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COMPARISON OF RAINGAUGE PERFORMANCE UNDER TROPICAL CLIMATE CONDITIONS

1984

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Bahagian Parit dan Tali Air
Kementerian Pertanian
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COMPARISON OF RAINGAUGE PERFORMANCE UNDER TROPICAL CLIMATE CONDITIONS 1984

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SUMMARY

Rainfall is measured on the basis of the vertical depth of standing water that would accumulate on a level surface. Any open receptacle with vertical sides can serve as a raingauge but because of varying exposure and installation the measurements are not comparable.

Six raingauges of different exposure and installation, including the DID standard raingauge, were established at the Research Station of the Drainage and Irrigation Department, located 6 km east of Kuala Lumpur. Based on the data collected from these six raingauges, this study compares the effects of different raingauge exposure and installation on rainfall catch and also correlate the raingauge performance of different types of raingauges to the DID standard raingauge.

1. INTRODUCTION

The raingauge has a long and varied history and it is widely supposed that measuring rainfall is a simple task.

In their simplest form they are hollow cylinders which are open at one end. Funnels are added to aid in collecting and recording the catch. Such funnels also serve the purpose of minimising evaporation and are shaped to control splash.

However the exposure of a raingauge such as height above ground level, shape, diameter of orifice, material and even the method of installation can vary widely. Each of these factors, in addition to the prevailing climatic conditions will affect the actual catch of a raingauge.

Therefore it was considered essential to study the effects of exposure on rainfall catch under tropical climate conditions as experienced here in Malaysia.

To date, the Drainage and Irrigation Department (DID) maintains a total of about 1,050 rainfall stations in the whole of Malaysia. The DID standard raingauge is that of 203 mm (8 in) diameter orifice at 1.37 m (4 ft 6 in) above ground level and fitted with a standard windshield.

As such the study mentioned above also includes a comparison in raingauge performance of the DID standard raingauge to other types of raingauges. Such a study was undertaken by DID in Kuala Lumpur (Lat. 3° 9′ 20″ N, Long. 101° 45′ 00″ E).

2. OBJECTIVE

The objectives of this study are:

—to compare the effects of different raingauge exposure and installation on rainfall catch, and

—to correlate the raingauge performance of different types of raingauges to the DID standard raingauge.

3. INSTRUMENTS

Six raingauges of different exposure and installation were established at the Research Station of the Drainage and Irrigation Department, located 6 km east of Kuala Lumpur. A description of the raingauges is given below:

(a) Gauge A—a 127 mm (5 in) diameter orifice raingauge installed in a pit with a grid surround, and with the orifice at ground level (Fig. 1). This pit gauge is the recommended standard of the World Meteorological Organisation (WMO).

(b) Gauge B—a 203 mm (8 in) diameter orifice raingauge installed in a pit with a grid surround, and with the orifice at ground level (Fig. 1). This gauge replaces Gauge A above from July 1973 onwards.

(c) Gauge C—a 203 mm (8 in) diameter orifice raingauge installed with orifice at 1.37 m (4 ft 6 in) above ground level and fitted with standard windshield (Fig. 2). This is the DID standard raingauge.

(d) Gauge D—a 203 mm (8 in) diameter orifice raingauge installed with orifice at 1.37 m (4 ft 6 in) above ground level but without windshield (Fig. 2).

(e) Gauge E—a 203 mm (8 in) diameter orifice raingauge installed on a 2.13 m (7 ft) tower, with the orifice at 2.52 m (8 ft 3 in) above ground level and fitted with standard windshield (Fig. 3). This is a typical raingauge installation for telemetering flood forecasting stations in Malaysia.

(f) Gauge F—a 203 mm (8 in) diameter orifice raingauge placed on the ground and enclosed by a circular earth bund of diameter 3.05 m (10 ft) and 380 mm (15 in) high (Fig. 4).

A layout plan showing the position of each raingauge is given in Fig. 5

4. DATA

Daily rainfall totals were collected at each of these raingauges and the duration of rainfall records available is summarized in Table 3. For the purpose of analyses, weekly and monthly rainfall data were also prepared from a summation of the daily rainfall totals. However in the analyses of daily rainfall totals, only days with rain were considered.

