pumps. Testing the prototype used 2 methods, namely by using the volumetric method and the comparison method. The artifact used for calibration is a tipping bucket sensor with a resolution of 0.2 mm. The results of calibration of artifacts using prototypes compared to the results of rainfall calibration, obtained the difference in the intensity of 0.22 mm / minute with an error of 6.25%.

**Keywords:** Automatic, calibrator, portable, rainfall.

## 1. Introduction

Rain is a liquid precipitation, in contrast to non-liquid precipitation such as snow, ice cubes and slits. Rainfall Rainfall is one of the weather elements whose data is obtained by measuring it using a rain gauge, so that the amount can be known in millimeters (mm). Rainfall 1 mm is the amount of rain that falls on the surface per unit area ($m^2$) provided that nothing evaporates, absorbs or flows. Thus, rainfall of 1 mm is equivalent to 1 liter / $m^2$ [1]. Rainfall is limited as the height of rain water received at the surface before experiencing surface runoff, evaporation and infiltration into the ground.

Rainfall is defined as a liquid or solid product from condensation of water vapor that falls from clouds or is deposited from the air to the ground. This includes rain, hail, snow, dew, rime, haar and haze. The total amount of precipitation reached land in the stated period is expressed in vertical depth of water (or equivalent to water in this case solid form) which will cover horizontal projections of the earth's surface. Snow falling is also expressed by the depth of the newly falling snow which covers the flat surface [2].

Rainfall Intensity. Rainfall intensity is defined as the amount of rainfall collected per unit time. According to this definition, rainfall intensity data can be derived from measuring the amount of precipitation using ordinary rainfall gauges. In that sense, the intensity of precipitation is a secondary parameter, which is derived from the amount of rainfall the primary parameter has.

However, the intensity of precipitation can also be measured directly Unit and scale Rainfall units are linear depths, usually in millimeters (volume / area), or kg m - 2 (mass / area) for liquid precipitation. The amount of daily rainfall should be read to the nearest 0.2 mm and, if appropriate, to the nearest 0.1 mm; weekly or monthly quantities must be read closest to 1 mm (at least). Daily rainfall measurements must be made at a fixed time common to the entire network or network of interest. Less than 0.1 mm (0.2 mm in the United States) is generally referred to as a trace [2]. From equation (1) So in the form of an intensity equation it can be written as follows:

$$I = \frac{h}{t} \tag{1}$$

where: I = intensity (mm/menit), h = rainfall (mm), t = time (menit)

The height of rainfall is assumed to be the same in the vicinity of the dosing area, the area covered by a rain gauge depends on the homogeneity of the area and other weather conditions. Rain penakar divided into two groups, namely the type of manual and automatic type. If all that is desired is the amount of daily rain, then the manual type is used. More information is obtained from automated devices. The tools used are in the field. The more sophisticated a device, the more skills and abilities.

Tipping Bucket. The tipping bucket sensor works by calculating the unity time pulse which is determined from the amount of water that enters the sensor mouthpiece. So that from these pulses can be known the amount of rainfall unity broad unity of time. Rainwater is collected into a tipped pot. If water fills a reservoir that is equivalent to a rain height of 0.5 mm or according to the sensor specifications will be tipped and water is removed. There are two vessels which alternately collect rainwater. Every tipping motion of a mechanic is recorded on the pile or moving the counter. The count is multiplied by 0.5 mm or according to sensor specifications is the height of the rain that occurs. Tipping buckets are not as rigorous as other standard instruments, because the rain may stop before the tank seesaw because the rainfall has not yet reached the value of 0.5 mm. so that rainfall values below 0.5 mm are not recorded. When the vessel is tipped, it moves the switch (like a reed switch) which is then recorded electronically. The workings of the rain gauge are shown in Figure 1.

