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AN AUTOMATIC RAIN GAUGE WITH PULSE OUTPUT

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ABSTRACT

A new rain gauge is described which gives a suitable output for interfacing with a data logger or printer. Alternatively, for use in remote areas it can operate a counter. The model described is designed for use in tropical wet areas and gives one pulse for one millimetre of rain when a standard five inch diameter collector is used. It will perform satisfactorily at rates of rainfall up to 400 mm/h.

INTRODUCTION

In a comprehensive review of rain gauges Kurtyka (1953) lists some hundreds of devices employing floats, levers, pulleys, syphons and buckets dating back to a tipping bucket gauge attributed to C. Wren in 1662. From this review it is clear that most recording rain gauges operate either on the principle of the tilting bucket or on the storage and syphoning of a given volume of rain, each tilt of the bucket or each syphoning cycle operating a counter or a recording pen. Lucas (1970) has drawn attention to the deficiencies of these mechanical devices many of which have delicate operating mechanisms and critically balanced components subject to wear and frictional errors. With instruments of the syphoning type there is also a loss of recorded rainfall during the syphoning period which is a serious disadvantage in areas with heavy rates of rainfall. In the system devised by Lucas the collected water is metered by a peristaltic pump attached to an electric motor and a counter. However this is itself a rather complex system not suitable for continuous tropical use or for remote operation.

In the gauge described these disadvantages have been overcome while robustness in construction and simplicity in design have been retained by using a mechanically linked double valve operated by a solenoid. This enables a fixed volume of rainwater to be metered and then discharged through one valve. During the discharge period the second valve cuts off the inflowing water. The operation of the valves is controlled electronically through a switch module.

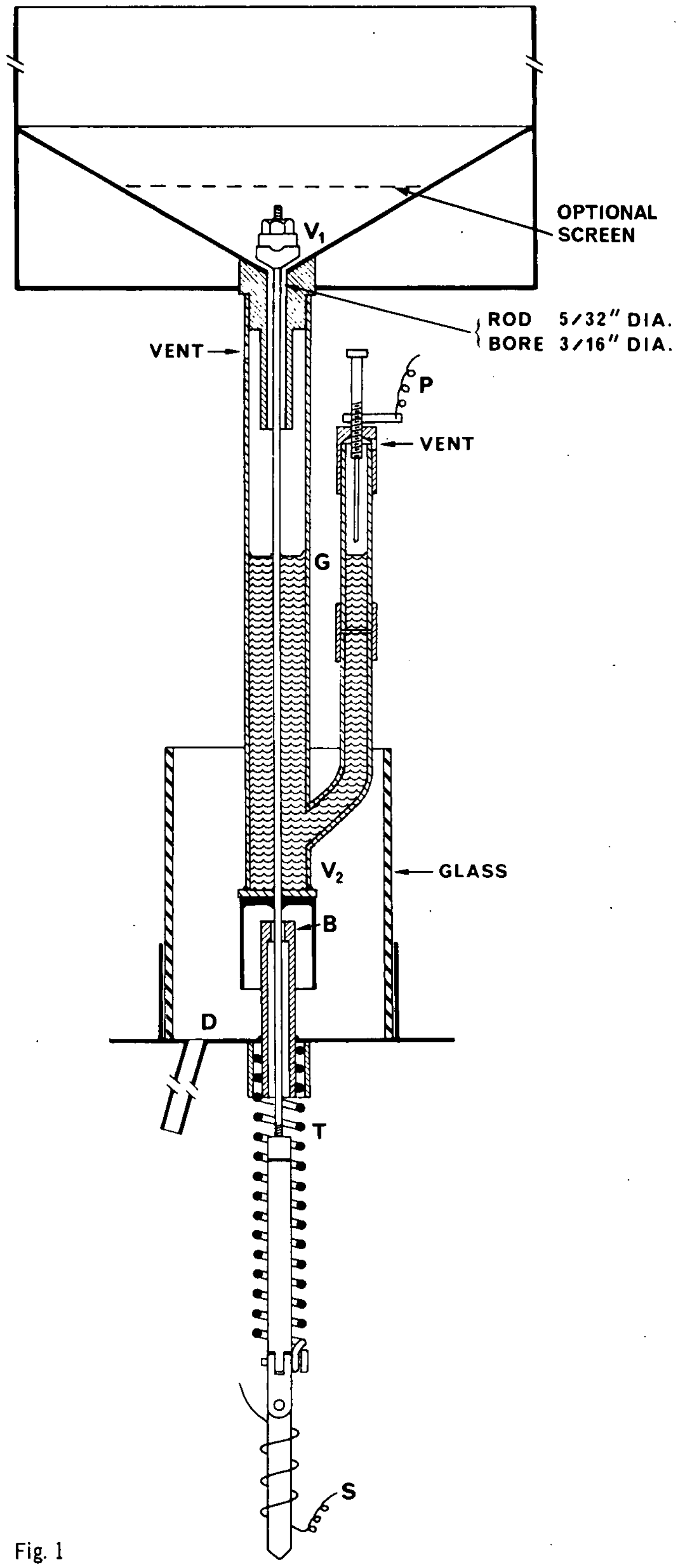
OPTIONAL
SCREEN
V_1
ROD 5/32" DIA.
BORE 3/16" DIA.
VENT
P
VENT
G
V_2
GLASS
B
D
T
S

