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## PRECIPITATION MEASUREMENTS STUDY

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*John Jones*



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PRECIPITATION MEASUREMENTS STUDY

ANNUAL REPORT

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. Methods of Measuring Precipitation For  
Use With The Automatic Weather Station

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## PURPOSE

A study of all known methods of measuring precipitation was made with a view to adapting one of these techniques to unattended automatic weather station operation.

## ABSTRACT

A comprehensive review of literature pertaining to methods and instruments for measuring rain and snow was made. A brief discussion of methods and instruments found in the review is presented. Illustrations are used, in most cases, to clarify description of the various gages. A partially annotated bibliography with subject index is included. It is concluded that present day gages, although adequate for rain measurement, must be improved to satisfactorily measure snow.

## REPORTS AND CONFERENCES

Progress Reports, No. 1 through 3., written by Illinois State Water Survey under SCEL Contract No. DA-36-039 SC 15484, covering quarterly periods from 15 February 1952 through 15 November 1952,

Numerous informal discussions were held on precipitation measurement with the following: Malcolm Rigby, Editor of the American Meteorological Society's Meteorological Abstracts and Bibliography; William Hiatt, Walter T. Wilson, B. C. Haynes, Ross Gunn, all of the U. S. Weather Bureau; C. F. Brooks and John Conover, Blue Hill Observatory, Harvard University; D. Keily, Massachusetts Institute of Technology and R. M. Boyd, Evans Signal Laboratory.

## RAIN AND SNOW GAGING METHODS

by

J. C. Kurtyka, Research Meteorologist, Illinois State Water Survey -

### HISTORICAL

The first rain measurements were no doubt taken about the time the first bowls or vessels made were left exposed to the elements, intentionally or otherwise. Mention is made of the measurement of rain in India as early as 400 B.C. in "Arthashastra" by Kautilya (483): on page 64, "In front of the storehouse, a bowl (Kunda) with its mouth as wide as an Aratni (18 inches) shall be set up as a rain gage (Varshanana)." And on page 143, "Quantity of rain that falls in the country of Jangala is 16 dronas; half as much more in moist countries; 13½ dronas in the country of Asmakas . . ." "The forecast of such rainfall can be made by observing the position, motion and pregnancy of the Jupiter, the rise and set motion of the Venus and the natural or unnatural aspect of the sun." "Hence i.e. according as the rainfall is more or less, the superintendent shall sow the seeds which require either more or less water . . ." Evidently rainfall records were kept thousands of years ago.

Horton (423) reported in 1919: "in the Mashnah, a collection of religious writings of the First Century, there have been found recorded measures of rainfall in Palestine during the First Century of our era. These are probably the first quantitative observations of precipitation now in existence." "Dr. Y. Wada, Director of the Korean Meteorological Observatory, has shown that rain gages were in use in Korea as early as 1442. . . . A gage of the period 1770 was found by Wada on an inspection trip at the Observatory at Chemulpo, Korea."

In western civilization, Benedetto Castelli wrote a letter to Galileo in 1639 and informed him that he had measured rain. Sir Christopher Wren of England invented the self-recording tipping-bucket gage in 1662. In 1807, S. DeWitt (423) of Albany (Fig. 1), introduced into the United States a conical-shaped rain gage.

About 1769, experiments by Heberden (396) disclosed that the catching of rain by rain gages appeared to be a function of height. A most interesting episode in the history of the measurement of rain followed this disclosure when Benjamin Franklin (295) in a letter to Sir Percival suggested that perhaps a drop of rain was comparable to a bottle of cold water condensing dew upon itself as it fell through the atmosphere. The fact that hail occurred was taken as further evidence that rain came from a very cold region. Franklin then concluded that proofs at the time were not conclusive enough to accept any hypothesis.

In spite of his words of caution, Franklin's suggestion that raindrops grew by condensation

in the lower layers was generally accepted as a hypothesis; A half century later, the hypothesis was the subject of controversy between many illustrious researchers. This controversy was finally terminated through the efforts of men like Bache (49), Jevons (462), and Symons (899), who showed that the decrease in the catch with height was a function of the wind velocity which increases with height.

The next notable event in the measurement of rain resulted from G. J. Symons' interests in the subject. Symons devoted a large part of his life (approximately 35 years) to the measurement of rain and was instrumental in establishing many precedents that are still practiced. Symons organized a large group of voluntary observers in England to furnish rainfall observations for the British Isles. He was instrumental in instigating carefully controlled experiments on the construction, exposure, form, and operation of rain gages through the medium of his magazines, British Rainfall and Meteorological Magazine.

The measurement of snow followed as the next point of interest and, unfortunately, remains as a problem to be solved. In the last decade, a considerable amount of research has been devoted to the measurement of snow. . . .

In the last 5 years, the necessity of adequate precipitation instruments to calibrate radar for precipitation measurement has pointed out the primitiveness of the present-day rain gage. As a climatological tool, the rain gage maintains a respected position; however, for engineering purposes, such as runoff forecasting, and for radar and cloud physics studies, the present-day rain gage is inadequate. In all likelihood, the rain gage of the future may be radar, for even in its present developmental stages, radar measures rainfall more accurately than a fairly dense climatological network of one rain gage per 200 square miles (1069).

In summary, it may be stated that the use of rain gages falls into 3 principal categories: (1) climatology, a field in which non-recording gages are used to a large extent, (2) hydrology, where forecasting of runoff calls more for self-recording gages and totalizers, and (3) cloud physics and radar studies, where a demand exists for a calibration-type rain gage that accurately portrays rates of rainfall as well as amount.

### SPECIFICATIONS OF GAGES

#### Material

Early experiments with gages indicated that copper was quite satisfactory for construction

purposes and time has substantiated this conclusion. Ebonite was shown by Crallan (197) and Griffith (354) to be equal or superior to copper as funnel material, but the small improvement and added cost precludes the use of ebonite. Zinc, galvanized metals, glass, plastics, etc., have been used in gage construction, but, in general, copper has been most popular. In gage construction; open joints and soldered or welded seams should be held to a minimum. Periodic testing of gages for leaks should be made since leaky seams may cause either high or low results (635). Spun bronze parts offer the possibility of eliminating seams in raingage housing and funnels. Some experiments along this line have been carried on in England (95).

Painting of the raingage funnel is frowned upon, for as the paint surface ages, oxidation causes the paint to swell and to become blotter-like in effect (354). Beyerlein (90) has noted that surface adhesion losses for an unpainted gage could amount to 2 inches or 3 inches on an annual basis. Dines (233) has shown that for 5-inch or 8-inch gages, the surface film required to wet the gage, and which is subsequently lost by evaporation, amounts to 0.003 inch. Using Beyerlein's shower frequency of 400 per year, this evaporation loss would amount to 1.2 inches or slightly less than Beyerlein's figure. Horton's (423) tests with the U.S. Weather Bureau 8-inch gage showed a wetting loss of 0.0034 inch per wetting and is in good agreement with Dines' results. Horton calculated that for 100 showers the annual loss would be 0.34 inch. Austin (48) measured the adhesion of the British Meteorological Office 8-inch gage and found it to be 0.004 inch, while a Hellmann (6.28-inch diameter) read 0.012 inch. Austin attributed this large difference between the 2 gages to the difference in surfaces, the British copper being smoother than the Hellmann galvanized iron, and thus retaining less.

In instances where painted, lacquered, or shellacked funnels were used in an attempt to provide a perfectly smooth runoff surface, it was found that small droplets would cling to the walls of the funnel instead of rolling down into the receiver (146). This clinging effect has been one of the serious drawbacks to the use of heated funnels for the measurement of snowfall. Many small snowflakes, upon striking the heated surface, melt, cling, and evaporate rather than roll or flow down into the receiver. Use of hydrophobic surfaces appears to accentuate this clinging effect, and there are indications that the best receiving surface for melting snow is a wet one. To overcome this problem of clinging losses in gage funnels, Nilsson (686) has used an oil-coated antifreeze solution in the funnel in much the same manner as in totalizers and storage precipitation gages. An overflow is provided to maintain the solution at the same level.

Differences of raingage readings resulting from evaporation losses due to color of the gage have been investigated by Wild (990) and Kandasamy (476). A white gage was found to read about 1 per cent more than a black gage. In most cases, this is a negligible consideration in com-

parison with the effect of exposure. Dymond (245) investigated evaporation losses with respect to a gage whose receiver was sunk into the ground to keep it cool and his results were of the same magnitude (+ 1 per cent). Horton (423) made measurements that showed an evaporative loss of 0.10 inch of water (equals 0.01 inch rain) from the receiver of a U. S. Weather Bureau rain gage for 7 days at a temperature of approximately 70° F. Carter (164), during the summer of 1928, observed that the 24-hour evaporation loss averaged about 0.01 inch for the U. S. Weather Bureau standard gage. He noted that 70 per cent of this loss occurred during the 12-hour night period. A possible explanation for this is that the water was probably cooler than the air during the day and warmer than the air during the night, thus increasing night-time evaporation. This would not necessarily be the case during rainfalls where the receiver is emptied at the end of each 12-hour period.

### Form

A prime requisite for all rain gages is that the orifice be level. This is accomplished by firmly anchoring the gage so that wind, bumps, and operation will not disturb the normal gage position. Small gages on the order of 1 inch in diameter, or less, are especially difficult with which to maintain a level orifice. A rule-of-thumb allowance (901) for tilt is that the gage will read 1 per cent in error for each degree of tilt. This error will be positive should the tilt be into the wind.

Wind tunnel tests by Mercanton (605) indicate that a square orifice and gage should read less when the path of the wind is normal to a side than when the wind is parallel to the diagonal of the gage. This finding has not been borne out by actual field operation in Norway.

Wherever a wind shield is used, the square orifice and gage should be reconsidered in the light of wind tunnel tests by P.L. Mercanton with a square Norwegian gage in 1938-39. He showed that by lowering the screen (Nipher shield) 7 centimeters, there is no more re-entrance of air into the orifice and the flow is parallel to it. Mercanton concludes: "that the optimum is 6.5 centimeters, and that in these conditions the rain gage (i.e., with a Nipher shield) is practically neutral in the wind." Whether this neutrality is partly due to the squareness or the shape of the mouth of this particular gage poses an interesting question. It is possible that the square-shaped funnel would be less favorable to vorticity in the funnel than a round shape, and thus, in some respects, decrease wind effects in the funnel (317).

For use in snow measurements, most governments have provisions for removing the raingage funnels during winter operation. This allows the snow to drop into the receiver and not pile up in the funnel where it could be blown out. In the Sacramento and Mougins totalizers (described later), the gages are not equipped with funnels and the sides of the gage drop away from

Table 1.  
Relative Variation of Catch With Gage Diameter

Location	Gage Diameter in Inches and % Catch							
	1	2	4	5	6	8	12	24
Calne (4 1/2 Years)	91.4	95.6	99.7	99.6	102.6	103.6	100.0	100.0
Strathfield-Turgiss (2 years)	: 91.6	97.8	100.2	97.8	100.9	99.1	100.0	101.3

the rim. This "dropping-away" is a design feature to prevent sticky snow from bridging over and blocking the orifice.

The housing of the gage below the funnel section is often built up to suit the individual, but as a general rule, it is cylindrical and always of substantial material. In a few cases, where due to gage size it becomes necessary to place the lower part of the gage in the ground, the bottom part of the gage is splayed out to provide firmer anchorage.

#### Diameter of Orifice

The question of size of gage orifices was one problem that originally had been considered as solved. Independent experiments with gages greater than 1 inch in diameter in America, England, and Germany, proved beyond much doubt that the gage catch was more or less independent of its size, and any difference that did exist was in gages less than 3 inches in diameter. These smaller-sized gages read 3 to 6 per cent low, and this was attributed to difficulty in measuring small amounts, and to losses due to surface wetting-

Results reported by Wild (990), in 1885, referred to the Calne and Stratfield Turgis experiments performed in England about 1870. Table I shows results of this test of gage sizes related to a 12-inch gage catch.

These indicate that orifices greater than 4 inches in diameter agree within 1 or 2 per cent. Wild also reported the results of 4 years of experiments covering 24 summer months where the catch of a 10-inch gage differed by 2 per cent (less) from that of a 44.5-inch gage. Codman (187), in tests at Philadelphia with 2-inch and 24-inch gages for 3 years, found agreement within 1 per cent.

One summer's (1952) results on the "Graveyard" network of the Illinois State Water Survey gave results as indicated in Table 2. These gages were selected from a network of 25 gages located on approximately 6-foot centers and at approximately the same level.

Recent experiments by J. Conover (189) at

Table 2

Comparison of Catch of Gages  
With Respect to Diameters

Diameter in Inches	Type of Gage	Depth of catch in inches
12.62	Friez Recording	9.74
12.00	-Tipping Bucket	9.80
8.00	U.S. W. B. Standard	9.39
8.00	U. S. W.B. Standard	9.49
2.50	Larson (Wedge)	9.39
0.75	Victor	9.28
0.75	Victor	9.08

the Blue Hill Observatory with Victor rain gages (3/4-inch orifice) have given results indicating that small gages caught more rain than large ones, and J. Howell (433) in a mathematical treatment of rain gages supports Conover's findings on a theoretical basis;

#### Height of Gage

The height of the rim of the catching ring above the ground varies a great deal throughout the world, but, in general, the range is small. Russian gages are at 2 meters; American gages are at approximately 31 inches; and English gages are at 12 inches. The rest of the world varies between this range of 1 foot to 6.56 feet (2 meters). In special cases where totalizers are used, the height of the gage is placed above the maximum expected snowfall and may be from 15 to 20 feet above the ground. The effect of height on the catch of rain gages will be discussed later in paragraphs on exposure.

The standards throughout the world vary in diameter and height as shown in Table 3. However, the observational principles used are similar and results are mostly of comparable accuracy.

The majority of the other countries use one of these tabulated gages. The U.S. Weather

Table 3.

## Comparison of International Standard Gages

Country	Type Gage	Diameter (inches)	Height of Orifice (inches)
England	M. O. pattern	8	12
England	Snowdon	5	12
Australia	8-inch type	8	12
France	Tonnelot	8.88	28.3
Austria	Kostlivy	9.93	30.3
United States	U.S. Weather Bureau Standard	8	31±
France	Scientific Association	8.88	39.4
China	Board	7.91	39.4
South Africa	5-inch type	5	48
Holland	DeBilt	8.88	59.1
Germany	Hellmann	6.28	59.1
Sweden	Swedish	14.06	59.1
Russia	Russian	9.93	78.8

Bureau Standard, Fig. 2, is used in the Philippines and in Panama. The German Hellmann gage, Fig. 3, is popular in Spain, Argentina, Yugoslavia, Rumania, Lithuania and Finland. The Russian gage, Fig. 4, as of 1932, was used in Estonia and the Ukraine, while the English M. O. pattern, Fig. 5, and Snowdon gage, Fig. 6, are standards in many of the lands of the British Commonwealth.

Exposure

If an approximation of errors in the measurement of precipitation were to be made, the following table would probably closely approach that which actually occurs in practice.

Table 4.

Approximate Errors in Precipitation Measurement		% error
Evaporation		-1.0
Adhesion		-0.5
Color		-0.5
Inclination		-0.5
Splash		+1.0
Total		-1.5
Exposure		-5.0 to -80.0

The effects are nearly always in the negative direction, and for this reason, many investigators judge a gage on its ability to catch more rain than others. The wind or exposure error, as is apparent, is greater in magnitude than all other effects combined.

No single item in rain or snow measurement is more important than exposure. The gage site, with respect to topography, cover, and structures, should be representative of the area. For example, to represent a flat plain, the rain gage site should certainly not be on the summit of a hill overlooking this plain. In effect, the exposure of an area is analogous to the area's coefficient of friction to the moving air and the site of the rain gage should have the average coefficient of friction for the area it represents.

The rain gage itself is an obstruction to the wind. The wind blowing over and around the gage increases in velocity, while eddies form in the funnel and in its lee. The increase in wind velocity over the gage results in the transport of small drops across the orifice instead of through it into the gage. The eddies, in turn, may sweep rain out of the funnel. These effects are func-

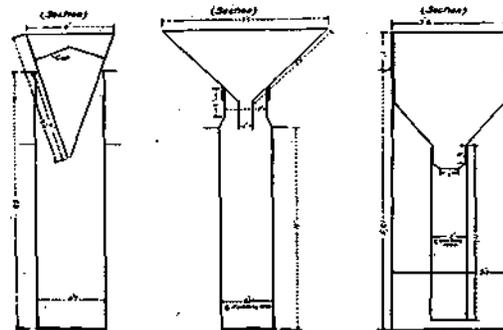


Fig. 1. Early American rain gages, De Witt, Smithsonian, and Fuertes. 1800 to 1900.

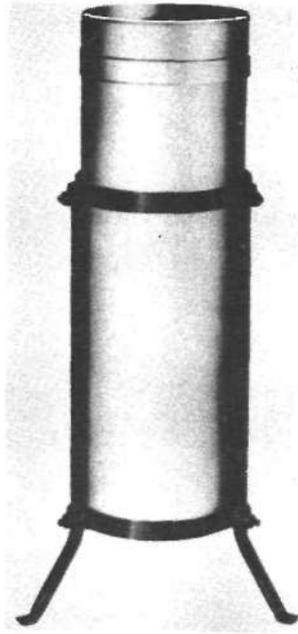


Fig. 2. U. S. Weather Bureau standard 8-inch rain gage in iron-tripod support.

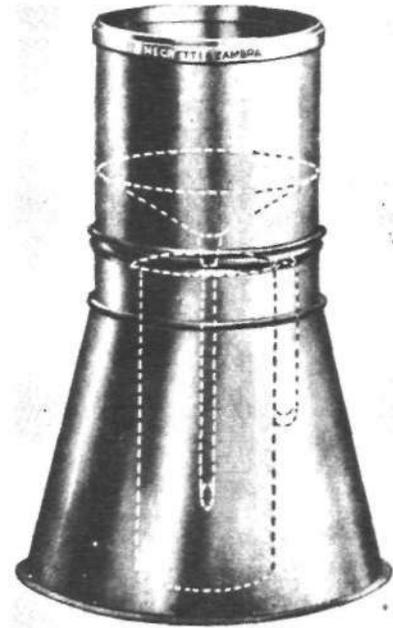


Fig. 5. British Meteorological Office standard 8-inch rain gage.



Fig. 3. German standard Hellmann rain gage.

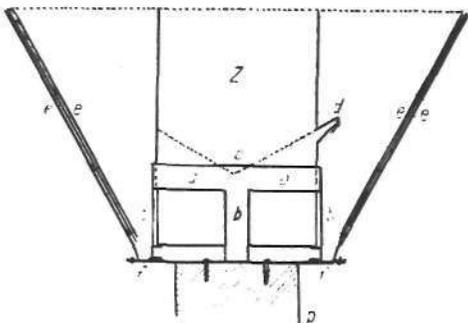


Fig. 4. Russian standard rain gage with Nipher-type shield.

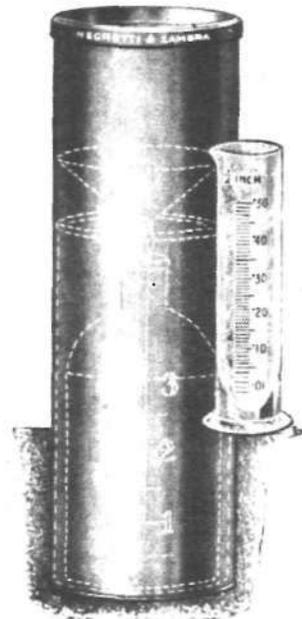


Fig. 6. British Standard 5-inch Snowdon rain gage.

tions of the wind velocity and, as the velocity increases, the loss due to this buffeting becomes greater.

In order to better understand the effect of exposure on the catch of gages, an examination of past experiments is necessary. As early as 1769, Heberden (396) showed that the catch of a rain gage was a function of the height. His work may be summarized as follows:

Table 5.

Heberden's Variation of  
Catch With Height Experiment

Place	Height (ft. )	Percent of Catch at Ground	
		Catch, (inches)	
Garden	1	22.61	100
House Top	30	18.14	80
Abbey Tower	151	12.10	54

This variation was explained by the hypothesis that there was a very rapid growth in rain drops as they approached the ground.

In 1819, the effect of wind (597) on the catching efficiency of a rain gage was considered. Meikle suggested that the upward flow of air in front of the mouth of the gage could prevent some rain from reaching the gage.

In 1838 Bache (49), at Philadelphia, showed that variation of catch with height was related to eddies and wind. Bache placed 4 gages on the 4 corners of a 12-foot-square tower 162 feet above the ground. He was able to show that gages to the lee of the tower caught significantly more than those to the windward. Differences of catch having a ratio of 1 to 2.3 between lee and windward sides were observed although averages were more like 1 to 1.5. To further examine wind effects, Bache mounted gages on poles 6 feet above those on the tower parapet. He observed that the differences between these gages were trifling, being of a ratio of 1 to 1.08, while the gages on the parapet had a ratio of 1 to 1.68 during this test.

In 1861, Jevons (462) reviewed the rainfall-height problem and showed, diagrammatically, that the influence of wind was to cause a deficiency on the windward side of objects. This was attributed to the velocity of the wind and is referred to by some writers as the "Jevons' effect."

In 1881, Symons (899) showed from the results of many experimenters that the variation of catch by rain gages at various heights was due to the impact of the wind. Some interesting results on this problem were presented by Symons in Table 6.

These averages will vary slightly, depending on the exposure of the area. The more open the location, the greater will be the differences of catch with elevation. Symons also showed that a rain gage in the center of a large flat roof would agree well (within 2 per cent) with a gage near the ground.

In 1878, Nipher (688) invented his inverted cone shield and publicized his results. He found that the use of his shield improved the amount of catch of rain gages. In one season's test, a gage on a pole 18 feet above the roof of a building, equipped with a shield, read the same as a gage in the court. Nipher suggested that there could be no decrease of rain with height. The Nipher shield, Fig. 7, has become one of the most popular methods for guarding against the effects of wind.

In a detailed summary in 1893, Abbe (5) showed that, among other things, the texture of the rain was to be considered; and that adverse effects of wind on the gage were more pronounced in snow or drizzle than for heavier forms of precipitation. Bornstein's (117) results were helpful in demonstrating Abbe's conclusions and are tabulated in Table 7. They show the comparison of catch between protected (Nipher) and unprotected gages for heavy and fine rains with varying wind speeds.

Abbe concluded that a pit gage was most reliable for measuring rain. A shielded gage near the ground was his second choice. Abbe also deduced for non-shielded gages the equation:

$$\text{Percentage deficiency} = 3.32\sqrt{H}$$

H is the height of the gage in feet. When applied to the U. S. Weather Bureau gage at 31 inches, it gives a deficiency of 5.3 per cent as compared to Symons' results of 2.7 per cent at 31 inches.

Table 6.

Variation of Catch With Height

Height Above Ground	<u>Inches</u>				<u>Feet</u>				
	2	4	6	8	1	1.5	2.5	5	20
Catch in percent of that at 1 foot	105	103	102	101	100	99.2	97.7	95.0	90.0

Table 7.

Variation of Unshielded Gage Catch With Wind Velocity and Rain Intensity Compared With a Shielded Gage (After Bornstein)

Wind (mph)	43 Heavy Rains		26 Fine Rains	
	Number of Days	% Deficit	Number of Days	% Deficit
0- 1			4	23
1- 3	17	6	8	25
4- 7	13	13	6	18
8-12	7	14	6	46
13-18	6	17	2	52

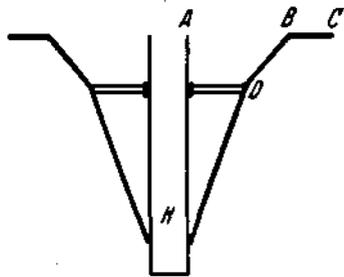


Fig. 7. Schematic cross section of Nipher shield, 1878, United States.



Fig. 8. Photo of a stereoplumiometer used as the catching element in a pit gage. Note that the slope of the orifice is cut the same angle as the slope of the ground surface.

Table 8

Velocity of Fall of Precipitation Elements

Drop Diameter mm	Rain (After Laws 1941)		Type	Snow (After Schaefer)	
	Suspension Velocity Meters per Second	Average Terminal Velocity Meters per Second		Average Terminal Velocity Meters per Second	
0.5	2.3		Stellar crystals	0.41	
1.0	4.2		Hexagonal plates	0.54	
2.0	6.6		Hexagonal columns	0.56	
3.0	8.0		*Rimed Stellar crystals	1.00	
4.0	8.9		#Graupel	1.80	
5.0	9.3		#Hail, 10 mm. dia.	12.0	
			#Hail, 20 mm. dia.	16.0	
			**Hail, 76 mm. dia.	52.0	

Note - 1 mps = 2 237 mph

\*After Nakaya, #After Houghton, \*\*After Humphrey

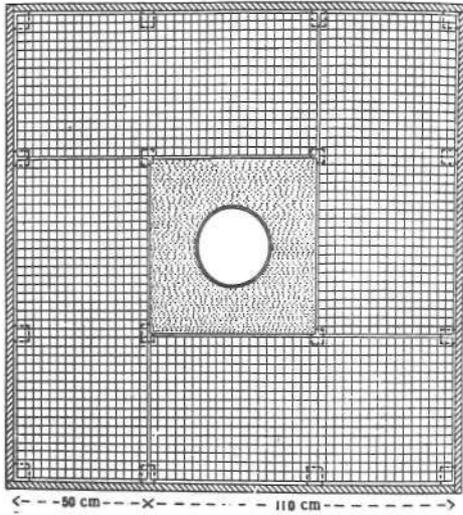


Fig. 9. Koschmieder grate type pit gage, 1934, Germany.

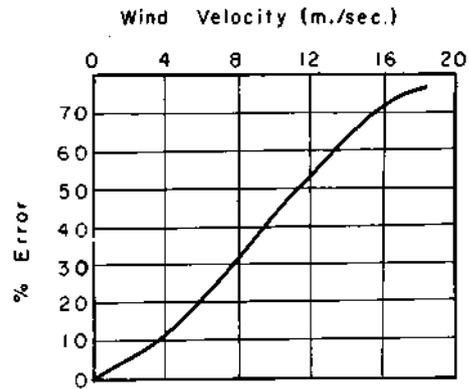


Fig. 10. Koschmieder graph illustrating per cent error in an unprotected gage as related to wind velocity when compared to a pit gage.

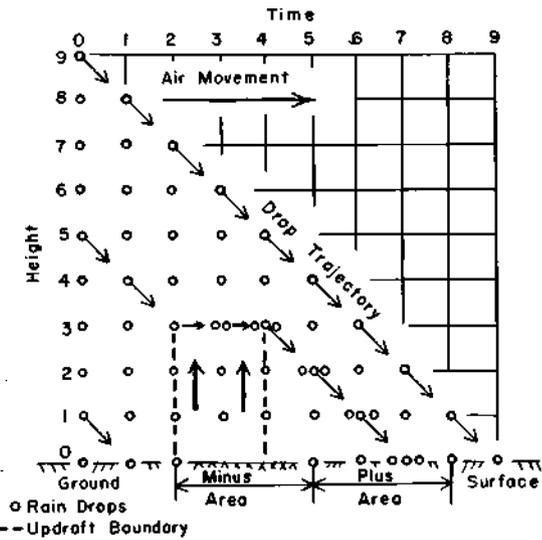


Fig. 11. Life history of 10 raindrops as they approach a confined updraft of sufficient velocity to completely cancel their vertical component, and the resulting surface rainfall distribution.

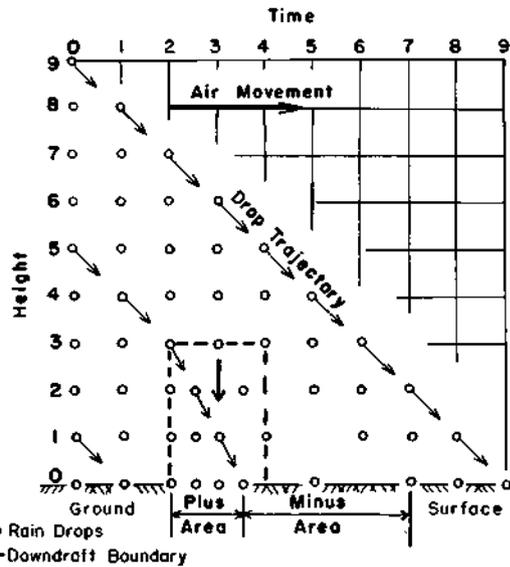


Fig. 12. Life history of 10 raindrops as they approach a confined downdraft of sufficient velocity to double their vertical component, and the resulting surface rainfall distribution.

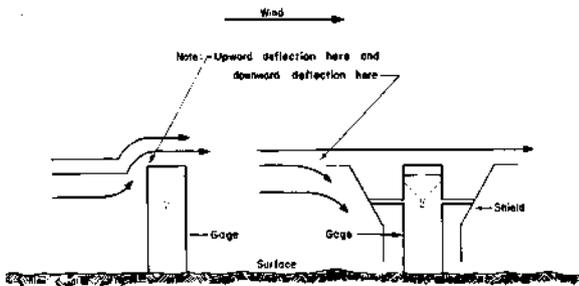


Fig. 13. Deflection of air by rain gages without shield and with shield.

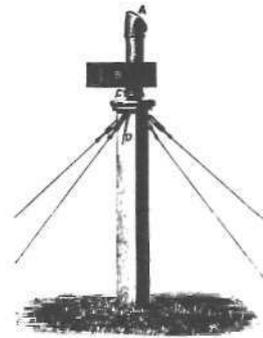


Fig. 14. Rotating 45-degree vectropluviometer as used by Arnold, 1870, England.

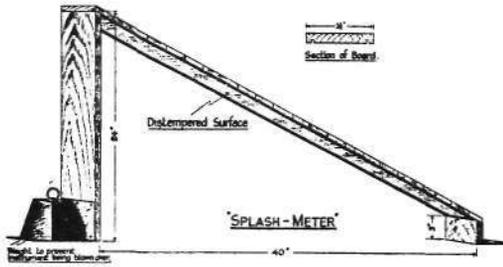


Fig. 15. Bilham splash-meter, 1932, England.

In 1919, Horton(423) also carefully reviewed the subject of rainfall measurement. Among his findings he pointed out that windward slopes of hills would catch more rain than the leeward slopes because of inclination of the rain. This finding was applied by Pers (726) in the development of the stereopluviometer, Fig. 8, a gage whose orifice is parallel to the slope of the ground. Pers noted that the catch of a stereopluviometer exceeded that of a horizontal gage by a percentage equal to the tangent of the angle of slope times the tangent of the angle of inclination. In recent years Storey, Wilm (866), and Brooks have investigated the question of slanting the orifice of the gage parallel to the average slope of the ground. Brooks (150) also points out that in mountainous regions a horizontal gage would not intercept precipitation moving upwards (due to wind) even though it was deposited on the mountain side.

In 1931, Koschmeider (511) experimented with pit gages employing the use of a brush mat and honeycombed grid to cover the pit, Fig. 9. He compared his results with an upright Hellmann gage of conventional design and at a height of 110 cm. Fig. 10 is a graph of deficiency vs. wind velocity that he determined for these gages.

In review, the exposure of gages is beyond doubt a most important consideration in the use of rain gages. Figs. 11 and 12 illustrate one of the events that takes place when rain drops are subjected to updrafts or downdrafts.

These figures are idealized cases and they serve to show that updrafts and downdrafts change the distribution of rain reaching the ground but not the total amount. The effect of windshields on rain gages is to divert the flow of air down and around the gage so that there is no updraft in the region of the orifice of the gage to cause a corresponding area of minus precipitation, Fig. 13.

Perhaps one of the most significant experiments in precipitation measurement was that performed by Arnold, and reported by Symons (890) in the 1870's. Arnold had two rotating vectopluiometers, Fig. 14, with orifices cut at 45 degrees, mounted on poles at elevations of 5 feet and 30 feet and rotating to face the wind. Over a period of 5 years, Arnold's gages caught almost exactly the same amount of rain, and were in good agreement (+ 0.5 per cent) on a monthly basis.

The effect of a 45 degree-orificed vectopluiometer is to catch an amount of rain equal to the sum of equal horizontal and vertical areas (facing the wind). If there was any difference in the concentration of rain present at these two levels, the gages could not have read as similarly as they did.

### Miscellaneous Effects

Another important aspect of exposure that has received attention in recent years is the effect of splash on raingage catch. Because of its design, the rain gage is better able to receive splash than to lose it. Therefore, the effect of splash is largely additive with little compensating outsplash. In 1931, Gold (343) found that a wet surface was necessary in order for splash to occur. In a mathematical treatment, Gold found that drops of 2-mm. size could splash to heights of 4 ft. Table 9 illustrates the height to which drops breaking into different numbers of smaller drops will splash. Gold obtained these results by assuming that 1/2 the energy of the falling drop is dissipated in wave energy, while the other half is devoted to rebounding.

Experiments by the author with drops about 3 mm. in diameter, splashing in a glass vessel containing 1/8 inch of water, inferred that case "d" in the table probably occurs most frequently.

A splashmeter, Fig. 15, was designed by Bilham (1012) in 1932 to test the height to which splash would occur. The splash board has grooves along each edge on the under side to protect the undersurface from under flow. A water-sensitive paint, coated on the undersurface, is used to indicate the height to which drops splash. No quantitative measurements other than the number of drops is made with this arrangement.

Ashmore (46), 1934, clearly demonstrated the splash effect over different surfaces, and showed that the actual results were in fair agreement with Gold's earlier calculations. Figs. 16 and 17 show graphically the height of splash vs. rate of rainfall for various surfaces tested by Ashmore.

Table 9

Height of Splash as Related to Drop Diameter (After Gold)

Diameter of drop (mm)	Height of splash in feet			
	(a)	(b)	(c)	(d)
1	1.3	1.2	1.1	0.5
2	2.4	2.1	2.0	1.4
3	3.3	3.0	2.9	1.9
4	4.2	3.8	3.8	2.2
5	4.2	4.2	4.2	2.7

- (a) Falling drop = 1 splashing drop  
 (b) Falling drop = 2 splashing drops  
 (c) Falling drop = 8 splashing drops  
 (d) Falling drop = 64 splashing drops

The graphs clearly illustrate that the height to which splash occurs is a function of the rate of rainfall, since the average drop size normally increases with increasing rainfall rate. In 1935 Whipple (986) compared the catch of a gage installed over concrete with a gage over grass, both at 1-foot elevation. The gage over concrete read 1 per cent in excess of the gage over grass. Austin (48) in 1939 illustrated the relation between gage height and splash. For 26 calm periods, each averaging 0.18 inch of rain, the catch of a gage at 12 inches exceeded the catch of a gage at 39 inches by nearly 1 per cent.

In recent years splash has been studied in much greater detail in regard to soil erosion. W. D. Ellison (1025) has measured soil transport by splash, and has designed instruments for this purpose. He has also made excellent photographs of drops in the act of striking a wet surface and splashing.

The question of the amount of water reaching the earth's surface has been investigated. Findings show that condensation of moisture can account for 21 per cent (1034) of the total moisture received by the ground from the atmosphere. In monolith lysimeter tests at Coshocton, Ohio, this amounted to approximately 0.025 inch daily. Condensation in rain gages has not been considered as a problem and very little has been written on this subject. Griffith (353) has noted that a 24-inch diameter gage collected dew because of the excess metal that was exposed. Over a 10-month period he observed that this gage caught an excess of 0.16 inch of rain in comparison with smaller gages. He attributed this to condensation.

## NON-RECORDING GAGES .

### The Standard Gage

Essentially the use of the standard gage is for the year-round determination of precipitation on a climatological basis.

### Catching of Precipitation

Nearly all of the gages used by the various countries were designed primarily to measure rain. Snow, if a problem at all, was considered of secondary importance.

The height of the rim above the funnel varies but, in general, is in excess of 1 inch with 3 inches being a figure often recommended by investigators. Angle of inclination of the funnel with the vertical walls is also variable ranging from 45 degrees for New Zealand to 20 degrees in Croatia. The rim and funnel should be designed to: (1) provide a sharply defined orifice of substantial metal that will not be easily bent, (2) provide a rim high enough to prevent splashing out of the gage, (3) provide a steep enough funnel to bring the water smartly into the receiver and reduce splash out of the gage, (4) provide a minimum wetting surface, and (5) have a hole

small enough to retard evaporation but not be easily clogged. The use of a rim above the funnel is mandatory if loss from splash is to be prevented. This is especially true when shallow-sloped funnels are used. None of the standard gages used today are rimless.

Flanges on the outside of the rim are used by some countries for added strength. It has been shown (354) that these flanges may cause the gage to read slightly high due to an associated minor updraft at this point causing water to flow from the flange into the gage. Shielding of standard gages against wind losses has not generally been accepted, mainly because of additional cost.

### Holding of Precipitation

After the rain has been caught, it becomes necessary for the receiver to hold it until such time as it is measured. Evaporation is a principal cause of losses in receivers, and investigations along this line have led to remedial features. The first consideration is for the hole in the funnel to be of such small size that passage of air be discouraged, yet large enough to pass the water promptly without being easily stopped by such obstructions as stones, leaves, twigs, and droppings. Use of a small-diameter tube to direct the flow of water from the funnel hole and into the receiver is very desirable where evaporation losses are high. The tube acts to restrict flow of air and is thereby effective in reducing evaporation losses. The U. S. Weather Bureau standard gage locks the receiver and funnel together to restrict the flow of air. By having the housing air-tight, using a small-hole funnel (a 1/4-inch tube approximately 6 inches long), and a narrow-necked bottle, most temperate-climate evaporation losses are minimized. In hot climates it may be necessary to insulate the inside of the gage, paint the outside of the gage white, and set the lower portion of the gage into the ground. These precautions lower interior temperatures and thus reduce evaporation.'

### Measurement of Rainfall

Rain can be measured in one of three ways.

Weighing the catch.--This method involves emptying the contents of the gage into a container of known weight, weighing, and converting to inches of rain by use of suitable tables. This method probably has few users. Records show it was used at Gresham College, England, about the turn of the century, but may no longer be in use.

Use of a graduated measuring glass.--This method is used in most countries. A bottle may be used as a receiver, and its contents transferred to an accurately graduated measuring glass. In lieu of a bottle, metal vessels may be used as receivers, and they have the advantage of being more durable. Some gages use taps in their bottoms from which water may be drawn off directly into a graduated receiver. This practice is on the decline since experience shows that many taps start to leak after 4 or 5 years of exposure and use.

Use of a measuring stick.--This American method is simple and direct. A graduated stick is used to measure the depth of water in a receiver. The receiver may also be smaller in diameter than the orifice, thus giving a magnified catch. In any event, the graduations on the stick are calibrated to read in inches of rainfall. Figure 2 is a picture of the U. S. Weather Bureau standard 8-inch gage mounted on iron supports. Figs. 5 and 6 show the British 5-inch and 8-inch models, and Fig. 3 illustrates the German post-mounted Hellmann gage. Fig. 18 shows the Netherland's DeBilt gage with Nipher shield, and like the Russian gage, Fig. 4, and Austrian Kostlivi gage, Fig. 19, it has a spout incorporated in the housing to facilitate emptying. Figs. 20 through 26 are mostly miscellaneous types that were introduced as standard gages.

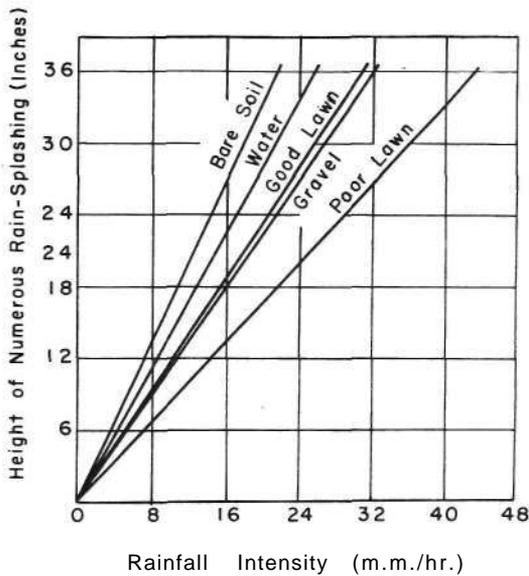


Fig. 16. Splash height of numerous drops with respect to rainfall intensity for various surfaces (by Ashmore).

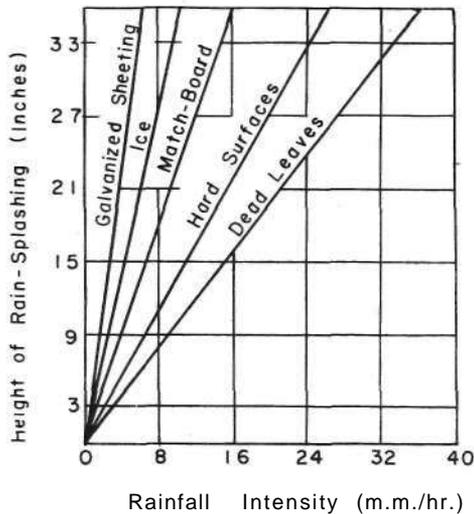


Fig. 17. Splash height of numerous drops with respect to rainfall intensity for various surfaces (by Ashmore).

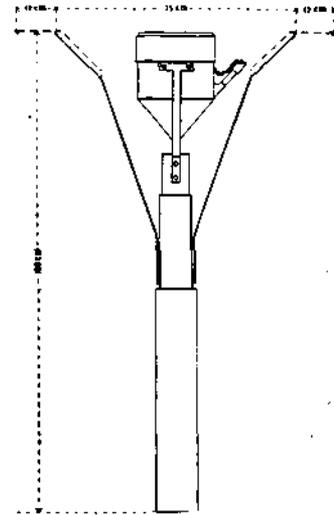


Fig. 18. Netherland's DeBilt standard gage with Nipher shield.

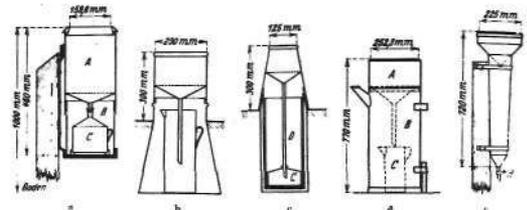


Fig. 19. European Gages. Left to right: Hellmann (Germany), British M.O., British Seathwaite, Kostlivi (Austria), and Tonnelot (France).

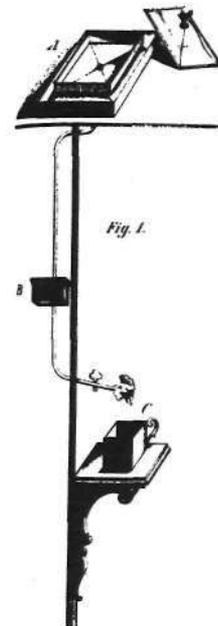


Fig. 20. Early roof top rain gage used in Germany in first international climatological network.

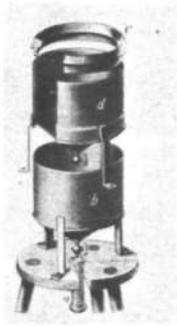


Fig. 21. Assman rain and snow gage, 1885, Germany.



Fig. 22. Glaisher's rain gage, 1870±, England.

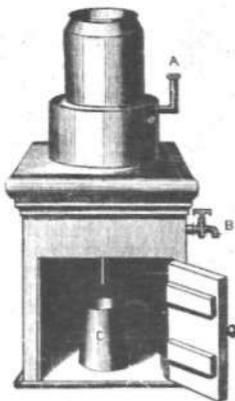


Fig. 23. Sidebottom's rain and snow gage (hot water poured in at A), 1890, England.

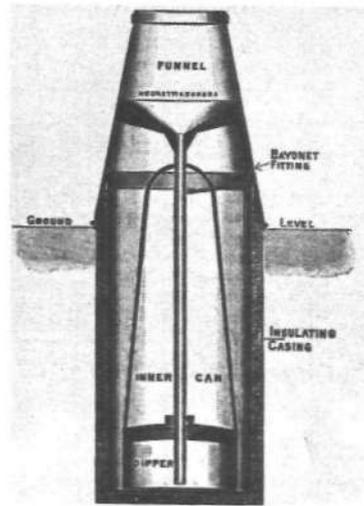


Fig. 24. Seathwaite large capacity rain gage, England.

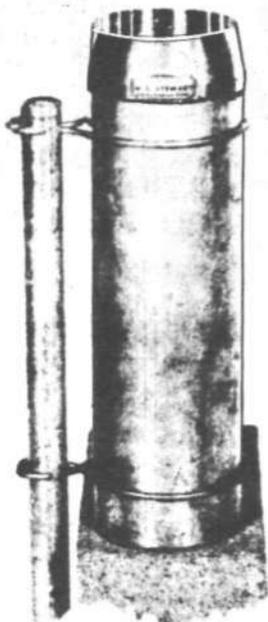


Fig. 25. Stewart 3-inch rain gage, 1940±, United States.



Fig. 26. U. S. Forest Service rain gage.

### Snow Gages

Since nearly all countries use their rain gages also to measure snow, an analysis of the rain gage with respect to snow measurement should be profitable. Snow measurement with standard gages has been and still is unsatisfactory. Hudleston (443), after 7 years of exhaustive studies and experiments in precipitation measurement, noted that: "In snow, every kind of rain gage, whether it be bare or sheltered by artificial means, becomes utterly unreliable. . . . The only sound procedure, so far as I can see, is to take a 'cheese' of the snow off the ground at some place where it seems to be of average depth and melt it at your leisure." The adverse effect of exposure on snow gages cannot be denied. The lightness and surface area of the individual flakes greatly increase wind effects.

In spite of the adverse criticism of the rain gage by various investigators, it is still the instrument that is most frequently used to measure snow, and as such it has its limitations. Long, Guy, and Horton have shown that in comparison with snow sections the average rain gage (funnel removed) catches approximately 80 per cent of the snow under average conditions. With a wind shield attached, the catch increases to roughly 90 per cent of that which falls. However; it must be emphasized that these average conditions were for snow occurring with winds of 8-15 mph. As soon as the wind increases above these values, the accuracy of the gage decreases very rapidly regardless of whether shielding is provided.

#### Catching the Snow

No remarks will be made on form or exposure for snow measurements, as what applies to rain gages in these respects usually applies to snow gages.

Material.--Some experiments have been made with anti-icing and hydrophobic compounds (331) to determine their use as surface coatings for gages. These compounds are used commercially as release agents for icing and their contemplated use for snow gages is to retard side clumping and capping. To date no written report has appeared regarding the results of this study. In regard to capping, heated catch rings have shown some promise in preventing this.

Diameter. — The effect of diameter on the snow gage is very considerable and may be divided into two parts as follows:

Capping.—The value of a small orifice gage will quickly be destroyed by capping; No measurements of this phenomena have been made although there is considerable evidence of its existence. Where wet types of snowfall occur, flakes over 1 inch in diameter are not uncommon and their effect is to completely block small-diameter gages. Gages with orifices 8 inches in diameter are known to cap over in sticky snows. The sloping sides of the U. S. Weather Bureau Sacramento gage (described later) were specifically designed with this in mind. The reason-

ing was that since the wall of the gage fell away, they would not offer as much support for side clumping as would vertical walls.

Effective catch-area.--An aspect of snow-gage construction that has not been seriously studied is the effective catch-area of the orifice. This may be defined as the catch-area normal to the average path of the precipitation flow. The effect of increasing wind on snow is to increase the angle of incidence with which the flakes fall, causing the flakes to approach the gage at a very flat angle. The effective catch-area becomes less as the angle of incidence becomes greater. With sufficiently high winds, the orifice that is presented to the flakes is a thin ellipse too small for the flakes to enter without being cut by one or both rims.

Table 10 illustrates the angle and effective catch-area of snow falling into an 8-inch gage for various wind velocities, when a terminal velocity for snow flakes of 50 cm. per sec. is used. Fig. 27 shows diagrammatically how the snow would fall and how the orifice of the gage would appear to the snow when an average wind of 10 mph is blowing. The extent to which the catch of a gage will be affected by its rim may be governed by the percentage of rain drops or snow flakes that come in contact with the rim. Preliminary calculations by the author have shown that with average conditions of wind blowing at 10 mph, and snow flakes treated as 1/16-inch diameter plates, approximately 18 per cent of the flakes entering the gage would come in contact with the rim. A possible method of minimizing this rim effect would be to increase orifice diameters.

There is also a need for additional consideration of the aerodynamic effects of shielding and turbulence on gage catch.

#### Holding the Snow Catch

Wild (990) in the 1880's found that after snow fell into the gage it could be blown out easily. With this in mind, he designed a cross partition consisting of two sheets of galvanized metal, interlocked at right angles and placed in the interior of the gage. The cross partition has been used widely in Russia for both rain and snow with good results. It is effective in reducing eddying within the gage. Its principal weakness is that the wetted surface area within the gage is increased;

Other methods of retaining the snow consist of removing the funnel of the gage or increasing the depth from the gage catch ring to the funnel.

#### Measuring the Snow

The most accurate method of measuring snow is to weigh the contents of the gage. If a balance or suitable spring scales are not available, the snow may be allowed to melt in the receiver by placing in a warm room near a heater. Another method consists of pouring a known quantity of warm water into the receiver to melt the snow, measuring the total liquid content; and subtracting the original addition of water..

Taking snow sections offers a reliable method of measuring depth of snow and its water content. Horton has used a beaver board, 16 inches square and covered with white fannel, with good results. The snow board (or mat) is placed on the ground or old snow surface. In making the measurement, the board is lifted out and an 8-inch round plug is cut from it with the inverted end of the overflow receiver of the rain gage. It is advisable to make this measurement soon after the snow has finished falling and thus decrease errors due to drifting and evaporation. The snow board should be located in a place that is consistent with the exposure of the area the gage represents.

Snow stakes are used at some stations to measure the depth of the cover. These stakes are made from wood about 2 inches square and are secured in an upright position. Appropriate graduations indicate the depth of snow. Where a depression around the poles has been scoured out by wind or by melting, the level of the snow not thus affected is given. Where possible, the stakes should be on level ground as slopes are more affected by the influence of the sun.

Other appliances that have been used in standard snow measurement include:

Angot's snow basket. — This device is a wire mesh basket that allows snow to fall into it from any angle. When the basket is lifted, it contains a volume representative of the snowfall during the observation period.

Snow tables (a platform 1 meter square).— These tables have been used in France with satisfactory results when winds are not strong.

The snow bin.— This device, shown in Fig. 28, received considerable attention in western U. S. during the turn of the century. Louvres were used inside the bin to keep snow from being blown out.

The use of the 1/10th rule or any other ratio to measure the water equivalent of snow is misleading. The density of snow varies over a wide range for individual storms and areas. In general, the density of snow decreases with decreasing temperature. Currie (208) has shown that in Canada average ratios between 13 to 1 and 16 to 1 would be more realistic. In a study of 70 storms, the ratio ranged from 50 to 1 to about 10 to 1 with an average of about 13 to 1.

Special Purpose Gages

These gages are used to collect additional data that would not be available from standard gages.

Vectopluiometers

Directional gages of the rotating and non-rotating types have been in use for many years (Phillips 1837). They are used primarily to determine the direction and inclination of the average rain as controlled by wind.

Rotating types.-- These gages are built on the order of a wind vane so that their orifices face the wind. The orifice may be inclined at any desired angle, Figs. 29 and 30. Usually just one receiver is used and the results obtained are combined with the results of a horizontal gage, in a tangent formula, to give the average angle of incidence of the rain. Chrimes (1872) used them to show the variation of the angle of rain with the wind velocity. In order to use this type for a rain rose, it is necessary to keep a record of the wind direction during periods of rain. The construction of the gages depends upon the person using them as they are custom built.

Fig. 31 is a Russian vectopluiometer designed by V. Kusnetsov to measure drifting snow. The vertical orifice is pointed into the wind by the vane and admits the entry of the snow-laden air. Upon entering the gage, the air deposits its load of snow, and escapes out a hole in the top rear of the gage.

Non-rotating type -- The vectopluiometer, Fig. 32, consists of 4 or 8 vertical orifices arranged to point in cardinal directions. The horizontal orifice is usually placed in the center to determine rainfall per unit horizontal area. These gages are also custom built and provide the same data as the rotating type, plus rain rose data, without the use of moving parts. On the other hand, they do not lend themselves to streamlining as well as the vane type.

Fig. 33 illustrates a staff gage used to catch a vertical section of the rain. Water, intercepted by the staff, drops into the jug where it can be measured later. The amount of vertical surface that is presented is constant, and the amount of rain that will be intercepted will increase as the angle of incidence of the rain increases. The catch of this gage then can be applied to the tangent equation as the horizontal factor for determining the angle of incidence of rain. Considerations that limit this gage's usefulness are (1) splash loss, (2) evaporation loss, (3) area of top of staff.

Table 10  
Effect of Wind on Angle of fall of Snow  
and Effective Catch Area of an  
8-inch Gage

Wind Velocity MPH	Angle of Snowfall from Horizontal in degrees and minutes	Effective Catch Area 8-inch Gage in <sup>2</sup>
0	90-00	50.3
5	12-35	11.0
10	6-22	5.6
15	4-15	3.7
20	3-12	2.8
25	2-33	2.2
30	2-08	1.9
40	1-36	1.4
50	1-17	1.1
60	1-04	0.9



The vectopluiometer is a simple and effective research tool that shows considerable promise for precipitation studies. This gage, with standard wind equipment such as an anemometer and wind vane, can provide the following data:

1. The average horizontal directions from which the rain comes.--The non-rotating gage is excellent for rain rose studies. Lacy (519) with his octagon-shaped vectopluiometer employed paraffin in his receivers to restrict evaporation, and thus made readings on a monthly basis.

2. Average inclination of the rain. --Either a rotating or non-rotating type may be used, although the rotating is more convenient. The rotating type also lends itself to use with a recording gage, although to date this procedure has not been reported. To determine incidence of rain, the following equations may be used:

$$\tan i = R_h \div R_v$$

$i$  = Angle of incidence (from the vertical)

$R_h$  = Horizontal component of the rain as measured by the vertical orifice

$R_v$  = Vertical component of the rain as measured by the horizontal orifice

In the case of the rotating vectopluiometer, the above equation is all that is necessary. However, for the non-rotating types, the area of the vertical orifices presented to the wind varies as the direction of the wind normal to the surfaces. For instance, with a 4-orificed gage when the wind is from the north the gage would have 1 orifice facing the rain. However, if the wind were from the northwest (diagonally) there would be 2 orifices exposed, with a surface area normal to the wind equal to 1.41 times the orifice area.

For a gage with 8 orifices, the average angle of incidence was deduced by Lacy to be as follows:

$$\tan i = [\text{total catch in vertical apertures} \div 2.53] \div R_v$$

The factor 2.53 is an average between 2.40 and 2.61, the minimum and maximum area (or number) of normal orifices that are exposed by the gage. Applying the same methods to gages with 4 vertical orifices, the average angle of incidence would be determined by the relationship:

$$\tan i = [\text{catch in vertical apertures} \div 1.20] \div R_v$$

The factor 1.20 is then an average of 1.00 and 1.41, the minimum and maximum area (or number) of normal orifices that can be exposed by the gage.

Use of these formulas is subject to a small error as the average rain-bearing wind may favor a direction other than that indicated by the factor averages of 2.53 and 1.20.

3. "Equivalent drop size."—This can be calculated using the angle of incidence and average wind velocity. From these factors the average vertical velocity may be computed, and by comparison with terminal velocities, an equivalent drop size determined. Lacy notes that, "If all the rain that fell consisted of drops of the equivalent drop size, then the incident angle would be equal to that actually measured."

Maximum Catch Gages

These gages include a rotating vane-directed type, Figs. 34 through 39, and non-rotating stationary type, Figs. 40 and 41. The purpose seems to be to catch as much rain as possible without any attempt to measure the angle of fall. Results with gages of this type are questionable, as correlation with precipitation per unit horizontal area is not possible.

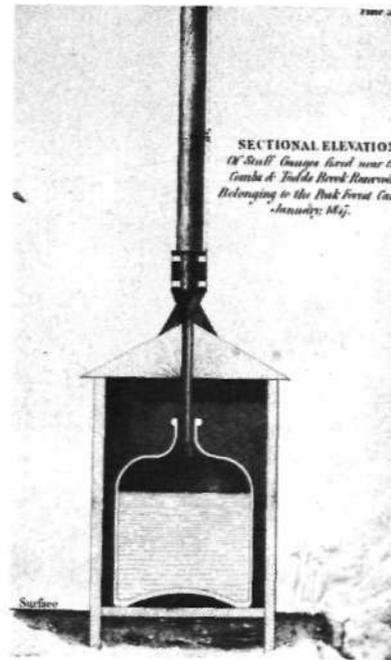


Fig. 33. Staff gage (vectopluiometer), 1847, England.

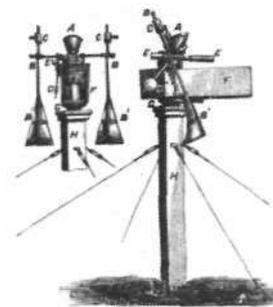


Fig. 34. Early English rotating maximum catch gage, 1850+.

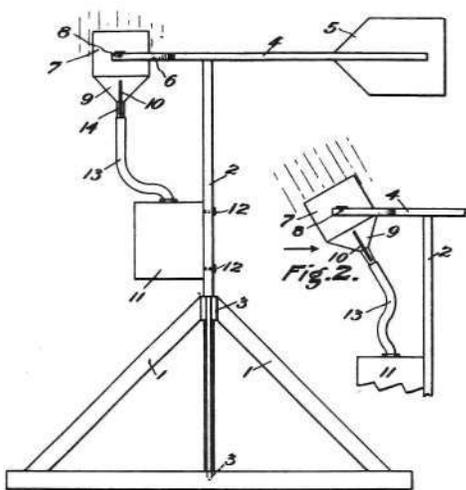


Fig. 35. Thomson rotating maximum catch gage, 1908, Australia.

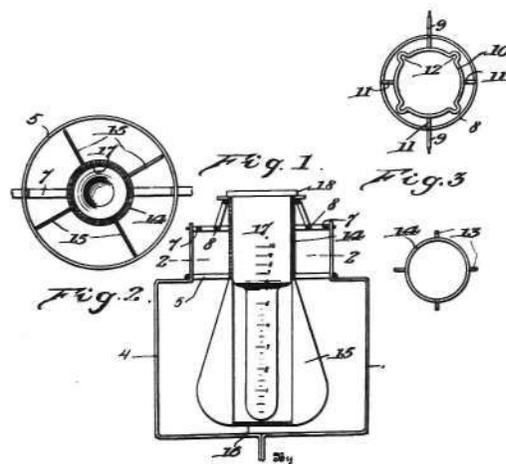


Fig. 36. Beard gimbal hung rotating maximum catch gage, 1914, United States.

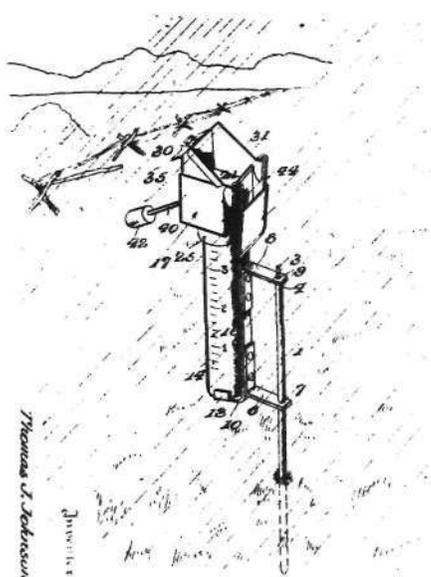


Fig. 37. Johnson rotating maximum catch gage, 1922, United States.

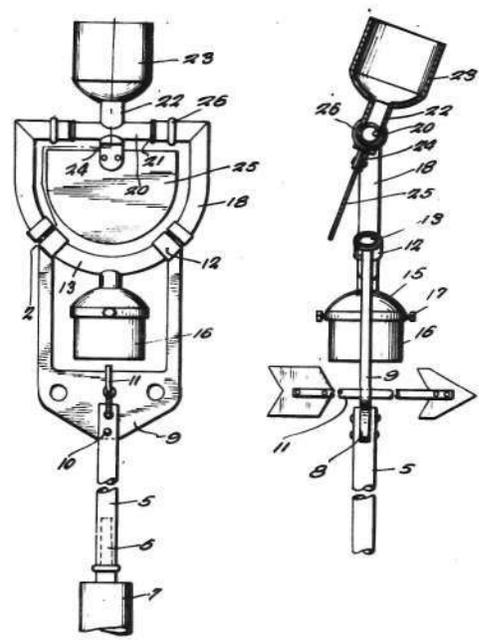


Fig. 38. Moore rotating maximum catch gage, 1945, United States.

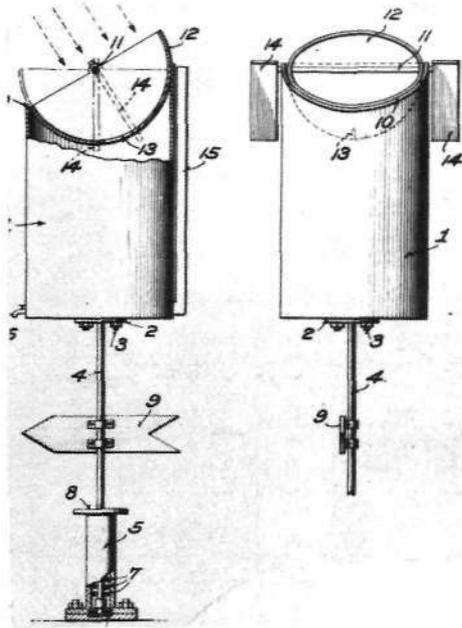


Fig. 39. Quinteros rotating maximum catch gage, 1951, Argentina.



Fig. 41. Haas-Liitschg spherical maximum catch gage, 1937, Germany.

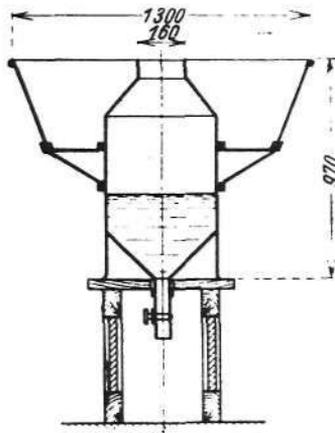


Fig. 43. Mougín totalizer with Billwiller-Niphe shield, 1910, France.

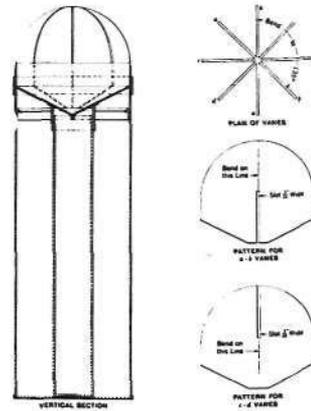


Fig. 40. Hall vane type maximum catch gage, 1931, United States.

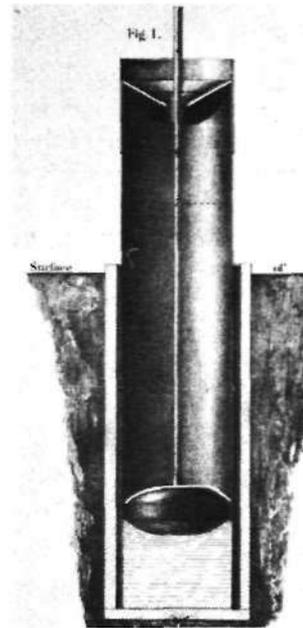


Fig. 42. Casella's mountain gage, 1867, England. The rod is removed in normal operation.



Fig. 44. Sacramento totalizer with Alter shield, 1945, United States.

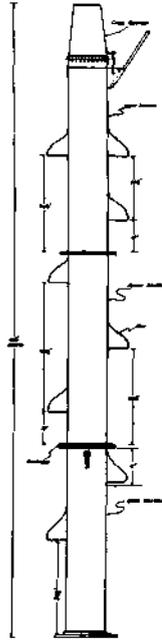


Fig. 45. U. S. Weather Bureau standpipe totalizer. An Alter shield is attached when in operation.

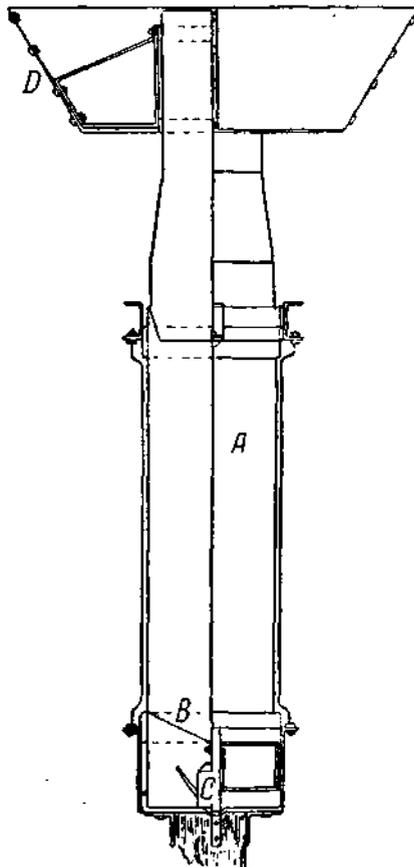


Fig. 46. Russian totalizer with Billwiller-Nipher type shield, 1937+.

Rotating types --There are many rotating types of maximum catch gages, all of individual design. The principle in all cases is to: (1) present a vertical vane to point the gage into the wind, and (2) to present a second vertical or inclined plane that is perpendicular to the wind, and so connected with the orifice of the gage as to cause the orifice to tip into the wind according to the wind velocity. Thus, there is an orifice pointing into the wind at an angle proportional to the wind velocity but not necessarily perpendicular to the falling rain, as required for maximum catch.

Non-rotating type maximum catch gages.--Such gages are of 3 types. They appear to be designed on the principle that a spherical surface presented to the atmosphere will at all times present an equal section to the falling rain regardless of direction, and therefore obtain a maximum true catch.

A contributing factor to the development of this type of gage has been the requirement for the measurement of precipitation in mountainous regions. The reasoning seems to have been that since all the precipitation in the air will be intercepted by the mountain slope, the maximum flow per unit area should be measured. Such gages are not suitable for snow measurement. A description of these gages is given below.

1836 (no figure), Robinson gage, England.--This gage consisted of a ball nearly as large as the funnel in which it was placed. Splash effects must have been considerable and only a half-sphere was presented.

1931 (Fig. 40), L. S. Hall, vane-type gage, United States.--This gage is similar in design to the Robinson Ball gage except that round plate partitions are used instead of a ball. Once again, only a half-sphere is presented, thus not fulfilling the requirements of the maximum catch definition.

1937 (Fig. 41), Haas-Lütschg spherical gage.--This gage has a large number of round orifices placed over its spherical surface. It appears that the gage would always catch a maximum amount--barring splash. The gage stands about 4 feet high.

#### Totalizer Gages

Totalizers fill a need for the measurement of precipitation in isolated areas where inspection occurs at long intervals. The use of oil-covered calcium chloride solutions in the totalizers facilitates their use for cold climates where snow is abundant. The first gages of this type, Fig. 42, were used by Symons in the mountains of England. These mountain gages were large-capacity (4 feet long) zinc cylinders, tarred on the outside and heavily insulated. Their lower section was buried in the ground so that the funneled orifice was 1 foot above the surface. A float inside the gage was of such an area that it barely cleared the sides of the cylinder. Since only a very small area of water was exposed, evaporation losses were low. The height to which



Fig. 47. Mougin-type totalizer, 1945+, Argentina.



Fig. 48. Sykes' desert totalizer, 1925, United States.

the float rose was measured with calibrated rods on a monthly basis. Salt was added to keep the solution in a liquid state and thus protect the float.

In 1887 J. Ziegler, Germany, reported on the use of an oil-coated glycerine solution to receive and preserve rain and snow. This may well have been the first use of an oil-coated antifreeze solution as is used in present-day totalizers. In 1901 Axel Hamberg, a Swedish geologist, reported results with his totalizer used in the northern mountains of Sweden. Hamberg used an oil-covered salt (NaCl) solution. Of the many totalizers tried, the Mougin pattern, Fig. 43, used in Europe, and the Sacramento model, Fig. 44, used in America, have emerged as accepted standards in the field. However, some other types, such as the Maurer

and Marvin totalizers, are in use. The outstanding feature of the two standard types is their shape, i.e., the walls of the housing slope away from the orifice so that bridging or capping by snow is not supported and large capacity is provided.

**Construction.**--Totalizers are of different sizes, depending on the expected precipitation. The side slope of the Mougin gage is 1 to 2.35 and that of the Sacramento is 1 to 6. Drain taps are provided in their bottoms, and are of a similar metal to discourage electrolysis. They are fabricated from heavy-gauge galvanized iron and all seams are welded tight. In addition, the Sacramento gage is painted on the inside with a corrosion-resistant asphaltic compound, and the outside is painted flat black to assist in melting the snow in solution by use of heat of absorption. Both are equipped with wind shields, the Sacramento gage having an Alter shield while the Mougin gage uses a Billwiller-Nipher shield. The catch rings are sharp-edged, and are fabricated from turned brass or bronze. Diameters are 8 inches for the Sacramento and 6.3 inches (159.6 mm.) for the Mougin. They are mounted on three-legged towers of height sufficient to keep the gage 4 or 5 feet above maximum accumulation of snow, and are cleaned and checked for leaks on an annual basis.