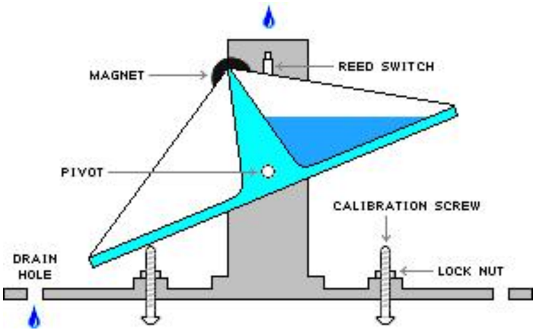


**FIGURE 1.** Tipping bucket sensor

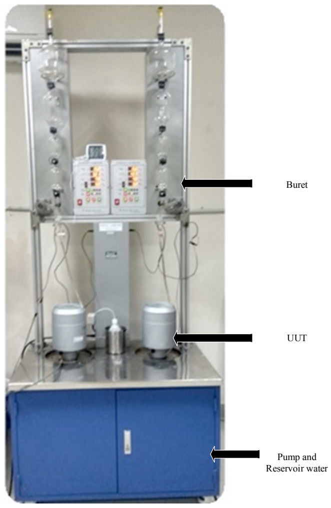


**FIGURE 2.** Rainfall calibrators at the BMKG calibration laboratory

The principle behind the operation of this instrument is simple. The twisting rain gauge uses a twin or metal bucket balance of plastic to measure the water entering in parts of the same weight. When one bucket is full, its center of mass is outside the pivot and tip of the balance, disposing of the collected water, and bringing the other bucket into position for collection. The bucket compartment is shaped so that the water is emptied from the lower one. The mass content of the bucket water is constant (m [g]). Therefore, using water density ($\rho$ = 1 g / cm$^3$), the corresponding volume (V [cm$^3$]) comes from the weight of the water and, consequently, the appropriate accumulation height (h [mm]) is taken using the collector area ( S [cm$^2$]). The equation is:

$$V = \frac{m}{\rho} = h.S \quad (2)$$

where: m = massa (gr), V = Volume (mm$^3$), $\rho$ = water density (gr/cm$^3$), h = high rainfall (mm), S = Size of container area (mm$^2$).

So, using water density, h is calculated, where 1 mm corresponds to 1 g of water over an area of 10 cm$^2$. To have a detailed record of rainfall, the amount of rain must not be more than 0.2 mm. For an area of 1,000 cm$^2$, this corresponds to the contents of a 20 g bucket of water [2].

Rainfall Calibrator. Calibration is an activity to determine the conventional correctness of the value of measuring instruments and measuring materials by comparing them with traceable standards to national and international standards for measurement units and or international standards and certified reference materials.

Equipment calibration (see figure 2) is carried out regularly every year for digital equipment. Currently rainfall gauges spread across various regions in Indonesia are calibrated by the BMKG One-Stop Service, which is located in Central Jakarta. The limited number of calibrators is an obstacle for BMKG to carry out calibrations at weather monitoring stations, which amount to 180 locations [3]. This rainfall calibrator also needs to be traced to the International Unit (SI) standard to guarantee the measurement results.

LIPI has made a portable, easy-to-use rainfall calibrator to support the traceability of rainfall measurements in Indonesia. In this study using a peristaltic pump with a volume of 1 liter. So in this study, researchers built a prototype of rainfall using a submersible pump.

## 2. Research Method

The method used in the preparation and analysis of this study are:

