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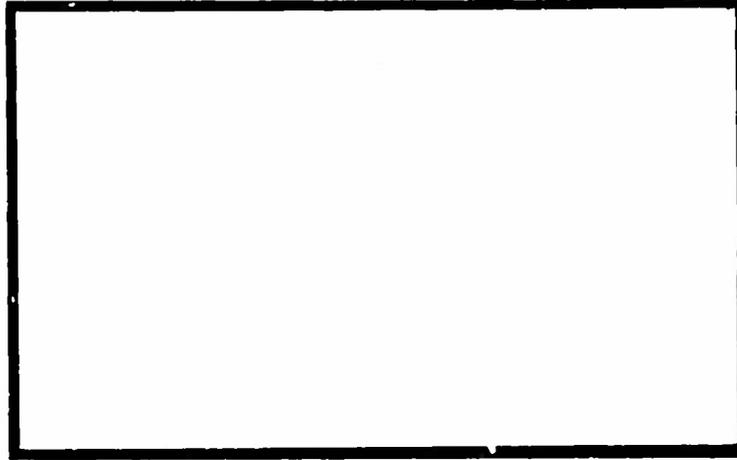
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REPORT



ILLINOIS STATE WATER SURVEY
METEOROLOGIC LABORATORY
At The
University of Illinois

#4

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PRECIPITATION MEASUREMENTS STUDY

SIXTH QUARTERLY REPORT

15 May 1953 to 15 August 1953

Signal Corps Contract No.: DA-36-039

SC-15484
Dept. of the Army Project: DA3-36-02-042

Signal Corps Project No: 794C-0

Methods of Measuring Precipitation for
Use with the Automatic Weather Station

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PURPOSE

The purpose of Part I of this Quarterly Report is to present the results of a study to determine the suitability of known precipitation gages to meet the Signal Corps requirements for an unattended Arctic weather station, as specified under Signal Corps Contract No: DA-36-039-SC-15484. Part II summarizes progress made in the development of an ombroscope for use at an unattended Arctic weather station.

ABSTRACT

An evaluation is made of known precipitation gages, with respect to their ability to satisfy existing Signal Corps technical requirements for an Arctic automatic weather station. It is concluded that none of these gages satisfy the existing requirements. With lowering of these requirements, it is concluded that a weight-type gage, with certain modifications may offer a partial solution to the problem. Suggestions for gage modifications and for further basic research are presented.

A summary of the progress made in the development of an ombroscope is presented. A field model has been installed and work is proceeding on certain modifications to improve the instrument's applicability for automatic weather station use.

PUBLICATIONS AND CONFERENCES

Publications

On June 30, 1953, authority to declassify the annual report, "Precipitation Measurements Study" was granted by the Signal Corps. Four file copies of the report on hand at this office were declassified according to instructions from the University of Illinois security office. Revision of the cover and table of contents of the report has been made in preparation for publication by the State Water Survey.

Conferences

June 1, 1953. A conference on precipitation gage evaluation with respect to Arctic use was held with staff members of the Survey.

June 25, 1953. A meeting was held at Belmar, New Jersey between Signal Corps contract representatives and staff representatives of the Illinois State Water Survey to outline the program for the remainder of the contract period.

June 30, 1953. A conference on results of the aforementioned meeting with Signal Corps representatives was held with staff members of the Water Survey.

Part I

Evaluation of Precipitation Gages

Reference

This report should be used in conjunction with the Annual Report, "Precipitation Measurements Study", February, 1953 since frequent reference is made to material and illustrations appearing in it. All page numbers, figure numbers, and reference numbers used in Part I refer to the above report.

Summary of Signal Corps Technical Requirements

The technical requirements for a precipitation gage, as set forth in Signal Contract No. SCL-15484, are as follows:

1. Measurement of precipitation to report the amount since the preceding observation to the nearest 0.01 inch, with a capacity of three inches.
2. Measurement of the precipitation shall be possible for all conditions of temperature from -60°F to 120°F and for wind speeds up to 150 mph.
3. The apparatus considered for this application shall be of a type that is capable of unattended operation for a period of at least one year.

Pertinent to the selection of a suitable gage is the electrical power available in the automatic weather station. Signal Corps Contract No. SCL-15484 states that a minimum amount of electrical power from a 6-volt storage battery source will be available at all times in the automatic weather station. In addition, 115-volt, 60-cycle, a-c power will be available at the time of observation, or for approximately three minutes once every three hours.

Limitations of Precipitation Measurements

A precipitation gage samples the rainfall or snowfall at a point. Due to inaccuracies resulting from wind and turbulence effects about the gage, the point sample does not always represent the actual or true precipitation at that point, especially during strong winds. Gaging inaccuracies are generally more pronounced with snowfall than with rainfall due to the density differences. When a gage is accepted as representing precipitation in a given area, further sampling errors are introduced since precipitation will vary with distance. This sampling inaccuracy, of course, will be greater in shower types than in steady types of precipitation. It also will depend upon topography. The sampling inaccuracy will be less pronounced when precipitation is averaged over longer periods of time, that is, the areal variations tend to decrease with time.

Standard gages now in existence do not provide an accurate measurement of snowfall. The literature reveals that the snow-section-method is still accepted as the most accurate method for measuring snowfall. Several comparative studies made by independent observers (References 53, 556, 329, 147, 369) between the catch of a gage and snow sections have shown that the average gage catch is approximately 80% of that obtained by snow sections. These studies were generally conducted with winds less than 15 mph. With stronger winds, it is to be expected that this difference would increase due to greater wind and turbulence effects.

Discussion of Arctic Gaging Conditions

The Signal Corps has designated two Arctic locations, Shemya Island and Point Barrow, as representative sites where the required precipitation gage is to be used. Therefore, a summary of the climate at these two locations is presented in the following paragraphs. The significance of various climatic factors in the selection of a suitable Arctic precipitation gage will be discussed later in the evaluation of existing types of gages.

Arctic Climatology. Shemya Island and vicinity has a maritime climate under the influence of the Aleutian low. Climatic records of the Air Weather Service and U.S. Weather Bureau indicate that precipitation in this section of the Aleutian Chain averages about 60 inches a year and ranges between 20 inches and 90 inches. The precipitation records for Shemya show an annual average of 25 inches, based on less than 10 years of record. In view of the rather uniform climatic exposure of the area, and the much larger amounts reported by neighboring stations such as at Attu (60 inches), Atka (70 inches), and Adak (53 inches), the reported amount of rainfall appears to be approximately 50 percent deficient with respect to the region it represents. The average snowfall is 75 inches (approximately 7 inches water equivalent) and occurs during the months from October to May. Maximum snow depth does not exceed two feet. Considering the average winter temperature and the small annual average range of temperature (19°F +) in this area, a moist sticky snow may be expected on occasions. Approximately 16 days per month will have precipitation of 0.01 inch or more. The heaviest amounts of precipitation occur in the late fall and early winter, while the lightest amounts are usually recorded in late spring or early summer. The temperature of the Shemya area, in keeping with maritime provinces, fluctuates over a comparatively small range with few extremes being recorded. The yearly average is about 39°F, varying from an average of 50°F for August to 31°F for January. Persistent and strong winds are an outstanding characteristic of the Aleutian Chain and are due to the Islands' exposure to the sea, coupled with the cyclonic effects of the Aleutian low. On a yearly basis, the wind will exceed 15 mph about 50 percent of the time, with summer winds being the lightest while winter winds will be the strongest. Gales (40 mph plus) are frequent and may be

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expected at any time during the year.

