DEVELOPMENT OF A WEIGHING TYPE RAIN GAUGE

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ABSTRACT

Rainfall measurement is the core of all hydrological measurements. For automated recording of rainfall data, tipping bucket rain gauges are generally used. It has been reported that the tipping bucket rain mechanism of such rain gauges frequently malfunction and give erroneous data, especially during high intensity rainstorms. Weighing type rain gauges are considered worldwide as the most accurate as well as reliable.

For the first time in India, an attempt was made to develop a weighing type rain gauge using components and systems available indigenously. A load cell is used to weigh the accumulated rainfall. A collector rim of 205mm diameter is used on an outer container from which the water pours down through a funnel into an inner container. The inner container rests on the load cell and is designed to store 10 cm of rainfall. The accumulated rain water, after reaching a preset level, is drained out using a solenoid valve. A microcontroller based data logger controls the sampling and data storage frequency, the operation of the solenoid valve, and stores the measured data alongwith the date and time in an on-board memory.

The rainfall data from the reported Weighing Type Rain Gauge (WRG) and non-recording type rain gauge (ORG) was compared at a site in Roorkee. Initial results of the field testing are presented.

1. INTRODUCTION

The standard and common practice for measurement of rainfall has been to measure the total accumulated rainfall on a daily basis. To characterize a precipitation event, however, information is required on (1) duration, (2) intensity, and (3) total amount of precipitation. Moreover, there is an increasing need for more detailed time resolution of precipitation measurements, and also for precipitation recordings from remote areas.

Many different kinds of recording rain gauges are available worldwide. However, various errors are associated with the syphon type and tipping bucket raingauges. For example, in the syphon type raingauge, some amount of water is required to uplift the float which gets evaporated if there is a considerable gap between two consecutive rains. Secondly, the amount of rainfall during the draining period remains unaccounted. Similarly, in tipping bucket rain gauges, the accuracy of measurement depends on the capacity of the bucket. This limitation leads to a significant percentage error during high intensity rainfalls. Also, the tipping bucket rain gauge usually has nonlinear characteristics. Successive tips do not represent constant rainfall depths (Simic and Maksimovic, 1994). Weaknesses of the traditional rain gauges, and the resulting errors, have been discussed in the past by various authors (e.g. Sandsborg, 1972; Sevruk, 1987).

With a view to make a reliable rainfall measuring system, rain gauges based on weighing have been reported. These are of two types - with spring and recording pen arrangement and with a rotating potentiometer built into the weighing gauge. Although the former type (e.g. manufactured by Belfort, USA) is still in use, the latter type was discontinued due to its inherent limitations. A weighing type precipitation gauge based on a vibrating-wire strain gauge was reported by Bakkehol et al. (1985), mainly for solid precipitation measurements.

Keeping in view the above difficulties, it is desired to have a rainguage which should be free from the above stated problems and should suit the Indian environment. The paper reports the developments of a reliable, automated Weighing Type Rain Gauge (WRG), using components and systems available indigenously, which is especially suitable for use in remote locations.

2. DESIGN

The reported instrument is based on a weighing mechanism. A load cell is used to weigh the accumulated rainfall. The accumulated rain water, after a preset level, is drained out using a solenoid valve. A collector rim of 205 mm dia is used on an outer container from which the water pours down through a funnel into an inner container. The inner container rests on the load cell and is designed to store 10 cm of rainfall. The solenoid valve is operated to drain out the accumulated water either when the inner container becomes full or after a pre-specified time, whichever is earlier.

Initially, after designing a weighing type sensor using strain-gauge based load cell, a commercially available data logger (CR10 of Campbell Scientific, USA) was used with the sensor for measuring and recording the rainfall data. Extensive laboratory and field testing was carried out with this set up. Later on, a microcontroller (Intel's 80C31) based data logger was designed using indigenously available material. The design presented in this paper is that of the indigenous data logger, and is shown in Figure 1.

