PRECIPITATION MEASUREMENT IN NEW ZEALAND REPRESENTATIVE AND EXPERIMENTAL BASINS

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ABSTRACT

This paper discusses the manual and automatic instrumentation of precipitation measurement on experimental and representative basins, as carried out in New Zealand by the Ministry of Works. The performances of a sample of available recording precipitation gauges are compared and the optimum resolution of time and rainfall for the different purposes and climatic situations discussed.

INTRODUCTION

Water resource investigations in New Zealand conducted by the Ministry of Works were, until 1960, concerned mainly with the measurement of stream flow. These investigations have now been extended to include the study of the hydrological characteristics in a network of representative and experimental basins (Toebes, 1965). The installation and servicing of precipitation gauge networks are fundamental to these investigations. The accurate measurement of precipitation in a country where the prime factor governing climate is the steep relief, and the annual precipitation varies between 10 and 400 inches over distances less than 100 miles, is proving difficult. Extremes of temperature and the importance of snowfall in certain basins call for the use of elaborate recording equipment. Economic considerations dictate the use of simplified recording equipment where possible — and hence the desirable standardization of equipment cannot be achieved.

MANUAL GAUGES†

The manual sampling of precipitation is carried out by means of the standard British gauges of 5-inch diameter orifice and of 8-, 27- and 50-inch capacity. These gauges are essentially suited to a mild climate because (although the latter two are fitted with a rubber hose which effectively prevents frost-induced mechanical

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† The mention of any particular brand of gauge in this paper does not necessarily imply the preference of the New Zealand Ministry of Works.

damage) their performance in a severe climate, either because of snow blockage and possible freezing of the funnel-shaped orifice or because of snow being blown out of the funnel, must be unsatisfactory. When freezing of the contents takes place, the withdrawal of the rubber hose and subsequent removal of ice requires the application of controlled heat — a facility seldom available. When buried in soil to the standard height of one foot above ground level, these gauges, protected by the outer insulating container, seldom freeze, but at the orifice height of one foot the gauge is easily buried in snow. The rain catch resulting from the melting of the snow covering the raingauge is not inconsiderable and is frequently recorded in good faith as a measure of precipitation; this is particularly true in regions where snowfall and melt tend to be cyclic occurrences throughout the winter season.

Storage Gauges

The standard 27- and 50-inch capacity gauges, as distinct from the daily read 8-inch gauge, are essentially storage gauges. Grant (1960) pioneered the use of an alternative storage gauge which when fitted with a 5-inch orifice has a capacity of either 150 or 180 in. These gauges, consisting of modified milk cans (two types) and described as Type C gauges, are fitted with an expanding neck which presents the minimum of obstruction to the entry of solid precipitation. The gauge has also been shown (Grant, 1962) to withstand freezing of the contents down to temperatures of minus 14°F. Excessive evaporation is prevented by addition of a light, pure mineral oil.

The Type C gauge is used to extend the basin precipitation network to remote areas where servicing periods, because of access difficulties, may have to be extended up to six months. This gauge has not found favour in some districts because of its weight and lack of sensitivity. (The rainfall depth scale is approximately 1:8.) Dipstick measurements must be taken with extreme care so as to avoid large percentage errors particularly where rainfall quantities are small. Grant (pers. comm.) now employs 1 in. $\times \frac{1}{4}$ in. alloy dipsticks calibrated to read in inches; it is possible to obtain a reasonably accurate reading to the nearest 50 points provided the initial position on the concave base of the container can be relocated at each reading. Palmer[1] found for the West Coast humid climate, where frost was unimportant and where gauge siting required unreasonable manual transport, that a simple light copper cylindrical gauge of 8-inch diameter and 5-inch orifice diameter was satisfactory. The height of the gauge is based on the expected rainfall (200 to 400 in. per annum).

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Chandler,[2] for the South Island East Coast where rainfall was low and frost protection important, made a return to the double container type of buried gauge, but eliminated the octapent type funnel. This gauge has certain attractive features, particularly the ease of access to the 8-inch diameter container which, with a 5-inch orifice, has a capacity of 37.5 in. The addition of 40 points of Shell light separator oil in the summer season is recommended in order to reduce evaporation. A graduated half-inch aluminium angle is employed as a dipstick.