Point Barrow is on the shores formed by the northern coast of Alaska and the Arctic Ocean, and lies in an area above the Arctic Circle. The area is open and wind-swept during most of the year. Conditions are truly Arctic. Precipitation in the region is scant, averaging less than five inches per year. Of this five inches, about 50 percent (2.5 inches) falls in the form of rain during the summer months of June, July, and August, with July being the wettest month of the year having an average of 0.86 inch. The other 50 percent (2.5 inches) of precipitation falls as snow during the remaining nine months, and amounts to less than 30 inches in depth on an annual basis. The actual snow cover will average between 20 and 30 inches. October is credited with the most snowfall of the year with 7.1 inches as a mean monthly total. The temperature range in the Arctic area follows more along continental lines in spite of the presence of the Arctic Ocean. Approximately nine months of the year, the Arctic Ocean is covered by ice. The mean daily minimum temperature for January is -21.6°F and the mean daily maximum temperature is -8°F . For July, the mean daily minimum temperature is 33.3°F and the mean daily maximum is 46.0°F . Temperature extremes reported for Point Barrow are -56°F and $+78^{\circ}\text{F}$. The average wind speed is 11.9 mph with October being the windiest month having an average of 14.2 mph. Other factors that need to be considered in Arctic conditions, such as are prevalent at Point Barrow, are the existence of drifting and blowing snow. Drifting snow constitutes the movement of snow over the ground, usually in a height within one foot of the surface. Blowing snow, however, has been observed at heights over 50 feet.

Physical Characteristics of the Arctic. Arctic topography is characterized by level tundra extending 200 miles inland from the shores of the Arctic Ocean. Bluffs along the shore vary in heights from 5 to 30 feet above sea level. The surface area of the tundra is approximately one-half water in the form of ponds, lakes, streams, and marshes. The soil is saturated with moisture, permanently frozen and subject to surface thawing to a depth of 12 to 16 inches during the short summer season. The ice fields themselves are comparatively level in nature. Topography must be considered in gage exposure.

Certain animal and insect life exists in the Arctic that may interfere with gage operation. Wolves, bears, muskrats, beavers, rabbits, and elk are quite common and such birds as ptarmigan, ducks, and crows may be expected. Some insects that may be expected two or three months each year are mosquitoes, gnats, and flies.

Summary of Instrumental Problems. Because of Arctic climatic conditions, a suitable precipitation gage should incorporate provisions pertinent to the accurate measurement of precipitation in this region. These include:

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1. Wind shielding of the gage to reduce wind and turbulence effects about the orifice.
2. Elimination of capping over of the gage orifice in wet, sticky snow.
3. Liquifying of the snow in the gage to keep the required gage capacity within reasonable limits.
4. Wind compensation of the recording elements to reduce large vibrations and, consequently, obtain acceptable measurement accuracy.
5. Temperature compensation of the recording elements to maintain suitable sensitivity and accuracy over a wide temperature range.
6. Proper exposure with respect to the existing snow surface and blowing snow.

These problems will be discussed in detail in later sections of this report.

Applicability of Known Types of Gages to Arctic Operations.

Float Gages. Twenty-seven float-type designs (pages 33 to 39), covering the period from 1840 to 1952, were revealed by the literature survey. The use of the float gage allows simple magnification, and for this reason it may be made to record to within 0.01 inch accuracy.

An advantage of the float gage is that wind compensation is not required since the recording unit is separated from the collecting mechanism. Since these gages are primarily designed for rain measurement, a heating system must be employed to keep stored water from freezing and damaging the float and other working parts of the mechanism when they are used for snow measurement. A limited amount of power is available at the automatic weather station on a continuous basis. However, to continuously heat a large-sized apparatus, such as a float siphon rain gage, would take on an average over 100 watts on a continuous basis during winter use in the Arctic. Since heating is required to keep the water in a liquid state, temperature compensation and antifreeze solutions would not be necessary, but wind shielding would be required. In view of the limited power available on a continuous basis at the weather station, this type of gage does not appear satisfactory for the contemplated use.

Oil and Mercury Float Gages. In order to overcome the effect of freezing, a few inventors (page 39) have transferred the action of the water in float gages to fluids, such as oil and mercury, that remain liquid at low temperatures. Six oil

and mercury float gages, developed during the period from 1870 to 1951, were found in the literature (pages 39-41). Three of these, the Beckley gage, fig.101; the Osnaghi gage, and the Fuess gage, fig.102, used a siphon system to discharge water and, therefore, are not being considered for the automatic weather station due to the high power and heat requirements necessary (+100 watts) to keep them at a temperature above freezing. Another gage, the Cappleman (fig.104) piston gage is untested. It appears that it would have large frictional effects besides being inoperable below -40°F, at which temperature a mercury bath would solidify. The Rossi snow gage (Fig.103) was especially designed for snow measurement. It is a gage that requires daily attendance and has a capacity of only two inches. For these reasons it is not acceptable for use with the automatic weather station.

The Japanese Weather Service gage (Fig.105) was especially designed for all forms of precipitation. This gage does have some possibilities for Arctic use, although its capacity is limited. It will be discussed in greater detail in the following section. In general, the oil and mercury gages require heat to forestall capping, have a low capacity, need antifreeze solutions, temperature compensation, wind shielding, and possibly wind compensation.

Weight-Type Gages. Twenty-four weight-type gages (pages 41-47), covering the period from 1837 to 1952, have been revealed by the literature survey. Twelve of these have not been found suitable for consideration as Arctic gages because they are continuous-operating types designed mainly for measuring rainfall and require continuous heating and, consequently, the power requirements are too high for use in the automatic weather station. These twelve gages are as follows:

1. Osler's fig.106
2. Dr. Kreils, fig.107
3. Casella's, fig.108
4. Capello's, fig.109
5. Dottingers, fig. 110
6. Draper's, fig.111
7. Ellery's, fig.112
8. Richard Freres, fig.113
9. Rung's, fig.114
10. Maurer's, fig.115
11. Halliwell's, fig.119
12. Imber's, fig.123

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Of the remaining twelve gages; six, Marvin's gage, fig.117; Grover's gage, fig.118; Sprung's gage, fig. 122; Slettenmark's gage, fig.127; Maltais' gage, fig.128; and Conover's gage, fig. 131, are made for attended operation and would not be satisfactory for unattended operation.

The Stevens type Q12M (Figure 189) was especially designed for remote recording and large capacity. In its present form, with the telemark coding mechanism, it could be used for an automatic weather station. However, it is extremely doubtful that the Signal Corps technical requirements would be met by this gage in its present form. The Friez (Figure 125), the Fergusson (Figure 116), the Rohrdanz (Figure 120), and the Hellmann (Figure 121), are weight-type gages having limited capacities that would make them unsuitable for use at an unattended weather station in their present forms. The Nilsson rain and snow gage (Figures 129 and 130) was designed for attended operation. However, there is a possibility that it could be used in low precipitation areas where its capacity would not be exceeded. Of the weight-type gages mentioned, all can be equipped with standard wind shielding except the Nilsson. Special provisions would be needed by all of the gages to overcome capping. In most cases, capacity is not sufficient for areas such as Shemya Island and an antifreeze problem must be considered, along with temperature compensation, wind shielding, wind compensation, and capping.

Rate Recorders. Twenty-six rate recorders (pages 47-55), covering the period 1862 to 1952, were found in the literature search. Since all of them require continuous heating to prevent measuring inaccuracies and instrument damage due to ice formation, they would not be suitable for use with the automatic weather station where power requirements are limited.