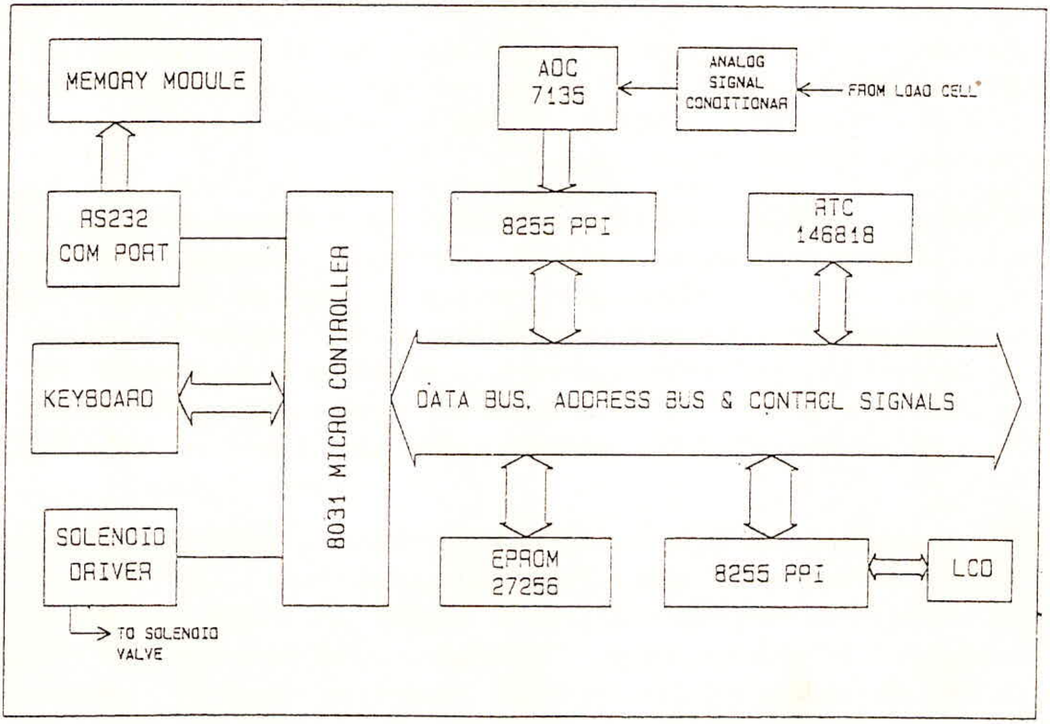

Fig.1 Block Diagram: Rainfall Measurement Using WRG

Further developments in microprocessor technology have made possible a better type of small computer, one with not only the CPU on the chip, but RAM, ROM, Timers, Counters, VARTs, Ports, Clock Circuit, and other common peripheral I/O functions also. The microprocessor has become the 'microcontroller,' and a microcontroller is meant to fetch data, perform limited calculations on that data, and control its environment based on those calculations (Ayala, 1991). With a view to design a general purpose data logger based on state-of-art technology, with compact and power-efficient design, it was decided to use a microcontroller for the data logger.

The reported system uses a 8031 microcontroller alongwith other required peripheral chips, such as 8255 Programmable Peripheral Interface (PPI), 146818 Real Time Clock (RTC), ICM 7135 12-bit Analogue-to-Digital Converter (ADC), a few digital ICs, signal conditioning circuitry. A load cell to convert the weight of accumulated rainfall into an electrical signal (in mV). The solenoid valve is operated through a solenoid driver circuit.

A 4x4 key matrix and a 20x4 intelligent LCD display are used for programming and display purposes, respectively. The measured data is stored in an 128KB memory module through an RS232 serial communication port. The monitor programme in 8031's assembly language, which controls the complete operation, is stored in a 32kb EPROM (27256). The microcontroller controls the sampling and data storage intervals, operation of the solenoid valve, and stores the measured data, alongwith the date and time, in the memory module.

The complete sensor assembly of the WRG is shown in Fig.2. It consists of an outer container with 205mm dia and 500mm height; an inner container of 175mm dia and 190mm height, and a load cell of 10kg capacity. A ½" solenoid valve, 12V dc operated of normally open type, is used to drain out the accumulated water from the inner container. An aluminium base plate with suitable mounting and levelling arrangements is used for mounting the outer container.