Fig. 1

DESCRIPTION

Referring to Fig 1, a conventional collector delivers through valve V1 and a short tube into the metal main gauge body G, which is screwed to the base of the collector. Near the lower end of the gauge body is a parallel side arm terminating in a short section of glass tubing. This carries a metal cap with an adjustable probe of platinum wire. The gauge body is vented to the atmosphere by a small hole above the end of the delivery tube and the probe cap is similarly vented by a horizontal hole level with the top of the glass tubing.

A central rod through the delivery tube and coaxial with the gauge body carries two valves of silicone rubber; at the top a hemispherical valve V1 which seats on the collector funnel and lower down a flat valve V2 which closes the end of the gauge body. The valve rod extends down through a bearing B and is screwed to a coupling attached to the armature of a solenoid. The lower valve is normally held closed by a tension spring T attached to the coupling. The spring is close wound and with an extension of 10 mm provides a closing force of about 300 g (3N) on the lower valve. This has been found sufficient to seal the gauge against loss of residual water for long periods when no rain is falling.

The rainwater discharged when the lower valve opens is collected in a metal cup with a loosely fitting glass or plastic shield and flows away through a drain tube D. The metal cup carries the valve rod bearing which in turn also serves to anchor and centralize the spring. The bearing is counterbored to contact at the top only, thus making the alignment of the rod less critical. The bearing and lower mechanism are protected from water by an "umbrella" integral with the backing disc of the lower valve, this eliminates the need for a precision seal and avoids possible trouble from friction or leakage. The upper part of the rod bears very freely in the delivery tube and acts as a metering rod to control the flow of water into the gauge body during extremely heavy downpours. However, as the upper valve is effectively self-centring an adequate seal is provided at the collector during the short period when the gauge is emptying.

The level of water in the side arm gives a measure of the volume in the gauge independent of disturbances in the main body. The water level is sensed by the platinum probe which operates the solenoid through the switch module.

CONTROL AND PULSE CIRCUIT

When water contacts the probe the switch module must energize the solenoid for a sufficient time to allow the gauge body to drain. Experiment has shown that consistent results can be obtained with a pulse duration of 3 s, most of the water being discharged in the first second. The pulse, in addition to operating the solenoid, is also used to operate a counter, recorder or data logger. The rate of rainfall can be extracted from the record by the addition of a time base. A system found to be very convenient is to use a modified time punch which prints on a roll of paper the date and time for each unit of rainfall.