Remote Recording Gages. Ten instruments designed specifically for remote operation were studied. Five of these gages were eliminated from consideration for Arctic use since they were designed for the measurement of rain only. These five gages are as follows:

1. Cerebotani and Silberman's gage, fig.186
2. T.V.A. gage, fig.187
3. U.S. Signal Corps gage, fig.138
4. Japanese gage, fig.193
5. A.E.C. gage, fig.140

The latter five are as follows: the Stevens Type Q12M (Figure 189), the Diamond-Hinman modified Friez (Figure 190), the U.S. Weather Bureau modified Friez (Figure 192), the Bureau of Reclamation radio reporting gage, and the radioactive snow gage (Figure 163). All but the radioactive snow gage require cap prevention, temperature compensation, wind compensation, and wind shielding. The Stevens and Friez gages will be discussed in greater detail later.

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Evaluation of Specific Gages.

A total of 97 gages were evaluated for Arctic use. None of these gages in their existing form are satisfactory for continuous operation at an unattended Arctic weather station under the conditions of the Signal Corps technical requirements. It is doubtful that any of these gages with feasible modifications can meet the rigid requirements, which specify an accuracy of 0.01 inch with operation in a temperature range of -60°F to $+120^{\circ}\text{F}$ in winds up to 150 mph and yearly maintenance. With certain modifications it appears that some existing gages, such as the Stevens Q12M, could be used in the Arctic as an interim solution to the problem. The foregoing conclusion recognizes that the Signal Corps requirements would not be entirely met and the gages might not operate satisfactorily on every occasion. Considering the unavoidable errors inherent in present day gaging techniques, especially in snow measurement, lowering of the technical requirements appears logical.

The following gages in their present forms present some possibility for unattended operation.

The Japanese Weather Service Gage (Figure 105) has its receiver and platform floating in oil. As the receiver descends due to the addition of precipitation, a record is made of the platform's progress on the chart of a clock-operated drum, similar to a water stage recorder. The instrument would need special shielding as its shape is not suitable for available Alter shields. Capping would be a problem with the gage, and some method would have to be incorporated to overcome this. The capacity of the gage is limited and appears to be less than 18 inches. No provisions are made for converting the snow into water equivalent and thus reducing its volume. Temperature compensation of the oil is not made and wind compensation would have to be considered. Detailed plans and specifications for this gage are not available at this laboratory.

The Stevens Weight-Type Q12M Gage, with telemeter recorder Q12MR (the telemark), is designed for automatic weather station operation. The gage operates on a counter balance system. It is available in capacities up to 60 inches of precipitation and has provisions for 60 inches of antifreeze solution. A swinging baffle type shield is provided with the gage. Provisions would have to be made for reducing capping effect at the orifice. Temperature and wind compensation would have to be considered. The Stevens gage is the only commercially available gage designed specifically for remote operation.

Other weight-type gages such as the Friez, the Hellmann, Rohrdanz, and Fergusson, with design modifications, might be made applicable. Conventional shielding could be used on all these gages. These gages do not have capacity enough for unattended operation in the Arctic, although with modifications they could possibly be used. Temperature compensation, wind compensation, wind shielding, and capping are other factors that

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would have to be considered.

The Bureau of Reclamation has designed a radio-reporting gage especially designed for unattended operation in regions that have a large amount of snow. The gage incorporates a heated catch ring to prevent capping and apparently uses a weight-type system for reporting. No plans or data are available on the gage's operation at this time. However, such information has been requested through the proper channels, and an evaluation will be made upon receipt of this information.

The radioactive snow gage was designed specifically for remote recording operation and the measurement of depth of snow on the ground. In its present form it is not suitable to measure rain. According to Gerdel, one of the developers of the gage, it would not be suitable for Arctic operation because of the excessive amount of cosmic interference to the measuring system. A method would have to be developed to make the gage suitable for rain measurement. Capping, wind shielding, wind compensation, and temperature compensation are not problems with this gage. The gage capacity of 55 inches would not be suitable for Shemya on an annual basis.

Discussion of Instrumental Problems

Wind Shields. The function of the wind shield is to place the orifice of the gage 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. Of the many shields developed (pages 28-31), only the swinging baffle type of gage (Figure 73) has proven applicable to unattended operation. The reason for this is that the baffle movement decreases ice and snow accumulation. The Nipher shield (Figure 7) has enjoyed considerable success where it was used at attended stations, and comparisons in the field has shown it to catch a small amount (1-5%) more than the Alter.

C.C. Warnick, of the University of Idaho, has been conducting wind tunnel tests of baffle-type shields and has developed models that show an improved catch over previous shields. His "Modified Alter I", developed as a result of wind tunnel tests, has been field tested and has proven to be a rugged and effective wind shield. Recent wind tunnel tests with a newly developed "Shasta" shield have given indications of being even more effective. The "Shasta" shield employs the swinging baffle of the Alter shield in conjunction with the cutting edge to windward of the Nipher shield.

The efficiency of a shield decreases rapidly as the wind speed increases above 15 mph (References 314, 150), and for catching snow, it is very low when the winds exceed 40 to 50 mph. Results of the rim effect study, presented in the Fifth Quarterly Report, further support these findings with respect to decreased catch efficiency with increasing wind speed. Although ~~the~~ Warnick's developments apparently improve the catch efficiency with respect to other shields in use, it is doubtful that

accurate snow measurements can be accomplished over a wide range of wind speeds with shielded gages. At unattended stations, where snow sections cannot be taken, this catch efficiency with existing gages must be accepted when high wind speeds occur.

Capping. The orifice of a precipitation gage is likely to cap over when wet sticky snow falls, the wind is light, and the temperature is near 32°F. The use of continuously heated catch rings for the gage orifice is the most acceptable means for preventing capping. The effectiveness of intermittent heating is questionable, but it might be effective when capping conditions are not severe. Commercially available gages are not equipped with heated catch rings, but it is believed that the necessary modifications can be incorporated into these gages. The capping problem is probably greater in the Shemya area than at Point Barrow, where near freezing temperatures have a low frequency of occurrence. The limited amount of power available on a continuous basis at the automatic weather station makes the solution of this problem difficult.

Liquifying of Snow. An oil-coated antifreeze solution is the usual means for liquifying snow. Calcium chloride is most often used as it melts the snow by its heat of solution. An oil film prevents loss of the catch by evaporation. The freezing point of an antifreeze solution rises rapidly as the solution becomes more dilute due to the precipitation. The amount of initial charge of the antifreeze depends on the following three factors:

1. Date of charging
2. Anticipated precipitation
3. Minimum temperature

In the Shemya area, the snow season appears to be from November through March. Using precipitation data from Attu and Atka as being more representative, due to the short and questionable record at Shemya, the anticipated precipitation (rain and snow) during this period is 33 inches, or for periods of extremes, approximately 50 inches. The minimum temperature reported at Shemya is 18°F. This should be a safe lower limit for estimating anti-freeze needs. Using the above data, an initial charge of 30% calcium chloride of 29 inches would provide protection to +18°F during the period. Considering that approximately 40 inches more precipitation could occur during the remainder of the year (April - October), the total gage capacity required for an extremely wet year would be 29+50+40 or 119 inches. The date of charging with calcium chloride as indicated by climatological records, should be during the first week in November.