Other less used totalizer gages such as the storage can, Maurer's, Marvin's, and the stand-pipe (Fig. 45), may be constructed somewhat differently but the same precautions against corrosion, leaks, and wind are taken. The Russian totalizer, Fig. 46, does not employ a calcium chloride solution although oil is used to retard evaporation. Fig. 47 shows an adaptation of the Mougin totalizer that is used in the Andes Mountains of South America by the Argentine weather service. Fig. 48 is a desert rain gage developed by Sykes. The instrument is buried in the ground to the level of the spigot and oil is used in the receiver to preserve the catch. It may be left unattended for a period of a year.

**Retention.**--Retaining the catch for future observation is accomplished by charging the gage with an oil-coated calcium chloride solution. The objectives are (1) to provide an antifreeze solution that will melt the snow by chemical reaction, and (2) to provide an oil-coating to prevent evaporation and preserve the catch.

**Antifreeze.**--Early investigators with totalizers used a salt (NaCl) solution but later switched to calcium chloride as it was less corrosive. It is important that the correct quantities of calcium chloride and water be used in charging. The United States Weather Bureau recommends a mixture of 29.6 per cent pure calcium chloride and 70.4 per cent water by weight. This provides an antifreeze with a freezing point of  $-59.8^{\circ}\text{F}$ . The use of even a slight excess (2-4 per cent) of calcium chloride will result in a rapid rise of the freezing point, and also introduce the possibility of forming a solid hydrate precipitate that is difficult to dissolve. The former hazard also exists for solutions that may be made slightly too dilute. In no case is it advisable to put dry calcium chlor-

ide into the gage. The charge should always be made with the calcium chloride already dissolved. The quantity of the initial charge should not exceed 1/3 the capacity of the gage and should be based on the expected maximum precipitation between observations. An initial charge equal to 1.5 times the normal precipitation, placed in the totalizer in the Fall, is normally sufficient on an annual basis. The effect of increasing the freezing point by dilution of the solution is illustrated in Table 11.

Sometimes during the winter the solution may freeze in the upper layers due to stratification of the calcium chloride solution. Experience has shown that the stand-pipe gage is more susceptible to this action than is the Sacramento. Intermittent stirring of the solution will forestall such action.

The corrosive action of calcium chloride solutions may be reduced by the addition of potassium chromate and hydrated lime to the solutions. Tests (948) showed that the addition of 2 pounds of potassium chromate and 3/4 pound of hydrated lime to 100 gallons of solution would reduce the potential corrosion rate by 80 to 90 per cent. In recent years the development of automotive antifreezes such as alcohol and glycol suggests possible substitutions for the calcium chloride solutions. Some investigation along this line has been made by the U. S. Weather Bureau but to date the results have not been published.

Oil-coating.--The solution should be oil-coated to prevent evaporation. The oil must be of such a viscosity that it easily allows the passage of the precipitation, and at the same time, completely covers the solution. The U.S. Weather Bureau recommends a light motor oil, S.A.E. 5, specific gravity 0.87, and pour point of -60°F, for use in the Sacramento gage; while the Swiss weather service uses a liquid paraffin of a density of 0.8. Thickness of the oil film varies from 1/8-inch for the Mougins, to 1/5-inch for the Sacramento, to 1/2-inch for the standpipe. In summary, the chief rules for use of an oil are: (a) Use an oil of as low viscosity as practical, one that will pass precipitation and stay liquid at the

lowest expected freezing point of the solution. (b) Allow sufficient coverage so that slight wave action will not expose the calcium chloride solution to evaporation. (c) Do not use an oil that will evaporate significantly.

Measurement.--The most reliable method of measuring the precipitation of totalizers is to weigh the catch, subtract the weight of the initial charge, and convert the result to inches of precipitation. Taps are provided in the bottom of the gage for quick draining. At the same time, a maintenance check is usually run.

Volumetric checks, that is, measurements from the top or from the bottom of the gage to the surface of the liquid, should be made. Two factors that affect the reliability of volumetric measurements are (1) specific volume of the solution, and (2) a dilution effect in which the addition of a measured volume of water will, when mixed with the calcium chloride solution, add up to a slightly less volume than a sum of the portions prior to mixing.

Comparison of precipitation caught by totalizers has been made with records of snow surveys and results, although at times erratic, have often compared favorably (418).

#### Registering Gages

These gages visually show the amount of water that has collected in the gage. They may be constructed on a weight, float, or transparent receiver principle. Many registering-type gages are in effect self-recording gages without a clock operated drum. For this reason, the subject is treated lightly here to avoid duplication later.

Float gages.--Some of the early type gages employed a float in a receiver in which the rain water was collected, Fig. 49. Protruding out of the upper side of the funnel was an appropriately graduated indicating rod. A hole in the funnel allowed the rod to rise as water filled the receiver. This may have been a convenient method to measure precipitation. However, as soon as the rod rose above the level of the orifice, it vitiated the action of the gage, as rain not in-

Table 11.

Effect of Dilution on the Freezing Point

Initial Charge (1.5 x avg. ann. precip) Inches	Precipitation Inches	Total Charge Inches	Freezing Point, °F.
150	0	150	-60
150	75	225	+1
150	150	300	+22

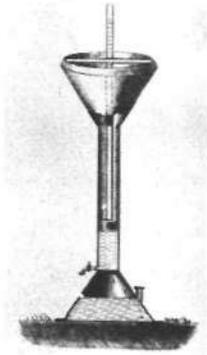


Fig. 49. Indicating float rain gage, 1850±, England.

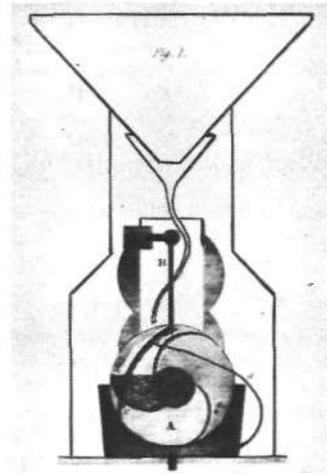


Fig. 52. Taylor's water-wheel gage, 1827, England.

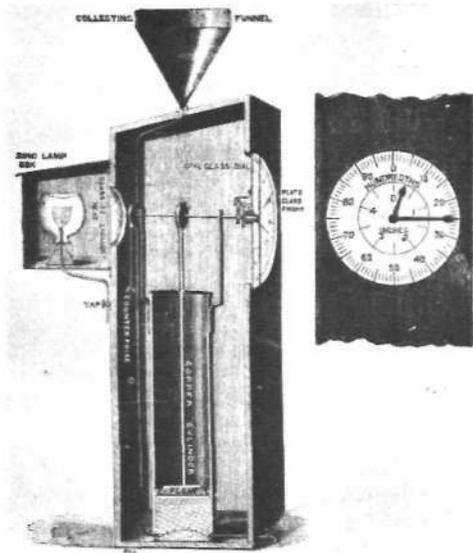


Fig. 50. Symons' improved float gage, 1870, England.



Fig. 53. Side-tube indicating gage.

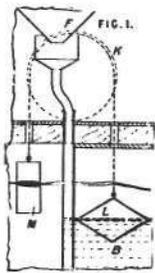


Fig. 51. Hudson's float-dial gage, 1894, England.

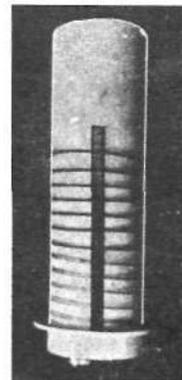


Fig. 54. Pollack side-tube gage, 1932, Germany.

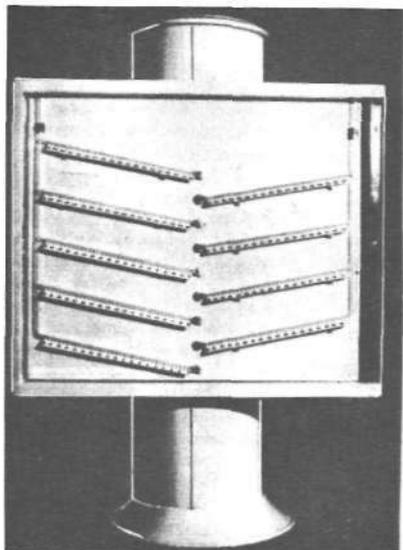


Fig. 55. Pollack-Fuch side-tube gage, 1936, Germany.

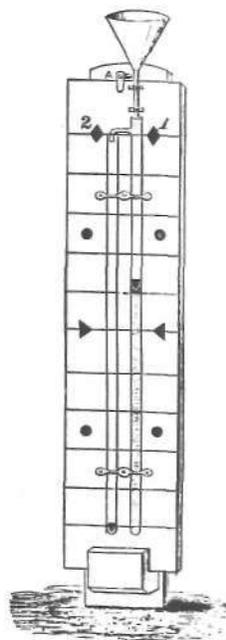


Fig. 56. Symons' storm gage, 1868, England. Magnification is 24 to 1.

tended for the gage would strike the rod and flow down into the receiver, thus giving an erroneous record.

1877 (Fig. 50), Symons' storm gage.--This gage was developed as a successor to his earlier glass-side tube gage. The principal purpose of the gage was to provide an indoor observer with a magnified indication of the rate of rainfall. A

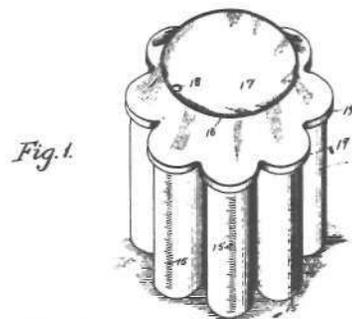


Fig. 1.



Fig. 2.

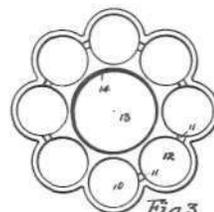


Fig. 3.

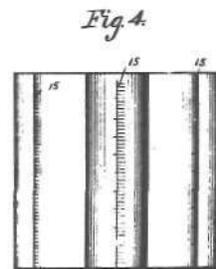


Fig. 4.

Fig. 57. Thomas overflow gage, 1904, United States.

night light was placed within the casing and the transparent dial was graduated for a capacity of 5 inches. The observer, by timing the sweep of the hand, was able to calculate the rate of rainfall.

1893 (Fig. 51), W. Hudson, England.--The Hudson gage is very similar in operation to the Symons' storm gage.

Tipping bucket gages.--These gages, employing the two-compartment design, were used with a counter system that indicated the number of times that the bucket tipped.

Water wheel gage (1827, J. Taylor, Fig. 52).--This was a well-designed and well-constructed gage that operated on a compartment system. A wheel-type container, as Fig. 52 illustrates, was divided into 3 compartments. As a compartment was filled with water, the weight of the water would cause the stop pegs to overcome the resistance of the spring stop, and the wheel would revolve 120 degrees presenting another empty bucket to be filled. The number of turns of the wheel was indicated on a dial at the back of the instrument which was calibrated to read inches of water.

Side tube gages (Fig. 53).--A glass tube attached to the outside of the gage, and appropriately graduated, enabled the observer to quickly determine the amount of precipitation that was in the receiver. Some modern variations of this theme are illustrated in the two German gages, Figs. 54 and 55, which are so arranged as to greatly magnify the readings. Gages of this type use antifreeze solutions in freezing weather. They frequently develop leaks at their fittings, and they are difficult to handle.

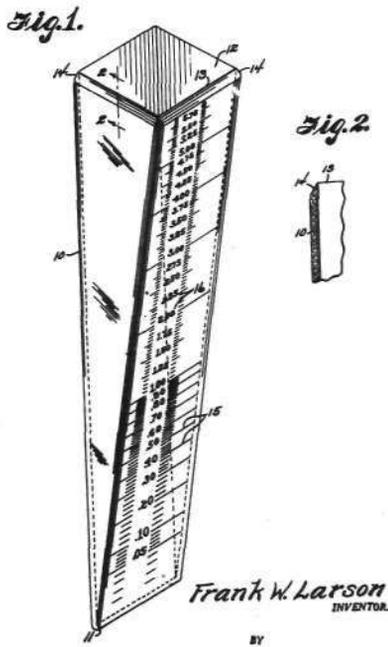


Fig. 58. Larson plastic ram gage, United States.

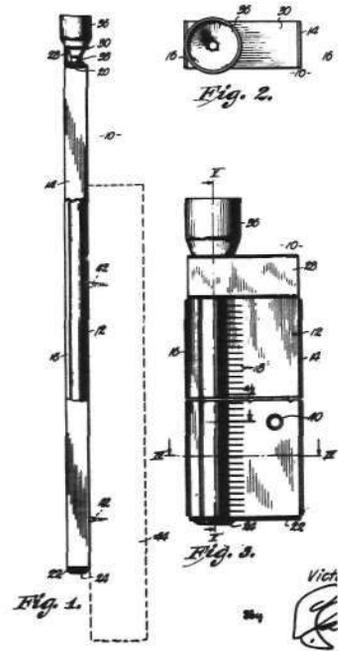


Fig. 59. Victor 3/4-inch orifice rain gage, 1950+, United States.

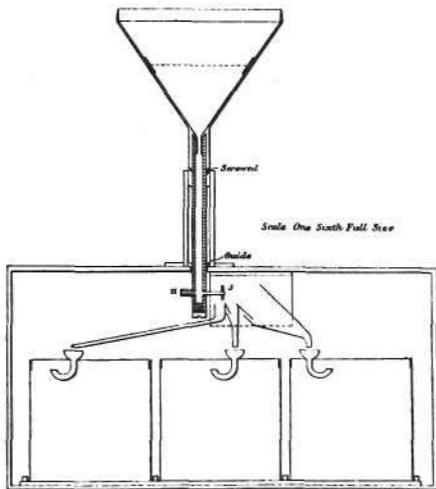


Fig. 60. Field's leak principle rate gage.

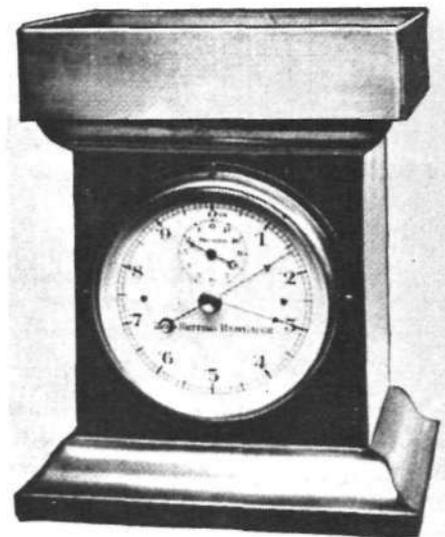


Fig. 61. Dial rain gage, 1880±, England.

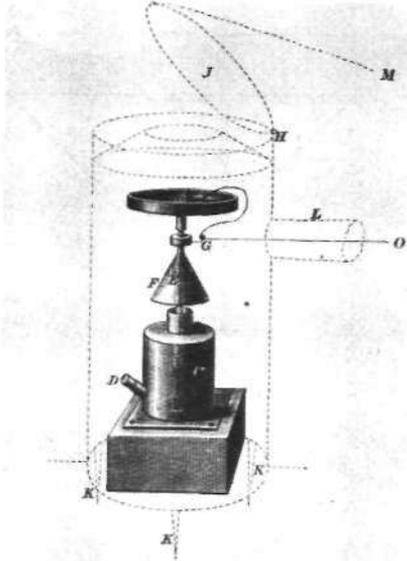


Fig. 62. Elster and Geitel insulated gage for determining charge on rain drops, 1888, Germany.

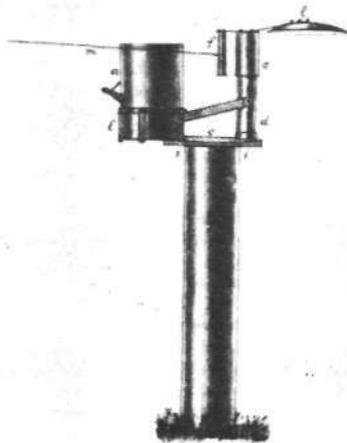


Fig. 63. Berg rain intensity gage, 1903, Russia.

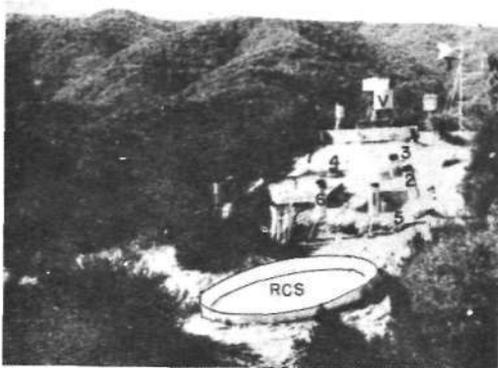


Fig. 64. Rain gage hill illustrating the use of a control (RCS) catchment area, 1943, United States.

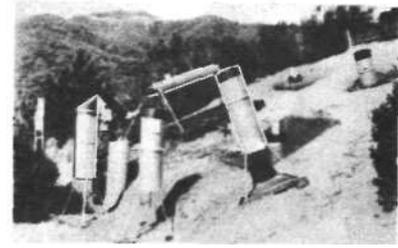


Fig. 65. Rain gage hill illustrating a stereopluiometer (foreground) and trough gage (background).

Transparent receiver type gages.--These gages, shown in Figs. 56-59, have many different patterns and essentially are built to appeal to the amateur. Most of them have a graduated receiver, smaller than the orifice, so as to magnify the catch. Fig. 56 shows Symons' first storm gage which was of value since it furnished an inside observer with a magnified view of the storm. The rise of the water was clearly visible during daylight, and the numbers were large so they could be read at a distance. Magnification was 24 to 1.

Few, if any, of the inventors have taken any precautions against evaporation or freezing. When properly used, the gages can give good results.

Jet principle gage (Fig. 60).--The flow from the funnel of this unusual gage is restricted by a calibrated orifice. The vessel to which its water jet will shoot is assumed to be an indication of the rate of rainfall. The collected and compared amounts from each vessel indicate what rates occurred during a particular storm.

Dial-type weight gage.--This type, Fig. 61, shows directly the amount of water in the gage by a clock-like dial on its face. The receiver of the gage is supported by the platform of a spring-type balance in connection with an indicating arm.

#### Miscellaneous Gages

These include various types of experimental and special purpose gages that are not of a recording variety. Fig. 62 illustrates Elster's and Gietel's insulated gage used to test the electrical properties of rain. Fig. 63 is a Berg rate-determination gage that is manually opened and closed by pulling or releasing the cord attached to the cover. This enables the observer to measure any part of the storm he desires. In Fig. 64 may be seen a catchment area labeled (RCS), and in Fig. 65 a stereo-type gage and trough gage (in the background) are shown. The catchment area is a 5-foot radius concrete pan used as a control surface for rain-gage experiments. Symons used a 1/1000 acre catchment area, as an experimental control, that was placed flush with the ground. The stereo gage has its orifice in a plane parallel to the slope of the ground to more efficiently catch that precipitation which falls on a hillside. The trough gage is placed on a slope with its long axis pointed down the slope. It is 9 inches wide

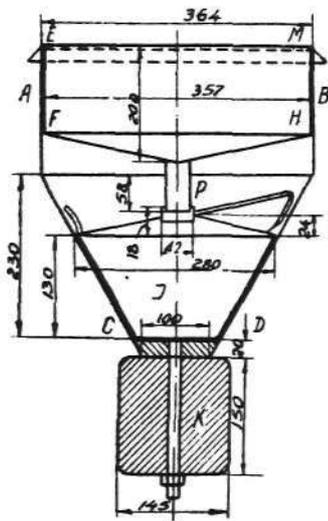


Fig. 66. Oldekop marine rain gage, 1937±, Russia.

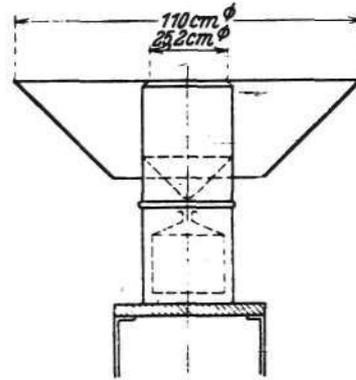


Fig. 69. Schematic of Billwiller shield, 1909, Switzerland.

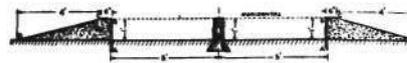


Fig. 70. Huddleston turf-walled pit gage, 1925±, England.

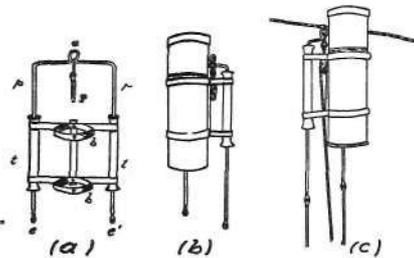


FIG. 12. METHOD OF SUPPORT OF A RAIN GAGE ON BOARD SHIP. (a) Frame. (b) Rain Gage and Frame. (c) Rain Gage Hoisted to Stay.

Fig. 67. British marine rain gage for use on ships at sea.

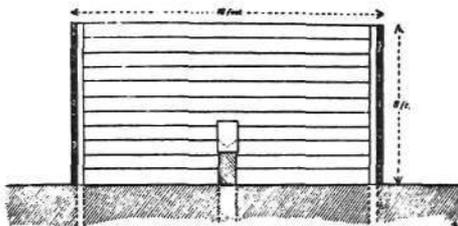


Fig. 68. Wild snow fence, 1885, Russia.

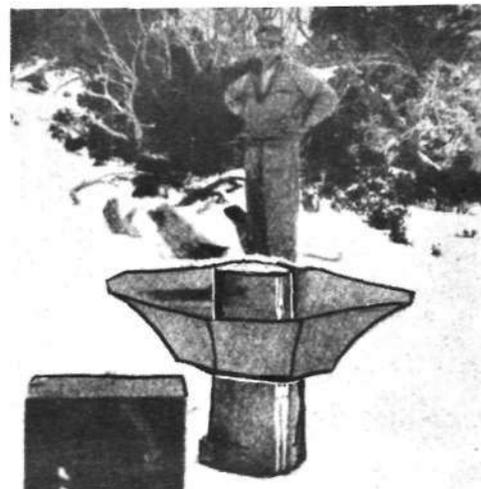


Fig. 71. Modified Nipher shield, 1935, Australia.

and a sliding cover is adjusted to expose a projection of 220 square inches. Excellent results (866) have been reported in its use.

Fig. 66 illustrates the Oldekop marine gage (Russia) that is used to measure precipitation over the surface of the sea. The gage has a weight in the bottom to stabilize it while it floats.

A rain gage for use on ships at sea\*, Fig. 67, has been used by the British (106).

### SHIELDED RAIN GAGES

The need for shielding gages against the effects of wind has long been recognized. Several designs have been proposed and built, yet no shield as presently used has completely solved the problem. Perhaps it is the vagueness of the problem itself that causes this difficulty.

The function of the wind shield is to place the orifice in an undisturbed flow of air by diverting the wind flow down and around the gage and preventing updrafts along the body of the gage (see Fig. 13). In performing these functions, the shield must not influence the catch of the gage by introducing such factors as splash and snow capping. Various wind shields developed are described in the following paragraphs.

1842 (no fig.), T. Stevenson, pit gage.--Stevenson experimented with a pit gage whose orifice was flush with the ground. Thick brushbristles to prevent splash surrounded the gage.

1853 (no fig.), J. Henry, United States.--Professor Henry designed a shield that consisted of a tin collar (a circular horizontal plate) 5 inches wide and soldered an inch below the rim of the orifice. In recent years, Warnick (1078) has wind-tunnel tested a flat collar shield quite similar to Henry's and found that its aerodynamic characteristics were excellent, i.e., the airflow over the orifice was undisturbed. Unfortunately, the collar or plate is vulnerable to splash and also collects snow which can drift into the gage.

1870 (no fig.), Rev. Stow, England.—The use of a gage in a hollowed-out depression in the ground, with the orifice of the gage at the same level as the ground, was described by Stow.

1878 (Figs. 7 and 13), F. E. Nipher, United States.--Nipher designed and tested a trumpet-shaped shield. Results were good and the Nipher design has been very popular since.

1882 (no fig.), Dr. Wild, Russia.--Experiments with a cross-partition of zinc improved the catch of the Russian gages. The partition consisted of 2 sheets of zinc intersecting each other at right angles, and placed in the gage about 2 inches below the orifice. The partition decreased eddying within the gage and was effective in keeping rain and snow from being blown out.

1885 (Fig. 68), Dr. Wild, Russia.--Wild sur-

rounded a gage with a snow fence of wood 8 feet high by 16 feet square. The gage was placed in the center of the enclosure, thereby obtaining an improved catch.

One year's comparison between the catch of a gage within the enclosure and a gage equipped with a Nipher shield (no flat collar) agreed within 1 per cent (903). An unprotected check gage had a 7 per cent deficit based upon the catch from the other two gages. The over-all effect of the fence enclosure is to decrease the angle of incidence of the falling snow flakes, and thus increase the effective catch area of the gage. However, it does not fulfill the requirements of a shield since it will cause a disturbance in the flow of air before the drops or flakes reach the gage. Compensation for this disturbing effect is not presently feasible.

1910 (Fig. 69), R. Billwiller, Germany.--Billwiller cut out the bottom of the Nipher shield to allow snow to pass through the gage and not pile up in the shield. He also eliminated the outer rim which many investigators later considered a most important feature of the Nipher shield.

1926 (no fig.), S. L. Bastamoff and W. Witkewitsch, Russia.--In wind tunnel tests they reaffirmed the desirability of using a level, screen-covered rim with the Nipher shield.

1928 + (Fig. 70), F. Huddleston, England.--This turf-walled gage is similar to a pit gage. However, in this case, walls are built up around the gage from the original ground level, thus facilitating drainage. A gentle outer slope to the walls and a vertical inner wall were pointed out as desirable features towards the reducing of splash. Huddleston stressed that the sloping walls be covered with turf as another splash-preventing feature.

1934 (Fig. 9), H. Koschmieder, Germany.--The pit gage with the rim of the gage flush with the ground was recommended by Koschmieder. In addition, a steel 6-centimeter mesh, 4 centimeters thick, covers the pit. This gage has been recommended by several investigators as an excellent rain gage. Some pertinent points that increase the effectiveness of the Koschmieder pit gage are: (1) The grating can be walked on which facilitates gage changing and reading; (2) The grating is effective in reducing splash; (3) The presence of the gage offers no obstruction to the wind.

1936 (Fig. 71), L. T. Guy and P. L. Mercanton, Australia and Switzerland.—In independent wind tunnel tests, these two investigators, one in Australia, the other in Switzerland, arrived at the same conclusion—that the rim of the catch ring of the gage should be placed about 3 inches above the level of the Billwiller-type Nipher shield.

1937 (Figs. 72 and 73), J. C. Alter, United States.--The Alter shield with loosely hanging slats arranged around the gage was introduced in 1937. The advantage of this method over others is that the swinging leaves do not readily accumu-

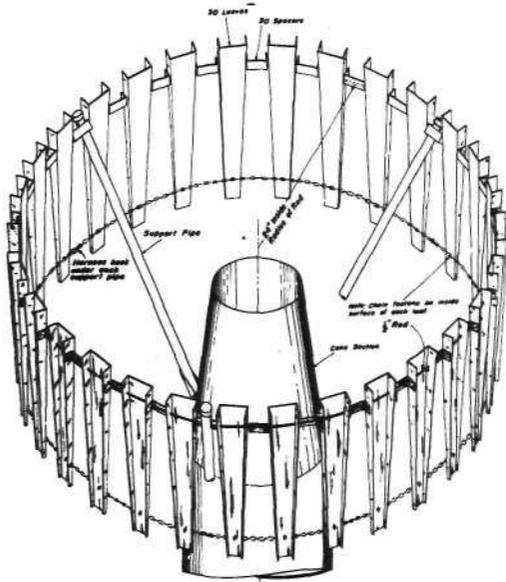


Fig. 72. Alter shield, 1937, U.S.A.

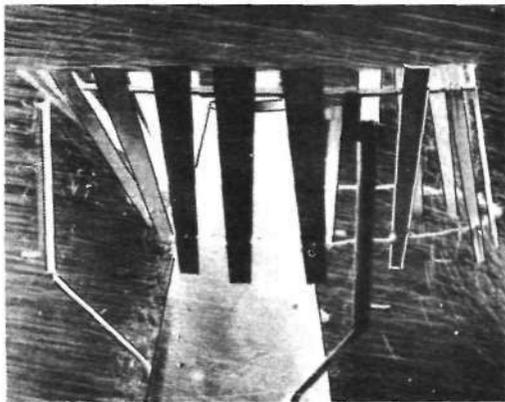


Fig. 73. Alter shield in action on a Sacramento totalizer in Warnick's wind tunnel.

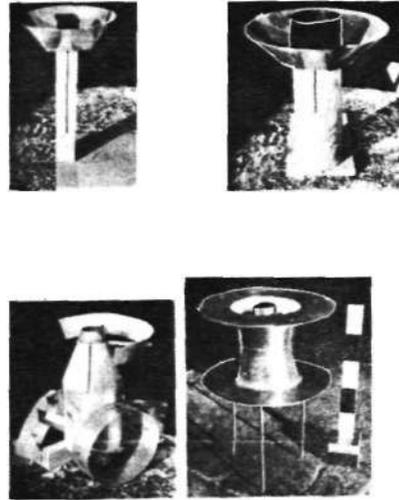


Fig. 74. Mercanton pulley-shaped shield, 1939, Switzerland (in lower right hand corner. Others are miscellaneous gages being tested).

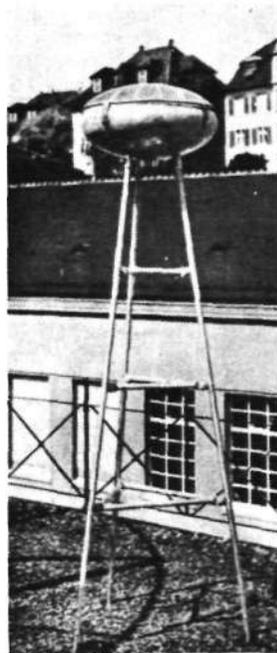


Fig. 75. Mercanton ellipsoidal shield, 1939, Switzerland.

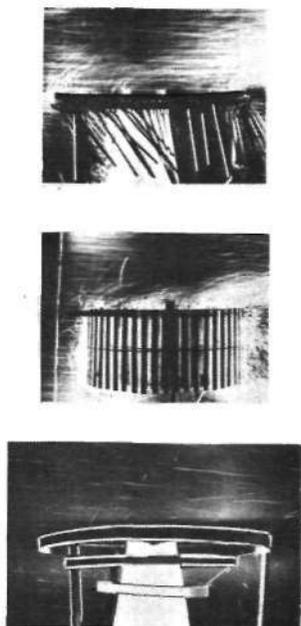


Fig. 76. Hanging wire shield, snow fence shield and floating ring shield being tested in Warnick's wind tunnel.

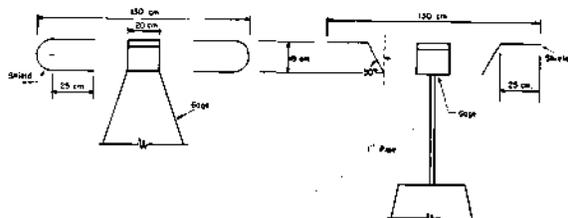


Fig. 77. Ellipsoidal and truncated cone-shaped shields tested by Sanuki, Lsuda, and Kimura in Japan.

late snow. This feature is valuable where gages are unattended, and for this reason, the Alter shield has become standard equipment on the U. S. Weather Bureau Sacramento totalizer.

1939 (Figs. 74 and 75), P. L. Mercanton, Switzerland.--Mercanton recommended, as the result of wind tunnel experiments, pulley and ellipsoidal type shields as those most nearly demonstrating aerodynamic neutrality. Of the two, he prefers the ellipsoidal type since its action is better in undulating currents. In order to satisfactorily measure snow, Mercanton has recommended the installation of a heater within the ellipsoidal gage. Field tests with the shield are underway in Switzerland.

1941, C. F. Brooks (147).--In conclusion of an exhaustive study on wind shields, Brooks has shown that the Nipher shield with a flat rim and skirt gives excellent results. Brooks' adaptation of the Nipher shield has a wire screening on the flat rim to deter splash effects. The bottom or skirt of the shield is brought down to the bottom of the gage so that the gage is completely enclosed within the shield. This prevents horizontal wind currents from reaching the gage and being deflected upward. An annular opening is provided in the bottom of the shield to allow the snow to fall through. Brooks notes that the surfaces of the gage will collect snow and does not recommend the Nipher shield for unattended stations.

1952 (Figs. 73 and 76), C. C. Warnick.--Warnick has recently completed exhaustive wind tunnel tests with Sacramento gages and Alter shields wherein he substituted sawdust for snow. He tested several patterns of gages including a circular disk-type, ring type, snow fence and modified Alter shields. His modifications for the Alter shield led to improved catches. Warnick also developed a unique method for testing the theoretical true catch of gages. This method consisted of a vertical orifice to catch a vertical section of the sawdust and a photographic technique to determine angle of incidence and velocity of the sawdust particles.

1952, Sanuki, Lsuda and Kimura (Fig. 77).—These investigators reported on results of hydrodynamic and wind tunnel tests of shields for Japanese unattended gages. The forms used for the shield suggest a similarity between the Nipher cone and Mercanton ellipsoidal shields. In this instance, the Nipher-type shield with the flat rim was most effective. Two-inch perforations in the rim and shield were incorporated in an attempt to prevent snow accumulation without undesirable wind effects. If proven successful, this should make the shield more practical for unattended gages.

#### SELF-RECORDING GAGES

Self-recording gages fill the need for more accurate determination of rainfall time and rates, and many are designed with hydrologic use in mind. As with non-recording gages, most of the early models were hand-tailored according to the needs of the individual. Many of the present-day gages are individual types that may stress one particular feature of precipitation. An attempt has been made to classify the gages according to their mode of operation and most prominent features.

The salient features of the gages, with regard to specifications such as material, form and diameter, will not be considered since these factors are the same for recording gages as for non-recording gages. In many respects the self-recording gage is a standard gage with recording elements. The recording elements should be accurately constructed of permanent metals and compensated for such factors as temperature and

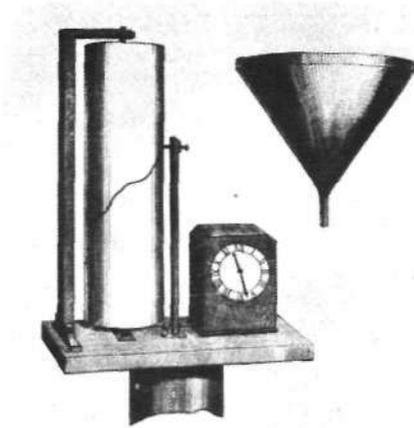


Fig. 78. Bevan's float gage, 1817, England.

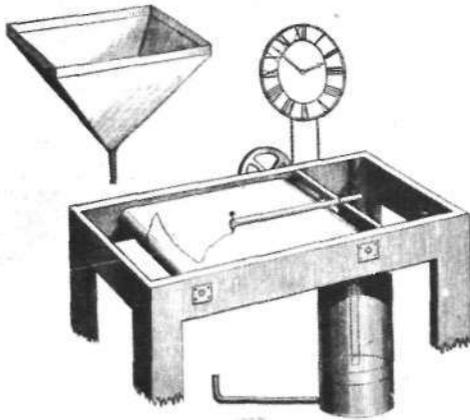


Fig. 79. Dolland's float gage, 1846, England.

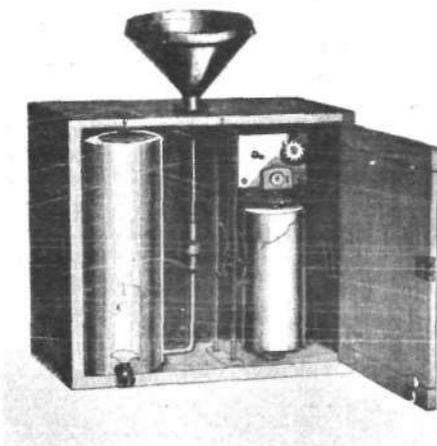


Fig. 80. App's float gage, 1866, England.

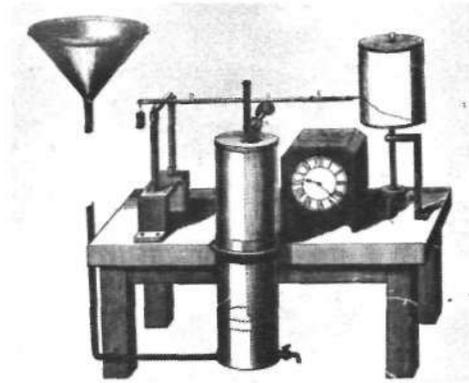


Fig. 81. Breguet's float gage, 1876, France.

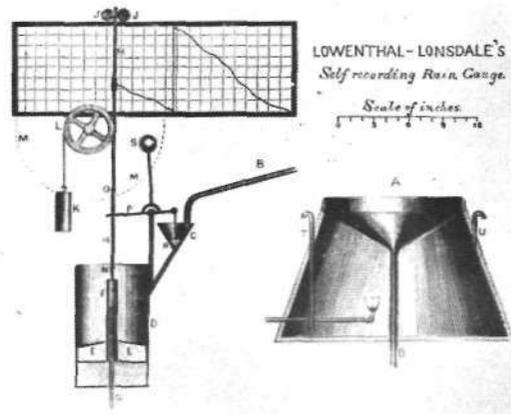


Fig. 82. Lowenthal-Lonsdale float-siphon gage, 1879, England.

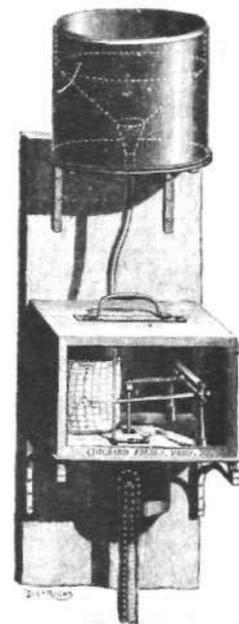


Fig. 83. Richard Frères electric float-siphon gage, 1886, France.

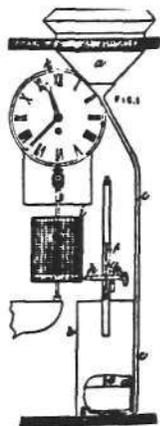


Fig. 84. Tomes float gage, 1889, England.

wind. A minimum of moving parts should be used to achieve low frictional losses. Lag time must be kept low and the gage must be sensitive but rugged. Materials used for moving parts in all cases should be of non-corrodible or stainless metals, especially so if antifreeze solutions are used.

#### Float-Type Gages

These gages operate on a displacement basis. A float in the receiver of a rain gage rises as water is admitted into the receiver. The rise of the float is calibrated and mechanically connected with a clock-operated recording system. The float-type gage may be further classified into 3 subdivisions designated by the nature of the recording system.

1. Limited-register gages.--These have no facilities for continuous action and must be emptied and reset whenever the pen arm has reached the limits of the paper.

2. Continuous-action gages.--Such gages have mechanical provisions for cyclically returning the pen arm to the zero line of the chart and will operate to the capacity of the receiver.

3. Intermittent emptying gages.--These types combine continuous recording with an emptying action that drains or siphons the receiver cyclically, and thus are truly continuous in nature. A major difficulty has been the attainment of a prompt siphoning action, and toward this end there have been a considerable number of improvements and inventions.

A description of various float-gages is given in the following paragraphs.

1817 (Fig. 78), B. C. Bevan, England.--Bevan's gage, a limited-register type, had a 12-inch funnel and a receiver 3 feet long by 6 inches in diameter, which gave a 4:1 magnification. The float-to-pencil rod action was direct. Gage ca-

capacity was 8 inches.

1846 (Fig. 79), G. Dolland, England.--How Dolland accomplished his purpose of returning the pen arm is not clear. Quoting from Symons, ". . . in this there is an air float, connected with a set of inclined planes, each inclined plane being equal to 1 inch of rain." Each plane apparently moves the pen arm its one inch, is discarded, and the pen arm returns to zero. This action repeats itself for a 6-inch capacity. Dolland's gage was the first gage with the continuous-action recorder.

1854 (no fig.), G. Fagnoli, Italy.--Fagnoli's gage was almost a duplicate of the early Bevan gage (Fig. 78).

1866 (Fig. 80), A. App, England.--App's limited-register gage used cords, pulley's and track guides for his recording action, instead of the direct-recording rod.

1867 (no fig.), Padre Seichi, Italy.--Seichi used a float gage similar to App's (Fig. 80), except that he employed a disc recorder instead of a clock-operated drum.

1872 (no fig.), H. C. Russell, Wales.--Russell used a gage very similar in appearance to Bevan's (Fig. 78), except that the clock moved the pencil and the rain moved the drum--the reverse of Bevan's.

1876 (no fig.), A. Eccard and D. Gibbon, United States Signal Service.--These men designed a gage similar to App's (Fig. 80), for the Philadelphia Exhibition about 1876.

1876 (Fig. 81), M. Breguet, France.--This is the usual continuous-action float gage with direct-acting rod. The system employs a heart-shaped cam, actuated by a rack and gears on a rod, which causes the pen arm to drop to zero whenever a complete turn or revolution is made.

1879 (Fig. 82), L. Lonsdale, England.--This gage is in two parts. The receiving area is on the outside while the recording mechanism is inside a building protected from the frost. As the float rises and nears the top of its cycle, a stud on the float rod engages another rod that closes the funnel while the receiver is siphoned empty. This prevents the loss of any rain during emptying. As the float descends during emptying, another stud engages the opening device and the funnel is reopened and ready for operation. The gage cycle is 1 inch. Provisions were made for gas heating the funnel for winter snowfall measurement.

1886 (Fig. 83), Richard Freres, France.--This was a float, automatic-siphon gage that worked on the usual direct-acting float-siphon principle, with the siphon tube running up the central axis of the receiver. Later, to overcome the difficulty of a dribbling siphon, an electromagnet was employed that plunged the float a short distance into the receiver whenever the full-position (10 mm.) contact was reached. This resulted in a very positive siphon action.

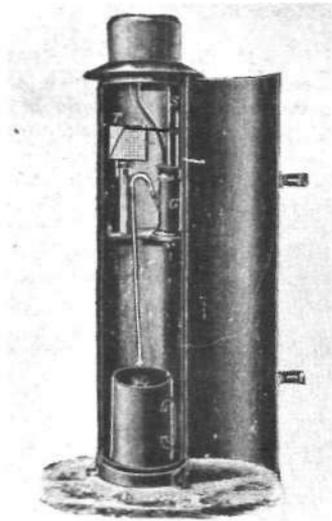


Fig. 85. Hellmann's float-siphon gage, 1897, Germany.

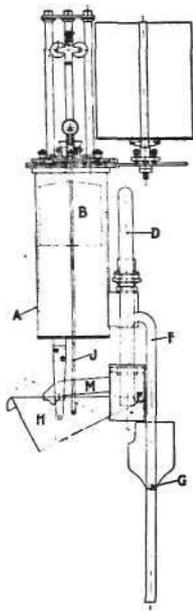


Fig. 86. Negretti-Zambra Fernley float-siphon gage, 1900±, England.

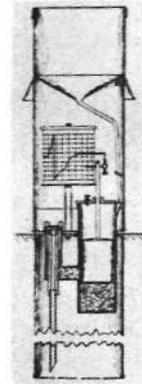


Fig. 87. Negretti-Zambra float-siphon gage, 1900±, England.

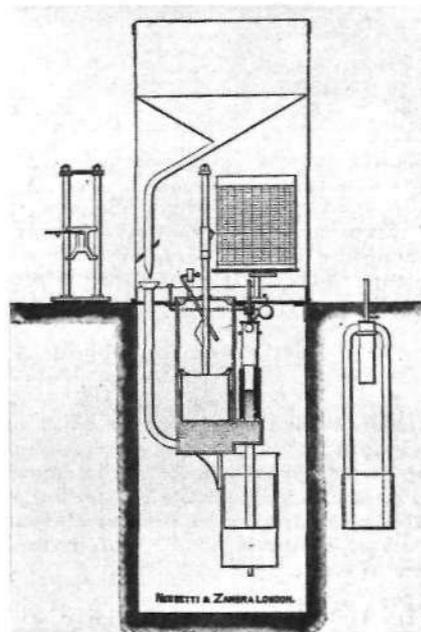


Fig. 88. Halliwell's float-siphon gage, 1901, England.

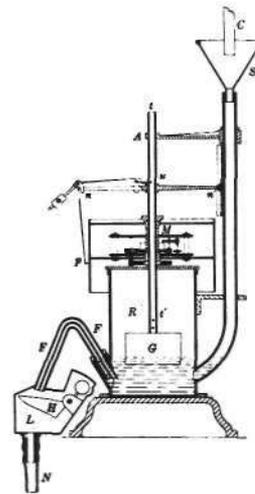


Fig. 89. Palazzo float-siphon gage, 1905, Italy.

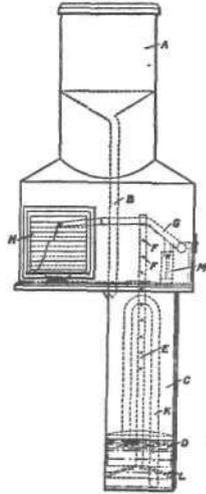


Fig. 90. Halliwell's hyetograph, 1908, England.

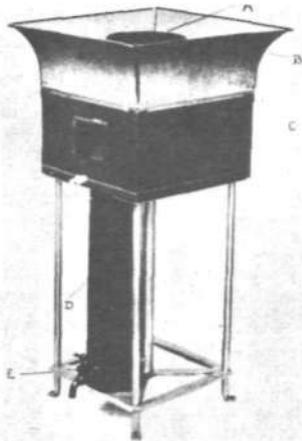


Fig. 91. Marvin's float gage with modified Nipher shield, 1915, United States.

1889 (Fig. 84), R. Tomes, England.—Tomes obtained a patent on a float rain gage almost exactly the same in design as Bevan's (Fig. 78). It is a limited register, direct-acting, rod-float gage.

1897 (Fig. 85), Dr. G. Hellmann, Germany.—The Hellmann gage has been widely used throughout central Europe and has in some respects become a standard for this type of gage. The catch ring of the orifice is 159.6 millimeters (6.28 inches) in diameter and 1 meter above the ground. The water is directed into the receiver where a float rises as it is displaced. A rod on the float records directly on a clock-operated drum. When the receiver is filled, water flows into the siphon tube and initiates a siphon action. The gage cycle is 10 millimeters of rain and magnification is 8 to 1. The long siphon tube insures accurate siphon action.

1900 ± (Fig. 86), Negretti-Zambra, Fernley gage, England.—A tipping bucket and suction action similar to the Palazzo (Fig. 89) gage, to insure rapid siphoning, is employed in the Fernley float-type gage. Otherwise it is similar in action to other direct-acting float gages.

1900 ± (Fig. 87), Negretti-Zambra, England.—The Negretti-Zambra natural siphon gage introduced in the early 1900's has been popular in England. This gage employs a side tube with a narrow annular siphon opening to insure rapid and complete siphoning. The end of the long leg of the siphon tube is enlarged to retard dribbling.

1901 (Fig. 88), F. Halliwell (Negretti-Zambra), England.—This is a patented float-type gage that has a siphoning period of approximately 5 seconds. The usual direct-recording float system is employed. In addition to this, a side tube is used for siphoning. As the float in the receiver reaches the siphon point (1/2 inch of rain), it engages a trigger that allows a suspended siphon tube to drop and plunge down into the water in the side tube. This immediately starts a full bore siphon action that quickly empties the receiver into another receiver just below it. This second receiver has a float in it that lifts the siphon tube to its trigger position as the second receiver becomes filled. A small hole in the bottom of the second receiver slowly empties it. A mercury seal is necessary for the suspended siphon tube.

1905 (Fig. 89), L. Palazzo, Italy.—This is a siphon-type gage that has been used in Italy. In operation it is similar to the other float-siphon gages. However, a tipping bucket insures rapid siphoning. The tipping bucket is at the end of the long-leg of the siphon tube, and as dribbling fills the bucket, it causes the bucket to tip and suddenly discharge. The resulting suction starts a full bore siphon action that takes 11 seconds to empty the receiver.

1908 (Fig. 90), F. L. Halliwell, England.—The hyetograph is a very popular and efficient gage extensively used in England. Mill (654) notes the action of the gage as follows: "A float (D), carrying a rod (E), rises as the chamber fills. On this rod there is a row of projecting studs (F), at equal intervals, and the pen lever (G), which is hinged at the right hand end. It rests lightly, by means of a side plate, on the first of these studs with the pen arm at the bottom of the chart when the gage is empty. As the float rises, the stud carries the lever up with it until the pen reaches the top of the chart, thereby recording one-half inch of rain. At that point the lever plate slips off the stud and falls until it is caught up by the next lowest stud with the pen at the bottom of the chart again. An oil brake (M) checks the fall of the levers so that it drops quite gently onto the lower stud. The process is repeated until the receiver is full (4 inches). There is no mechanism for automatic emptying and consequently nothing to go wrong."

1915 (Fig. 91), C. F. Marvin, United States Weather Bureau.—Marvin designed a float gage using cord and pulley for the transmission of the float position on the recording system. Weekly

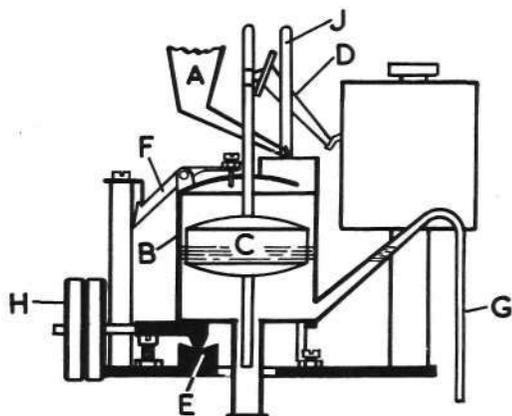


Fig. 92. Schematic of the mechanism of Dines tilting float-siphon gage, 1920, England.

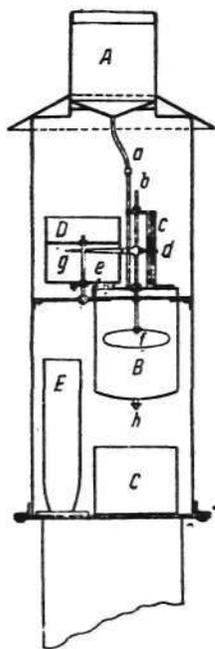


Fig. 93. Berg float gage, 1925, Russia.

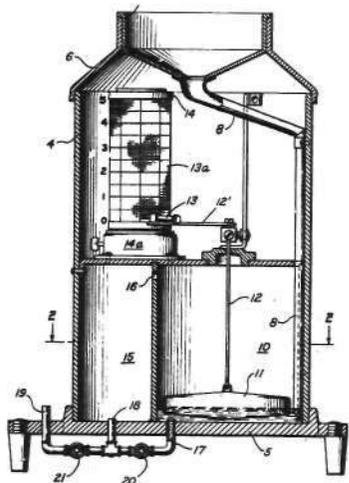


Fig. 94. Chappell floatgage, 1938, United States.

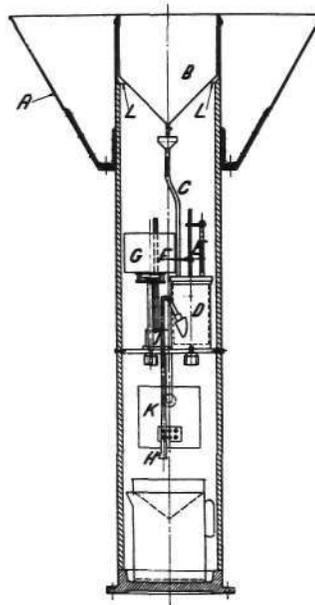


Fig. 95. Korhonen-Ahti modified Hellmann float-siphon gage, 1937, Finland.

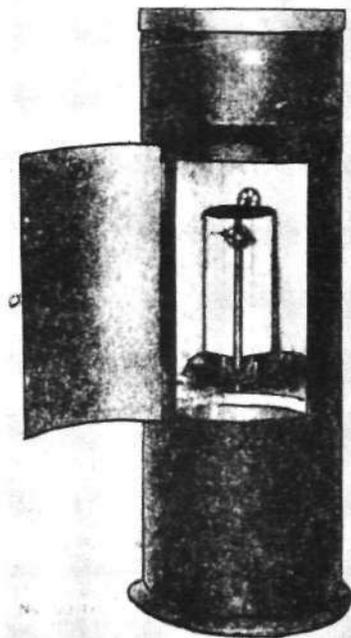


Fig. 96. Lietz float gage, 1940±, United States.

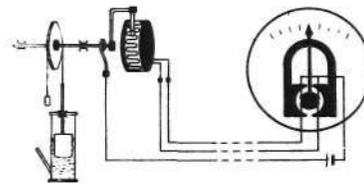


Fig. 97. Linke electric rain gage, 1940, Germany.

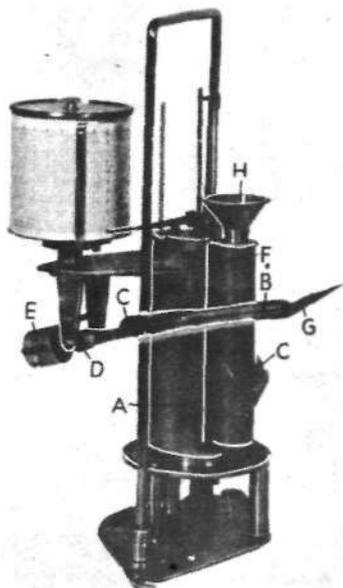


Fig. 98. DeBilt pluviograph, 1950, Netherlands.

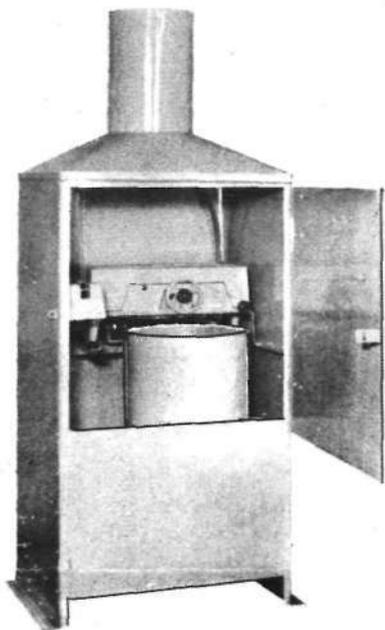


Fig. 99. Stevens\* float gage, 1950±, United States.

capacity is provided and the pen moves sinusoidally with a cycle of 1/2 inch. Magnification is 2 to 1.

1920 (Fig. 92), W. H. Dines, England.--The tilting siphon gage has been a widely accepted gage in England and many are in operation. The usual float and siphon system is employed with one exception. When the float reaches the top of its cycle, a trigger is engaged which allows the receiver to tip in its unbalanced condition. This tipping suddenly fills the siphon tube and a full bore siphon action takes place. Thirteen seconds are required to empty the receiver. When the receiver is empty, a counterweight returns it to its original position, and the pen arm is returned to the paper at the bottom of the 0.2-inch cycle.

1925 (Fig. 93), Berg, Russia.--This is a simple direct-acting float gage that operates to the capacity of the receiver. A tap is located in the bottom of the receiver for manual emptying.

1935 (Fig. 94), Chappell, United States.--A direct acting float gage that has no provisions for continuous action was developed by Chappell.

1937 (Fig. 95), V. V. Korhonen and L. E. Ahti, Finland.--This is a modification of the Hellmann siphon gage to adapt it for winter use in Finland. A thermostatically controlled electric heater (K) warms the air within the insulated housing, and thus indirectly warms the non-insulated funnel. The heated funnel then melts the snow. The discharge end of the siphon tube has been fluted to retard dribbling.

1940 + (Fig. 96), Lietz, United States.--The Lietz gage simply combines the use of a water level recorder (such as is popular in hydrologic work) with a large receiver into which the funnel drains.

1940 (Fig. 97), Linke, Germany.--The direct action of a float-siphon gage is applied to an electrical indicating system that provides a dial to show rainfall rate and amount to an indoor observer.

1950 (Fig. 98), DeBilt, Holland.--The DeBilt pluviograph, as used by the Royal Netherlands Meteorological Institute, appears to be the ultimate in float-siphon design. A simple direct-acting float siphon is used. The siphoning action employs a counter-balanced tube in connection with the receiver. At the end of the cycle, the tube begins to fill with water. Only a small amount of water will cause the tube to fill, rapidly rotate about pivot C, and discharge its contents, thus starting a full bore siphon action. This action takes place suddenly, and as a result, empties the receiver in 4 1/2 seconds for every 10 millimeters of rain with an accuracy of 0.1 millimeter. As soon as the receiver and tube are empty, the counterweight swings the tube back to its original position, and the cycle is complete with the pen arm at the bottom of the sheet.

1950± (Fig. 99), J. C. Stevens, United States.--The Stevens rain gage employs a large capacity

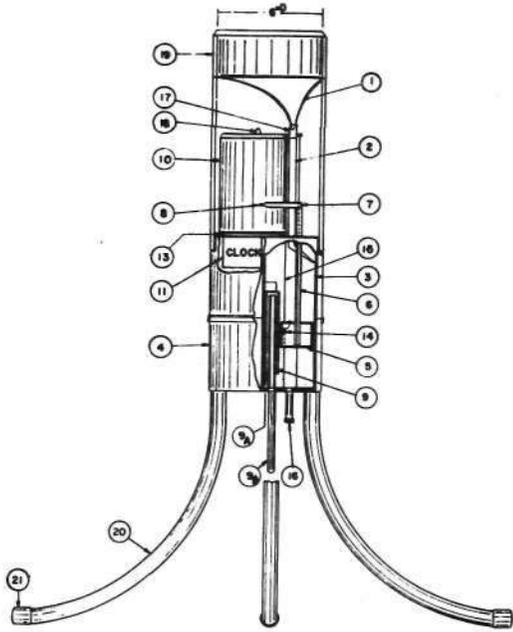


Fig. 100. Lange plastic-float-siphon gage, 1952, United States.

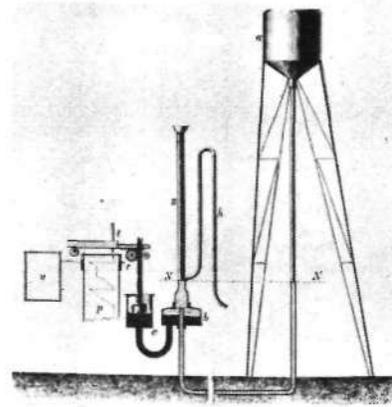


Fig. 102. Fuess mercury manometer gage, 1883, Germany.

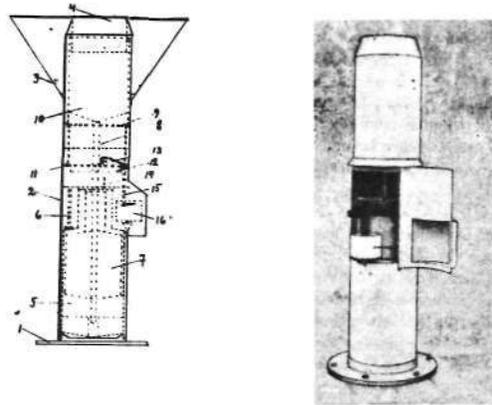


Fig. 103. Rossi oil-float gage, 1947, Finland.

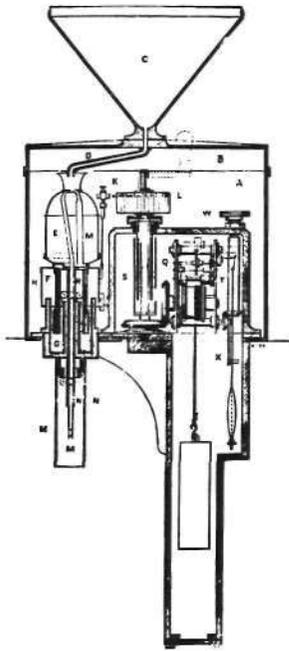


Fig. 101. Beckley's mercury-float gage, 1870, England.

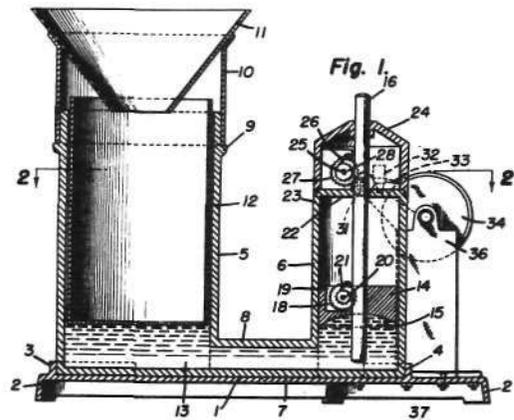


Fig. 104. Cappleman, mercury-piston gage, 1950, United States.

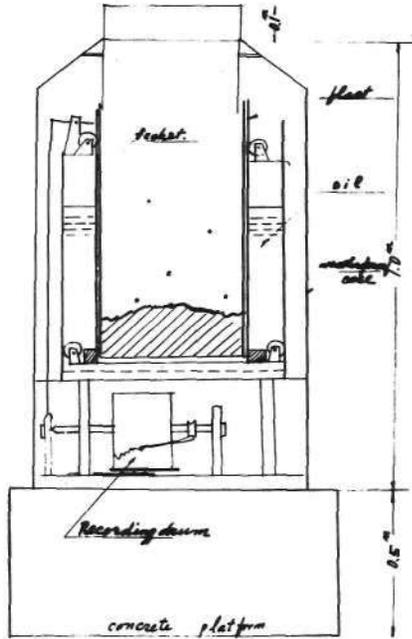


Fig. 105. Japanese hydrometer gage, 1952±.

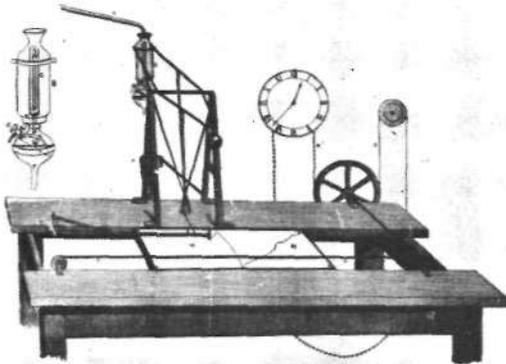


Fig. 106. Osier weight-siphon gage, 1837, England.

reservoir in conjunction with a float-operated recorder, such as is used in stream gaging.

1952 (Fig. 100), Lange, United States.--This gage is made almost entirely of clear plastic. It has been used at the University of Kentucky. It is very similar in operation to the Negretti-Zambra natural siphon gage. Operation is on a 1-inch cycle and siphoning time is 10 seconds. Surprising as it seems, this is the only siphon gage found in the United States literature.

#### Oil and Mercury Float Gages

In order to overcome the effects of freezing, a few inventors have transferred the action of the water in float gages to fluids, such as oil and mercury, that remain liquid at low temperatures.

Two gages on the foregoing principle were introduced about 1870.

1870 (Fig. 101), R. Beckley, England.--This gage employs a receiver that floats in mercury. The pen arm is attached to the receiver, and a direct record is made on a clock-operated drum. A siphon in the receiver provides the means of emptying, and action is on a continuous basis. An interesting feature of this gage is that operating parts are hermetically sealed. Funnel diameter is 11.3 inches and the siphon acts on a 0.20-inch cycle.

1870 (no fig.), Dr. Osnaghi, Austria.--Dr. Osnaghi devised a gage operating on essentially the same principle as the following illustrated and described gage.

1883 (Fig. 102), R. Fuess, Germany.--This gage, employing the use of mercury, answers the description of the Osnaghi gage in all the details, except that the pen arm movement of the Osnaghi gage was multiplied by a lever system, while the Fuess gage employs a rack and gear assembly. In the Fuess gage, the bottom of the receiver is a mercury bath that is in a manometer arrangement with a float-recording system. The level of the mercury in the receiver alternates as a function of the short leg of the siphon and the weight of the water in the long leg. A 2-millimeter cycle is used. No reports on results with this gage are available.

1947 (Fig. 103), V. Rossi, Finland.--This gage employs a receiver directly supported by a float in oil. The position of the float is calibrated to record millimeters of rain on a clock-operated drum. When the receiver has descended to the bottom of its cycle (10 mm. of rain), a weight attached to the receiver is released and the receiver bobs up to its original position. There are 4 such weights on the receiver, each being released at the bottom of the cycle. The capacity of the gage is 50 millimeters of rain and operation is on a daily basis. Some difficulties have been experienced with volumetric changes in the oil at low temperatures.

1950 (Fig. 104), H. L. Gappleman, United States.--This is a patented rain and snow gage that operates on a pressure basis. As snow or rain falls into the receiver, piston pressure is exerted on the mercury and is transmitted to the float-piston of the recording apparatus. The motion of the float-piston of the recording apparatus is calibrated to record on the clock-operated drum. The receiver has no provisions for self-discharging. No results have been reported with this gage.

1951+ (Fig. 105), Japanese Weather Service, Japan.--This gage has been under test in northern Japan. The receiver of the gage and its platform float in oil. As the receiver descends due to the addition of precipitation, a record is made of the platform's progress on a clock-operated drum similar to a water-stage recorder. Guide wheels are used to prevent the receiver from bobbing in the horizontal plane, and the receiver is manually discharged.

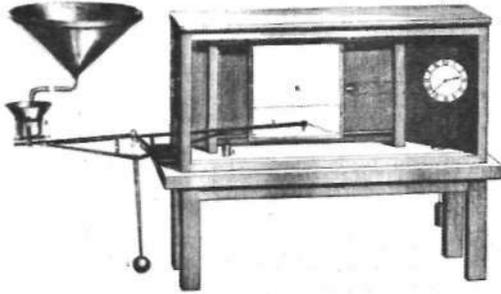


Fig. 107. Kreil's weight-and-tipping-bucket gage, 1848, England.

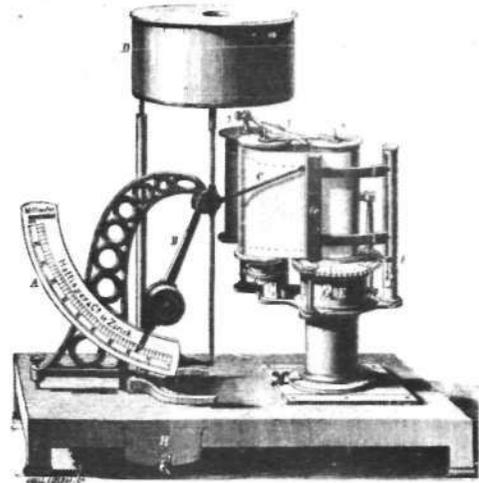


Fig. 110. Hottinger weight gage, 1877, Germany.

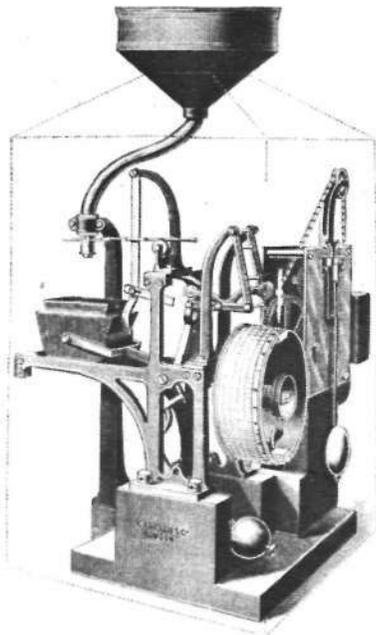


Fig. 108. Casella's weight-and-tipping-bucket gage, 1871, England.

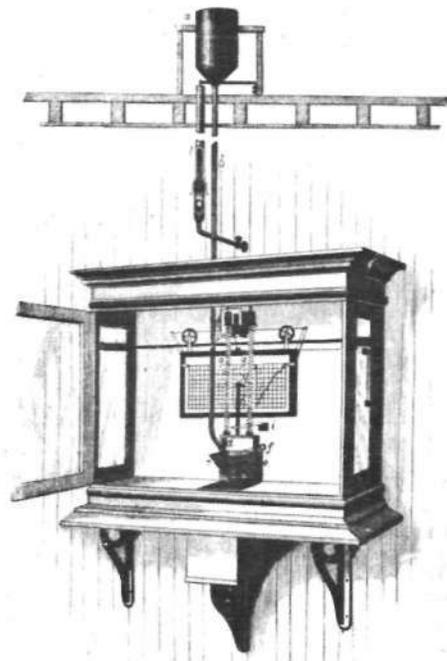


Fig. 111. Draper's weight-type tipping-bucket gage, 1879±, United States.

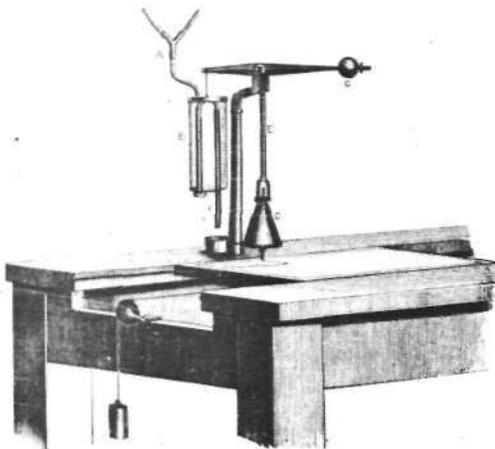


Fig. 109. Capello's weight-siphon gage, 1864, (France?).