Suitable circuits for the switch module are shown in Fig 2. Circuit 2(a) is adequate when working from a 12 V battery for field use, while the modified circuit 2(b) is suitable for a power supply operated from the mains, being less sensitive to transients injected into the supply line from other equipment. Other circuits could be used based on the recently available Integrated Circuit Timers such as the NE 555.

Current drain for the switch module is 2mA continuous and approximately 1A during the 3 s pulse. Thus with the gauge set to give one pulse per millimetre of rain a battery of capacity 50 A/h should not drop below half charge after an annual rainfall of 8000 mm. The limitation would be the need for servicing and possibly a nickel-cadmium battery would be more convenient for field operation. The battery could be trickle charged from solar cells or a windvane generator.

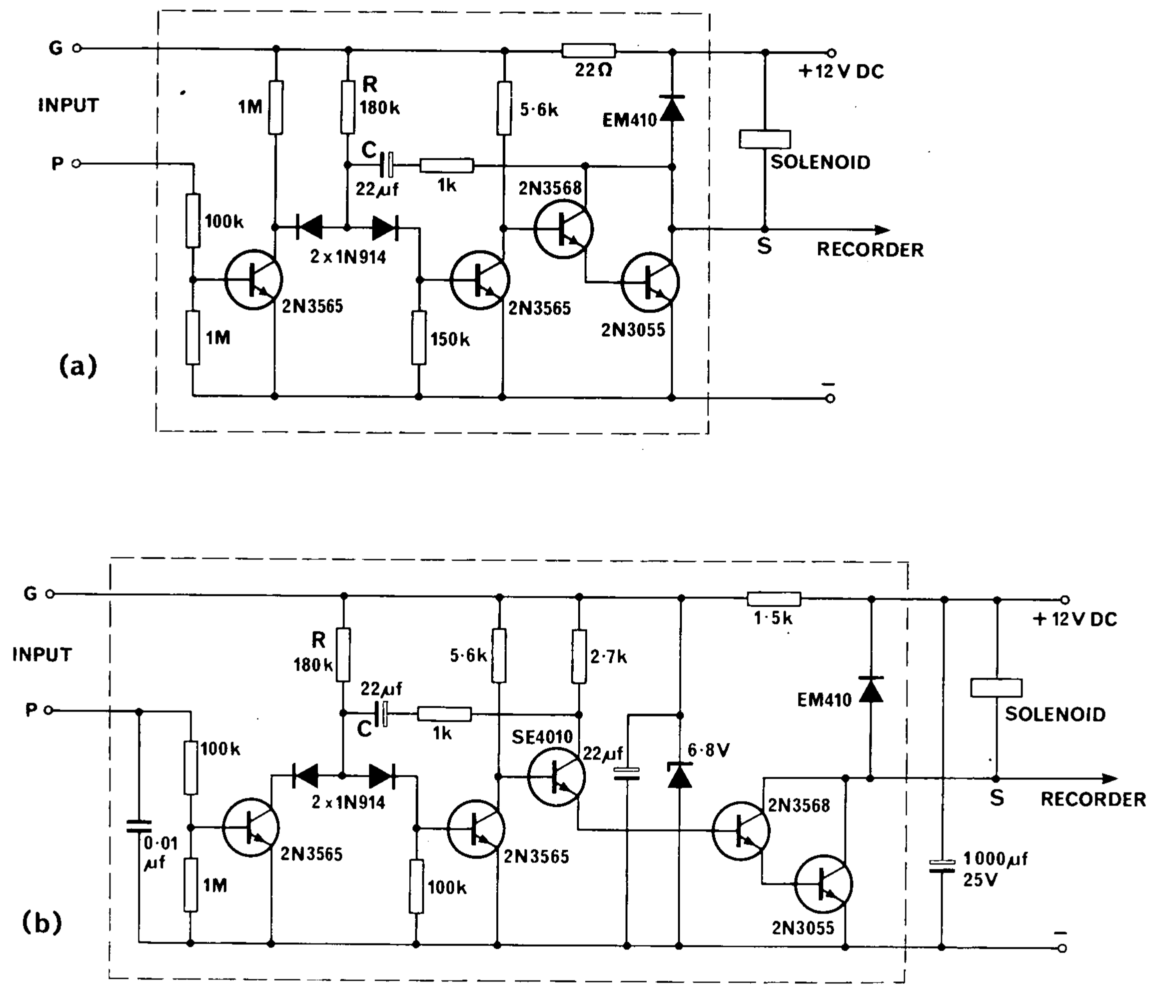

Fig. 2 Switch module. Components protected by epoxy resin.
Pulse duration determined by R & C.

INSTALLATION AND CALIBRATION

The solenoid operates efficiently when the screwed coupling on the valve rod is adjusted and locked so that the armature "bottoms" with the lower valve opened 3 to 4 mm. The top valve is then screwed to the end of the valve rod and locked, allowing 1 to 2 mm movement between the closing of the two valves.

Using a standard five inch diameter collector one millimetre of rain corresponds to a volume of 12.7 ml. By turning the screw the probe P is adjusted so that the gauge delivers this volume at each pulse, averaged over 20 or more pulses. For setting the probe it has been found convenient to run into the collector a volume of water corresponding to an integral number of pulses. Starting with the water level just under the probe the difference, if any, in the initial and final levels is noted and any fine adjustment is made if required.

In a typical calibration 250 ml of water was added from a standard flask and the final addition of 3 to 4 ml made from a burette. A difference of less than 0.5% was found between measured totals whether the water was added in separate drops over the course of an hour or added all at once. These conditions correspond to rates of rainfall of 20 mm and 450 mm per hour respectively, the latter figure being determined by the metering effect of the valve rod.

For calibration in the field a check vessel may also be placed under the drain tube.

DISCUSSION