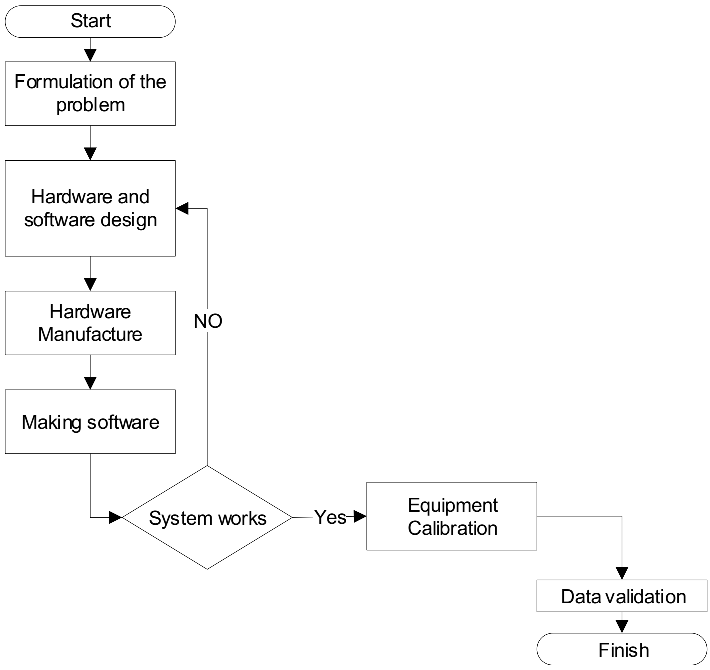


**FIGURE 4.** Flowchart of research methods

### 2.1. Hardware Design

Submersible Pump. This pump works with a voltage of 2.5 to 6 volts operating by pushing, as opposed to drawing, liquids during the pumping process. This is very efficient because the pump uses a liquid head where it is submerged to operate and no energy is spent to draw the liquid into the pump. The motor is cooled by the surrounding fluid, preventing overheating.

Many submersible pumps in the oil and gas industry operate according to the principle of Electric Submersible Pumping (ESP). This is a cost-effective method for removing large amounts of liquid from deep wells. The motor used in the ESP system is designed to operate under high temperature and pressure. They need special power lines and can be expensive to run [4].

**FIGURE 3.** Submersible pump

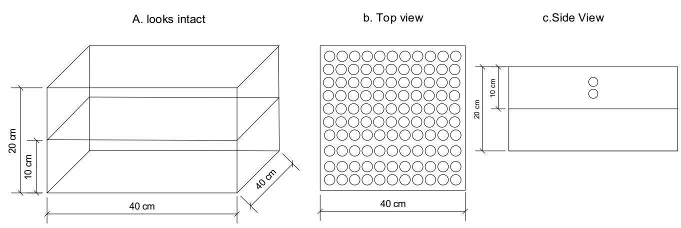


**FIGURE 4.** Reservoir water

In figure 3 and 4, water storage and as a place for equipment to be calibrated. The reservoir has a length of 40 cm, width 40 cm, and height 20 cm. Inside the tub, there is a perforated plate so that water spilled from the tipping bucket sensor can be accommodated below.

The material used is a cheap alklichic material, Acrylic is a plastic that resembles glass. However, acrylic turns out to have properties that make it superior to glass. One difference is the flexibility of acrylic. Acrylic is a material that is not easily broken, lightweight, and also easy to cut, file, drill, grind, polish or paint. Acrylic can be formed thermally into a variety of complex shapes [5].

Its break-resistant nature also makes acrylic an ideal material for use in applications in places where the rupture of the material will have fatal consequences, such as in submarine windows. In addition to being break resistant and resistant to weather, acrylic also will not shrink or change color even if exposed to long-term sun exposure. This makes all products from acrylic materials can be used indoors or outdoors.

### 2.2. Software Design

In figure 5 shown the folwchart of software design process. The following display software used in this prototype is in accordance with Figure 6. In figure 8 the prototype scheme of the equipment will be made as a field calibrator equipment to calibrate the Tipping bucket type rain gauge.