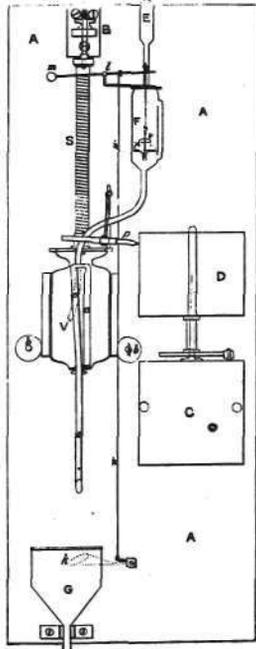


Fig. 112. Mechanism of Ellery's weight-siphon gage, 1879+, England.

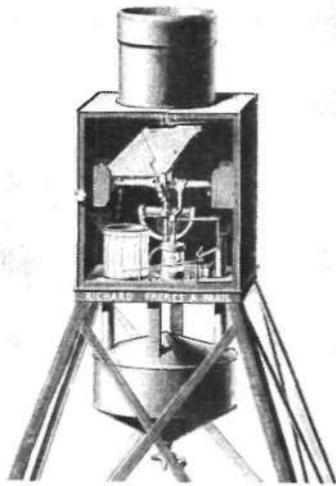


Fig. 113. Richard Freres' weight-tipping-bucket gage, 1882, France.

#### Balance or Weight Type Gages

These gages operate on the principle of a descending counterpoised receiver. This method has an important advantage over the float gage, namely, that the amount of snow (water equivalent) may be measured in some cases without being melted. However important this provision may be, in most cases, it precludes the possibility of the gage being used for truly continuous action, as a practical method of emptying the accumulated snow and ice has not been developed.

1837 (Fig. 106), A. F. Osier, England.--The receiver of this gage is counterbalanced by

weights hung on the opposite side of the fulcrum. This weighted end is connected to a rod that swings the pencil over the clock-operated sliding paper in a manner proportional to the amount of water in the receiver. The receiver contains a siphon that empties it on a cycle of 1/4-inch of rain. Record magnification is 8 to 1. A tipping bucket at the end of the long leg of the siphon tips as it becomes filled with dribblings. This sudden tipping fills the outlet tube and causes enough suction to start a good siphon. The same effect was later adopted in the Palazzo and Fernley gages, previously described in the section on float gages.

1848 (Fig. 107), Dr. Kreil, Austria--The counterbalanced receiver is a bucket that tips and empties when it becomes filled. This action is calibrated and recorded on the chart of a clock-operated drum.

1871 (Fig. 108), Casella, England.--A counterbalanced tipping-bucket gage was developed by Casella. Operation was on a 0.2-inch cycle for an 8-inch diameter orifice.

1879+ (Fig. 109), Capello.--This is a weight-type gage employing a siphon action to empty the receiver, thus providing a continuous action.

1877 (Fig. 110), Hottinger fe Co., Germany.--The movement of a counterweighted receiver is calibrated and a record punched (every 10 minutes) on a continuous roll of paper. A dial is also used to indicate visually the amount of rain that has fallen. An overflow handles the water when the gage is filled, and the gage was designed purposely for use in rain. The orifice diameter is 9.95 inches and the capacity of the receiver is 3.94 inches of rain.

1879 (Fig. 111), P. Draper, United States.--This gage employs a bucket hung by 2 light springs. The tension of the spring acts in the place of the counterbalance. The bucket tips when it is filled and magnification is 10 to 1. The temperature of the funnel is kept above 40° F. by a gas heater thermostatically controlled. A pen arm connected to the bucket provides direct recording on a moving sheet of paper.

1879± (Fig. 112), R. Ellery, England.--This gage is very similar to Draper's except that a siphon empties the bucket rather than a tipping action. A valve closes the funnel by the impact of the water from the siphon hitting a pallet in connection with the valve. This prevents loss of water during the siphonings. The cycle is for 1/4 inch of rain and takes 9 seconds.

1882 (Fig. 113), Richard Freres, France.--A single compartment tipping-bucket gage was developed. The pivot that supports the bucket is counterpoised and descends as water fills the bucket until the tipping point is reached. This action is recorded and calibrated. A catch of 10 millimeters represents the cycle of the gage, and magnification is 8 to 1.

1884 (Fig. 114), G. Rung, Denmark.--The Rung gage is very different in appearance from the others described, yet its operation is similar.

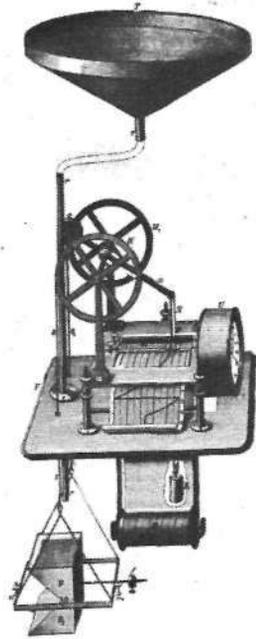


Fig. 114. Rung's weight-tipping-bucket gage, 1884, Denmark.

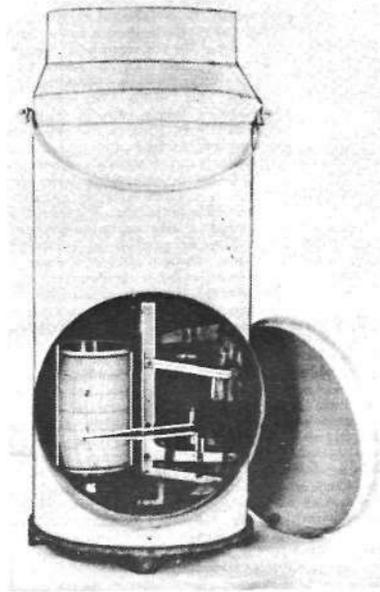


Fig. 116. Fergusson rain and snow gage, 1889, United States.

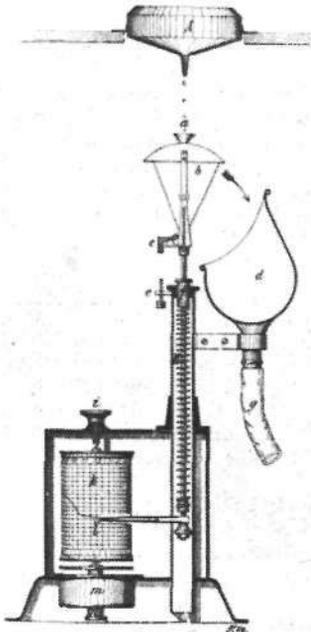


Fig. 115. Maurer-Hottinger weight-tipping-bucket gage, 1884, Germany.

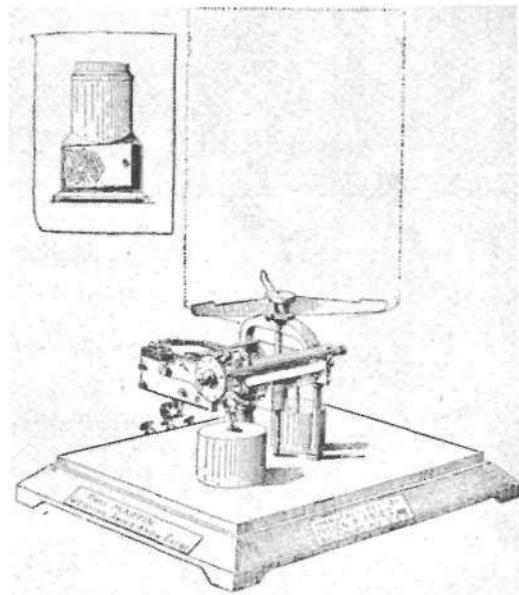


Fig. 117. Marvin weight and electro-magnetic recording gage, 1893, United States.

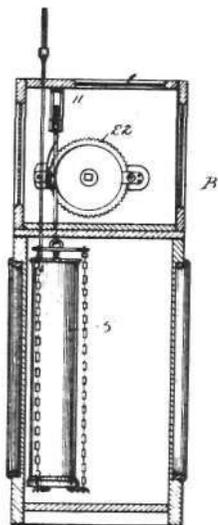


Fig. 118. Grover's weight gage, 1894, United States.

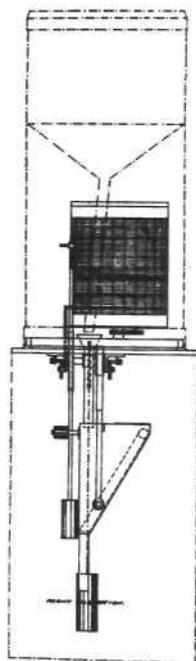


Fig. 119. Halliwell's weight-tipping-bucket-siphon rain gage, 1900, England.

The buckets are hung by 2 cords strung around a pulley and act against the pull of a counterbalancing weight (K). As the bucket-receiver fills, it descends and a pen arm attached to the axle of the pulleys records on a continuous roll of paper. When the bucket is filled (5 mm.), it turns over, dumps the water, exposes the opposite side, and rises to the top of the cycle. Magnification is 20 to 1 and the paper speed is 2 cm./hr. The funnel is designed to be placed on the roof of a building with a pipe leading to the gage.

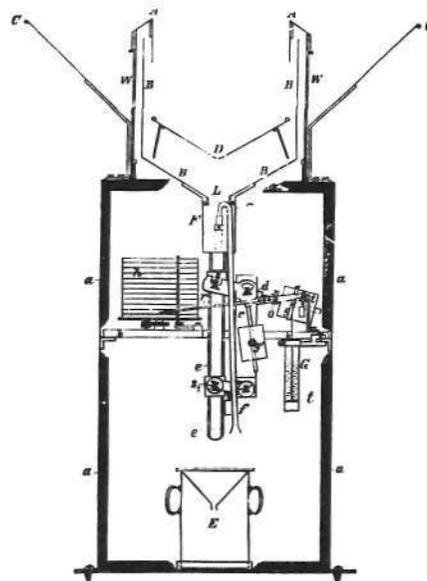


Fig. 120. Rohrdanz rain and snow gage, 1906, Russia.

1884 (Fig. 115), H. Maurer (Hottinger), Germany.--The Maurer gage uses a spring for action and a tipping bucket to dispose of the water. It closely resembles Draper's gage. The descent of the bucket is calibrated, and a pen arm marks its progress on the paper of a clock-operated drum. When the bucket reaches the bottom of its cycle (20 mm.), a stud trips a trigger which allows the bucket to tip and empty. It then rights itself and returns to the top of the cycle.

1889 (Fig. 116), S. P. Fergusson, United States.--The Fergusson gage marked a turning point in the measurement of precipitation and is one of the United States' most important contributions to this field. The principal innovation with the gage is that the funnel is removed, and rain or snow is allowed to fall directly into the receiver where its weight is recorded. The receiver or pail rests on a platform that is supported by a calibrated spring. The downward motion of the pail, as it becomes filled, is transmitted to a recording chart on a clock-operated drum.

1893 (Fig. 117), Marvin, United States.--The Marvin gage is very similar in its working arrangement to the Fergusson gage, wherein a counter-balanced receiver is used without a funnel to directly catch precipitation. An electromagnetic circuit is employed to operate the recording system.

1894 (Fig. 118), A. J. Grover, United States.--A simple counterbalance gage that calibrates and records the descent of a receiver as it becomes filled was developed by Grover.

1900 (Fig. 119), F. L. Halliwell, England.--This is a bucket-siphon gage in which the bucket descends against a weight on the opposite side of a pulley. The descent is calibrated and directly

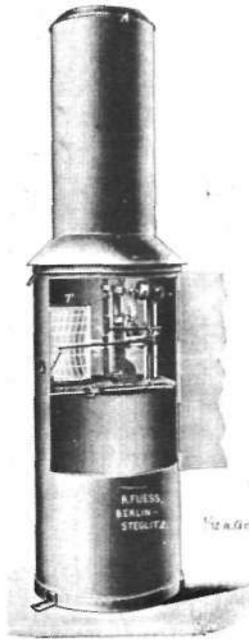


Fig. 121. Hellmann's snow gage, 1906, Germany.

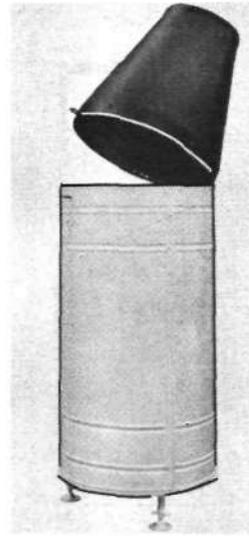


Fig. 124. Stevens weight gage, 1930±, United States.

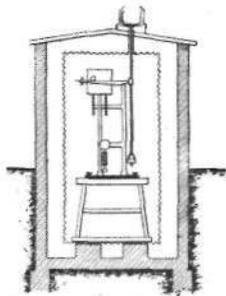


Fig. 122. Sprung snow gage, 1908, Germany.

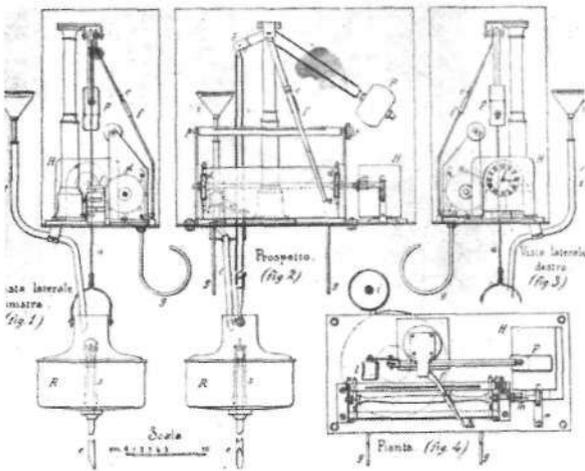


Fig. 123. Imber weight-siphon rain gage, 1927, Italy.

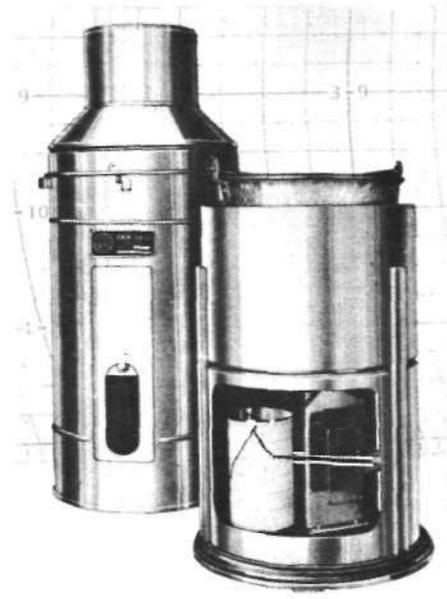


Fig. 125. Bendix-Friez weight gage, 1930±, United States.

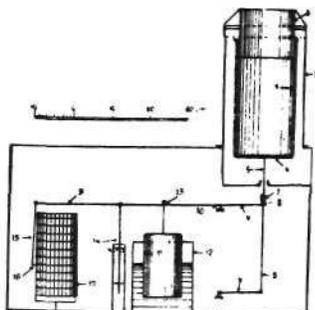


Fig. 126. Schematic of Slettenmark oil-float gage, 1932, Sweden.

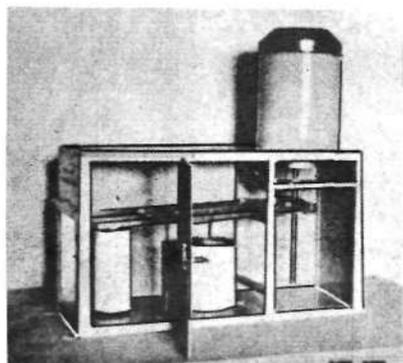


Fig. 127. Slettenmark oil-float gage ready for operation.

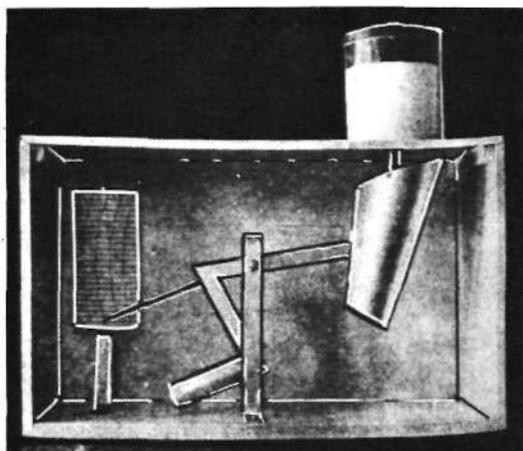


Fig. 128. Maltais weight gage, 1936, Canada.

recorded on a clock-operated drum. The bucket tips just enough to create a full bore siphon and empties in 9 seconds at the bottom of its cycle, thus making the gage continuous in nature.

1906 (Fig. 120), Rohrdanz, Russia.--This ingenious gage had a siphon in its receiver so that it acted on a continuous basis in the summer when only rain was encountered. Whenever 10 mm. of rain collected, a siphon at the bottom of the receiver went into action. In the winter, the siphon was disconnected, and operation was on a simple counterbalance basis with snow falling directly into the receiver. A dash pot was used to dampen wind vibrations that occurred.

1906 (Fig. 121), G. Hellmann, Germany.--This simple counterbalance-type gage has a capacity of 35 millimeters. The lack of a dash pot gives an erratic trace due to the wind.

1908 (Fig. 122), A. Sprung, Germany.--A counterpoised-type gage with the recording parts within a weather-tight and insulated shelter was devised by Sprung. The cover and rim of the gage were heated to keep rime from forming. The gage was principally developed for snowfall measurement.

1927 (Fig. 123), Imber, Italy.--This gage calibrates the descent of a counterbalanced cylinder as it fills with water. When the bottom of the 20 millimeter cycle is reached, a siphon empties the receiver and it returns to its original position. Recording is on a continuous strip of paper.

1930± (Fig. 124), Stevens, United States.--This gage is designed on the same principle as the others and uses a counterbalance system for measurement of rain and snow. Improvements, such as siphons, increased sizes and capacities, the use of antifreeze solutions for dissolving snow, and telemetering equipment, have increased the importance of this gage.

1930+ (Fig. 125), Bendix-Friez, United States.--This gage is very similar in operation to the Fergusson gage. A linkage device added to the recording system allows the pen arm to make one return trip, and as in the Fergusson gage, springs are used in lieu of weights.

1932 (Figs. 126 and 127), G. Slettenmark, Sweden.--Gage operation is on the counterpoised receiver principle. The counterbalance weight is immersed in oil to further dampen wind effects on the recording. Initial capacity for the gage is 40 mm. but can be manually increased to 160 mm. by addition of weights to the counterbalance.

1936 (Fig. 128), J. B. Maltais, Canada.--This gage employs the element of a counterbalanced receiver in its simplest form. Magnification on the gage is 3 to 1 and the capacity is 2.30 inches.

1937 (Figs. 129 and 130), O. F. Nilsson, Sweden.--The schematic clearly illustrates the operation of the improved Nilsson pluviometer. A 4-bucket compartment wheel is counterbalanced.

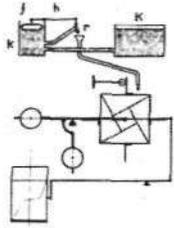


Fig. 129. Schematic diagram of Nils son rain and snow gage.

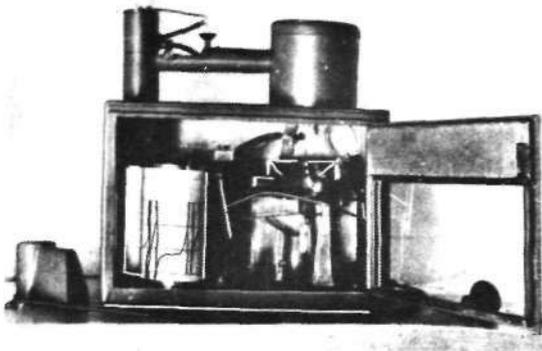


Fig. 130. Nilsson weight-tipping-bucket rain and snow gage, 1937, Sweden.

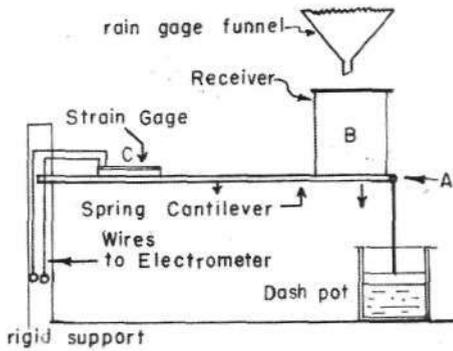


Fig. 131. Conover's snow and rain gage employing the use of a strain gage, 1952, United States.

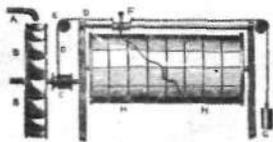


Fig. 132. Wild-Hassler overshot water-wheel rain gage, 1875, Russia.

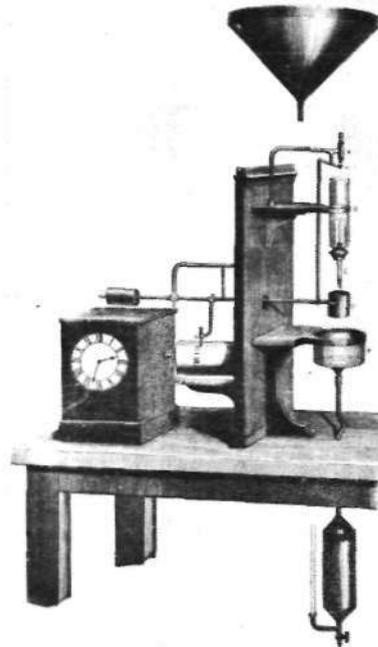


Fig. 133. Dr. Fines siphon-bucket rain gage, 1876, France.

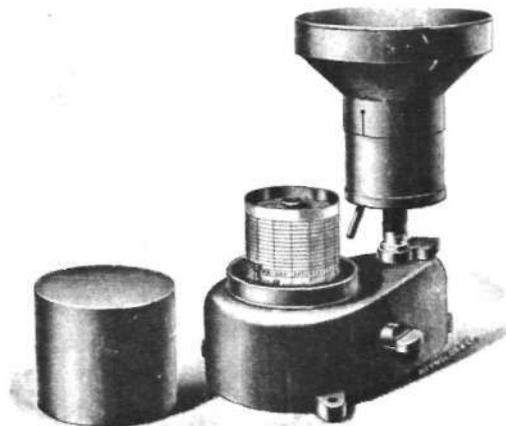


Fig. 134. Lege et Cie tipping-bucket gage, 1897±, France.

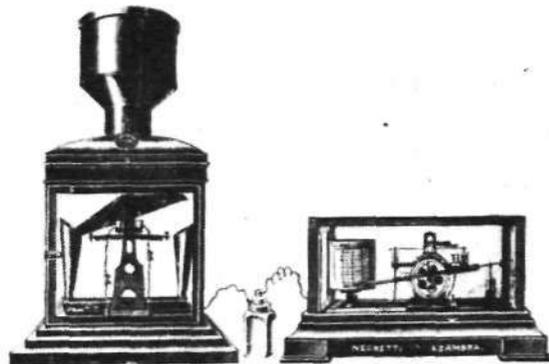


Fig. 135. Negretti-Zambra tipping-bucket gage, 1898, England.

As a bucket is filled, it descends and this descent is calibrated and recorded on the paper of a clock-operated drum. When the bucket is filled, its descent has carried it past a catch that releases the bucket. This allows the wheel to turn 90 degrees, empty the bucket, and return to the top of the cycle with another bucket in position. A novel method is used to catch snow. The orifice of the gage is filled with an oil-covered calcium chloride antifreeze solution. Another container (K), in hydraulic connection with the orifice receiver, has a float-controlled hose that keeps the 2 containers at the same level by instantly draining into the gage that amount which is added to the system. Heat from a lightbulb in the gage allows smooth operation of the working parts and keeps the solution warm enough to quickly melt snow. Working parts of the gage are of stainless metals to forestall corrosion. The gage operates on a 3 mm. cycle and magnification is 40 to 1. The antifreeze solution must be strengthened periodically.

1952 (Fig. 131), J. Conover, United States.—This gage is in the experimental stages. A simple spring-type gage is used with a receiver of a very limited capacity. The receiver is supported by a cantilevered strip of thin spring steel (A). As snow or rain falls into the container (B), a deflection is produced in spring (A). This deflection is calibrated and measured by the strain gage (C) whose electrical resistance is proportional to the strain imposed on it. Results may be obtained by use of a galvanometer. Considerable difficulty has been experienced with the wind causing an erratic trace in spite of a dash pot.

#### Rate of Rainfall Recorders

In many respects, gages classed as rate recorders are also adaptable to recording amounts if a proper integrating system is employed. Three classifications include most gages of this type. One class, the tipping bucket, depends on a fixed volume being systematically filled and emptied. The second class, timed-entry gages, contains those gages whose receivers are exposed for a definite period of time on a continuous basis. The third class, the calibrated orifice type, operates according to the calibration of flow from small orifices, tubes, or weirs.

#### Tipping Bucket or Fixed Volume Gages

The tipping bucket gage is probably one of the most popular gages in use. Some objections to it are: (1) when it rains hard the water enters more rapidly than the gage can operate; (2) the record is a series of steps and not a smooth curve; (3) evaporation may cause a loss of a small amount; and (4) it is unsuitable for winter work. Most of these objections have been eliminated by improved design. The tipping bucket gage was the first recording gage invented and since its invention, it has steadily increased in use. A description of the various fixed volume gages is given in the following paragraphs.

1662 (no fig.), C. Wren, England.--This gage

consisted of a wedge-shaped container. When it became filled it would tip and empty itself. The manner in which the record was made was not disclosed by Wren.

1827 (Fig: 52), J. Taylor, England.--This gage (water wheel) is repeated here, for even though it is not a self-recording gage, it belongs in this class as it is the forerunner of this type.

1829 (no fig.), Crossley, England.--The first use of the vibrating, double-compartment, tipping-bucket gage was introduced by Crossley in 1829.

1876 (no fig.), A. M. Festing, England.—An electrical apparatus was employed to register dots for each .01-inch tip of a tipping-bucket gage.

1875 (Fig. 132), Wild-Hassler, Russia.--This gage employs an overshot water wheel that winds up a cord as water turns the wheel. The cord in turn pulls a marker across the clock-operated drum and this motion is calibrated. The gage was constructed to operate in conjunction with an anemometer.

1876 (Fig. 133), Dr. Fines, France.--Each siphoning of the receiver (1-mm. cycle) is recorded by the water filling a counterbalanced cup and thereby causing the attached pencil to mark the paper on the clock-operated drum. A small hole in the cup then empties it, and a counterweight then raises the pencil from the paper to end the short cycle.

1889 (no fig.), A. Sprung and R. Fuess, Germany.--They presented a double-compartment, tipping-bucket gage where each tip caused an electric contact.

1895+ (no fig.), W.H. Dines, England.—Dines employed the same principle as used in the Sprung and Fuess gage.

1897+ (Fig. 134), Lege et Cie, France.—This gage employs the same principle as the Sprung and Fuess gage, except by mechanical action the recording is a stepped sinusoidal curve.

1898+ (Fig. 135), Negretti and Zambra, England.--This gage is the same as the Sprung-Fuess except a sinusoidal curve is recorded.

1904 (Figs. 136 and 137), Lancetta, Italy.--Six small buckets are arranged in the form of an overshot wheel. As each bucket fills, its weight overcomes a spring catch and the wheel revolves 30 degrees placing another empty bucket on the spring catch. A cog wheel on the axle of the water wheel closes a contact each time a bucket is emptied, and an electrical recorder indicates the amount.

1920+ (Fig. 138), Friez, United States.—This is a U. S. Weather Bureau standard tipping-bucket gage operating on the same general principle as the Negretti-Zambra and Richard Freres gages.

1950± (Fig. 139), Mori, Japan.--This is a tipping-bucket gage of the usual design.

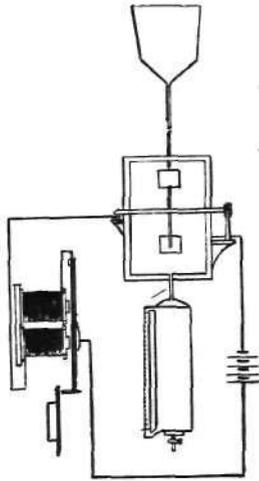


Fig. 136. Front schematic of Lancetta water wheel tipping-bucket gage, 1904, Italy.

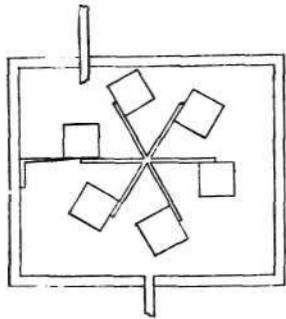


Fig. 137. Side schematic of Lancetta water wheel tipping-bucket gage.

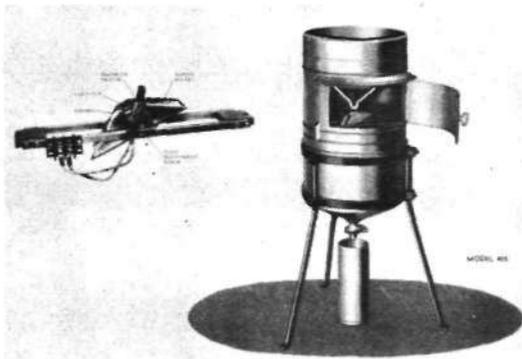


Fig. 138. Bendix-Friez tipping-bucket gage, 1920±, United States.

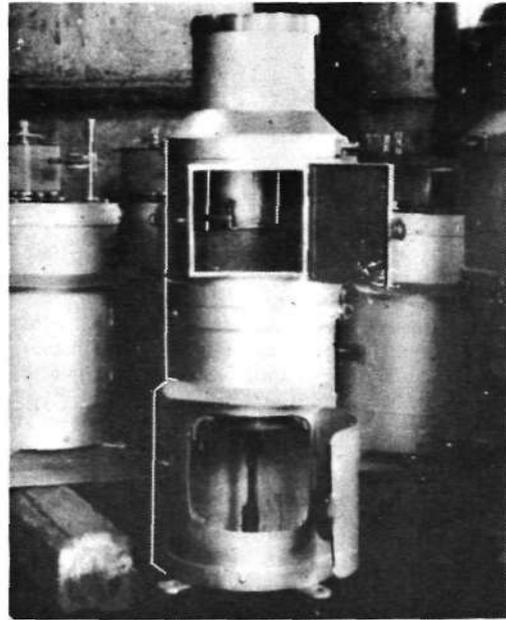


Fig. 139. Mori tipping-bucket gage, 1950±, Japan.

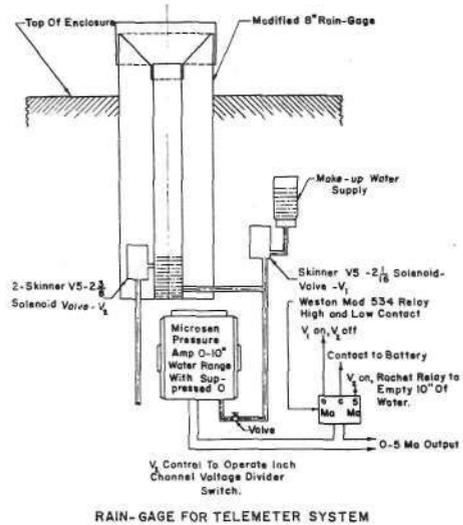


Fig. 140. Meyers' proposed pressure-type gage, 1952, U. S. Weather Bureau.

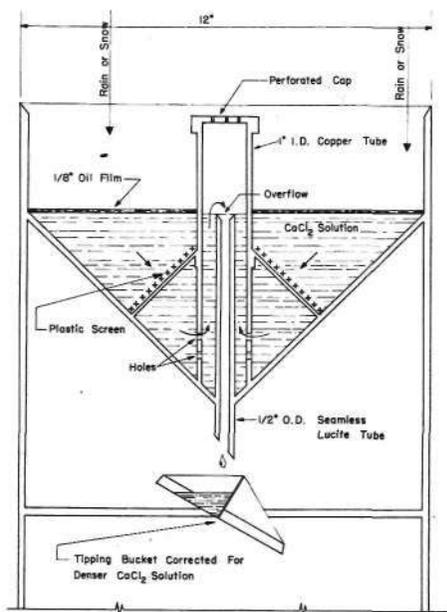


Fig. 141. Illinois State Water Survey modified rain and snow gage employing an antifreeze solution as a catch area, 1952, United States.

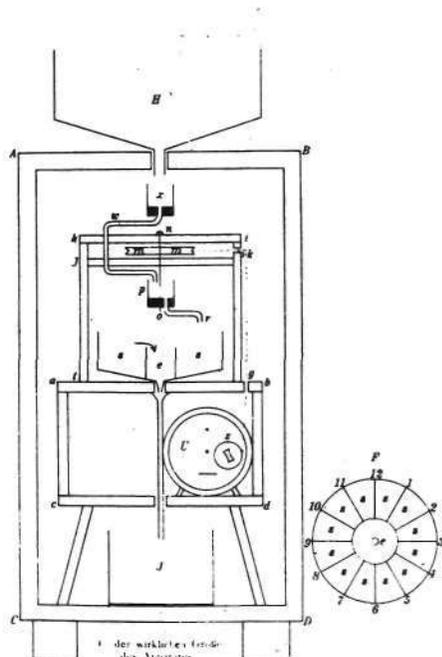


Fig. 142. Weyde timed-entry gage, 1911, Germany.

1952 (Fig. 140), R. F. Meyers, United States.-- This gage is in the design stage and has not yet been assembled. A receiver is exposed and the height to which water rises in this receiver is measured by a microsen transducer. When the receiver is filled, a valve is actuated and empties the receiver in 6 seconds. The data from the transducer is relayed by radio to the weather station. The capacity is 1 inch of rainfall and magnification is 10 to 1.

1952 (Fig. 141), Illinois State Water Survey, United States.-- A U. S. Weather Bureau tipping-bucket gage has been modified to adapt it for measurement of snow as well as rain. An oil-covered antifreeze, calcium chloride ( $\text{CaCl}_2$ ), fills the funnel and a sharp-rimmed, plastic 1/2-inch pipe in the center of the funnel acts as an overflow. A 1-inch pipe surrounds the overflow and separates the oil from the solution. A plastic screen is placed in the solution to retard wind effects. The instrument is in the process of being tested.

#### Timed Entry Gages

This class of gages has not seen wide usage. The principle is to have a receiver exposed for a known length of time. An average rate of rainfall is thus obtained.

1911 (Fig. 142), F. Weyde, Germany.-- This gage is placed here since it is the forerunner of this type. It is not recording. A circular receiver is divided into 12 compartments, and a clock rotates a spigot from the funnel of the gage so that it is over each compartment 2 hours. The amounts are measured periodically and the vessels emptied.

1945 (Figs. 143 and 144), J. M. Sil, India.-- This gage has 3 receivers that go through the following 3-step cycle: (1) a receiver is exposed to the rain; (2) the amount in the receiver is measured by a float within it; and (3) the receiver is emptied. Each of the receivers goes through this cycle on a continuous basis with a 1-minute interval between steps. The amount measured is for the 1-minute period and emptying is automatically accomplished by a valve. Rates as low as 0.02 in./hr. are measured and magnification is 20 to 1.

#### The Calibrated Orifice Type Gage

This type gage usually employs a tube, hole, or weir whose dimensions are such that with a small variation in head, the amount of water that flows through it can be quite accurately calibrated.

1887 (Fig. 145), W. Gallenkamp, Germany.-- The tube of the funnel of a gage ends in an S-shape with a narrow outlet orifice. Flow is subject to head, capillarity, and siphon action and is in the form of uniform drops having a volume of 0.2 cubic centimeter. Forty drops are equal to one millimeter of rain. The arrangement in this case also used an electric contact by which the record of individual drops was transferred to the recording drum chart, by the drops striking

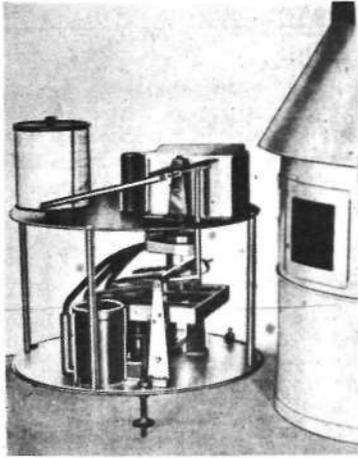


Fig. 143. Sil rain-intensity gage, 1945, India.

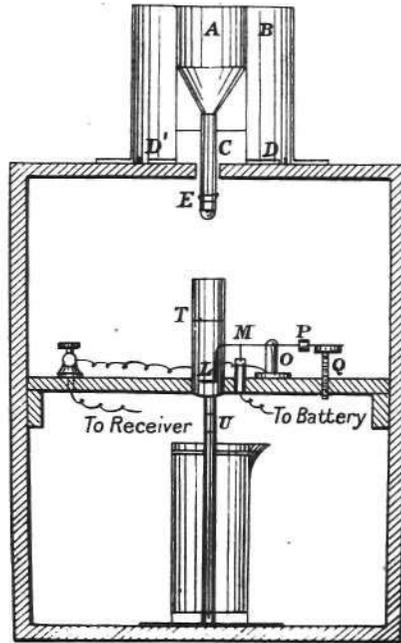


Fig. 146. Binnie drop recorder, 1892, England.

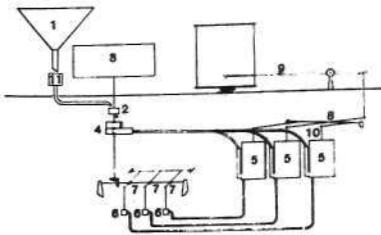


Fig. 144. Schematic of Sil rain-intensity gage, 1945, India.

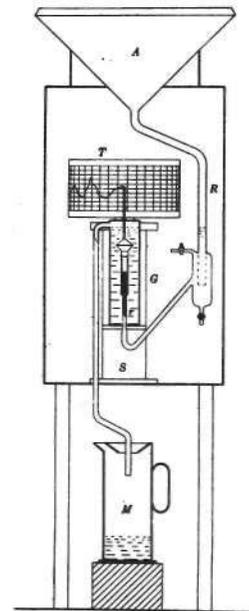


Fig. 147. Sprung rainfall-rate gage, 1905, Germany.

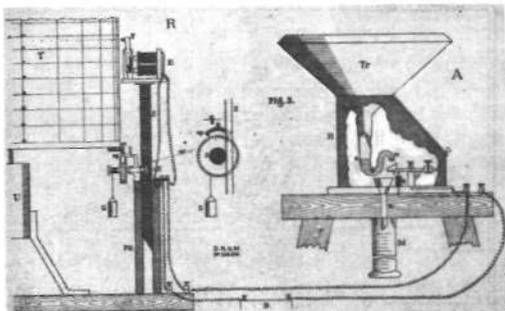


Fig. 145. Gallenkamp drop recorder, 1887, Germany.



Fig. 148. Schematic of Esclangon air pressure rainfall-rate gage, 1914, France.

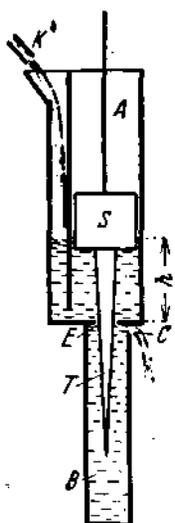


Fig. 149. Schematic of Jarde rainfall-rate gage, 1921, Spain.

ing a pallet contact. This early drop recorder was a success and has found considerable use in Germany.

1892 (Fig. 146), W. J. Binnie, England.--The principle is similar to that of the Gallenkamp gage but its attainment is different. The receiver in this case employs a gage within a gage. The receiver is of such a size (2-inch diameter) that each drop from the outlet tube of the funnel represents 0.01 inch of rain. A piece of cambric is used over the end of the tube to provide a uniform drop area. In industrial areas this cambric needs weekly changing. The closing of an electric contact by the drops is recorded on the chart of a clock-operated drum as 0.01 inch of rain.

1905 (Fig. 147), A. Sprung, Germany.--A weight-controlled valve over the inlet orifice from the funnel of the rain gage varies in vertical position as a function of the rate of flow. The higher the valve is pushed, the more water it

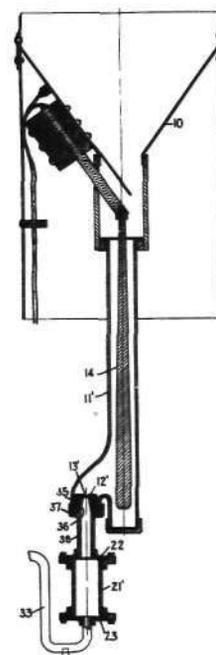


Fig. 150. Ross electrical rainfall-rate gage, 1940, United States.

passes. This upward movement is calibrated and recorded on the chart of a clock-operated drum as rate of rainfall.

1914 (Fig. 148), E. Esclangon, France.--This gage is an experimental model and measurement of rainfall rate is by the air pressure generated in the receiver (R). Water flows from the orifice (O), at approximately a constant rate. Water backing up into the receiver (R) creates an air pressure proportional to the head (h). The air pressure in this receiver, since it is a function of head (h), is calibrated in rate of rainfall and recorded on the chart of a clock-operated drum.

1921 (Fig. 149), R. Jarde, Spain.--The Jarde rain-intensity gage operates on somewhat the same principle as the Sprung gage, except that the valve is float-operated rather than weight-operated. The height to which the float rises is proportional to the rate at which water flows through the system and this action is calibrated. This gage has been widely used throughout the world for determining rainfall rates.

1940 (Fig. 150), P. M. Ross, United States.--A calibrated orifice restricts flow so that a head builds up in the receiver. The water acts as a conductor between a rod and the receiver walls. Since the path the electrical current must follow becomes shorter due to water filling the receiver, the resistance becomes less. This change in resistance is calibrated and recorded as rate of rainfall on the chart of a clock-operated drum.

1941 (Fig. 151), F. J. Cornick, United States.--In this patented rate recorder, a bucket with ori-

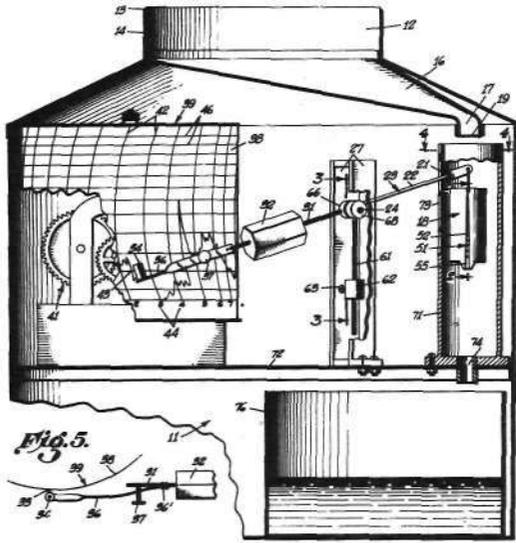


Fig. 151. Cornick rate-of-rainfall gage, 1941, United States.

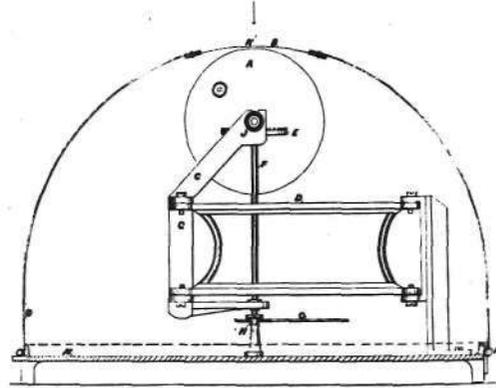


Fig. 154. Fergusson ombroscope, 1905, United States.

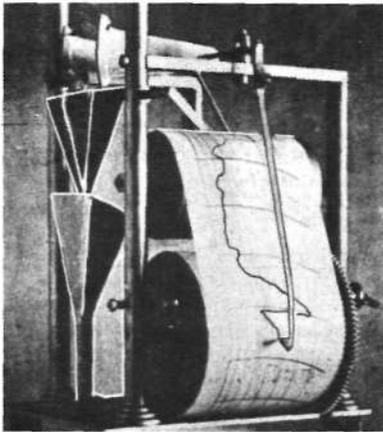


Fig. 152. Nell rate-of-rainfall gage, 1949, England.

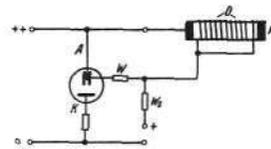


Fig. 155. Schematic of Barnothy and Bell electrical ombroscope, 1935, Hungary.

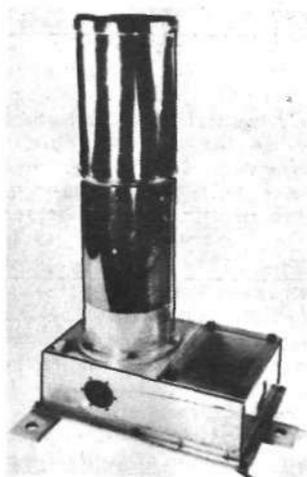


Fig. 153. British M.O. drop recorder, 1952.

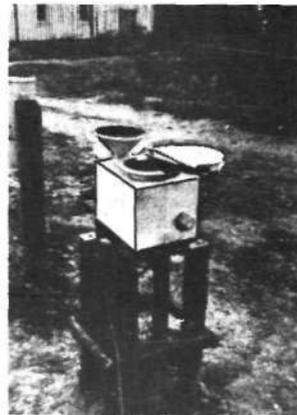


Fig. 156. Marz schauerchronograph, 1936, Germany.

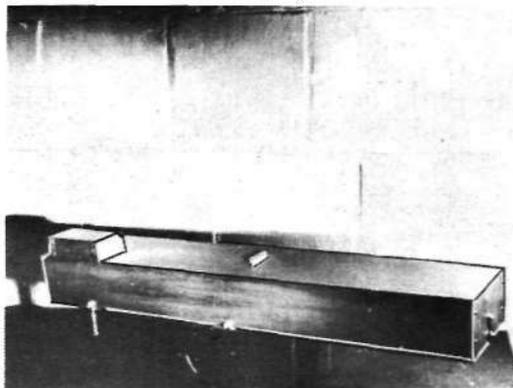


Fig. 157. Neuberger ombrograph, 1941, United States.

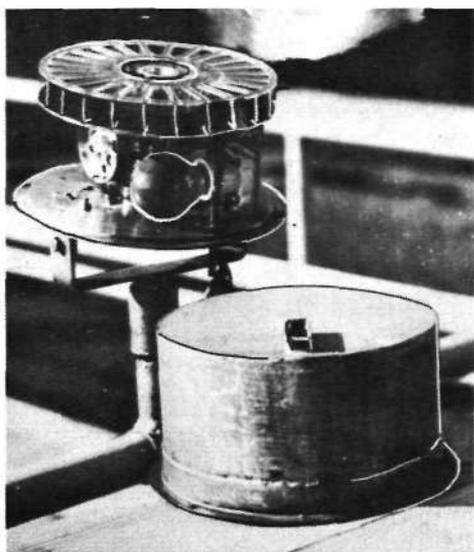


Fig. 158. Neuberger improved ombrograph, 1944, United States.

face holes is weighed. Water from the funnel flows into this bucket and is restricted from flowing out by the vertical row of holes. This causes a head to build up, and this added head is weighed and calibrated to rate of rainfall.

1950 (Fig. 152), C. Nell, England.--This gage is almost the same as the Cornick gage except that Nell uses a long narrow slit in one wall of the bucket to restrict flow, instead of the perforations employed by Cornick. As water head accumulates, it is weighed and recorded as rate of rainfall.

1952 (Fig. 153), British M.O., England.--This drop recorder is very similar to the Binnie gage in operation. A funnel diameter of 5 inches and nozzle diameter of 0.330 inch give a

uniform drop representing 0.01 millimeter of rain. Recording is accomplished by the drop striking a pallet in connection with a mercury switch. The British M.O. gage employs neither the gage within a gage, nor the cambric as is used by Binnie. When used with the Bibby impulse recorder, a very clear record of rate of rainfall during each minute is obtained.

#### Trace Recorders or Ombrosopes

Trace recorders or ombrosopes fit the need for precipitation detectors and alarm systems. Water-sensitive surfaces are exposed and indicate the presence of precipitation, either as a record or by tripping an alarm system. In order for the surfaces to be free from false recordings due to condensation, they must be heated to above the prevailing dew point. To register snow it is necessary to provide a surface whose temperature is above the freezing point. The instruments record or indicate the presence of precipitation without regard to amount.

1905 (Fig. 154), S. P. Fergusson, United States.--This ombroscope is completely covered except for a small slit at K. A clock-operated drum of paper inside the case rotates at a constant rate. Rain falls through the slit onto the paper of the drum, where it makes a mark on indelible lines.

1935 (Fig. 155), J. Barnothy and B. Bell, Hungary.--A paper-covered heated electrical coil exposed to rain indicates by a short-circuit the time of rain or snow. This impulse is transmitted electrically to a recording system. Heating of the instrument dries it quickly at the end of precipitation. The warm surface also permits use of the instrument as a snowfall indicator, and does not allow dew or frost to form on it, thereby falsely indicating precipitation. This is the only indicator reported that operates for both snow and rain.

1936 (Fig. 156), E. Marz, Germany.--The Schauerchronograph employs a screened area exposed to the rain. The rain strikes the screen, closing a circuit, and a cover pivots over the screen. A Gallenkamp drop recorder then takes over and measures the precipitation. When the drop recorder stops operating, the lid opens again, exposing the dried screen. A heater is used to dry the screen. If the precipitation is light and does not trip the drop recorder relay, the lid slides open when the screen becomes dry, thus completing a cycle.

1941 (Fig. 157), H. Neuberger, United States.--This ombrograph is similar in action to the Fergusson, except in this case, a continuous water-sensitive strip of paper is exposed beneath the slit, through which rain may fall. The rate of feed of the paper is set for one complete belt in 24 hours. Provisions are made to drain the box, and a light bulb within the case assists in drying the smoked paper.

1944 (Fig. 158), H. Neuberger, United States.--This is a well designed instrument that indicates the number of hours that precipitation occurs. A

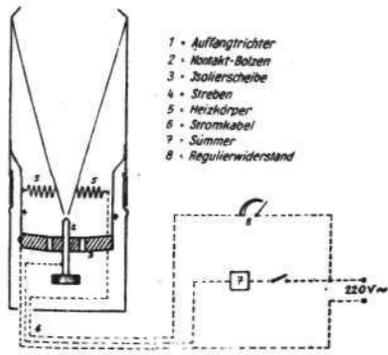


Fig. 159. Schematic of Sprenger rainfall alarm, 1948, Germany.



Fig. 162. Williamson electric rain gage, 1948, England.

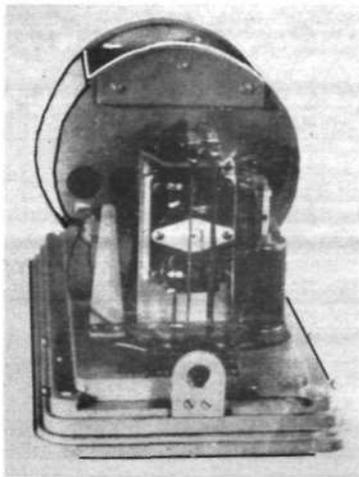


Fig. 160. Meteorologie Nationale ombrograph, 1950, France.

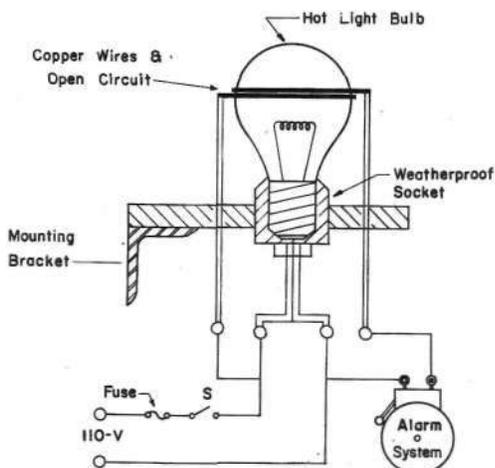


Fig. 161. Illinois State Water Survey light bulb ombroscope, 1952, United States.

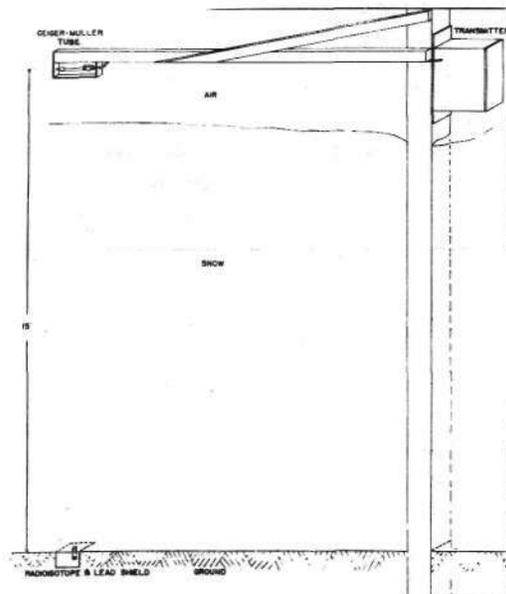


Fig. 163. Gerdel, Hansen, and Cassidy radio-active gage, 1950, United States.

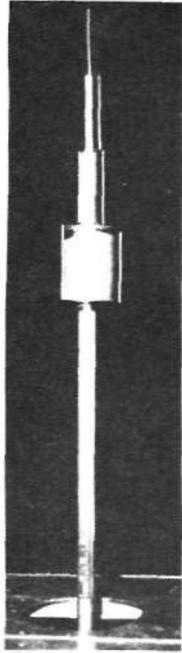


Fig. 164. Rotating cylinders, 1950±, United States.

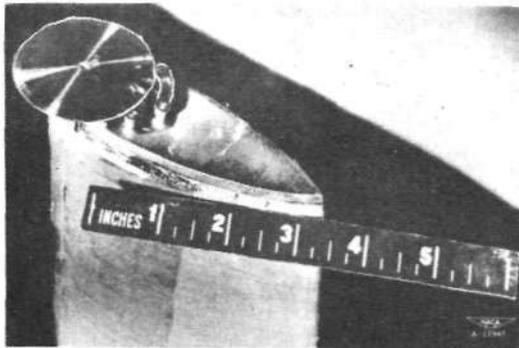


Fig. 165. Rotating magnetic disc, 1950±, United States.

circular turntable has been divided into 24 pie-shaped segments, one segment of which is permitted by a clock escapement mechanism to rotate past the slot in the lid once each hour. Sooted, polished metal discs are placed in the segments and are the sensing element. Efficient drainage is provided by tilting the instrument towards the slot. A light bulb beneath the plate keeps it warm.

1948 (Fig. 159), K. Sprenger, Germany.—An electric contact is made whenever rainwater flows out the funnel tube. The contact point is exposed so that one drop will cause the necessary short-circuit. A bell system is in connection with this circuit and awakens the observer whenever it starts raining.

1950 (Fig. 160), Meteorologie Nationale, France.—A wire plastic grid is exposed to the rain. When the grid is hit by rain, a short-circuit indicates the presence of precipitation.

A cover then rotates over the grid to allow a lamp to dry it. When it has dried, the cover rotates back, thus re-exposing the grid and completing the cycle.

1952 (no fig.), Auto-up, United States.—Fingers or pins of a wire grid, through an insulator, trip an alarm when rain strikes them and causes a short-circuit. The device is used to close the tops of convertible cars, windows, ports, etc. No provisions are made to heat the apparatus.

1952 (Fig. 161), Illinois State Water Survey, United States.—This is an instrument in the design stage that employs the use of a light bulb covered by a wire grid. The exposed light bulb burns continuously and acts as the water-sensitive surface. The grid, in turn, trips an alarm system whenever water on the surface of the light bulb causes a short circuit between the grid elements. It is anticipated that this ombroscope will operate effectively for rain or snow.

#### Miscellaneous Recording Gages

These include gages that do not fit into the previous classifications.

1948 (Fig. 162), H. Williamson, England.—An electric probe is suspended in the receiver of the gage. As the level of the water rises and touches the probe point, a circuit is closed and an electric motor reels the probe up until the circuit is again open. The progress of the point rising in the receiver is calibrated, and is recorded on the chart of a clock-operated drum as inches of rain.

1950 (Fig. 163), R. W. Gerdel, B. L. Hansen, and W. C. Cassidy.—Radioisotopes have been used by these investigators to measure water equivalent in snowpack. This method will be discussed in a later section.

#### Cloud Drop Size and Water Content Measurement

In recent years much emphasis has been placed on cloud physics. This has brought about the development of instruments to measure: (1) water content, (2) droplet size, and (3) droplet distribution within clouds. Since this field is closely related to the measurement of precipitation, some of the instruments are briefly presented here.

Rotating and non-rotating cylinders (Fig. 164).—When exposed normal to an air stream in which icing conditions are present, the cylinders will be covered by a layer of ice whose thickness is proportional to the drop size, water content of the air stream, and size of the cylinder (467).

Rotating magnetic disc (Fig. 165).—This is an airborne instrument employed in the same manner as the rotating cylinders, but measures water content only. Measurement of the thickness of the ice on the rim is on a continuous basis. A magnetic circuit (955) is employed for this purpose.

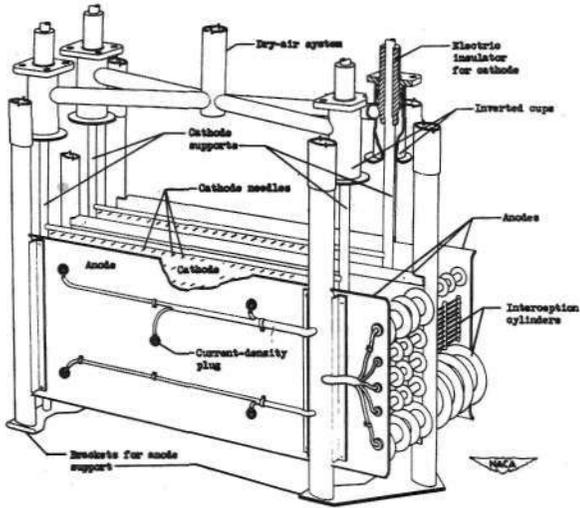


Fig. 166. Schematic of coronal-discharge precipitator, 1950±, United States.

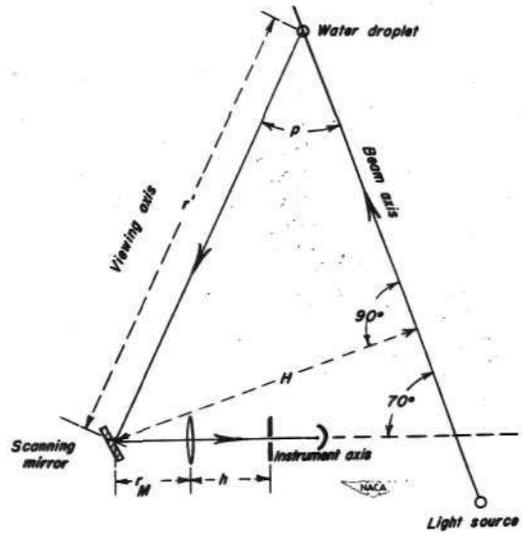


Fig. 169. Diagram for rainbow recorder, 1950±, United States.

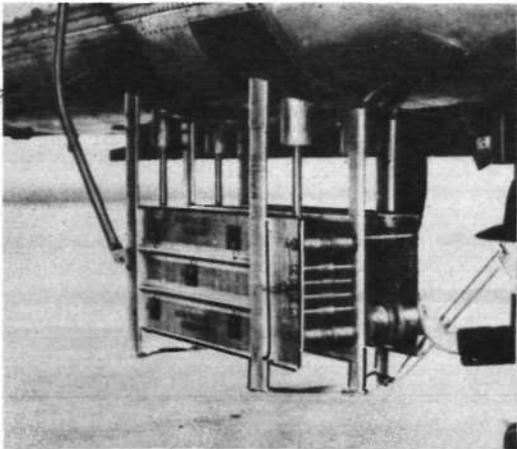


Fig. 167. Coronal-discharge precipitator mounted in operating position.

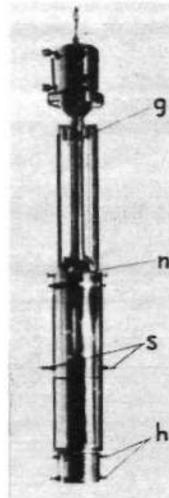


Fig. 170. Kohler's dew-point detector, 1928, Sweden.

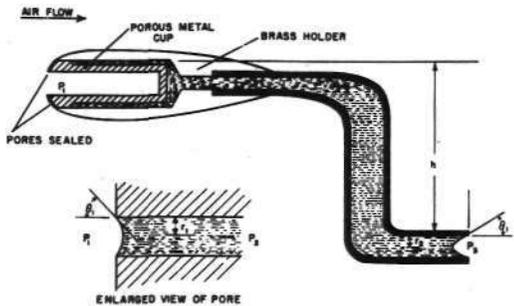


Fig. 168. Vonnegut capillary collector, 1952f, United States.

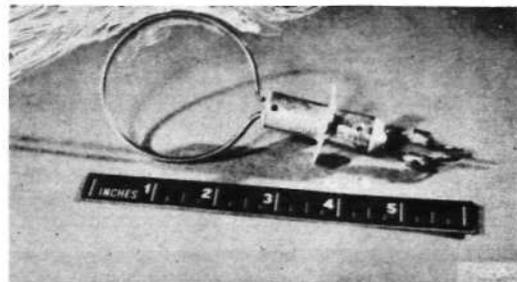


Fig. 171. Hot-wire-loop-heating unit, 1950±, United States.

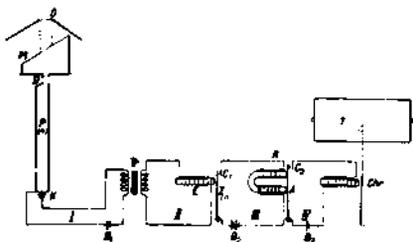


Fig. 172. Schematic of Schindelhaur acoustical detector, 1925, Germany.

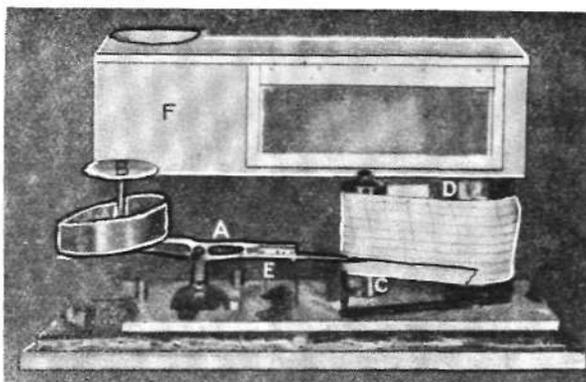


Fig. 173. Neal and Bayer mechanical impactometer, 1940, United States.

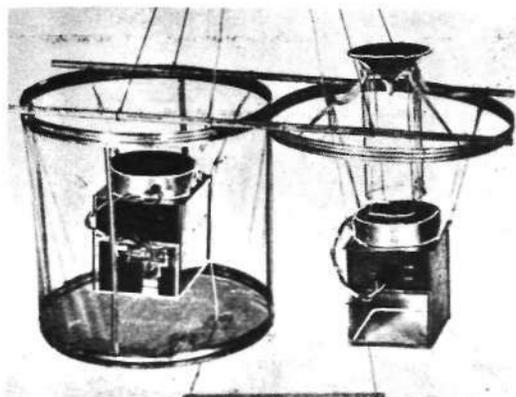


Fig. 174. Cooper's airborne rain gage and rain-drop-size detector, 1951, Australia.

Coronal discharge method.--Figs. 166 and 167 show an airborne instrument used for measuring droplets that are above freezing. An electrical charge is placed on the droplets in an air stream by coronal discharge between plates. Cylinders of different sizes are then exposed to this air stream. The charge collected by the different-sized cylinders is a function of the droplet size and distribution. In this respect, the instru-

ment acts similar to the rotating cylinder, i.e., the small-size collecting cylinder will collect more of its charge from the small drops than will the large cylinder (156).

Capillary collector (Fig. 168).--This is an airborne instrument that measures liquid water content of clouds by exposing a porous metal cup to an air stream. The displacement of water in a glass capillary tube connected to the cup is measured visually. The porous cup faces into the air stream, and water entering it is sucked up by the capillary action of porous metal, and carried back into a glass tube to the rear (954).

Rainbow recorder (Fig. 169).--This recorder is based on the varying intensity of rainbow light for an oscillating mirror scanning an air stream in which a modulated beam of light has been projected. The intensity of the light is proportional to the water content and drop size in the air stream (467).

Dew point recorder (Fig. 170).--This instrument is used for determining the water content of fog and clouds. A sample of the cloud air is heated so that the free water is evaporated, and the temperature and dew point of the heated sample are measured. These are functions of the water content (495).

Heating units (Fig. 171).--These are experimental airborne instruments designed to measure water content. The amount of energy necessary to keep their surfaces dry when exposed to a cloud-laden air stream is calibrated to indicate water content.

Acoustical surfaces.--The sound of rain or snow striking surfaces such as membranes has been recorded and calibrated to indicate drop size. Several of the instruments built are tabulated below.

1925 (Fig. 172), E. Schindelhaur, Germany.--Schindelhaur reported on the use of a listening device. The instrument did not employ vacuum tubes and was sensitive only to large-sized drops (809).

1940 (Fig. 173), Neal and Bayer, United States.--A mechanical impactometer, wherein the impact of the drops causes a pen arm to be displaced for each impact. The amount of displacement is calibrated to drop size and recorded on the chart of a clock-operated drum.

1951 (Fig. 174), B. F. Cooper, Australia.--Cooper (192) used the acoustical method to probe clouds and determine: (1) raindrop size by calibration of the amount of impact on an exposed membrane, and (2) water content by the use of a drop-type rain gage. The orifice of the small rain-gage funnel (on the right hand side of the picture) was calibrated to release drops of a constant size. These drops in turn would strike a second membrane and be radio-transmitted to the station. The number of drops and the rate with which they struck the membrane were proportional to the amount and rate of rainfall. The instrument was sent aloft by a balloon, and the results were broadcast to the station by an FM



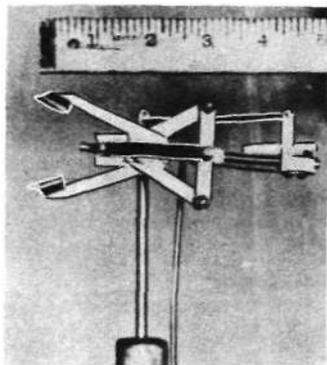


Fig. 182. Cloud droplet sampler, 1950±, United States.

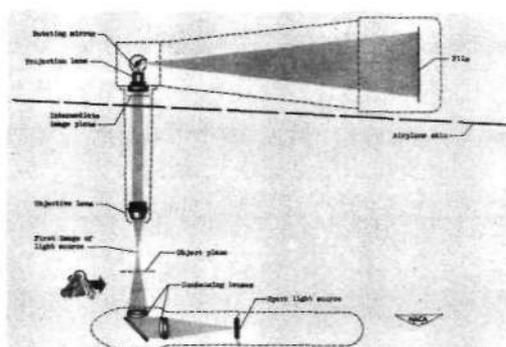


Fig. 183. Cloud droplet camera, 1950, United States.

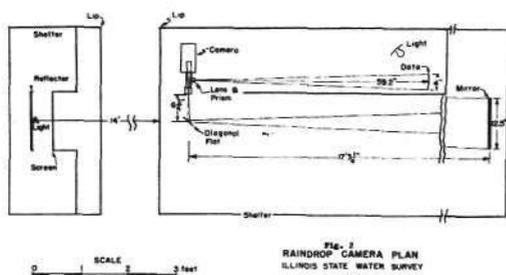


Fig. 184. Jones' raindrop camera, 1952, United States.

radio. Cooper was able to distinguish the impact of raindrops as small as 0.5 millimeter in diameter.

1951 (Figs. 175 and 176), J. Maulard, France.--Maulard used an exposed pallet connected to an acoustical membrane to record the impact effect of rain and snow. A pronounced difference in the recorded impact was indicated by different types of precipitation (590).

1952 (Fig. 177), B. Smulowicz, United States.--An airborne momentum disdrometer (impactometer), utilizing an electromagnetic transducer with a fluid coupling, has been introduced by Smulowicz. Operation is limited by recovery time, and two instruments are needed to cover a raindrop-size range from 0.5 to 5 mm. (837).

1952 (Fig. 178), I. Katz, United States.--An impactometer is used in conjunction with a capillary collector. A microphone is imbedded in the water chamber behind a porous membrane and detects raindrop size by the impact of drops. This is an airborne instrument used for determining cloud drop-size distribution and water content.

Highly insulated induction rings (Fig. 179).--These rings indicate the presence of charged particles passing through their electrical field (367). The charged particles induce an opposite charge on the ring, and when this is amplified, it may be examined for sign and magnitude. Since most raindrops and snowflakes carry some charge, some preliminary tests were made at the Illinois State Water Survey to determine the induction ring's potentiality as an ombroscope. It was found that the instrument, although possibly satisfactory for rain, would be too sensitive to be practical for snow with present-day electronic equipment.

Electrical resistance (Fig. 180).--A continuous strip of paper is fed and exposed under a slot on the wing of an airplane. The electrical resistance across this paper is a function of the water content of clouds encountered by the plane (964).

Cloud sampler (Fig. 181).--This sampler is a Cascade impactor with which cloud droplets are caught on a water-sensitive surface according to their size distribution. The instrument is airborne and is mounted under the fuselage of a plane. The flow of air through a chamber is carefully controlled by outlet flaps. Within the chamber, cloud droplet samples are taken by impactors at each 90 degree turn that the air stream is forced to make (545). Another cloud sampler (Fig. 182), is manually operated and takes one oil-wetted slide at a time. The water-sensitive disc is exposed to an air stream, and samples are taken at the observer's leisure.