5. ANALYSES

In this study, analyses were purely statistical in nature involving techniques such as significance tests, regression and linear correlation.

In studying the effects of different raingauge exposure and installation on rainfall catch, the following comparisons were made:

(i) Gauge C and Gauge D
to study the effect of windshield on rainfall catch.

(ii) Gauge C and Gauge E
to study the effect of height on rainfall catch.

In each comparison, the two sets of data were subjected to Fisher's F-test to test the homogeneity of the two variances, the result of which would decide whether the Normal test, Student's t-test or the d-test would be used to test the homogeneity of the means of the two sets of data. A significance level of 95% was used throughout.

It has been found from Fisher's F-test that the variances for all the corresponding two sets of data were homogeneous. All the data sets showed a skewed distribution which did not favour the use of the Normal test. As such for testing the homogeneity of the means, the Students's t-test was used for all comparisons.

For the second objective, the raingauge performance of the DID standard raingauge (Gauge C) was compared to the other gauges (Gauges A, B, D, E, F) respectively.

In each comparison, a regression line was first obtained for the two sets of data. The regression line can be expressed in the form of a general equation:

$$Y=A+BX$$

where Y is the rainfall catch of the gauge concerned
X is the rainfall catch of the DID standard raingauge
A is the intercept
B is the slope

The intercept (A) and slope (B) of this regression line were then tested using the t-test for a confidence level of 95%.

6. RESULTS

Results of the analyses are given as follows:

Table 4: gives the results of the tests of homogeneity of means and variances using the F-tests and t-tests.

Table 5: gives the slope, intercept and correlation coefficient of the regression lines of the DID Std Gauge and the other gauges respectively.

Table 6: gives the results of the t-test on the slope and intercept of the regression lines.

7. COMMENTS

From Table 4, by comparing the t or d statistic with their critical values for α = 95% for all rainfall durations, it is observed.

(i) that the use of a windshield has a significant effect on the rainfall catch. *The Gauge without a windshield records a lower catch than that with a windshield;*

(ii) that rainfall catch *measured by a gauge at 2.52 m (8 ft 3 in) is significantly lower than that measured at 1.37 m (4 ft 6 in) above ground level.*

From Table 6 it is observed that in general a good correlation exists between the raingauge performance of the different gauges with the DID standard raingauge for all three rainfall durations, at a confidence level of 95%. However correlation of daily rainfall data of the raingauge at 2.52 m (8 ft 3 in) with the DID standard gauge is poor, although the weekly and monthly data correlate well.

For all the different raingauges that correlate well with the DID standard raingauge, the regression equation $Y=A+BX$ can be used to convert the rainfall catch obtained from the various raingauges mentioned to the expected rainfall catch had a DID standard raingauge been installed.

Example: Given that the monthly rainfall total measured by a raingauge with orifice at 2.52 m above ground level is 350 mm, to find the expected monthly rainfall total (X) measured by a DID standard raingauge.

From Table 5 $A = 1.8976$
From Table 5 $B = 0.9752$
If given $Y = 350$ mm

Equation
$$Y = A+BX$$
$$X = (Y-A)/B$$
$$= (350-1.8976)/0.9752$$
$$= 357 \text{ mm}$$

Although the equation $Y=A+BX$ gives the best correlation between two given sets of data, it becomes unrealistic when either $X=0$ or $Y=0$. The ideal regression line should pass through the origin (i. e. $A=0$) and the centroidal point $(\bar{X}, \bar{Y})$. The slope of this regression line is then given by $B' = \bar{Y}/\bar{X}$. The adjusted regression equation is:

$$Y=B' X$$

This adjusted equation should be used in preference to the one mentioned earlier. Values of the adjusted slope B′ are given in Table 1.