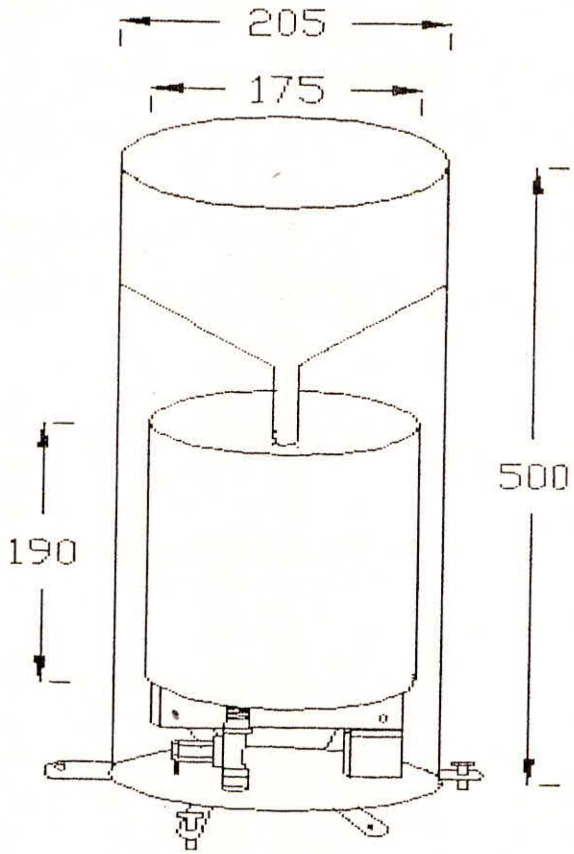

Fig.2 Sensor Assembly of WRG

3. OPERATION

The Intel's 80C31 micro-controller CPU is the heart of the hardware design. The software, written in 8031's assembly language, controls the overall measurements. The WRG is operated using instructions as shown in the flow chart (Fig 3).

As shown in the flow-chart, the process starts by initializing the system's peripherals. When a 'start' command is detected from the keyboard, data from the load cell (weight) is obtained through the Analogue-to-Digital Converter (ADC) on completing the sampling interval. This data is then multiplied with the calibration constant to convert the weight into mm of rainfall. The rainfall data, alongwith the date and time, is stored in the memory module through a serial communication port until accumulated water reaches 100mm.