Photographic techniques.-- Photographic techniques involve the photographing of the drops (or their images) as they fall through the atmosphere. Two devices have been tried. One (Fig. 183), permits photographing of cloud droplets and is designed for a small object area and very

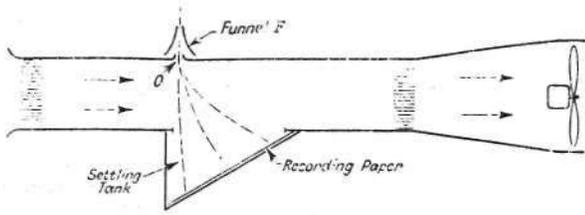


Fig. 185. Bowen and Davidson raindrop spectrograph.

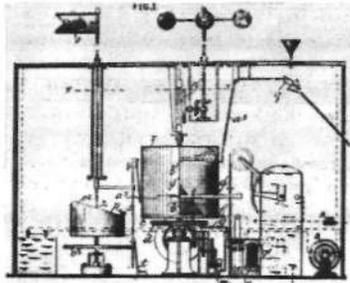


Fig. 186. Cerebotani and Silberman automatic weather station, 1907, England.



Fig. 189. Stevens'-type Q12M telemetering rain and snow gage, 1950±, United States.

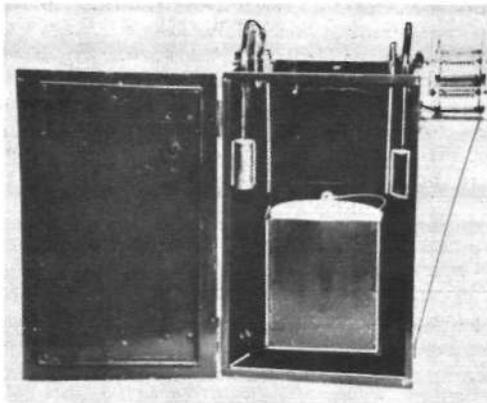


Fig. 187. T.V.A. weight-type gage, 1950±, United States.



Fig. 190. Diamond-Hinman-National Bureau of Standards telemetering rain and snow gage, 1940, United States.

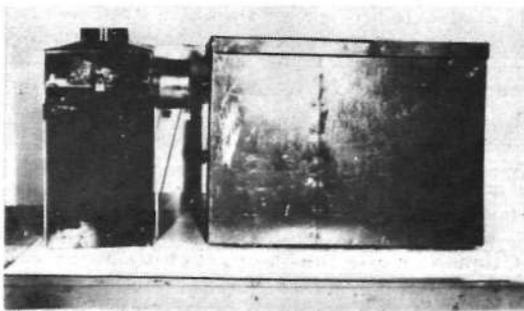


Fig. 188. T.V.A. telemetering rain gage, 1950±, United States.

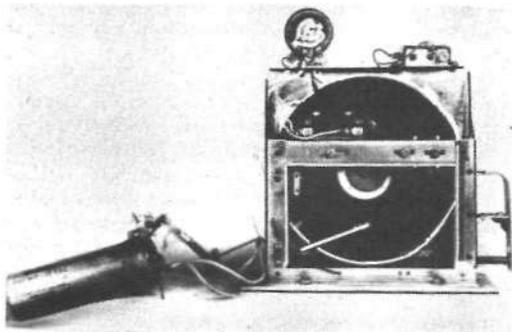


Fig. 191. U. S. Weather Bureau record-telemetering device, 1952.

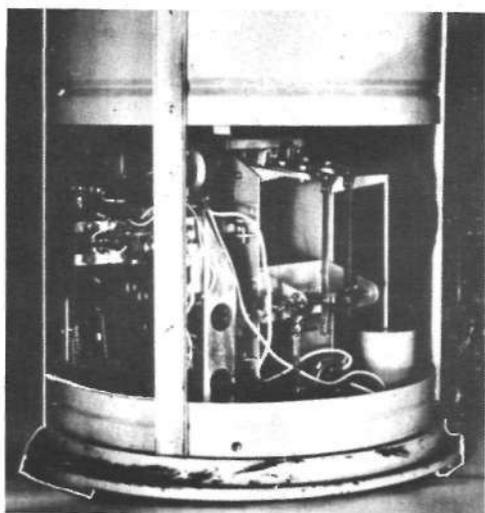


Fig. 192. U. S. Weather Bureau modified Bendix-Friez gage with record telemetering device.

small drops (467). The other (Fig. 184), is designed to photograph the size and number of raindrops in a fixed volume. The latter device is undergoing modification and testing by the Illinois State Water Survey (466).

Bowen and Davidson raindrop spectrograph (Fig. 185).--This instrument was designed to specifically measure the size spectrum of rainfall. Rain falling into a chamber through a narrow slit enters an air stream moving at a constant velocity (18 ft./sec.). As the rain falls into the air stream it is spread out in a band whose width is proportional to the raindrop size distribution. The resulting band falls on the water-sensitive surface of a continuous strip of paper being fed under the slit. The record may be closely studied for drop-size spectrum.

#### Telemetering Instruments Presently in Use

Telemetering can be applied to most of the recording gages previously mentioned. A few types that have been used in recent years are here described.

1907 (Fig. 186), Cerebotani and Silberman, England.--This instrument apparently made a mark on the chart of a clock-operated drum every time that water from the funnel struck the pallet (q) to which the pen arm was attached. It has the distinction of being the first remote weather station reported.

T.V.A. Gage (Figs. 187 and 188).--T.V.A. has a weight-type recording gage that has been adapted to transmit coded messages every 2 hours. The gage has a standard 8-inch orifice and must be emptied whenever the water in the bucket equals 9 inches of rain. Snow can be measured as water equivalent, but this is not a problem in Tennessee. The gage is custom-built and operates on a counterbalance system. The platform supporting the bucket is counter-weighted by weights pivoting on a central axis. The rotation of the axle is calibrated to inches of rainfall and operates a coding mechanism. A telemetering component of the gage is separately housed. The operation of the unit is reported to be satisfactory.

Radioactive snow gage (Fig. 163).--The Corps of Engineers and the U. S. Weather Bureau have developed a radio-telemetering snow gage which employs radioactive cobalt in a counter system to determine the amount of water equivalent in snow pack. A small sample of radioactive cobalt-60 is placed in the ground in a lead-shielded collimator container. A collimated beam is set in a vertical direction to strike an overhead Geiger-Muller tube. The number of counts received by the Geiger-Muller tube is a function of the water equivalent between it and the radioactive cobalt. The gage operates in remote localities and transmits data by radio to a central station periodically. The range of water equivalent is from (approximately) 0.01 to 55 inches and is accurate to within 2 or 3 per cent. Half-life of the cobalt-60 is 5 years. Forty millicuries of radioactive cobalt-60 are used for each gage (330).

Stevens gage (Fig. 189).--The Stevens weight-type Q12M gage with telemeter recorder Q12MR, the "Telemark," is designed for automatic weather station operation. It is available in capacities up to 60 inches of precipitation. A 60-inch model actually has a capacity of 60 inches of concentrated calcium chloride solution in addition to the 60 inches of precipitation, a total of 120 inches. The U. S. Weather Bureau, in cooperation with the manufacturer, is field testing this instrument at the present time.

The Diamond-Hinman telemetering gage (Fig. 190).--H. Diamond and W. Hinman, National Bureau of Standards, United States, modified a Friez weight-type gage for use with an automatic weather station. No provisions were made for continuous action (229).

U.S. Weather Bureau Telemetering Device (Figs. 191 and 192).--The U.S. Weather Bureau recently designed a telemetering device to be used on a Friez weight-type gage. This employs the use of a phonograph record which indicates the position of the pen arm that swings over the record as the weight of the receiver increases due to rain.

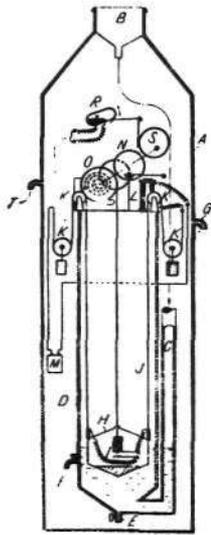


Fig. 193. Japanese remote-recording-float rain gage, 1950.

U. S. Signal Corps Gage (Fig. 138).--The U. S. Signal Corps employs the use of a standard tipping-bucket gage in its automatic weather station.

Japanese Gage (Fig. 193).--The Japanese Weather Service recently developed a large capacity gage operating on a float principle which has a capacity of 1,000 millimeters of rain. The float operates with an electric contact that indicates the relative position of the float. This information is telemetered. In some respects it closely approaches the Williamson gage (Fig. 162) in mode of operation. A probe is suspended in the receiver and hangs freely within the float of the gage. As the float rises in the receiver, a contact is made with the probe and an electric motor reels up the probe until the contact is broken. The progress of the float is calibrated in this manner and is transmitted to a central receiving station.

A.E.C. Gage (Fig. 140).--The U. S. Weather Bureau, at the Atomic Energy Commission, Oak Ridge, Tennessee, has designed a telemetering gage that uses "Microsen pressure transducer, 0- to 10-inch Range" as the sensing element, in conjunction with a standard 8-inch gage. This gage was previously described in the section on rate of rainfall recorders.

## CONCLUSIONS

In summary, it may be stated that the use of rain gages falls into 3 principal categories: (1) climatology, a field in which non-recording gages are used to a large extent; (2) hydrology, where forecasting of runoff calls more for self-recording gages and totalizers; and (3) cloud

physics and radar studies, where a demand exists for a rain gage that accurately portrays rates of rainfall as well as amount.

For most climatological purposes the present day rain gages are adequate. For hydrological purposes, such as runoff forecasting, the recording gages are usually satisfactory although there are limitations in the measurement of precipitation imposed by such factors as gage density. For radar and cloud physics studies, where rates of rainfall and amounts must be accurately portrayed for short time intervals, the present day recording gages are frequently inadequate.

The Nipher and Alter shields are satisfactory developments towards the achievement of aerodynamic neutrality over the orifice of the rain gage. Perhaps the most effective method of realizing aerodynamic neutrality would be the adaption of the Koschmieder-type pit gage.

The measurement of snow by gages is a problem that remains to be solved. There is a need for studies relating to the geometry of precipitation entering a gage as suggested by Warnick's true catch procedures (1967), and as mentioned in the section on effective catch areas in this report.

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2. Abbe, Cleveland, "Determination of the amount of rainfall." American Meteorological Journal, 6(6):241, Oct. 1889, 1 table, 2 refs., 3 eq.  
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Results of experiment with gages placed at various heights.
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A detailed report on measurement of precipitation. Brings out that the main cause of differences being measured in precipitation is the wind effect. In Geographical distribution - the error for a 3 year experiment with 21 gages in 15km. square was 6% (hydrologic error). Yearly variation of 18% from average.
6. Abbe, Cleveland, "Reliability of the rain gage." Monthly Weather Review, 22(1):25-26, Jan. 1894, 1 table, 1 ref.  
The wind effects on rain gages can be considerable. Some methods for diminishing the effects of wind are: (1) Prof. Joseph Henry's circular plate of tin 4 in. or 5 in. wide soldered 1 in. below orifice, 1853, (2) Nipher shield 1878, (3) Bornstein surrounding fence a few feet away and same height of gage, (4) Pit gage.
7. Abbe, Cleveland, "Effect of wind on catch of rainfall." Monthly Weather Review, 27:308-310, July, 1899, 1 eq.  
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10. Abels, G., "Protection for rain gages." Meteorologicheskii Vestnik, p. 113-116, 1925.  
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14. Aderkas, O., "The exposure of gages and the effect of wind on the catch." Meteorologicheskii Vestnik, p. 191-196, 1926.
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Sil autographic intensity rain gage. A sketch of the gage and its records is presented with a brief account of its use.
16. Agricoltore Etneo, "Pluviometro registratore Lancetta." Agricoltore Etneo, 11:165-167, 1906.
17. Air Force, "Meter measures icing rate." Air Force, 32(2):39, Feb. 1949, 1 fig.  
Instrument developed by General Mills and tested at Wright Field determines quantity and rapidity of accumulation of ice on surfaces.
18. Albright, J. G. , "Physical meteorology." Prentice -Hall, Inc. , New York, p. 250-256, 1939, 4 figs.  
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19. Alfieri, "Sulla misura delle precipitazioni nell 'alta montagna." (On the measurement of precipitation in high mountains), Parma, Ministero del Lavori Pubblici, Ufficio Idrografico del Po., 1936, 6 figs, 6 refs.  
On the use of totalizers. The standard rain gage of the Hydrographic office stood 1 meter 10 cm. above the ground. - A cylindrical gage whose orifice has an area of  $1/10 \text{ m.}^2$  (dia. 0.357 m) is used. The totalizer uses a Nipher shield and an oil covered  $\text{CaCl}_2$  solution.
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27. American Meteorological Journal, "Dr. Draper's rain and snow gage." American Meteorological Journal, 1(11):487-88, March, 1884-5, 1 fig.  
An 8 in. orifice above the roof of a building catches the rain and a tube brings it inside the building to the gage. The water flows to a gravity bucket suspended by springs. As the bucket fills it gradually sinks and it is this motion that is calibrated. When it has filled, the bucket suddenly tips and empties -the bucket rises to its zero position and the cycle is complete. •
28. American Meteorological Journal, "Observations with different rain gages." American Meteorological Journal, 8(2):92, June, 1891.  
Summary of article by Dr. Hellman in No. 3 of the *Abhandlungen des K. Preuss Met. Inst.* Eleven gages consisting of 2 Von Bezold, 6 Hellman, 2 Assman, and 1 Hottinger gages were arranged in a circle in a field--all orifices at 1.25 meters and about 1.25 meters apart. Over a 10-month period their readings differed by as much as 9% in the winter and 6% in the summer.
29. American Meteorological Journal, "Exposure of rain gages." American Meteorological Journal, 9(2):95, June, 1892-3.  
Summary of an account by Dr. Hellman in Annual Report for 1892 of the Berlin Branch of the German Meteorological Society.. (1) The more a gage is exposed to the wind, the less it records. (2) Adjacent stations agree better together in spring and autumn and wet years.
30. American Philosophical Society, American Philosophical Society Proceedings, 1(1):66, Nov. 1771.  
At a meeting of the Society in 1771, Nov. 1, the following was noted: "Nairn's rain; gages—to be put up under such inspection as they shall agree upon, for observing the quantity of rain that falls at different heights, agreeable to Mr. Nairn's request, and Dr. Heberden's experiments in the Philosophical Transactions." This must have been one of the earlier gages in use in the U.S.A.
31. Anderkp von Homorod, Aunel, "Ein neuer ombrograph." (A new ombrograph), Meteorologische Zeitschrift, Vol. 21, p. 518-521, Nov. 1904, 8 tables.  
A combination weight type and tipping gage. It was made at the University of Budapest:
32. Anderson, Lloyd J., "Drop-size distribution measurements in orographic rain." American Meteorological Society Bulletin, 29(7):362-366, Sept. 1948, 5 figs., 1 table, 3 refs.  
Measurements on rainfall near Hilo, Hawaii are described. Quartile deviations of drop size distribution are plotted versus intensity of rain. Curve showed fairly good correlation between median diameter and rain intensity (+10%). Median diameter increased as intensity increased. Measurements made on a blotter.
33. Anfossi, G., "Esperimenti di confronto fra diversi pluviometri." (Experiments comparing different rain gages), Parma, Ministero dei Lavori, Pubblici Ufficio Idrografico del Po, 1915.
34. Anfossi, G., "Per la misura delle precipitazioni in montagna." (The measurement of precipitation in mountainous areas), Elettrotecnica, (Rome), 2(11):242-247, April, 1915, 5 figs, 5 refs.
35. Angervo, J. M., "Über die genauigkeit der daenischen sommerniederschlagmesser, pluvius und ginge." (Finn) (About the accuracy of the Danish Ginge and Pluvius summer rain gage), Terra, 61(1):1-6, 1949. 6 figs., 1 table, 1 ref.  
The float type with rod gage found to be inaccurate due to rod collecting water.

36. Angot, A. , "Sur la mesure de la neige." (On the measurement of snow), Annuaire de la Societe Meteorologique de France, 56:157-159. 1908.
37. Arago, D. F. J. , "Tableau de la quantite de pluie qui est tombee a l'observatoire Royal en 1821, sur la plate-forme et dans 24 cour. " (A table of the amount of rain which fell at the Royal Observatory in 1821, upon the platform and in the court), Annates de Chimie et Physique (Paris), Ser. 2, Vol. 18, p. 410, 182T
38. Arago, D. F. J., Annuaire de Bureau des longitudes, p. 161, 1824.  
In support of the theory that the increase in rain drop size in the lower atmosphere because of condensation on the drop is the cause of difference in readings of elevated gages.
39. Arago, D. F. J., "Pluie Moyenne a Paris. " Annates de "Chimie et Physique, Ser. 2, Vol. 27, p. 399-402, 1824.
40. Archives des Sciences Physiques et Naturelles, "Observations Meteorologiques Faites au Grand Saint-Bernard Pendant la mois de Mai 1917. " - (Meteorological observations made at Grand Saint Bernard during the month of May, 1917), Archives des Sciences Physiques et Naturelles, 43:517, 1917.
41. Arctowski, H. , "Sur le manque de precision des mesures pluviometriques. " (On the lack of precision of rain gage measurement), Institut de Geophysics et de Meteorologie de Lwow: Communications, 1(3): 1-7, 1922, 3 tables.  
Discusses the effect of wind and exposure on rain gage catch. Tries to analyze the causes of differences in catch. This is\* an abstract of an article appearing in Kosmos.
42. Arctowski, H. , "On the lack of precision of rain gage measurement. " Kosmos Bulletin de la Societe polonaise des Naturalists, Leopold, 1923.
43. Arctowski, H. , "Sur le manque de precision des mesures plirviometriques. " (On the problem of precision in rain measurement), La Meteorologie, 69(2):250, 1926.
44. Arenberg, D. L. and Harney, Patrick, VThe Mount Washington icing research program." American Meteorological Society Bulletin, 22:61-63 , Feb. 1941, 4 refs. , 8 eq.  
Problems taken up in program are: (1) measurement of liquid water content, (2) measurement of drop size distribution, (3) structure and physical properties of rime and ice, (4) testing and possible development of de-icing equipment, and (5) study of meteorological conditions necessary for severe icing.
45. Asher, A., "Anleitung zur Messung und Aufzeichnung der Niederschlaege." (Introduction to the measurement and recording of precipitation.) Royal Prussian Meteorological Institute, Berlin, 1899.
46. Ashmore, S. E., "The splashing of rain. " Royal Meteorological Society, Quarterly Journal, 60:517-522, 1934, 4 figs. , 2 tables, 6 refs.  
In experiments with a "splash-meter" it was found that in moderate rain you can get numerous drops bouncing up to 2 feet above the ground. For a rainfall rate of 10 mm/hour numerous splashing occurred to a height of: poor lawn = 8 1/2 in. , dead leaves = 10 1/2 in. , gravel = 11 in. , good lawn = 11 1/2 in. , water = 14 in. , hard surfaces = 14 1/2 in. , bare soil = 16 1/2 in. , ice = 25 in. On 3 occasions when sleet fell, the splash was unexpectedly high. Max. splash for 10 m m/hr. for poor lawn = 14 in. , good lawn = 25 in. , hard surface = 26 in. , and bare soil 34 in. Suggests highest splash would approach 4 ft. No attempt made to measure amount.

47. Assman, R.. "Der combinirte Regenmesser." Zeitschrift fuer Instrumentenkunde, 5:227-232, July, 1885, 1 fig.  
The Assman non-recording rain gage that is easily adaptable to snow.
48. Austin, J. M. , "Comparison of rain gages at Apia." New Zealand Journal of Scientific Technology, Wellington, 21(1B):52B-56B, July, 1949.  
Independent experiment with Hellman-Fuess, Dines, and Meteorological Office (British) gages. An attempt has been made to consider and explain differences in catch due to evaporation, exposure, splashing, height of gage, etc. In an experiment, it is shown that the British M. O. gage will lose 0.004 in. and the Hellmann, 0.012 in. due to adhesion and evaporation. Explains this as the funnel material being smooth copper for the M. O. and rough galvanized metal for the Hellmann. For a year of 205 rainfalls at 110 in. per year it amounts to 0.82 in. for the M.O. and 2.46 in. for the Hellmann. For 26 periods of rain in calm conditions, the M.O. at 12 in. height exceeded the Hellmann at 1 meter by 0.7%. The average fall was about 0.18 in. during these calms.

## B.

49. Bache, A. D. , "Note on the effect of deflected currents of air on the quantity of rain collected by a rain gage." Transaction Section, British Association for the Advancement of Science: Report, p. 25-27, 1838, 1 table.  
Experiments with 4 gages placed at the 4 angles of a tower. "—In general, gages to the leeward received more rain than those to the windward." "The effect of eddy winds upon the phenomena observed, was by no means a secondary one."
50. Bache, A. D. , American Philosophical Society, Proceedings, 2(21):164, 1842.  
A note on making Osier's self-registering gage available for winter use by heating the funnel with steam.
51. Bacso', F., "Vergleichsmessungen mit dem Niederschlagsammler Mougin Totalisateur," (Comparative measurements with the Mougin totalizer precipitation collector), Az Idojaraz, Budapest, p. 209, Sept. -Oct. , 1935.
52. Bagossy, B. , "An instrument for distant-measurement of rime thickness on free surfaces." Az Idojaraz, Budapest, 15:229-230, 1939.
53. Bailey, R. A., "Nipher, Alter and other shields on snow gages compared." American Meteorological Society Bulletin, 28(4):198-199, April, 1947, 1 table, 1 ref.  
Short note on measuring snow. 4 in. gage caught more than 8 in. Suggested oilcoated brine to fill funnel to catch snow and stop bridging.
54. Baldit, A., "Observations sur l'electricite et le pluie penent l'ete 1910 au Puy-en-Velay." (Observations of electricity and rain during the summer of 1910 at Puy-en-Velay.) Annuaire de la Societe La Meteorologie de France, 59:105-116, 1911.
55. Baldit, A. , "Dispositie special du pluviometre association, destine a la fusion sur place de la neige." (Special installation of the association rain gage for melting snow on the spot.) La Meteorologie, 78(11, 118): 32-38, 1935, 10 figs.

56. Baldit, A. , Gilbert, J. , Philbert, R. , and Fayel, L. , "Comparaison dun nivometre "Mougin" a lecture annuelle avec un pluviometre "Association" a lecture journaliere. " (Comparison of a "Mougin" nivometer (totalizer) for annual reading with an association rain gage for daily reading. ) Etudes Rhodaniennes (Lyon), 15(1,2&3):11-17, 1939.
57. Baldwin, H. I. , and Brooks, C. F. , "Forests and Floods in New Hampshire. " New England Regional Planning Commission Publication, No. 47, 1936.
58. Balsillie, J. G. , "Australian Patent No. 1952/16, Sept. 4, 1916. " Australian Official Journal of Patents, 26(30):776, August 14, 1917, 1 fig.
59. Bamford, A. J., "The design of rain gages. " Meteorological Magazine, London, 57(681):240-243, October, 1922, 4 tables, 1 ref.  
In tests conducted in Geylon, it was shown that in light rains, evaporation from the gage was an important factor. Recommendations were that, the mouth of the receiver under the funnel should be less than 1/2 the diameter of the gage. A bottle in an insulated gage would be desirable.
60. Bamford, A. J. , "On the design of rain gages for tropical use." Meteorological Magazine, Vol. 65:81-87, May, 1930, 1 table.  
Improvement in rain gage design to retard evaporation in a tropical rain gage. All unnecessary metal in the funnel should be avoided as all metal gages in the tropics tend to underestimate. Inner receivers of bottles with small mouths should be used. A hot surface of a funnel can evaporate a considerable amount of rain.
61. Barkow, E. , "Untersuchung ueber den Tropfregennmesser. " (Research on raindrop measurement) Veroffentlichungen des Kgl. Preussischen Meteorologischen Institutes, No. 267:67-71, 1913.
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Description of a very sensitive instrument which permits the study of places having very little precipitation.
63. Barnothy, J., Bell, B. , "Regenanzeiger fuer minimale Niederschlagsmengen. " (An indicator of traces of precipitation), Zeitschrift fur Instrumentenkunde, 55:264-265, June, 1935, 1 fig. , 3 refs.  
A paper covered electrical coil is exposed to the weather and is very sensitive to becoming wet. It is constantly heated so that the paper is quickly dried when precipitation stops. Its main function would be the indication of the beginning and ending of precipitation.
64. Bartishvili, I. T. , "K voprosu o roli "zaschity." vopredelenii osad Kov. (Russian). " (On the role of shielding in precipitation gages). Meteorologiya i Gidrologiya, 4:41-43, December, 1950.
65. Basco, N. , "A Mougin-fele csapadekgyuito muszer egyevi eredmenyel. " (The results of a year's observation with the totalizer pluviometer of Mougin) (Resultats d'une annee d'observation avec. Le Pluviometre . Totalisateur de Mougin), Az Idojaras, Budapest, 39:184-185, 1935.
66. Bastamoff, S. L. , "Regenmesserschutz durch.Zaeune. "[(Rain-measurement shielded by fences (hedges)], Meteorologische Zeitschrift, 45: 481-483, December, 1928, 2 figs, 1 ref.  
Wind, tunnel experiments with fences, etc. to determine their relationship to catch of gage.
67. Bastamoff, S. L. , "Sur les pluviometres. " (Concerning rain gages) La Meteorologie, Paris, 75(8):94-98, 1932, 6 figs.

68. Bastamoff, S. L. , Witkewitsch, W. J. , "Aerodynamische Spektren der regenmesser. " (Aerodynamic spectra of rain gages), Bull. of Geophysical Inst. of Moscow, Ausg D. Geophys. U. Aerolog. Observ. Moskau, Vol. 10, 1926.
69. Bastamoff, S. L. , and Witkewitsch, W. J. , "Les spectres aerodynamiques des pluviometres. " (Aerodynamic specters of rain gages), Geophysicas Institute, Moscow, Bulletin, No. 10, 1926.
70. Battandier, A., "Description dun nouveau pluviometre inscripteur. " Le Cosmos, p. 34, April, 1888, 2 figs.  
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On the Brassard tipping bucket gage. The usual tipping bucket idea is used and a dial indicated how many tips occurred.
71. Baxendell, Joseph, "Description of Halliwell's self-recording rain gage." Royal Meteorological Society (London) Quarterly Journal, 26:281-286, June, 1900, 1 fig. , 1 ref.  
On the use and construction of a recording gage combining the tipping bucket and automatic siphon. As a triangular shaped bucket filled, it descended against the pull of a weight. When the bucket was full it tipped, thus bringing a siphon into play and emptying the bucket in 6 seconds. The bucket then returned to zero position. This action was recorded on a drum. Heating of gage made it acceptable for winter use.
72. Baxendell, Joseph, "Dew in rain gages. " Symons' Meteorological Magazine, 37:90, 1902.
73. Beard, H. A. , "Apparatus for catching falling rain. " United States Patent Office; Letters Patent 1,118,259, Nov. 24, 1914, 4 figs.  
A maximum catch gage supported on a gimbal joint structure. Air vanes keep the vessel parallel to the wind and facing into it.
74. Beard, H. A. , "Canadian Patent No. 160,127, rain gage. " Canadian Patent Office Record, 43(1):133, January, 1915, 1 fig.
75. Becker, A. , "Zur Messung der Tropfengroessen bei Regenfall nach der absorptions methode. " (About the measurement of drop-sizes in rain, according to the absorption method), Meteorologische Zeitschrift, 42(6):247-261, June, 1907, 1 fig, 6 tables, 8 refs.
76. Behur, M. F. , "The handbook of measurement and control, chapter 7 - pressure and vacuum. " Textbook: The Instruments Publishing Co., 1951, 17 figs, 11 tables.  
A general recapitulation of industrial pressure measuring instruments by type, range and accuracy. The general types used are schematically illustrated and briefly described.
77. Belcher, D. J., Herner, C. H. , Cuykendall, T. H. , and Sack, H. S. , "Use of radioactive material to measure soil moisture and density. " Report presented to meeting Committee D-18, A. S. T. M. at Cleveland, Ohio, March 5, 1952, p. 0-11, 1952, 12 figs. , 2 tables, 1 ref.  
Radio-active material in a pipe shaped probe 13/16 in. diameter, mounted below and shielded from a G M radiation counter is used to determine soilmpisture and densityby counting scattered and returned neutrons. A flat iron model is used that may be laid directly on the ground. Radio-active Cobalt 60 is used to determine density while Rad-Be is used for moisture. Water could be measured to +2% while density measurements were erratic but indicative.
78. Belgrand, "Experiences sur les instruments de differents diameters. " (Experiences with gages of different diameters), La Meteorologie, 3:200-203, April 24, 1855, 1 table.  
Communication.

79. Berg, E., "Kritische Untersuchung der Angaben freier und geschuetzter Regenmesser." (Critical examination of the data of shielded and unshielded rain gages), Bulletin de Academie Imperial des Sciences, de St. Petersburg, Ser. 5, Vol. 3, No. 2, p. 193, 1895.
80. Berg, E., "Regenmesser zur speziellen Messung der Regengusse und starker regenfalle." (A rain gage for special measuring of rain showers and heavy rainfall), Central pour la Russie d'Europe (St. Petersburg), 11(5):1-3, 1903.
81. Berg, E., "Perfected instrument for measuring precipitation." Monthly Meteorological Bulletin, (Russian) (St. Petersburg), 13(3):1-2, 1905, 2 figs.  
 A non-recording manually operated gage is illustrated and described. The usual type of gage sets on a platform on a post. Adjacent to the gage is a post that supports an arm for the cover of the gage. When one desires, the cover on the gage is removed by pulling a cord attached to an opposite arm. When the cord is pulled, the cover lifts slightly and then, rotating in a horizontal plane, it uncovers the receiver of the gage. Tension is necessary on the cord to keep the lid off the gage. To cover the gage the tension on the cord is released and the cover rotates automatically to its closed position. The gage is useful for determining maximum rates of rainfall.
82. Berg, E. J., "Pluio-graphe de Hellmann-Muller." Bulletin Meteorologique Mensuel de l'Observatoire Physique Central pour la Russie d'Europe St. Petersburg, 14:10, 1906, 2 figs.
83. Bergeiro, J. M., "Necesidad de perfeccioner la medicion de la lluvia. Un Nuevo Pluviometro; Modelo del Autor." (Need for perfecting the measurement of precipitation. A new pluviometer. Model by the author), (Montevideo) Revista Meteorologica, 3:282-284, 1944, 1 fig.  
 A rotating type vecto-pluviometer with an orifice at 45° has been constructed by the author and arrangements for tests are being made.
84. Bergeiro, J. M., "Instalacion del Vecto-Pluviometro Modelo 'J. Ma. B. en el servicio M del Uruguay." (Installation of the vecto-rain gage model 'J. Ma. B.' in the Uruguay service), Montevideo, Revista Meteorologica, 7:130-132, 1948.
85. Bergeiro, J. M., "A proposito del vecto-pluviometro de orientacion anemoscopia." Revista Meteorologica, 11(41):246-248, April, 1952, 2 figs.  
 A rotating vecto-pluviometer using an orifice tilted at 45°. (Appears to have one orifice facing the wind and the other facing away from the wind).
86. Bernard, M., "Weather Bureau's mountain snowfall work." Civil Engineering, 9(3):173-175, March, 1939, 8 figs.  
 Improved type of gage; relation between snowfall and runoff, multiple gage units; Marvin gage; gage shields with metal leaves; deviation of individual gage from mean; comparison of equivalent water depths as measured by snow gages.
87. Berry, F. A., Bollay, E., Beers, N. R., "Handbook of Meteorology." Textbook: McGraw-Hill Book Co., Inc., 1945, 4 figs.  
 In chapter on Meteorological Instruments, 2 pages are devoted to rain gages. The U. S. standard 8 in., tipping-bucket, Alter shield, and Fergusson weight-type gage are illustrated and described. General problems of rain gaging are briefly discussed.

88. Besson, L., "Le pluviometre 'Ville de Paris,'<sup>1</sup> modele 1923." (The "Ville de Paris" rain gage, 1923 model), La Meteorologie, 68(1):86-87, March-April, 1925, 1 fig.  
(Extract from Annales des Services Techniques d'Hygiene de la Ville de France, Vol. 5, 1924).  
Orifice diameter = 0.226 m. A wire mesh keeps funnel from clogging with dirt or leaves. Receiver is emptied by a tap on the bottom. It is 0.720m. long and the receiver is 0.115 m. while the rim is 0.053 m. high.
89. Best, A. C. , "The size distribution of raindrops. " Royal Meteorological Society, Quarterly Journal, 76:16-30, January, 1950, 3 figs., 11 tables, 11 refs., 22 eq.  
Experimental data relating to drop size distribution in rain are examined and it is shown that in many cases size distribution follow formula.
90. Beyerlein, Fr. , "Einige Versuch uebor den Wasserverlust bei Regemessungen durch Verdunstung und durch Befeuchtung des Regemessers." (Several experiments with water loss in rain meters through evaporation and wetting), Meteorologische Zeitschrift, 34: 217-219, May, 1899, 1 table, 1 ref.  
Experiments with wet and dry rain gages to determine effects of evaporation and surface adhesion. Noted that the effect of loss by evaporation was less than by surface adhesion and for a year with 400 showers (?) the loss would be 2 to 3 in.
91. Bibby, J. R. , "An instrument for recording the rate of rainfall or the wind velocity. " Royal Meteorological Society, Quarterly Journal, 70(306):277-281, 1944, 3 figs.  
An instrument is described which records the number of times an electric circuit is made and broken in successive 2-min. intervals. This can be arranged to give an autographic record of the rate of rainfall. .The new British rate of rainfall recorder is discussed. This consists of a control on the outlet of a funnel emitting a fairly constant sized drop as the rain collects in the bottom of the funnel. These drops will fall at a rate proportional to the rate of rainfall.
92. Bigelow, F. H., "A manual for observers in climatology and evaporation." Government Printing Office, Washington, p. 19-24, 1909.
93. Bigelow, F. H. , "Important problems in climatology - precipitation. " Monthly Weather Review, 37:980, November, 1909.  
The following types of snow gages were discussed:  
1. 8 in. rain gage - not good for snow, orifice too small.  
2. 10 ft. platform - not good because wind blows snow off.  
3. " 10 in. stand pipe 10 ft. high - not good for snow, orifice too small.  
4. 5 ft. x 5 ft. x 10 ft. high snow bin.  
5. 5 ft. x 5 ft. x 10 ft. high - louvered inside and shielded - most promising. Inside louvers to keep snow from blowing out.
94. Bigelow, F. H. , "The catchment of snowfall by means of large snow bins and towers." Monthly Weather Review, 38:968-973, June, 1910, 5 figs., 2 tables.  
A thorough test of devices to catch snow was made in the West. The units tested were: (1) snow bin, (2) snow bin with louvers, (3) rain gage, (4) 10 ft. platform, (5) snow scale and (6) 10 ft. and 10 in. standpipe.  
The conclusion was' that the snow bin with louvers was by far the best method devised for catching snow. The rain gage was not very good, while the standpipe and platform were completely unreliable.

95. Bilham, E. G. , "The design of rain gages. " Meteorological Magazine, 62:101-103, June, 1927, 3 figs.  
 Recommends that soldered seams be eliminated to improve gage accuracy. The 3 main seams to watch for leaks on the gage are: (1) the vertical seam of the cylinder, (2) the horizontal seam where funnel meets the cylinder and (3) the sloping funnel. Experiments with spun, seamless gages are being carried out.
96. Bilham, E. G. , "Rain gages in winter. " Meteorological Magazine (M. O. 313), 64(767):252-255, December, 1929, 1 fig.  
 A rubber tube inserted in a receiver with one end (lead plugged) in the water and the other above the water will usually prevent breaking of receiver when the water freezes. The end of the tube is one-tenth the area of the receiver.
97. Bilham, E. G. , and Lewis, L. F. , "A 'day and night' rain gage and some problems arising from its use." British Rainfall, 74:294-299, 1934.  
 Annual evaporation loss from a can 11.5 cm. in diameter is 35 mm. , and from bottle with mouth 2 or 4 cm. across, 21 mm, cfb. The loss due to pouring out of the receiver was measured as less than 0.03 in. of rain.
98. Billwiller, R. , "Die Notwendigkeit des Windschutzes von Regenmessern auf Bergstationen. " (The necessity of wind shield for rain gages at mountain stations), Verhandlungender schweizerischen Natur Zorscher Gesellschaft, 92:218-219, 1909.
99. Billwiller, R. , "La necessity de proteger les pluviometres des stations de montagne contre vent. Modele d'un pluviometre a protection (Modification de l'entonnoil de Nipher), " [The need for protecting the rain gages of mountain stations against wind. Model of a protective rain gage (modification of the Nipher shield)], Archives des Sciences Physiques et Naturelles (Geneva), 28:366-368, 1909.
100. Billwiller, R. , "Ein neues model eines geschuetzten Regenmessers (abgeaenderter Nipherischer Trichter). " (A new model of a shielded rain gage, a variation of the Nipher funnel), Meteorologische Zeitschrift, 27(5):193-198, May, 1910, 2 figs, 3 tables, 6 refs.  
 Nipher shield without horizontal rim, opened at base, to discharge snow, mounted on posts so it could be raised as snow depths increased. Unshielded gage in Gotthard Pass caught 67% of the shielded in snow at wind B 0-4 and 52% at wind B 6 or more.
101. Billwiller, R. , "Die Niederschlaege und ihre Messung, " (Rains and their measurement), Elektrizitaet, Technisches Zeitbild aus der Landes-Ausstellung, 1939.
102. Binnie, W. J. E. , "Account of an electric self-recording rain gage." Royal Meteorological Society (London) Quarterly Journal, 18:6-12, January, 1892, 1 fig.  
 A tube in the bottom of a receiver had a bottom of porous cambric. As the water collects, drops fall from the cambric, hitting a pan contact of an electrical circuit. The rate of all of the drops is recorded and this in turn is proportional to the rate of rainfall. The cambric needed weekly replacement. The gage read to 7 inches per hour rate at accuracy of about 3%.
103. Birch, Thomas, "History of the Royal Society of London. " London, No. 4, 1756-57.

104. Birkinbine, Carl Peter, "Variations in precipitation as affecting water works engineering." Journal of the American Water Works Association, 3(1): 1-103, March, 1916, 29 figs, 11 tables.  
A detailed presentation of the forms, amounts and character of precipitation that must be considered by water works engineers.
105. Black, W. , "Gages for ocean rainfall." Nature (London), 7:202, January 16, 1873.  
A new design marine gage. Cylindrical gage suspended on gimbals.
106. Black, W. , "Ocean rainfall." Meteorological Magazine, 11(122):33-36, April, 1876, 1 table.  
Notes on results with a marine 6 in. gage. "The faster a ship sails or steams, the less rain will she collect in passing through a given area——." Suggests that the rain at sea is less than on land. (The gage may have been on gimbals to keep the mouth level. )
107. Blair, T. A. , "Climatology, general and regional." Textbook, Prentice-Hall, Inc. , p. 32, 1942.  
A paragraph is devoted to method of measuring precipitation and some problems connected with it.
108. Blandford, H. F. , "Description of a rain gage, with evapometer, for remote and secluded stations." - Asiatic Society of Bengal, Calcutta Journal and Proceedings, Letters, etc., 50(2):83-85, 1881, 1 fig, 1 table.  
A test was made with a rain gage and evapometer of the same diameter (8 1/4 in. ) and charged each month with 4 in. of water. The difference in contents measured at the end of each month would be the rain for that month. Comparison of the results with a daily check gage indicated that the losses were too high, probably because the evapometer evaporated more water than the rain gage. Adjustment was needed.
109. Blaetter fuer Zuckerruebenbau, "Regenmesser und Bedeutung fuer die landwirtschaft liche Praxis." (Rain meters and their significance for agricultural practice), Blaetter fuer Zuckerruebenbau, p. 108, 1907.
110. Blue Hill Meteorological Observatory, "Bibliography of meteorological instruments." Blue Hill Meteorological Observatory, Cambridge, Mass., Harvard University, 165 p. , 1950.  
The catalog cards on meteorological instruments from the library of the Blue Hill Observatory were laid out three or four to a page, in the order in which they would appear in the U. D. C. scheme for meteorology, and reproduced. There are about 600 entries, some of which are annotated. No subject or author index is provided.
111. Boase, H. , "On the differences in the annual statement of the quantity of rain falling in adjacent places," Annals of Philosophy (London), Vol. N. S. 4, p. 18, July, 1822.  
"——difference of the quantity of rain received in a gage placed on top of a building, and one ata level with the surface of the ground, is, for some reason or other, proportional to the velocity of the wind."
112. Boccardo, G. , "Pluviometro, pluviometrografo." (Rain gages and recording rain gages), Nuova Enciclopedia Italiana Torino, 17:900-902,' 1884, 2 figs.  
Describes the Matteucci Pluviometrografo which is illustrated. Appears to be a float-type recording gage with no provision for siphoning.

113. Boisquiraud, N. , Annales de Chimie et de Physique, Ser. 2, 33:417, 1826.  
 "—rain is sufficiently cold to produce precipitation even when the air is far from being saturated." Quote from Jevons, Philosophy Magazine, 1861, p. 431, review of article.
114. Bonacina, L. C. W. , "The effects of exposure to wind upon the amount of rain caught by rain gages and the methods of protecting raingages from them." British Rainfall, London, 46:27-45, 1906, 2 figs, 3 tables, 45 ref.  
 Includes an extensive bibliography. A review of wind effects on rain gages. Discusses: (1) Pit gages, (2) Cross partitioning, (3) Wind shields and (4) Fence enclosures. Fence enclosures were rated as best with the Nipher shield a close second.
115. Bonacina, L. C. W. , "Rain gage exposure and protection." Nature (London) 76:672-673, 1907.
116. Bornstein, R. , "Ueber den von Nipher vorgeschlagenen Schutztrichter fuer Regenmesser. " (Concerning the protecting funnel suggested by Nipher for rain gages), Meteorologische Zeitschrift Band I Berlin, 1:381-392, October, 1884, 6 tables, 9 refs.
117. Bornstein, R. , "Ueber die Bestimmung der wahren Regenmenge mittels hoch aufgestellter Regenmesser. " (Concerning the determination of the real amount of rain by means of highly placed rain gages), Meteorologische Zeitschrift, 1:381-387, 1884.  
 An unshielded gage caught 88% of a shielded, ranging from 92% with winds Beaufort 2, and 87% with Beaufort 3 and 4, to 69% with Beaufort 5 and 6, and 54% with snow alone. Downpours 96%. cfb.
118. Borovikov, A. M. and Vulfson, N. I., "About horizontal protection of rain gages and comparison of their operation with other systems of protection." Meteorologija i Hidrologia, No. 7:143-149, 1938.  
 (Translation at Blue Hill) Using 6 years of comparative data an analysis was made to determine the effectiveness of (1) no protection, (2) Nipher shield (without horizontal rim), (3) Nipher shield with horizontal rim, and (4) cross partition in the gage. Results showed that the Nipher shield with the horizontal rim was far superior for winter work and that in all cases the use of cross partition improved the catch.
119. Boutaric, A., "Les recentes progres des methodes pluviometriques. " (Recent improvements in the methods of measuring precipitation), La Nature (Paris), 2918:489-494, December, 1933.
120. Boutaric, A. , "Les recentes progres des methodes pluviometriques. " (The recent progress in rainfall measurement) Genie Civil, 107(2779) 467-469, November, 1935, 6 figs.  
 New type rain gage, consisting of usual gage with horizontal aperture on top and two supplementary gages at right angles to each other, having lateral apertures only for receiving inclined rain jets. Use of gage for more precise determination of rainfall on watershed of various slopes. Also recommends the stereopluiometer, the orifice of which is parallel to the general slope of the ground.
121. Boutaric, A., "Recent progres des methodes pluviometriques vecto-pluviometre et le stereopluiometre." (Recent progress of rain gage methods, the vecto-rain gage and the stereo-rain gage), Genetics, Brooklyn, 107:467.
122. Boys, H. A., "Amateur rain gages." Meteorological Magazine, 10(111): 39- , April, 1875.
123. Boys, H. A. , "Demerits of rain gages, 'one foot from the ground'. " Meteorological Magazine, 52(618):76-77, July, 1917. "  
 Correspondence.

124. Braak, C. , "Einfluss des Windes bei Regenmessungen. " (Influence of the wind in measurement of rain), Beitraege zur Geophysik, 50: 231-35, 1937.  
Compares results at standard height, 1.5 m. above ground with those at ground level.
125. Braak, C. , "Invloed van der wind op regenwaarnemingen. " (Influence of the wind on rainfall measurement), S<sup>1</sup> Gravenhage (Koninklyk Nederlandsch Met. Inst. No. 102, Medeelingen eh verhandelingen No. 48) 48(102):7-74, 1945, 12 figs, 8 tables, 6 refs.  
Statistical and regional study of sources and amount of error in rain gage measurements. Comparison of types of gage used in Germany, France, Belgium, England, etc. , with different types in use in Holland. As a result of experiments conducted at six stations in different regions of Holland, it was recommended that the height of rain gages be reduced from 1.5 to .4 meters above the ground, and that in particularly windy places the rain gage be surrounded with a turf wall of the English pattern. Statistical study of daily, monthly and annual catches at six stations shows average correction of 5.5% necessary, ranging from 3 per cent in calm to 10 per cent in relatively windy places. Lowering height of gage more effective than shielding.
126. Brassart, F. , "L'udmetro - contatore dei fratelli Brassart." (Rain gage of the Brassart Brothers), Ufficio Centrale Meteorologico e. Geddinamico Italiana e Meteorologia. Geofisica Roma VII Annali, 1885.
127. Brazier, C. E. , "Sur la mesure correcte de la pluie. " (Concerning the correct measurement of rain), La Meteorologie, Paris, 70(3): 385-395, 1927, 9 figs.  
Fairly satisfactory results obtained from use of flaring shield covered with wire netting to an inner metal cylinder.
128. Brazier, C. E., "Quelques remarques a propos de la note M. Bastamoff 'Sur les pluviometres'." (Some remarks "a propos" of M. Bastamoff's note on rain gages), La Meteorologie, Paris, 75(8):99-101, 1932, 2 refs.
129. Breitung, W. , "Auswertung von Regenbeobachtungen und Bestimmung der Regenabflussnengen fuer Staedtische Kanale. " (The value of rain observations indetermining runoff for drainage canals), Leipzig or Stuttgart, 1912, 1911.
130. Bricard, J. , "Determination of the number of drops per unit of volume and the relative humidity in the clouds. " Academie des Science, Paris, Comptes Rendus, 214:439-441, 1942.
131. British Association for the Advancement of Science, "On the Kew Observatory. (Rain and vapor gage)." British Association for the Advancement of Science, p. 128-129, 1844, 1 fig, 9 tables.
132. British Association for the Advancement of Science, "On the rainfall in the British Isles. " British Association for the Advancement of Science, p. 281-352, 1866, 1 fig. 9 tables.  
Remarks are made about inclined and tipping funneled gages that rotate. Mentions that Mr. Chrimes was conducting an experiment containing these gages. Some figures of gages in use in 1866 are presented.
133. British Association for the Advancement of Science, "Second report of the rainfall committee - On rainfall in the British Isles. " British Association for the Advancement of Science, p. 448-467, 1867, 2 figs, 3 tables.  
Figure of gages in 1866 is again printed.

134. British Association for the Advancement of Science, "Report of the rainfall committee for the year 1867-68; On the rainfall in the British Isles." British Association for the Advancement of Science, p. 432-473, 1868, 6 figs, 4 tables.  
The results of the Calne height experiments are briefly mentioned. An altimeter for determining the angle of elevation of trees, buildings, etc. above rain gages is described.
135. British Association for the Advancement of Science; "Examination of rain gages." British Association for the Advancement of Science, p. 392-401, 1869, 1 table.
136. British Association for the Advancement of Science, "Examination of rain gages." British Association for the Advancement of Science, 1870, 1 table.
137. British National Committee for the Polar Year, "British polar year expedition, Fort Rae, N. W. Canada, 1932-33." Smithsonian Institution. Annual Report, 60(256):107, 118, July, 1934. British National Committee for the Polar Year and the Royal Society, Vol. 1, 1937.  
Discussion of results: Meteorology; snowfall could not be separated from drift caught simultaneously. Hourly precipitation difficult owing to wind disturbing balance of Hellmann-Fuess recording gage.
138. British Rainfall, "Colonel Ward's experimental rain gages at Calne." British Rainfall, No. 4:12-13, 1864.
139. British Rainfall, "Detection of sea-spray when mingled with rain." British Rainfall, No. 6:11-22, 1866.
140. British Rainfall, "On float gages adapted for mountain work."- British Rainfall, p. 46-52, 1870, .8 figs.  
A metal float gage 4 ft. in depth has been used as a monthly totalizer. The float had to be reinforced as buckling gave it erroneous readings.
141. British Rainfall, "Rain gage in theory and practice." British Rainfall, No. 50:67-78, 1910.  
Describes in simple language the theory of the rain gage as illustrated by the standard pattern. Some volume relationships are given.
142. British Rainfall Organization,- "Bibliography on rainfall measurement, 1901-1925." British Rainfall, London, 65(M. O. 285):270.-277, 1925, 1 ref.  
A short, partially annotated-bibliography on rain mapping and measurement intended as a supplement of Dr. H. R. Mill's bibliography in "British Rainfall," 1900. Only articles that were in "British Rainfall" appear, in the bibliography.
143. British Rainfall Organization, "On errors in the measurement of rainfall." British Rainfall, London, 65(M. O. 285): 13-18, 1925, 2 figs.  
"Overexposure, especially to up - slope winds, to be avoided; small quantities, to be carefully measured; gage to be checked for leaks annually. . cfb." Maximum drop size is 0.22 inch (dia. ) and maximum terminal velocity is 16.9 mph.
144. British Rainfall Organization, "Exposure of rain gages in windy localities." British Rainfall, 66:280.-28.1, 1926.  
Wire screen fence rising above the gage to half the height of the distance reduced the catch, even when 2-inch mesh used. Concludes that a wire fence is unsuitable and that a built up turf, wall is more effective.

145. British Rainfall Organization, "Note on a comparison between rain gages with different exposures at Salt Island, Holyhead." British Rainfall, London, 66:282-284, 1926, 1 fig, 2 tables.  
Exposed gage caught 10% less than one in enclosed yard. Turf wall about exposed gage brought it up to yard catch.
146. British Rainfall Organization, "Experiments with rain gages with black and white funnels." British Rainfall, London, 69:284-287, 1929, 5 tables, 1 ref.  
A loss of 3.4% due to painting the funnel was determined by experiment. Apparently the slickness of the surface is fundamental in causing drops to cling to the funnel and this be evaporated.  
Moral - the funnel of a gage should never be painted.
147. Brooks, Charles F., "Need for universal standards for measuring precipitation, snowfall and snow cover." International Geodetic and Geophysical Union Bulletin, Sec. B, No. 23:37-52, 1938, 17 figs, 3 tables, many refs.  
A detailed summary on many of the most important methods of measuring precipitation. Concluded that the most important item would be the adoption of wind shields for gages. Contains selected, annotated bibliography on the measurement of precipitation, snowfall, and snow on the ground.
148. Brooks, C. F., "Wind-shields for precipitation gages." American Geophysical Union, Transactions, Part 1, p. 539-542, August, 1938,  
Construction of the Nipher shield and some results.
149. Brooks, C. F., "Further experience with shielded precipitation gages on Blue Hill and Mt. Washington." American Geophysical Union, Transactions, Part 2, p. 482-485, July, 1940, 2 tables, 5 refs.  
The outer horizontal ring of a Nipher shield is necessary to effectively deflect the wind. The screening reduces splash by approximately 3%. There is no substitute for the Nipher shield at this time.
150. Brooks, C. F., "The measurement of snowfall with shielded gages." Central Snow Conference, East Lansing, Michigan, Proceedings, 1:193-195, December, 1941, 7 refs.  
The Nipher shield, open below for the discharge of snow, has been proven effective for snow precipitation measurement. An important point that must be remembered is that the shield and gage must be perpendicular to the general slope of the ground and the catch then multiplied by the secant of angle of slope in order to determine catch per unit horizontal area. In high winds even the Nipher shield is unsatisfactory.
151. Brooks, C. F., "Impracticability of Precipitation gages that are kept pointed into the wind." American Meteorological Society Bulletin, 26:98, March, 1945, 5 refs, 1 eq.  
Gages with other than horizontal mouths are affected by wind velocity and by rate of fall of the precipitation products. Since rain-drop sizes are not uniform, no single relationship can be assumed to hold good. Nipher type shield found quite efficient.
152. Brooks, C. F., "Recommended climatological networks based on the representativeness of climatic stations for different elements." American Geophysical Union Transactions, 28(6):845-846, December, 1947.  
Recommends one precipitation gage for every 5000 square miles for climatological purposes.

153. Brun, E. , Demon, L. and Vasseur, M. , "Mesure des diametres des gauttelletes d'un nuage." (The measurement of the diameters of the droplets of a cloud), Academie des Sciences, Paris, Comptes Rendus , 224:1518-1519, 1947, 2 refs.  
Discusses (1) an oil method of catching drops, (2) an electrical method and (3) a mechanical method. The procedures are generally mostly for laboratory work.
154. Brun, E. , and Pauthenier, M. , "Determination of the essential characteristics of clouds and fogs by the use of an ionized electric field." Meteorologie Paris (3rd Series), Ser. 3, No. 43-54:70-98, January-June, 1943, 17 figs, 29 refs, 5 eq. -  
An electrical method for determining the number and size of drops of fog per unit volume. A method for determining the amount of condensed water and relative humidity of clouds.
155. Brun, E. , and Vasseur, M., "Depot, sur un obstacle, de particules en suspension dans un courant fluide." (The deposits upon an obstruction of particles in suspension in a fluid current), Comptes Rendus, Paris , 218:636-638, April 17, 1944.  
An oil coated disc method of drop size determination.
156. Brun, R. J. , Levine, J. , and Kleinknecht, K. S. , "An instrument employing a coronal discharge for determination of droplet-size distribution in clouds." National Advancement Committee for Aeronautics, Note 2458, p. 0-53, 1951, 12 figs, 4 tables, 13 refs.  
"The method of separation involves the use of cylinders of various sizes placed in the path of the droplets.---Collection efficiencies of the different sized cylinders are a function of drop size and cylinder diameter. The charge deposited on each cylinder represents measure of the total number of droplets intercepted." This calibration is for cloud droplets above freezing. An electrical charge is placed on the droplets by the coronal discharge between plates having a 25,000 volt difference in potential. The readings are instantaneous, continuous, and the response is fast.
157. Buchan, Alexander, Handy Book of Meteorology, 1867.
158. Buchan, A. , "On a protecting wire screen for the rain gauge." Scottish Meteorological Society, Journal , 4(61-62):146-149, April, 1874.
159. Buenos Aires Servicio Meteorologico National, "Instrucciones-hidrologicas." Precipitation Publ., Buenos Aires, Ser. D, Part 3, 23 p. , 1945, 9 figs, 2 tables.  
The measurement of precipitation as prescribed by the government of Argentina. Two types are described. A snow gage using the Nipher shield is illustrated as is a totalizer.
160. Buist, British Association for the Advancement of Science, Trans. Section, p. 25, 1852.  
On 4 simultaneous measurements on the Island of Bombay to determine the fall of rain at different heights below 200 ft. "---did not give uniform results, ---sometimes the most elevated gages having the greatest fall of rain, and at other times the lower."
161. Byers, Horace, R. , "General Meteorology." Textbook: McGraw Hill Book Co., Inc., New York, p. 85-90, 1944, 4. figs.  
In chapter on "observations and station instruments," the measurement of precipitation is discussed. The U. S. Weather Bureau Standard Gage, Fergusson Weight gage , Alter Shield and Nipher Shield are illustrated and described. A general discussion of rain gaging is given.
162. Byers, Horace R. , "Use of radar in determining the amount of rain falling over a small area." American Geophysical Union Transactions, 29(2):187-196, April, 1948.

163. Cappleman, Homer L., Jr., "Rain or snow gage." Patent No. 2,497,759, U. S. Patent Office, February 14, 1950, 5 figs, 6 refs.  
A recording rain and snow gage operating on the weight principle. The receiver of a rain gage rests on a column of mercury. When rain or snow collects in the receiver, it moves down and the mercury is forced into a smaller receiver beneath a piston, which in turn moves upward to balance the system. This upward movement is calibrated by a suitable mechanism to record the amount of precipitation. The receiver maybe emptied by siphoning and the system is leak tight and will operate at low temperatures.
164. Carter, H. G. , "Evaporation from rain gages. " Monthly Weather Review, 57:96, March, 1929, 1 table.  
Daily average of evaporation was 0. 01 in. to 0. 02 in. Suggests observers should read gage soon after rain.
165. Casella, C. F. , British Patent No. 10,879, "Rain gage. " Great Britain Patent Office, Abridgement of Specifications, Class 97, 1907.
166. Casella, C. F. , British Patent 27,915, "Rain gage." Great Britain Patent Office, Abridgement of Specifications, Class 97, p. 467-468, 1907.
167. Cavallo, Tiberius, "Elements of natural or experimental philosophy." Second American Edition, Philadelphia, 1819, Vol. 4, 1803.
168. Cerebotani, L. , Silbermann, A. , "British Patent 12, 098. " Great Britain Patent Office, Abridgement of Specifications, Class 106, p. 41, 1897-1900, 1 fig.  
An automatic weather station for electrically transmitting (1) pressure, (2) temperature, (3) humidity, (4) wind direction, (5) wind velocity and (6) rain.  
In the rain gage, drops fall from the funnel into a small receiver. Apparently the impact of the falling drop causes the arm, on which the receiver is spring-suspended, to move on a fulcrum and to close a contact. No mention is made as to how quantity is measured.
169. Chambers, Charles P. , "Graduation of rain glasses. " Symons' Meteorological Magazine, 39:48, 1904.
170. Chappell, R. R. , Colt, R. B. , Patent No. 2,118,459, May 24, 1938, "Float-type rain gage. " U. S. Patent Office (Official Gazette, summarized), 3 figs.  
A float self-recording gage with an overflow arrangement is patented. Two receivers (one with a float) of the same volume are interconnected by a pipe and valve between the bottoms of the containers and a weir overflow arrangement at the top. When the float chamber is filled to the overflow point, the valve is opened manually and the water comes to the same level in both receivers thereby doubling the capacity of the gage.
171. Chilton, G. , "Description of an improvised rain gage." American Journal of Science, 7:326-327, 1824.
172. Chrimes, R. , "Rotherham rain gage experiments. " British Rainfall, p. 31-36, 1872, 1 fig, 8 tables.  
On rain inclination, direction and elevation. "The elevation difference is almost wholly due to the horizontal movement of air." Conclusions were: (1) In winter and spring rain drives rather than falls, its angle from the vertical being about 50 degrees. Gages at 25 ft. caught 20% less than those at 1 ft. above the ground. Daily wind motion was 175 miles; (2) During summer the rain falls at approximately 22 degrees from the vertical and the deficiency in the upper gage is 10% with average wind of 116 miles per day.

173. Church, J. E. , "Progress of the Mount Rose weather observatory." Nevada University, Agricultural Experiment Station, Bulletin No. 67, p. 1-36, June, 1908.  
An early totalizer for Mount Rose is described.' Oil, but not salt, was used. The orifice was 8 in. in diameter at the top of a pipe of the same diameter rising 14feet from the summit and passing down into the rock 6 ft., to the top of a cylindrical tank 4 ft. high and 30 in. in diameter. The catch was unsatisfactory.
174. Church, J. E. , "Snow surveying: its problems and their present phases with reference to Mount Rose, Nevada and vicinity. " Pan American Scientific Congress, 2nd, Washington, U. S. A., Proceedings, No. 2: 496-549, December 27-January 8, 1915-1916, 3 figs, 46 tables.
175. Church, J. E. , "Report of committee on snow, 1941-42. " American Geophysical Union Transactions, 25(Part 2):393-462, November, 1942,' 20 figs, 2 tables, many refs.  
Page 432. Stevens and Fergusson gages are discussed. The U. S. Forest Service is using thermostatically controlled gas heating elements for melting snow in tipping bucket gages. Heating of the catch ring on gages was found to be satisfactory, for gages operating under freezing conditions. One of the main problems was failure of batteries during cold weather.
176. Church, J. E. , "Snow-study program at Soda Springs near Donner summit of central Sierra Nevada. " American Geophysical Union Transactions, 24(Part 3):77-90, November, 1943, 14 figs, 3 tables.  
A general report on the program at Soda Springs. With regard to measuring precipitation, some conclusions were: (1) Unshielded gages show a catch deficiency over shielded gages. (2) Use of oil has been very effective in preventing evaporation. (3) Calcium chloride solutions are more efficient when stirred occasionally. (4) Heating collar of gage was effective in preventing clogging of orifice (with batteries). (5)Suction of the wind passing over the orifice will cause more oscillation of the pen than impact.
177. Church, J. E. , "Research committee on snow. " Western Snow Conference, 1945, 1946.
178. Church, J. E. , and Marr, James C. , "Further improvement of snow-survey apparatus. " American Geophysical Union Transactions, Part II, Washington, p.607-618, 1937.  
Detailed presentation of many improvements.
179. Clark, E. J., "Shortage in shallow-funnel rain gage compared with Snowdon gage." Meteorological Magazine, 57(681):244, October, 1922, I table.  
In a comparison made in a fairly open location for 15 years, the shallow funneled gage gave an annual average deficit of 1% over a deeper funneled gage.
180. Clarke, Peter, Bateman, J. F. , "Report. ... (of) the committee appointed for superintending the measurement of rain falling along the lines of the Rochdale, Ashton-Under-Lyne, and Peak Forest canals. " Manchester Literary and Philosophical Society, Memoirs, 2nd Ser . 9:1-28, 1851.
181. Clarke, Hafstad K., "Spacing of rain gages and the measurement of flood producing rain. " American Geophysical Union Transactions, 23(Part 2):557-558, November, 1942.  
On three watersheds of more than 300 square miles the flood-depth was underestimated in only 2 out of 14 cases, with 1 gage for every 167 square miles. On small watersheds, the flood depth was more frequently underestimated. These conclusions were arrived at by a statistical study.

182. Codd, A. R. , "Shielded storage precipitation gages. " American Geophysical Union Transactions, Part 1, p. 77-79, 1 fig, July, 1939.  
Note on stand and Alter shield for 8 in. gage which may be used for catching rain or snow.
183. Codd, A. R. , "Calcium-chloride solutions in the operation of precipitation gages. " American Geophysical Union Transactions, Part 3, p. 913-915, 1940, 1 fig.  
Over 143 automatic recording rain gages have been used in the West and operate to temperatures of -43°F. CaCl<sub>2</sub> solutions plus oil film are melting agencies. Solution and charts need periodic attendance. Has a chart showing freezing point of CaCl<sub>2</sub> solution . Recommends using acid and alkaline resistant paint to protect inside of bucket from brine solution.
184. Codd, A. R. , "Seasonal storage precipitation gages in Alaska. " American Geophysical Union Transactions, 25(Part 2):443-446, November, 1942, 2 figs.  
55-gallon drum storage gage was made for use in isolated mountain areas. Alter shielded. 200-inch capacity using 50 pounds of CaCl<sub>2</sub> and 8 gals. water and 1 pint turbo oil.
185. Codd, A. R. , "Seasonal storage precipitation gages. " American Geophysical Union Transactions, 28(6):899-900, December, 1947.  
Anon-recording winter storage precipitation gage used successfully in the regions of heavy snowfall in the Sierras of California. Calcium chloride used as the melting agent with a 1/16 in. oil film to prevent evaporation. (Suggests painting inside to keep the CaCl<sub>2</sub> from eating metal-asphalt emulsion. ) A cork in the funnel will hold down evaporation.
186. Codman, J. E. , "Report. " Report, Bureau of Water, Philadelphia, p. 301, 1891, also 1892-3-4-5.  
On size of rain gages.
187. Codman, J. E. , "Rainfall observations at Philadelphia. " Engineering Record, 26:360-361, November, 1892, 2 figs, 2 tables.  
Results of observations to determine effect of different elevation on reading of gages. Also 3. years of record on gage diameter experiments indicated that a 2 in. gage was as accurate as a 24 in. gage. Philadelphia Water Works.
188. Codman, J. E. , "Notes on the use of automatic rain gages. " American Meteorological Journal, 9(8):341-345, December, .1892/3, 3 figs. 1 table.  
Gages with orifices from 2 in. to 22 in. were placed close to each other and at the same level. Three years of results (45 in./yr. ) showed that the size of the orifice did not cause any difference in catch (three-fourths percent). Some data given for the correlation of height with catch of gage.
189. Conover, J. H. and Nastos, T. G. , "Tests of Stewart and Victor precipitation gages." Blue Hill Report, Contract CWB-8120, July, 1951, 4 figs, 1 table, 3 refs.  
Test showed that for rain, the Victor gage (3/4 in. diameter) performed very well. Was not recommended for snow. Suggests that a gage with a small orifice is much more effective for fine precipitation because it does not obstruct the flow of air as much as a large gage.
190. Conrad, V., "Die Messung von Regen und festem Niederschlag Köppen-Geiger. " (Measurement of rain and solid precipitation), Köppen-Geiger's Handbook for Climatology, Handbuch der Klimatologie, Berlin, 1(Part B):459-465, 1936, 5 tables, 20 refs.  
Summary of ordinary gages, totalizers, difficulties of precipitation measurement, windshields. A note on the dimensions of gages in France, England, Austria, and Germany.

191. Cook, A. W. , "Comparison of rain gage can and the Horton snowboard measurements of snowfall at Grand Forks, North Dakota. " Monthly Weather Review, 52:538-540, November, 1924, 1 fig, 2 tables, 1 ref.  
In one winter's test, a snowboard consistently caught more snow than did the gage. In very light snow, the gage seemed to catch more but did not exceed snowboard. The average snow-to-water ratio was 14 to 1 and in general was very erratic.
192. Cooper, B. F. , "A balloon-borne instrument for telemetering raindrop-size distribution and rain water contents of cloud." Australian Journal of Applied Science, 2(1):43-55, March, 1951, 9 figs, 1 table, 2 refs, 6 eq. )  
Constructional and circuit details are given. "Drops are detected by their impact on a horizontally-mounted microphone, the force of impact being a measure of drop size. On the ground a receiver demodulates the transmission and reproduces impulses which are a measure of drop size. Drop size ranges are determined on a counter system. Rain water content is measured on a similar transmitter having a catching funnel mounted above its microphone. Water caught in the funnel falls onto the microphone in drops of a known size and are counted. Some preliminary results indicate: (1) Number of drops increases down to the cloud base. (2) Beneath cloud base there is a decrease in numbers of drops indicating considerable evaporation. (3) There is little growth of drops after they reach the melting phase.
193. Cornick, F. J., "Gage for determining rate of rainfall. " U. S. Patent Office, No: 2,251,352, p. 1-6, August 5, 1941, 5 figs.  
A movable counterweighted small bucket having a series of small perforations in its wall at various distances above its bottom so that the number of perforations through which water will flow is proportional to the rainfall rate, determines the action of this gage. A pen arm is attached on the opposite side of a fulcrum in connection with the bucket and its movement and the record on a drum is calibrated to rate of rainfall. It was found that if each orifice was of small diameter (0.01 in.) and relatively long (1/8 in.), it will start discharging water as soon as the surface of the water reaches the lower edge of the orifice. Capillarity overcomes the surface tension and causes the water to flow through the orifice even though the level of the water has not raised above it. The lowest orifice is level with the bottom and keeps the bottom quite dry by the sucking capillary action. A groove for the perforations on the outside of the bucket decreases dribbling and an apron on the bottom of the bucket under the groove keeps water from covering the bottom of the bucket.
194. Cosmos, Cosmos, Paris, Vol. NS 31, No. 540:257, June 1, 1895.  
"A communication of Dr. Vogelstein states that the rain gage was already in use during the first 2 centuries of our era and that they used special receptacles to measure the quantities of water fallen from the sky. "
195. Costello, D. F., "Homemade gage measures rainfall." Popular Science, Vol. 160; No. 4, p. 227, April, 1952, 1 fig.  
Describes how to make a homemade gage from easy to get materials. Uses 7.91 in. funnel and 2.50 in. collector which gives a magnification of 10.
196. Crallan, T. E. , "On rain gage experiments at Framfield Lodge, Hurst Green, Sussex." British Rainfall, p. 21-23, 1866, 1 fig, 1 table.  
Twelve types of gages are arranged on a shelf so that all their orifices are one foot above the ground. It is hoped that this experiment will enable the selection of a standard gage.