TABLE 1—VALUES OF ADJUSTED SLOPE B′

Correlation between DID standard raingauge (Gauge C=X) with	*B′* Daily Totals	Weekly Totals	Monthly Totals
127 mm Pit Gauge (Gauge A=Y)	1.0202	1.0203	1.0214
203 mm Pit Gauge (Gauge B=Y)	1.0053	1.0027	1.0019
203 mm Gauge at 1.37 m without windshield (Gauge D=Y)	0.9930	0.9918	0.9904
203 mm Gauge at 2.52 m with Windshield (Gauge E=Y)	0.9835*	0.9837	0.9836
203 mm Gauge with Circular earth bund (Gauge F=Y)	0.9985	0.9960	—

* Poor correlation (*see* t-statistic in Table 6)

Referring to the same example

From Table 1, $B'=0.9836$
If given $Y = 350$ mm
Therefore
$$X = Y/B'$$
$$= 350/0.9836$$
$$= 356 \text{ mm}$$

Based on the results in Table 1, the percentage difference in rainfall catch between the DID standard raingauge and the other raingauges was calculated and shown in Table 2.

Table 2—PERCENTAGE DIFFERENCE IN RAINFALL CATCH

	Percentage Higher (+) or Lower (–) than DID Standard Raingauge (Gauge C)		
	Daily Totals	*Weekly Totals*	*Monthly Totals*
127 mm Pit Gauge (Gauge A)	+2.02	+2.03	+2.14
203 mm Pit Gauge (Gauge B)	+0.53	+0.27	+0.19
203 mm Gauge at 1.37 m without windshield (Gauge D)	−0.70	−0.82	−0.96
203 mm Gauge at 2.52 m with Windshield (Gauge E)	−1.65	−1.63	−1.64
203 mm Gauge with Circular earth bund (Gauge F)	−0.15	−0.40	—

This study was carried out based on data collected from the different raingauges located at the Research Station of the Drainage and Irrigation Department in Ampang, Kuala Lumpur, on the west coast of Peninsular Malaysia. It is recommended that similar studies be carried out in other climatic regions in the country such as the east coast of Peninsular Malaysia, Sabah or Sarawak, to verify the results of this study.