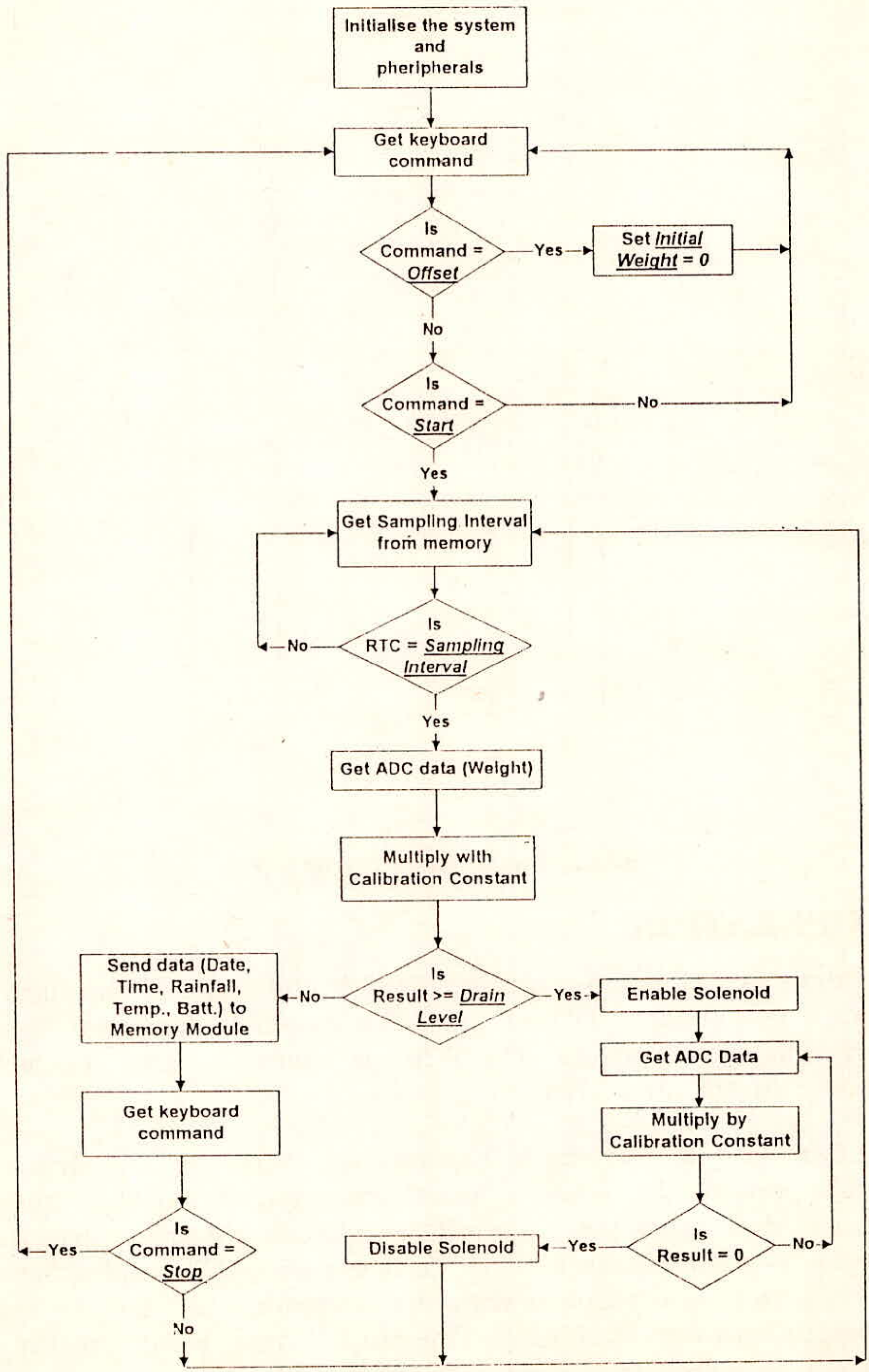

Fig.3 Flow Chart of Rainfall Measuring Using WRG

When the accumulated water in the inner container reaches 100mm of rainfall, the solenoid valve is operated. Again the ADC data is monitored, and when the accumulated water is completely drained, the solenoid valve is closed.

The complete system is halted on receiving a 'stop' command through the keyboard. In this case, the system is reset and waits for the keyboard command of 'start' and, then, the complete cycle is repeated. The system starts collecting data from the load cell and adds the present value to the previous reading.

4. FIELD TESTING AND RESULTS

A prototype of the instrument, using an available 10 kg load-cell and solenoid valve was fabricated in July, 1994. The operation and accuracy of the load cell based weighing mechanism was tested in the lab using an available imported date logger (model CR10 from Campbell Scientific, Inc.). The weighing mechanism alongwith the CR10 data logger was installed in the institute's observatory site. A Hitachi make SMF battery (12V, 7AH) and solar panel based battery charging system was used for the power supply.

During operation of the instrument, it was found that the solenoid valve malfunctioned once and did not return to the close position, thereby consuming a lot of battery capacity. The solenoid valve was then replaced by another valve with suitable specifications. When the solenoid valve is operated on reaching a threshold capacity (10 cm rainfall at present), the data logger keeps record of the measured data every second so as to account for the rainfall data during the draining period. After initial tests, this feature was introduced through an instruction to the data logger. The results are presented in Fig 4. Subsequently, an 8031 micro-controller based data logger was developed and tested for use with the sensor.