Snow Storage Gauges

Where snow is deep a gauge sufficiently high to avoid burial in snow must be used. Gillies (1964) in the Fraser Basin (Otago) employed 5-inch diameter stand pipes of varying heights up to 12 ft, complete with Alter shields. Because of the blizzard conditions, icing over of the shields took place and considerable quantities of snow lodged in the pipes and failed to reach the anti-freeze solution. The small diameter of the stand pipes and the low temperatures contributed to the snow blockage.

The Snowy Mountains Authority of Australia has successfully employed a 1-foot diameter pipe with an 8-inch orifice, reading the water level in the high stand pipe by means of a flexible hose fixed at a low level to the stand pipe. The hose outlet, normally positioned at a high level, can be lowered until the water becomes visible. The level of the water in the hose is then measured against a gauge board mounted on the pipe. This reading method can be successful only if the precipitation is retained in the liquid form and if the hose pipe is kept dry by covering the mouth piece. The procedure adopted for the addition of anti-freeze is to charge the stand pipe initially with 3 gallons of 100% ethyl glycol and thereafter to recharge with one gallon of ethyl glycol at the specific gauge heights of 69, 92, 115 and 138 in. Some authorities contend that the solution of water and anti-freeze will, unless artificially agitated, tend to separate out with the water remaining on top. As a preventative measure nitrogen may be bubbled through the mixture. Freezing of the surface water defeats the purpose of the anti-freeze by preventing the snow from coming into contact with the anti-freeze mixture.

Shields

A Shasta-type shield mounted at a level two inches below the gauge orifice is claimed to increase the catch substantially, giving better results, at least for snow, than does the Alter shield.

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(2) Engineer-Hydrologist, South Canterbury Catchment Board.

RECORDING PRECIPITATION GAUGES

Recording gauge operation, performance, scales and relative accuracy are reviewed as an approach to establishing the specifications of the gauge type or types best suited to the experimental and representative basin research projects of the New Zealand Ministry of Works.

Operation

The operations of the simpler precipitation recorders are governed by four main principles — the tipping bucket, the float and syphon, the float and storage tank, and the storage tank weighing.

Some examples of instruments well known in this country which employ these principles are:

Tipping bucket — Negretti Zambra weekly, the Pyrox Sumner and the 95-day Casella.

Float and syphon — The Dines daily tilting syphon, the Casella weekly natural syphon and the Lambrecht weekly and monthly natural syphon.

Storage tank weighing — The Fischer and Porter punched tape recorder — a single unit is on trial use in this country.

Float and storage tank — The float and storage tank method, as yet not employed in New Zealand, is extensively used in other countries.

Performance

Both the tipping bucket and the float and syphon principle operate most satisfactorily under temperate climatic conditions. When exposed to snowfall the best that can be expected is a delayed response when melting of the snow quantities which have remained ~~The float and storage tank method~~, within the orifice area occurs. It is not difficult to prove also that, when exposed to high intensities, these gauge types, because of syphoning time (12–15 sec.) or tipping time (0.2 sec.) must underestimate. (A check gauge provides a correction factor for these errors but the correction is applied generally rather than in the area of the record where the underestimation occurs.) The good qualities of the tipping bucket include unlimited capacity, freedom from frost problems, and adaptability to electronic methods of recording or telemetering. For this reason the gauge is extremely popular in countries where snowfall is not important.

Recorders electronically applying the tipping bucket principle are the Pyrox Sumner gauge and the Barker gauge of Australia. Its use as a triggering device with the Limpet Logger is proposed in England (Strangeways et al., 1965).

The float and syphon principle gauge is also of unlimited capacity but is highly susceptible to float damage unless protected against severe frosts. Dribbling without positive syphoning in low-intensity rainfalls is an unfortunate feature successfully overcome by the positive syhoning of the Dines tilting syphon recorder; clock stoppage is a fault common to both these recorder types but is particularly evident when a strip chart is employed with the float and syphon gauge.

The strip chart is employed to extend the operational period so as to take advantage of the unlimited capacity. It is noticeable that a strip chart recorder on trial in the workshops will perform faultlessly but when exposed to temperature variations, moisture and grit, the chart will foul or the clock will repeatedly fail in operation. Gear train irregularities in the lower-priced recorder, because of inferior workmanship, are a contributing feature.

The weight-driven clock is frequently employed in preference to the spring clock because of its much greater torque, and hence greater ability to overcome the variable loads encountered when a strip chart with its accompanying slipping clutch is used.