197. Crallan, T. E. , "Rain gage experiments at Framfield Lodge, Hurst Green, Sussex." British Rainfall, p. 45-48, 1867, 4 tables.  
Objects of this experiment are: (1) Merits of funnel materials. (2) Merits of different designs. (3) Differences due to daily versus monthly readings. (4) Evaporation from an open vessel. Ebonite best for funnels while glass or earthenware poorest because of capillary attraction. Zinc seemed to work alright. A dull smooth surface allows rain to flow freely. A long funnel tube was better than a short one in decreasing evaporation; width didn't seem to matter. A steep funnel is better than a shallow one.
198. Crestani, G. , "L'installazione del pluviometro. " (Installation of rain gages.)Societe Meteorologique Italiana Bollettino Bimensal, p. 17, January-March, 1923.
199. Crestani, G. , "Il Pluviometro e il vento: ricerche sperimentale. " (Rain gage and wind: experimental studies, ) La Meteorologia Pratica, Montecassino, 5(6):213-215, November-December, 1924.
200. Crestani, G., "L'acque che penetra nelpluviografo a galleggiante durante lo scarico." (Water which enters the float rain gage during emptying) Meteorologia Pratica, 6(3):116-118, May-June, 1925, 1 fig, 1 table.  
On Palazzo gage.
201. Crestani, G. , • "Sul funzionamento del pluviometro a galleggiante 'Palazzo'." (On the operation of the "Palazzo" float rain gage. ) La Meteorologia Pratica, 6(4):164-170, August, 1925, 1 fig, 4 refs .  
On the functioning of the Palazzo combination float and siphon recording gage.
202. Crestani, G. , "Influenza che hanno sulla missura delle precipitazioni atmosferiche alcune alteraziohi della bocca di cattura del pluviometro." La Meteorologia Pratica, 6(5-6): 181 - 185, September-December, 1925, 2 tables, 3 refs.
203. Crestani, G., "L'Accuratezza nelle misure pluviometriche." (Accuracy in rain gage measurement), La Meteorologia Pratica, 7:108-110, May-June, 1926.
204. Crestani, G. , "Cause di perdita della pioggia gia penetrata nel pluviometro." La Meteorologia Pratica, Vol. 8, No. 5, 1927.
205. Crestani, G. , "Sulla determinazione dell'equivalente in acqua e della densita della neve." pn determining the water equivalentand density of snow), Annali dei Lavori Pubblici, Roma, Vol. Fasc. 6, p. 1-19, 1937.
206. Crestani, G. , "Del pansaneve lo strumento e il metodo. " (The instrument and the method of weighing), B. C. Geod. Geof. Cons. Na z. Ricerche, Milano, Vol. 7, p. 211-217, 1937.
207. Critikos, N. , "Ueber die Struktur des Taues. " (On the structure of dew), Gerlands Beitrage zur Geophysik, 21:33-35, 1929.
208. Currie, B. W. , "Water content of snow in cold climates. " American Meteorological Society Bulletin, 28:150-151, March, 1947.  
Seventy days of snowfall were studied in Canada and the average . density of snow was 0.081 (1/12 in. ) at that locality.
209. Curtis, G. E. , "Effect of wind currents on rainfall." U. S. Signal Service Notes, No. 16, 11p., 1884.  
Diverse catch of non-shielded gages in different exposures on Mt. Washington. Of four non-shielded three inch gages those in windward positions caught 13% less rain than the leeward and all caught about 23% less than an eight inch gage. The deficiency was 5% at 15 mi./hr. ; 18% at 40; 34% at 60; and 46% at 75 mi./hr.

210. Curzon, H. , British Patent. 13, 085, 1884, Great Britain Patent Office, Abridgement of Specifications, Class 106, p. 40, October 2, 1884-88.  
A non-recording gage with a tapered glass receiver so that visual readings could be easily made. Recommends the insertion of rubber tube to prevent bursting or freezing.
- D.
211. D'Abbadie, "Pluviometre compteur de M. Porro." La.Meteorologie, 5:57-58, April 17, 1857.
212. D'Abbadie , "Pluviometre a bascule de Horner." La Meteorologie, 9:111-112, April 9, 1861.
213. Daigo, Y. , and Maruyama, E. , (Japanese), "The remarks on the observation of precipitation for flood forecasting." Journal of Meteorological Research; Tokyo, 2(7):191 - 196, July, 1950, 7 figs, 4 tables, 12 refs.  
A-statistical study of the effectiveness of rain gages in catching a representative sample of rainfall which could be used inflood forecast or design of reservoirs, etc. It was found that only 31% of the possible catch was recorded during strong winds and that the smaller the raindrops, the smaller the percentage catch when strong winds occurred.
214. Dallet, G. , "Manuel de Meteorologie Populaire." (Manual of Popular Meteorology), Bibliotheque des Connaissances utiles, J. Bailliere et fils, Paris, p. 114-115, 120-121, 1890, 2 figs, 1 table.  
A simple 500 cm. funnel type non-recording rain gage is illustrated and described. The Brequet recording gage used at Montsouris Observatory is also illustrated and-briefly described.
215. Dalton, J., "Meteorological Observations and Essays." 1788.
216. Dalton, J. ,. "Rain." Rees's Cyclopaedia, 1819.
217. Damman, W. , "Zur Frage der Auswertung der Aufzeichnungen von Schreibreggenmessern." (On the question of evaluating the records of recording rain gages), Zeitschrift fuer angewandte Meteorologie, p. 162-167, May, 1938.  
"A survey of all-current methods of evaluation. Suggestion for a uniform method of work. "
218. Dansey, R. P., "Rain gages on the Black Mountains." Meteorological Magazine,- 42(497):91-94, June, 1907, 3 figs.
219. Dausse, "Sur Les Quantites de pluieresques par pluviometres a des hauteurs differentes." (On the quantities of rain caught by rain gages at different altitudes), Annuaire Societe Meteorologique de France (Succeeded by La Meteorologie), 27:89, 1879.
220. David, W. E. , "Measurement of precipitation above forest canopies." Journal of Forestry, 37(4):324-329, April, 1939, 4 figs, 23 refs.  
The degree to which interception of rainfall by the forest canopy may modify the runoff relationship is important in forecasting stream flow. A method has been devised whereby rainfall may be measured at the tree crown surface in order that true values may be obtained. A standard gage is hoisted up a pole so that the top of the gage is at a desired level. A pulley arrangement is used to hoist and lower the gage.

221. Davitaia, F. F. , "Sur la densite du reseau pluviometrique a l'usage de l'agriculture. " (On the density of the rain gage network adapted to the use of agriculture), Meteorologiya i Hidrologiya (Moscow), No. 5:54-58, 1946, 2 figs.
222. Davy's, M. , "The instruments of the Mountsouris Observatory. " Annuaire Meteorologique et Agricole, 1870.
223. Denison, F. N., "Comparison of rain gages. " American Meteorological Society, Bulletin, 22(2):65-67, February, 1941, 2 tables.  
Canadian gage found to record 2.3 per cent and 2.9 per cent more than the U. S. gage. Diameter of Canadian gages 3.57 in. Suggests that U. S. Weather Bureau apply stick correction of .01 in./1 in. precipitation. Height of Canadian gage is 31" above the green sward.
224. Denton, B. , "On the advantages of a daily register of rainfall. " Journal of the Society of Arts, 6:114, 1858.
225. Denza, F. , "Anemografo e pluviografo. " (Wind measurement and rain measurement), Natura, No. 3, 1879.
226. Descamps, A. , "Etude aerodynamique de pluviometres. " (Aerodynamic study of pluviometers), Ciel et Terre, Bruxelles pis 3, 55:205-220, June-July, 1939.
227. Dewey, Stanley F. , "Importance of setting rain gage level. " Meteorological Magazine, 47(564):245, January, 1913.  
Correspondence.
228. De Witt, S. , "Description of the 9-inch conical rain gage. " American Journal of Science, 22:321-324, 1832.
229. Diamond, H. , Hinman, W. S. Jr. , "An automatic weather station. " Journal of Research of the National Bureau of Standards, 25:133-148, August, 1940, 14 figs, 5 refs.  
In the automatic weather station described, a Friez type weighing gage is used. A resistor replaces the drum and the information broadcast is the relative position of the pen arm on the resistor. No mention is made as to how the pail would be emptied or the snow melted.
230. Dieckmann, A. , "Versuch zur Niederschlagsmessung aus treibendem nebel. " (Attempt at precipitation measurement in a driving fog), Meteorologische Zeitschrift, 48:400, October, 1931, 1 table.  
Use of a wire mesh as a rain, fog, and drizzle trap.
231. Diem, M. , "Measurement of the size of cloud elements. " Annalen der Hydrographie und Maritimen Meteorologie, 70:142-150, 1942, 5 figs. 5 tables, 11 refs.  
Three methods of measuring cloud particle size are used: (1) Corona and glories measurements, (2) Albrecht's deposition method using three rods, 6, 12 and 30 mm. in diameter, (3) Microscopic method of employing an oil coated surface that is exposed for 1/50 sec. The results of many flights are tabulated. Flights were made thru many different types of clouds.
232. Diem, M. , "Messungen an einer Schneedecke. " (Measurement of snow cover), Zeitschrift fuer angewandte Meteorologie, 61:37-49, 1944..  
Includes some consideration of apparatus used.

233. Dines, G., "Difference of rainfall with elevation." British Rainfall, p. 15-25, 1877, 4 tables, 4 refs.  
 (1) One gage only on top of a building cannot be depended upon to give the amount falling on the ground. (2) Rainfall on a roof is heaviest on the lee side. (3) The faster the wind and the smaller the rain drop, the greater the difference with increased elevation. (4) When no wind is present the rain collected at 50 ft. is equal to that on the ground. (a) Rain temperature in general is higher than the dewpoint. (b) Surface film clinging to receiver is about 0.003 in. for 5 in. and 8 in. gages.
234. Dines, G., "Difference of rainfall with elevation." British Rainfall, p. 13-16, 1880, 1 fig, 2 tables, 3 refs.  
 No conclusions arrived at. More tables of material presented.
235. Dines, J. S., "Locking of rain gage funnels." Meteorological Magazine, 67(804):289-290, December, 1933.
236. Dines, W. H., "Rain gages with rims of different shapes." Meteorological Magazine, 55(653):94, June, 1920.
237. Dines, W. H., "Tilting rain gages - A new autographic instrument." Meteorological Magazine, 55(654):112-113, July, 1920, 2 figs.  
 A combination tilting and siphoning gage. When a float rises to the top of its travel, it hits a trigger which allows the receiver to tilt and siphon off. When it is at zero a counterweight returns it to the original position.
238. Di Ricco, G., "Brevi considerazioni preliminari sulle precipitazioni misurate ai pluviometri totalizzatori de Servizio Idrografico, Italiano." (Brief preliminary considerations on precipitation measured by totalizers of the Italian Hydrograph Service), Comitato Nazionale Geodetico e Geofisico, Bull. 15, 1927.
239. Doremus, John A., "Radioactive snow gage with telemetering system." National Electronics Conference Proceedings, Vol. 6, 1950, 11 figs, 2 tables, 3 refs.  
 A system has been devised in which a small sample of radioactive material is buried close to the surface of the ground at a place where measurement is desired. A Geiger-Mueller tube is suspended over the spot and detects the radiation from the sample. As snow falls, it fills the space between the sample and the G-M tube and thereby attenuates the radiation. The attenuation is a function of the water content of the snow cover and therefore gives the desired data at one reading. Impulses from the G-M tube are conducted to a tele-coder which turns these pulses into signals which can be readily transmitted via radio, in this case a frequency - modulated transmitter.
240. Draper, D., "Draper's self-recording meteorological instruments." Engineering (New York), 40:535-536, December 4, 1885T 7 figs.  
 On Draper's tipping bucketgage and other meteorological instruments at a New York City Observatory (Abstracted in "Zeit. fur Instrumentkunde" 1886, page 142). The gage is actually a combination weight and tipping bucket gage. The bucket is suspended on springs and as it descends due to the weight of the water, an attached pen arm makes a record on a moving sheet of graph paper. When the bucket is filled, it tips and empties and the action is repeated. Gas heat controlled by a metallic bar thermometer controls the temperature (40°) of air from a tube that keeps the funnel warm to melt snow and hail.

241. Dubois, B. , "Mesures des precipitations effectuees au Mont-Ventoux de 1934 a 1937 (French). " (Measurements of precipitation made on Mt. Ventoux from 1934 to 1937), La Meteorologie, Ser. 3, p. 157-161, July-December, 1940, 3 figs, 1 table.  
The observatory is on the summit (1912 m) in a region of strong winds greatly influenced by relief. A rain gage with a horizontal aperture is inaccurate; measurements were made with various types of "Vectopluviometers" on a round hillock near the summit. The "Mougin"gage gave a mean excess of 19% over the "Association" on the peak.
242. Dubois, B. , "Le pluviometre, instrument de travail indispensable au cultivateur." (The rain gage, indispensable working tool of the farmer), La Meteorologie, 73(6):221-222, January-June, 1930.
243. Dymond, E. E. , "On rain gages. " British Rainfall, p. 35-38, 1874, 1 fig.  
Advocates recessed funnels at least 5 in. below the rim and receivers buried below the surface of the ground for insulation.
244. Dymond, E. E. , "On rain gages. " British Rainfall, p. 25-27, 1875, 1 fig.  
Six different types of gages were placed close together (10 ft. circle)and a wind vane and anemometer close by. Early trials showed that the gages differed in readings. Object of experiment is to test amount of evaporation taking place.
245. Dymond, E. E. , "On rain gages. " British Rainfall, p. 20-23, 1876, 1 fig, 2 tables, 1 ref.  
Shows a temperature curve for the inside of two gages, one being completely above ground and the other has its receiver below the surface level. Concludes that there is consistent slight evaporation loss by the gage that is entirely above ground.

## E.

246. Edge, H. N. , "Measurement of rainfall." Country - Side Monthly, (London), 4:9-10, 1912.
247. Elges, C, "Problem of using calcium chloride in precipitation gages. " American Geophysical Union Transactions, No. 3:911-913, 1940, 1 fig, 1 table.  
Deals with the freezing point of calcium chloride solutions. An 8 in. gage charged to protect 10 in. of precipitation to -20°F. would initially require 26.9 lbs. of CaCl<sub>2</sub> and 35.8 lbs. of water.
248. Ellery, R. L. J. , "On a new form of self-registering rain gage. " Royal Society of Victoria, Transactions, 15:12-13, 1878, 1 fig.  
Adescription of Ellery's early type self-recording gage that did not have a provision for cutting of the flow thru the funnel during siphoning.

- 249: Ellery, R. L. J., "Improved ombrograph, or self-registering rain gage;" Royal Society of Victoria, Transactions, Vols. 15 and 17: 62-65; 1878, 1 fig, 1 ref.
- A new self-recording rain gage is described. A vase or receiver is spring mounted so that as it fills with water it lowers itself. A direct connection with an inked pen records this motion on a clock-operated drum: When 1/4 in. of rain has fallen; the receiver is filled and a siphon action takes place which empties the receiver in nine seconds, and of course, the receiver returns to its upper level. A unique system to record all rainfall is used. As soon as the siphon begins to empty the receiver; the falling water from the siphon tube hits a pallet that is connected to a valve in a small tube between the funnel and the receiver; This pallet; being depressed by the falling water; closes the valve which cuts off the flow of water to the receiver until the siphon action is completed. In this manner no rain is lost while the siphoning takes place.
- 250: Ellison, W. D. ; and Pofnerene; W. H. , "A rainfall applicator: "Agricultural Engineer (Repr in raindrop erosion studies; Washington; Department of Agriculture); 25:220, June; 1944, 1 fig; 1 ref.
- A device to make raindrops is described. Two sizes were made; 3.5 mm. and 5.1 mm. to a  $\pm 5\%$  accuracy. Intensity could be controlled to  $\pm 3\%$  and variation of distribution was  $\pm 10\%$ ;
251. Ellison; W. F. A. , and Bilhafn, E. G. , "Suggestions for improving in details of certain instruments. " Meteorological Magazine, 63(755): 258-'61, December, 1928.
252. Ellison, W: F. A., Dines; L. H. G; , "Deposit of dew in rain gages. " Great. Britain Meteorological Office; Circular No. 36, p. 3, No.- 38, p. 2; 1919.
253. Elster, Julius and Geitel, Hans, "Ueber eine methode, die elektrische natur der atmospharischen niederschlaege zu bestimmen. " (A new method to determine the electrical nature of precipitation), Meteorologische Zeitschrift, 23:95-100, March, 1888; 1 fig, 3 tables; 2 refs.
- An instrument is described that is designed to measure the electrical charge of rain collected in a shallow insulated pan.
254. Engineering News Record, "Recorder designed to register snow, rain and temperature." Engineering News Record, 116:900, June, 1936. Snow-rain-recorder. Stevens weight type gage.
255. Engineering Record, "Self registering rain gages and their use for recording excessive rainfall." Engineering Record, 23:74-75, January, 1891. 7 figs; 1 table.
- Article describes several gages. The Hottinger combination weight and tipping bucket gage, and the Fuess float type gage using a mercury manometer arrangement connection with an automatic siphon gage.
256. Ephemerides, "Hyetometrum. " Ephemerides. S6c. Meteor: Palatine, Manheimii, p. 82-84, 1781, 1 fig:
- An early rain gage. (The first weather network, included such places as Berlin; London, Rome; Copenhagen; Harvard U. )
257. Efedia; Anna; "Sulla misura delle precipitazioni acqu.ee." (On the measurement of aqueous precipitation); Annali dei Lavori Pubblici, 76(6):508-512; June; 1938, 4 figs, 1 table, 8 refs, 2 eq.
- Theory of rain gaging and review of recent improved models of rain gages.

258. Eredia, Filippo, "Sui recenti impianti di pluviometri nella Provincia di Catania." (On recent installation of rain gages in the Province of Catania), L'Agricoltore Calabed - Siculo (Catania), 28:338-340, 1903.
259. Eredia, F. , "Sulla misura della neve." (On the measurement of snow), Riv. Met. Agraria, November 3, 1908.
260. Eredia, F. , "Sulla misura della quantita delle precipitazioni acquee." (On the measurement of the quantity of precipitation), Rivista Scientifico-Industriale (Florence), 40:1-3, 1908.
261. Eredia, F. , "Gli strumenti di meteorologia e aerologica, descrizione e impiego." (The instruments of meteorology and aerology, description and use), Rome: Liberia Bardi, p. 1-415, 1936, 307 figs .  
Ordinary rain gages, totalizers and the effect of wind on catch are described. Three airflow diagrams. CFB. Chapter 13 is devoted to rain gages. Several types of recording gages (Hellman Siphon, Palazzo, and tipping bucket) are illustrated. The effects of shielding are discussed.
262. Eredia, F. , "Recenti contributi sul funzionamento dei pluviografi." (Recent contributions to the functioning of recording rain gages), Annali dei Lavori Pubblici, 74(5):344-346, May, 1936, 7 figs, 3 refs.  
A description of several new recording rain gages. The Slettenmark weight type recording gage widely used in Sweden by the meteorological and hydrological Institute of Stockholm. The Dines tilting siphon type gage, and the Jardi rain intensity recorder.
263. Eredia, F. , "The distribution of the drops and the content of free water in fog formations." Rivista di Meteorologia Aeronautica (Italy Ministero dell' Aeronautica, Rome), 7:24-29, 1943.
264. Eriksson, G. L. , "Testing a new construction of Kohler's apparatus for determining the water content of clouds." Geografiska Annaler Stockholm, 20:276-307, 1938, 3 figs, 4 tables, 22 refs, 42 eq.  
An improvement on the design of Kohler's water content instrument. Operates on the principle of measuring temperature and humidity of the fog or cloud laden air after it has passed a heating coil that would dissipate the water droplets. The sources of possible error are thoroughly discussed.
265. Esclançon, E. , "Sur un enregistreur de l'intensite des chutes de pluie." (On the recording instrument of the intensity of sheet rainfall), Academie des Sciences, Comptes Rendus, Paris, No. 158:1467, 1914, 1 fig, 2 eq.  
Rain is led into a tube that has a small opening at the lower end. When the inflow into the tube exceeds the outflow a head of water builds up in the tube. This head of water traps air in a small cylinder connected with the tube. The air pressure in the cylinder is proportional to the head of water which in turn is proportional to the intensity of rainfall. Measurement of the air pressure thus furnishes the means of calibration. It works best when it pours.
266. Esclançon, E. , "Enregistreur de l'intensite des chutes de pluie." (Recording instrument for the intensity of rainfall), Revue Scientifique (Paris), 52:698, 1917.  
The author suggests a method for measuring the intensity of precipitation. Rain from a large orifice is directed to a tube of a smaller diameter which has a small hole in the bottom. When the rate of flow into the tube exceeds that out the small hole, a head of water builds up. He suggests calibrating the height of this head in relation to intensity.
267. Eyre, W. L. W. , "Graduation of rain glasses." Symons' Meteorological Magazine, 39:48, 1904.

268. Faulkner, T. Felton, "Rain gages in tropical countries." Meteorological Magazine, 8(91):109, August, 1873.
269. Favaro, A. , "Benedetto Castelli nella storia della scienza." La Meteorologia Practica, 1920.  
Information on meteorology (rain gages) that was discussed in correspondence between Galileo and Castelli.
270. Favaro, A. , "Carteggia di D. Benedetto Castelli con Galileo circa l'invenzione del pluviometro." (Letters of B. Castellito Galileo on the invention of the rain gage), La Meteorologia Practica, 1(4-6): 167, 1920.  
. Historical note on rain gage inventions (1639 +).
271. Feldhaus, Technik, 1914.  
A note about the Korean rain gage used in 1441 and a picture of it.
272. Fergusson, S. P. , "A new self-recording gage." American Meteorological Journal 5(7):321, November, 1888.  
A brief description of a gage working on the weight principle (the original Fergusson gage).
273. Fergusson, S. P. , "Self-recording rain or snow gage." United States Patent Office, p. 1-6, December 17, 1889, 5 figs.  
Essentially a spring-balance mechanism carrying a reservoir to receive rain, etc. "As it falls, a continuously rotating and recording cylinder or drum, a mechanism for rotating said cylinder. a marker to mark the surface of said cylinder while under rotation, and a mechanism connecting said marker with and to operate it from said spring-balance----."
274. Fergusson, S. P. , "New recording rain and snow gage." American Meteorological Journal, 7:213-233, 1890, 1 fig.
275. Fergusson, S. P., "Two new meteorological instruments; 1. The automatic polar star light recorder; 2. The ombroscope." Royal Meteorological Society, Quarterly Journal, 31:309-316, October, 1905, 7 figs, 1 table.  
The ombroscope, an instrument for determining time and duration of rainfall, is described. A semi-cylindrical case with an 0.4 in. x 0.4 in. aperture on its top houses a clock-operated cylinder under the aperture. The paper on the cylinder has indelible inked lines which smear when rain starts. Every 24 hours the cylinder moves back and the operation repeats. (Very dry snow may not register and dew may pass, as a trace. In heavy rain, the rain may flow down side).
276. Fergusson, S. P., "Improved gages for precipitation." Monthly Weather Review, 49(7):379-386, July, 1921. 14 figs, 2 refs.  
An improved type of weight gage with more compact balance mechanism and device for obtaining two or more traverses of pen arm. Suggests a new long period indicator where a clock driven funnel moves over receivers arranged in a circle (non-recording). In discussion on gages, he classified automatic recorders:
1. Float type
  2. Intermittent gage (tipping bucket)
  3. Weight type.
- Recommends use of ombroscope or hygrograph for measuring small amounts.

- 277; Fergusson, S. P. , "On the design of rain gages. " Monthly Weather Review, 50:82, February, 1922, 2 refs.  
 Discussion of article appearing in Meteorological Magazine, July, 1921. Article said Howard Glaiser gages were not acceptable due to their inaccuracy. Recommended, "Meteorological Office, " "Snowdon, " "Bradford," and "Seathwaite. " Tipping buckets and syphon gages generally not satisfactory.  
 Gage design.
1. Knife edged brass ring 5 in. or 8 in. diameter for rim.
  2. 4 in. to 6 in. from rim to top of funnel.
  3. a. Inner, removable collecting container.  
 b. No taps.
  4. Body to sink at least 6 in. in ground.
  5. No rivets.
  6. 10 in. of rain capacity.
278. Fergusson, S. P. , "Relative catch of Fergusson recording weighing rain gage and standard gage. " Letter to U. S. Soil Conservation Service, June 10, 1936.  
 A selection of 16 heavy summer rains totalled 26.69 inches in standard gage and 26.37 in recorder.
279. Field, R. , "Difference of rainfall with elevation. " Symons<sup>1</sup> Meteorological Magazine, 13(141):99-103, August, 1878, 2 figs, 1 table.
280. Field, R. , "Verchiedenheit der regenmenge bei verschiedener hohe der auffanggefaesser. " (The effect of altitude on the catch of rain gages), Zeitschrift Osterreichischen Gessellschaft, 14:448-450, 1879, 2 figs, 1 table, 1 ref.  
 A recapitulation of an article on the same subject in British Rainfall - 1877.
281. Fittinger, Herman J., "Low-cost-storage-type precipitation gages." American Geophysical Union, Transactions, 28(6):901-902, December, 1947, 2 figs.  
 A non - recording, large - capacity, precipitation gage for the measurement of heavy rainfall in isolated areas of the coastal ranges. Low cost.
282. Fitzgerald, Desmond, "Report of the committee to determine the patterns of rain gage which can be adopted and recommended by the New England Meteorological Society." American Meteorological Journal, 1(8):301-302, December, 1884.  
 Many gages examined by Fitzgerald over the previous 5 years were of poor construction or were not properly exposed. The society has had constructed three properly designed gages to be used as standards for measuring precipitation. One gage was 14.85 inches in diameter while the other two were 8 inches. Mentioned that an experiment with gages at different heights was being conducted in Boston at Chestnut Hill.
283. Flaugergues, M. , "Memoir on the quantity of rain and the number of days of rain, snow and drizzle at Viviers, during 40 years. " Annals of Philosophy, 14:108-116, July-December, 1819, 9 tables.  
 Less rain will fall into the horizontal opening of the rain gage when the rain is inclined than if it fell vertically or in a direction less inclined.
284. Flora, S. D. , "Concrete rain gage support. " Monthly Weather Review, 53:359, August, 1925.  
 A 12 in. square concrete pad with four pipes 21 in. long out of each corner makes a good support for a rain gage.

285. Fontserre, E. , "Intensitätspluviograph nach Jardi. " (Intensity rain gage according to Jardi), Meteorologische Zeitschrift, 3 9:89, March, 1922, 1 fig, 1 ret:'. .
286. Fprchheimer, Th. , "Regenmesser. " (Rain gage), Geschichtsblaetter der Technik, Industrie und Gewerbe, •No. 2:185, 1916.  
An extract of H. Vogelstein's book on Agriculture in Palestine. Berlin 1894. There is evidence that successful rain measurements were made at the time of Misnah (189A.D.). Results given: first rain period 9 cm. of rain, second period 18 cm. of rain, third period 22 cm. of rain. The rain was caught with the help of a container.
- 287.. Fordham, George, "On an improved method of fixing rain gages." British Rainfall, '56:26-27, 1916.  
"In order to insure that the funnel of the rain gage is kept horizontal, it is recommended that the gage be mounted in a drainpipe sunk in the ground.
288. 'Fprster, Adolph E. , "Die Niederschlagsmessungen auf dem Spnnblick und anderen Gipfelobservatorien. " (Precipitation measurements at the Sonnblick and other mountain summit observatories). Jahresbericht des Sonnblickvereines, Vienna, 38:20-25, 1929.  
Impression that little of snow is caught. Cannot separate drift.
289. Forster, A. E. , and others, "Das meteorologische Observatorium auf der Bjelasnica (2067 m. ) bei Sarajevo. " [The Meteorological Observatory on the Bjelasnica (2067 m. ) near Sarajevo], Jahresbericht des Sonnblick-Vereines, Vienna, 26-27:12-18, 1917-1918, 4 tables, 2 refs.  
Four standard gages have from 419-506 mm. A rotating gage, 807 mm.
290. Foster, E. E. , "Rainfall and runoff. " Textbook: Mac Millan Co. , p. 43-50, 1948, 2 tables.  
A general discussion of rain gaging. U. S. W. B. Standard 8 in. gage, tipping bucket, Fergusspn weight gage and Marvin float type gage are described. Some problems of gaging are discussed.
291. Fourcade, H. G. , "Some note's on the effects of the incidence of rain on the distribution of rainfall over the surface of unlevel ground. " . Royal Society of South Africa, Transactions, 29:236-254, 1942.
292. Fourcade, H. G. , "A note on multiple rain gage. " American Geophysical Union, Transactions, 26(2):267-268, October, 1945, 1 fig, 1 table, 2 refs, 5 eqs.  
, This gage has five- 10 square inch orifices; one in the center that is horizontal, and four vertical orifices facing the four cardinal-points of the compass. Each orifice has its own container. By means of equations, it is shown how the average direction and slope of rainfall may be obtained.
293. France Office National Meteorologique, Lexique Meteorologique, Paris, Nivometre, 6:281-287, 1909.  
Several different types of gages are illustrated and their usefulness is discussed. Vaussehat's snow gage, Vallot's gage and the Mouglin totalizer are described. In tests with snow catch a small orificed gage caught consistently less than a large mouthed gage over a period of eight years (16% less). . . . .
294. France Office National Meteorologique et Spciete Meteorologique de France, "Bibliographic Meteorologique Internationale. " Vol. 1-12, 1927-32, 1927;

295. Franklin, Benjamin, "Letter to Dr. Thomas Percival." Memoirs of Thomas Percival, London M. D., Appendix B., 1771, Quoted from Jevons, W. S. Philosophical Magazine, 22:428, 1861.  
 "Franklin compared a drop of rain to a bottle of cold water condensing dew upon itself when brought into a warm room. That rain, even in the hottest days, he adds, comes from a very cold region, is obvious from its falling sometimes in the form of ice."--In a letter to Dr. Percival, Franklin suggested possible electrical attraction as explaining Heberden's finding that rainfall decreased with height. He pointed out as an example that hail probably grew as it descended. As such, he indicated that more facts were necessary before a hypothesis could be made. In any case, this probably marks the beginning of it. (Also in "The Works of Franklin," by J. Sparks, 6:337-338, 1882).
296. Franklin Institute Journal, "Rain gages." Franklin Institute Journal, 30:195-196, August, 1840, 1 eq.  
 To determine the rainfall for any sized orifice the following formula may be used:  $h = \frac{w \times 2.2}{d^2}$  where h = rainfall in inches, w = ounces of water caught and d = diameter of the funnel.
297. Franklin Institute Journal, "New rain gages." Franklin Institute Journal, 31:60-61, January, 1841. Professor Phillips designed a five mouthed gage (vectopluiometer). Four orifices were vertical and faced cardinal points of the compass and one orifice was horizontal. Each orifice had its own receiver. Direction and inclination of rain could be easily determined.
298. Franklin Institute Journal, "Directional rain gage." Franklin Institute Journal, 91(Third series, Vol. 6):10-11, January, 1871.  
 The description of a rotating horizontal orificed gage that faces the wind. Eight collectors arranged in a circle around that gage determine from which direction the wet winds came.
299. Free, G. F., "Soil movement by raindrops." Agricultural Engineering, 33(8):491-496, August, 1952, 5 figs, 3 tables, 13 refs.  
 A study of the effect of natural rain on soil. Loss from pans facing wind was three times that facing opposite direction. Splash losses were 50 to 90 times wash off losses, and amounted to 6 tons/acre for Honeoye soil. (This is for elevated pans--no income, all loss.) A stationary vectopluiometer with eight vertical orifices was used for measuring rainfall amount, direction and inclination.
300. Fried, M. I., and Jackson, M. L., "Sulfur collection in precipitation by means of an all-weather non-corrosive rain and snow gage." Science, (Summary of paper No. 294 in Purdue University Agricultural Experiment Station Journal), 106(2740):19-20, July, 4, 1947, 2 figs, 4 refs.  
 A highly insulated gage is designed for use in catching rain to be subjected to sulfur tests. Aluminum is used to hold down corrosion and its effects. The two general requirements to be met were:  
 1. Prevent absorption of sulfur in gaseous form from the air.  
 2. Effective functioning in winter and in summer. A wire screen was placed around the gage to decrease bird droppings and to act as a wind shield.
301. Friedrich, Wilhelm, "Erfahrungen mit Niederschlagssammlern, (Totalisatoren)." (Experiences with precipitation collectors), VI Baltische Hydrologische Konferenz, Bericht 15-A, Vol. 2, 1938, 6 figs, 3 refs.  
 The development of the Friedrich-Haase totalizer. A totalizer is mounted on two poles so that the orifice is well above maximum snow level and the influence of the poles. It is charged with the usual CaCl<sub>2</sub> oil coated solution and is left unattended for a season. No shielding is used.

302. Friez, J. P. , "Rain gage." United States Patent Office, Letters Patent No. 756,109, p. 1-2, March 20, 1904, 4 figs.  
Patent on the original Friez non-recording gage that follows the U. S. Weather Bureau Standard. Shows provisions for the metal sleeves used to position the measuring tube and also the design of a metal holder for the gage.
303. Friez, J. P., and Sons, Baltimore, Md. , "Erection instructions for rain gage steel tower supports; 1. For Friez tube type rain gage; 2. For Friez recording rain gage." 50 pages.
304. Fritz, G. , "Totalisatoruntersuchungen auf dem Brocken." (Investigations made with a totalizer of the Brocken), Meteorologische Zeitschrift, 55:113, 1938.  
In winter the various rain gages show great differences. The problem yet unsolved.
305. Frosini, P., "Recente Progressi sui metodi pluviometrici." (Recent progress in rain gage methods), Annali del Liavori Pubblici, 74:141, 1936, 3 figs, 1 ref, 6 eqs.  
On the French vectopluviometer and stereopluviometer.
306. Fuchs, P. , "Meteorologische Instrumente." (Meteorological instruments), Deutsche Mechanikerzeitung, p. 105-115, 1898.
307. Fuess, R. , "Neue registrierende meteorologische Apparate, 1 registrierender Regenmesser." Zeitschrift fuer Instrumentenkunde, 3:192-194, June, 1883, 3 figs.  
The Fuess self-recording gage is described. It is a natural siphon-type gage where the action is transferred to a mercury manometer arrangement. The movement of the float (floating in mercury) is calibrated to furnish the necessary record. Siphoning repeats every 4 mm. of rain.
308. Fuess, R. , "German society for mechanics and optics meeting proceedings." Zeitschrift fuer Instrumentenkunde, 8:440, December , 1888.  
Announcing" Sprung's combination spring and tipping bucket recording gage and Fuess' mercury automatic siphon-type gage.

## G.

309. Galle, J. G. , "Ueber die Regenmenge in Breslau und einige neuere Versuche die Abnahme derselben mit der hohe betreffend." (The amount of rain in Breslau and some new research). Zeitschrift Oesterreichischer Gesellschaft fuer Meteorologie, 17:41, 1882. (Now Meteorologische Zeitschrift).
310. Gallenkamp, W. , "Ueber den Verlauf des Regens, (Eine neue methode der regenmessung)." [About the runoff of rain, (A new method of measuring rain)], Meteorologische Zeitschrift, 22:1-10, January, 1905, 17 figs, 3 tables.  
On the operation of the Gallenkamp drop recorder. Forty drops equals 1 mm. of rain and 1 drop approximately 0.2 cm<sup>3</sup>. The bottom of a funnel ends in an S-shape thus causing a small head to build up before water will flow out of the funnel. The flow is in the form of drops that are controlled by (1) size of orifice, (2) head build up, and (3) siphon properties of last bend. As each drop falls from the orifice, it strikes a contact and a record is made. Since the drops are quite uniform in size, the count of drops is proportional to the rate of rainfall.
311. Gallenkamp, W., "Automatische, Aufzeichnung bei Regenintensitat." (Automatic registration of rain intensity), Das Wetter, p. 169-171, 1905.

312. Gallenkamp, W. , "Messung des Regenverlaufs. " (Measurement of the fall of rain), Die Umschau, No. 36, 1905.
313. Gallenkamp, W. , "Ueber die automatische Aufzeichnung der Regenintensitaet." (About automatic registration of rain intensity), Wetter, 22:169-171, 1905, 2 tables.  
The Gallenkamp drop recorder is a simple apparatus that gives good results when properly maintained.
314. Gallenkamp, W., "Ein Vergleich der Aufzeichnungen meines Regenautographen mit denen des Hellmannschen und Sprungschen Apparates. " (A comparison of the registrations of my rain intensity gage with those of Hellmann and Sprung). Das Wetter, 25:28-33, 1908, 6 figs.  
One of the difficulties of his drop receiver was the running together of the dots on the paper.
315. Gallenkamp, W. , "Ueber die Sprungsche Vereinfachung meines Regenauffangapparatas und ueber einen neuen Regenautographen. " (Concerning Sprung's simplification of my apparatus for collecting rain and concerning a new self registering rain gage), Zeitschrift fuer Instrumentenkunde, 28:33-38, February, 1908, 3 figs, 3 refs. "  
Sprung's addition of a platinum wire contact to the Gallenkamp drop recorder constituted a considerable improvement. A rain-intensity gage designed by Sprung is critically reviewed. A weight controlled valve acts against the flow of water from the funnel of a rain gage. The amount the valve is raised to permit the water to flow is proportional to rain intensity. Indications are that the gage is not sensitive enough.
316. Gardiner, Robert H. , "Notes on barometer, rain and snow gages." Smithsonian Institution Annual Report, 18 58, p. 432-433, 1859.  
A funnel one foot square leading to a pail, was the gage. Determined amount by weighing sample and deducting for pail. We noted that in his opinion, snowfall could not be measured accurately during violent storms.
317. Garnett, Thomas, "Observations on rain gages." Royal Irish Academy, Transactions, 5:257-263, 1794, 1 fig, 1 table.  
Two problems in rain gaging are: (1)Effect of evaporation from a gage, (2) Wind blowing drops from the funnel. Recommends a rim 1 in. to 2 in. high around the funnel to nullify the wind effects. Suggests a square gage would give higher readings than a round one as a round gage seems to increase the effect of the wind.
318. Garstka, W. D. , Peasley, P., Goodell, B. C. , "Progress in snowmelt of Fraser Experimental Forest, the 1948 snowmelt season, Progress Report No. 1. " U. S. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo., Report No. 1, November, 1949, 12 figs, 11 tables, 6 refs.  
A technical report on results of five projects conducted during 1948 at the Fraser Experimental Forest in Colorado for the purpose of making better forecasts of runoff from snow melt. Projects comprised: performance of Weather Bureau Sacramento-type shielded storage gage, interpretation of degree-days above 32° F. derived from daily maximum and minimum temperatures, analysis of rates of snow melt, calculation of evaporation losses from the snow blanket, and forecasting the rate of runoff from snow melt hydrograph. Detailed data on hourly wind, humidity, evaporation, temperature and runoff presented. The bulk of the report consists of graphs, nomographs, charts and tables.
319. Gasthuys, P., "Instructions pour les observations pluviometriques et thermetriques." (Instruction for the observation of rain and temperatures), Bulletin de Agriculture du Congo Beige, Brussels, 1923.

320. Gautier, R. , "Temperature et precipitations au Grand Saint-Bernard. " (Temperature and precipitation at the Grand St. Bernard), International Geographical Congress 9th, Geneva, 1908. Cpmpte Rendu" des Travaux du Congress, 2:348-352, 1910.
321. Gautier, R., "Climatologie du Grand Saint Bernard temperature et precipitations. " (Climatology at the Grand St. Bernard, temperature and precipitation), International Geographical Congress 9th, Geneva, 1908, Compte Rendu des Travaux du Congress, 21466-468, 1910:
322. Gautier, R., "Resume rneteprolpgique de lannee 1917 pour Geneve et le Grand Saint-Bernard." (Meteorologic resume' of the year 1917 for Geneva and the Grand Saint-Bernard), Archives des Sciences Physiques et Naturelles, 45:374, May, 1918
323. Gautier, R. , "Nouvelles mesures des chutes de pluie et neige au Grand Saint-Bernard." (New measurements of rain and snowfall on the Grand Saint-Bernard), Archives des Sciences Physiques et Naturelles, Geneva, 5(4):343-353, September-October," 1922, 2 figs, 2 tables.  
Describes totalizers, forty of which are in use in the Alps, often above 3, 000 meters. Then gives total of rain and melted snow, recorded by old and new pluviometers on Grand Saint-Bernard ,1917-1922 and ratio.
324. Gay, R. W. , "Rainfall records and studies in the Tennessee Valley Authority. 'American Meteorological Society Bulletin, 20(9):378-383, November, 1939, 2 tables.  
A general discussion of rain gaging in the T. V. A. area.
325. Geddes, A. E. M. , "Meteorology. " Meteorology-Blackie & Son, Ltd., London & Glasgow, p. 5, 185-7, 1930, 103 figs, 29 tables, many refs.  
1. Records of rainfall made in Palestine in first century, A. D.  
2. Koreans had a rain gage in 1442.  
3. Benedetto Castelli had a gage in Italy in 1639.
326. Geiger, Rudolf, "Forest meteorology from climate of the air layer near the soil. " Die Wissenschaften, 78(236): 145-183, 1927.  
Fog-drip precipitation in a mountain forest ranging up to 300% oyer ordinary precipitation, but decreasing toward the interior of the forest.
327. Geiger, R. , "Messungen des Expositipnsklimas. "(Measuring the climate of exposure), Forstwissenschaftliches Zentralblatt Berlin, 51:37-51, 1929 (49:665-675, 853-859, 914-923; 1927. 50:73 -85, 437r448, 633-644; 1928).  
Gages placed perpendicular to slope caught about same on both windward and leeward sides of a hill.
328. Gerdel, R. W. , "Snow studies at Soda Springs, California." Annual Report Cooperative Snow Investigation, U. S. Weather Bureau and University of Nevada, p. 3, 1943-1944.
329. Gerdel, R. W. , Codd, A. R. , "Snow studies at the; cooperative snow research project, Soda Springs, California." U. S. Weather Bureau-University of Nevada Snow Research Project, p. 1-19, 1945, 21 figs, 4 tables.  
A study of precipitation gages for measuring seasonal and intermittent snowfall and the thermodynamic and hydrodynamip prperties of mountain snow packs. Some results were: (1) large capacity of the Sacramento gage deferred freezing, (2) adaptation of basic principles of the Sacramento gage to recording gages improved their operation, (3) soil temperatures were higher during- midwinter and spring than during peak of snow melt season, (4) average holding capacity of wet snow was 7. 4% (0. 38 in./ft. ), and (5) in all cases, shielded gages (Alter) caught more than unshielded.

330. Gerdel, R. W. , Hansen, B. Lyle, and Cassidy, W. C. , "Use of radioisotopes for measurement of water equivalent of snow pack." American Geophysical Union, Transactions, 31(3):449-453, June, 1950. 2 figs, 1 table, 2 refs.  
The authors discuss the theoretical presuppositions and the design of a radiotelemetering gage that uses the principle of absorption by water (liquid or solid phase) of the gamma emissions from an artificial radioactive isotope. The apparatus employing Cobalt 60 as a source of gamma rays has been used to measure up to 55 water equivalent inches snow by counting pulses from a suitably located Geiger-Muller tube. The pulses have been relayed by radio. The article contains a sketch of the field installation of the radioactive telemetering snow gage and a calibration curve for the apparatus.
331. Gerdel, R. W. , and Mansfield, C. E. , "The use of radioisotopes in research on snow melt and runoff." Western Snow Conference, Proceedings, 18th Annual Meeting, Fort Collins, Colorado, p. 5-17, October, 1950, 11 figs, 2 tables, 3 refs. ~
332. Gerhardt, "Regenschreiber von Hellmann und Fuess." (Rain registrar of Hellmann and Fuess), Centralblatt der Bauverwaltung. . . (Berlin), 21(15):92-93, February, 1901, 2 figs.  
An explanation of the Hellmann (or Hellmann-Fuess) self-recording gage. A 159.6 cm. gage acting on the float and siphon principle. The automatic siphon action is fast and is set for every 1 cm. of precipitation. The gage has become a standard in Central Europe.
333. Giandotti, "Sulla ricerca delle precipitazioni nel l'alta montagna e sul funzionamento del pluviometri totalizzatori nel l'alto bacino del Po." (Investigation of precipitation on high mountains and the functioning of the pluviograph totalizer in the high basin of the Po), Parma, Ministero del Lavori Pubblici Ufficio Idrografico del Po, p. 3-19, 1936, 12 tables, 19 refs.  
Contains paper by Mr. Giandotti published in 1918 and recent paper by Alfieri read in September, 1935 at the fortieth annual meeting of the Italian Electro-technical Association.
334. Gilbert, J. J., "Origin of the Snowdon gage." Symons' Meteorological Magazine, 48:108, 1913.
335. Glasspoole, J. , "Insplashing into and outsplashing from the funnel of a rain gage." Meteorological Magazine, 64(76 1): 118-119, June, 1929.
336. Glasspoole, J. , "Experiments on the shielding of rain gages at Lympne Aerodrome, near Hythe, Kent." British Rainfall, 30:272-279, 1930, 1 fig, 6 tables, 5 refs.  
In experiments with wire fencing, pit gage and a standard gage, the pit gage caught more (by 1%) and the wire fencing was not at all effective--especially so in high winds. The height of the fence did not seem to matter for the heights of 2 ft. 6 in. , then 1 ft. 6 in. , and finally 1 ft. The experiments were over a period of three years.
337. Glasspoole, J., "Raingage funnels of different depths." Monthly Weather Review, 59:157-158, April, 1931, 1 table, 7 refs.  
The 5 3/4 inch depth to the funnel in the standard 8-inch British Met. Off. gage permits less outblowing of spray or snow than the 1/2 inch depth still in use at nearly one-third of the stations in the British Isles.

338. Glasspoole, J. , "Discussions at the Meteorological Office. " Meteorological Magazine, 66(791 ):256-258, December; 1931, 3 refs.  
 Discussion of H. R. Puri's historical note on the catch of rain gages, India Meteor. Dept. Sci. Notes 1931, and Huddelston's Experiments. (1) A turf wall will reduce losses due to wind, but will not eliminate such losses. (2) Turf walled gage would only be used when natural shelter is not available. • (3) Natural shelter should be in the direction from which the rains come.
339. Glasspoole, J., "Snow in the" rain gage." Meteorological Magazine, 71(851):256-258, December, 1936.  
 Summary of recommendations of observers generally favor use of hot water poured on snow in funnel to melt it. Comments on Hancock and Pinnock method of melting snow.
340. Glasspoole, J., "The measurement of rainfall on windy slopes." Water and Water Engineering, 47:550,' December, 1944, 4 refs.  
 A summary of G. L. Hayes' experiments with stereotype gage placed on a slope. The gage is in a pit six feet square and the orifice is level with the ground. A splash proof mat surrounds the gage.
341. Gold, E. , "Exposure of rain gages." Meteorological Magazine, 57(681): 231-235, October, 1922, 1 fig, 1 table, 2 refs.  
 Remarks on an experiment with a pit gage. . Concluded that although the gage averaged 15% over a standard check gage, the difference was probably due to insplashing from the sloping walls of the pit. Recommended further experiments along the line of wind effects. on rain measurement and that future test pits have vertical walls.
342. Gold, E., "Wind at the level of a rain gage. " Meteorological Magazine, 63(746):39-40, March, 1928.  
 (Gage at 4 ft. in lighthouse yard found to have no more wind than ordinary exposure at 1 ft. Maximum wind velocity in strong winds only 10-15 mi./hr. at 1 ft. level), (B. R. 70:280-283).
343. Gold, E. , "The Splashing of rain. " Meteorological Magazine, 66(787): 153 -158, August, 1931, 1 table, 3 eqs.  
 The splashing of rain is due to the rain falling on a wet surface, and is not due to its falling on a hard surface. A dry surface would prevent splash as the kinetic energy of the falling drop is converted mostly into potential energy of surface tension. Calculations show that a 2 mm. drop could rebound up to 4 ft. above the ground.
344. Golding, C. E. , Glasspoole, J., "Insplashing and outsplashing from the funnel of a rain gage. " Meteorological Magazine, 66(787):170, August, 1931, 1 ref.  
 In a hard rain(1. 61 in. in 65 min. )mud splashes came to within 1/2 in. of the top of the rim of the gage. No mud was found inside the funnel. Gage rim at one foot.
345. Goltsman, M. I., "The survey of works in meteorological instruments for the last 20 years. " Meteorologija I Hidrologia, 5(4):122-123, April, 1939.  
 In chapter on rain gages, states that rain gages are far behind the rest of the field. Bastamov and Savinov have experimented at Slutsk and concluded that the disturbance of the aerodynamic field was the cause of the main failure in gages. Suggest large catchment area surrounded by hedge or fence.
346. Gorton, Richard, "Difference in rain gages." Meteorological Magazine, 17(200): 123, September, 1882.
347. Goulier, C. M., "Influence de la position d'un pluviometre sur la quantite de pluie qu'il indique." Bull. Inter. Observatoire de Parts, April, 1864.

348. Gradenwitz, A. , "Das Lancettasche pluviometer, ein neuer registri-  
erapparat fuer und unterbrechung von regenfallen. " (The Lancetta  
pluviometer, a new registration apparatus for measuring of duration  
and interruption of rainfall), Der Mechaniker (Berlin), 11:62-63,  
1903.
349. Great Britain, Air Ministry, "Rain gage, 5-inch, Mark I. " Great Brit-  
ain Meteorological Office Specifications No. 103 London 2nd Issue,  
1950.
350. Great Britain, Air Ministry, "Rain gage, 5 - inch, Mark II. " Great  
Britain Meteorological Office Specifications, No. 293, 2nd Issue  
London, 1950.
351. Great Britain Meteorological Office, "The Observer's Handbook."  
Vol. M. O. 191, p. 35-37, 75-76, 1910, 1 fig.  
Instructions for making observations of precipitation. Self re-  
cording gages are classified (1) Tilting bucket gages, (2) Float  
gages, and (3) Balance gages.
352. Griffith, C. H. , "A new enemy to rain gages. !" Meteorological Maga-  
zine, 1(7):66, August, 1866.  
Correspondence.
353. Griffith, C. H. , "Rain gage experiments at Strathfield Turgiss, Read-  
ing. " British Rainfall, p. 12, 1868, 10 figs, 3 tables.  
Magnitude Series: Orifice size irrelevant if funnel is provided  
with a sharp and level rim. Elevation Series: Collection decreases  
with increase of height. Material Series: Ebonite receiver plus  
Casella's long, felt-protected gage plus bottle receiver. Angled Rim  
Series: No conclusions.
354. Griffith, C. H. , "Rain gage experiments at Strathfield Turgiss, Read-  
ing. " British Rainfall, p. 25-36, 1869, 2 figs, 5 tables.  
A continuation of the magnitude, elevation, and material experi-  
ments with rain gages. Magnitude--orifice size irrelevant. Eleva-  
tion--nothing to add. Material--copper is almost as good as ebonite.  
Paint is not good for funnels because it absorbs water when it be-  
comes aged.
355. Griffith, C. H. , "Rain gage experiments at Strathfield Turgiss, Read-  
ing. " British Rainfall, p. 23-25, 1870, 1 table.  
This concludes the experiments at Strathfield. It is noted that  
the decrease in rainfall on a horizontal surface with elevation very  
likely follows a definite law.
356. Grinsted, W. A. , Adams, A. , "A note on the measurement of rainfall. "  
Mem. E. Afr. Met. Dept. , 2(2):1-13, 1948, 1 fig.  
(East African conditions).
357. Grinsted, W. A. and Adams, A. , "A note on the measurement of rain-  
fall with special reference to East African conditions." East African  
Meteorological Department. Memoirs, 11(2):11, 1940, 1 fig, 58  
refs.
358. Grohmann, "Der Regenschirm im landwirtschaftlichen Betriebe." (The  
rain gage in agricultural management), Illustrierte Landwirtschaf-  
liche Zeitung (Berlin), 27:441, 1907.
359. Grover, A. J. , "Patent No. 530,338, December 4, 1894, Self-recording  
rain gage. " U. S. Patent Office, Official Gazette, Vol. 69, p. 1,298,  
December 4, 1894, 6 figs.  
A weight-type self-recording gage with the receiver suspended  
from the arm of a pair of scales to which a pen arm is attached.  
Movement is recorded on a clock-operated drum which is appropri-  
ately calibrated.

360. Gshwend, Peter, "Beobachtungen ueber die elektrischen Ladungen einzelner fegehtffeh und schneeflocken: " (Observations on the electrical charge on individual rain drops and snowflakes); (Year-book) Jahrbuch der Radioaktivitaet und Elektrophik; 17:62-79, 1920; 1 fig, 1 table, 31 refs.  
A laboratory experiment where rain drops and snowflakes were caught on filter paper and their electric charge determined:
361. Giirarihi, E. ; "Pluviometre enregistreur Lancetta: " Cosmos; 50:268-269, 1904; 3 figs:  
The Lancetta gage employing a wheel of buckets is pictured and described: Each bucket holds a predetermined amount and when the bucket is filled the wheel turns (30°); placing another bucket in a collecting position and emptying the filled one. Each movement of gage may be recorded electrically By means of cogged wheel contact.
362. Guest, W. E. ; "Snow gage: " Smithsonian Institution; Annual Report, p. 433, 1859.  
A tin tube; 2 feet long was used to catch rain and snow; In the case of snow, the content was melted and results were then recorded:
363. Guillaume; C. , "Presentation dun pluviometre enregistreur automatique de grande sensibilit6; " (Presentation of an automatic registering rain gage of great sensitiveness); Journal de Physique, Ser. 7; 4(2):158-159, December, 1933.  
. Description of an apparatus which permits the registration of deposits of dew and even of fall from fog. The precision of the apparatus is higher than one-fiftieth of a millimeter. The instrument incorporates the ordinary two sectional tipping bucket gage with an arrangement whereby the bucket is lowered as it becomes filled: This lowering of the bucket and its tipping are calibrated to give a sensitive recording of precipitation.
- 364; Gunn; R. , Naval Research Laboratory Tech. Report A676A, October; 1944.  
Rain drop mass by catching on blueprint paper and measuring resultant splash.
365. Gunn, R. , "The electrical charge on precipitation at various altitudes and its relation to thunderstorms." Physical Review, 71(3): 181= 186; February, 1947, 5 figs, 7 refs, 1 eq.  
Proximity of charged precipitation. Two inducing rings mounted in a truncated sheet metal cone and hung under the plane record the passage of charged drops thru the rings; Drops needed a minimum of 0.01 e. s. u. to be recorded on the oscillograph and charges exceeding 0.1 e. s. u. are rare:
366. Gunn, R. ; "The free electrical charge on thunderstorm rain and its relation to droplet size:" Journal of Geophysical Research; 54(1): 57-63, March, 1949, 3 figs, 4 refs, 2 eqs.  
Using a new induction type of apparatus simultaneous measurements are made of the free electrical charge and the mass of raindrops falling from active thunder clouds. Free charges on raindrops are computed: Negative droplets are more massive than positive. After two droplets of one sign fall, there is a High probability that the next droplet will be of opposite sign;

367. Gunn, R. , "Electronic apparatus for determination of physical properties of freely falling raindrops. " Review of Scientific Instruments, 20(4):291-296, April, 1949, 4 figs, 4 refs., 1 eq.  
 Device measures mass, free electric charge of raindrops. System has two vertically separated rings so arranged that charged raindrops fall through them, inducing pulses on grid of vacuum tube amplifier which in turn operates tape oscillograph. From the characteristic double pulses produced, the charges and transit time may be determined. The mass of the droplet is simultaneously determined by measuring the size of the spot produced when the drop falls on blueprint paper traversing the oscillograph.
368. Gunn, R. , "A vertical shaft for the study of precipitation mechanics. " Journal of Applied Physics, 23(1):1-4, January, 1952, 6 figs, 3 refs.  
 A mine shaft 0.210 km. deep has been sealed and adapted to the production of clouds. Electronic reporters are being used to time the fall of a drop of water, thereby determining whether there is any evaporation or addition to the drop. Measurements have been made on the rate of growth of water droplets of various sizes falling through the artificial cloud.
369. Guy, L. T. , "Snow studies on Bogong High Plains by State Electricity Commission of Victoria, Australia." Bull. N. 23, Sixieme Assemblee Generate a Edinbourg du 14 au 26 September, 1936, Assoc. Int. Hydrol. Scien. Part II, Trans. Int. Comm. Snow & Glaciers; Riga 1938, p. 213-243, 1936, 27 figs, 3 tables.  
 Snow bins were tried but found useless under conditions with high winds. Standard snow gages, 8 in. diameter were not satisfactory as losses in blizzards ran to 70%. Evaporation pans were used to measure snowfall. The pans were 14-7/8 in. in diameter and 6 in. deep. They were filled with snow to 2 in. from the top and placed in the snow with the rim 2 in. above the general snow cover. Good results were obtained (except in thaws) but the operation was cumbersome. Wind tunnel experiments with shields were made and a Nipher type shield with a gage 14-7/8 in. in diameter was settled on. The shield was placed about 3 in. below the level of the rim of the gage. Conclusions - "shielded snow gages are still deficient in catch and appear to collect only 80% of the actual snowfall."
370. Guyot, Arnold, "Directions for meteorological observations, intended for the first class of observers." Smithsonian Institution, Washington, 40 p. , 1850, 3 figs.  
 Early U. S. gage was sunk in a barrel and its orifice exposed 6 inches above the ground, the barrel top soldered over. A gage 2 feet high was used for snow; but when amount exceeded 1 inch, if without rain, the catch" of the can was discarded and a section of the snow was cut through to the ground or to a board platform 2 or 3 feet square on the ground. Snow was melted by standing in a warm room.
- H.
371. Haeghens, J. , "Sur les observations pluviometriques faites a deux niveaux differents pendent, 32 annees consecutives, de 1817 A 1848. " (On rain gage observations made at two different levels during 32 consecutive years from 1817 to 1848), Annuaire de Societe Meteorologique de France (Now La Meteorologie), 3:155, 1851. -
372. Haeuser, J. , "Niederschlagsmessungen in unbewohnten Hochlagen der bayerischen Gebirge. " (Measurement of precipitation in isolated regions of the Bavarian Mountains), Veroffentlichung der Bayerischen Landesstelle fuer Gewaesserkunde, p. 11, 1925.

373. Haeuser, J. , "Hoehe und Wassergehalt der Neuschneedecke; Ergiebigkeit und Dauer starker Scheefaelle in Muenchen. " (Depth and water content of new fallen snow; amount and duration of snowfalls in Munich), Zeitschrift fuer angewandte Meteorologie, p.- 257-270, 1933.
374. Haeuser, J. , "Messungen des Wassergehalts der Schneedecke und der Schneedichte in den Hochlagen der Bayerischen Alpen." (Measuring depth and water content of snow cover in high regions of the Bavarian Alps), Zeitschrift fuer angewandte Meteorologie, p. 69-80, 105-119, 1935.
375. Hagemann, V. , "A method for determining the size of fog and cloud elements." Beitraege zur Geophysiks, 46:261, 282, 1936.  
Oil method; photographed under microscope within about 10 seconds.
376. Hall, F. , "Communication theory applied to meteorological measurements." Journal of Meteorology, 7(2):121-129, April, 1950, 8 figs, 19 refs.  
An analysis of techniques for measuring or communicating measurements of ail kinds of meteorological variables. Frequency response, phase distortion and linearity are discussed theoretically and illustrated graphically. Application to improvement of characteristics or design of meteorological instruments and records is fully discussed.
377. Hall, L. Standish, "Improving the accuracy of instruments." Civil Engineering, 1(12):1098-1101, September, 1931, 4 figs.  
Addition of a semicircular system of vertical fins projecting above top of gage to balance losses due to wind when angle of precipitation exceeds 45°. Catch 50% in excess of standard gage when wind 180 mi./day.
378. Halliwell, F. L. , "British Patent 8214. " Great Britian Patent Office. Abridgement of Specifications, Class 106, p. 33, 1901, 1 fig.  
The usual float-siphon gage with a novel attachment to increase rate of siphoning. As the float rises to the limit, a trigger is tripped that allows a mercury sealed siphon tube to drop into the water, thus assuring the start of speedy siphon action. The water is siphoned into a vessel that has a float to which the siphon tube is attached and the tube is then returned to its original triggered position for the next cycle. The water is finally allowed to drain off (more slowly) thru a small hole in the bottom of the second receiver.
379. Halliwell, F. L. , "British Patent 27, 174, Rain gage. " Great Britian Patent Office, Abridgement of Specifications, Class 97, p. 471, 1907.
380. Halliwell, F. L. , "Design of rain gages. " Meteorological Magazine, 56:190, August, 1921.  
Correspondence.
381. Halpine, G. C. , "A Pilot's Meteorology." D. Van Nostrand Co., New York, 2nd Printing, 1942, 1 fig.  
A page on the rain gage. A Friez weight-type gage is illustrated.
382. Hamilton, E. L. , "Rainfall measurement as influenced by storm characteristics in southern California mountains." American Geophysical Union. Transactions. 25 (Pt. 3):502-518, 1944, 14 figs, 3 tables, 17 refs.  
Records from a novel rain gage which rotated according to the wind direction, permitted the development of a directional storm pattern and computation of the angle of inclination of rainfall from the vertical which could be correlated with wind velocity and rainfall intensity. The study indicated that southern California storms follow definite patterns which can be classified. Did not mention measuring snow.

383. Hamilton, E. L. , "San Dimas tipping-bucket rain-gage mechanism. " American Meteorological Society Bulletin, 28(2):93-95, February, 1947, 2 figs.  
The mechanism is a tipping-bucket of the usual design that can be fitted inside a standard 8 in. rain gage can. Recording is made electrically by a small permanent magnet attached to the bucket activating a mercury switch by means of a small soft-iron armature sealed in the tube with the mercury. The cost of the unit is \$12-\$15.
384. Hamilton, E. L. , and Andrews, L. A. , "San Dimas rainfall and wind velocity recorder." American Meteorological Society, Bulletin, 32(1):32, January, 1951, 3 figs.  
A vertical-drum water stage recorder was modified for operation with an electro-magnetically operated pen. Records impulses for tipping bucket gage and anemometer. Will run eight days for 75 lineal feet of impulses. 12 in. x 18 in. chart with speed of 4 1/2 in. per hour. Can easily define rates up to 5.76 in./hr.
385. Hancock, D. S. , Pinnock, E. V. , "Melting hail, snow, and soft hail in the rain gage. " Meteorological Magazine (M. O. 403), 71(849):206-209, October, 1936, 1 fig.  
Recommends adding a heating unit using solid fuel to the gage to melt snow or ice (really no improvement over old method - ed. ).
386. Hann, J. , Lehrbuch der Meteorologie (Leipzig), p. 234, 1906.
387. Hanzlick, S. , "Nouveau rapport sur l'unification des reseaux pluviometriques. " (New report on unification of rain gage networks) , Prbces-Verbaux des seances de la section de meteorologie, Union Geodesique et geophysique International Quatrim Assemblée Generate Stockholm - Aout, , Vol. 2 Annexes, p. 18-29, 1930, 2 tables.  
A report on the rain gages used by the different countries of the world. The types of gages, their dimensions, height above ground, exposure, hours read, recording made are presented. Also recording gages, snow measurement, and number of stations are discussed.
388. Hartman, Wilhelm, "Die Messung der Wirklichen Niederschlagsmengen auf Berggipfeln. " Wetter, 37:77, 1920.
389. Hartman, Wilhelm, "Ueber die Wirkung des Nipherschen Schutztrichters. " Meteorologische Zeitschrift, 42:446-447, November, 1925.  
Recommends experiments in a wind-tunnel to find satisfactory shield, if possible, and apparently overlooks the obvious remedy of simply tilting the shield. Prefers square gages to round ones.
390. Hauer, A. , "A new recording rain gage. " Journal of Scientific Instruments, 28(3):84-85, March, 1951, 2 figs, 3 refs.  
An automatic siphon rain gage is described. The instrument is a float gage which when filled to a certain level is emptied by a tilting tube. The construction makes it impossible for preliminary dribbling of the rainwater to occur. The instrument has few moving parts and its functioning cannot be easily spoiled by dirt or corrosion. After 10 mm. has been collected, the tilting tube empties the system in 4.5 seconds. Accuracy is to 0.1 mm. The instrument was designed at Royal Netherlands Meteorological Institute, De Bilt, Holland.
391. Hayes, G. L. , "Reliability of the Forest Service type rain gage." Monthly Weather Review, 70(2):267-268, December 1942, 1 fig, 1 table.  
Simple forest service type gage (7.65 in. dia. on a standpipe) was found to be in good agreement with U. S. W. B. gage for measuring rain (1%).

392. Hayes, G. L. , "A method of measuring rainfall on windy slopes." Monthly Weather Review, 72(5): 111-114, May, 1944, 2 figs, 2 tables, 7 refs.  
Standard vs. pit gages. Tests showed that in a valley bottom where light winds prevailed, gages were in good agreement. As you went up the valley slopes, the precipitation increased and also the discrepancy between gages increased. Recommended that a pit gage with sloped orifice (stereo type) parallel and on the same level as the ground be used. A splash sheet to cover all the pit but the orifice , was found necessary. This setup on windy slopes proved most consistently good.
393. Hayes, G. L. , and Kitteredge, J. , "Comparative rain-measurements and rain gage performance on a steep slope adjacent to a pine stand." American Geophysical Union Transactions, 30(2): 295-301, April, 1949, 2 figs, 4 tables, 12 refs.  
Measurements from two rows of rain gages extending outward along contours from the edge of a pine plantation on a steep slope, showed that the 45 foot high trees influenced the amount of rain reaching the ground for a distance not exceeding 34 ft. from the edge of the plantation. Seven gages were tested on a windy slope. Best results were obtained with shielded and tilted gages. Trough gages were good.
394. Haynes, B. C. "Meteorology for pilots. " Civil Aeronautics Bulletin, No. 25, p. 36-37, January, 1945, 2 figs.  
The U. S. W. B. Standard and the Friez weight type gage are illustrated and briefly described.
395. Hazen, H. A. , "Fort Leavenworth rainfall. " American Meteorological Journal, 5(8):370-372, December, 1888, 1 ref.  
Two gages about 3 miles apart have records dating back to 1837. There appears to be a question as to the reliability of the records.
396. Heberden, W. , "Of the different quantities of rain, which appear to fall at different heights, over the same spot of ground. " Philosophical Transactions, 59:359-362, December, 1769, 1 table.  
This appears to be the first mention of the variation of rainfall with height. A gage on the ground for 1 year read 22.61 in. A gage on top of a nearby house read 18.14 in. and one on top of Westminster Abbey read 12.10 in. The reason postulated was that electricity was concerned with this phenomena.
397. Hellmann, G. , "Reportorium der Deutschen Meteorologie. " Leipzig, 1883.
398. Hellmann, G. , "Neuer Regenund Schneemesser. " (New rain and snow gage), Zeitschrift fuer Instrumentenkunde, 5:89-90, March, 1885, 1 fig, 1 ref.  
Hellmann's presentation of his non-recording gage.
399. Hellmann, G. , "Die Anfaenge der meteorologischen Beobachtungen und Instrumente. " (The beginning of meteorological observation and instruments), Himmel und Erde, 2(3 and 4):113-125, 1890, 3 figs.  
It is claimed Ferdinand II of Toscanhad a rain gage in Florence, Italy early in the 17th Century.
400. Hellmann, G. , "Resultate des Regenmess-Versuchsfeldes bei Berlin 1885-1891." (Results of rain gage field experiments near Berlin 1885-1891), Meteorologische Zeitschrift, 27:173-181, May, 1892, 1 fig, 7 tables, 1 ref.  
Wind is the major factor that influences accurate rain measurement.

401. Hellmann, G. , "Resultate des Regenmess-Versuchsfeldes bei Berlin 1885-1891." (Results at the rain measurement experimental field at Berlin, 1885-1891), Berliner Zweigverein der Deutschen Meteorologischen Gesellschaft, 1892.  
Same as article in Met. Zeits, 1892, p. 173-181.
402. Hellmann, G. , "Eine neuer registrierender Regenmesser (R. Fuess). " (A new registering rain gage), Meteorologische Zeitschrift, 32:41-44, January, 1897, 2 figs.  
A description of the Hellmann siphon-type rain gage.
403. Hellmann, G. , "Ueber die Auswertung des Aufzeichnungen selbsregistrierender Regenmesser. " (Interpretation of registration of self-registering gage), Meteorologische Zeitschrift, March, 1900, p. 136-137.
404. Hellmann, G. , "Entwicklung der Meteorologischen. Beobachtungen bis zum Ende des 17. Jahrhunderts. " (Development of meteorological observations to the end of the 17th century), Meteorologische Zeitschrift, 36:145-157, April, 1901, 6 refs.,  
Historical survey of meteorological instruments.
405. Hellmann, G., "Die Niederschlaege in den Norddeutschen Stromgebieten, Berlin. " (The precipitation in the North German air current territories), Berlin, p. 21-31, 1906.  
Roof-edge exposures poorest. Gages at 1 m. in exposed place catch 3-10% less than at .33 m. and at less exposed location 0.3 to 2.2% less.
406. Hellmann, G. , "E in neuer registrierender Schneemesser. " (A new registering snow-gage), Meteorologische Zeitschrift, 23(8): 337-339, August, 1906, 3 figs, 1 ref.  
Pictures and describes the Hellmann-Fuess weight-type snow and rain recording gage. Counter weights, not springs are used to oppose the action of the receiver. Precipitation is caught in a bucket that sits on the platform of a weighing mechanism.
407. Hellmann, G. , "Gage-Ombrograph-Rohrdanz. " Meteorologische Zeitschrift, 24:39-40, January, 1907.  
Remarks on the similarity between the Hellmann-Fuess snow gage and the Rohrdanz gage.
408. Hellmann, G. , "Ueber die Verteilung der Niederschlaege in Norddeutschland. " (Concerning the distribution of precipitation in North Germany), Sitzungsberichte der Koeniglich Preussischen Akademie der Wissenschaften zu Berlin, No. 38:980-990, November 5, 1914.
409. Hellmann, G. , "Fruehe Regenmessungen an Bord von Schiffen." (Early rain measurements aboard ships), Meteorologische Zeitschrift, 41: 279-280, September, 1924, 1 table.
410. Henry, J., "Rainfall of United States." Report of the Chief of the Weather Bureau, p. 318-319, 1898.  
". . . absolute amount of precipitation as registered by the Weather Bureau gages, when placed on high buildings, falls short of the true amount by quantities varying from 5 to 10 percent of the true rainfall. "
411. Henry, J., "Collected Writings. " Vol. 2, p. 262.  
Describes simple shield, to divert upward current, of 1853 or earlier. '
412. Herrmann, C. , "Mechanisch verbesserter Wind, Regen und Trockenheits Beobachter. " Freyberg, Vol. 8, 1789.