At Point Barrow, the use of calcium chloride as a liquifying agent is questionable. The freezing point of a maximum concentrated calcium chloride solution (30%) is -59.8°F, and a small addition of water quickly raises the freezing point of the solution. The mean annual minimum for areas over the Arctic Ocean appears to be near -50°F. If the gage were initially charged

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at the beginning of the snow season in September, according to climatological records, an approximate maximum of four inches (water equivalent) of snow may be expected to occur through the end of the season in May. An initial charge of 148 inches of 30% calcium chloride solution would be necessary to provide protection to -50°F during the snow season. A total gage capacity of 156 inches would be required for an average year even though the annual mean precipitation is only 4.21 inches.

The capacity of the gage usually depends upon the amount of initial charge required. If the gage were serviced more than once per year, then an important reduction in capacity required could be made at Shemya. By servicing at the beginning and end of the snowfall season, the required capacity could be reduced from 119 inches to 79 inches. At Point Barrow, by servicing the gage at the beginning of the snow season (September) and again in midwinter (January), a capacity of 80 inches would be sufficient.

Calcium chloride solutions react rather rapidly with some metals in the presence of oxygen causing corrosion. This action may be reduced by applying a protective coating of asphalt, or galvanizing the parts that come in contact with the solution. Care must be exercised to avoid splashing any of the solution on the weighing mechanism when charging the gage.

According to Gerdels' graph on the freezing points of antifreeze solutions presented in the Fifth Quarterly Report, the only other chemical that has a freezing point suitable for Arctic use is Ethyl alcohol. A 72% (by weight) solution has a freezing point of -60°F . At Point Barrow, where low temperatures exist throughout the winter, there is a possibility that Ethyl alcohol might be used as an antifreeze. Vapor pressure of Ethyl alcohol varies from 0.39 mm at -40°F to 5.6 mm at 14°F . This compares favorably with that of water at low temperatures. If the use of the alcohol were confined to months when temperatures less than 14°F prevailed, then the estimated loss of solution would be 0.5 to 1.0 inch per month. The temperature during the snow season is normally less than 14°F . The required initial charge would amount to approximately 30 inches compared to 148 inches with calcium chloride. Tests would be needed to determine the solubility of ice in alcohol, heat requirements, rate of evaporation from the gage and corrodibility. Due to the high vapor pressure at higher temperatures, alcohol could not be used effectively at Shemya.

The use of an oil film to prevent evaporation would not be absolutely necessary since the loss of catch due to this cause would be recorded by the gage. Not using an oil film also improves the liquifying action of the solution and slightly decreases the necessary gage capacity. Improvement of the liquifying action is brought about by the fact that light, dry snow experiences difficulty penetrating the oil film.

Wind Compensation. With weight-type gages, wind compensation is a factor whenever the funnel allows the entire surface of the receiver to come in contact with internal eddies formed when the wind blows over the gage. Oscillations of the pen arm occur at high wind velocities and dampening is difficult without closing the gage orifice. Oscillations of the pen arms of 0.02 to 0.03 inch have been noted on weight-type gages when the wind was 50 mph. Depending on the scale ratio used, this could result in errors from ± 0.05 inch for a 1:1 ratio to ± 0.12 inch for a 5:1 ratio.

Temperature Compensation. At Point Barrow where the temperature ranges from -56°F to $+78^{\circ}\text{F}$, temperature compensation of the recording elements would be required. In the Shemya area, this would not be as critical a factor as the temperature ranges from about $+18^{\circ}\text{F}$ to $+58^{\circ}\text{F}$. The problem of temperature compensation for precipitation gages depends upon the method of operation that is selected. This in turn depends upon the type of gage selected. Manufacturers of Stevens and Friez gages state compensation is made for a temperature range from -20°F to $+120^{\circ}\text{F}$.

Gage Exposure. It would be desirable to place the precipitation gage at a sufficient height to be above the expected maximum snow level and above the level of blowing snow. A height of five or six feet at Shemya and four feet at Point Barrow should place the gage above the maximum snow level. Blowing snow, however, may occur to heights of 50 feet and may occur approximately 35 times per year at Point Barrow. Data on the frequency of blowing snow at Shemya are not available.

Due to added wind effects at an elevation of 50 feet, placement of the precipitation gage at this level is not recommended. Blowing snow will occur with relatively strong winds. In view of the low catch efficiency of gages with snow in strong winds, it is doubtful that blowing snow will introduce a serious quantitative error in snow measurement over a season, especially when all other sources of error are considered. It will, of course, make snow frequency studies difficult with data from unattended stations.

Discussion of Signal Corps Requirements

Referring to paragraph 1 under the listing of Signal Corps technical requirements, a sensitivity of 0.01 inch for the measurement of rain may be accomplished by magnification of the catch. This is accomplished by directing the precipitation over a large area, such as the orifice of a gage, into a container having a small cross-sectional area. The resulting concentration may then be measured by its weight which is a multiplication of the actual precipitation. In order to achieve large capacity, a repeating, cyclic, emptying action is employed to dispose of the measured contents. Since snow will not flow as a liquid unless it is melted, the foregoing method of concentration and continuity is not feasible where

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it must be treated in the solid state. The weight-type gage, so often used in snow measurement, sacrifices sensitivity for capacity since an acceptable automatic method to dispose of the catch has not been found. According to the manufacturer, the Bendix-Friez Universal Recording Gage, has an accuracy of 0.06 inch over a temperature range of -20°F to +140°F while the Stevens Q12M, 48-inch capacity recorder is accurate to 0.02 inch. The Stevens 60-inch capacity gage is supposedly accurate to 0.1% full scale or 0.06 inch. A weight-type recording gage appears to be the most satisfactory available gage for the automatic weather station, considering all factors, although achievement of the 0.01-inch accuracy does not appear feasible at this time. The requirement for a 3-hour capacity of three inches can be easily met by the weight-type gages under consideration.

The requirement for operation over a temperature range of -60°F to +120°F would probably necessitate modification of the temperature compensating mechanism in existing weight-type gages. Furthermore, the antifreeze problem becomes critical at -60°F. Calcium chloride, generally accepted as the best antifreeze, has a freezing point of -59.8°F in its most effective concentration, and the freezing point rises as precipitation dilutes the solution.

As stated previously, the Friez and Stevens gages maintain their rated accuracy over a range of -20°F to 120°F. The Stevens gage employs a temperature-compensated linkage while the Friez gage used a temperature-compensated spring. Some investigators (References 505, 529, 687) have used heaters within the housing of the gage to melt snow and also keep the moving parts of the mechanism warm. Estimates indicate that more than 400 watts would be necessary to keep the interior of an insulated 8-inch standard gage at 35°F, when the air temperature is -60°F, and the wind velocity is 150 mph.

To achieve satisfactory operation at wind speeds of 150 mph presents a structural problem. Experience has shown that structural failure often occurs in wind shields before wind speeds reach 100 mph. The gage itself would require reinforcement and special anchoring devices. Table I illustrates the amount of wind pressure on the Stevens high and low capacity shielded gages, and on an Alter shield with winds of 50, 100 and 150 mph.

TABLE I

EFFECT OF WIND VELOCITY ON TOTAL WIND PRESSURE ON SHIELDS AND SHIELDED HIGH AND LOW CAPACITY GAGES

Apparatus	Projected Area Sq. Feet	Approximate Total Pressure in Pounds		
		Wind Velocity MPH		
		50	100	150
Alter Shield	5.5	29	115	264
High Capacity shielded gage	14.0	75	290	670
Low Capacity shielded gage	6.4	34	134	307

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Calculation of stresses involved when the wind is 150 mph indicate that strengthening of the chains, bolts, screws, and fasteners on the large capacity gage would be necessary. The calculated safety factors of the large capacity equipment were 10 for collapse of housing but only 2 for the endurance limit of the 3/8 inch anchor bolts. The calculations are supported by correspondence with the gage manufacturer who indicates that the base would need modification by using 1/2 inch anchor bolts. Experience has shown that failure of wind shields was due to fatigue or repeated stress during the buffeting that occurs in high winds.