The switch module is triggered when the external resistance falls below 5 MΩ and no difficulty has been experienced with the rainwater resistance path in the gauge as described. However, in evaluating a prototype gauge with a glass body using distilled water it was found necessary to decrease the conducting path with a piece of copper wire extending from near the valve rod to within a few millimetres of the probe. Experiments with a two electrode probe indicated that trouble might easily be experienced through bridging of the gap between the probes by water droplets or by a film of moisture across any insulating support. These effects should be borne in mind if it is attempted to modify the design by using a glass or plastic gauge body.

Another problem arose with the glass prototype, which has a separate upper cup fed by the collector. It was found that the volume corresponding to one pulse was independent of the rate up to rates of 250 mm/h but above this rate the volume per pulse decreases. For example at 400 mm/h the volume delivered was about 5% below the true volume. This was due to the sudden release of water from the upper cup when the valve opened resulting in surging and bubble formation in the side arm. This does not occur in the present gauge provided the clearance of the valve rod in the delivery tube is not increased unduly beyond that shown. This requirement limits the delivery rate and at extremely heavy rates of rainfall the rate recorded may be modified due to the temporary hold-up of water in the collector, without of course affecting the total amount of rainfall recorded. However, instantaneous rates of over 250 mm/h are likely to be met only rarely even in the high rainfall areas.

Evaporation losses from the gauge are small since it records each unit of rain instantaneously, while loss of residual water is minimised by having the small venting holes in a protected position under the collector body. For use in areas with a low rainfall the gauge as described could readily be set to operate at one point per pulse by using a ten inch diameter collector. As no high precision components are required and tolerances are not critical the rain gauge itself can be constructed easily from stock materials at minimum cost. The switch module uses only cheap and standard components and a simple pulse counter can be connected to give a system suitable for recording of total rainfall also at minimum cost.

The actual construction of the gauge is shown in Fig 3 while Fig 4 shows it set up in the field. All parts of the gauge are enclosed within a cylindrical extension of the collector making one self-contained unit easily mounted on a vertical stake or pipe.