A weight-driven clock requires space for the weight to drop; this weight drop is normally at the rate of five feet per month. The total depth requirement could be troublesome where two or three months unattended recording is desired.

The storage tank weighing gauge is best suited to the measurement of solid precipitation because it is theoretically unnecessary for the precipitate to be in the liquid form. Where up to six feet of snow may fall in a single storm, however, the necessity to employ a liquefying agent to convert snow to water is obvious — otherwise the capacity requirements of the gauge become too great. The weight of the catch is a factor which limits the gauge capacity. The weighing mechanism is of the precise balance type and is therefore unsuited to the support of large quantities of liquid. Both a dump valve and a syphoning system have been proposed for use with this gauge, but it is difficult to see how such mechanisms could be successful in sub-zero temperatures. Moreover, it would be unfortunate to reintroduce the syphoning time error, greatly increased in this case because of the comparatively large quantities of liquid involved. The inertia of a large volume of liquid is also an important factor limiting capacity because of the increased reaction to wind-induced atmospheric pressure variations. The best approach to increased capacity is simply to reduce the orifice area at the expense of sensitivity.

The Fischer and Porter weighing gauge, installed on a trial basis at an altitude of 4,700 feet in the central South Island, has operated well. At this elevation frequent winter snowfall is a feature and temperatures regularly go below 20°F. There were some teething troubles associated with tape advancement and battery failure but these faults could not be associated with failure to withstand the severe climatic environment. The instrument has a capacity of only 20 inches which is unfortunate, as otherwise it can operate continuously for three months, recording to the nearest 10 points of rainfall.

The float and storage tank gauge, probably the most versatile and expensive, is particularly reliable because of the employment of the well tried recording equipment associated with water level recorders.

The Snowy Mountains Authority of Australia is successfully employing the float and storage tank principle to operate a telemetering gauge in sub-Arctic surroundings.

The following features are incorporated in the assembly: gas heating — thermostatically controlled — to prevent capping of the orifice by ice and blizzard driven snow, a Shasta wind shield reported to improve the solid precipitation catch by 25%, a Stevens Type A35 water level recorder and a Stevens Type C telemetering sender which transmits a pulse for each 5 points of precipitation (0.1 in. on the chart).

Scales (Rainfall Depth and Time)

The resolution of rainfall depth and time must be sufficiently accurate for the purpose intended — micro-studies where absolute relations are examined will require a higher degree of resolution than will be necessary for the larger basins where a precipitation index only will be required.

Rainfall depth scales for recorders employing the float and syphon and the tipping bucket principles are more than adequate, because mechanically it is convenient. (For the float and syphon gauges the rainfall scale is equal to the area of the orifice divided by the area of the float chamber.)

The Dines daily recorder with float and tilting syphon has a rainfall depth scale of 10:1. The chart width is two inches (50 mm) recording 20 points of rain (5 mm) for a single traverse of the chart.) Thus one-tenth of an inch of chart corresponds to one point of rain, permitting rainfall amounts of less than half a point to be read. This degree of resolution has little practical significance and is unnecessary for most purposes.

The storage tank weighing gauge is handicapped, in the case of the chart recorders, by the limited chart height available (12 in.) and the precise balancing mechanism employed for weighing is not suited to the support of large quantities of precipitation. Rainfall depth scales are therefore at best 1:1 for a capacity of 12 in., and for capacities in the order of 60 in. the rainfall scales are 1:5. Chart interpretation accuracy is to about 5 points of rainfall for the 1:1 ratio (smallest chart division = 1/10 in. = 10 points of rain) and to 25 points for the 60 in. capacity recorders.

The Stevens Type Q 12M weighing gauge with a monthly weight-driven clock has rainfall scales of 1:1 and 1:2, recording a total of 12 or 24 in. of rain on a 12 in. chart.

The Bendix Friez Type 775 C weighing gauge, with a weekly clock, employs a pen-reversing system to record a total of 12 in. of rain with a rainfall depth scale of 2.5:1. This rainfall depth scale of 1/10 in. of chart to 4 points of rainfall is reasonably adequate but the capacity is insufficient for remote-area recording.

The float and storage tank gauge overcomes the chart height limitations by the use of a reversing pen. Standard gauges do not, however, utilize storage tanks of great height; capacities of 30 in. with a rainfall depth scale ratio of 1:1 and of 60 in. with a rainfall depth scale ratio of 1:2 are usual.