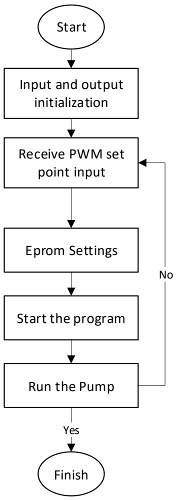


**FIGURE 5.** Software flowchart

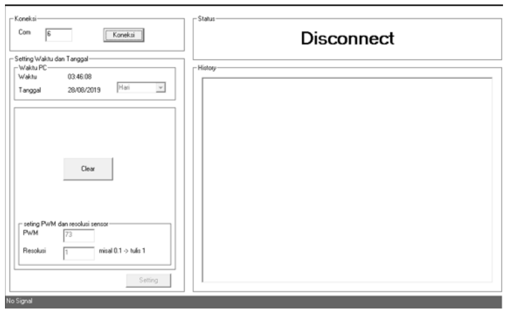


**FIGURE 6.** Software display

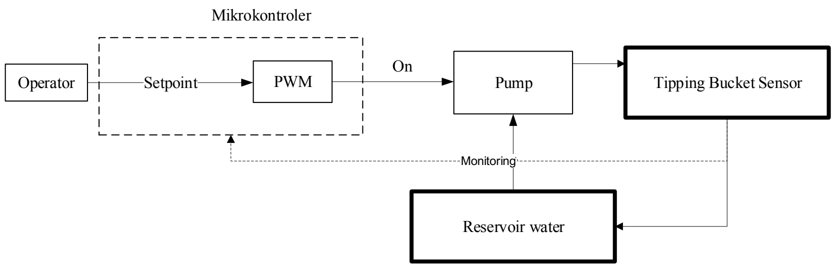


**FIGURE 7.** Flow diagram

### 2.3. Volumetric Method For Setting Water Volume

The volumetric method calculation is done by collecting water that comes out of rainfall using a calibrated measuring cup. Then the glass is weighed using a scale. Similarly, the calibrator prototype. To determine the volume of water in the calibrator used is the difference in the mass of the container filled with water ($I_L$) with the period of the empty container ($I_E$).

$$m_{air} = (I_L - I_E) \qquad (3)$$

Determination of the volume of water in the calibrator is based on the law of conservation of mass flow rate, that is the mass of water in the calibrator ($\Delta m_p$) which is driven by a pump through the hose and channeled the same as the mass of water through the hose ($\Delta m_c$)

$$\Delta m_p = \Delta m_c \tag{4}$$

The mass of water in the calibrator is related to the volume of water ($V_p$) multiplied by the density of water flowing in the hose ($\rho_a$) o that to calculate the volume of basic water in the calibrator a formula can be used:

$$\Delta V_p = \frac{\Delta m_c}{\rho_a} \tag{5}$$

For the estimation of the correct value of the volume that is accommodated or will be transferred from volumetric equipment for use in different environments the reference temperature of 20 $^0$C can be calculated by:

$$V_{20} = (I_L - I_E) \times \left(1 - \frac{\rho_{udara}}{\rho_{m_{ref}}}\right) \times \left(\frac{1}{\rho_{air} - \rho_{udara}}\right) \times (1 - \gamma(t - 20)) \tag{6}$$

where: $I_L$= weight of a vessel with water, $I_e$= Empty vessel weight, $\gamma$= 3 $\alpha$,$\alpha$ = Volume expansion coefficient , t = temperature ( $^0$C), $\rho_{m_{ref}}$= the reference mass density used is based on the OIML table, Water density ($\rho_a$) calculated from the temperature of the water ($T_a$) in the storage tank.

$$\rho_a = 999.974950\left(1 - \frac{(T_a - 3.983035)^2 (T_a + 301.797)}{522528.9 (T_a + 69.34881)}\right) \tag{7}$$

This volume is influenced by the density of water, the density of this water is affected by temperature as in equation (7). For environmental conditions also affect the measurements produced such as air pressure, temperature and humidity, through the appropriate approach (ISO / TR 20461: 200) and issued by NIST is:

$$\rho_u = \frac{k_1 P_u + RH(k_2 T_u + k_3)}{(T_u + 273.15)} \tag{8}$$

where: $k_1$ = 0.34844 (Kg/m$^3$) $^0$C/hPa, $k_2$ = -0.00252 Kg/m$^3$, $k_3$ = 0.020582 (Kg/m3)$^0$C, $P_u$ = pressure ( mb), $T_u$= temperature, RH = relative humidity.

### 2.4. Determination of Rainfall Intensity

After the volume of water collected and rainfall is known, the equation of the intensity of each tool can be calculated. So that reference intensity and measurement intensity are obtained.

### 2.5. Calculation of Correction Values

For correction values based on rainfall intensity in the WMO Guide are as follows:

$$e = \frac{I_m - I_r}{I_r} . 100\ \% \tag{9}$$

where $I_m$ is the intensity resulting from the measurement using the instrument to be calibrated, while for $I_r$ is intensity reference.