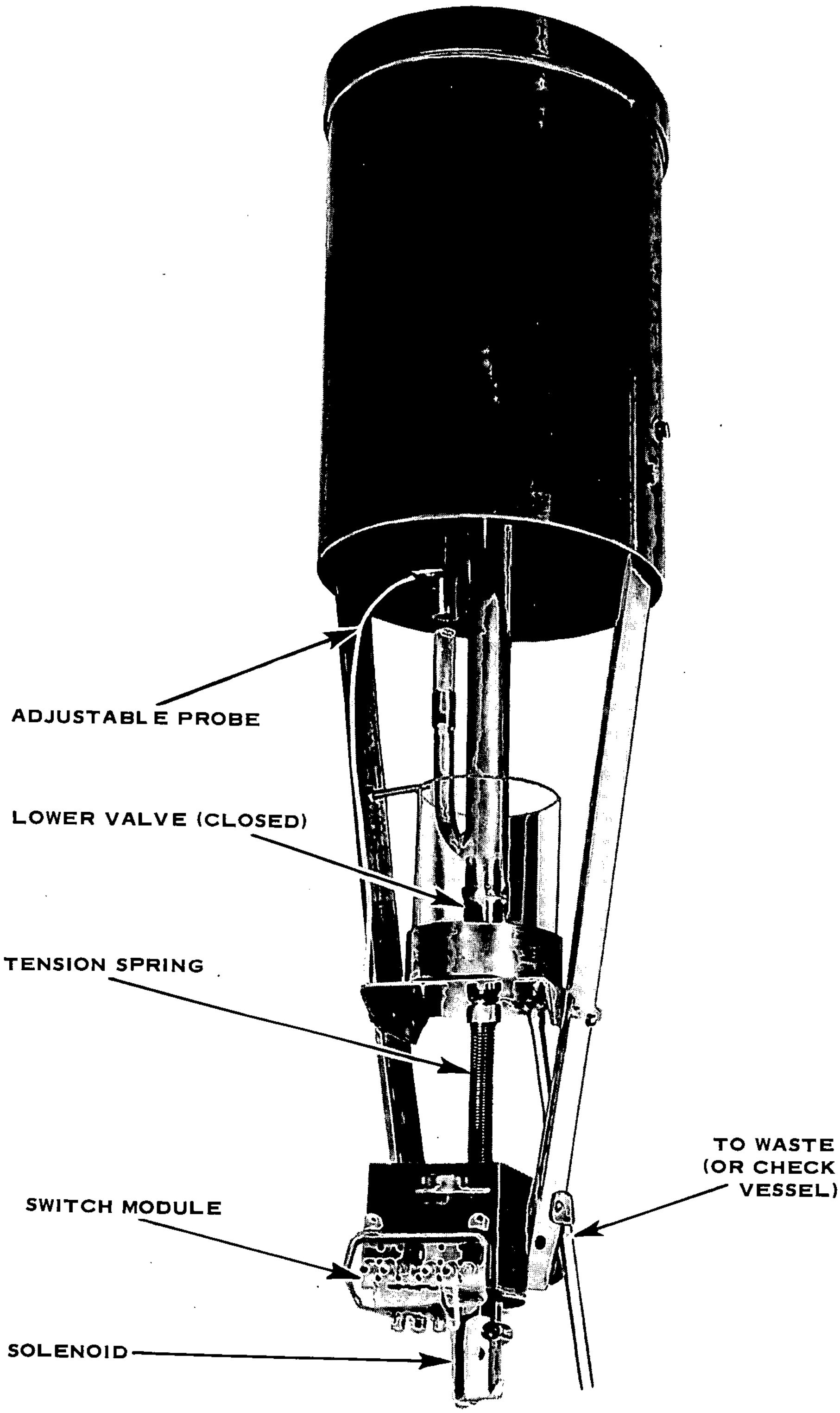

Fig. 3 Construction of the gauge.