The Stevens Type QA float and storage tank recorder employs a Stevens Type A35 water level recorder with reversing pen and strip chart to record 30 in. of precipitation with a 1:1 rainfall depth scale ratio. The accuracy of recording is therefore in the order of 10 points of rain because of the allowable recording error (1/10 in.) associated with float-type recorders.

The Snowy Mountains Authority has adapted the Type QA recorder to give a rainfall depth scale of 2:1 (1/10 in. = 5 points). This scale has been achieved by increasing the standard 8-inch orifice diameter to a diameter of 11.31 in. (the 11.31-inch diameter orifice gives an area twice that of the 8-inch diameter orifice), and by employing a float chamber diameter of 7.31 in. together with a recorder chart scale of 10:12. The 2:1 scale tends to limit the servicing period to a month because of the excessive tank height requirements. A 50-inch precipitation total requiring a tank height of 100 in. creates its own problems, although in a deep snowfall area this height requirement could be considered an asset.

Time Scales

Time scales expressed in units of chart length to a given time are directly related to the chart speed. When a single chart drum is used the time scale can be increased either by enlarging the drum diameter, or by increasing the chart speed with consequent reduction of the period of record. The strip chart, associated with the more expensive recorders, has largely solved the problem of time resolution but has highlighted the need for improvements in the associated equipment. Chart speed is, above a certain figure (generally 9.6 in. per day), acquired at the expense of clock reliability and spring-driven clocks have to be replaced by alternative power sources.

The Dines daily tilting syphon gauge has a time scale of 11.4 mm of chart to one hour — say 1 mm per five minutes. It is clear that, providing the time keeping is correct, time resolution to the nearest five minutes is possible, and for most quantitative purposes this is adequate. When high intensity storms are recorded on the Dines daily chart the trace is almost vertical and successful interpretation of high-intensity recordings requires that consideration be given to the thickness of the trace. Taking a storm of 20 points (one chart width) as occurring in five minutes, this is equivalent to an intensity of 2.4 in./hour; the trace appears almost vertical wtih a slope of 1/50. It it possible in this case, where the rainfall rate has been constant for five minutes, to be reasonably confident of the actual intensity, but for equivalent intensities for periods shorter than five minutes, it is almost impossible to estimate to within 100% of the actual intensity. The importance of measuring short-period intensities accurately is relative, and in practice is of concern only to micro-studies (run-off plots).

A time scale of 2 mm per five minutes would reduce the corresponding slope to 1/25 and this is obviously a more suitable scale for recording intensities. Because the 1/50 slope expresses the relation time scale/rainfall depth scale it is apparent that the slope may also be reduced to 1/25 by reducing the rainfall depth scale to one half of its original value (10).

The daily Dines recording gauge under discussion has an orifice diameter of 11.31 in. (area 100 sq. in.) and the reduction to an 8-inch diameter (area 50 sq. in.) would thus be advantageous. The value of the smallest chart division (1/10 in.) would equal two points of rainfall and a recorded trace with a slope of 1/50 would indicate an intensity of 4.8 in./hour. This intensity would occur extremely infrequently and most reasonably high-intensity storms would be recorded by a trace sloping at less than 1/25.

The time scale/rainfall depth scale relation provides a means of comparing the performance of chart recorders. Table 1 contains a sample of the available recording gauges and provides a convenient means of examining gauge qualities. An intensity of 100 mm/hour has been chosen as the basis for the comparison of the storm intensity interpretation qualities of the recorders. It is suggested that for this intensity the time/rainfall depth relation as given by the chart trace ideally should be not less than 1/50.

The time scale of 11.4 mm/hour as used in the daily Dines recorder is the most open chart scale presently in use in New Zealand. It is closely followed by the Lambrecht Model 1509 with a time scale of 10 mm/hour. The 95-day Casella tipping bucket recorder has a time scale of 25.4 mm/hour but this trace is not continuous, consisting of chart prickings at each 10 points of rain.

The Fischer and Porter storage tank weighing gauge records at five-minute intervals on punched tape. This time resolution is more than sufficient for precipitation gauge accuracy as in the regions of extreme climate where this elaborate gauge will normally be employed, an index of precipitation is as much as can be expected.