This reference intensity results in the calculation of the intensity carried out in the laboratory using rainfall data, for $I_m$ is the intensity calculation using data from the measurement results of the rainfall calibrator prototype.

This research was conducted at the BMKG Calibration Laboratory. Measurements were made using the calibration method. Scales are used to measure the empty weight of the measuring cup and the weight of the measuring cup plus the volume of water in accordance with the rainfall that is owned by the BMKG Calibration Laboratory. Before conducting research, the volume of water used as a reference must be compared between rainfall and prototype.

The flow calibrator prototype is regulated according to flow rainfall. Flow speed settings on this prototype are set via the computer by changing the PWM value, this PWM value will produce an output voltage that will drive the pump. This speed must match the flow velocity generated by rainfall. This flow velocity will produce the same intensity which is 5.54 mm / min. This flow is used to calibrate the Unit Under Test (UUT).

For data collection, rainfall is done according to the laboratory calibration method. For prototypes done 10 times. Environmental conditions such as temperature, humidity, air pressure and water temperature are measured at the start of the calibration and the end of the calibration.

## 3. Result and Discussion

Calibration was carried out under pressure conditions (1009.5 ± 2) mbar, temperature (24.3 ± 1) $^{0}$C, humidity (54.3 ± 1)% RH, and water temperature ((24.3 ± 1) 0C. In tabel 1 the measuring cup was weighed in a state empty, and the glass filled with water for rainfall table 2 The weight of the measuring glass is empty and the weight of filled glass is water for prototype.

**TABEL 1.** Rainfall volume

| No | Empty vessel weight gr | weight of a vessel with water gr | Weight of water gr | Water volume ml |
|---|---|---|---|---|
| 1 | 374,62 | 688,25 | 313,63 | 304.20 |
| 2 | 374,62 | 688,14 | 313,52 | 308.41 |
| 3 | 374,62 | 687,7 | 313,08 | 306.47 |
| 4 | 374,62 | 687,77 | 313,15 | 305.78 |
| 5 | 374,62 | 687,81 | 313,19 | 307.26 |
| 6 | 374,62 | 687,79 | 313,17 | 308.62 |
| 7 | 374,62 | 687,92 | 313,3 | 309.02 |
| 8 | 374,62 | 687,96 | 313,34 | 309.02 |
| 9 | 374,62 | 688,4 | 313,78 | 312.39 |
| 10 | 374,62 | 688,65 | 314,03 | 311.75 |
| **average** | | | 313,419 | 308.29 |

**TABEL 2**. Prototype calibrator

| No | Empty vessel weight gr | weight of a vessel with water gr | Weight of water gr | Water volume ml |
|---|---|---|---|---|
| 1 | 374.94 | 692.86 | 317.92 | 308.67 |
| 2 | 374.94 | 692.59 | 317.65 | 308.41 |
| 3 | 374.94 | 690.59 | 315.65 | 306.47 |
| 4 | 374.94 | 689.88 | 314.94 | 305.78 |
| 5 | 374.94 | 691.4 | 316.46 | 307.26 |
| 6 | 374.94 | 692.8 | 317.86 | 308.62 |
| 7 | 374.94 | 693.22 | 318.28 | 309.02 |
| 8 | 374.94 | 693.22 | 318.28 | 309.02 |
| 9 | 374.94 | 696.69 | 321.75 | 312.39 |
| 10 | 374.94 | 696.03 | 321.09 | 311.75 |
| **average** | | | 317.99 | 308.74 |