The requirement for an unattended period of one year necessitates use of large capacity gages. For example, the precipitation in the western portion of the Aluetian Chain averages about 60 inches annually. This is beyond the capacity of most gages unless a means a catch disposal is employed. Catching of snow often requires an antifreeze solution as a liquifying agent which in turn increases the size of gage necessary for a given capacity.

The limited amount of power available restricts the use of power on continuous basis for such functions as liquification of snow, deicing, and temperature compensation. The calculated heat requirements of an insulated, 8-inch, U.S.W.B. standard gage, kept at 35°F. with an outside temperature of -60 F., are as follows:

<u>Wind Velocity. mph</u>	<u>Estimated Power Consumption. watts</u>
15	104
60	340
150	416

Suggestions for Modification of Signal Corps Requirements

It is recommended that Signal Corps technical requirements be modified, at least for the present, to make the use of commercially available gages feasible at the automatic weather station. The suggested modifications are as follows:

1. Lower the accuracy requirement from 0.01 inch to 0.06 inch.

2. Permit use of a -50°F minimum temperature instead of -60°F for those stations or areas where climatological records show -50°F to be within the limits of record lows. This permits the use of calcium chloride as an antifreeze in areas such as Barrow. Calcium chloride is not satisfactory at -60°F since it has a freezing point of -59.8°F in its most effective concentration, and its freezing point rises as the solution is diluted by precipitation.

3. Permit use of a maximum wind speed of 75 mph instead of 150 mph in regions here climatological records show this to be realistic. It is doubtful that available wind shields can meet the structural requirements for operation at 150 mph without sacrifice of operational efficiency.

4. Permit gage maintenance two to three times per year instead of once per year. This will simplify gage capacity requirements and increase the utility of antifreeze solutions.

Selection of Interim Precipitation Measuring Equipment

With the suggested modifications to the technical requirements, it appears that one of the existing weight-type gages, with modifications, offers a partial solution to precipitation measurement at an unattended Arctic weather station. A modified weight-type gage should be satisfactory under most weather conditions for collecting precipitation data for climatological and forecasting purposes. Considering both applicability and availability, the Stevens appears to be the best choice among presently available gages.

Wind Shielding. The Alter swinging baffle type of shield (Fig. 73) is most suitable for Arctic use as constant movement of the baffles decreases snow and ice accumulations. The "Modified Alter I" shield developed by Warnick has been proven in field trials and is recommended for any immediate use. The field trials of the more recent Warnick development, the "Shasta" shield, should be followed since wind tunnel tests indicate this shield may be more efficient than the "Modified Alter I".

The "Modified Alter I" is not available commercially. Plans and specifications are available in the Transactions, American Geophysical Union, Vol. 34, No. 3, June 1953. If necessary further details can be obtained from Professor Warnick at the University of Idaho.

Antifreezes. The use of an antifreeze solution in the precipitation gage for the automatic weather station should be avoided, if possible. This is desirable because of the added capacity that is necessary to accommodate the initial antifreeze charge and because of instrument damage which may result from the corrosive nature of the more effective types of antifreezes.

In the Shemya area, the anticipated snowfall is approximately 75 inches during the winter. At Point Barrow approximately 45 inches of snow may be expected. The capacity requirements are easily met by the Stevens Q12M which has an overall capacity of 120 inches.

Without the use of an antifreeze, the snow is likely to pile up on the side of the receiver that is opposite to the prevailing wind during times of precipitation. It is quite possible that this piled-up snow can be liquified by heating

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the bucket during the coding intervals. Field trials would be necessary to evaluate this problem. The receiver of the gage would need to be constructed so that repeated freezing of the water would not burst its seams.

If this method is unsatisfactory, the use of calcium chloride as an antifreeze is then recommended for those stations where the expected minimum temperature does not reach below -50°F . Tests have shown this to be the best antifreeze presently available for most purposes (see Fifth Quarterly Report). Initial charge of the antifreeze will depend upon expected minimum temperature, expected precipitation, and frequency of gage attendance. Proper proportioning within a gage may be obtained from tables in "Operations and Maintenance of Storage Precipitation Gages" (Reference 948).

The maximum available overall capacity in existing commercial gages is 120 inches (precipitation plus antifreeze) provided by the Stevens Q 12M. Calculations have been made of capacity requirements for the Shemya and Pt. Barrow areas. Calculated maximum capacity for Shemya is 119 inches on an annual basis and 90 inches on a seasonal semi-annual basis. This allows for 90 inches of annual precipitation and antifreeze protection to 18°F .

At Point Barrow, the calculated capacity requirement is 156 inches on an annual basis and 80 inches on a semi-annual basis. This provides for an annual precipitation of 8 inches and antifreeze protection to -50°F . The 120-inch capacity gage would have to be charged twice yearly, with initial charging at the beginning of winter and recharging in mid-winter.

In order to obtain maximum efficiency from the calcium chloride, some means of agitating and heating the solution should be considered. The need for this exists since undisturbed solutions tend to stratify with the heavier calcium chloride sinking to the bottom, while the lighter solution forms a layer of ice on the top.

Evaporation from the receiver in Arctic areas during the winter months is less than one inch per month and would be less than 0.01 inch between 3-hour observations. Experience has shown that maximum evaporation effects would occur at Shemya during the summer months and would be no greater than approximately 0.01 inch per 3-hour period. Should this rate be objectionable, it may be reduced by an initial charge of light oil in the receiver. However, where an antifreeze is used, the use of oil is not recommended since any benefits obtained by reducing the evaporation may be overcome by the increasing difficulty for snow to penetrate the oil film and reach the solution.

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Tests should be conducted to determine if heating the solution during the three-minute coding period at the weather station would increase the effectiveness of the antifreeze. It is possible that enough convection would be caused in the solution to prevent stratification and at the same time improve the rate of solubility of the snow. An electrical, resistance-type heater placed on the bottom and outside of the receiver is suggested as a possible method of accomplishing this. This three-hourly application of heat during coding time could also be sufficient to make calcium chloride satisfactory to temperatures of -60°F , as specified in the technical requirements.

In the event that heating does not prevent stratification, a mechanical method of agitation should be considered. A bellows or displacement type of agitator has been tried by Gerdel. A rubber sleeve is made to expand and contract in the solution. This causes displacement of the solution and a raising and lowering of the level of the liquid. It is effective in breaking the ice layer, as well as bringing snow that may be piled on the ice into solution. A propellor or electrical-mixer type of agitator, such as are commercially available, should be considered. These are available in 50 to 100 watt range. Design, fabrication, and mounting of the agitator depend on the type of gage selected.

The interior of the receiver of the gage should be painted with an asphaltic paint to prevent the solution from coming in contact with the metal and causing corrosion.

As an alternative to the use of calcium chloride, ethyl alcohol should be considered for use during the snow season at Point Barrow where temperatures may drop below -50°F . Tests would be necessary to determine its solubility of ice, heat requirements, corrosiveness, and evaporation under operating conditions. A preliminary estimate indicates that rate of evaporation of ethyl alcohol would be about 0.02 to 0.03 inch a day, resulting in a required season capacity of approximately 30 inches. Because of the higher temperatures and, consequently, greater evaporation, ethyl alcohol would not be satisfactory at Shemya.