The Stevens Type Q 12M weighing gauge with a monthly chart 12 in. wide and $18\frac{1}{2}$ in. long and rainfall scales of 1:1 and 1:2 has the smallest chart division (1/10 in.) equal to four hours. With these scales it is possible to define the storm length and total quantity of precipitation but intensities as given by the time scale/rainfall depth scale relation would be poorly defined, the slopes being respectively 1/160 and 1/80 (storm intensities corresponding to a slope of 1/25 would be in the order of $\frac{5}{8}$ in./hour and $1\frac{1}{4}$ in./hour respectively). For the Type Q 12M recorder, therefore, the best all round performance could be expected when the rainfall scale is 1:2, the capacity is 24 in. and the possible accuracy is to the nearest 10 points of precipitation.

The Stephens Type QA float and storage tank gauge is normally operated in conjunction with the Stevens Type A35 water level recorder. This recorder has various time scales and also a 25-yard strip chart with reversing pen. The maximum chart speed is 9.6 in./day, equivalent to 1/10 in. per 15 minutes or 10 mm/hour. This gauge, powered by a Chelsea clock and an auxiliary negator spring motor, is capable of operating continuously for a period of three months at a chart speed of 9.6 in./day. The unmodified version (see previous description of the Snowy Mountains Authority modifications) employs a funnel to transfer the rain catch to the float chamber and hence is not suited to the measurement of solid precipitation.

The gauge is capable of outstanding intensity resolution, an intensity of 10 in./hour with a time scale of 9.6 in./day (0.4 in./hour) and a rainfall scale of 1:1 has a time scale/rainfall depth scale ratio of 1/25 (0.4/10).

This degree of resolution is unnecessary and a rainfall scale of 4:1 coupled with a time scale of 9.6 in./day is a more practical arrangement of scales. In practice, as mentioned previously, the necessary storage tank height could then prove an embarrassment.

The QA gauge with certain modifications to permit of a greater rainfall scale is therefore the ideal recorder. The cost price of over $800, leads to such considerations as the temporal and spatial variability of precipitation and the need for gauge replication, rather than absolute accuracy at a point, in order to define adequately mean basin precipitation.

The use of a modified QA gauge as carried out by the Snowy Mountains Authority of Australia is justified only at a site which has an established correlation with the basin mean rainfall, or where a flood warning or storage regulation system is to be based on a single point recording.

CONCLUSIONS

Manual Gauges

The 8-inch orifice gauge may be expected to give better results than the 5-inch orifice gauge where rainfall totals are relatively low. Since it will be necessary to adapt gauges to fit each type of situation, there is no good reason why the standard 5-inch orifice octapent gauge should be universally employed in representative and experimental basins.

For general purposes the Type C gauge, fitted with an 8-inch orifice and an expanding neck as detailed by Grant (1960), is an excellent and economical substitute for a 50-inch octapent. The sensitivity of such a gauge with a rainfall scale ratio of 1:3 is reasonable, and the capacity of 55 in. compares favourably with that of the 50-inch octapent (capacity 53 in.).

When used with an 11-inch orifice the Type C gauge is an effective substitute for the 27-inch octapent, having a rainfall scale ratio of approximately 2:3 and storage capacity of 29 in. Note that in this case the neck immediately below the orifice will be slightly funnel shaped (a milk can is 9 in. in diameter at the neck and 14 in. at the base). In the summer season it will be necessary to use anti-evaporation oil with these open-type gauges and, seasonally, in situations where snow is important, the anti-evaporation oil must be replaced by anti-freeze to assist snow melt.

Recording Gauges

To establish the specifications for the recording gauge type(s) best suited to experimental and representative basin research the investigation must include consideration of climate (temperate or extreme), purposes of record (intensive analyses or storm depth and duration study), and convenience of servicing periods (gauges remote or local).

Both rainfall and precipitation recorders will be required and rainfall recorders will be subdivided into those suitable for short periods of operation with scale resolution suitable for experimental basin analyses, and those with less open scales suitable for longer periods of continuous operation as will be required for representative basins. Where snowfall represents an important part of the total precipitation, recorders suitable for the recording of snowfall will be necessary.

A rainfall recorder suitable for experimental basin research should have specifications which include the following:

- — a time scale of at least 9.6 in./day (10 mm/hour) and preferably 20 mm/hour.
- — a rainfall depth scale not less than 5:1 and not greater than 8:1.
- — the slope of the chart trace time scale/rainfall depth scale for an intensity of 4 in./hour to be not less than 1/50.
- — be capable of continuous satisfactory recording for a period of at least eight days.