**TABLE 3.** Calculation of rainfall intensity with rainfall

| STANDAR | | | | | | | | Unit under test | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Buret | | | Stop Watch | | | high | intensity | | | |
| reading | corection | Volume | reading | corection | time | | | reading | | intensity |
| ml | ml | ml | detik | detik | Detik | mm | mm/mnt | Tip | mm | mm/mnt |
| 308.3 | -0.2 | 308.1 | 176.0 | -0.2 | 175.8 | 15.38 | 5.25 | 72.0 | 1.4 | 4.91 |
| 308.3 | -0.2 | 308.1 | 178.0 | -0.2 | 177.8 | 15.38 | 5.19 | 71.0 | 1.4 | 4.79 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 308.3 | -0.2 | 308.1 | 178.0 | -0.2 | 177.8 | 15.38 | 5.19 | 70.0 | 1.4 | 4.72 |
| 308.3 | -0.2 | 308.1 | 176.0 | -0.2 | 175.8 | 15.38 | 5.25 | 71.0 | 1.4 | 4.85 |
| | | 308.1 | | | 176.8 | | 5.22 | | | 4.82 |

This research used a tipping bucket with a resolution of 0.2 mm and a diameter of 159.72 mm, so that the cross-sectional area of 200.71 mm was used. for rainfall, the sensor is placed under the UUT, then the water comes out of the reservoir until it runs out. From this process we will get the amount of tipping generated by the sensor and time. For the prototype sensor placed above the reservoir, the water will move up and into the tipping bucket sensor. From this process, we will get the amount of tipping data from the sensor. From the data obtained, the intensity can be calculated. In table 3 the intensity produced by rainfall is obtained, while for table 4. The intensity produced by the prototype

**TABLE 4.** Calculation of rainfall intensity with the rainfall calibrator prototype

| No. | PWM | Time | Water volume | Amount of tip | Kalibrator | Unit Under Test (UUT) | intensity | |
|---|---|---|---|---|---|---|---|---|
| | | | | | High | high | Prototipe | UUT |
| | | detik | ml | | mm | mm | mm/mnt | mm/mnt |
| 1 | 81 | 170 | 308.67 | 74 | 15.41 | 14.80 | 5.44 | 5.22 |
| 2 | | | 308.41 | 74 | 15.40 | 14.80 | 5.44 | 5.22 |
| 3 | | | 306.47 | 73 | 15.30 | 14.60 | 5.40 | 5.15 |
| 4 | | | 305.78 | 73 | 15.27 | 14.60 | 5.39 | 5.15 |
| 5 | | | 307.26 | 72 | 15.34 | 14.40 | 5.42 | 5.08 |
| 6 | | | 308.62 | 73 | 15.41 | 14.60 | 5.44 | 5.15 |
| 7 | | | 309.02 | 73 | 15.43 | 14.60 | 5.45 | 5.15 |
| 8 | | | 309.02 | 72 | 15.43 | 14.40 | 5.45 | 5.08 |
| 9 | | | 312.39 | 73 | 15.60 | 14.60 | 5.51 | 5.15 |
| 10 | | | 311.75 | 71 | 15.57 | 14.20 | 5.49 | 5.01 |
| **average** | | | **308.74** | | **15.42** | **14.56** | **5.44** | **5.14** |

For the calculation of rainfall using rainfall obtained at 1.54 cm (15.39 mm), while for the prototype of rainfall obtained at 1.54 cm (15.42 mm). For the results of the calibration of rainfall intensity using rainfall of 5.22 mm / minute using the Unit Under Test (UUT) of 4.82 mm / minute. For the results of the calibration of rainfall intensity using a rainfall calibrator prototype of 5.44 mm / minute using the Unit Under Test of 5.14 mm / minute.

The results of calibration of artifacts using prototypes compared to the results of rainfall calibration, obtained the difference in the intensity of 0.22 mm / minute with an error of 6.25%

## 4. Conclusions

In this study it can be concluded that the volume of water used at an intensity of 5.54 mm / min is for rainfall of 308.29 ml and the prototype of a rainfall calibrator is 308.74 ml. From the calculation results that the intensity produced by rainfall is 5.22 mm / minute and the prototype is 5.44 mm / minute. The error value generated by the prototype is 6.25%.

This prototype needs to be developed using a more stable submersible pump. And made more precise water reservoirs to be used as a portable field calibrator equipment, which will be used by calibration officers in conducting field calibration of tipping bucket type rainfall equipment in the field.

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