Snow Capping. This phenomenon should only occur occasionally since it usually takes place near 32°F with little or no wind blowing. A continuously heated catch ring is desirable for the prevention of capping. Due to the limited power available on a continuous basis at the automatic weather station, continuous heating may not be feasible. Since capping occurs infrequently, it is possible that heating during the three-minute coding time at three-hour intervals, when temperatures range between 30°F and 40°F , would be sufficient to break the grip of the cap.

By using a catch ring of bronze, 1-inch wide by $1/8$ -inch thick and insulating it from the rest of the gage, it is estimated that 40 watts would be sufficient to raise its

temperature 40°F which should be adequate to quickly melt the snow. A thermostatically-controlled switch would be necessary to confine operation to the 30°F to 40°F temperature range. If field trials showed that intermittent heating was unsatisfactory, then continuous heating could be considered, at a power requirement of 5 to 10 watts for periods when the wind is less than 15 mph.

Temperature Compensation. Commercially available gages, such as the Friez and Stevens, do not provide sufficient temperature compensation of the working parts for temperature of -60°F. Both of these manufacturers rate their gages satisfactory in the -20°F to +120°F range. Consequently, the thermal compensating units would have to be modified for operation with a -60°F. temperature. This involves investigation into the gage mechanism, fabrication of the necessary compensating element, and calibration under field conditions.

An alternative method to compensate for temperature would be to insulate and heat the operating elements of the gage mechanism to a temperature within their present rated operating range, where consistent results could be expected. Estimates of the heat required indicate that approximately 70 watts per pound of metal would be necessary during a two-minute period to raise the temperature of the working mechanism from -60 F. to -30 F.

Wind Compensation. Wind compensation is normally accomplished by using an oil dampening dash pot. Experience has shown that sufficient dampening has not been provided by commercially available gages. Increasing the size of the dash pot would possibly be sufficient to overcome this difficulty. Care must be exercised in the choice of oil that is used in the dashpot in order to have consistent results. Silicone oils, such as the Dow Corning 200 Fluids, are excellent for dampening since their viscosity-temperature slopes are remarkably flat in comparison to petroleum oils. Oils having a pour point at -100°F, and a viscosity of approximately 100 centistokes in the -60°F. to 0°F. should be considered. The amount used in the dashpot should allow for evaporation over a period of one year. Estimate of the evaporation should be made when the oil is selected. For comparative purposes petroleum oil, SAE 10, will evaporate approximately one-half inch in a dashpot per year of use in temperate climates.

As an alternative in the event that increase in size of dashpot does not provide the necessary dampening, it is recommended that a method of closing the orifice of the gage be considered. By closing off the orifice of the gage from vertical air movement during coding time, the source of energy of eddies causing oscillation of the receiver platform would be blocked and oscillation should stop. A device for accomplishing this would have to be designed, built and tested in the field before it could be installed.

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Suggested Gages. Of the commercially available weight-type gages, the Stevens Q12MR and the Bendix-Friez universal recording gages have been selected as most applicable to unattended Arctic use, with the Stevens being the first choice because of its greater existing capacity. The Bureau of Reclamation gage, previously mentioned, may be an improvement over these, but plans and specifications have not yet been received. As stated previously, evaluation of this gage will be made at a later date. The following paragraphs are concerned with a further description of the Stevens and Friez gages.

The Stevens, type Q12M (Fig. 189), remote recording gage is fabricated in capacities up to 120 inches. The gage has been especially designed for snow as well as rain. It is the only gage manufactured specifically for remote recording and high capacity. For this reason, it requires less modification than the Friez for use at an unattended station. With the use of antifreezes, it has sufficient capacity for both the Shemya and Point Barrow areas on a semi-annual attendance basis. If anti-freezes can be eliminated, its capacity is sufficient for annual attendance.

1. Material. The metals used throughout the gage are mostly of a stainless variety and are well suited for their purpose. The catch ring is of turned bronze, the nousing of aluminum sheet, and working parts are mostly brass and pot metal. The complete unit rests on a heavy (1/2 inch) steel base. The bearing straps supporting the counterweight are of steel and have been known to fail due to corrosion in less than a year. Replacement of the straps with brass stock should be made.

2. Form. The throat of the gage is that of an upright truncated cone. This form has been found most acceptable since it decreases capping and snow-clinging in the vicinity of the orifice. The lower portion of the gage is cylindrical and rests on a 1/2-inch steel base which is supported by three, 3/8-inch, leveling screws. Dimensions are 23 inches in diameter and 66 inches in height.

3. Construction and operation. In the type Q12M recorder, the weight of the precipitation accumulating in the catch bucket moves a pen arm to record inches of precipitation on the paper of a clock-operated drum. Since interval reporting and not continuous recording will be used, the clock-operated drum would not be necessary in the gage for the automatic weather station. The weight is balanced by a cam and counterweight. Vibration of the pen arm is dampened by an oil dashpot. A catch bucket accommodates a charge of calcium chloride in addition to the precipitation recording capacity of the instrument. A compensating weight is provided to balance the liquifying charge. Accuracy of the instrument is ± 0.02 inch to ± 0.06 inch, and depends on the gage capacity. A radio telemetering attachment, the "Telemark" is available. The "Telemark" has a pickup accuracy of 0.1% of full scale.

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4. Field results. Field trials of the gage has been made by the U. S. Weather Bureau and the Corps of Engineers. The following quotes are made from correspondence with the U. S. Weather Bureau regarding the performance of this gage.

a. "Theoretically the cam and counter weight system of the Stevens gage is superior to spring weight, but the field tests showed some serious deficiencies, due in part possibly to the extreme sensitivity of the gage."

b. "The mechanisms of the gages had too little clearance and occasionally one part would get hung up on another. We found it difficult to service the gage in the field without disturbing the suspension. It was too easy for calcium chloride to spill on the mechanism."

c. "While strong wind was evidenced by a wide ragged pen trace which merely made the charts hard to read, some bias might also have been caused by the wind."

5. Modifications. These would be according to previous discussion.

The Bendix-Friez Universal Recording Gage is fabricated for a capacity of 12 inches of precipitation and is used most frequently where it receives weekly attention.

1. Material. The metals used throughout the gage are mostly of a stainless variety and are well suited for their purpose. The catch ring and housing of the gage are of 27-gage (0.017 inch) silicone-bronze, the working parts are of brass, aluminum, and plated steel material, and the base is of a stamped 1/4-inch circular steel plate.

2. Form. The throat of the gage is an 8-inch cylinder, 5 1/2 inches long, that flares out at approximately 45 degrees to a 13-inch diameter ring that forms the metal cylinder which houses the working mechanism of the gage. The cylindrical housing rests on a steel plate that is bolted to a concrete base. Leveling is accomplished by shimming. Dimensions are 36" x 13 7/16".

3. Construction and operation. The bucket of the gage rests on a spring-type weighing mechanism which moves a pen arm to record inches of precipitation on the paper of a clock-operated drum. A dual traverse system is used; that is, when the pen moves to the top of the chart (6 inches precipitation), it reverses its direction until it reaches a limiting position on the bottom of the chart (12 inches precipitation). A dash pot is used to dampen wind vibrations in the pen arm. Accuracy of the gage is ± 0.06 inch between -20°F and $+120^{\circ}\text{F}$. An overflow attachment is available for localities where the capacity may be exceeded.

4. Field results. The Illinois State Water Survey has over 70 Friez gages in operation. Performance with the gage

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for purposes of measuring rain has been excellent. They are comparatively easy to install, operate and maintain. Records are consistently good. Servicing the gage presents few difficulties.