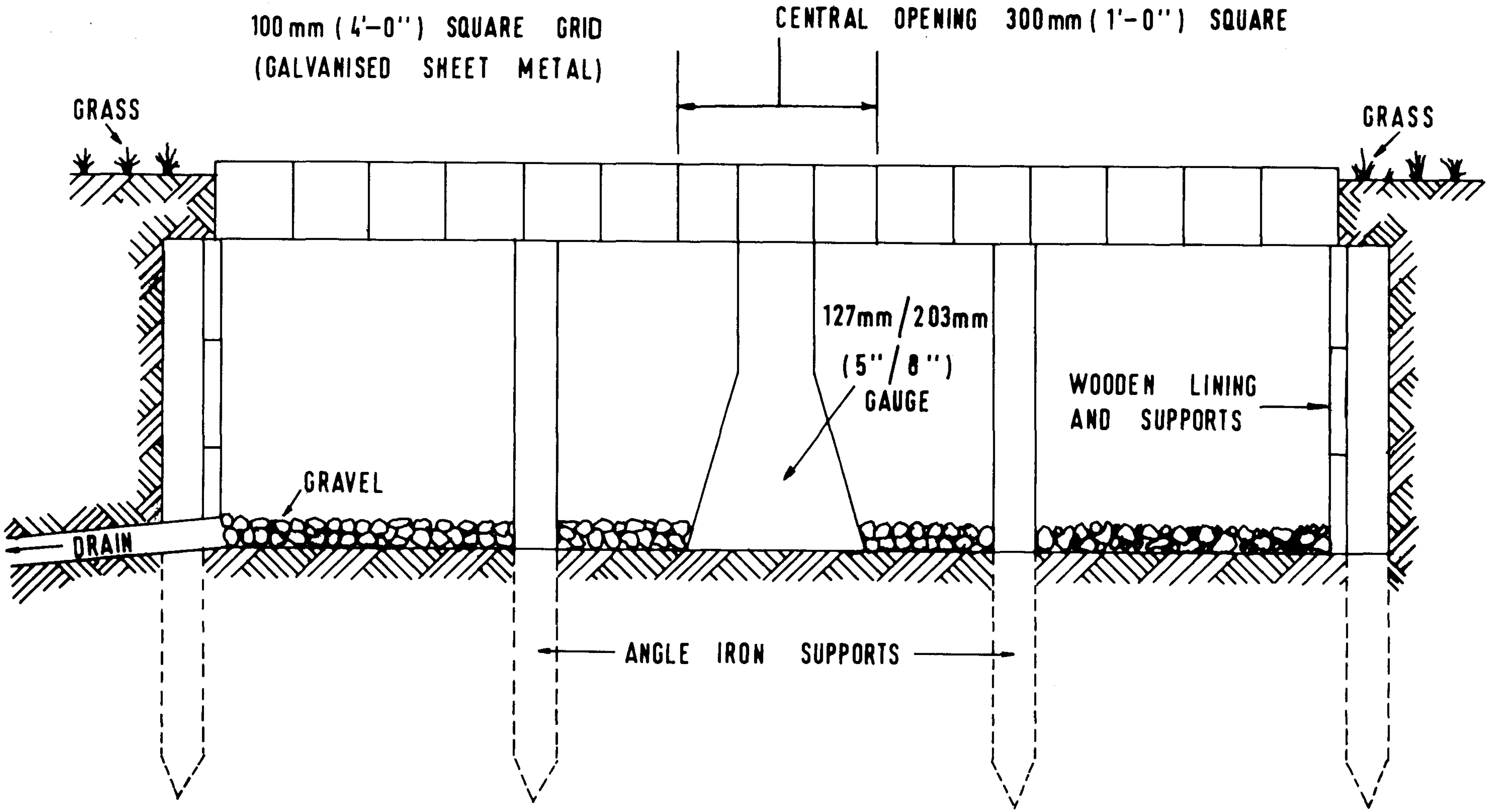

FIG. 1:- WMO REFERENCE PIT RAIN GAUGE (Gauge A / Gauge B)