413. Herschel, J. , "Essay on meteorology. " Encyclopedia Britannica, 8th Ed., 1853-1860.  
The increase in size of a drop in the last few hundred feet of its descent would be infinitesimal.
414. Herve'-Mangon, "Note sur un Nouveau Pluvioscope." (Note about a new rain gage), La Meteorologie, 8:183-184, December 11, 1860.
415. Hesselberg, T. , "Zur Wirkung des Schirmes auf die Niederschlagsmessungen (German)." (On the effect of shields in precipitation measurement), Meteorologische Annalen, 2(4):207-222, 1945.  
In mountainous areas gages did not give reliable results.
416. Hesselburg, T. H. , Langlo, K. , "As a contribution to the question whether the precipitation gages should be shielded or unshielded and to the question of the best exposure for the gages. " CIR-IMO/T/16, 15/7/47 CIMO-DOC. 11, 1947, 1 fig, 3 tables, 1 ref.  
It is concluded from one to two years of comparative records and tables that a shielded gage is better than an unshielded one, especially for measuring snow fall; and that where possible the gage orifice and the ground-in the immediate vicinity should be horizontal.
417. Hibbard, F. N. , "New type of rain timer. " Monthly Weather Review, 53:398-399, September, 1925, 2 figs. -  
Drops from a 12 in. funnel hit a small aluminum pan. The impact causes a circuit to be closed, thereby indicating time precipitation began. Fog and dew have characteristic trace that cannot be confused with rain.
418. Himmel; J. M. , "Variation of depth of precipitation and water equivalent of snow on the ground. " Proceedings of the Western Snow Conference, p. 117-132, 1948.
419. Hoeck, E. , and Thams, J. , "Zum problem der Niederschlagsmessung, (German)." (On the problems of precipitation measurement), Geofisica Pura e Applicata, 19(3-4):220-226, 1951, 2 figs, 2 tables, 3 refs.  
Comparative measurements were made during a 13 month period (May 1950 through May 1951) among three rain gages, one flush with the ground, one protected (shielded), 1.5m.; and one unprotected, 1.5m. The flush gage caught more than the unprotected 90% of the time, and more than the protected gage 78% of the time. These results are more remarkable because of the light winds at the site (on the Magadino Plain) and are in agreement with similar studies on Schneekoppe by Koschmieder (1934). The mean annual catch was 6% higher in the sunken gage and 4% higher in the protected gage than in the unprotected gage.
420. Homersham, S. C. , "Report and supplement on the supply of surplus water to Manchester and Stockport with some remarks upon the construction of rain gages and the annual depth of rain falling in different localities around Manchester." London, 1848 4 figs, 10 tables.  
Rain gages used to determine runoff were of the float variety and the staff protruding from the funnel led one to believe that the rainfall increased with height and that the amounts were in excess of what they should be. "These conclusions, of course, were erroneous."

421. Hondo, Kotaro, "On a pluviograph, recording the intensity of rainfall." Tohoku University Science Reports, Sendai, 4(5):333-338, 1915, 5 figs, 4 eqs..  
A receiver with a notched outlet is suspended from a spring and an arm extends from the spring to a clock-operated drum. As rainfall is funneled into the receiver, it will also flow out of the notched weir. The amount of water building up in the receiver is proportional to the rainfall rate and this in turn is recorded on the drum. Special arrangements were necessary to overcome capillarity in flowing out the weir as a small amount of water would be retained. A small quantity of water dripping into the receiver at a constant rate overcame this difficulty.
422. Horton, R. E. , "Evaporation from snow; errors of rain gage when used to catch snowfall." Monthly Weather Review, 42:99, February, 1914, 1 fig, 1 table.  
The measurement of evaporation from snow indicated monthly average of 1-inch water with average brisk winter conditions.
423. Horton, R. E. , "The measurement of rainfall and snow. " Journal of the New England Water Works Association, 33(1): 14 - 72, March, 1919, 21 figs, 13 tables.  
A thorough investigation of precipitation measurement up to 1919. Discusses many of the instruments in use and those used in the past. "Considering all experiments cited, it cannot be definitely stated which is the best type or size of gage. "
424. Horton, R. E. , "Measurement of rainfall and snow. " Monthly Weather Review, Vol. 47, p. 294-5, May, 1919, 1 ref.  
This is a review of Horton's previous article. In discussion, S. P. Fergusson indicates that gage size may not be so important and recommends use of Nipher shield and wire enclosure not closer than twice the height of the enclosure.
425. Horton, R. E., "Rainfall interception." Monthly Weather Review, 47(9): 603-623, September, 1919, 17 figs, 21 tables, 10 refs.  
Interception storage loss for trees was 0.02 in. to 0.07 in. Interceptometers were galvanized iron pans 17 in. in diameter and 5 in. deep, with a 1/2 in. nipple in bottom side to guide water into a gallon jug. Gage was one foot above ground.
- 426.. Horton, R. E. , "Comparisons of snowfall and rain gage can measurements of snowfall. " Monthly Weather Review, 48:88-89, February, 1920, 1 fig, 1 table.  
Ratio of board to can catches in 12 falls of snow varied from 0.26 to 1.73, and averaged 1. 16.
427. Horton, R. E., "Statistical distribution of dropsizes and the occurrence of dominant drop sizes in rain." American Geophysical Union Transactions, 29:624-630, October, 1948, 5 figs, 4 tables, 8 refs, 6 eqs.  
An analysis and comparison of data on drop size distribution by Laws, Landsberg, Newberger, Lenard and Bentley and attempts to show that such distribution would follow from the thunderstorm model which he has developed. Suspension velocity, volume, and dominant drop sizes studied for rain, snow, sleet and hail. Evidence exists that sizes are significantly often multiples of dominant size, indicating (as Defant suggested) coalescence in falling at uniform size .
428. Hough, G. W. , "Self-recording evaporation and rain gage. " Nature, About 1874.  
Dudley Observatory at Albany--Weight-type gage.

429. Houghton, H. G. , "On the measurement of drop size and liquid water content in fogs and clouds." Massachusetts Institute of Technology, Papers in Physics, Oceanography and Meteorology, 6(4), 1938.
430. Howard, L. , Climate of London, London, 2:158, 1833. ,  
Speaks of a strong wind robbing a higher gage.
431. Howard, L. , "Beobachtungen ueber den regen und ueber die regenmesser." (Observations about rain and rainmeters), Annalen der Physik, 1st Series, 41:417-425, 1812. " 7
432. Howard, L. , "On the difference of the quantity of rain at different heights above the surface of the neighboring ground. " British Association for the Advancement of Science, Trans. Section, p. 563-564, 1834.  
Howard does not accept theory advanced by Phillips that the rain decreases with elevation because of condensation on the cold drop. Fails to clearly explain the reason.
433. Howell, W. E. , Blue Hill Report, 1946, 5 refs, 2 eqs.  
Shows mathematically that a small gage should be less affected by wind than a large one. Recommends: the use of gage coefficients and suggests that a gage with several small receivers be used.
434. Hoyt, J. C. , "A 900 inch gage on a peak of Kauai. " Engineering News Record, 84(24):1166, June 10, 1920.  
900 inch gage on Hawaiian peak. 6 in. orifice;
435. Huber, Anton, "Die Niederschlagsmessungen auf dem Plattachferner und auf der zugspitze." (Measurement of precipitation on the side of a glacier and at the top of the Cog-railroad), Deutsches Meteorologisches Jahrbuch fuer Bayern, Anhang A , 1923.  
A Mougins totalizer 387 m. below the summit caught 2.3 times the ordinary catch on the summit.
436. Huddleston, F. , "On certain experiments with rain gage shields, made during the winter of 1926-27, at Hutton John, Cumberland. "British Rainfall, 66:285-293, 1926, 4 figs.  
The openly exposed gages generally caught from 71 to 100 percent of that in a well sheltered gage; the shielded ones being about half-way between the catches of the unshielded and the check gages. A wall at half the height of its distance made a very definite shadowing.
437. Huddleston, F. , "Reports on experiments with shields during the period 1 March 1927 to 29 February 1928, at Hutton John, Penrith. " British Rainfall, 67:288-290, 1927, 1 fig, 2 refs.  
A sloping turf wall around a gage at the exposed top of a hill enabled it to catch as much as check gage in 80 days with high winds.
438. Huddleston, F. , "Report on experiments with rain gage shields and rain gages under the lee of a high wood during the period 1 May 1928 to 30 April 1929 at Hutton John, Penrith." British Rainfall, 68:258-269, 1928, 3 figs, 1 table, 2 refs.  
In strong winds a gage no farther from a grove than its height caught but 69% of standard, at twice the distance, 98%, and at 4 times, 95%. An unshielded gage on the windward slope of 1:8 caught only 80% of that on summit. Even shielded gages on windward slope are deficient, suggesting to author that in strong winds much rain cannot reach the ground there but falls beyond crest.

439. Huddleston, F., "Report on experiments with rain gage shields and rain gages under the lee of a high wood, May 1, 1929 to April 30, 1930." British Rainfall, 69:288-298, 1929, 2 figs, 3 tables, 2 refs.  
The addition of six inches to the height of a turf wall bringing it well above the gage reduced the catch by 7%. The addition of a turf wall to the gage openly exposed and four times as far from trees as they were high improved the catch by 4% in strong winds, and brought it up to 99% of the check gage. Turf walls make catch of drift snow excessive.
440. Huddleston, F., "Report on experiments with shields in exposed positions, May 1, 1930 to April 30, 1931 at Hutton John, Penrith." British Rainfall, 70:264-271, 1930, 2 figs, 3 tables, 4 refs.  
Catch of pit gage best, then turf walled, then incomplete Nipher-shielded, and last, bare, Nipher shield's advantage over bare gage began at 25 miles/hr. and increased to 15% in whole gale. Submitted that the Nipher shield was a mistake. He also preferred a turf walled gage over a pit gage for reasons of better drainage.
441. Huddleston, F., "Report on experiments with shields in exposed positions, May 1, 1931 to April 30, 1932, at Hutton John, Penrith." British Rainfall, 71:275-285, 1931, 2 tables.  
On windward slope gage in pit 8 ft. in diameter caught 85% of check in fresh to strong winds, while gages in turf-walled craters caught 79%. A shallow funneled gage caught 73% of check in winter and deep funneled 79%.
442. Huddleston, F., "Report on experiments with shields in exposed position, May 1, 1932 to April 30, 1933 at Hutton John, Penrith." British Rainfall, 72:278-288, 1932; 4 tables.  
Twelve gages were used, all of them 5 inches in diameter and four were surrounded by turf walls. "A bare Snowdon (deep funneled) gage (i.e. a normally exposed gage) is 10% better than a bare British Association (shallow) gage, while it is 10% worse than sheltered Snowdon gages in pits or turf walled enclosures. A gage when completely buried under snow will give a fairly true record of the whole quantity of water in the snow that has covered it."
443. Huddleston, F., "A summary of seven years' experiments with rain gage shields in exposed positions 1926-1932 at Hutton John, Penrith." British Rainfall, 73:274-293, 1933, 2 figs, 1 table, 2 refs.  
Concluded that experiments show that: (1) turf walled gage best in an exposed location, (2) Nipher shield was unreliable, (3) the rule that gages should be twice the height of an obstruction away from the obstruction was a sound rule, and (4) there is no reliable method of measuring snow.
444. Hudson, W., "British Patent 3, 168, 1894." Great Britain Patent Office Abridgement of Specifications, Class 106, p. 104, 1893-96.  
Float-type gage with electrical means for recording the height of the float. Operates to the capacity of the receiver.
445. Hunn, O. W., Hunn, J. D., "Patent.No. 2,507,206, Rain gage, May 9, 1950." U. S. Patent Office (Official Gazette Summarized), May 9, 1950, 1 fig, 6 refs.  
A rain gage of the usual round orifice has a large funnel and receiver. The receiver is transparent and is large enough to hold a month's catch of rain. The receiver is filled with oil to begin with and rain settles to the bottom where it can be measured. The oil eliminates the meniscus and prevents evaporation. Amount of rain is read by the graduations on the transparent receiver. At the end of each month the water is drained from the receiver to a larger reservoir capable of holding a year's supply.

446. Ingold, H. , "Pluviometre et pluviometrie. " (Rain gages and rain measurements), La Meteorologie, 75(8):77 -88, 1932, 2 figs, 5 refs.  
The present practice and critique of measuring; Further contributions by Philibert, Jagot, Bastamoff, Brazier, and Pers on the following pages; 89-113 in the Jahrgang for 1932, and 473 in the Jahrgang for 1934. (New constructions of rain gages, especially for mountains).
447. Innes, R. T. A., "Rain gage exposure in the Transvaal." Symons' Meteorological Magazine, 42(494):21-23, March, 1907.'
448. Institute of Water Engineers, Joint Committee, "Determination of the general rainfall over any area. " The Institute, Westminster, p. 1-26, 385-390, 1937.
449. Instruments, "The 1948 Instruments Index. " Instruments (An extra issue), Pittsburgh, Vol. 21, 1948.  
Rain gage manufacturers listed: 1. Ballauf Mfg. Co., 2. Central Scientific Co. , 3. Friez and Sons, 4. Fuess, Inc. , 5. Green, Henry J., 6. Gurley, W. & L. E. , 7. Henson Co., Fred C. , 8. Keuffel & Esser Co. , 9. Precision Therm. , 10. Steward, M. C. , 11. Taylor Inst. Co., 12. Warren-Knight Co. , 13. White Co.  
Rainfall Recorders: 1. Esterline Angus Co. , 2. Friez & Sons, 3. Fuess, Inc., 4. Gorrell & Gorrell, 5. Green, Henry J., 6. Leupold & Stevens, 7. Taylor Inst. Co.
450. Instruments, "Air-launched automatic weather station. " Instruments, Pittsburgh, 24(9):1053, September, 1951.  
Describes the Grasshopper, " an automatic weather station, which transmits weather data by radio. It can be parachuted from aircraft onto inaccessible territory, has a land range of more than 100 miles and can transmit weather reports at 3 hour intervals for more than 15 days. Records the following: 1. Pressure, 2. Temperature, and 3. Humidity. Designed by National Bureau of Standards Tech. Rep. 1534 for U. S: Navy.
451. Italy, Ufficio Idrografico del Po. , "Instruzioni per la misura delle precipitazioni meteoriche concordate coi servizi interissati nelle, Conferenze del Febbraio 1913 Presso l'Ufficio Centrale di Meteorologia e Geodinamica," (Instructions for the measurement of meteorologic precipitation agreed upon by the participating services in the conferences of February, 1913), Parma, Tipografie Riunite Donati, 3 parts, 1913.
452. Italy, Ufficio Idrografico del Po. , "Il Pluvionivometro totalizzatore del l'Ufficio Idrografico del Po." (The rain and snow totalizer of the Po Hydrographic Office), Parma, 1914.  
A Mougins that has been modified. Has a float inside for measurement, and the spigot for emptying is different.
453. Italy, Ufficio Idrografico del Po. , "Quarta e quinta relazione annuale del direttore. " (Fourth and fifth annual reports of the director), Venezia, No. 58, p. 22, 1914.  
On page 22 is a picture of their nivometer.
454. Italy, Ufficio Idrografico del Po., "Esperimenti di confronto fra diversi pluviometri in relazione alla quantita di precipitazione." (Experiments comparing different rain gages with respect to the quantity of precipitation collected), Parma, 1915. .  
The small mouthed pluviometer proved more accurate than the large mouthed ones, there being relative differences of from 3% to 9%. Wind influence's the catch. One of the experiments lasted 2-1/2 years.

455. Ives, R. L., "Capacitor-discharge recorder applications." Electronics, 22(21):104-108, February, 1949, 7 figs, 7 refs, 2 eqs.  
Recorder circuits incorporation capacitor-discharge networks. Adaptability to gages recording rainfall. (Can be used on the tipping bucket gage. )

## J.

456. Jagot, M. A. , "Le Pluvioscope. " (A rain recorder), La Meteorologie, 75(8):92-93, January-February-March, 1932.  
Discusses various possible types of trace recorders that can operate with water sensitive paper tapes or discs, water sensitive string or a small receiver below a funnel with an electric contact.
457. Jakobi, N. O., "Erforschung der verschiedenen Systeme von Schutzvorrichtungen am Regenschirm." (Investigation into the various systems of shielding rain gages), Iswestia G. G. O. Nr. 4 Leningrad, 1929.
458. Jarde, Ramon, "Un pluviograph d' intensitats. " (A pluviograph of intensity), Barcelona, 12 p. , 1921.
459. Jarrold, P. F. , "Experiments with a shielded rain gage. " Meteorological Magazine, London, 61:87-88, May, 1926, 1 fig, 1 table.  
One year's comparison between shielded and unshielded gages showed that the shielded gage averaged 5% over the unshielded, and in light rain as much as 10%. The shield was similar to the Nipher except that it was much flatter and the cone was filled with splash-preventing cinders.
460. Jelinek, C. , "Die neuen Regenschirm und Messrohre der K. K. Central Anstalt fuer Meteorologie in Wien, " (The new rain gage and measuring tubes of the Royal Institute for Meteorology at Vienna), Zeitschrift Osterreichische Gesellschaft fuer Meteorologie, 10(6): 91-92, March, 1875.  
Rain gage sizes and specifications. Constantinople - 22 cm. dia. , Karlsruhe - 25 cm. dia. , Copenhagen - 1/10 sq. meter; Edinburgh - 3 in. , 5 in. , 8 in. , 12 in. , London - 8 in.
461. Jennings, A. H. , "World's greatest observed point rainfalls. " Monthly Weather Review, 78(1):4-5, January, 1950, 1 fig, 2 tables, 19 refs.  
Maximum observations:  
1 min. - 0.65 in. - California, U.S.A.  
5 min. - 2.48 in. - Panama  
42 min. - 12.00 in. - Missouri, U.S.A.  
4 hrs. - 23.00 in. - West Indies  
24 hrs. - 45.99 in. - Philippine Islands  
3 days - 81.54 in. - Formosa  
5 days - 150.00 in. - Cherrapunji, India  
31 days - 366.14 in. - Cherrapunji, India  
1 year - 1041.78 in. - Cherrapunji, India
462. Jevons, W. S. , "On the deficiency of rain in an elevated rain gage, as caused by wind. " London, Edinburgh and Dublin Philosophical Magazine, (Signal Service Notes. No. XVI.) Ser. 4, 22:421-433, 1861, 3 figs, 13 tables, 20 refs, 3 eqs.  
(3)—measurements of rain, or even monthly totals, are examined with reference to the strength of the wind at the time, it becomes obvious that there is a connection, (4) Wind must move with increased velocity in passing over an obstacle. It follows demonstratively that raindrops falling through such wind upon the windward part of the obstacle will be further apart in horizontal distance than where the wind is undisturbed and of ordinary velocity. "

463. Johnson, T. J., "Patent No. 1,407,068, February 21, 1922." U. S. Patent Office, Official Gazette, February 21, 1922, 6 figs.  
A directional rotating type of gage with a plate to tilt the orifice into the wind. A counter weight is used to resist tilting into the wind, so that a greater resistance will be offered as the wind velocity increases. A transparent tube is used to enable the observer to make visual readings.
464. Johnston, J., "On a new rain gage." British Association for the Advancement of Science, Transaction Sec., p. 211, 1840.  
A rotating gage that faces the wind and also tips up into the wind by action of horizontal vanes. This may have been the original maximum catch, rotating type of gage.
465. Joly, J., "Partial rain measurement." The Scientific Proceedings of the Royal Dublin Society, p. 283, November, 1900.  
(A gage to catch samples for chemical analysis.)
466. Jones, D. M. A., "A raindrop camera and some preliminary results." Third Radar Weather Conference, McGill University, Montreal; Proceedings, p. E 9-E 16, September 15-17, 1952, 6 figs, 6 refs.  
A photographic technique for measuring rain drops falling through a column is described. A telecentric system employing a 305 mm. diameter paraboloid mirror, 4, 575 mm. focal length, and a diagonal flat surface mirror mounted along the axis of the paraboloid direct the light rays to the camera. The silhouettes of the drops are taken by a 35 mm. camera, and action during rain is on a continuous basis.
467. Jones, A. R., and Lewis, W., "A review of instruments developed for the measurement of the meteorological factors conducive to aircraft icing." National Advisory Committee for Aeronautics Research Memorandum A9CQ9, April 26, 1949, 10 figs, 1 table, 15 refs.  
Nine instruments for the procurement of meteorological data on icing are discussed with respect to quantities measured, operation, range, etc., and advantages or disadvantages associated with their use: (1) Rotating cylinder (best), (2) Fixed cylinder (good), (3) Rotating disc Icing - Rate meter (promising), (4) Capillary Collector (useful above freezing), (5) Rainbow Recorder (not very promising), (6) Dew point recorder (not reliable below freezing), (7) Visibility Meter (needs proving), (8) Sooted Slides (tedious), and (9) Drop Photography (not good).
468. Jones, T. R., "Gethin rain gage ice pillar." Meteorological Magazine, 49(580):72, May, 1914, 1 fig.  
Correspondence.
- . K.
469. Kadel, B. C., "Mountain snowfall measurements." Monthly Weather Review, 41(1):159-161, January, 1913.  
Accumulated snow on ground on north slope (at around 9000 ft. above sea level) may be as much as 20% greater than total catch of well-sheltered gages; therefore, gages and bins are misleading, and snow-surveying should be substituted.
470. Kadel, B. C., "The most intense rainfall on record." Monthly Weather Review, 48:274-276, May, 1920, 2 figs.  
Of 2.47 inches falling in 3 minutes, the tipping bucket gage tipped fast enough to record only about 60% of the fall. (This 2.47 inches would make the 1-minute average 0.82 in.).

471. Kadel, B. C. , "Patent No. 1,492,711, May 6, 1924." U. S. Patent Office, Official Gazette, May 6, 1924, 5 figs.  
Two alarm clocks, three graduated receivers and a swinging funnel are used to convert an ordinary rain gage into one that can determine rainfall time. The length of time that the funnel is over one of the receivers is governed by the clock settings which have a simple connection between the funnel and the winding stem. The action is not cyclic and the apparatus is mainly for use during the night.
472. Kadel, B. C. , "Rain gage of standard commercial materials and parts." Monthly Weather Review, 53:66-67, January, 1925, 2 figs, 2 tables.  
A gage made principally from parts easily available at a cost of \$6.53. The brass ring would be the only part needing machining. Measuring glass in drams from a local druggist; receiver is a half-gallon jug. Diameter - 5.359 in.
473. Kadel, B. C. , "Rainfall catch as affected by different depths of funnels in the rain gage." Monthly Weather Review, 58:282-283, July, 1930, 4 tables.  
Of two rain gages having the same diameter, the one with the deeper rim catches the most rain, presumably because some of the drops splash out of the shallower funnel. In the case of the U. S. Weather Bureau gage the tests made indicate that the advantage of using a deeper funneled gage would be about 1%. This 1% is within the limits of error of measuring precipitation.
474. Kadel, B. C. , "Measurement of precipitation." U. S. Weather Bureau Circular E. , 4th ed. Rev., 25 p. , 1936.  
Instructions for the measurement and registration of precipitation by means of the standard instruments of the United States Weather Bureau. Contents - Exposure and installation, snow measurement, snow stakes, snow surveys.
475. Kamtz, Ludwig F. , "Lehrbuch der Meteorologie, Textbook for Meteorology," Leipzig, p. 412, 1831.  
Bibliographical footnotes.
476. Kandasamy, A. P. , "Evaporation in rain gages." Ceylon Journal of Science (Sec. E) (Successor to Colombo), 2:107-112, 1937.  
Comparative tests with rain gages painted white and black. Some advantages found by painting white.
477. Kassner, C. , "Der Grosse Schneefall am 16. und 17. November, 1909." (The heavy snowfall on the 16th and 17th of November, 1909), Veroeff. d. Koen. Preuss. Met. Inst. , Nr. 193, Bericht ueber die Taetigkeit d. K. P. M. I. im Jahre 1909, Berlin (Publications of the Royal Prussian Meteorological Institute No. 193; Bericht ueber (Report on) die Taetigkeit des K. P. M. I. im Jahre 1909, Berlin), p. 124-133, 1910.  
The precipitation measured by pressing deep snow straight down into the gage; the snow collected over the top of a gage was found to be 24.2 mm. whereas a cross-section gave 26.0 mm.
478. Kassner, C. , "Bemerkungen ueber Regenmesser." (Remarks on rain gages), Mitteilungen der Deutschen Landwirtschafts -Gesellschaft, 25:308-309, 1910.
479. Kassner, C. , "Ueber die zulaessige Genauigkeit der Auffangflaeche von Regenmessern." (About acceptable accuracy of the catch area of rain gages). -Koeniglich Preussische Meteorologische Institut-Abhandlungen, [Abhandlungen (Transactions) of the Royal Prussian Meteorological Institute], 229:64-66, 1911, 1 table, 7 eqs.  
On inaccuracy of gages due to warping of orifice ring because of soldering, temperatures, etc. The error is mostly small; e.g. , for orifice of 200 cm<sup>2</sup> an error in diameter of 3 mm. would be necessary for 0.1% variation.

480. Kassner, C. , "Die aeltesten Regenmessungen." (The oldest rain measurements), Meteorologische Zeitschrift, 29:173-174, April, 1912, 2 refs.  
An abstract of an article on the early history of rain measurement. There were measurements of rain in India in the 4th Century . B. C.
481. Katz, R. E. and Cunningham, R. M. ., "Aircraft icing instruments; instruments for measuring atmospheric factors related to ice formation on airplanes. II." Mass; Institute of Technology, De-icing Research Lab., Cambridge, Mass., March, 1948, 16 figs," 4 refs.  
Detailed, well-illustrated discussion of instrumental developments in operation includes: icing rate meter, liquid water content measurement by capillary collector, microrotometer and orifice type of flow meter, spray tunnels, the small tunnel, and the new high speed tunnel.
482. Katz. I. "A momentum disdrometer. " Third Radar Weather Conference, McGill University, Montreal. (Proceedings), p. E-17 to E-20b, September 15-17, 1952., 6 figs, 2 refs.  
Basically a capillary collector with a microphone imbedded in a chamber behind the porous collecting membrane. A flow meter calibrates the size of drops striking the membrane. The instrument is mounted on an airplane and is 6 1/2 in. long and 2 in. in diameter. Some preliminary results are presented, and it "shows promise to measure both drop mass and liquid content in rain from aircraft. "
483. Kautilya, "Arthasastra, translated by R. Shamasastri. " Government Oriental Library Series, Bibliotheca Sanskrita, No. 37, Part 2, Bangalore, 1915, 321-296, B. C.  
". . . In (front of) the store house, a bowl (Kunda) with its mouth as wide as an aratni (24 angulas), 18 inches, shall be set up as rain gage (Varshamana). . . ." (page 64). (This refers to the grain store house kept by the government chamberlain). Page 143. "The quantity of rain that falls in the country of Jangala is 16 dronas; half as much more in moist countries; 13 1/2 dronas in the country of Asmakas; 23 dronas in Avanti; and an immense quantity in western countries, the borders of the Himalayas, and the countries where water channels are made use of in agriculture. When 1/3 of the requisite quantity of rain falls both during the commencement and closing months of the rainy Season and two-thirds in the middle, then the rainfall is (considered) very even. A forecast of such rainfall can be made by observing the position, motion, and pregnancy of Jupiter, the rise and set motion of Venus and the natural or unnatural aspect of the sun." (A drona is a cubic measure). . . . Hence, i.e. , according as the rainfall is more or less, the superintendent shall sow the seeds which 'require either more or less water'. . . . (Implies that accurate record of rainfall was kept).
484. Kingston, G. T. , "Canadian rain gages." Meteorological Magazine, 14(161):70-71, June, 1879.  
Correspondence: lengthy editor's note.
485. Kleinschmidt, H. , "Regen-und Schneemessung. " (The measurement of rain and snow), In F. Linke's Meteorologisches Taschenbuch, Leipzig, p. 202-205, 1931, 2 figs.  
Diagrams of Nipher shield and Mougins totalizer. Describes heating of gages.
486. Kleinschmidt, H. , "Niederschlagsmessung. " (Measurement of precipitation), Handbuch des meteorologischen Instrumente. Berlin, p. 275-288, 1935, 12 figs, 2 tables, 28 refs.  
A chapter of this book is devoted to the measurement of precipitation. Many gages, both recording and self-recording, are discussed together with several diagrams. The major problems of measuring precipitation are brought out.

487. Klengel, F. , "Eine neue Methode der Regen-Messung. " (A new method of rain measurement), Wissenschaftliche Beilage zur Leipziger Zeitung, No. 94, 1905.
488. Kling, R., and Gallet, G., "Concerning a method for the study of rapidly growing fogs. " Academie des Science, Paris, Comptes Rendus, 213:985-988, 1941, 1 fig, 3 refs.  
 The determination of drop size in a fog is accomplished by optical methods where coronal (?) rings are measured on a plate. An accuracy of measurement of 10% is possible in a range of diameters from 10 $\mu$  to 100 $\mu$ .
489. Knoch, K. , "Die Entwicklung unserer Kenntnis des Windschutzes bei der Aufstellung der Regenschirm. " (The development of our knowledge of wind shields in the erection of rain gages), Wetter (Berlin), 25:97-102; 129-131; 151-158, 1908.
490. Knox, T. , "On a new rain gage." London & Edinburgh Philosophical Magazine, 11(Ser. 3):260, 1837, 1 fig.  
 Presented 26th June. A vectopluiometer. Eight tubes, corresponding to the cardinal points of the compass are rotated beneath an orifice from a tube which leads from the funnel of a stationary gage. The rotation of the tubes is directed by the wind, and thus the direction from which rain falls may be obtained. This may be the first vectopluiometer.
491. Knox, T. , "On a new rain gage. " Franklin Institute Journal, 21:64, January, 1838.  
 This is an abstract of an article appearing in London and Edinburgh Philosophical Magazine. A gage used to determine the direction from which the rain comes. The rain water was made to flow into one of eight (cardinal points) receivers of an annular shaped vessel by means of a wind vane.
492. Koch, J. P., and Wegener, A., "Wissenschaftliche Ergebnisse der Daenischen Expedition nach Dronning Louise-Land und quer ueber das Inlandis von Nordgroenland, 1912-1913. " (Scientific results of the Danish Expedition to Dronning Louise-Land and across the inland ice of North Greenland, 1912-1913), Abteilung Part II, p. 417, 440-441, 1930.  
 Actual measurement only in case the snow fell during light wind, but estimate where snow fell and drifted at the same time. Basis for estimating obtained when snow fell in light wind and was subsequently drifted. Hellmann mountain rain gage, unshielded, used one meter above the snow. General check on the precipitation through the winter obtained by measuring the density of the snow cover in spring over large area around gage.
493. Kofler, "Windeinfluss auf Niederschlagsmesser, " (The influence of wind on rain gages), Meteorologische Zeitschrift, 44:71, February, 1927, 1 ref.  
 An abstract of Bastamoff and Witkewitsch's article on "Aerodynamic spectra of rain gages." Nipher was not completely effective. Wind tunnel tests on models were made.
494. Kogan-Beletskii, G. I. , "About methods of measuring rain. " Meteorologia i Gidrolgia, 5(9):109-111, September, 1939, 2 figs.  
 As an improvement on the Nipher protector and Koschmieder pit, a pit covered by a honey-combed grating is recommended for the accurate measurement of rain.
495. Kohler, H. , "Eine neue methode zur Bestimmung des Wassergehaltes der Wolken. " (A new method for the determination of water content in clouds), Medelanden fran Statens Meteorologisk-hydrofiska anstalt, Stockholm, Vol. Bd. 5, No. 2, 1928.

496. Koloskov, P. I. , "Enregistrement et cartographie des precipitations atmospheriques, servant a l'etablissement dun bilan hydrique ainsi que dans d'autres buts pratiques. " (Registering and charting atmospheric precipitations for the establishment of a hydraulic balance as well as for other practical purposes), U.S.S.R. Acad. Sci. : Probl - lem i Fizicheskoi Geografii French Resume, Vol. 7, Russian article, p. 85-86; 55-84, 1939, 32 refs.
497. Koloskov, P. I. , "(Russian). " (It is time to revise and improve the methods of calculation and cartography of atmospheric precipitation). Meteorologiya i Gidrologiya, 4(1): 114-116, January, 1938.  
 "Important conclusions about the source of error in measuring rain. " (1) Precipitation as measured today is low in measurement because of wind effects. This is especially true of areas where snow is predominant. (2) Fog, which is important in forest regions, is not measured. (Rain measurements are 50-60% accurate and snow measurements 30-50% accurate.) More attention must be paid to exposure and the effect of topography on rain measurement. (a) Recommends Koschmieder pit gage for rain. (b) Protective system of Bastamoff, Witkewitsch and Skipski gage. Also protective system of Nezdyyurov.
498. Kopp, W. , "Niederschlagsanalysen mit dem Tropfenschreiber. " (Rainfall measurements with the drop recorder), Deutscher Wetterdienst in der U. S. Zone, Berichte (Reports), 12:241-247, 1950, 6 figs, 3 tables, 3 refs.  
 A simple clock-driven rainfall recorder is described and some records reproduced. These are used to analyze the rainfall in showers, occlusion and warm front. A paper covered disc is rotated under an exposed slit. The time and some indication of intensity of rain is indicated by the raindrop marks left on the treated paper disc.
499. Kopp, W. , "Auswertung von Tropfeschreiberregistrierungen und Vergleich der Registrierungen benachbarter Stationen. " (Evaluation of rain drop recordings and comparison of records of neighboring stations), Deutscher Wetterdienst in der U. S. Zone, Berichte, No. 35, p. 312-316, 1952.
500. Koppen, W. , Geiger, R. , "Handbuch der Klimatologie. " edited by Koppen, W. , and Geiger, R. , (Handbook for climatology), 1:B459-B465, 1930-36, 1 table, 16 refs.  
 Short summary of rain measurements.
501. Korhonen, W. W. , "Untersuchungen ueber die Niederschiagsoehe in Finland. " (Research on rainfall in Finland. Studies about the precipitation), Mitteiluneen Meteorologiska Centralanstalt des Finnischen Staates, Helsinki, 9:1-98, 1921.  
 Gage at 1.5 m. with Nipher shield without horizontal rim caught 20.2% more snowfall, 13.8% more snow and rain, and 4% more rain than unshielded. Records from unshielded gages were corrected accordingly. Gage at 0.4 m. collected 7.4% more dry snow and 1% more rain than at 1.5 m. Water content of snow cover, including frost, was found to exceed total precipitation caught in gages by 17% and locally 100%.
502. Korhonen, W. W. , "Schneedichtemesser. " (The snow density gage), Mete prolog is che Zeitschrift, 39:180-182, June, 1921, 3 tables.  
 A cylinder is used for taking snow sections.

503. Korhonen, W. W. , "Ein Beitrag zur Kritik der Niederschlagsmessungen ueber die Dichte des Neuschnees. " (A contribution to the criticism of precipitation measurement of the density of newly fallen snow), Mitteilungen der Meteorologischen Zentralanstalt des Finnischen Staates. (Helsinki), Vol. 18, p. 3-19, 1926.  
In comparing catch in gages against the snow section method it appears that (1) the lighter or less dense the snow, the less the gage caught, and (2) the greater the wind, the less the catch of snow. At four stations the gage caught 15% less snow over a period of three years.
504. Korhonen, W. W. , "Ein selbstregistrierender Regenmesser. " (A self registering rain gage), Suomalainen Tiedeakatemia, Helsingfors Esitelmat Ja Poytakirjat, Proceedings and Protocols, 13(2):81-84, 1932  
Notes that the Hellmann siphon gage is not adequate for winter use, as heating the receiver causes evaporation and lag is considerable. Hellmann's weight gage had high evaporation losses in summer, the 35 mm. capacity was not enough for heavy storms, and the trace was very garbled on windy days. In Korhonen's new design an oil dashpot is added to the weight type gage to dampen wind effects. A siphon is added to give continuous summer action, and provisions are made for doubling the 35 mm. capacity by a weight release mechanism when the top of the trace is reached.
505. Korhonen, W. W. , and Ahti, L. E. , "Ein selbstregistrierender Schnee und Regenmesser." (A self-registering snow and rain gage), Sitzungsberichte der Finnischen Akademie der Wissenschaften. Suomalainen Tiedeakatemia, Helsingfors, p. 158-160, 1939, 1 fig.  
A gage similar in design to the Hellmann automatic siphon type gage is illustrated and described. The collection area is 500 cm.<sup>2</sup> and the siphon operates on a 10 cm. cycle. A Nipher shield is used to dampen wind effects on collection efficiency. A thermostatically controlled electrical heater keeps the gage warm so that snow will be melted in the funnel. The heater is an air heater and is situated near the bottom of the gage, thus the heating of the funnel is indirect, but effective. A triple layer of cork insulation on all the interior walls except the funnel keeps the electric current usage low.
506. Korhonen, W. W. , and Ahti, L. E. , "Itsepurtava vesi- ja lumisademittari." (Self-recording rain and snowfall gage), Lectures and minutes of meetings Academia Scientiarum Fennicae (Finnish Academy Science & Arts.) p. 139-141, 1939, 1 fig.  
An account of the new rain and snowfall gage, the height of which is 150 cm. and the collection surface 500 cm.<sup>2</sup> and which is equipped with a Nipher wind shield. By installing an electric heating apparatus the gage can be also used in winter.
507. Korhonen, W. W. , "Ueber die lokale Veraenderlichkeit der Schneedecke. " (Concerning local variations in the snow cover), Meteorologische Zeitschrift, 49(2):72-74, February, 1932, 7 tables, 1 ref.  
Small open places surrounded by forest or spots in deciduous or light mixed forest are best suited for snowfall measurement.
508. Korhonen, W. W., "Zur Kritik der Niederschlagsmessung." (A critique of precipitation measurement), Meteorologische Zeitschrift, 49: 154-155, April, 1932.  
The Nipher rain gage. Importance of the exposure for rain and snow measurements.
509. Koschmieder, H., "Methoden und Ergebnisse. definierter Regenmessungen." (Methods and results of definite rain measurements), Meteorologische Zeitschrift, 48:85, 271, 1931.  
Describes gage catches in metal honeycomb or bristle-covered pit 1-1.5 m. in diameter. Impracticable for snow.

510. Koschmieder, H. , "Methoden und Ergebnisse definierter Regenmessungen." (Methods and results of definite rain gages), III. Hydrologische Konferenz Baltischer Staaten, Warschan, p. 7, May, 1930, 3 figs.  
Use of a rain gage sunk in the ground', with a brush around the edge as protection against splashing.
511. Koschmieder, H., "Methods and results of definite rain measurements . III Danzig Report." Monthly Weather Review, U. S. Weather. Bureau, 62:5-7, January, 1934, 4 figs, 4 tables, 7'refs.  
(A translation of Koschmieder's report). In tests between (1) Upright Hellmann gage, (2) Brush pit gage and (3) Honeycomb pit gage. Splash effect was eliminated by using 2 pit sizes. In even (upslope) N to NW winds the pit gages were in excess of the upright gage. Wind velocity measurements provided a correlation of 4% excess at 4 mps. and 45% at 12mps. The curve character and check were very good to 12 mps. Koschmieder observed that the brush pit was in slight excess to the honeycomb; although the honeycomb (4 cm. thick and 6x6 cm. holes) was more practical. In light mists or drizzle the upright gages were in excess of the pit gages by large amounts (40%), possibly because of mechanical effects. Suggests that the flow of air and rain undulates. Recommends the pit gage as a satisfactory rain gage; but not for snow.
512. Koster, C. , "Over een eenvoudigen, door mij zelf vervaardigden, zelf-registreerenden regenmeter. Naschfirt door G. Braak." (Concerning a simple self-registering rain gage invented by myself. Described by G. Braak), Hemel en Dampkring, 40:276-279, 1942. .
513. Kostlivy, S. , "Niederschlagsmessungen in verschiedenen Hoehen ueber dem Erdboden." (Measurement of precipitation at various levels above ground), Zeitschrift Oesterreichische Gesellschaft fuer Meteorologie (Now: Meteorologische Zeitschrift), 13(10):153-157; 1878.  
Discussion of results in many places throughout the Austrian Empire in which comparison of rain catch with height were made.
514. Kraebel, C. J. , and Sinclair, J. D. , "The San Dimas experimental forest." American Geophysical Union, Transactions, No. 1:84-92, July, 1940, 8 figs, 4 tables, 4 refs.  
A general description of the experimental facilities and projects. Noted that tilted gages gave consistently larger catches than vertical gages.
515. Krein, T. , "Model testing of precipitation gages." The Idaho Engineer, 29(3):10, 11,30, March, 1952, 5 figs, 1 table.  
A slow speed wind tunnel using a simulated sawdust snowstorm tested various gages with and without wind shields. Special photographic techniques were used to evaluate and improve shield design. A theoretical true catch method was devised, using a selector tube and pictures. C. C. Warnick was in charge of this project.
516. Kroncke, H. , "Selbstzaehlender Regenmesser." (Self - counting rain gage), Praktische Schulphysik, p. 195, 1924.
517. Kurmangalin, N. , "Zur Frage der Messung von Niederschlaegen." (On the question of measuring precipitation), Meteorologische Zeitschrift, 48:222-227, June, 1931, 1 fig, 7 tables, 3 refs.  
"Experiments with an improved Nipher' rain gage under Siberian conditions. Critique and suggestions for improving it."
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518. Lachkevitch, K. A. , "On calculation of the quantity of precipitation and how it is influenced by forests." Meteorologija i Gidrologia, 6(5-6): 117-118, 1940, 1 table.

519. Lacy, R. E. , "Observations with a directional rain gage." Royal Meteorological Society, Quarterly Journal, 77(332):282-292, April, 1951, 7 figs, 1 table, 5 refs, 5 eqs.  
An octagonal raingage, which was set up to study the way in which rain impinged on vertical surfaces, is described. In the London area, walls with moderate exposure to the wind and facing SW. received most rain, equivalent to about 1/4 of the normal' rainfall, and walls facing N. receive least, about 1/16 of the normal rainfall. An equation connecting the mean incident angle of the rain on the ground with the' wind speed is derived, and an attempt is made to obtain an indication of raindrop diameter.
520. Laird, C. A. , "How to construct a practical rain gage." Weatherwise, 1(2):42, April, 1948, 1 fig.  
A simple homemade gage that can be constructed from materials that are easily obtainable. The orifice of the gage is 6.32 in. in diameter and the height is 14 in. When measuring snow, the funnel is removed.
521. La Meteorologia Practica, "Carteggio diD. Benedetto Castelli con Galileo Circa l'invenzione del Pluviometro. " (Letters of Castelli to Galileo on the invention of the rain gage), La Meteorologia Practica, 1(3): 105-108, 1920.  
Invention of rain gage 1639+.
522. La Meteorologia Practica, "Sul funzionamento del pluviografo a galleggiante 'Palazzo'." (On the functioning of the pluviograph with the float type "Palazzo"), La Meteorologia Practica, 6(4): 164-170, July-August, 1925, 1 fig, 2 refs, 1 eq.  
On the "Palazzo" rain gage.
523. La Meteorologie, "Pluviometre enregistreur du Dr. Fine. " (Dr. Fine's self-recording rain gage), La Meteorologie, 24:156-159, July, 1876, 1 fig.  
Description, illustration and operation of Dr. Fine's recording rain gage.
524. Lancetta, P. , "Pluviopolverometro. Novo apparecchio meteorologico per la pioggia e per le polveri atmosferiche. " (Rain-dust gage. A new meteorological apparatus for measuring rain and atmospheric dust. ) Moddica, 1880.
525. Lancetta, P. , "Pluviometro registratore. " (Registering rain gage), Elettricit , 20(49):775-777, December, 1901, 1 fig.  
A bucket-wheel that is triggered to turn 30°; every time one of the sixbuckets becomes filled with a predetermined amount of water, the weight of it overcomes the trigger. Each time a bucket empties, an electrical circuit records it. The water from the bucket flows into a receiver with a standpipe to be used for checking results.
526. Lancetta, P., "Pluviometro con registratore meccanico e elettrico delladurata edella interruzione della Pioggia che duo cadere durante il periodo di 24 ore. " (Pluviometer with a mechanical electric register of the duration and interruption of rainfall during a twenty-four hour period), Girgenti, (Montos, Salvatore), 12 p. , 1902.
527. Lander, A., "New series of self-recording weather instruments, hygrometer and rain gage. " East Kent, Scientific and Natural History Society Transactions, Series 2, 3:33-36, September, 1903, 5 figs.  
A simple float-operated, direct-acting recording gage used in conjunction with a hair hygrometer, is diagrammatically illustrated. The gage is emptied by a draincock in the bottom of the receiver. A water jacket around the funnel melts the snow in the winter time.

528. Lander, A., "Lander self-recording rain gage." Symons<sup>1</sup> Meteorological Magazine, 42:37, 1907.
529. Landsberg, H. , "A convenient heated precipitation gage." American Meteorological Society Bulletin, 20:383-385, November, 1939, 1 fig, 2-tables.  
One winter's test showed that heating funnel with light bulbs did not cause a large loss due to evaporation.
530. Landsberg, H. , "Physical Climatology." Textbook, Pennsylvania State College, p. 27-30, 1941, 3 figs.  
The U. S. W. B. standard 8 in. gage, Hellmann combination float and automatic siphon gage and tipping bucket gage are diagrammatically illustrated and described. Suggests that a source of error in tipping bucket gages is the inertia of water flowing into the bucket causing the bucket to tip before being filled. A general discussion of rain measurement is given.
531. Lang, C. , "Ueber Messung der Niederschlagshoehen." (Measurement of the height of rainfall), Meteorologische Zeitschrift, 1:431-437, December, 1884, 1 fig, 3 tables, 4 refs.  
Experiments with 5 forms of rain gages, made to be tested; 2 were 16.0 cm. dia. and 2 were 25.2 cm. dia. The shapes of the rims were varied.
532. Larkin, H. H., Jr., "A comparison of the Alter and Nipher wind shields for precipitation gages." American Meteorological Society Bulletin, 28(4):200-201, April, 1947, 1 fig, 1 table.  
A single year's comparison showed this order for catch:  
1. Nipher 27.90 in.  
2. Alter 26.94 in.  
3. Unshielded 24.87 in.
533. Larrison, G. K., "Uncle Sam's dampest corner." Monthly Weather Review, 47:303-305, May, 1919, 8 figs, 3 tables.  
Totalizer with receiver area ten times orifice; capacity 300 inches. Orifices had 6 in. diameter and rim vertical for 2 in. Average precipitation for Mt. Waialeale was 476 in.
534. Larson, F. W. , "Patent No. 2,381,602, August 7, 1945." U. S. Patent Office, Official Gazette, August 7, 1952, 2 figs.  
A square-orificed, wedge-shaped, transparent receptacle to be hung on a post. The outer side has graduations printed on it so that visual reading of the amount of rain caught may be made. The edges of the orifice are beveled. "A one-piece transparent graduated receptacle——." Made of plastic.
535. Laskowski, B. R. , "Exposure of rain gages." Tycos, Rochester, 16: 105-106, July, 1926.
536. Laskowski, B. R., "Exposure of rain gages." Monthly Weather Review, 57:506-507, December, 1929, 2 tables.  
Gage on ground caught 9% more than one on flat roof surrounded by 5 ft. parapet over a five year period.
537. Latham, Baldwin, "Experiments on the influence of the lip of rain gages on the quantity of water collected." British Association for the Advancement of Science, 1879, 1 table.  
Comparison of the catch of different types of gages.
538. Lee, F. W. , "A new depth meter for ice and snow." International Geodetic and Geophysical Union Bulletin, 23:761-771, 1938.
539. Lenard, P. , "Ueber Regen." (Concerning rain), Meteorologische Zeitschrift, 21:249-262, June, 1904, 2 figs, 3 tables, 19 refs.  
Rain drop size as measured by catching on treated absorbent paper. Treatise on rain.

540. Lennon, Richard T. , "Unattended rain gage. " Melbourne Australian Monthly Weather Report, 4:499-502, 1913.
541. Le Temps Qu'il Fait, "Pluviometres enregistreurs. " (Recording rain gages), Le Temps Qu'il Fait, (Bruxelles), 2(13):48-50, January, 1905, 2 figs.  
The Negretti and Zambra tipping-bucket rain gage is illustrated and described. An electrical system which permits separating the gage and the recording unit is discussed.
542. Leupold and Stevens Instruments, Inc. , "Stevens precipitation recorders." Bulletin 19, 4thEd. Leupoldand Stevens Instruments, Inc. (note: A trade circular)Bull. 19, 4th ed. p. 1-7, 1950 +, 10 figs, 3 tables .  
A trade circular discussing, illustrating and giving specifications for the Stevens' rain and snow gages. Two types of recording gages are manufactured - (1) Weight type and (2) Float type. The weight type gage is without springs, ensuring greater accuracy. Standard records are available from 6 in. to 60 in., and periods from six hours to several months. A telemetering device is available for distant recording. The float-type gage is for rain only and employs a water-level indicator for determining and recording amount of water in the receiver.
543. Leutmann, J. G. , "Instrumenti Meteorognosia Inserventia. . ." (Instruments serving for meteorological knowledge), Wittenberge, 1725.
544. Levert, C. , "Uiterst zware Regens. " (Netherlands), (Extreme heavy rain), Hemel en Dampkring, 49(2):32-35, 1951, 2 figs, 1 ref.  
Author plots greatest rainfall  $h$  mm. in time  $t$  minutes (log  $h$ , log  $t$ ) and fits straight lines of the form  $h = a\sqrt{t}$ , from 1 minute to 1 week, for the whole world  $a = 47$ , for Holland, all stations since 1850  $a = 66$ , for DeBilt pluviograph 1926-48  $a = 2.3$ . (Netherlands)
545. Levine, J. , and Kleinknecht, K. S. , "Adoption of a cascade "impactor to flight measurement of droplet size in clouds. " National Advisory Committee for Aeronautics, Research Memorandum E51G05, September 18, 1951, 12 figs, 6 refs, 13 eqs.  
A cascade impactor has been adopted for flight cloud-droplet studies. This instrument relies on inertia to separate droplets from the air stream according to size, in a manner more direct than the multi-cylinder method. Coated slides are located at 4-90° turns, imposed on an air stream whose velocity is increasing; thus each slide catches a different size range.
546. Levy, L., "Van Rysselberghes algemeiner Meteorograph. " (Van Ryselbergh's general meteorograph), Zeitschrift fuer Instrumentenkunde, 2:233-238, July, 1882, 2 figs.  
A tipping-bucket gage, electrically operated, is incorporated in a meteorograph that measures several elements.
547. Lindholm, F., "Is the accuracy of precipitation measurement dependent upon the area of the receiver of the gage?" Monthly Weather Review, 52:262-264, May, 1924, 5 tables, 2 refs.  
Unshielded gages of 200 and 1000 cm<sup>2</sup> caught same rainfall within 2.4% and snowfall within 3.9%. Shielded catches same in rain, but smaller gage 4.5% more in snow. Shielded gage at Sarna caught 33% more than unshielded from November to April and 5% more from May to October. Shielded at Abisko 9%, 11%, 23% and 14% more snow at 0-4, 4-9, 10-14, and above 14 m/s, and 2 to 3% more rain.

548. Linke, F., "Niederschlagsmessungen unter Baeumen." (Rain measurements under trees), Meteorologische Zeitschrift, p. 277, September, 1921, 1 table.  
Notes that under a tree the catch may be affected by fog condensing on the leaves and dripping into the gage.
549. Linke, F., "Zwei neue meteorologische Fernregistrierapparate." (Two new meteorological distant registering apparatuses), Bioklimatische Beiblaetter der meteorologischen Zeitschrift, 7:142-144, 1940, 4 figs.  
Two distant recording devices to transmit temperature, humidity and precipitation are described. The rainfall registering device is on the float principle, and the design was made adaptable to the Hellmann-Fuess automatic-siphon self registering gage. The rotation of a wheel of variable resistance is calibrated to transmit the required intelligence.
550. Leopold, Jacob., "Theatrum staticum universalis, sive theatrum staticum, das ist:" "Schau-Platz der Gewicht-Kunst und Waagen..." (Gallery of ingenious accomplishment with weights and scales), Leipzig, 1726, 9 figs.
551. Linsley, R. K., "New precipitation gage used by the Weather Bureau." Engineering News-Record, 135:127, October 4, 1945, 1 fig.  
Gages (Sacramento type), capable of holding 200 inches of precipitation, are mounted on high towers and left throughout the winter to record snowfall. Alter shields are used as windshields and CaCl<sub>2</sub> keeps the solution in a liquid form.
552. Linsley, R. K., "Nipher, Alter, and other shields on snow gages compared." American Meteorological Society Bulletin, 28(9):443-444, November, 1947.  
Nipher probably slightly better than Alter, but needs attendance.
553. Lipp, H., "Ueber die Ausmessung von Gidrien und ueber die Ausmessung des hypelhelarmigen Nebelbigens." Meteorologische Zeitschrift, 50:161,165, 1933.
554. Loewenherz, L., "Der meteorologische Pavilion und die meteorologischen Instrumente." (The meteorological pavilion and meteorological instruments), Berichte ueber die allgemeine deutsche Ausstellung auf dem Gebiete der Hygiene und des Rettungswesens, 1882-3, p. 118-140, 1885, (Breslau) 12 figs, 1 ref..  
Figures of recording instruments-and description of their operation. The Sprung-Fuess float-gage, employing mercury for the float in manometer connection with a self-siphoning rain gage, is illustrated and described. The siphon cycle operates every 4 mm. of rain. Many non-recording weather instruments are described.
555. London Science Museum, "Catalogue of the collections in the Science Museum, South Kensington, Meteorology." His Majesty's Stationery Office, London, p. 65-71, 1922.  
A resume<sup>1</sup> of rain measurement. Descriptions are given of 19 non-recording gages and 6 recording gages that are on exhibit.
556. Long, T. L., "A comparison of snowfall catch in shielded and unshielded precipitation gages." American Meteorological Society Bulletin, 28(3):151-153, March, 1947, 1 table.  
Results of 2-year snow measurement experiment at LaCrosse, Wisconsin in an exposed location.
- |                              |           |          |      |
|------------------------------|-----------|----------|------|
| Alter shielded - Std. 8 in.  | 17 storms | 6.59 in. | 96%  |
| Unshielded-recording (Friez) | 17 storms | 5.14 in. | 75%  |
| Unshielded-Std. 8 in.        | 17 storms | 4.43 in. | 65%  |
| Ground Measurements          | 17 storms | 6.86 in. | 100% |
- 90% of snow fell with winds under 15 mph.

557. Lonschar, C. , "Pluviometri. " (Rain gages), Filotecnica (Milan), 1938.
558. Lowe, Frederick, "Demerits of rain gages 'one foot from the ground'." Meteorological Magazine, 52(620):91-92, September, 1917.  
Correspondence.
559. Lundstrom, C. F. , "Simple and cheap rain gages. " Kongl Landbruks - Akademiens Handlingar och Tidskrift (Stockholm), 42:134-135, 1903.
560. Lutschg, O. , "Ueber Niederschlag und Abfluss im Hochgebirges." (About precipitation and runoff in high mountains), Schweizer Wasserwirtschaftsverband, Verbandschrift, Zurich, No. 14:109, 1926.
561. Lutschg, O. , "Zur Erforschung der Niederschlagsverhaeltnisse des Hochgebirges." (Research on precipitation conditions in high mountains), Schweizerische Meteorologische Centralanstalt Annalen 1938, Zurich, An. 1(65):10-14, 1930.  
(Parde M. , Precipitation et ecoulement en haute montagne, Revue de Geogr. Alpine, 14:p. 818-838; and Parde, M. Les reserches hydromet de M. O. Lutschg en haute montagne, Ann. de Geogr. 1931: 292-294) - Swiss windshield totalizers highly recommended, though in greater number than usually employed, also with greater care as to site. A shielded gage one year caught .1. 7% excess over unshielded, and 21.6% excess another year. These two gages were not far apart, but in different exposures. One February the shielded was 49% in excess.
562. Lutschg, O. , "Zur Wasserwirtschaft des Kraftwerkes Waeggital." (Concerning the operation of the Waggital power house), Siebnen, Switzerland, p. 23, 1930.
563. Lutschg, O. , "Zur Hydrologie des Hochgebirges der Schweizer Alpen. " (The hydrology of the high mountains of the Swiss Alps), 13th International Geographical Congress, Paris, Comptes Rendus, 2:378-407, 1933  
Re-emphasis of importance of numerous stations and effect of wind on catch in different spots. Runoff was found to be 0. 9 of the measured precipitation. CFB.
564. Lutschg, O. , "La Baye de Montreux, Rapport sur le but des recherches enterprises dans le bassin de la baye de Montreux, les installations que ces essais ont necessitees et le methode de travail adoptee." (The Bay of Montreux. A report on the aim of research undertaken in the basin of the Bay of Montreux. The installations and method of operation), L'Institut Federal de Recherches Forestieres, Annales De Zurich, 19(1), 1935.
565. Lutschg, O. , "Der Kugelniederschlagsmesser. Haas-Lutschg, Ein Beitrag zur Loesung des Niederschlagsproblems im schweizerischen Hochgebirge." (The spherical precipitation recorder Haas-Lutschg. A report on the solution of the precipitation problem in the high mountains of Switzerland), Gerlands Beitrage Zur Geophysik, Vol. 50: 423-444, 1937.  
A "dynamic precipitation gage," spherically shaped with numerous round holes covering the surface. On a steep windward slope, near a crest, the gage gave an excess of 14-35% over 4 years of summer precipitation.
566. Lyons, H. G. , "An early Korean rain gage." Royal Meteorological Society, (London) Quarterly Journal, 50:26, 1924, 2 refs.  
"They were in the form of heavy bronze cylindrical vessels about 15 in. high and 7 in. in diameter, and were set up in stone blocks which were recessed to receive them." Weighed about 15 lbs. Existing ones date from the end of the 18th century and the beginning of the 19th. One series was made in 1770.

567. McAdie, A. J., The Principles of Aerography, p. 210, 1917.  
Catches of rain gages on roots are low.
568. McCullough, S., and Perkins, P. J., "Flight camera for photographing cloud droplets in natural" suspension in the atmosphere." National Advisory- Committee for Aeronautics, Research Memorandum E-0-Kola, June 29, 1951, -10 figs., 2 refs., and 1 eq.  
A camera designed for use in flight has been developed to photograph cloud droplets in the atmosphere. A magnification of 32 times is used to measure droplets greater than five microns in diameter.  
Flight tests have shown that approximate droplet size distribution studies, can be made by use of the camera.
569. Mace, J., "Rain gage measuring glass." Symons' Meteorological Magazine, 37:73, 1902.
570. Mace,, J., "The design of rain gages." Meteorological Magazine, London, 57(683):308, December, 1922.  
In a short note, it was pointed out that for fifty years; the gage with a higher rim (Snowdon) caught more than the British Association gage with no rim above the funnel.
571. Mackereth, T., Manchester Literary and Philosophical Society, Proceedings, 9:28, 1869-1870.  
The relation between rain and wind.
572. Mackereth, T., "Results of rain gage and anemometer observations at Eccles near Manchester." Manchester Literary and Philosophical Society, Memoirs and Proceedings, 9:124, 1869-70.
573. Mackereth, T., "Results of rain gage and anemometer observations at Eccles near Manchester." Manchester Literary and Philosophical Society, Memoirs and Proceedings, 10:140, 1872-73.
574. Mackereth, T., "Results of rain gage and anemometer observations at Eccles near Manchester." Manchester Literary and Philosophical Society, Memoirs and Proceedings, 11:113, 1873-74.
575. Maclear, J. P., "Rain gages." Symons' Meteorological Magazine, 39 (468):233, January, 1905.
576. McNutt, J. J., Alcorn, W. B., "Weight vs. Melting method for determining density of snow." American Geophysical Union, Transactions, Pt. 2, p. 655-657, July, 1937, 1 table.  
The Weather Bureau section-cutting method is compared with the Mt. Rose snow-sampler to determine the water content of snow cover. Over a 2-year period the Weather Bureau Method was consistently less (3%). Difference attributed to: (1) difficult Weather Bureau procedure, (2) blunt edge of rain gage, and (3) no provision for releasing air in rain gage.
577. Maille, P. H., "Nouvelle theorie des hydrometres" (New theory of hydrometers), p. 278, Paris, 1853.
578. Malkus, W. V., Bishop, R. H., and Briggs, R. O., "Analysis and preliminary design of an optical instrument of the measurement of drop size and free-water content of clouds." National Advisory Committee for Aeronautics, Tech. Note, 1622, June, 1948, 17 figs., 6 refs., many eqs.  
. . . A method for determination of drop size and free water in clouds based on an interpretation of an artificially created rainbow. "A recording galvanometer having a deflection proportional to photocell current and having uniform film speed will generate a curve representing rainbow function as a function of viewing angle." This preliminary design heeded laboratory conditions to operate..
579. Malsch, W., "Vergleich von Niederschlagsmessungen mit. einen freistehenden und einem in die Erde yersenkten Regenmesser" (Comparison of rainfall measurements with a free rain gage and one sunk in the ground), Deutscher Wetterdienst in der U.S. Zone, Berichte No. 35, p. 316-320, 1952:
580. Maltais, J. B., "New recording rain gage." Scientific Agriculture, 16: 495-498, May, 1936, 7 figs., 1 eq.

A weight-type weekly recording gage is described and illustrated. It consists of a counter-poised receiver on one side of a fulcrum and a weight and pen-arm on the other side. Water is led into the receiver from a 5 in. gage funnel and as the receiver descends, due to this added weight, the counter weight and attached pen-arm move upward. This upward movement is calibrated and a record is made on a clock-operated drum. The capacity of the gage is 2.30 in. of rain and magnification is approximately 3 to 1. No provisions are made for automatically siphoning or emptying of the receiver. In operation, results were reported as satisfactory.

581. Maguene, H., "Recherche, surle pouvoir emissif des feuilles" (Research on the emissive power of leaves). Academie des Sciences, Paris, Comptes Rendus, 80:1357-1359, 1875.  
 (Reviewed in Osterreichische Gesellschaft duer Meteorologie 10 (22):353, November, 1875). Rain gages were not good for dew measurement. Painting them black resulted in some improvement.
582. Marriot, W., (Exhibition of rain and evaporation gages and other meteorological instruments), Nature (London), 43:446, 1891.  
 A discussion of rain gages exhibited.
583. Marsh, B., "Effect of wind on rainfall." Civil Engineering, 11(10):611-12, October, 1941, 1 fig.  
 A vertical surface will catch more precipitation as the wind velocity increases.
584. Martin, J. E., "Nivometres Totalisateurs" (Snow gage totalizers). La Meteorologie, 3(22):230-232, July-August, 1939.  
 Concludes that records of snow gage totalizers, as far as fall of snow are concerned, are at present worthless; only personal observation of snowfall can be relied on.
585. Marvin, C. F., "A self-recording rain gage." Science, 11:97-98, February 24, 1888, 1 fig.  
 [(Sig. Service Dept.) Abstract in Zeits. fuer Inst. 1888, p. 180-181, float-type gage.]
586. Marvin, C.F., "Aneight-day mechanically recording rain gage." Monthly Weather Review, 43(1):26-28, January, 1915, 4 figs.  
 Marvin gage designed on a float principle and a 10-inch capacity. A valve is provided for emptying the receiver. Pen-arm oscillates so that one cycle equals 1 in. precipitation. Square Nipher shield is provided.
587. Marz, E., "Schauerchronograph" (Showerchronograph). Zeitschrift fuer Instrumentenkunde, Berlin, 56(167-170), April, 1936, 5 figs.  
 An ingenious device that combines a precipitation detector with a Gallenkamp intensity recorder. A screened area is exposed to the weather. As soon as a drop of water hits the screened area an electrical circuit is closed and in  $\frac{1}{2}$  minutes a door or lid rotates over the detector and protects it from the rain. The closing of the lid actuates a heater that quickly dries the detector. By interlocking with the Gallenkamp intensity gage the lid stays shut, if rain is falling. As soon as it stops, the lid swings open and the apparatus is ready for future falls. Fog is detected but the first drops of snow are not recorded. It is anticipated that by minor design changes, it can be made to operate in all weather.
588. Massachusetts Institute of Technology. Dept. of Meteorology, De-icing Research Laboratory, "Reduction of rotating cylinder data; instructions for calculating the liquid water content. Effective drop size and effective drop distributions from rotating cylinder data obtained from average speed aircraft." Mass. Institute of Technology, De-icing Lab., Cambridge, Mass., October, 1945, 15 figs.
589. Matthews, L. S., "A cause of error in self-recording rain gages." Meteorological Magazine, 72(864):283-287, January, 1938, 2 figs., 1 eq., 1 ref.  
 Characteristic curves are presented for losses of a Dines tilting siphon gage during siphoning action (average - 17 sec). At a rate of 6 in./hr. about 0.03 in. of the record would be lost each time the gage siphoned. Siphoning for this particular gage (11.3 in. dia.) amounted to 5 mm. or about .20 in., approximately 15%.

590. Maulard, J., "Mesure dunombre de gouttes de pluie" (Measurement of the number of raindrops). Journal Scientifique de la Meteorologie, 3 (10):69-73, April-June, 1951, 6 figs.  
A distant recording device has been constructed which will measure the number of snowflakes or raindrops falling per minute (or second) over a given area, without the presence of an observer. A telephone receiver is modified to reduce the effects of the sound waves and to allow the water to run off. Each drop which strikes the membrane creates an impulse which is amplified and sent to a recorder. Wiring and schematic diagrams and examples of records are presented. Differences between records for rain storm, a snow storm and a thunderstorm is shown vividly.
591. Maurer, H., "Selbst-registrierender Regenschauer aus der maschinistischen Werkstaette von Hottinger Zurich & Cie" (Self-registering rain gage from the Hottinger and Co. shops in Zurich). Zeitschrift Oesterreichische Gesellschaft fuer Meteorologie, 19:179-181, 1884, 2 figs., 1 ref.  
Maurer's combination tipping bucket and weight-type gage is pictured and described. The bucket (or receiver) descends until a total of 20 mm. precipitation is caught. A tripping action allows the bucket to tip and empty and to ascend to its original position. This action is calibrated for recording.
592. Maurer, H., "Zur Methode der Untersuchungen uber die Schwankungen der Niederschlagsmengen" (Methods in research on fluctuations in quantities). Meteorologische Zeitschrift, 28(3):97-114, March, 1911, 3 figs., 7 tables, 4 refs .
593. Maurer, J., "Einige Ergebnisse unserer hoechsten Niederschlagssammler im Firngebiet" (Some results from our highest precipitation collectors in the glacial region). Meteorologische Zeitschrift, 32:16-20, 1915, 2 figs., 1 table, 2 refs.  
Earliest totalizer, 1897, cubic bin with 1 sq.m. opening was not satisfactory. Replaced about 1910 with Mougins gage 50 x 95 cm. with 200 cm<sup>2</sup> orifice, and in 1913 surrounded by Nipher shield lacking horizontal lip, which increased catch about 20%. CaCl<sub>2</sub> used to prevent freezing and vaseline to prevent evaporation.
594. Maurer, J., Collet, L., "Die Niederschlagsmessung im Hochgebirge" (Precipitation measurement on mountains). Schweizerische Wasserwirtschaft, 7(6/9), from Archives der Sciences Physiques- et Naturelles, Ser. 5(4):344. Resume in Annalen der Schweiz crischen. Meteorologischen Zentral anstalt 1913, p. 4-5.
595. Mawley, E., "A few simple directions for the measurement of snow under various conditions." British Rainfall, p. 35-38, 1880.  
Instructions given to observers using shallow rimmed gages, deep rimmed gages, and snow gages. Recommended using warm water to melt collected snow.
596. Meares, J. W., "The experimental development of an automatic integrating intensity rain gage without clock work." The Institution of Civil Engineers, Selected Engineering Papers, London, No. 2, p. 1-29, 1923, 15 figs., 10 tables.  
Two gages that J. H. Field was instrumental in designing are described. (1) A registering gage developed on the leak principle. Water from a funnel flows out of a horizontal orifice. The length of its trajectory is proportional to the rainfall rate. Three containers, each representing a rate of precipitation, are arranged beneath the nozzle and the catch thereby gives a total and indication of the intensity. (2) A recording gage whereby water flows into a receiver suspended from a counterweighted arm connected to a recording system (drum and pen arm). A nozzle on the bottom of the receiver will empty the receiver at a constant rate. When the inflow exceeds the outflow the increased weight of the receiver is transmitted to the recording system. This is proportional to the rate of precipitation.
597. Meikle, H., Annals of Philosophy, Vol. 14:312', 1819.  
"Perhaps the winds being made to rush with greater rapidity, and a little upward in beginning to pass over the mouth of the gage, prevent the rain from falling into that part of it which is next the wind."