Estimates of various effects by field men are as follows:

a. Extremes of temperature (temperate conditions) may cause ± 0.02 -inch variation in the record. Survey gages are without a temperature compensated spring.

b. Winds of 60 mph may cause ± 0.02 -inch to ± 0.05 -inch oscillations in the record.

c. Jarring the gage can dislodge pen arm and put gage out of order.

d. Calibration of the gage is difficult.

5. Modifications. The modifications recommended in the preceding section for capping, wind and temperature compensation and for antifreeze solutions, would be necessary. Capacity of the gage should be increased. In addition, the dual traverse movement would lead to difficulty in reading when the pen arm changes direction.

a. Form. The throat and shoulder upper section could be changed to the truncated cone form of the Sacramento gage (Reference 948) to improve performance. The cylindrical trunk would need modification to permit increased capacity of the gage. This increase in size would depend on the capacity needed.

b. Mechanism. The platform and bucket of the gage would need to be increased in size to accommodate a larger capacity. Assuming that an eleven-inch diameter bucket could be accommodated (approximately one-half inch clearance), then to hold a larger capacity, the necessary height of the bucket would be as follows:

<u>Capacity (inches)</u>	<u>Height (inches)</u>	<u>Approximate Weight of Precipitation (pounds)</u>
12"	6.4	22
21"	11.1	40
35"	18.6	80.0
123"	65.3	247.0

The dual traverse of the gage should be changed to single traverse. This in turn leads to a need for stronger springs. The added weight due to increase in capacity would also necessitate an increase in spring strength.

Because of its smaller existing capacity, the Friez gage requires more modification than the Stevens for use at an

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Arctic station. This laboratory has been unable to find any record of specific tests comparing the utility and reliability of Stevens and Friez gages under the same field conditions. Such tests would be desirable before undertaking modification of either for Arctic use.

Suggestions for Further Research on Precipitation Gages

The use of upright forms, such as a gage, to catch snow offers so many aerodynamic difficulties that if a method were devised to measure precipitation as it hits the ground, rather than by a cylinder or other container, then many of the present problems of precipitation measurement would not exist. The only gage that does this for snow is the radio-active snow gage. Unfortunately, the large cosmic action in the Arctic regions, according to Gerdel, does not make the gage suitable for Arctic operation. The principle of the radioactive snow gage is acceptable and warrants further investigation. In most instances, such factors as shielding, capping, capacity, and temperature and wind compensation, do not enter into the operation of this gage. A method needs to be incorporated to measure the rain as well as the snow. Perhaps, a Koschmieder pit gage (Fig. 9), that accurately measures rain as it is received by the ground could be utilized. Monolith lysimeters (Ref. 1034) used at Coshocton, Ohio also provide a method of measuring the precipitation reaching the ground. These gages do not present obstructions to the wind and, therefore, do not have the many problems associated with wind which upright gages have. The most difficult problem of adapting these techniques is isolating the sample.

It might be possible to use a rotating type of lysimeter, wherein a round platform of the gage would be level with the ground surface. By slowly rotating the platform it is possible that only a core of snow would remain in the platform. A weight recording mechanism could be placed in a pit beneath the platform to measure the amount of precipitation received by the platform.

Since the principle of the radio-active gage is good, an investigation of the applicability of other types of radiation, such as sound and infra-red, might be desirable. An indicating head mounted on a rotating cross arm, such as is used in the radio-active gage (Fig. 163), could give a profile of the snow and water equivalent, provided the technique were feasible.

Should the preceding types be unacceptable, a collector-type of gage would have to be used. A gage in the shape of a bird bath (sphere segment) filled with an oil-covered anti-freeze solution and provided with an overflow device would present a more aerodynamically neutral obstruction to the wind than many of the storage-type gages presently used.

Conclusions

As a result of the evaluation of known precipitation gages it is concluded that:

1. No known precipitation gage in its present form satisfies the existing Signal Corps technical requirements.
2. With the suggested modifications to the technical requirements and with the suggested modifications of the Stevens and Friez weight-type gages, a partial solution to the problem appears possible. However, the suggested gage modifications necessitate design, fabrication and field testing of the modified equipment.
3. Further basic research is needed to develop a satisfactory gaging method for use in the Arctic with an unattended weather station.

Ombroscope Development

The purpose of the ombroscope ~~development~~ is to detect the presence of precipitation during time of observation at the automatic weather station. Sensitivity of existing gages is insufficient for this purpose

Type

As a result of a study of ombrosopes, the system employed by Barnothy and Bell was chosen, since it appeared to be the most promising type of precipitation detector. The Barnothy and Bell unit employes a heated metal cylinder covered by blotter paper over which wire is wrapped. A drop of water on the blotter closes a circuit between the wire and cylinder, and the resulting flow of current trips an alarm. The heat from the cylinder evaporates the water, thus re-opening the circuit and completing the cycle. It was anticipated that snow would also be detected since the cylinder was heated.

Test Equipment

Development to improve this design has been conducted in the hydraulics laboratory of the Illinois State Water Survey. An apparatus was built that employed a water sprayer to provide drizzle-type of precipitation at an approximate rate of 0.02 inch per hour. This was the minimum rate specified in the contract. Fog and mist producing devices were also assembled. A low pressure steam line provided steam fog, while a water sprayer was used for the large fog to mist range. The drop type-size distribution adopted was as follows:

<u>Drop-Type</u>	<u>Diameter in Microns</u>	<u>Terminal Velocity in MPS</u>
Fog	1 - 60	0 to 0.1
Mist	60 - 100	0.1 to 0.25
Drizzle	100 - 400	0.25 to 1.5
Rain	400+	1.5+

The ice cream hardening room of the University's Dairy Sciences building was periodically available for low temperature tests. A temperature of approximately -10°F is maintained in the room. Hoar frost crystals of ice deposited on the refrigerating pipes were used to simulate snow.

Choice of Materials

The alloy, Nichrome V, was selected as being suitable for the conducting elements of this type of instrument. Nichrome is a nickel-chromium alloy of 80-20 proportions that has a high electrical resistivity, a low temperature coefficient, a high resistance to oxidation and alteration over a wide temperature range, and excellent workability.

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Tests for suitability of insulation material were conducted on blotter paper, linen, cotton, nylon, rayon, wool, asbestos and Fiberglas. Fiberglas was found to be most suitable since it is strong, has excellent wetting properties, and resists deterioration due to high temperature, sunlight, wind and water.

Wood was selected as foundation material as it is easily worked, is durable, and when heated does not mildew. For temperatures in excess of 375°F, aluminum was used in place of wood as foundation material.

Dow Corning Silicone Varnish 935 was used as a bonding agent for the heater construction, since it is a flexible, fast drying varnish that has high heat and electrical resistance and excellent chemical, weather and moisture resistance.

Form

The form of the models is that of a truncated pyramid (Fig. 1), having side slopes of 12 1/2 degrees from the vertical. The size was based on estimated drop distribution during the beginning and ending portions of a shower where precipitation is lightest. The sloping sides allow effective drainage of water and yet have sufficient horizontal projection (1/2 sq. in.) to detect light rain.