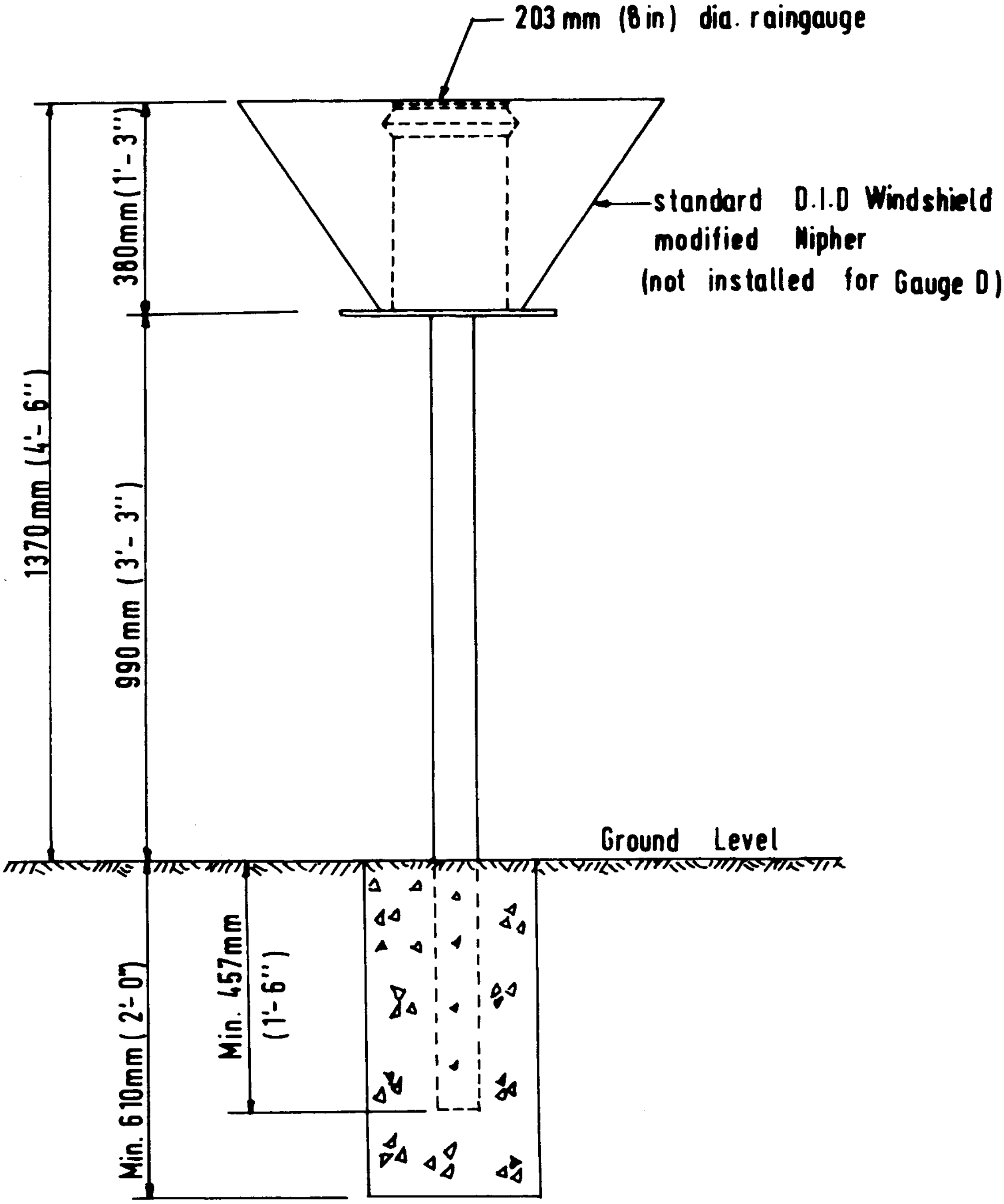

FIG. 2 :- STANDARD DID 203mm (8 in) MANUAL RAINGAUGE

(Gauge C / Gauge D)