598. Meinzer, O. E., "Hydrology." Textbook; McGraw-Hill Book Co., Inc., New York, p. 40-45, 1942, 3 figs., 3 tables.  
In a chapter on precipitation by M. Bernard, brief mention and description of an illustrated Friez gage is given. The gage is equipped with an Alter shield.
599. Melin, R., "Snow surveying in Sweden." Bull. N. 23, Sixieme Assemblée Generale a Edinbourg du 14 au 26 Sept. 1936. Assoc. Int. d'Hydrologie Scien. Transactions of meetings of the Int. Comm. of Snow and of Glaciers (Riga), p. 123-132, 193b, 4 tables, 3 refs.  
Comparison between snow survey and rain gage showed the rain gage deficient by 35% (avg.) for eight years. The gages were not shielded. Preliminary work was being done with totalizers of the Mougins type and indications were that they would be unsatisfactory in Sweden.
600. Mellet and Mercanton, "Application de l'analyse chimique a la mesure du contenu des totalisateurs des precipitations, systeme Mougins" (Application of chemical analysis to measuring the contents of totalizers). Archives des Sciences Physiques et Naturelles. Geneve. December 15, 1916.  
(Appears in "Giornale del Genio Civile--May, 1917.)
601. Mercanton, P. L., and Lugeon, J., "L'electrosonde MZA pour la Mesure du contenu des totalisateurs de precipitation (Mougins)" (Electrical sounder of the Central Meteorological Station for the measurement of (Mougins) totalizers of precipitation content). Schweizerische Meteorologische Zentralanstalt. Annalen, 72(8), 1935, 2 figs., 1 eq.  
An electric rod lowered into the totalizer measures the depth to the surface of the liquid, through the oil layer, with an accuracy of 0.1 mm. The CaCl<sub>2</sub> solution being an electrolyte gives a positive response as soon as the tip of the rod touches it.
602. Mercanton, P. L., and Billwiller, R., "Indications pour l'emploi des totalisateurs de precipitations" (Instruction for the use of totalizers). (MZA). Annalen der Schweizerischen Meteorologischen Zentralanstalt., 72(7a), 1935, 2 figs., 1 table.  
A Mougins totalizer equipped with a modified Nipher shield is described, and instructions are given for the observer. Weighing is recognized as the most accurate method of determining content.
603. Mercanton, P. L., "Un totalisateur de precipitations simple" (A simple totalizer for precipitation). Zurich, Schweizerische Meteorologische Zentralanstalt, Annalen 7, Vol. 74, No. 7, 1937, 1 fig.  
An ordinary can (cylindrical type) gage enlarged to hold a large amount is mounted on a tower. The totalizer is charged with an oil-coated CaCl<sub>2</sub> solution.
604. Mercanton, P. L., "La Mesure correcte des precipitations atmospheriques" (The correct measurement of atmospheric precipitation). La Meteorologie, Paris, Series 3(7-12):136-139, March-April, 1937.  
(U.G.G I. Assn. Met. Proc. Verb. Edinburgh, 1936, No. 2:297-301.)
605. Mercanton, P. L., "Recherches de technique pluviometrique."  
I. Comportement aerodynamique de Quelques pluviometres.  
II. Le pluviometre aerodynamiquement neutre. Deux Realisations. (Investigations of pluviometric technique.) Schweizerische Meteorologische Zentralanstalt. Annalen Pls. 3, 75(8), 1938, 26 figs., 5 refs.  
Tests of various gages hydrodynamically and aerodynamically indicated that a lowering of the wind shield with respect to the orifice was desirable. Many different types of gages are presented with comments on their practicability. An ellipsoidal shield displayed was recommended for laboratory use, as wind tunnel tests indicated it was aerodynamically neutral.
606. Mercanton, P. L., "Un pluviometre aerodynamiquement neutre" (An aerodynamically neutral rain gage). Helvetica Physica Acta, 11:553-556, Basel, 1938.  
This is a summary of a previous article written by him in the Schweizerische Meteorologische Zentralanstalt Annalen on the requirements of an aerodynamically neutral rain gage. Again recommends an ellipsoidal shield that completely encloses a Hellmann gage. The upper portion of the gage is perforated to prevent splash and heating melts accumulations of snow or rime.

607. Mercanton, P. L., "Recherches de Technique Pluviometrique. III Essais Comparatives sur le toit de la station meteorologique centrale a Zurich." (Investigations of pluviometric technique. III) Schweizerische Meteorologische Zentralanstalt. Annalen, 76(9):1-5, 1939, 4 figs., 1 table, 1 ref.  
Comparative tests on the roof of the Meteorological Central Station at Zurich. Tests were made to determine an aerodynamically neutral shield. Two shields, one of an ellipsoidal shape, and the other shaped as a pulley were tested and found satisfactory. Hydrodynamic and aerodynamic tests were made on several models of European gages. Most experiments indicated that the orifice of the gage should be an inch or two above the level of the shield. One surprising observation was that the Norwegian square gage and shield (when orifice was 7 cm. above shield) was practically neutral in the wind.
608. Mercanton, P. L., "Recherches de technique Pluviometrique, IV-VI" (Research in techniques of measuring precipitation). Schweizerische Meteorologische Zentralanstalt, 77:1-8, 1940, .5 figs., 2 tables., 4 refs.  
IV. A new non-electrical sounder; V. Layout of field used for gage tests at Sentier, Vallee de Joux; VI. On determining the density of calcium chloride solutions.
609. Mercanton, P. L., "Recherches de technique pluviometrique."  
VII. Comparaison de totalisateurs a la Grimsel.  
VIII. Comparaison de fonctionnement d'un pluviototalisateur avec un pluviometre normal.  
IX. Essais a la MZA du pluviometre a ecran on forme de poulie, (Investigations of pluviometric technique). Schweizerische Meteorologische Zentralanstalt, Annalen, Zurich, 81:46, 1944, 2 figs. 1 table, 1 ref.  
VII. Comparison of Grimsel totalizers. VIII. Comparison of the functioning of a pluvio-totalizer with a normal pluviometer; IX. Tests at the Swiss Central Meteorological Station with a pluviometer having a shield in the form of a pulley. Earlier tests showing that the orifice should be above the level of the shield have not been carried out because of snow filling the annular space between gage and shield, and thus vitiating the readings.
610. Mercanton, P. L., "Les recherches de technique pluviometrique et la nouvelle carte des precipitations de la station centrale Suisse de Meteorologie" (Research on rainfall technique and the new rainfall chart of the Swiss Central Meteorological Station). La Meteorologie, Ser. 4(15):173-178, July-September, 1949, 4 figs.  
Brief summary of results of investigations carried out at Zurich and published in the Annals of that station for the years 1937, 1938, 1939, 1940 and 1944. An attempt has been made to devise aerodynamically neutral rain gages, and automatic snow and rain gages for high mountain stations and to improve control of CaCl<sub>2</sub> solutions in such gages. Comparisons were made between types of gages and exposures at mountain stations. An improved rainfall chart for Switzerland is described. Says that two gages have proven to be aerodynamically neutral: one gage in the form of an ellipsoid and the other in the form of a pulley.
611. Mescart, J., "Mesure de la hauteur de la pluie." Revue Generale des Sciences Rures et appliques, No. 41:434-436, Paris, 1932-33.
612. Meteorologie Nationale, "Notice sur le pluviometre 'Association' Mesure des precipitations" (Note on the pluviometer "Association" measurement of precipitations). Meteorologie Nationale, Paris, p. 9, 1948, 14 figs.
613. Meteorologia Practica, "Un nuovo recipiente graduato per misurare la Pioggia" (A new graduated receptacle for measuring rainfall). Meteorologia Practica, p. 60, January-February, 1925.
614. Meteorological Magazine, "On fixing rain gages." Meteorological Magazine, 1(3):25, April, 1866.
615. Meteorological Magazine, "Rain gage experiments." Meteorological Magazine, Vol. 1, No. 12, p. 105, January 1867.  
Correspondence.

616. Meteorological Magazine, "Incomplete rain gage experiments." Meteorological Magazine, 1(11):96-97, December, 1866.
617. Meteorological Magazine, "Beckley's self-recording rain gage." Meteorological Magazine, 6(64):53-55, May, 1871, 2 figs.
618. Meteorological Magazine, "Raingages and the Vienna conference." Meteorological Magazine, 9(101):77- , June, 1874.  
Quote from "Nature."
619. Meteorological Magazine, "Science at South Kensington; rain gages." Meteorological Magazine, 11(130, 131):141-143, 153-154, November-December, 1876, 2 figs., 11 refs.  
Two rain gages are pictured and discussed. (1)The Stutter self-recording gage, consisting of gage with 12 or 24 compartments arranged in a circle. A clock regulates a tube from the funnel so that the time and amount of rain may be obtained by the amount of water in the compartments. (2) A Yeates (improved Crosley) tipping bucket gage with an electric system for registering the number of tips.
620. Meteorological Magazine, "M. Herre - Mangon's pluviroscope." Symons' Monthly Meteorological Magazine, 22(261):135-136, October, 1887, 1 table, 1 ref.  
An ombroscope that exposes a water-sensitive disc to the atmosphere to determine hours of precipitation. Some results for 10 years in Paris (1860-1870). Avg. number of days with rain, 188; avg. number separate fall days, 662; avg. number separate fall nights, 576; avg. duration shower, 21 minutes; average 1 1/4 hours precipitation in 24 hours.
621. Meteorological Magazine, "A lost opportunity-recording rain gage." Meteorological Magazine, 30(354):88, July, 1895.  
Lists observatories not having rain gages. An important storm was missed.
622. Meteorological Magazine, "Negretti and Zambra's self-recording rain gage." Meteorological Magazine, 34(399):36-38, April, 1899, 1 fig.  
Tipping bucket.
623. Meteorological Magazine, "Graduation of rain glasses." Symons' Meteorological Magazine, 39:30-31, 1904.
624. Meteorological Magazine, "Lander and Smith's new pattern rain gage." Symons' Meteorological Magazine, 39:89, 1904.
625. Meteorological Magazine, "Lander recording rain gage." Symons' Meteorological Magazine, 42:4-5, 1907.  
Siphon gage (automatic).
626. Meteorological Magazine, "Casella's insulated rain gage." Symons' Meteorological Magazine, 45:182-183, 1910.
627. Meteorological Magazine, "British rain gage." Meteorological Magazine, 48(574):183, November, 1913.
628. Meteorological Magazine, "Rain gages with rims of different shapes." Meteorological Magazine, 55:94, 1920.  
Two tapers of rim were tested for five months. A very small difference (1 part per 1000) in favor of sharp edge on the inside of the rim.
629. Meteorological Magazine, "On the design of rain gages." Meteorological Magazine, London, 56(666):142-145, July, 1921.  
Specifies 7 points for ordinary gages and 6 for recorders. (1) Stout, sharp edge brass rim, (2) 4 in. to 6 in. from top of rim to top of funnel, (3) a removable inner collecting receiver, (4) at least 6 in. of body to be firmly fixed in the ground, (5) avoid rivets, (6) strength and durability, (7) minimum daily capacity of 10 in.
630. Meteorological Magazine, "Standardized rain gages." Meteorological Magazine, 57(674):49, March, 1922.  
In a short article, it was pointed out that dial gages are unreliable after 2 or 3 years because of faulty indicators.

631. Meteorological Magazine, "Comparison of rain gage sites." Meteorological Magazine, 57:104, May, 1922.
632. Meteorological Magazine, "Rain gages in the London parks." Meteorological Magazine, 59:214, October, 1924.  
Correspondence.
633. Meteorological Magazine, "Testing of rain gages." Meteorological Magazine, 59(706):247, November, 1924.
634. Meteorological Magazine, "Tapered rain measure." Meteorological Magazine, 61:191, September, 1924, p. 265, December, 1925, and p. 14-15, February, 1926.
635. Meteorological Magazine, "Leaky rain gages." The Meteorological Magazine, London, 61(722):46-47, March, 1926.  
Leaky gages were found to: (1) give high values as well as low ones, (2) have large errors due to apparently insignificant leaks. In periodic tests of rain gages, each part should be tested by filling with water to insure that it is water tight.
636. Meteorological Magazine, "Experiments with a shielded rain gage." Meteorological Magazine, 61(724):87-88, May, 1926.
637. Meteorological Magazine, "Rain gages in frosty weather." Meteorological Magazine, 65:162-163, August, 1930.
638. Meteorological Magazine, "New 'Octapent' mountain rain gage." Meteorological Magazine, London, 66(784):87-89, May, 1931, 1 fig.  
A British 8 in. gage is equipped with a 5 in. rim and funnel to provide a gage with large capacity for locations where it may be left unattended.
639. Meteorological Magazine, "The Dines tilting siphon gage." Meteorological Magazine, 70(838):237-238, November, 1935, 2 figs.  
The Dines tilting siphon gage was chosen because in tilting, a positive siphon action took place and therefore did not give dribbling trouble during light rain. To make the point of tipping more regular in action, a holding catch, triggered by the rising float, was added. (Siphoning interval is between 15 and 20 seconds.)
640. Meteorological Magazine, "A time-recording rain gage." (Typescript). Meteorological Magazine, p. 10, December-February, 1943-1944.  
Devised by H. Neuberger, has 24 glass plates with smoked surface which revolve so as to expose one each hour" Examination of smoked plates subsequently serves to determine beginning and duration of rainfalls.
641. Meteorologicheskii Vestnik., "Hionograph von Hellmann und pluviograph von Rordanz" (Hellmann's hionograph and Rohrdanz' pluviograph). Messageur Meteorologique (Met. Vest.), 16:502-504, 1906, 1 fig., 1 ref.  
A description of the Rohrdanz gage. This gage is unique in that it has a siphon section in the bottom of the catch bucket that permits emptying every 10 mm. of precipitation. For winter use, a cap is screwed over the siphon section to isolate it, as the siphon is not operated at temperatures below freezing. Thus, it is a combination weight-siphon gage in the summer and a weight-type in the winter. The drum rotates once every 24 hours.
642. Meteorologie Nationale, "Notice sur le detecteur 'Avertisseur' de precipitations - Modele MN - 1948" (Note on the detector "Announcer" of precipitations - Model M.N., 1948), Centre d'Essais et de controle technique. Meteorologie Nationale, Etablissement Central de la Meteorologie, 0 June, 1949, 3 figs.  
A precipitation detector is described that consists of a grid on a plastic plate exposed to the atmosphere. Water droplets hitting the grid caused a short circuit, which was relayed to a recording system. This, in turn, caused a cover to rotate over the grid and protect it from exposure until an enclosed light bulb dried the grid. When the grid became dry the operation was repeated. Troubles: (1) too many relays that are over-sensitive, (2) the grid was difficult to dry, (3) dry snow was ineffective in producing a short circuit, and (4) fog and dew caused the apparatus to work.

643. *Meteorologie Nationale*, "Instruction concernant le montage et L'entretien du detecteur avertisseur de precipitations. Modele M.N. 1948" (Instructions for erecting and maintaining the detector "Announcer" of precipitations. Model M.N. 1948). *Meteorologie Nationale, Paris, C. T. M. Secretariat General a l aviation civile et commerciale*, January, 1950, 1 fig.  
Instructions for operating a rain detector. A wire grid is exposed and the short circuit is the mode of indication.
644. *Meteorologische Zeitschrift*, "Genauigkeit bei Regenmessen" (Accuracy in rain measurement). *Meteorologische Zeitschrift*, 24(6):156, April, 1889-90.  
This is an abstract of an article on an experiment in Basel, Switzerland, with two rows of different type gages whose orifices are at the same elevation.
645. *Meteorologische Zeitschrift*, "Einfluss der Hoehe der Aufstellung des Regenmessers auf die gemessene regenmenge" (Influence of altitude on the registration of rain gages and the total catch). *Meteorologische Zeitschrift*, 33:193, 1898, 1 table, 3 refs.  
Note on Heberden's and Symons' work on altitude with relation to rain gage catch.
646. *Meteorologische Zeitschrift*, "Partielle Regenmessung" (Partial rain measuring), (J. Joly. Avs. Scientific Proceedings of the Royal Dublin Society, 1900). *Meteorologische Zeitschrift*, 19(37):575-576, December, 1902, 1 ref.  
An abstract of an article appearing in Royal Dublin Society Science Proceedings, November, 1900, p. 283 on catch of rain samples for chemical analysis.
647. *Meteorologische Zeitschrift*, "Zur Niederschlagsmessung auf einen Berggipfel" (The measurement of rain on a mountain top). *Meteorologische Zeitschrift*, 52:33-34, January, 1935, 1 table, 2 refs.
648. Meyer, A. F., "Elements of Hydrology." *Textbook; John Wiley and Sons, New York*, p. 78-86, 1917, 8 figs., 1 table, 1 ref.  
In a chapter on precipitation the U. S. Weather Bureau standard gage, tipping bucket, and Marvin Float recording gage are illustrated and described. Exposure of rain gages is discussed as are some of the difficulties of snow measurement.
649. Middleton, W. E. K., "A new electrical rain gage." *American Meteorological Society, Bulletin*, 19:265, June, 1938.  
Author's abstract on improvements in a tipping bucket gage.
650. Middleton, W. E. K., "Meteorological Instruments." *Toronto, University of Toronto Press*, 2nd ed., p. 102-116, 1943, 169 figs., 10 eqs., many refs.  
In this second edition of the book, that was published first in 1941, the author discusses the underlying principles, construction and use of meteorological instruments usually found at meteorological stations. The book is copiously illustrated and contains references to original papers.
651. Mill, H. R., "The development of rainfall measurement in the last forty years." *British Rainfall*, 40:23-45, 1900, 7 figs., 4 tables, numerous refs.  
Summarizes some experimental results over a period of 40 years; (1) copper makes a very good funnel, (2) a sharp rim is necessary to minimize splashing, (3) variation of catch with height, and (4) diameter of gage is not important with regards to accuracy. On point (4) Symon concluded "The less the diameter of an elevated gage, the less that it will indicate." A good bibliography included.
652. Mill, H. R., "Best form of rain gage, with notes on other forms." *Royal Meteorological Society (London). Quarterly Journal*, 33(144):265-274, October, 1907, 6 figs., 3 tables.  
A discussion of the requirements of a good rain gage. Concluded that the Snowdon, Bradford, and Meteorological Office 8 in. gage were the most acceptable. The Glaisher gage—because of poor construction—was no longer considered acceptable.

653. Mill, H. R., "British rainfall organization, with rules for rainfall observers," 12 p., London, 1907.
654. Mill, H. R., "New recording rain gages." British Rainfall, No. 48:22-27, 1908, 5 figs., 1 ref.  
The mechanism of the Halliwell and Hyetograph recording rain gages is described with diagrams and reproductions of the actual traces. The mechanism of the "Natural Siphon" pattern gages, which are now available, is simpler and these are now recommended.
655. Mill, H. R., 'Seathwaite' pattern rain gage." British Rainfall, No. 52: 56-58, 1912, 1 fig.  
The Seathwaite gage is intended for use at very wet stations and to be read only once a month. It holds about 30 inches of rain. The gage is recessed into the ground and has a double wall of insulation to retard freezing. A 5-in. dipper is provided for simpler emptying.
656. Mill, H. R., "'British' rain gage." Symons' Meteorological Magazine, 48:183, 1913.
657. Mill, H. R., "Recording rain gages." Nature, (London) 95:262-265; May, 1915, 4 figs., 1 ref.  
There are 3 general types of rainfall recording gages. (1) The double tipping bucket on a fixed pivot, (2) the descending counterpoised receiver, and (3) the ascending float. Of the first type, the U. S. Weather Bureau Model is the best. The Beckley rain gage is the better of the second type and the Halliwell is superior for the third type. "The depth scale must be magnified at least by four, and preferably, eight times. . . ." The receiver should be large enough to hold 4 in. of rain and the return of the pen-arm should be made by a device unconnected with the discharge. The fewer the moving parts, the less the effect of friction.
658. Mitteilungen von Forschungsreisenden und Gelehrten aus deutschen Schutzgebieten, "Erfahrungen ueber verschiedeneu Regenmesser-modellae" (Experiences with various types of raingages). Mitteilungen von Forschungsreisenden und Gelehrten aus deutschen Schutzgebieten, p. 1-5, 1904.  
Extra copy to German "Kolonialblatt" (Newspaper).
659. Mohn, H., "On the dimensions of rain gages, and on the position in which they should be placed." International Meteorological Congress, Rome, April, 1879.  
Translated version in British Rainfall, 1879, pages 26-30. In the light of experiments on gage height and size, it was recommended that the Congress change its height specification from 4 ft. 10 in. to a lower acceptable level and that the diameter be changed from 14 in. to something larger than 3 in.
660. Monteria, U., Ricerche sul funzionamento dei pluviometri totalizzatori in alta montagna" (Research on the functioning of the pluviometer totalizer in high mountains). Bullettino Comitato Glaciologico Italiana, Turin, p. 235-251, 1929, 4 photos.
661. Monthly Meteorological Chart, "Rainfall at sea, by marine gage." Great Britain, Meteorological Office, Monthly Meteorological Chart, Indian Ocean, July, 1916.
662. Moore, J., Meteorology, Practical and Applied, 2nd ed., 1910, 12 figs., 2 refs.  
Textbook treatment on history of rain gages. Has pictures of and describes many recording and non-recording gages in use early in the 1900's. General problems of rain gaging are discussed. Indicated that experiments show that accuracy of a gage was independent of the size of orifice.
663. Moore, J., "Patent No. 2,384,954, rain gage, September 18, 1945." U. S. Patent Office (also in Official Gazette), September 18, 1945, 5 figs.  
A gage on the vectopluiometer principle with a provision to tip the orifice into the wind. "... a pivotally mounted receiving cup swingable on a horizontal axis, together with a blade responsive to the wind for swinging the cup with its mouth in a direction facing the wind and a weather vane arranged to maintain the blade transversely

of the direction of the wind." Since the orifice is only horizontal during a calm, it is not apparently adaptable to measuring precipitation per unit horizontal area.

664. Moore, J., "Patent No. 2,520,557, rain gage, August 29, 1950." U. S. Patent Office. (Official Gazette Summarized), August 29, 1950, 6 figs., 4 refs.  
 Patent of a gage on the vectopluiometer principle with a provision for the wind to turn an orifice to more or less face the wind. Consists of wheel-shaped hollow receiver disc with a horizontal axle to allow vertical movement. It is mounted on a vertical axle rod which allows it to swing with the wind like a vane. A cup-shaped orifice or tubes on the rim of the wheel permit collection and measurement of the rain as they tip into the wind due to an attached vane. No apparent correlation between the collection on the orifice and the amount of rain falling on a unit horizontal area exists, as the axis is only horizontal in a calm.
665. Mordecai, A., "Report of some meteorological observations made at Frankford Arsenal near Philadelphia." Franklin Institute Journal, 26: 30-37, July, 1838, 4 tables, 1 ref.  
 The results of three years' experiments showed that a gage in a tower 52 ft. above the ground caught an average of 5% less than the gage on the ground.
666. Mori Factory, "Telerecording rain gage, MF type." Mori Instrument Co. Catalog, Tokyo, Japan, p. 1-2, 1950+, 3 figs., 1 table.  
 Mori tipping bucket gage using a 20 cm. orifice and 1 mm. capacity buckets is used for telemetering purposes. It is based on the usual tipping bucket principle and is presented with telemetering in mind.
667. Morikofer, W., "Zur Registrierung des Schneefals." (For registering of snowfall). Meteorologische Zeitschrift, p. 330-331, November, 1920.  
 Recommends heating of rain gages by electrical lights, and says the losses are low compared to other methods.
668. Morris, A. J. T., "Treatise on Meteorology; the Barometer . . . , Rain Gage. . . . With Rules and regulations to be observed for Their Correct Use. . . ." Textbook, p. 47-51, 1866, 1 fig., 1 ref.  
 A popular treatment of a non-recording gage. Recommends the (now defunct) float-gage and gives simple instructions for observing rainfall.
669. Mougins, M., "Etudes glaciologiques en Savoie par M. Mougins, Inspecteur des eaux et forets" (Glaciological studies in Savoy by Mougins, Inspector of Waters and Forests). Annales du Ministere de l'Agriculture (Paris), fasc. 44, 1912.  
 Height vs. rainfall.
670. Mougins, M., "La Nivometrie" (The measurement of snow). La Meteorologies, 70(3):254-268, 1927, 9 figs., 4 refs.  
 On measurement of snow (Angot's basket nivometer and Hellmann's cylindrical nivometer are pictured).
671. Munchen, K., Bayer Hydrotechnisches Bureau, "Instruktion duer die Aufstellung und Beobachtung der Regenmesser des Koeniglich Bayrischen Hydrotechnischen Bureaus" (Instructions for the installation and observation of the rain gage of the Royal Bavarian Hydrotechnical Bureau). Jahrbuch de Hydrotechnischen Bureaus (\*Munchen) 2(2):1-7, 1900.
672. Murday, T. J., "British Patent 5,322, 1889." Great Britain Patent Office Abridgement of Specifications, Class 106, p. 20, March, 1880-1892, 1 fig.  
 A telemetering device that could be used on many instruments, including rain gages.
673. Murphy, E. W. M., "A curious old raingage." Meteorological Magazine, 61(724), p. 86-87, May, 1926.
674. Myers, Robert F., "The development of a digital telemeter system." U. S. Weather Bureau, Atomic Energy Commission, Oak Ridge, Tennessee, Progress Report, 1951, 8 figs., 1 ref.

A progress report on an automatic weather station using a Metro-type Digital Converter. The rain gage is designed to protrude out of the top of the weather station cabinet. A "Microsen 0-10 in. Pressure Transducer" is used as the sending element and a dump valve empties the system every one inch of precipitation. Either a 40° F. instrument temperature or calcium chloride will be used to melt snow. The transducer is accurate to 0.5%. The system requires 10 seconds to empty.

675. Nature, (London), "Note on a new form of raingage, the 'Seathwaite,' Constructed by Messers Negretti and Zambra." Nature, London, 91:65-66, 1913.
676. Nature, (Paris), "Impactometrie de gouttes de pluie" (Measurement of the impact of raindrops). Nature, -Paris, 68(3064):445, December, 1940, 1 fig.  
 A short discussion of an instrument designed by Neal and Bauer of the United States to measure the impact of rain drops. An aluminum disc 10 cm. in diameter is exposed to the rain. The disc is connected to a pen arm (spring tensioned), and as drops hit the disc, a line, the length of which is proportional to the impact, is made on a clock-mounted drum of paper.
677. Negretti and Zambra, "Cheap mountain rain gage." Meteorological Magazine, 14(117):181, December, 1879, 1 fig.  
 Correspondence.
678. Negretti and Zambra, "New recording rain-gage." Weather, 1(2):62, (back cover) May, 1946.  
 A float-type gage with a draincock to empty the reservoir.
679. Nell, CHR., A. C., "Rate of rainfall recorder." Weather, 4(1):25-26, January, 1949, 2 figs.  
 Comparison of the Nell and of the Bibby rate of rainfall recorder. An account of this instrument was first published in "de Nature," No. 6, June, 1939. Rain passes from a funnel into an inverted triangular bucket which is suspended on a lever balance which moves a recording arm. Water runs out of the bucket thru a vertical slit in one wall. The amount that flows out depends on the amount in the bucket, which in turn depends on the rate of rainfall.
680. Neuberger, H., "Simple precipitation time recorder." The Central States Snow Conference, Proceedings, 1:196-197, December, 1941, 1 fig.  
 A smoked paper belt is run under an aperture so that the complete belt runs through in 24 hours. Rain or snow entering through the aperture are recorded on the paper to within 7 minutes. Light bulbs are used to heat the instrument and provisions are taken to drain the system.
681. Neuberger, H., "On the measurement and frequency of traces of precipitation." American Meteorological Society, Bulletin, 25:183-188, May, 1944, 3 figs., 3 tables, 7 refs.  
 Results of observations with apparatus in use at Pennsylvania State College compared with observations at Harrisburg, 1941-1942. Designed to report traces, the instrument exposes a 1 in. x 2 in. smoked glass or cardboard plate every hour. The plates are kept warm by a light bulb underneath them. Plates are mounted on a circular clock-operated table that holds 24 plates.
682. Neuberger, H., and Stevens, F. B., "Weather and Man." Textbook, Prentice-Hall, Inc., p. 27-28, 1948, 1 fig.  
 A paragraph on measuring rain with the U. S. W. B. standard gage. The gage is illustrated.
683. Nicolle, J. N., "Essay on Meteorological Observations." U. S. War Department, Washington, D. C., 1839.
684. Niederdorfer, E., "Messung der Groesse der Regentropfen" (Measurement of the size of rain drops). Meteorologische Zeitschrift, 49(1):1-14, January, 1932' 5 figs., 2 tables, 11 refs., 4 eqs.  
 Absorbent paper method for measuring drop size.
685. Niessl, "Einfluss der Aufstellung des Regenmesser" (Influence of location on rain gages). Meteorologische Zeitschrift, 21(39):238, May, 1904, 1 table.

686. Nilsson, F., "Ein neues Instrument duer genaue Niederschlagsregistrierung" (A new instrument for exact recording of precipitation). Meteorologische Zeitschrift, 54:72-75, February, 1937, 6 figs.

This instrument is a combination of the tipping bucket and weighing type gages. It has a wheel of four buckets restrained from turning by a stop which bears against any one of four radial prongs. The whole system is balanced by a weight and moves downward as the rain falls into the top bucket. This movement is recorded on a tracing. When 3 mm. of rain has fallen, the stop releases a wheel which moves in a counter-clockwise direction, emptying out the water and lightening the wheel, which is then read with the next bucket in position. A greatly magnified record is obtained. A new arrangement for catching snow is shown. The snow falls into an oil covered calcium chloride solution that fills the orifice of the gage. A float-controlled outlet tube directs the precipitation into the gage.

687. Nilsson, F., "Fabian Nilssons registrer ande nederbordsm'atre eller pluviometer." Stockholms Bokindustri A-B N:r 5241, Stockholm, 1939, 21 figs., 1 table.

A summary of the problems of snow measurement by recording gages and a description of the Nilsson recording gage. Some disadvantages of a weight gage were: (1) snow sticking to the sides of the pail will affect accuracy. (2) Melting snow around the orifice can come down slowly or suddenly as a clump, but not necessarily while the precipitation is falling. (3) Freezing rain may lock the receiver and housing. (4) Scale ratio is not adequate. The Nilsson gage operates in all weather conditions and measures snow as accurately as it measures rain. An oil covered calcium chloride solution is presented to the atmosphere and a float operated outlet tube directs the water to the measuring buckets. States that the oil (1) prevents evaporation, (2) prevents absorption of water by hygroscopic CaCl<sub>2</sub>, (3) retards wave action on solution by the wind. A grate within the solution is used to discourage wind action.

The brim drain (Float arrangement) has a 6 to 1 ratio and the magnification of the scale is 40 times. The buckets operate on a 3 mm. cycle.

688. Nipher, F. E., "On the determination of the true rainfall in elevated gages." American Association for the Advancement of Science, 27: 103-108, 1878, 1 table.

Nipher considers the measurement of rain and suggests a metal sheet "with square cells of equal size, each drained by equal openings at the bottom, one or more of those near the center being used as collectors, and the others being used for a rain gage." Nipher also describes the development of the morning glory shield that he invented. Two gages at six feet, one unshielded, tested about five months, showed that the shielded gage exceeded the unshielded by 3%. To further test this, several (161) gages were placed on the roof of a nearby tower and compared, but results were erratic. A gage placed on a pole and elevated 18 ft. above the roof (118 ft. above ground) gave the same results as the one in the court, when the shield was elevated 3/4 in. above the rim of the gage. Nipher concludes that: (1) altitude correction can be reduced to nil by using shields, and (2) a gage may have any convenient altitude, when not on a roof. The conclusions in the most part are apparently from one summer's rainfall tests. The gages in the court were surrounded by buildings.

689. Nipher, F. E., "Über die Bestimmung der wahren Regenmenge mittels hochaufgestellter Regenschirm" (Concerning the determination of the real amount of rain by means of highly placed rain gages). Zeitschrift der Oesterreichischen Gesellschaft duer Meteorologie, Wien, 14:250-254, 1879, 1 fig., 1 table, 2 refs.

(American Association for the Advancement of Science, St. Louis, 1878, p. 103-108, Salem, 1879). Inverted solid 45° cone lined with fine wire screening (to prevent splash, which also extended as flat shelf around outer edge. Gage in this shield caught as much at any height as on ground.

690. Nunnari, R., "Contributo alla Stereopluviometria" (A contribution to stereo-rain measurement). La Meteorologia Practica, 17(2), 1936.

691. Nunnari, R., "Contributo alia stereopluviometria (Italian)" (Contributions to stereopluviometers). La Meteorologia Practica, Turin, 18 (2):66-81, March-April, 1937, 6 figs., 7 tables, 2 rets., 1 eq.

- "Measurements at Messina. Angle of rainfall, and intensity of rain diffusion according to direction of wind. Pers' vectopluiometer used." Use of Pers' stereopluiometer is discussed.
692. Ochenden, C. V., "Sea-spray in-the rain gage." Meteorological Magazine, 63(750):137-138, July, 1928.  
Correspondence.
693. Oddone, Prof., "Sulle variabili che concorrono nella funzione: la quantità di pioggia" (Variability in quantities of rain). Annali dell'Ufficio Centrale Meteorologico e Geodinamico Italiano, Vol. 30, Second series, Part 1, 1908.  
Height variation.
694. Ogasawara Industrial Co., Ltd., "Weather Instruments Catalog." Ogasawara Industrial Co., Ltd., 618 Karagasaki-cho, Megro-Ku, Tokyo, Japan, 1950+, p. 1-14, 24 figs., 1 table.  
A catalog of instruments for meteorological purposes. Three rain gages are described: two non-recording gages, similar to the British Meteorological Office gage; one non-recording gage has provisions to be stuck into the ground, while the other had the lower two-thirds sunk into the ground. The recording gage is constructed on the float and automatic natural siphon principle and in appearance the working mechanism is similar to the Hellmann gage.
695. Ohasi, WaSabro, Geophysical Magazine, (Central Meteorological Observatory, Tokyo), Vol. 34, fifth year of Meji, p. 199.
696. Okada, T., (Meteorological Instruments). (Japanese Textbook) Iwanami, 1931, 219 figs., many refs.  
A chapter in a textbook on Meteorological Instruments. The Hellmann (automatic siphon), Sprung (tipping bucket), Rung (siphon-weight) recording gages are discussed. Rain-intensity gages discussed were the Ohasi (leak), Honda (leak), Jardi, and the Gallenkamp (drop).
697. Oldekop, E., (Instructions in choosing the exposure of a mountain raingage and in the methods of reading it). Tasitkent, (Russia), 1916.
698. Omond, R. T., "The winds and rainfall of Ben Nevis in 1886." Scottish Meteorological Society Journal, 3rd Series, 8:18, 1887.  
Upslant of rime indicating ascending wind at lip of gage.
699. Omori, S., "On the protection of the rain gage against the wind." Japanese Journal of Astronomy and Geophysics, Tokyo Transactions and Abstracts, 4(3):13, 1927.
700. Osier, F., "An account of a new registering anemometer and raingage, now at work at the Philosophical Institution at Birmingham, with diagrams giving a condensed view of the observations recorded during the first eight months of the year 1837." British Association for the Advancement of Science, Report of 7th meeting, 6:32-33, (transactions) 1837.  
A review of a meeting where Osier presented his gage, which worked in combination with an anemometer. "The rain is registered at the same time by its weight acting on a balance. . . . the receiver is so arranged as to discharge every quarter of an inch that falls, when the pencil again starts at zero."
701. Osier, F., "An account of the self-registering anemometer and rain gage erected at the Liverpool Observatory in the autumn of 1851 with a summary of records for the years 1852, 1853, 1854, and 1855." British Association for the Advancement of Science, p. 127-142, 1855, 6 figs., 8 tables.  
Pertains mostly to results of the records.
702. Ottolenghi, Michele, "Pluviometro Totalizzatore" (Totalizer rain gage). Torino (Mensio), 8 p., 1902.
703. Pagliuca, S., and Brooks, C. F., "The measurement of precipitation on a windy mountain summit." American Geophysical Union Transactions, No. 2:385-393, June, 1934, 5 figs., 2 tables, 19 refs.  
Catch to the lee of a hill is greater than on the windward side. Catch with shields is greater than without (300% for high winds and snow). Gage and rim of shield should be normal and parallel to slope.

704. Palazzo, L., "Ueber einen neuen registrierenden Regenmesser" (Concerning a new registering rain-gage). Zeitschrift fuer Instrumentenkunde, Bd. 27(6):202-203, June, 1907, 1 fig.  
A description of an automatic float-and-siphon-type gage. The orifice is 357 mm. dia. and the area is 1000 cm<sup>2</sup>. A small tipping bucket is used at the end of the siphon tube to help create a suction, speedily emptying the gage in eleven seconds. The receiver is of such dimensions that one cm. of rain completes a cycle.
705. Palazzo, L., "Un nuovo modello di pluviometro registratore" (A new model of a self-registering rain gage). Rivista Meteorologica-Agraria (Roma), 26:837-842, 1905.
706. Palm, A. and Roth, H., "Registrierinstrumente" (Registering instruments). Berlin-Heidelberg-Springer-Verlag, p. 108, 1950, 203 pictures.  
A brief remark on the tipping bucket gage.
707. Palmer, A. H., "Rainfall and its measurement." Tycos, 20:148-150, October, 1930, 1 table.  
General survey of the methods of measuring rainfall.
708. Paolini, B., La nostra Revista nel terzo centenario dell' invenzione del pluviometro, 1639-1939 (Our Review in the third centenary of the invention of the rain gage, 1639-1939). Meteorologia Practica, Perugia, 20:3-7, 1939, 4 refs.  
Claims that a Benedictine monk, B. Castelli, in 1639, in Italy, invented the rain gage. Regular observations began in Italy in 1654, at the Monastery of Vallombrosa.
709. Parde, M., Les études hydrométéorologiques de M. O. Lutschg dans le bassin de la Baye de Montreux (Hydrometeorological studies of Mr. O. Lutschg in the basin of the Bay of Montreux). Météorologie, Paris, Series 3:171-179, May-June, 1937, 2 figs., 3 tables":  
Work starting in 1931 with numerous mountain rain gages. Some of the tables show inverse variation with height. Includes brief account of Haas and Lutschg's rain gage (specially prepared to eliminate effects of wind).
710. Parma, Ministerio dei Lavori Pubblici, Ufficio Idrografico del Po, "Il Pluviometro-totalizzatore dell' Ufficio Idrografico del Po" (The pluviometer-totalizer of the Po Hydrographic Office). Parma, Ministero dei Lavori Pubblici Ufficio Idrografico del Po, 1914!  
Illustrations and instructions.
711. Parsons, D. A., "Calibration of a Weather Bureau tipping bucket rain gage." Monthly Weather -Review, 69:205, July, 1941, 1 fig., 1 table.  
Discusses rate of rainfall indicated by tipping bucket gage. Graph shows rate error for rates of 0 in. to 25 in./hr. At 7 in./hr., the rate error is approximately 5%.
712. Parsons, D. A., and Blaisdell, F. W., "Soil and water conservation instruments. No. 1. Notes on the operation of the Fergusson recording rain and snow gage." U. S. Department of Agriculture, Soil Conservation Service, Hydrologic Division Research, SCS-TP-44, p. 1 - 24, August, 1941, 3 figs., 1 table.  
Some troubles were encountered in calibration, but not to a degree that would seriously affect the accuracy of the gage.
713. Pastorelli, F., "Gimbal-swung rain gage." British Association for the Advancement of Science, 37, 1874.  
Gage has a spherical receptacle. Wind pressure tilts the funnel toward the point from which the rain is falling.
714. Patterson, B.G., "Patent No. 1,173,022, February 22, 1916." U. S. Patent Office, Official Gazette, 223:1292, February 22, 1916, 6 figs.  
An improvement on the tipping-bucket gage. An independent device is placed below the usual tipping bucket. The water spilling from the bucket hits a cup, depresses it, and by a system of levers and gears registers on a dial the number of tips.

715. Paulcke, W., "Aus meinem naturlichen Laboratorium fuer Schnee und Lawinenforschung" (From my natural laboratory for snow and avalanche research). Bergsteiger, Die Wochenschrift, Vienna, 332-342, 1932.
716. Pauthenier, M., and Brun, E., "Counting the droplets of a fog by means of an ionized electric field." Academie des Sciences, Paris, Comptes Rendus, 211:295-296, 1940.
717. Pauthenier, M., and Brun, E., "Methode electrique permettant l'evaluation statistique des diametres de gouttelettes de brouillard" (An electrical method that permits the statistical measurement of the diameters of fog particles). Academie des Sciences, Paris, Comptes Rendus, 212:1081-1084, June 23, 1941.  
An electrical method of drop-size determination.
718. Pauthenier, M., and Brun, E., "Study of the structure of fogs by the use of an ionized electric field." Revue Generale de l'Electricite, Paris, 51:58-67, 1942.
719. Pauthenier, M., and Brun, E., "Electric method permitting the measurement of the mass of condensed water per unit volume of a fog." Academie des Sciences, Paris, Comptes Rendus, 216:352-354, 1943, 2 refs., 3 eqs.  
A grounded cylinder with a negatively charged axis of wire caused droplets of fog to be deposited on the interior of the cylinder when air was circulated through it. In early tests all droplets were not caught, presumably because of the low voltages (10,000 volts). Amounts were determined by weighing the cylinder before and after tests.
720. Pauthenier, M., Brun, E., and Demon, L., "Complement a l'étude de la structure des brouillards à l'aide d'un champ électrique ionisé" (Supplement to the study of fog structure with the aid of an ionized electric field). Revue Générale de l'Electricité, Paris, 52(7):220-221, July, 1943, 2 figs., 2 refs.  
Discussion of the authors' work with electrically precipitated droplets of fog. By precipitating the droplets on water-sensitized calibrated paper, a study of fog-droplet size may be made. The use of oil instead of water-sensitized paper is not recommended.
721. Pellegrini, V., "Un pluviometro registratore" (A registering rain gage). Giornale di Agricoltura della Domenica, Piacenza, 16:45, 1906.
722. Pengelley, W., "On the rainfall received at the same station by gages at different heights above the ground." Devonshire Association for the Advancement of Science, Literature and Art. Report and Transactions, 4:109, 1871.
723. Peppier, A., "Fehlerhafte Aufstellung des Regenmessers beim Niederschlag in Hochenschwand" (Faulty location of a rain gage for precipitation in Hochenschwand). Zeitschrift für angewandte Meteorologie, 50:222-223, 1933.  
Gage sheltered by buildings and trees was adversely affected by blast concentrated between buildings and by shadowing of trees.
724. Perrault, Pierre, (pseudonym) "De l'origine des fontaines" (Concerning the origin of fountains). Paris, 1674.
725. Perrault, Pierre, "Origine des fontaines" (Origin of fountains). Royal Society of London, Philosophical Transactions, November 22, 1675.
726. Pers, R., "Note complementaire sur la stéréopluviométrie" (Complementary note on stereopluviometry). La Météorologie, 75(8):106-113, 1932, 3 figs., 2 tables.  
The actual receipt of rain on a slope exceeds that caught in a horizontal gage by a percentage equal to the tangent of the angle of slope times the tangent of the angle of slant of the rain. Thus with a 50% slope and rain slanting 30°, the excess is 29% on a windward slope and the deficiency 29% on a leeward one, or 129% vs. 71% of the catch in a horizontal gage.

727. Pers, R., "Relations entre les donnees pluviométriques et les percipitations totales recueillies par un bassin. Introduction a l'etude theoretique de la stereopluviometrie" (Relations between pluviometric data and the total precipitation collected in a basin. Introduction to the theoretic study of stereopluviometry). La Meteorologie, 75(8):101-106, 1932.
728. Pers, R., "Etude theoretique sur la variation des precipitations avec l'altitude et de l'influence du relief sur les precipitations en haute montagne. Premiers resultats experimentaux de stereopluviometres" (Theoretic study on the variation in precipitations with altitude and on the influence of relief on precipitations in the high mountains. First results of experiments with stereopluviometers). La Meteorologie, 77(10):468-475, 1934.  
Measurements were made of precipitation on the vertical component of a sloping surface by means of a vectopluviometer with vertical orifices facing N., E., S. and W., and by a stereopluviometer rain gage whose orifice is cut to simulate the slope of the drainage basin "covered" by the gage. Gages at height of about 5 m., but not shielded, vs. wind—.
729. Person, Hermann, "Entwicklung und Einsatz von unbemannten automatischen Wetterfunk-Stationen im Polargebiet" (Development and installation of unmanned automatic weather-radio stations in the polar area). Polarforschung, 18(1-2):6-9, January, 1948.  
An automatic weather station for land and sea that measures pressure, temperature, wind direction and velocity.
730. Petrovic, St., "Vyskum srazkovych pomeroy totalizatormi na hrebnoch slovenskych hor" (Research on precipitation with totalizers on the ridges of Slovak mountains). Meteorologicke Zpravy, Prague, 4(1-2):16-19, 1950.  
Mougin totalizer with Nipher shield used. Experimented with glass insert in cylinder to cut down corrosion. Glass burst, due to water seeping in between glass and wall and then freezing. Steel recommended over zinc.
731. Philadelphia Centennial Exposition 1876. "Descriptive catalogue of articles exhibited in the Signal Section of the War Department Exhibit Division of telegrams and reports for the benefit of commerce and agriculture." Philadelphia Centennial Exposition, 1876: Report of the Board on Behalf of the U. a. Executive Departments, 1:967-972, 1884 (Vol. 10 of the same: Reports on the International Exhibition of 1876).  
An exhibition of meteorological instruments. Private A. Eccard's float-type self-recording gage is described. It is a simple float-type gage without any automatic siphoning device. Lieut. Gibbons' self-recording gage is also described. This gage is the same as Pvt. Eccard's, except that all recording is by means of electrical contacts.
732. Philibert, M., "Comparaison entre un pluviometre-nivometre 'Mougin' protege et un pluviometre 'Association Ordinaire' au poste du Puy-Chadrac" (Comparison between a shielded "Mougin" pluviometer-nivometer and an ordinary "Association" rain gage at the station of Puy-Chadrac). La Meteorologie 75(8):89-91, January-March, 1932, 3 figs.  
Shielded Mougin totalizer caught 4.5% more than ordinary gage. C. E. Brazier's 4.8 % for pit gage vs. ordinary.
733. Phillips, J., "Report of experiments on the quantities of rain falling at different elevations above the surface of the ground at York." British Association Report for the Advancement of Science, Transactions Section, 3rd:403-41<sup>^</sup>, 1833, 5 tables, 1 ref., 1 eq.  
Gages used were simple 10 in. cubical boxes. Rim was 1 in. "... the effect of the eddying wind is quite unimportant." Recommends the equation  $m\sqrt{h}$  = diminution of rain with height where  $m = 2.29$  (approximately) and  $h$  = altitude. "... the whole difference in the quantity of rain, at different heights above the ground is caused by continual augmentation of each drop of rain from the commencement to the end of its descent, as it traverses successively the humid strata of the air at a temperature so much lower than that of the surrounding medium as to cause the deposition of moisture on its surface."

734. Phillips, J., "Second report on the result of twelve months' experiments on the quantities of rain falling at different elevations above the surface of the ground." British Association for the Advancement of Science, Report of Transactions Section, 4th:5b1-5b3, 1834, 3 tables.  
Noted that the deficiency in catch of elevated gages was a phenomenon of a wintry character.
735. Phillips, J., "Third report of experiments on the quantities of rain falling at different elevations above the surface of the ground at York." British Association for the Advancement of Science, Reports, 5th:171-179, 1835, 9 tables, 1 ref.  
In the formula  $m\sqrt{h}$  = diminution of rain with height, the constant "m" proved to be variable. Recommends a more dense raingage network.
736. Phillips, J., "New experimental researches on rain." British Association for the Advancement of Science, Transactions Section, p. 45-47, 1840, 1 fig., 2 tables.  
Presentation of a gage with one horizontal receiving orifice and four vertical ones, facing the four quarters of the horizon. This is possibly the first directional gage (stationary type) to be used.
737. Phillips, J., "Further researches on rain at York, by John Phillips, and at Harraby, near Carlisle, by Joseph Atkinson." British Association for the Advancement of Science, Transactions Section, p. 30-32, 1841, 3 tables.  
Three kinds of gages to be used in experiments: an ordinary funnel type, a globular gage, and an azimuth-and-inclination gage. A gage with an orifice at 45°, rotating to face the wind, was used.
738. Phillips, V. V., "Patent No. 2,509,522, rain gage, May 30, 1950." U. S. Patent Office, Official Gazette (Summarized), May 30, 1950, 5 figs.  
Patent on a transparent-tube rain gage. A slightly oversized orifice and funnel direct the rain water into a transparent tube, which is backed up by a calibrated scale for quick visual reading. It is mounted so that it can easily be attached to a fence post and may be the same as the "Victor" rain gage.
739. Pickering, Roger, "Geistlicher zu Deptford und Hoxton" (A Clergyman at Deptford and Hoxton). Royal Philosophical Society of London, Transactions, 1744.
740. Pike, Francis V., "Comparison of rain gages." American Meteorological Journal, 4:159-165, August, 1887-1888, 5 tables":  
An old U. S. Signal Service gage is checked by an American Meteorological Society gage (E. B. Badger & Son, No. 3). In almost all cases the catch of the old gage exceeded that of the new gage, especially during high winds. This was finally attributed to the seam in the outer case between the funnel and the case. Apparently the wind blew rain from the side of the gage into the seam and into the gage, thereby giving higher catches.
741. Pogendorff, Johann C, "Geschichte der Physik" (History of Physics). Leipzig, 1879.
742. Pollak, L. W., "Niederschlagssammler mit Wasserstandsglas in Spiralform zur Feinablesung": (Precipitation collector with water glass in spiral form for exact reading). Meteorologische Zeitschrift, 49:360-361, September, 1932, 2 figs.:  
'A glass tube is wound around a gage to magnify the reading. Can be read to 0.005 mm. A CaCl<sub>2</sub> solution may be used to decrease the possibility that the glass might be broken during freezing weather. In other respects the gage is installed in the usual manner.
743. Pollak, L. W., and Fuch, F., "Ein neues Modell des Niederschlagssammlers, mit Wasserstandsglas zur Feinablesung", (A new model of rain gage with a glass receptacle for exact reading). Gerland's Beitrage zur Geophysik, 48:209-212, 1936, 3 figs., 1 ref.  
The authors describe a new model of totalizer, supplied with a receptacle which permits exact reading. In this new model, the tube which is used to enclose the totalizer vessel in a spiral is replaced by a series of straight glass tubes, slightly inclined, which are connected with each other and with the inside of the totalizer vessel.

744. Popow, E., "Ueber die Messungen der Niederschlaege unter Polarverhaeltnissen" (Concerning the measurement of precipitation under polar conditions). Meteorologicheskii Vestnik, 6:157, .1929, (In Russian originally). Reviewed by A. Schoenrock in Meteorologische Zeitschrift, November, 1929, 445-446.  
Almost unconquerable difficulties in measuring winter precipitation (for instance, at Nowaya Zemlia). Experiments with a Nipher shield were not encouraging, as snow is blown out of gage. With a fence shield, wind blows snow into gage. A wide cross partition improved the catch slightly. No reliable method yet for snow measurement. Recommends taking snow sections. Some new suggestions made by M. P. Koslow, "Problems of the Arctic," 1937, 53-59. (Reference Annala Hydrologie, p. 368, 1938.)
745. Pouillet, Claude S. M., "Elements de physique experimentale et demeteorologie" (Elements of experimental physics and meteorology), 2nd ed., 1832; 5th ed., 1847; 6th ed., 1853; 7th ed., 1856.
746. der Praktische Maschinen-Konstrukteur, "Regenmesser" (Raingages). der Praktische-Maschinen Konstrukteur, 4(6):48, 1910.  
Beiblatt: Uhlands Technische Rundschau. Mentions a 100 cm.<sup>2</sup> orificed gage similar to the Howard gage, but easily attached to a fence pole.
747. Preussische Meteorologische Institute, "Anleitung zur Anstellung und Berechnung meteorologischer Beobachtungen" (Instructions for making and calculating meteorological observations). Publications of the Preussische Meteorologische Institute, Berlin, No. 268:37-38, 1913. Abstract in No. 347 of the same publications, p. 41-48, 1927.  
Hellmann mountain rain gage has receiving area of 500 sq. cm. and vertical depth of 50 cm. For winter use, when only snow falls, a perpendicular crossed division of metal is inserted to prevent eddying of snow in the gage. Cutting of snow sections and determination of water content described.
748. Puri, H.R., "Historical note on the catch of rain gages." Scientific Notes, Indian Meteorological Department, Calcutta, 3(18-3U):38-59, 1931, 19 figs., 21 tables., 10 refs.  
Summary on rain gaging. Conclusions were:  
a) Material - ebonite or copper (unpainted)  
b) Size - immaterial  
c) Form - cylindrical  
d) Shielding -  
(1) A Wild fence, 16 ft. x 16 ft. x 8 ft., wood or wicker  
(2) Nipher  
e) Exposure -  
(1) Distance of obstruction, 2 heights away  
(2) Minimum vertical angle at gage =  $26\frac{1}{2}^{\circ}$
749. Quinteros, E.F., "Patent No. 2,570,710. December 3, 1948, Pluviometer." U. S. Patent Office, Official Gazette (Summarized), 651(2):511, October 9, 1951, 2 figs., 6 refs.  
This patent concerns a rain gage on the vectopluiometer principle. The receiver, a vertical cylinder of the same diameter as the orifice, is mounted on a vertical axis, and has a glass standpipe for measuring and a drain cock for emptying. The orifice is round and movable on a horizontal axis thru its center. The gage is kept pointed into the wind by means of a vane and the orifice is rotated (vertically) to face the wind, more or less, depending on the impact of the wind on a paddle at each end of the orifice axis. In calm weather the orifice assumes a horizontal position and the paddles a vertical one. This gage could not be used for determining rain per unit horizontal area, as the plane of the orifice is variable and not necessarily perpendicular to the fall of the rain drops, as the inventor claims.
750. Raffo del campo, J. L., "Nuevo metodo para la medician de la precipitacion con los nivometros totalizadores" (New method for measuring precipitation with ihe totalizer gages). 1. American Scientific Congress 8th, Washington; 2. Proceedings Supplement, American Meteorological Society Bulletin, (1)7:325-328, 1942; (2) 23:325-328, December, 1942, 3 figs, 1 table.

Measurement of precipitation with the Mougins type totalizer in the Andes Mountains of Argentina. The gages are serviced once a year and depth of precipitation is determined by weighing the catch. Trouble has been encountered in the CaCl<sub>2</sub> precipitating. A minimum thermometer left at the site failed to register (the column was filled with bubbles).

- 751., Ragona, Annali del l'Ufficio Centrale di Meteorologia Italiano, Vol. 4, "Part 1, 1882.  
Rainfall vs. height.
752. Ratzel, F., "Messung der Dichtigkeit des Schnees" (The measurement of snow density). Kleine Schriften, p. 205-208, 1906.
753. Rawson, A., "To the editor." Meteorological Magazine, 10(111):122, 1875  
1 fig.  
About a defect in Glaisher's rain gage.
754. Reed, W.G., 'Note on the effects of rain gage exposure." Monthly Weather Review, 43:35-39, 318-322, July, 1915, 1 fig., 2 tables, 5 refs.  
Twelve gages were placed in a watershed of approximately 1 sq. mi. in the mountains. Considerable differences of measurement occurred over a 2-year period. Conclusions were: (1) rainfall heaviest near the heads of valleys and not the ridges, (2) gages should be shielded.
755. Reed, W. G., Loy, Howard M., "Water resources of Strawberry Creek, Berkeley, California." Monthly Weather Review, 43:35-39, January, 1915, 3 figs., 3 tables.  
Five gages in a small steep valley showed considerable differences during the winter of 1913-1914. The gages lowest in the valley had the greatest catch.
756. Refuggi, B., "La Misura del la Neve" (The measurement of snow). Meteorologia Practica (Perugia), No. 19:183-186, 1938.
757. Reichel, E., "Etwaige neue Verfahren zur Messung von Niederschlag insbesondere von Schneefaelen und Starkregen" (Some new methods for measuring precipitation, especially of snowfall and heavy rain). Hydrologische Konferenz der Baltischen Staten 6th Berlin, Hauptbericht 15, S. 1, 2(15A), August, 1938, 4 refs".  
Discusses the Friedrich-Haase totalizer and also Weinlander's addition of glass side gage to this totalizer..
758. Reiner, J., Die Meteorologischen Instrumente, 108-115, 1949, 135 figs., 14 tables, many refs.  
A general summary of the instruments used in measuring rain. Hellmann siphon gage with heating unit described. Measuring dew with Hiltner dew gage is shown. At best, it appears to be very uncertain.
759. Reinhold, F., "Die einheitliche Durchfuehrung von Niederschlagsmessungen" (A uniform technique for precipitation recording). Gesundheits-Ingenieur, Berlin, 58(46):692-700, 1935, 7 figs.  
The rules of the German Meteorological Organization for measuring precipitation are generally outlined.
760. Reinhold, F., "Einheitliche Richtlinien zur Auswertung von Schreibregennesseraufzeichnungen" (Uniform rules for evaluation of the records of automatic rain gages). Gesundheits-Ingenieur, 60(2,3,4):22-26, January, 1937.  
Proposed standard method for reduction of rain gage records.
761. Reinhold, F., "Schreib-Regenmessernetz in den deutscheh Staedten" (Self-recording rain gages in German cities). Jahrbuch der Deutschen Gesellschaft fuer Bauwesen, Berlin, p. 83-92, 1938.
762. Renou, E., "Sur les quantites de pluie par deux pluviometeres differant de hauteur ou de dimensions" (On the catch of 2 rain gages of different heights or dimensions). La Meteorologie, 2:69-74, April, 1863.
763. Renou, E., "Sur les quantites de pluie requeillies-a deux niveaux differentes" (On the amount of rain caught at two different levels). Annuaire de la Societe Meteorologique de France (now La Meteorologie) 13:162, 1865.

764. Renou, E., "Sur les quantites de pluie requillies a deux niveaux differentes" (On the amount of rain caught at two different levels). Annuaire de la Societe Meteorologique de France (now La Meteorologie), 27: 109-112, 1879.
765. Reusch, Hans, "Enny Nedborsmaller" (A new totalizer). Naturen (Bergen, Norway), 25:377-378, 1901, 2 figs.  
Describes a totalizer of Axel Hamberg (Swedish geologist) that is used in the northern mountains of Sweden. The gage was similar to the Mougín type and an open bottom Nipher shield was used to deter wind action. Salt was used to keep the solution fluid and an oil film prevented evaporation. Up to three meters of precipitation was caught and held.
766. Revue de l'Electricite de l'Eclairage, "Pluviometre Enregistreur Lancetta" (The Lancetta recording rain gage). Revue de l'Electricite et de l'Eclairage (Berne), 11:65-66, 1902, 1 fig"
767. Riesbol, H. S., "Results from experimental rain gages at Coshocton, Ohio." American Geophysical Union Transactions, Part 1:542-550, August 1938, 2 figs., 7 tables, 5 refs.  
Tests made with (1) gage in center of 24 ft. sq. 4 ft. fence, (2) gage inside a wire fence, (3) gage in center of 4 ft. dia. by 3 ft. masonry-lined pit, (4) pit gage with cocoa brush mat surface, (5) unprotected Fergusson gage, (6) gage with multiple vane-type shield (Hall), (7) multiple vane-type gage with slots to cut wind (buffer action), and (8) Nipher shielded gage.
768. Riesbol, H. S., "Report on exploratory study of rain gage shields and enclosures at Coshocton, Ohio." American Geophysical Union Transactions, Part 2:474-482, 1940, 6 figs., 7 tables, 4 refs.  
Extensive experiments with gages indicated that the Nipher type shield was most efficient. (Alter type was not among those tested.) (a) Pit, (b) Vane-type, (c) Snow fence, (d) Nipher.
769. Riggénbach, A., "Genauigkeit bei Regenmessungen" (Accuracy in rain measurement). Verhandlungen der Naturforschungs Gesellschaft zu Basel 8(3):579-590, 1888, 4 tables.  
Some notes on differences in old and new gages of the same pattern. The old read very close to the new. The old paint in the funnel retained approximately 0.02 in. rain. (1) The rain in small areas is quite variable for individual storms. (2) Small rain gages are sensitive to errors due to surface wetting.
770. Rinker, R. E., "The Stevens seasonal snow-rain recorder." American Geophysical Union, Transaction, No. 2:718-720, August, 1938, 3 figs.  
A Stevens gage has operated for two years and records available show that it was well designed. Some difficulty was experienced with wet snow sticking to the sides of the inverted cone.
771. Roberts, R. E., Yen, T., "Investigation of the sensitivity, accuracy, and lag of the Bendix-Friez 775-B.S. recording rain gage and the Stevens Type 06, recording gage." Special Report, Illinois State Water Survey, September 8, 1952, 7 figs.  
Accuracy--both are within 2% when 1 in. of rainfall is measured. Mechanical lag--negligible. Collector lag--15 seconds +. An indicator was made to facilitate rate reading from the charts. Concludes--Stevens superior because of ease of calibration (no springs), while the Friez is easier to use because it is not as bulky. Recommends a composite gage using the accuracy of the Stevens with the compactness of a Friez.
772. Robie, David, "Rain and Dalton gages." Meteorological Magazine, 17(204): 184-186, January, 1883.
773. Rogers, R. E., "A new recording gage." The Kentucky Engineer, 14(2): 19, February, 1952, 6 figs.  
Another adaptation of the siphon-type gage is similar in operation to the Negretti-Zambra natural siphon rain gage. As a receiver fills, the float with pen attached rises to record this process. When a certain level is reached, 1 in. of rain, the receiver siphons empty, and the process is repeated. A novel feature of the gage was the use of plastics for various parts of the gage. Siphoning time - 10 seconds.

774. Rogez, A., "Perte d'eau par rejaillissement sur les pluviometres au Cameron" (The loss of water due to splashing on the pluviometers at Cameron). Annales de Physique du Globe de la France, d'outre-Mer, 6(34):126, 1939..
775. Ron, J., "Mereni Onzdisnyoh Srazek Srazkomener nym Totalisatorem" (Measurements of atmospheric precipitations with a totalizer [in Czech]). Prague Statni Ustav Hydrol. T. G. Masaryk, Prace Stud (Prague), No. 60:25, 1946.
776. Ross, P. M., "Apparatus for measuring rate of precipitation." United States Patent Office No. 2,213,888, September 3, 1940, 6 figs.  
A gage comprising a receptacle having an escape orifice in the lower portion thereof, "an electrode extending into the receptacle, an electric circuit between the electrode and wall of the receptacle to pass an electric current thru the liquid and an ammeter to measure the current. The amount of current is proportional to the rate of rainfall. A separate reservoir is used' to subtract the effect of the resistance of the water being variable because of impurities.
777. Rossi, V., "Ein registrierender Schnee und Regenmesser" (A recording snow and rain gage). Geophysica, Helsinki, 3:220-224, 1948, 2 figs., 7 refs.  
An ordinary rain gage is of little use in Finland since snow, or snow and rain, occurs for seven months of the year. Various snow-rain gages are discussed critically. (Fergusson, Hellmann, Fuess, Korhonen and Nelson.) The recording gage developed for use in Finland works on the weight principle, using petroleum to float the weights. There are four weights, the first one released after 10 mm. is caught, and thus records up to 50 mm. Instrument which is illustrated, was installed for comparative purposes at Imlala in July, 1947. The results of the tests in winter will be published after some irregularities are corrected.  
The float is in direct connection with the receiving bucket above it, and is forced down to the limit of the pen arm, at which point one of the four weights is released. The pen arm and float then return to zero position. The paper on the drum is changed daily. Calibration was effected by volumetric changes in the oil due to low temperatures.
778. Rossmann, Clark G., "The Hudson design - Jardi type recording rain intensity gage and rainfall totalizer." American Meteorological Society Bulletin, 30(3):97-103, March, 1949, 8 figs., 1 ref.  
Description of a new type of recording rain gage which makes a continuous trace of rainfall intensity similar to the wind record from a Dynes Anemograph, and in addition, makes an independent record of rainfall amount by means of a tipping bucket. The collector is 5½ feet in diameter; the operation entirely mechanical to provide continuous records in case of power failure. Entire mechanism and assembly described and illustrated in detail.
779. Rostad, A., "Ueber die Wirkung des Nipherschen Schutztrichters" (Concerning the effect of Nipher's protecting funnel). Meteorologische Zeitschrift, 41:240-243, August, 1924, 4 figs., 3 refs.  
(A summary of "Verwendung von Nebelfrostabgerungen, un Stroemungslinien zu bestimmen" in Geophysica Pub. v. 3, Nr. 2 Kristiana.) A shielded gage placed with shield parallel to slope will have a truer catch.
780. Rostad, A., "Ueber die Wirkung des Nipherschen Schutztrichters" (Concerning the effect of Nipher's protecting funnel). Meteorologische Zeitschrift, 41:266-272, July, 1925, 6 figs., 2 tables, 3 refs., 4 eqs.  
At Halde Observatory in 19 months total catch of unshielded gage was 57% of shielded. The relative catch of shielded gage increased with wind and fineness of precipitation, being 2.2 times unshielded for snow at 16 m/s, though only 2.0 at 20-22 m/s. owing to outblowing in spite of shield.
781. Rotch, A. L., "First weighing recording snow gage." Harvard University Astronomical Observatory, Annals, 20(Pt. 1):13, 1889.  
(Results of the Meteorological Observations at Blue Hill Observatory, Mass., U.S.A. in 1886) - designed by Rotch, built by Richard Freres, installed March, 1886. Receiver rests on scale of platform type. Inner shield protected against clogging by sleet. Outer Nipher shield of copper wire mesh. Prototype of Fergusson gage.

782. Royal Meteorological Society, Great Britain, "Selbstregistrierender Regenmesser" (Self registering rain gage). Zeitschrift der Oesterreichischen Gessellschaft, 6(9): 129-132, May, 1871, 1 fig.  
A reprint of an article by the Royal Meteorological Society on the Beckley gage.
783. Royal Meteorological Society, Quarterly Journal, "Twelfth annual exhibition of instruments." Royal Meteorological Society, Quarterly Journal, 17(77):180-192, January, 1891.  
A list of rain gages and other meteorological instruments that were exhibited in London. Fifty-two of the exhibits were rain and snow gages.
784. Royal Meteorological Society, Quarterly Journal, "Early American rain gages." Royal Meteorological Society, Quarterly Journal, 38(164): 285-286, October, 1912.  
Five types of gages were in general use in America during the following periods: (1) Regent's gage, 1825-1833; (2) De Witt gage, 1834-1848; (3) Smithsonian gage, 1849-1889; (4) Fuertes gage, 1890-1899; (5) U. S. Weather Bureau, 1900 to date.
785. Royal Meteorological Society, "Bibliography of meteorological literature." Vol. 1-date, 1924-date.
786. Rudel, "Schreibregenschreiber Hellmann-Fuess" (Recording rain gage Hellmann-Fuess), Das Wetter, No. 2, 1915.
787. Ruggiero, P., "Un nuovo pluviografo" (A new rain gage). Bollettino della Societa dei Naturalisti in Napoli, Vol. 41, 1929.  
On the Imber (weight-type) self-recording gage.
788. Ruggiero, P., "Il Pluviografo--Imber" (The Imber self-recording gage). La Meteorologia Practica, 11(5):239-243, September-October, 1930, 6 figs., 1 ref.  
On the design of the Imber weight-type recording gage. A counterpoised vessel with an attached pen arm is the actuating device. As the vessel is filled, it descends and causes the pen arm to move across a drum. When the vessel is full, a siphoning action takes place and the action repeats itself. The orifice of the gage is 1/10 square meter and the action repeats itself every 10 mm. of rain. No springs are used in counterpoising and the scale of the drum is such that the instrument is very sensitive. The siphon design is such that there is little dribbling.
789. Ruggiero, P., "Considerazione per la diffusione dei pluviografi" (Some considerations concerning the diffusion of pluviographs). Meteorologia Practica (Perugia), 20(1):8-14, January-February, 1939, 1 fig., 2 refs.  
A discussion of weight, float, and tipping bucket rain gages and their faults. Recommends the balance gage, especially the Imber. This gage, when heated, will function for the measurement of snow.
790. Rung, G., "Ombrograph mit Sinuswage" (Weight type rain gage with tipping bucket). Meteorologische Zeitschrift, 1:461-464, November-December, 1884, 4 figs.  
Picture and description of Rung's weight and tipping bucket type self-recording rain gage. A tipping bucket is suspended by two cords attached on both sides of the bucket. The cords in turn are wrapped around a pulley and as the bucket descends, due to rain water being directed into it, the pulley rotates and an attached pen arm makes a record on a continuous sheet of paper. When the bucket reaches a predetermined level, it flops over, empties, and raises to zero position, thus completing a cycle. This is a gage developed in Denmark.
791. Rung, G., "Self-registering meteorological instrument" Verhandl d naturw - math, Abth.d.K. Dan, Akademie d. Wissenschaften zu Kopenhagen, Vol. 3, 1885"  
A brief discussion of meteorological instruments, including the Rung pluviograph.
792. Rung, G., "Registrierender Regenmesser (Ombrograph) Nach dem Prinzip der Sinuswage" (Self-registering rain gage according to the tipping bucket principle). Zeitschrift fuer Instrumentenkunde 5:246-247, July, 1885, 1 fig.

On Capt. Rung's combination weight and tipping bucket self-recording gage.