A rainfall recorder suitable for representative basin research should have specifications which include the following:

- — a time scale not less than 4.8 in./day (5 mm/hour) and not greater than 10 mm/hour.
- — a rainfall depth scale not less than 5:1 and not greater than 8:1.
- — the slope of the chart trace time scale/rainfall depth scale for an intensity of 4 in./hour to be not less than 1/80.
- — be capable of satisfactory continuous operation for a period of at least 32 days.

Finally, a suitable precipitation recorder where considerations of the inaccuracies due to climatic extremes lead to a relaxation of specifications should be capable of an extended operation period because of possible access problems and should be of a capacity sufficient to contain a possible excess precipitation. This latter aspect is probably best solved by either reducing the orifice area at the expense of sensitivity or by the elimination of access problems by the use of helicopters.

The specifications of the precipitation gauge should be as follows:

- — a time scale not less than 2.4 in./day.
- — a precipitation scale not less than 1:1 and not greater than 2:1.
- — be capable of continuous satisfactory operation for a period of at least six weeks.

The presently available recorders which are reasonably inexpensive and which, with modifications, fit the specifications are: For experimental basins — the Dines daily tilting syphon and the Lambrecht Type 1509 and 1509b. (The Dines daily tilting syphon recorder has been shown to operate satisfactorily as an 8-day strip chart recorder by the use of an inexpensive secondary chart drum (1½ in. diameter) mounted adjacent to the existing drum.)

For representative basins — the Lambrecht Type 1509 and the Fischer and Porter tape recorder. Alternative gauges are coming on the market as manufacturers become aware of the hydrologist's requirements, and it is advisable to maintain contact with developments in this field.

Finally it is recommended that:

(i) a period of one month be considered the basic time unit for the servicing of all remote recording and storage gauges. A recording gauge is unwarranted if missing records for periods exceeding one month can be tolerated,

(ii) the means for the economic employment of helicopters for gauge servicing be studied. For reasons of economy such an approach must entail the co-operation of all water authorities, since the work of a single small authority does not justify the use of a helicopter,

(iii) the development of simple plastic manual gauges be undertaken to reduce initial expense, transportation costs and laborious installations, and to permit of the economic installation of exploratory dense networks,

(iv) the use of metallic floats be discontinued in favour of plastic floats capable of withstanding severe frosts.

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TABLE 1 — Comparison of Recording Gauge Performance

Type	*Orifice Area (cm²) Dia. in.*	*Rainfall Depth Scale mm on Chart to 1 mm of rain*	*Time Scale mm/hr/ in./day*	*Slope of Trace for Intensity of (100 mm)/hr Time Scale/ Rainfall Scale × 100*	*Rainfall Recorded On One Chart Width mm/in.*	*Chart Duration*	*Operating Principle*
Dines tilting syphon	648 11.31	10	11.4/11	1/90	5/0.2	one day	Tilting syphon
W. Lambrecht Model 1509	200 $6\frac{1}{4}$	8	10/9.6	1/80	10/0.4	one month	Fixed syphon
W. Lambrecht Model 1509b	200 $6\frac{1}{4}$	8	20/19.2	1/40	10/0.4	one month	Fixed syphon
Casella	130 5	2.4	1.6/1.5	1/150	25/1.0	one week	Natural syphon
Leupold & Stevens Model Q 12 M	324 8	1	0.6/0.6	1/170	300/12	one month	Weighing
Leupold & Stevens Model Q.A.	324 8	1	10/9.6	1/10	250/10	three months	Float and storage tank
R. Feuss Model 95C	200 $6\frac{1}{4}$	8	10/9.6	1/40	10/0.4	$2\frac{1}{2}$ months	Fixed syphon
Negretti & Zambra	324 8	3	1.6/1.5	1/190	25/1.0	8 days	Tilting bucket
Negretti & Zambra	324 8	3	11/10.6	1/27	25/1.0	one day	Tilting bucket
Bendix Friez Model 775C	324 8	1	2.5/2.4	1/40	150/6.0	one week	Storage tank weighing
British Pitometer Co.	1460	6	25/24	1/24	25/1.0	one month	Float and storage tank