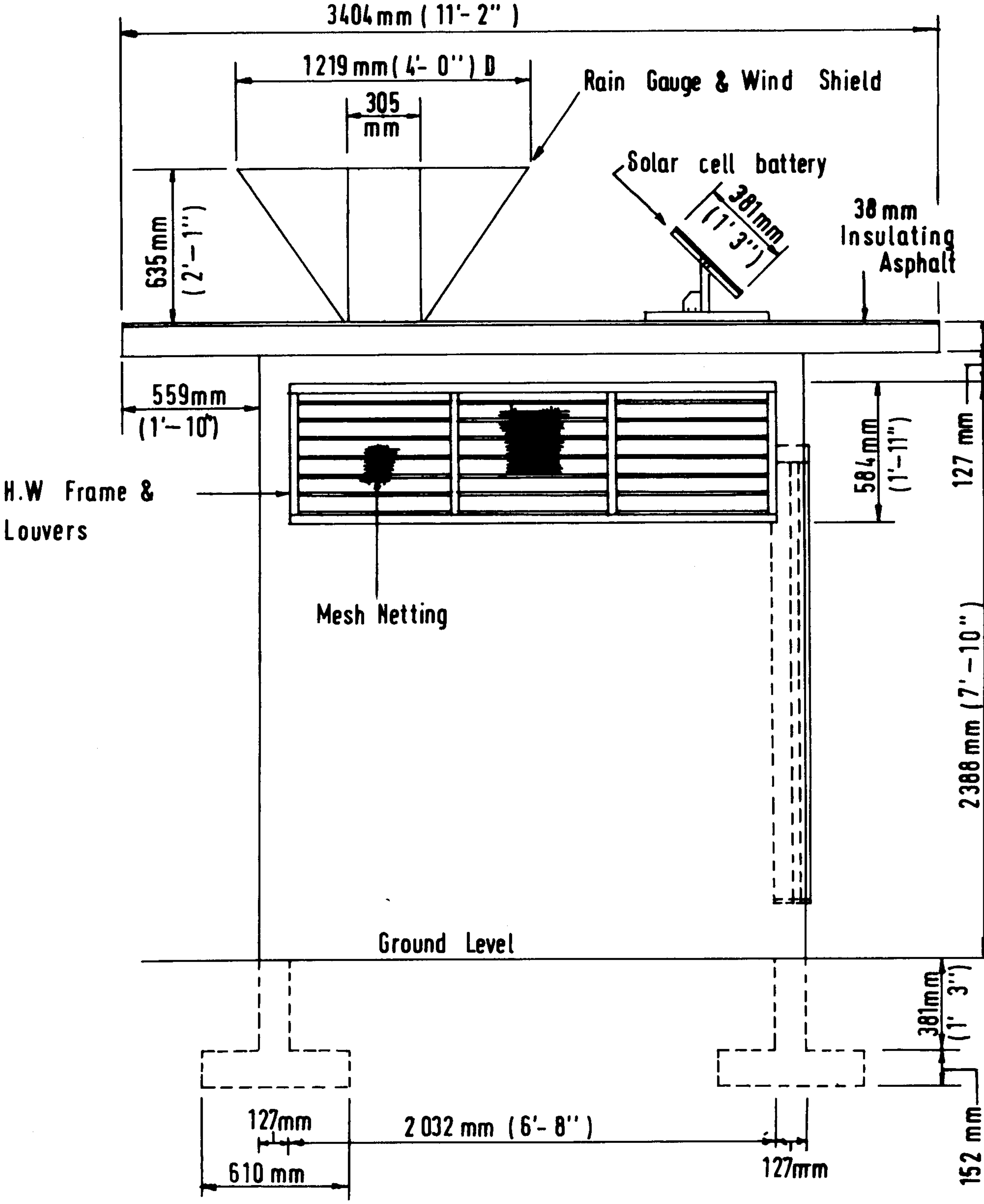

FIG. 3 :- RAINGAUGE INSTALLED ON ROOFTOP OF TELEMETERING STATION

(GAUGE E)

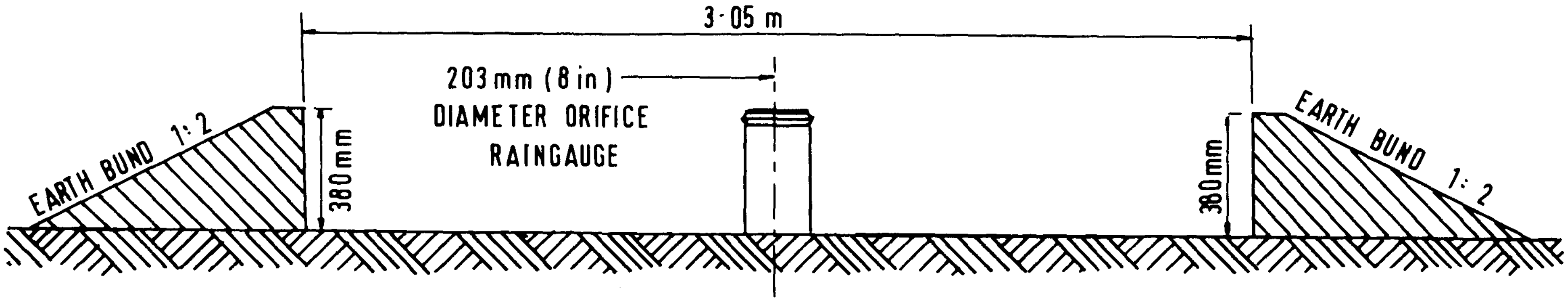

FIG: 4 :- A 203 mm (8 in) DIAMETER ORIFICE RAINGAUGE PLACED ON THE GROUND AND ENCLOSED BY A CIRCULAR EARTH BUND OF DIAMETER 3·05m (10 ft) AND 380 mm (15in) HIGH (GAUGE F)

TABLE 3—DURATION OF RAINFALL RECORDS

Gauge A - 127 mm (5in) gauge installed in pit with grid surround

Gauge B - 203 mm (8in) gauge installed in pit with grid surround

Gauge C - 203 mm (8in) gauge with windshield, 1·37m (4ft. 6in.) above ground level