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793. Russell, S., "Fencing around rain gages." Meteorological Magazine, 62: 163-164, 1927, 1 table.  
Picket fence 3½ feet high, 30 feet diameter, failed to increase catch in windy location. Two gages in a very exposed location and fifty yards apart caught almost exactly the same amount for a period of fourteen months.
794. Rycroft, H. B., "Random sampling of rainfall." South African Forest Association Journal, 18:71-81, August, 1949.
795. Sagara, D., and Tsukamoto, K., "Test of an automatic weather station, Parts I and II (Japanese)." Journal of Meteorological Research, Tokyo, 3(1):1-18, December, 1950, 6 figs.  
An automatic weather station on Mt. Tsukuba records pressure, temperature, humidity, and wind direction and speed by land lines. Tests showed defects and methods were found for improvement. Wiring diagram given.
796. Saint-Martin, P., "Du pluviometre et de son installation" (The raingage and its installation). Pau, 15 p., 1886.
797. St. Petersburg. Physikalisches Central-Observatorium, "Wage ombrograph, system des mechanikers K.K. Rohrdanz" (Scale-ombrograph, system of the mechanic K.K. Rohrdanz). St. Petersburg, Physikalisches Central-Observatorium, p. 7, 1903.
798. Sakahrov, M. I., (Methods of accounting for precipitation under forest cover), Meteorologija i Gidrologia, 5(9):116-117, September, 1939, 1 table.  
Recommends batteries of simple gages consisting of rimmed funnels inserted in bottles placed on poles one meter above ground on 1.5 to 2 meter coordinates.
799. Salter, M. de Carle S., "The Nipher raingage shield." British Rainfall, 60:278-285, 1920, 4 figs., 2 tables, 4 refs.  
History of Nipher types of shields; in British variant of Billwiller-shorter and lower. CFB. "Gages exposed in windy districts often do not catch a fair sample of the rainfall of the locality owing to wind eddies which form around the gage. The use of the Nipher shield to overcome this defect is discussed."
800. Salter, M. de Carle S., "Measurement of rainfall duration." British Rainfall, 56:32-40, 1916.  
Map showing the positions of the stations reporting duration is given and a comparison of the duration as obtained from the various types of recording gages.
801. Salter, M. de Carle S., "Exposure of raingages." British Rainfall, 59: 263-268, 1919.  
Some hints are given as to the best methods of avoiding defects in the exposures of raingages.
802. Sammadar, Jogindra Nath, "Indian meteorology of the 4th century B. C." Royal Meteorological Society, Quarterly Journal, 38(161):65-66, January, 1912, 1 ref.  
Correspondence. Quotes from the book by Chanakya entitled "Arthastra," or the Science of Politics, giving definite quantity of rain which fell. The author infers the existence of some-sort of rain gage in the 4th century in India.
803. Sanson, Joseph, "Les mesures pluviometriques" (Pluviometric measurements). Bulletin des Engrais, 6:7-8, January 10, 1933.  
After a brief description of the pluviometer and of the way to use this apparatus, the author shows the practical interest which rain measurements have for the farmer in connection with the numerous problems with which he has to deal; irrigation, sprinkling, drainage, installation of cisterns, indications as to yields from harvests, and fixation of the daily work in the fields. He advises the possession of a pluviometer in every agricultural exploitation which is at all important.

804. Sanuki, M., Tsuda, N., and Kimura, S., "Water tank and wind tunnel tests on rain gage and windshield." Papers in Meteorology and Geophysics, Vol. III, No. 1, Met. Res. Inst., Tokyo, 54-63, March, 1952.  
 "Two types of wind shield for rain gage, i.e., conical and hollow ring-shaped designs are tested in combination with integral and separated equipment housings, both in water and in wind tunnel. The flow patterns are photographed by means of aluminum powder spread over the water surface of the tank, or wool strings tied to the model in the wind tunnel. By the inspection of the photographs taken in two-dimensional aspect in water tank, together with those taken in three-dimensional aspect in wind tunnel, the conical wind shield with a flat circular edge combined with separated housing is found to be the most satisfactory, giving uniform horizontal flow and generating the minimum of eddies around the rain gage mouth." Holes were made in the housing of the shield to retard snow accumulation apparently with no adverse wind effects.
805. Sass, F., "Die Niederschlagsmenge in Barnaul nach dem neuen und alten Regenmesser mit und ohne Schutzvorrichtung von 1882 bis 1902" (The amount of precipitation in Barnaul according to new and old rain gages, with and without protecting devices, 1882-1902). St. Petersburg, p. 87-88, 1903.
806. Saville, C. M., "Some phases of southern New England hydrology." New England Water Works Association Journal, 48(3):255-271, September, 1934, 4 tables.  
 Rejected official rainfall normals for Providence, R. I., owing to deficient catch by gages on roof of skyscrapers. A water-works engineer wants rainfall data to determine drought and a drainage engineer for storm sewer design.
807. Schaefer, Vincent J., "Properties of particles of snow and the electrical effects they produce in storms." American Geophysical Union Transactions, 28(4):587-614, August, 1947, 16 figs., 8 tables, 18 refs.  
 Two types of atmospheric electricity were found to occur during storms. These have been related to specific forms of snow crystals and other properties which can be observed at ground stations. Measurement of falling velocity, quantity and sign of electric charge, mass, range in quiet air, variety of crystal forms, and other properties of single crystals are given. The frictional electricity produced when crystals are broken as they hit a metal surface, when compared to the charge carried by falling crystals, is found to be more than 100 times greater in some instances. A method is described for preparing snow-crystal replicas and for measuring the size and distribution of cloud particles.
808. Schaefer, V. J., and Smith, R. Johannsen, "Basic icing research by General Electric Company, fiscal year - 1946." U. S. Air Force, Air Materiel Command, Wright Field, Ohio, Technical Report, 5539' 1947.  
 Eleven reports on icing, icing meters, cloud meters, water content, etc.
809. Schindelbauer, F., "Registrierung der Tropfenzahl bei Regenfaell" (Experiment in the registration of drop count in rain). Meteorologische Zeitschrift, 42:25-27, January, 1925, 1 fig.  
 An early type of acoustical (listening device) gage. Light rain and snow could not be heard but it is suggested that the use of electronic tubes would make this easily possible.
810. Schipczinski, A., Meteorologicheskii Vestnik, p. 191, 1921.
811. Schipczinski, A., "The influence of exposure on rain gages." Meteorologicheskii Vestnik, p. 21-32, 1921.  
 Wind effects on snow gaging.
812. Schmeltz, "Registrierung der Regendauer" (Registration of duration of rain). Journal de Physique, May, 1882, 1 fig.  
 Abstracted in Zeits. fuer Instrumentenkunde, 1882, p. 297. Appears to be a strip of water-sensitive paper that is exposed to the rain.
813. Schmidt, W., "Eine unmittelbare Bestimmung der Fallgeschwindigkeit von Regentropfen" (A way of immediate determination of rain drop velocity). Meteorologische Zeitschrift, 26(4):183-184, April, 1909, 2 tables, 1 eq.

A unique method for measuring rain velocity by two horizontal revolving discs. The lower disc is covered with filter paper and the upper disc has a slit in it. The discs turn synchronously and from the speed of rotation distance between discs and the distance from slit to splotch, a relationship concerning the velocity of the drops may be calibrated.

814. Schmidt, W., "Zur Pruefung von Niederschlagsmessern" (To test rain gages). Meteor ologische Zeitschrift, 50:267-269, July, 1933, 1 table, 2 refs.  
 In mountain use the Hellmann 500 sq. cm. gage permits 5% loss by evaporation. A 200 sq. cm. gage is better--about 2% loss. Nipher shield on large gage increased catch of snow 49% and on small 64%. A metal snow cross in the gage improves catch 4% by reducing eddying. While summit location gives too little catch, because of upward winds, still the catch is representing the low precipitation on that point, which is not representative of the surroundings.
815. Schoenrock, A. F., "Zur Frage ueber die Ausblasung des Schnees aus den Eimern der Regenmesse" (On the problem of snow blowing away from rain-gage buckets). Me.teorologische Zeitschrift (?) No. 5, 1926.
816. Schoenrock, A. F., "Messung der Niederschlaege unter polaren Einflussen" (Measurement of precipitation under polar influences). Me-teorologische Zeitschrift, 46:444-445, 1929.  
 Nipher-shielded gage at 2 m. lost catch by wind at 8 - 10 mps. Catch reduced by lowering gage in shield. Another gage behind fence gained by drift at 6. - 8 mps.
817. Schoenrock, A. F., "Zur Frage der Messung von Niederschlaegen" (On the problems of precipitation measurements). Meteor ologische Zeitschrift, 49:76-78, February, 1932.  
 Describes the von Schipskij rain gage, emphasizing the wind shield; and a mechanical contrivance for neutralizing the effect of wind. Eighty-two gages of a simplified model were installed for testing. (Schipskij gage).
818. Schreib'ex, P., "Der Bruhnsche Regenmesser. Kleinere (Original) Mitteilungen" (The Bruhn rain gage. Smaller (original) reports). Zeitschrift fuer Instrumentenkunde, Vol. 8, June, 1888, 3 figs..  
 A non-recording gage of the usual design. Has a deep catch vessel and the receiver is water tight, so that the over-flow from the catching vessel will not be lost. Stands on three steel legs, similar to present U. S. Weather Bureau model.
819. Schreiber, P., "Ueber einen registrierenden Regenmesser." Zeitschrift fuer Instrumentenkunde, (About registering rain gage),- Vol. 9:143-146, April, 1889, 1 fig.  
 A gage on the float and automatic siphon principle. A night light is used for cold weather and a rod (attached to the float) indicates the amount that has fallen. Siphoning action takes about 10 min.
820. Schubert, J., "Wald und Niederschlag um Westpreussen und Posen und die Beeinflussung der Regen und Schneemessung durch den wind" (The forest and precipitation in West Prussia and Poson, and the influence .of wind on rain and snow measurement). Meteorologische Zeitschrift, 23:444, October, 1906, 2 figs., 5 tables, 3 refs.
821. Secondo Alfieri, Ing., "Sulla Misura delle precipitazione in alta montagna" (Measurement of atmospheric precipitation in high mountains). Atti della riunione della Associazione Elettrotecnica.  
 This gives the results of many years' observation in several stations in the region of the Piedmont Alps, which were supplied with raingages and totalizers. Analyzing the results of the two types of apparatus, it concludes that, in this region, the totalizers give results very close to the reality.
822. Seeley, Dewey A., "Instruments for making weather observations on the farm." Yearbook of Agriculture, p. 435-436, 1908.
823. Seletsky, I., "Methodes de Mesures de la couche de neige recouvrant le sol dans differentes directions" (Methods of measuring the layer of snow covering the ground in different directions). Meteorologia I Gidrologia (Moscow), Nos. 11-12:87-91, 1938.  
 Text in Russian.

824. Servizio Idrografico Italiano, "La Misura della precipitazioni a mezzo degli apparecchi totalizzatori: Risultati di misure di confronto" (Measurement of precipitation by means of totalizers and some comparisons of results). Conseil International de Recherches Section d'Hydrologie Scientifique, Bulletin 15, 1930.
825. Shaw, N., "Manual of Meteorology, Meteorology in History." Textbook, Cambridge at the University Press, England, 1:200-201, 1942.  
One page is devoted to a general discussion of rain gaging.
826. Sidebotham, T. W., "Graduation of rain glasses." Symons' Meteorological Magazine, 38:48, 1904.
827. Siebert, "Die Niederschlagsverhaeltnisse des Grossherzogthums Baden" (Precipitation conditions in the Grand Duchy Baden). Beitraege zur Hydrogie, Baden. H., 2:1-98, 1885, 18 figs., 10 tables, 31 refs.  
Illustrations and descriptions are presented of the old Mannheim raingage and of later models used in Baden. The Mannheim gage was rectangular with vertical sides about four inches high. A separate square box was used for catching snowfall and was provided with a heater.
828. Sievert, A. B. Max, (friiu) "Fabian Nilssons registreande Nederbordsmatare eller pluviometer" (Fabian Nilssons' rainfall rate recorder and rain gage). (A catalog or trade circular) No. 5241, 4-page circular.  
The Nilsson gage, consisting of a combination tipping bucket, weight type gage has been improved for winter operation. A unique tipping system allows the removal of solution in a receiver without disturbing oil film.  $\text{CaCl}_2$  is added periodically to the solution and a light in the casing keeps the temperature above freezing. The gage has been in operation in the northern parts of Sweden for many years and works well in snow and rain. The apparatus has an eight-day clock. For a 1 mm. fall of precipitation, the hose will be lowered 7 mm. Parts are constructed so as to guard against corrosion.
829. Sil, J. M., "Intensity rain gage." Journal of Scientific Instruments, 22 (5):92-94, May, 1945, 4 figs., 1 table, 3 refs.  
Records intensity of rainfall against the time on daily charts. Rain is successively collected in one of three receivers over a period of one minute. Floats operate pen arm. Sensitive to 0.02 inch of rain per hour. Amount indicated is + 5% accuracy for total rain. Has been operating several years and requires very little maintenance.
830. Sinclair, David, "Measurement of particle size and size distribution." U. S. Office of Scientific Research and Development, "Handbook on Aerosols," p. 97-116, 1950, 15 figs., 2 tables, 1b refs.  
Methods of measurement described. Light and electron microscope, sampling methods by centrifugal separation, thermal precipitator (favored for particles less than  $1\mu$ ), gravity settling, mass concentration by weighing or optical means. A differential settler is described. Other methods involve color and polarization and the scope-o-meter for average size by light transmission of various wave-lengths (instrument described).
831. Skinner, S., "The measurement of dew." Meteorological Magazine, 47 (557):99-100, June, 1912.  
Dew and raingages should be used together.
832. Skorobogatjko, W., "Zur Frage ueber die genauigkeit der Messungen der Winterniederschlaege mit den Regenmesser" (On the accuracy of precipitation measurement during the winter). Meteorologische Zeitschrift (?) No. 11, 1927.
833. Skorobogatko, B., (The water equivalent of snow caught in a gage compared to a section taken on the ground.) Meteorologicheskii Vestnik, p. 100-107, 1927.
834. Slettenmark, G., "En registrerande Nederboerdsmaetare av ny typ." (A registering rainfall rate recorder of a new type). Stockholm, 8 p., 1932, 4 figs.  
A gage wherein the counter weight is immersed in oil to apparently act as an additional dampner. The catch area of the gage

is 200 cm. and capacity of 40 mm. The capacity can be increased to 160 mm. by adding 40 mm. weights to it. The drum rotates once in every 24 hours and magnification is 5 to 1. A dash pot is employed to further dampen out wind effects. The gage is very sensitive and future use as an evaporation gage is suggested.

835. Smith, C. C., Barnes, A. A., Bilham, E. G., Glasspoole, J., Mill.H. R., McClean, W. N., "Determination of general rainfall Over any area." Water and Water Engineering, Vol. 39:639-651, 671-675, winter, 1937, 8 figs., many refs.

A precise determination of rainfall by: 1. adequate distribution of raingages, 2. periodic critical examination of records, 3. preparation of isohyetal maps. Has a figure showing: (a) Meteorological-offrifice gage, (b) Snowdon gage, (c) Bradford gage, (d) Seathwaite gage, and (e) Octapent gage. This is a joint report of the British Rainfall Organization, the Royal Meteorological Society and the Institute of Water Engineers, London, England. Also appears in: 1. London, Technical Institute of Water Engineering, and 2. Institution of Water Engineers, London.

836. Smulowicz, B., "Analysis of the impactometer, an instrument for measuring the distribution of raindrop sizes encountered in flight." Technical Report No. 19, Massachusetts Institute of Technology, 1-44, May 16, 1952, 15 figs., fa refs., 32 eqs.

The impactometer has been designed as an airborne instrument for the measurement of the momentum of impact of raindrops on a sampling surface. Distribution of raindrop sizes is easily obtained. It is demonstrated that due to the linearity and symmetry of the system, the response is independent of the position of impact on the sampling surface, and that the response peak amplitude is independent of elastic constants and viscous friction appearing in the system. Trial results in flight conditions have been encouraging.

837. Smulowicz, B., "Analysis of the response of a momentum disdrometer." Third Radar Weather Conference, McGill University, Montreal; Proceedings, p. E 21 to E 24, September 15-17, 1952, 4 figs., 1 ref., 1 eq.

The impactometer, an airborne momentum disdrometer utilizing an electromagnet transducer with a fluid coupling. Results are linear, and response is independent of position of impact along the sampling surface. Fluid coupling results in low values for coefficient of restitution. Operation is limited by its recovery time and two instruments are necessary for 500 to 5000 micromdrop size range. Experimental values of solid calibration showed close agreement to theoretical values.

838. South Continental Divide Snow-Survey Conference; reports and papers, American Geophysical Union Transactions, No. 2:603-663, July, 1937, 1b figs., 12 tables.

Reports and papers, Section of Hydrology, and South Continental Divide Snow-Survey Conference, Washington. Group of papers on all aspects of snow surveying, including apparatus, technique, maintenance of all the same snow courses year after year, and the relation of determinations of water content to subsequent run off.

839. Sperry, W. A., "Holder for a standard rain gage." Sewage Works J, 14: 713-714, May, 1942.

Describes a simple wooden support.

840. Spinnangr, F., Eide, Odd, "On the measurement of precipitation, I, Fanaraken Meteorological Observatory." Meteorologiske Annaler, 2(5): 223-236, 1945, 5 figs., 2 tables, 4 refs.

Discusses problems and experiments in measuring precipitation at a mountain station, including location of gages. A factor by which observed precipitation should be multiplied to get true precipitation was favorably compared with theoretical computation of precipitation at the height of the observatory, based on orography. Shielded gages and constant height of gage above snow surfaces are recommended. RWB.

841. Spinnangr, F., Eide, Odd, "On the measurement of precipitation, II, Lista Meteorological Station." Meteorologiske Annaler, 2(8):263-278, 1947, 2 figs., 7 tables, 3 refs.

Several sites are selected E, S, W, and N of a fixed gage, and measurements made for one year (1944-45). Daily measurements at

the five stations are tabulated and summarized and analysis made of comparative catch at the several stations with various prevailing winds. Stations in the lee of the headwind always got more precipitation than those on the windward slope, but the mean annual amounts at the four stations differed only slightly from that at the fixed gage. Effect of buildings noticeable when in close proximity to gages. A shielded (Nipher) gage was used for one year near the fixed gage, catching 105% (more) rain and 186% (more) snow than the unshielded gage; and the catch was the greater, the greater the wind speeds - M.R. Distances between gages estimated to be about 120 ft.

842. Sprenger, Klaus, "Elektrisches Niederschlagsmeldegeraet" (Electrical rain announcer). Zeitschrift fuer Meteorologie, 2:343-344, 1948, 1 fig.

An electric contact in the center of the hole of a funnel is used to indicate the presence of rain and is useful for rainfall time and duration. A drop of water between the funnel and contact sets off an alarm that notifies the observer.

843. Sprung, A., Fuess, R., "Registrierapparate fuer Regenfall und wind mit elektrischer Uebertragung" (Registration apparatus for rainfall and wind with electrical transmissions). Meteorologische Zeitschrift, 24(6):344-348, September, 1889, 4 figs., 1 ref.

A tipping bucket gage that sends an electrical impulse for each tip of the bucket is pictured and described.

844. Sprung, A., Fuess, R., "Neue Registrierapparate fuer Regenfall und Wind mit elektrischer Uebertragung" (New recording gages for rainfall and wind with electrical transmission). Zeitschrift fuer Instrumentenkunde, 9:90-98, March, 1889.

A tipping bucket gage is heated by a night light to record snow as well as rain.

845. Sprung, A., "Ueber Fern-Registrierung des Regens" (Distance registration of rain). Meteorologische Zeitschrift, 32:385-388, October, 1897, 1 fig., 1 ref:

More results with tipping bucket gage.

846. Sprung, A., "Ueber die automatische Aufzeichnung der Regen-Intensitaet" (About the automatic registration of rain intensity). Wetter, 22:56-58, 1905, 2 figs., 1 ref.

A discussion on the operation of the Gallenkamp drop recorder. A platinum contact would be an improvement over the present mercury contact.

847. Sprung, A., "Eine Vereinfachung des Gallenkampschen Regen-Auffangapparates" (A simplification of Gallenkamp's apparatus for collecting rain). Zeitschrift fuer Instrumentenkunde, 27:340-343, November, 1907, 2 figs., 3 refs.

The Gallenkamp drop recorder has been working successfully for 20 years and is a success. The use of platinum and copper as contacts is recommended.

848. Sprung, A., "Die registrierende Laufgewichtswage im Dienste der Schnee-Regen- und Verdunstungsmessung" (The sliding weight scale used for measurement of snow, rain and evaporation for rain measurement). Meteorologische Zeitschrift, Bd. 25:145-154, April, 1908, 6 figs., 1 ret., 5 eqs.

A weight type recording gage to be used all year around. The cover and rim of the gage are heated to keep rime from forming. The recording part of the instrument is kept in a well insulated shelter and the receiver protrudes above the roof.

849. Staas, F., "Die Niederschlagsmenge in Barnaul nach dem Neuen und ohne Schutzvorrichtung von 1882 Bis 1902" (Precipitation measurement in Barnaul according to new and old rain gages with and without shields from 1882 to 1902). Meteorologicheskii Vestnik, St. Petersburg, p. 87, 1903.

850. Stade, Hermann, "Die Niederschlagsmessungen auf Berggipfeln" (Measurement of precipitation on mountain tops). Wetter, Berlin, 18:201-205, 1901.

On the Brocken, Stade found that gages exposed to the wind caught appreciably less, especially of snow, than those in the lee of the summithouse, but 20 m. from it. The difference increased with wind velocity. -

851. Stanley, W. F., "A simple snow gage." Royal Meteorological Society, Quarterly Journal, p. 123, April, 1886.  
A can with a 5-in. opening.
852. Starr, C. V., "Evaporation from rain gages."- Meteorological Magazine, 65(775):161-162, August, 1930.  
A discussion of A. J. Bamford's article on evaporation from tropical gages. Confirms that this can be a very high figure, as his experience in Transjordan was along the same line.
853. Stehberger, K. H., "Eine elektrische Nase zur Kontinuierlichen beobachtung des atmosphaerischen Aerosols (German)" (An "electrical nose" for the continuous observation of atmospheric aerosols). Deutscher Wetterdienst in der U. S. Zone, Berichte, 12:171-176, 1950, 8 figs., 2 refs.  
The presence of floating particles decreases the conductivity of air proportionately to the number of particles per unit volume and their mean surface area. An instrument is described and illustrated, consisting of two large cylindrical condensers in a differential circuit, to measure the difference of conductivity of unfiltered and water-filtered air. Curves of diurnal variation are reproduced.
854. Steinhauser, F., "Niederschlagsmessungen im Sonnblickgebiet" (Precipitation measurement in the Sonnblick Region). Meteorologische Zeitschrift, 49:443-444, 1932.  
A shielded totalizer four meters high and therefore above the snow drifting gave 23% more than one of the two ordinary gages, but less than the other gage close by.
855. Steinhauser, F., "Neue Ergebnisse von Niederschlagsbeobachtungen in den Hohen Tauern (Sonnblickgebiet)" (New results from observations of precipitation in high mountains (Sonnblick area). Meteorologische Zeitschrift, 51(1):36-40, January, 1934, 2 figs., 4 tables, 3 refs.  
A shielded totalizer on the Sonnblick for the years 1930-1932 indicated that the long period annual precipitation on the summit is around 2700 mm. Its catch for the three years was 72% and 28% in excess of two unshielded gages.
856. Steinhauser, F., "Zur Niederschlagsmessung auf einem Berggipfel" (On precipitation measurements on a mountain top). Meteorologische Zeitschrift p. 33f, 1935.  
"Results on Mt. Washington (1915 meters). It is recommended to install more gages."
857. Stevens, J. C., "The Stevens annual snow and rain recorder." American Geophysical Union Transactions, No. 2:632-633, June, 1934, 1 fig.  
A weight type gage that has 100 in. capacity and claims to record within 0.05 in. of precipitation. Balance and recorder are sealed from exposure. A motor driven rotating receiver helps to keep wet snow from sticking to sides.
858. Stevens, J. C., "Hydrologic instruments." Iowa University Studies in Engineering Bulletin, 31:91-99, 1947, 9 figs.  
Hydrologic instruments manufactured by Leupold and Stevens. Instruments are briefly described and illustrated.
859. Stevenson, T., "On the defects of raingages with description of an improved form." Edinburgh New Philosophical Journal, 33:12-21, 1842, 2 figs.  
Recommended that the larger the gages (2 ft. - 3 ft. in diameter) the better the catch. Rim effects could be eliminated by burying the gage and keeping the mouth level with the surface of the ground. A brush mat would decrease splash effect. -
860. Stewart, Balfour, "Self-recording rain gage." British Association for the Advancement of Science, p. 52, 1869.  
Gage registers the fall of rain by means of the varying immersion of a float in a fluid. It is a clock-run mechanism, and the rain empties immediately upon reaching a certain height.

861. Stewart, C. D., "Exposure of rain gage." Meteorological Magazine, 58 (690):128-129, July, 1923.
862. Stewart, C. D., "Experiments on the shielding of rain gages." Royal Meteorological Society (London), Quarterly Journal, 52:55-72, 192b.  
"Nipher shield increased catch in exposed conditions 5 to 10%, but was no more effective in higher than in moderate winds. Pit gage increased catch 10%. CFB." Author concludes that catch of gage in 1 ft. pit 4½ ft. in diameter and with vertical sides is the best means for catching true rainfalls. Sloping sides to a pit was not very desirable because of excessive splashing.
863. Stohr, A., "Ombrometricches Versuchsfeld" (Ombrometric field for experiments). Wetter, 25:43-45, 1908.
864. Storey, H. C., "Topographic influences upon precipitation." Pacific Science Congress, 6th: Transactions, August, 1939.
865. Storey, H. C., and Hamilton, E. L., "A comparative study of rain gages." American Geophysical Union, Transactions, 24(1): 133-142, October, 1943, 6 figs., 2 tables, 11 refs.  
A detailed experiment on three slopes of a hill (S, E, and N.W.) with the following gages: (1) 8 in. Standard U.S. W.B. gage at varied slopes and ground heights, (2) Stereo raingage, (3) Trough gage, (4) 4 in. rain gage, and (5) 5 ft. radius concrete catchments. Concluded that orifice should be parallel to the general slope; deviation for rains of (a) 0 in. to ½ in. = 10.4%, (b) 5 in. to 1 in. = 5.5%, (c) 1 in. and over = 3.8%.
866. Storey, H. C., Wilm, H. G., "A comparison of vertical and tilted rain-gages in estimating precipitation on mountain watersheds." American Geophysical Union Transactions, 25(3):518-523, 1944, 3 figs., 2 tables, 11 refs., 1 eq.  
Question as to whether vertical or normal-to-slope gages are more likely to measure true catch on steeply sloping areas was tested in experiment with 22 pairs of gages, one of each pair being vertical and the other being normal to the orifice to the ground. The tilted gages recorded a higher average rainfall than the vertical in 54 of the 65 storms; and the excess catch in the tilted gages usually became greater with increasing size of storm.
867. Stow, F. W., "Raingage experiments at Hawsker, near Whitby, Yorkshire." British Rainfall, p. 9-22, 1870, 3 figs., 9 tables.  
This is the first of a series of articles on gages. Contains material series, magnitude series, form series, elevation series, and position series. It is shown that the "difference of the angle at which the rainfalls is the real cause of the decrease of rainfall upon a horizontal surface with elevation." Zinc would do well for gages not close to industrial areas.
868. Stow, F. W., "Rain gage experiments at Hawsker, near Whitby, Yorkshire, 1871." British Rainfall, p. 16-26, 1871, 3 figs., 6 tables.  
A dissertation on the change of precipitation, if any, with increasing elevation. He proposes that the difference in catch with the vertical is a function of vertical currents. Concludes "that the decrease with elevation has a direct connection both with the absolute obliquity of the path of the falling rain at the higher level, and with the difference in the obliquity at the two levels."
869. Stow, F. W., "Gages tilted at 45°." Meteorological Magazine, 7(79):131-132, August, 1872.  
Correspondence.
870. Strachan, R., "An investigation of the results from experimental rain gages at Rotherham." British Rainfall, p. 28-34, 1870, 4 tables, 7 eqs.  
Resume on experiments with directional gages. S.W. is the rainy quarter in winter, and N.E. the rainy quarter in summer. A rotating gage, like a vane, has some directional lag due to inertia. A tipping gage is not at all reliable.
871. Strachan, R., "On rain gages, parts 1 - 5." Horological Journal, London, 46:126-130, 140-143, 155-159, 1903-4; 47:8-9, 20-23, 1904-5.

872. Strachan, R., "On self-recording rain gages." Horological Journal, London, 47:35-40, 61-68, 88-92, 1904-05, 8 figs., many refs.  
Thirty-four self-recording gages are described and in a few cases, illustrated. Most of these were from Symons' series of articles on self-recording rain gages in "British Rainfall."
873. Suhring, Reinhart, "Meteorologische Apparate" (Meteorological apparatus). Fortschritte der Physik, 54(Pt. 3):362-383, 1900, 43 refs.  
Abstracts of articles on meteorological instruments.
874. Suzuki, S., "On the theory of the leaking pluviograph." The Geophysical Magazine, Japan, 2(3):156-157, 1929.
875. Swinton, A. E., "Importance of a Snowdon pattern gage during snow." Symons' Meteorological Magazine, 49:18-19, 1914.
876. Swinton, A. E., "Design of Raingages." Meteorological Magazine, 58(686):37, March, 1923.  
Correspondence.
877. Sykes, "Comment on four simultaneous experiments on the Island of Bombay to determine the fall of rain at different heights below 200 ft." By Dr. G. Buist, British Association for the Advancement of Science, Trans. Section, p. 25, 1852.  
Gage at various elevations below 200 ft. did not give uniform results.
878. Sykes, G., "Rain-recording instruments for isolated arid regions." Carnegie Institution of Washington, Yearbook, No. 25:183-4, 1925-1926. (See also desert rain gages, Taylor-Rochester, October, 1934, p. 92.)  
A note on a copper gage to be left in the desert for a study of desert rainfall. Oil protects water against evaporation.
879. Sykes, G., "Rainfall investigation in Arizona and Sonora by means of long period rain gages." Geographical Review, 21(2):229-233, April, 1931, 2 figs.  
Instrument embodying principle of protective oil film; has truncated conical vessel 9½ inches high, with same base diameter. Oil protects water against evaporation for over a year. Stations distributed over a large area. Orifice only an inch or two above ground. Has not been compared with other gages. Designed to be left in the desert for a year. The orifice being as close to the ground as it is, would probably be affected by splash.
880. Symons, G. J., "Description of the experimental series of rain gages erected at Calne." British Association for the Advancement of Science, Transactions, p. 26, 18b3.  
Announcing the beginning of investigation into the size and height of rain gages.
881. Symons, G. J., "Rain gages, and hints on observing them." British Rainfall, p. 8-13, 1864, 2 figs.  
On the use of rain gages, and some experimental results. Col. Ward's experiments showed that the catch of rain was in some way dependent on the height.
882. Symons, G. J., "Outline sketch of rainfall investigations from A. D. 1677 to A. D. 1865." British Association for the Advancement of Science, Report, London, p. 192-242, 1865, 2 figs., 5 tables.  
Mentions: (1) 1766 - Heberden's experiments to detect difference of rain with elevation, (2) 1834 - Phillip's findings that condensation on the cool drops is the cause of this difference, (3) 1840 - Barrington's finding that height above surface of the ground, not elevation, should be used in any equation. (No mention is made of Bache's very important Philadelphia experiments.) Experiments were now under way to investigate, (a) size of gages, (b) height of gages, (c) form of gage, (d) temperature of rain, and (e) percent of sea spray.
883. Symons, G. J., "Instruments and experiments." British Rainfall, p. 8-12, 1865, 2 figs., 2 tables.  
A new glass gage designed by Symons that could be easily seen thru a window for distances up to 80 ft. and a gage similar to Glaishers' that is possibly the forerunner of the British Association gage. Discusses some unusual gages that face into the wind with one having an

orifice whose inclination depends on the wind velocity. Col. Ward's experiment included a pit gage to reduce insplashing.

884. Symons, G. J., "1. Instruments and experiments, 2. Notes on some results of various sets of experimental gages, 3. Interim note on Mr. Chrimes' inclined and tipping gages." British Rainfall, p. 5-6, 21-35, 1866, 8 tables.  
 1. Various gages discussed. Results of a gage (turf) filled with cinders compared to standard exposure, considerable evaporation took place. 2. Gages at 2 in. to 20 ft. elevation are compared with lower gages giving the higher values. Also gages of different sized orifices are compared (1 in. to 24 in. diameter). Not much difference noted in gages 4 in. diameter and greater. 3. A note on inclined rotating gages and five mouthed gages.
885. Symons, G. J., "Rain:How, when and why it is measured." London, 1-86, 1867, 10 figs., 14 tables, 6 refs.  
 A popular account of rainfall measurement. The gages in use at the time (float gages, side tube gages, gages with measuring glass and mechanical gages) are reviewed and their merits and faults pointed out. Influence of the size of the gage is reviewed with experiments showing that sizes from 4 in. to 24 in. do not vary appreciably. Experiments showing influence of catch with height of gage are presented.
886. Symons, G. J., "On the results of the various sets of experimental rain gages." British Rainfall, p. 29-31, 1867, 3 figs., 3 tables.  
 Five inch gages are more affected by change in elevation than 8 inch gages. Inclined rotating gages show that the inclination of rainfall is steeper aloft. Mentions using float gages in the mountains as totalizers. A float covered most of the receiver area thus retarding evaporation. The gages were heavily insulated and the lower portion was buried in the ground to keep a moderate temperature within the gage. Readings were made monthly by measuring the height to which the float rose. A calibrated rod lowered into the funnel did the measuring. Salt was added to the solution to protect the float against freezing.
887. Symons, G. J., "1. Discussion of rainfall in elevation, 2. On some results of rain gage experiments." British Rainfall, p. 32-34, 35-38, 1868, 3 figs., 4 tables.  
 1. The mean deviation of rain\* from the vertical is  $45^{\circ} 9'$  with maximum in the winter ( $58^{\circ} +$ ), and minimum in the summer ( $7^{\circ} +$ ).  
 2. Funnel should be steep to get the maximum flow rate to bottle and to hold more snow and hail. A funnel without tube will lose 1%+ by evaporation from the receiver. A small-orificed gage does not get enough water and a large orificed gage condenses dew. At 20 ft., an 8-in. gage has 4% excess over a 5-in. gage.
888. Symons, G. J., "Description of the Rotherham experimental rain gages." British Rainfall, p. 11-24, 1869, 9 figs., 6 tables.  
 Rotating directional rain gages with orifices at various angles are described. March rains had greatest angle from vertical while July and August had the least. On a perfectly calm day it was noted that a gage at 25 ft. elevation caught more than the ground gage. The mean annual angle for rain is  $40^{\circ} +$  from vertical.
889. Symons, G. J., "Note on preceding papers (Hawsker, Rotherham, and Strathfield experiments)." British Rainfall, p. 43-45, 1870, 1 table.  
 Two experimenters, unknown to each other, arrived at a conclusion that gage orifice size is irrelevant over 3 in. Under 3 in. seems to be affected by losses in measurement such as capillarity, etc. Recommends that elevated gages be subjected to a correction factor. Gages with a vertical orifice do not catch enough due to lag of the vane.
890. Symons, G. J., "Notes on foregoing papers." British Rainfall, p. 56-57, 1871, 1 table.  
 In three years experiments the catch of 45 orificed rotating gages at 6 ft. and 30 ft. elevation agreed almost exactly (0.1% difference) and the yearly totals were within 0.3%.
891. Symons, G. J., "The measurement of snow, in this and other countries." British Rainfall, p. 9-23, 1872, 4 figs., 10 refs.  
 A detailed account of what was being done to measure snow and some problems connected with measurements.

- 892.. Symons, G. J., "1. Measurement of snow, 2. The rain gage' question at Vienna." British Rainfall, p. 8-9, 1873, 1 table.
1. Snowdon pattern gage is recommended because of the deeper rim allowing more snow to be caught. 2. The Vienna gage, of 14 in. diameter, 8 ft. 2 in. height was not found' desirable because (a) the orifice was far too large, (b) at the height it was to be installed, it would be about. 7% deficient.
893. Symons, G. J., "1. Note upon the foregoing paper (Col. Ward, 'On the measurement of snow'), 2. Rotherham experimental rain gages." British Rainfall, p. 23-25, 1875, 3 tables, 1 ref.
1. Refers to 1/12 rule for snow measurement and that in spite of its obvious inaccuracy it is better than no record at all at many of the stations. In tables of Col. Ward's work it is shown that this ratio may-vary from 6/1 to 120/1. 2. Fifteen gages will be used to investigate the change of the angle of precipitation with height.
894. Symons, G. J., "1. On the diminution in the amount of rain collected in' elevated gages, 2. Rotherham experimental gages." British Rainfall, p. 34-37, 1876, 1 fig., 2 tables.
1. An'excellent graph is presented on the height vs. percent fall at one foot, for six different experiments. Concludes: (a) deficiency produced from 1 ft. to 5 ft. elevation is nearly same as for 5 ft. to 20 ft. elevation, (b) the decrease is greater in higher winds, (c) the decrease is greater, the smaller the gage. (Suggests part c, may be partly due to mode of measurement.) 2. The first year's results of Rotherham experiments were very unusual in that the catch increased with increased elevation. No explanation given.
895. Symons, G. J., "The Rotherham experimental gages." British Rainfall, p. 26-27, 30-34, 1877, 3 tables, 1 ref.
1. Concludes that the unusual results of the elevation series gages is due to their exposed location. 2. Earlier storm rain gage, consisting of 2 long glass tubes of 1 in. capacity each and an enlarged scale, was abandoned because glass was so easily broken by frost and could not be read at night. New type has a float connected with a dial system to be read from a dial. It has provisions for a night light and is primarily for intensity study.
896. Symons, G. J., "(1) Rotherham experimental rain gages, (2) difference of rainfall with elevation, (3) self-recording gages." British Rainfall, p. 16-20, 21-30, 31-47, 1878, 9 tables, 11 figs.
- (1) Recommended that the Rotherham experiment be discontinued because of poor position. (2) More evidence of the height problem. A gage in the middle of a roof may make a fair catch. As for magnitude he states the more it is protected from direct impact of the wind, the more it will indicate. Discloses that in the year of 1871 . Stow's experiments with horizontal prificed and vertical orificed vectopluiometers, at 1 ft., 5 ft., and 10.ft. showed that the angle of fall of rain varied. With the upper gages, the angle from the vertical was least. A diagram clearly illustrates this. Color Sargent Arnold's conclusions'showing that the catch of a 45° vectopluiometer was the same at 30 ft. as it was at 5 ft. over a period of several years, while a horizontally mounted gage showed a considerable difference. (3) Twenty-eight recording gages are discussed and many are illustrated.
897. Symons, G. J., "(1) Rotherham experimental gages, (2) The International Congresses and the size of rain gages, (3) Self-recording gages." British Rainfall, p. 16-41, 1879, 2 figs., 3 tables.
- (1) Normal height curve 1 ft. - 100%; 5 ft. - 94%; 10 ft. - 91%; 15 ft. - 90%; 20 ft. - 89%; and 25 ft. - 88%. (2).The Congress was influenced to reverse its choice of a 14 in. diameter to minimum of 3 in. diameter on the basis of the magnitude series. - (Russians stated that there are no differences in gages due to color). (3) The addition of three recording gages brings the total of gages to thirty-one. Two types cover them all: A. Float, B. Balance. (A) can be broken down into: (a) register to width of sheet, (b) recording pen returns to a base line by mechanical action, and (c) one in which the float returns by means of an intermittent syphon. (B) may be broken down into: (a) limited quantity, (b) intermittent syphon, and (c) tilting bucket.

898. Symons, G. J., "On the amount of rain collected at very considerable heights above the ground." British Rainfall, p. 17-29, 1880, 9 figs., 5 tables, 2 refs.  
 In comparing records of gages on tops of buildings and towers with those on the ground over a long period the following conclusions were made: (1) On a building, the gage on the leeward side would catch more than the windward gage and could on some occasions exceed the catch on the ground. (2) The tower-to-ground catch ratio will be least in winter when the wind is the highest and snow is likely. (3) Above 25 ft., there is very little difference in the amount caught.
899. Symons, G. J., "On the rainfall observations made upon Yorkminster by Professor John Phillips. F. R. S." British Rainfall, p. 41-45, 1881, 2 refs.  
 A general review of the history of the investigation of rainfall vs. height from 1766 to 1881. One new point added was that a gage in the middle of a large roof would agree well(+ 2%) with one on the ground.
900. Symons, G. J., "Termination of the second series of the Rotherham experiments." British Rainfall, p. 34-36, 1882, 1 fig., 4 tables.  
 This unusual collection of data illustrates what poor position can do to a gage. In this elevation series, the five foot level gage read 10% less than the one foot gage while the gage at twenty-five foot level read 8%.
901. Symons, G. J., "(1)On possible errors in the observation of rainfall. (2) Rotherham experimental rain gages." British Rainfall, p. 19-28, 1883, 11 figs.  
 (1) Remarks on errors caught by leaking, overflowing, leveling, expanding and poor design in rain gages. (2) A new set of experiments relating to position has been started.
902. Symons, G. J., "Self-recording gages." British Rainfall, p. 18-24, 1884, 4 figs., 7 refs.  
 Four more types of self-recording gages are discussed.
903. Symons, G. J., "Dr. Wild on the influence of dimensions and position upon the indications of rain gages." British Rainfall, p. 11-23, 1885, 2 figs., 5 tables, 5 refs.  
 Dr. Wild, Director of Meteorology of Russia, was quoted as in favor of (1) a circular gage of zinc or copper; color indifferent, (2) a size of from 4 in. to 24 in. in diameter, and (3) the pit gage for rain. In comparing a gage in a 16 ft. fence enclosure 8 ft. high with the results of a Nipher shielded gage, the catches agreed within 1%.
904. Symons, G. J., "A rain gage at sea, (2) Rotherham experimental rain gages." British Rainfall, p. 28-30, 1885, 5 tables.  
 (1) In general because of the movement of ships, rain gages at sea are not consistent. (2) Three gages on a bank 110 ft. apart were in this agreement for one year; No. 3. 19.37 in., No. 4. 19.72 in., No. 5. 19.55 in. In this position series the bank is straight and the highest portion is at the middle where also the lowest readings take place.
905. Symons, G. J., "The measurement of snow." British Rainfall, p. 16-28, 1888, 1 fig., 2 tables, 19 refs.  
 In a general discussion of snow measurement, a recommendation made is to use a separate cylinder to catch snow. Sidebottom gage for melting snow and Rotch's gage for weighing are briefly discussed.
906. Symons, G. J., "Contribution to the history of rain gages." Royal Meteorological Society, (London) Quarterly Journal, 17(79):126-142, July, 1891, 2 figs., 16 refs.  
 A historical background of rain gaging. Sir Christopher Wren's tipping bucket in 1662 credited with first and P. Perrault's cylinder in Paris in 1668 credited with second. The first float gage credited to a Mr. Kite, an Englishman, in 1787. Some unusual and eccentric types mentioned were: the Dewitt, a conical vessel; spherical gage, a large ball placed in a funnel; and staff gage, a rod protruding vertically out of a container to catch the rain.

907. Symons, G. J., "Comparison of German and English rain gages." British Rainfall, p. 24-25, 1892, 1 table.  
The German gage described as "... 2 gages, carried one on each side of a post with its orifice about 5 ft. above the ground. A lid is provided, and at night no measurement is made, but the lid is moved from one gage to the other - therefore one collects the day rain and the other the night rain." A zinc double partition of an X shape is placed in the gage to reduce eddies and thus help keep snow from being blown out. This additional wetted area costs about ½ in. per year. Compared favorably with the British 8 in. gage. -
908. Symons, G. J., "Comparison of German and English rain gages, and of Mr. Sidebottom's snow gage at Camden Square." British Rainfall, p. 27-29, 1893, 2 figs., 1 table.  
The three types were in close agreement but assumed this order: (1) English 8 in. reduced 4%, 18.99 in., (2) Dr. Hellmann's gage, 18.82, (3) Sidebottom's gage, 18.58. Unfortunately they were all at slightly different elevations.
909. Symons, G. J., "Rainfall records in the British Isles." Journal of Society of Arts, London, p. 1-12, March 2, 1894, 5 tables, 1 ref.
910. Symons, G. J., "Meteorological instruments." Royal Meteorological Society, Quarterly Journal, 23(103):205-220, July, 1897, 3 figs.  
An exhibition of meteorological instruments used in the period of 1837-1897 to illustrate the development that had taken place in this time. Non-recording gages discussed are the Howard, Troughton's side tube gage, Marshall's side tube gage, Glaisher, Snowdon, Meteorological Office and Livingstone. Recording gages discussed are the Crosley, Bevan, Beckley, Cassella and Richard.
911. Symons, G. J., "Self-recording rain gages." British Rainfall, p. 16-24, 1898, 5 figs., 1 ref.  
Eight additional rain gages are described, bringing the total of self-recording gages to forty-three that have been described.
912. Symons, G. J., "Effect of wind on catch of rainfall." Monthly Weather Review, 27:454-455, October, 1899, 1 ref.  
Some insplashing at one foot, if no grass. Makes special appeal for establishment of American rainfall stations near the ground and placed where exposure is not likely to vary, also urges strongly an indication in annual reports as to whether the particular records were obtained on roofs or on the ground.
913. Talman, C. F., "The world's biggest rain gage." American Meteorological Society Bulletin, 13:224, December, 1932.  
Totalizer for 900 inches constructed by U. S. Weather Bureau for use in the Hawaiian Islands. The receiver was made much smaller in area than the container.
914. Taylor Instrument Co., (firm), Rochester, N. Y., "Weather and weather instruments." Taylor Instrument Co., Rochester, N. Y., p. 125-132, 1908.  
Covers rain gages up to 1908, such as the general stick type and also the recording tipping bucket gage. The "Glaisher" type gage is described. It is a normal type gage but the tip of the funnel is curved to prevent evaporation as it works like a water trap. All gages were of English design.
915. Taylor, John, "Description of a rain gage." Philosophical Magazine, London, Edinburgh & Dublin, Sec. 2, 70(2):406-408, 1827, 1 fig.  
A registering gage constructed on a water wheel principle. The water wheel is divided into three compartments each holding 2.4 cubic inches of water. One revolution equals 1/10 inch precipitation. A pin and weighted arm holds the wheel until a compartment is filled at which time the weight of the arm is overcome and the wheel revolves 1/3 of a revolution to place another compartment into position. The registering is done by a system of gears and dials and platinum and silver are used throughout the gage to retard corrosion.
916. Taylor-Tycos., "What does a snowfall weigh?" Taylor-Tycos, Rochester, 28(1):19, January, February and March, 1938.  
Discussed French method of weighing and checking volume of snow. No figures or data given.

917. T. V. A., "Photographs of TVA radio rain gages." Special Report to J. Conover, Blue Hill Observatory, Milton, Mass., June, 1950, 12 figs.  
A weight-type telemetering rain gage is illustrated and described. The precipitation enters the gage thru the orifice and falls into the bucket which is counter-balanced with the weights. As the bucket descends due to the added weight a contact wheel is turned. The impulses from the contacts are fed to a CW type keyer transmitter which sends the information to a central station. No special attention is given to snow.
918. Thorn, "On an improved rain gage." British Association for the Advancement of Science, Transactions, p. 210, 1840.  
On a float type registering gage, where the indicating rod protrudes out of the funnel hole.
919. Thomas, F., "Patent No. 764,315, July 5, 1904." U. S. Patent Office, Official Gazette, 111:177, July 5, 1904, 4 figs.  
A non-recording gage consisting of a standard orifice and eight cylindrical containers arranged in a circle around and beneath the orifice. This lower section is cast from glass and is in one piece. The rain water is directed to one of the tubes and as soon as it is full, the surplus flows thru a notch into the adjacent tube and so on until they have all been filled. The containers are graduated and visual readings give the amount of rain that has fallen.
920. Thomson, W. A., "Australian Patent No. 11,264." Australian Journal of Patents, Vol. 8, 1908.  
Prov. Acc. p. 342. Complete specification lodged, p. 732. Rain gage: catchment vessel wind tilted at right angles to direction of rain.
921. Thomson, W. A., "Patent No. 916,060, March 23, 1909." U. S. Patent Office, Official Gazette, 140:871, March 23, 1909, 6 figs:  
A rotating-directional-maximum catch gage. The receiver is mounted directly to the shaft of the vane and a tube brings the water from the funnel (tiltable) to the receiver. No mention is made as to what method is used to determine the angle of fall of the rain. This would be necessary to obtain true rainfall per unit horizontal area.
922. Thrustans, "Evaporation from rain gages." Meteorological Magazine, 2(22):115, November, 1867.  
One paragraph abstract of the paper.
923. Toljksy, A. P., "Zur Frage ueber die Vergleichbarkeit der Beobachtungen der Niederschlaege" (On the question of comparability of observations of precipitation). Leningrad, 1924.
924. Tomes, G. B., "British Patent 17,473, 1890." Great Britain Patent Office, Abridgment of Specifications, Class 106:132, 1887-1892, 1 fig.  
A simple float type recording gage. No provisions are made for the gage to be continuous in action.
925. Trail, Physical Geography, Encyclopedia Britannica; reprint, 7th Ed., p. 184, 1830-42.  
"... it probably arises from eddies being formed round the rim of the funnel, which divert part of the water."
926. Tredway, W. E., "Patent No. 1,153,355, September 14, 1915." U. S. Patent Office, Official Gazette, 218:389, September 14, 1915, 5 figs.  
An indicating gage wherein the receiver is a transparent-graduated tube. A pipe from the funnel leads the rainwater into the tube which may be installed inside a house. An overflow pipe and vessel are provided for heavy rain. Graduated indicators are placed on each side of the tube which may be used for comparative results.
927. Tribus, Myron, Young, G. B. W., and Boelter, L. M. K., "Analysis of heat transfer over a small cylinder in icing condition on Mount Washington." American Society of Mechanical Engineers-Transactions, 70: 971-976, 1948, 3 figs., 1 table, 12 refs., 16 eqs.  
Shows how a simple meter for measuring the liquid water content of a cloud through which an airplane is flying can be designed based upon heat required to run the instrument dry. Has a very high convective loss at low air speeds.

928. Tryselius, O., "A short comparison between the Finnish and Swedish snow samplers." Geografiska Annaler, Stockholm, 22:182-187, 1941.
929. Tschachtschichin, W., "Zur Frage ueber die Ausblasung des Schnees aus den Eimern der Regenmesser" (On the "problem of snow blown away from rain gage buckets). Meteorological Nacherm, No. 2, 1926. (Meteorologiska Vestnik?)
930. Tsukamoto, K., Tsuneoka, S., and Takahashi, K., "A new remote rain gage and its test on Odaigahara-San." Meteorological Research Institute, Mabashi, Suginami, Tokyo, Japan (Reprint from: Papers of Meteorology Geophysics), 2(2):191-195, June, 1951, 3 figs.  
 A telemetering remote rain gage having a float as the sensitive element. The actuating device depends on the float rising to close a contact. As soon as the contact is closed, current is relayed to a motor which raises the contact until it is again opened and the operation is repeated. This cycle operates for every 0.1 mm. Coding is on a number-of-contact counter from a conventional cup anemometer. The gage is 44 cm. in diameter and is 170 cm. high. Capacity of the reservoir is 1000 mm. of rain. The rain gage has been successfully tested where rainfall in amounts of 1000 mm. may fall in one day. No provisions were made for, (1) snow, (2) shielding from the wind, and (3) automatic siphoning. Telemetering is by land line.
931. Tycos, "Measuring raindrops." Tycos-Rochester, 15:151, October, 1925.  
 The most disturbing agency to proper collection of rainfall is wind.
932. Tycos, "Rain measuring device used in soil erosion studies." Tycos-Rochester, N. Y., 23:12, January, 1933.
933. Tycos, "Robot snow observer object of Weather Bureau Study." Tycos-Rochester, N. Y., 26:116, 3rd Quarter, 1936.
934. Uhlir, Pavel, "Pristroj na mereni zaponani tosnoko bodu" (Instrument for the self-recording of the dew point). Meteorologicke Zpravy, 2(5): 121-123, 1948, 4 figs.  
 On the Foxboro dew point gage.
935. Uhlir, Pavel, "Methody Mereni Kosy" (Methods of dew measurement). Meteorologicke Zpravy, 2(2):44-45, April, 1948, 12 figs., 13 refs.  
 General summary of dew measurement.
936. Die Umschau, "Regenschreiber von Hellmann und Fuess" (Raingages by Hellmann and Fuess). Die Umschau, p. 372, 1901, 2 figs.
937. U.S.A.F., "Harvard-Mt. Washington Icing Research Report 1946-1947." U. S. Air Force Air Materiel Command, Wright Field, Ohio, Technical Report No. 5676, 194V, 802 p.  
 Thirty articles by various authors on the problems of icing, liquid water content, icing meters, drop size, etc.
938. U. S. Forest Service, U. S. Bureau of Reclamation, "Progress in snow-melt investigations at the Fraser Experimental Forest, Report No. 2; 1949 Season." U. S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station; Fort Collins, Colo., Report No. 2, June, 1951, 60 figs., 15 tables, 31 refs.  
 A technical report of 5 projects conducted during 1949 at the Fraser Experimental Forest in Colorado. Performance of Weather Bureau shielded gage in comparison with accumulation measured by snow survey at site of gage was disappointing. Wet, sticky snow clogged the orifice and the annular space between the gage and Alter shield. Some comparative results were - Gage 3.00 in., 9.00 in., Survey 10.65 in.; 18.55 in. The gage portion concluded that under the conditions there, gages were not a reliable measurement of a total season's precipitation.  
 High carnauba content paste automobile finish wax when applied to the surfaces of sampling tube, prevented snow sticking to a snow sampler.
939. U. S. Navy, "Aerology." Textbook, Aerology, NAVPERS 10361, U. S. Navy, U. S. Government Printing Office, Washington, 1:79-84, 1944, 2 figs.  
 General rain measurement is discussed. The U.S.W.B. standard 8 in. gage and the tipping bucket gage are illustrated and described.

940. U. S. Signal Office, "Report of the Chief Signal Officer." Report of the Chief Signal Officer, War Department, p. 290-291, 1886, 2 figs.  
On the use of the rain gage by the Signal Service. In many respects the Signal Service gage is similar to the U. S. Weather Bureau gage. The orifice and receiver diameters are the same. The rim above the funnel is 1½ in. vs. 2 in. for the Weather Bureau. The outside case is 6 in. dia. vs. 8 in. for the Weather Bureau. Cutting sections of snow are recommended for snow measurement or using ratio of 10 in. to 1 in. for damp snow and 11 in. to 1 in. for light snow.
941. U. S. Signal Office, "Bibliography of meteorology; a classed catalog of the printed literature of meteorology from the origin of printing to the close of 1887, and an author index, ed. by O. L. Fassic and A. W. Greely." U. S. Signal Office, Washington, 1889-1891.  
Four volumes: V. 1, Temperature; V. 2, Moisture; V. 3, Winds; and V. 4, Storms.
942. U. S. Weather Bureau, Report of the Chief of the Weather Bureau Annually for the years 1908-1915, Washington, D. C., 1909-1916.  
Some remarks on the use of the snow bin and stand pipe to measure snowfall.
943. U. S. Weather Bureau, "Report of the Chief, 1913." U. S. Department of Agriculture, Annual Report, 1913, p. 69-70, 1914.
944. U. S. Weather Bureau, "Instructions for cooperative observers." U. S. Weather Bureau, Circular B and C, Instrument Division, 7th ed., p. 14-16, 1927, 2 figs.  
General instructions to U. S. Weather Bureau Observers on how to measure rain and snow.
945. U. S. Weather Bureau, "Instructions for the operation and maintenance of the Sacramento-type storage precipitation gage." U. S. Dept. of Commerce, Division of Climatological and Hydrologic Services, 1946, 9 p.
946. U. S. Weather Bureau, "Bibliography of precipitation measurement methods and instruments." U. S. Weather Bureau, Library Circular, Washington, 2(1), January, 1944, 4 p.
947. U. S. Weather Bureau, "Thunderstorm rainfall." Hydrometeorological Report No. 5, Pts. I and II, U. S. Weather Bureau, August 22, 1945, 155 figs., 32 tables.  
The reliability of areal and rainfall determination - sources of error, statistical theory, analysis of variability, effects of uniform gage spacing, experimental net work. Contains an excellent selected bibliography on thunderstorms.
948. U. S. Weather Bureau, "Operation and maintenance of storage precipitation gages." U. S. Weather Bureau, (Washington, D. C.), p. 1-20, 1951, 3 figs., 8 tables.  
An instruction manual for 8 in. can, Sacramento, and standpipe storage gages. Construction, CaCl<sub>2</sub> solutions, measurement, and tabulation are discussed and procedures relating to them are outlined. Some practical advice given was: (1) Potassium chromate plus caustic soda added to the solution will decrease its corrosiveness 90%, (2) Dissimilar metals in a gage will promote electrolytic deterioration, (3) CaCl<sub>2</sub> solutions must be weighed to determine the true water content, (4) Paint inside of gage with asphalt paint to hold down corrosion, and (5) Paint shield and gage black to absorb as much radiation as possible.
949. Utechin, N. V., "Ist es vorzuziehen die normale Aufstellung der Regenschirm durch die Aufstellung der selben auf einem Niveau mit der Erdoberflaeche zu ersetzen?" (Is the normal installation of rain gages preferable to an installation on a level with the ground?). Travaux de la conference d'agriculture experimentale a St. Petersburg, p. 251-256, 1905.
950. Vandenplas, A., "La pluie au Congo Beige" (The rain of the Belgian Congo). Institute Royal Meteorologique de Belgique, 16:1-130, 1943, 22 figs., 14 tables, 154 refs.

951. Venkiteshwaran, S. P., "Progress in the design and manufacture of meteorological instruments in the India Meteorological Department workshop in Poona. (Indian)." Indian Journal of Meteorology and Geophysics, 1(3):180-183, July, 1950, 3 figs.  
Among the meteorological instruments which are being manufactured in India, the following are mentioned and briefly described: cup anemometer and wind vane designed by J. M. Sil, an electronic distant indicating wind instrument, a snow-rain gage, Kew pattern " barometers, whirling "psychrometers, a marine bucket, hair hydrograph, wet and dry bulb thermograph, self-recording Casella natural siphon rain gage, barograph, the Dynes anemograph, charts for recording instruments, a tilting bucket rain gage, and the fan type radio-sonde. Also various seismological instruments such as the Wood-Anderson seismograph are being manufactured in India.
952. Visentini, Marco, "Nuovo pluviometro" (A new pluviometer). Ufficio Idrografico del Po Annali Idrologici, Parma, Italy, 1933.  
This gives details concerning a new model of a rain gage register studied and adopted by the Hydrographic Bureau of the Po. It is particularly suitable for regions which are rather inaccessible and have abundant snowfalls.
953. Vitruvius, Pollio, De Architectura.
954. Vonnegut, B., "A capillary collector for measuring the deposition of water drops on a surface moving through the clouds." Review of Scientific Instruments, 20:110-114, February, 1949, 8 figs., 2 refs.  
Instrument devised to measure the amount of water impinging on a small area moving through clouds, rain, or snow. From this measurement the liquid water content of the atmosphere can be evaluated. The instrument uses capillary phenomena to collect and retain water drops striking a small porous surface.
955. Vonnegut, B., Cunningham, R. M., and Katz, R. E., "Instruments for measuring atmospheric factors related to ice formation on aircraft." U. S. Air Force Air Materiel Command, Wright Field, Ohio, Technical Report 5519, August, 1949, 54 figs., 6 tables, 103 p.  
Included are analysis of design, operation, data, limitations, etc., of: Rotating cylinders, drop size measurement, rotating magnetic disc-icing rate meter, capillary collector, electric water collection rate meter, anti-icing heat meter, and spray tunnels.
956. Ward, M. F., "On the measurement of snow." British Rainfall, p. 25-34, 1874, 5 figs., 5 tables.  
Tests in Switzerland confirmed Col. Ward's opinion that the Snowdon gage was a better type for measuring snow, because of the recessed funnel providing more space for snow to accumulate. A sharp brass rim is recommended; copper makes the better funnel. In three years (winters) the Snowdon catch exceeded the ordinary pattern by 40% + . (1) Burying gages leads to corrosion. (2) Metal receivers are better than glass ones. (3) Measurement of water content by 1/12 rule is inaccurate.
957. Ward, M. F., "On the measurement of snow." British Rainfall, p. 21-22, 1875, 2 tables.  
For one summer, Snowdon gage read consistently more than the standard type--about % average. In general, the inverted funnel method of measuring snow is in good agreement with that caught by Snowdon, and if a difference does exist, the inverted funnel method will be on the low side.
958. Ward, M. F., "On snowfall measurements." British Rainfall, p. 13-16, 1878, 2 tables.  
Results of snow density experiments showed a maximum ratio of 6 to 1, a minimum of 33 to 1 and a mean of 14 to 1.
959. Ward, M. F., "Snowfall measurements." British Rainfall, p. 16-17, 1879, 1 table.  
In general, a snow ratio of 5 to 1 as a maximum and 39 to 1 as a minimum.
960. Ward, M. F., "Graduation of rain glasses." Symons' Meteorological Magazine, 39:47-48, 1904.

961. Ward, M. F., "Origin of the Snowdon gage." Symons' Meteorological Magazine, 48:52, 1913.
962. Ward, M. F., "Snowdon Gage." Symons' Meteorological Magazine, 48: 235, 1913. .
963. Ward, R., "A new rain gage." Science (Br.), 21n.s.:593, April 14, 1905.
964. Warner, J., Newnham, T. D., "New Method of stimulating convective clouds to produce rain and hail." Royal Meteorological Society, Quarterly Journal, 78(335):46-52, January, 1952, 6 figs., 6 refs.  
 A gage is described that depends on the change of resistance of a paper tape on being moistened by cloud droplets which impinge directly on it. A continuous and permanent record of the liquid water can be obtained. Not good for rain as opening becomes water logged.
965. Warnick, C. C., "Report of the Committee on Snow, 1948-1949." American Geophysical Union, Transactions, 30(6):907-910, December, 1949, 1 fig.  
 Brief description of snow survey of Andes. Wind studies of shielded snow gages and measurement of water transmission through snow. Wind study being carried on in two phases--(a) Wind tunnel tests, (b) Field test at Mullan Pass, Idaho.
966. Warnick, C. C., "Wind studies on shielded snow gages." Proceedings of the Western Snow Conference, p. 37-44, 1949.
967. Warnick, C. C., "Experiments with windshields for precipitation gages." Paper presented to Annual Meeting, Hydrology, American Geophysical Union, May, 1952, 12 figs., 5 tables, 2 refs.  
 A slow-speed wind tunnel has been used to study the effect of wind on catches of model storage precipitation gages. A simulated snow storm was produced with sawdust and various gage designs with and without different windshields were studied. Special photographic techniques were used to evaluate and improve windshield designs. Field studies at two remote mountain locations tended to bear out laboratory conclusions. A unique theoretical true catch method was developed consisting of selector tube with 1/2 in. catch orifice diverging to a 6 in., outlet orifice and a photographic technique for determining angle of precipitation. The results with a Sacramento-type gage showed that the unprotected gage caught 27% of the possible true catch and with a shield the catch was 60%, for the experiments under consideration.
968. Warren, G., "Rainfall registered by gages inclined at 45° at the elevation of 6 and 30 feet." Meteorological Magazine, 7(78):112, July, 1872.  
 Correspondence.
969. Water and Water Engineering, "Rainfall." Water and Water Engineering, 34(400-407):53-55, 118-121, 153-155,, 209-212, 298-361, 354-356, 393-395, February 20 - August 20, 1932, 10 figs., 13 tables.  
 On exposure of rain gages showing per cent caught by gages at various heights. Records of self-recording gages:  
 A. Standard (British) or Snowdon 5 in.  
 1. Knife edge rim  
 2. Vertical walls  
 3. Bottle to minimize evaporation  
 B. Types (all about the same as Std.), non-automatic  
 1. Bradford                      5. Howard  
 2. Seathwaite                    6. Glaisher  
 3. Octapent                      7. Fleming (Floating rod)  
 4. Symons  
 C. Shielding  
 1. Turf wall best (5 ft. R and vertical wall)  
 2. Pit gage  
 D. Automatic gages  
 1. Kent syphon  
 2. Negretti and Zambra (siphons in 6 sec.)  
 E. Size  
 1. 1/1000 acre, 8 in. and 5 in. in good agreement  
 2. Order - 1/1000, 5 in., 8 in.

970. Water and Water Engineering, "An automatic snow-rain recorder." Water and Water Engineering, 50:54, February, 1947.  
A very brief note on an automatic snow-rain gage with 100 inch capacity that transmits data by radio. When precipitation exceeds 0.20 inch per hour the catch is broadcast every hour, otherwise transmits once every 24 hours. No description given (probably standpipe).
971. Water and Water Engineering, "Some instruments on snow at the Physical Society Exhibition, rainfall recorder." Water and Water Engineering, 51:239, May, 1948.  
A brief description of rate of rainfall recorder put out-by Meteorological Office. "Rain is collected in a 5 in. funnel, whence it drips from a carefully made orifice so that each drop represents a rainfall of 0.01 mm." Each drop is then recorded by a mercury switch arrangement. A timing device returns pen to zero every three minutes so height of successive lines indicate precipitation during three minute interval.
972. Water Works Engineering, "Yield from a watershed." Water Works Engineering, 94:452-453, April 23, 1941.  
Discusses yield in general and describes the construction and use of rain gage.
973. Watson, W. H.; "Origin of the Snowdon gage." Symons' Meteorological Magazine, 49:37, 1914.
974. Weber, J. H., and Brooks, C.F., "On measuring snowfall." American Meteorological Society Bulletin, 4:15-16, January, 1923, 1 table.  
Snowfall measured at times of maximum depth exceeded by 36-50% the depths obtained by measurements only at 24 hour intervals.
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Experiments at the Jonkershoek Forest Influences Research Station in measuring rainfall, point to the desirability of various changes in standard procedure. It is proposed that random sampling be employed in the placement of a set of rain gages over a large tract. Circulating gages from point to point is advocated as a means of reducing the total number required. Shielding the gage from the wind is considered essential and the Nipher type shield is favored. The need of erecting gages perpendicular to the slope is stressed. Special gages designed by Fourcade to estimate direction and inclination of rain are described. Serious loss by evaporation in monthly-read gages was found, which was largely overcome by introducing liquid paraffin.--T. T. Munger, Biol. Abstract.
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Drop size as determined by catching on treated absorbent paper.
989. Wild, H., Yearbook of the Physical Central Observatory in St. Petersburg, 1873-74.  
(Influence of color in rain gage's catch.)
990. Wild, H., "Einfluss der Qualitaet und Aufstellung auf die Angaben der Regenmesser" (Influence of the quality and exposure on the data from rain gages). Repertorium fuer Meteorologie, St. Petersburg Commissionare der Kaislerlichen Akademie der Wissen Schaftan, 9(9):1-23, 1885, 27 tables, 13 refs.

Differences in catch between gages sheltered by buildings (1869-), by a solid wooden fence (1872-), and by a Nipher shield (1885-), and others exposed in the open showed the need for protection against wind. A Nipher shielded gage at 3 m. above the ground caught 29% more than an exposed gage and 2% more than a fenced-in gage. Size of gages--results presented, 2 in. in diameter and above indicate that the size is unimportant. Height of gages--quantity caught fluctuates with altitude. Recommends that standards be adopted so that results between places will be comparable.

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 1. Weather, 3:73, March, 1948.  
 2. Weather, 12:372-373, December, 1948, 1 fig.  
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 The effect of rain gage distribution for individual storms over small watersheds is discussed and data on experiments in the San Dimas Experimental Forest is presented. (In Bell Canyon there were 51 gages in an area less than 1 mile square.) A mechanical method of spacing gages is presented that gives reasonably consistent sampling results.
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996. Wood, W. J., "Recording rain gage designed for remote mountain station." Engineering News-Record, 127:85-86, October 9, 1941, 3 figs.  
 A tipping bucket gage mounted inside a regulation 8 in. gage has a capacity of 0.02 in. per tip. A mesh screen over the funnel prevents clogging, but renders gage ineffective for snow. A mercury switch operates the circuit to the recorder 12 miles away. The recorder is an integrating type. A heart-shaped cam guides the pen arm so that the recording is continuous, with 3 in. of rain corresponding to the height of the chart.
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 The 8 in. standard rain gage, tipping bucket, and Marvin gage' are briefly illustrated and described.

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Excerpts from T. Mackereth's article on wind effects on rain gage catch, 1868.
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## Supplementary References

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The construction of a splashmeter is illustrated and described. It consists of a sloping board supported on 2 uprights, one short and one long. A groove is cut just inside each lower edge to prevent water creeping from the upper side. Distemper is used to cover the under surface and a permanent record is made of water splash. The instrument is allowed to stand over a surface that is being tested. Losses in an evaporation tank are discussed.
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A technique of measuring raindrop size distribution using a nylon screen is described. Results of 63 rain samples obtained by this method at Cambridge give a value of  $Z = 269R^{1.55}$  by a regression of log Z on log R. The standard error is 47%. A better-fitting line, obtained by trial and error, is  $Z = 180R^{1.55}$  which reduces the standard error to 38%. (Z = radar reflectivity per cubic meter and R = rain intensity in mm. per hour.)
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A simple form of spectrograph is described. Raindrops are permitted to fall thru a narrow orifice into a steady moving air stream (18,ft./sec.) that is 10 inches deep. The amount the drop is deflected from its vertical path is proportional to its diameter. A moving strip of paper, sensitive to water, and below the aperture records the deflection and illustrates drop size distribution for the storms studied. The present design is suitable for drop sizes 0.3 to 1.5 mm. in diameter. A schematic of the instrument is provided as well as 4 illustrations of (1) steady rain spectrum, (2) continuous changes in spectrum, (3) shower, and (4) short showers.
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