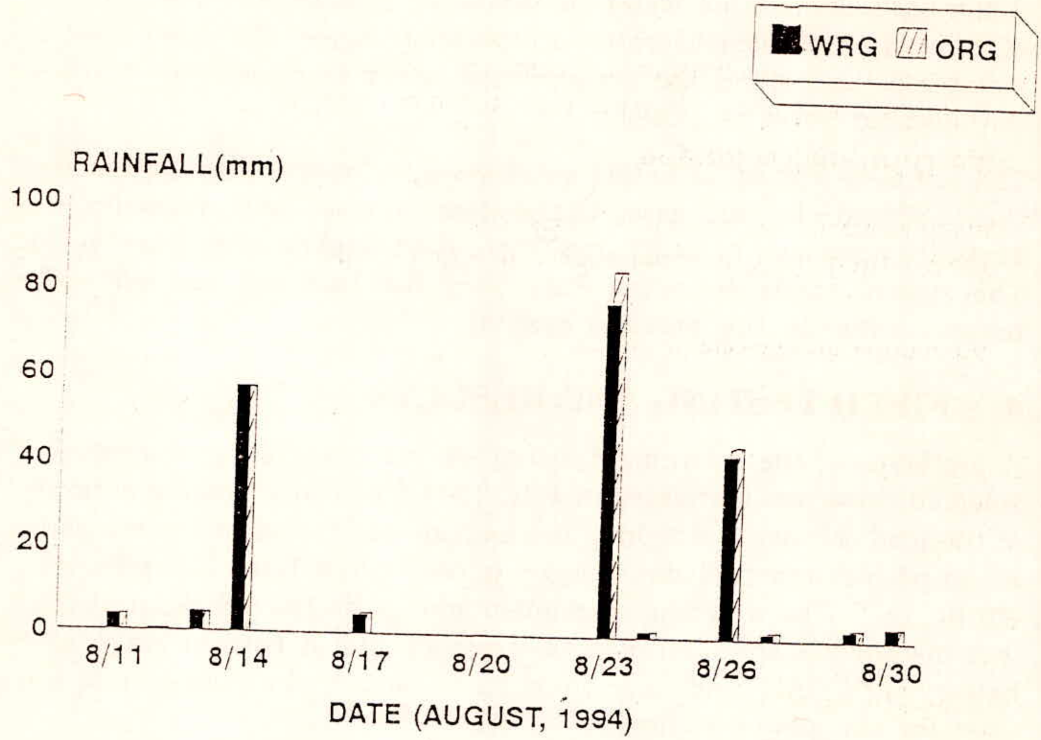

Fig. 4 Comparative Data of WRG and ORG

5. CONCLUDING REMARKS

A weighing type rain gauge with electronic data logging circuitry was designed and tested in the laboratory as well in the field. The complete unit is battery operated and consumes approximately 300mA during operation. The field testing confirmed an accuracy of better than 0.1mm of rain when compared with standard ORG and SRRG type rain gauges. In order to further improve the accuracy of the instrument, and to reduce its power consumption, the data logging circuitry is being re-designed. Special class wires, cables and connectors are being incorporated to minimize the effect of the environment on the instrument's operation.

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References

Ayala, K J 1991. The 8051 Microcontroller - Architecture, Programming and Applications, West Publishing Company, USA.

Bakkehol, S, Olen, K and Forland, E J, 1985. An Automatic Precipitation Gauge Based on Vibrating Wire Strain Gauge, Nordic Hydrology, 16, 193-202.

Kumar, B, Goyal, V C and Gupta, Sandeep, 1993. A New Automatic Rainfall Sensor, Proc. International Conference on his Hydrology and Water Resources , New Delhi, Dec. 20-22-1993.

Sandsborg, J, 1972. Precipitation Measurements With Various Precipitation Gauge Installations, Nordic Hydrology, 3, 80-106.

Sevruk, B, 1987. Point Precipitation Measurement : Why Are They Not Corrected?, Water for the Future, Hydrology in Perspective, Proc. of Rome Symposium, IAHS Publication No. 164.

Simic, M and Maksimovic, C, 1994. Effect of the Siphon Control on the Dynamic Characteristics of a Tipping Bucket Raingauge, Hydrological Sciences J1 ., 39, 1, 35-46.