Gauge D - 203 mm (8in) gauge without windshield, 1·37m (4ft. 6in.) above ground level

Gauge E - 203 mm (8in) gauge with windshield, 2·52 m (8ft. 3in.) above ground level

Gauge F - 203 mm (8in) gauge placed on the ground and enclosed by circular earthbund

YEAR	1972			1973												1974					
MONTH	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
GAUGE A	■	■	■	■	■	■	■	■	■												
GAUGE B										■	■	■	■	■	■	■	■	■	■	■	■
GAUGE C	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
GAUGE D											■	■	■	■	■	■	■	■	■	■	■
GAUGE E						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
GAUGE F						■	■	■	■												

TABLE 4—TESTS OF HOMOGENEITY OF MEANS AND VARIANCES

Comparison of Gauge Exposure and Installation	Test	F and t Statistics		
		Daily Totals	Weekly Totals	Monthly Totals
		X X_{cr}	X X_{cr}	X X_{cr}
Windshield	F	1.02<1.20	1.02<1.68	1.03<3.18
Gauge C—Gauge D	t	3.94>1.96	3.21>2.02	2.61>2.26
Gauge Height	F	1.04<1.10	1.04<1.50	1.05<2.40
Gauge C—Gauge E	t	6.27>1.96	4.83>2.00	3.86>2.13

α =95%

TABLE 5—RESULTS OF REGRESSION ANALYSIS

Correlation between OTD Std. Raingauge (Gauge C = X) with		Intercept, Slope and Correlation Coefficients		
		Daily Totals	Weekly Totals	Monthly Totals
127 mm Pit Gauge (Gauge A=Y)	A	0.0099	0.1264	2.3774
	B	1.0190	1.0225	1.0122
	R	0.9996	0.9996	0.9998
203 mm Pit Gauge (Gauge B=Y)	A	−0.0061	0.2251	1.1923
	B	0.9962	0.9984	0.9964
	R	0.9998	0.9996	0.9996
203 mm Gauge at 1.37 m. without windshield (Gauge D=Y)	A	0.0225	0.0335	1.5860
	B	0.9902	0.9911	0.9834
	R	0.9998	0.9999	0.9998
203 mm Gauge at 2.52 m. (Gauge E=Y)	A	−0.0377	0.1182	1.8976
	B	0.9798	0.9815	0.9752
	R	0.9995	0.9996	0.9997
203 mm Gauge with Circular earth bund (Gauge F=Y)	A	0.0036	0.3734	—
	B	0.9981	0.9894	
	R	0.9997	0.9998	

A = intercept, B = slope, R = correlation coefficient
* Poor correlation (see t-statistic in Table 6)

TABLE 6 - TEST OF INTERCEPT AND SLOPE OF REGRESSION EQUATIONS

Correlation between DID Std. Raingauge (Gauge C) and		t-tests on Intercept and slope		
		Daily Totals	Weekly Totals	Monthly Totals
		$t < t_\alpha$	$t < t_\alpha$	$t < t_\alpha$
127 mm Pit Gauge	A	0.23<1.96	−0.36<2.03	1.01<2.37
Gauge A	B	0.54<1.96	0.44<2.03	−1.06<2.37
203 mm Pit Gauge	A	0.22<1.96	0.80<2.01	0.56<2.23
Gauge B	B	0.44<1.96	1.08<2.01	−0.62<2.23
203 mm Gauge at 1.37 m without windshield	A	-0.83<1.96	0.18<2.02	0.86<2.31
Gauge D	B	1.69<1.96	−0.25<2.02	0.93<2.31
203 mm Gauge at 2.52 m ..	A	1.20<1.96	0.53<2.00	1.13<2.15
Gauge E	B	2.40<1.96	0.60<2.00	−1.24<2.15
203 mm Gauge with Circular Earth Bund	A	0.07<1.98	1.06<2.13	
Gauge F	B	0.14<1.98	−1.27<2.13	

A = intercept. B = slope. α = 95%

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