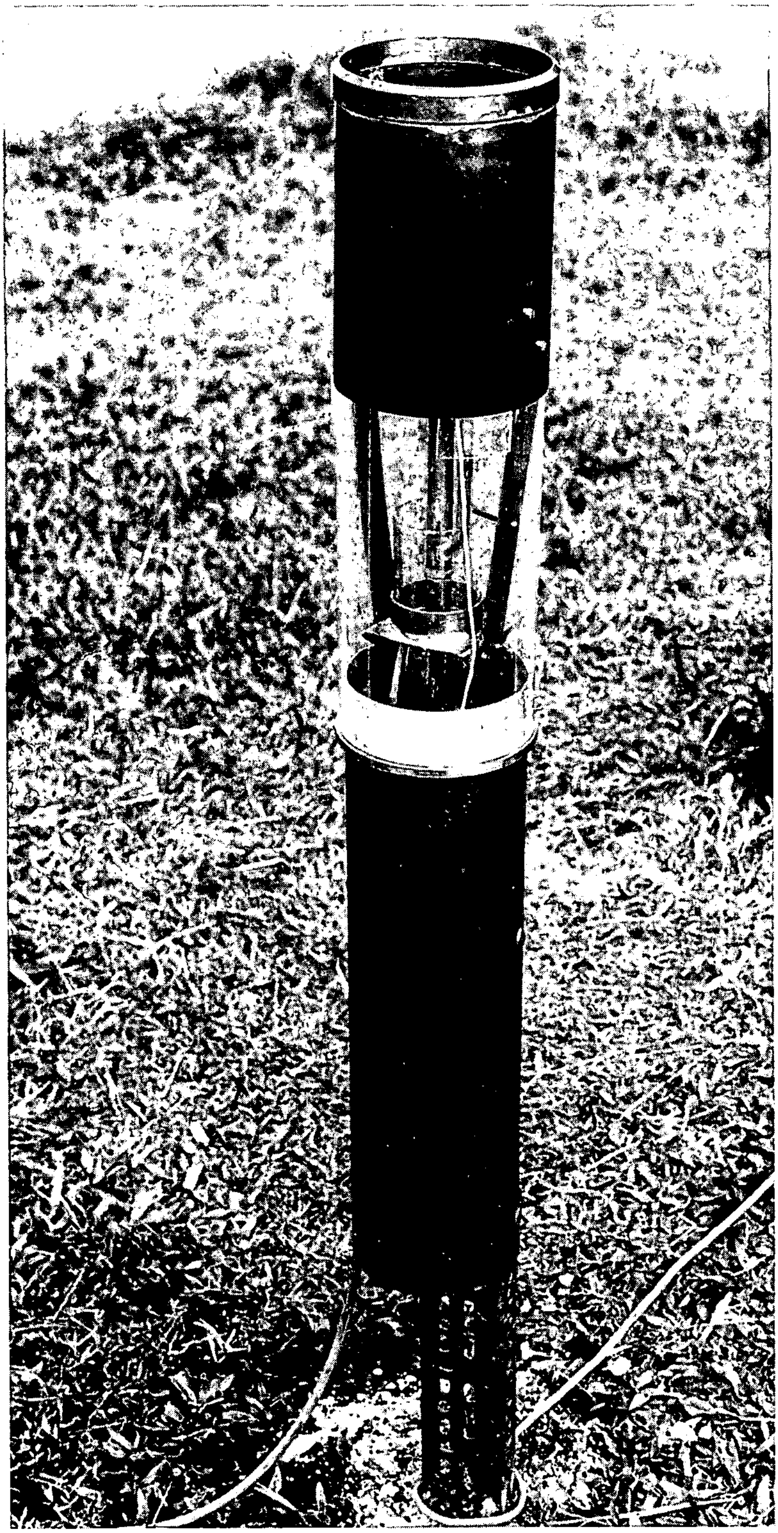

Fig. 4 Gauge set up in field

ACKNOWLEDGMENT

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