Results

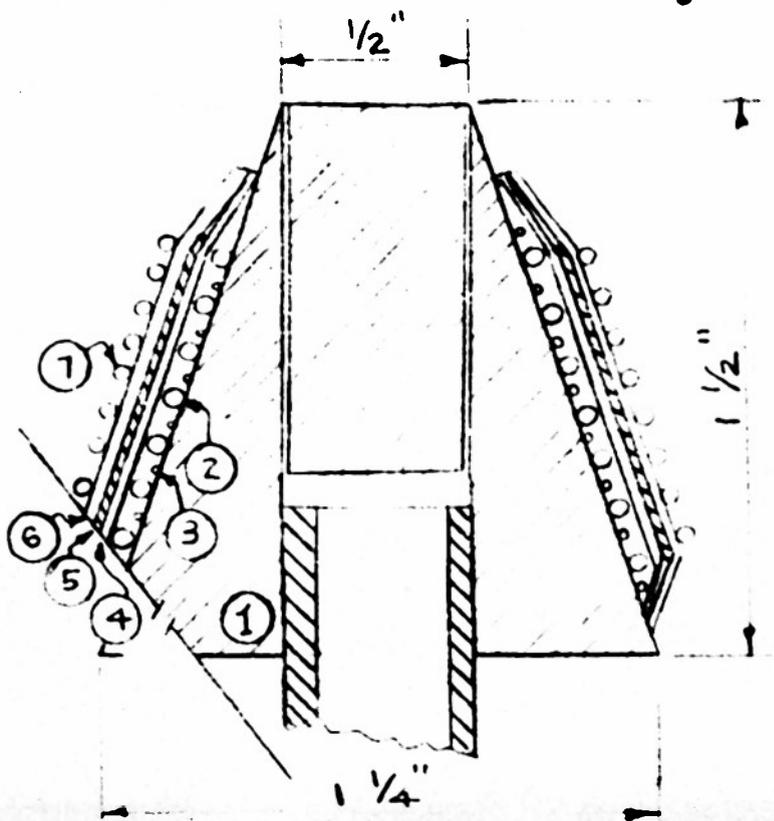
A series of models have been built, each one incorporating new materials and techniques in order to develop a satisfactory working model. The various models are as follows:

Model 1. The first designed model used a wooden base, whose sides were covered by #25 gage copper plate. Fiberglass 114 was used as the insulating material between the copper plate and the wire grid. The outer wire was Nichrome V #28 wire, wrapped in 20 turns around the instrument, and served the dual purpose of heating as well as detecting. After several hours of use under laboratory conditions, it was dismantled due to contamination of the insulator.

Model 2. This model duplicated Model 1 except that the copper plates were platinum coated to retard corrosion. In laboratory tests it was effective in detecting ice crystals and drizzle, yet was not activated by the steam fog. Corrosion of the outer wires took place and it was dismantled.

Model 3. This instrument was of the same construction as the previous types except that a cavity large enough to accommodate a thermometer was made between the upper copper plate and wood. The cavity was filled with mercury and data for heat and temperature analysis have been collected with it by use of an immersion-type thermometer placed in the cavity.

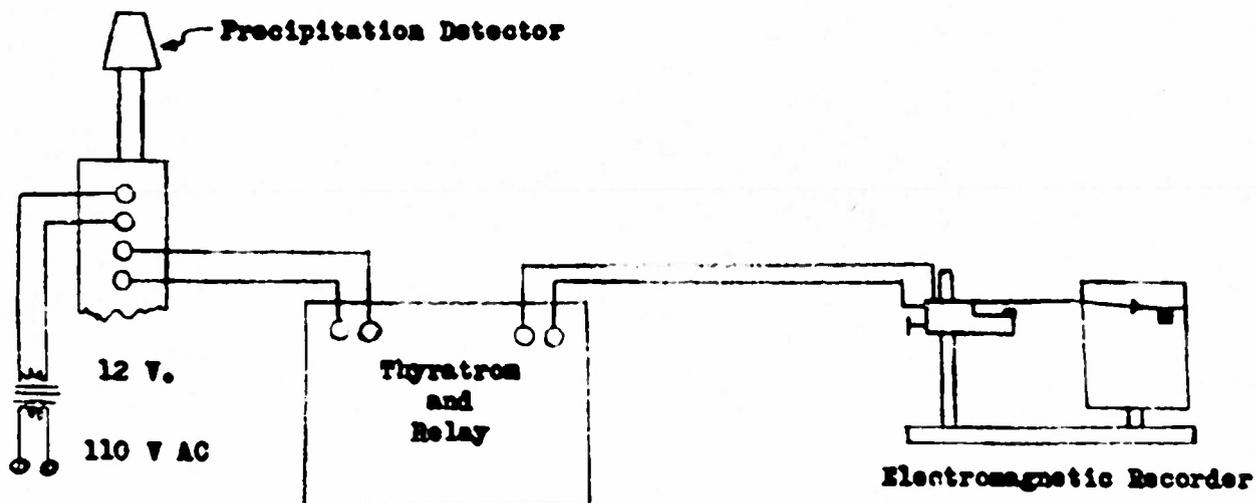
Model 4. In this model, a wood foundation, copper plates, linen 0.012" thick, and copper #28 wire were used. Its



- 1. Maple Block
- 2. Nichrome V #20 wire
- 3. Nickel #38 wire
- 4. Fiberglass #113
- 5. Aluminum foil
- 6. Fiberglass #126
- 7. Nichrome V #28 wire

Schematic Cross Section of Model 9

Schematic of Present Field Model and Recording System



operation was effective. However, corrosion was noted and it was dismantled.

Model 5 and Model 6. These models used a wood or lucite block but employed several different combinations of materials in an attempt to stop corrosion. By a process of elimination, it was found that the corrosion of the wires was due to the high current of the dual-purpose outside detector and heating wire producing electrolysis when wet.

Model 7. An aluminum block was substituted for the wood block and construction from the block outwards in layers was as follows:

- Item 1. Aluminum truncated pyramid.
- Item 2. A layer of Fiberglas 114 impregnated with Dow Corning Silicone Varnish 935.
- Item 3. A winding of 10 feet of Nichrome V #28 wire as a heating element.
- Item 4. A layer of varnish Impregnated Fiberglas 113.
- Item 5. An inner detector winding of several turns of Nichrome V, #26 wire replaced the copper plates as this simplified construction.
- Item 6. A layer of Fiberglas #113 as insulating material.
- Item 7. A winding of several turns of Nichrome V, #28 wire as the outside detector.

The purpose of this construction was to have a model wherein the heater element would be separated from the detector section and which would also be suitable for high temperatures. Drying tests were conducted with the instrument saturated with water. It was noted that at 60 watts input, 1.1 minutes were required to dry the model. Considerable heat was generated (500°F.+), and after several trials, the instrument lost sensitivity to drizzle. Loss of sensitivity was attributed to vaporization of the inner layers of silicone varnish and condensation upon the outer insulation of fiberglas. The silicone effectively destroyed the wettability of the glass fiber and, thus, the sensitivity of the instrument.

Model 8. The same construction was used as in model No.7 except that item 5, the inner detector winding, was replaced with aluminum foil (in lieu of Nichrome V metal which is on order) to act as a vapor barrier as well as a detector. A recording system has been built that employs an RCA 2050 thyatron tube as the switching element. An electromagnetically controlled pen arm is activated to record on the paper of a clock-operated drum. This model has been installed on the roof of the meteorologic building and is in operation at the

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present time. Some difficulty has been experienced with the electronic recording system.

Model 9. Construction of this model is similar to model 7. Considering it in layers from the block outwards, the construction is as follows:

- Item 1. Maple wood truncated pyramid block.
- Item 2. 15 turns of Nichrome V, #20 wire covered with silicone varnish as a heater element.
- Item 3. 15 turns of nickel #38 wire placed in between the turns of the Nichrome as a temperature control element.
- Item 4. A layer of varnish-impregnated Fiberglas 113 as insulation between the heater and detector elements.
- Item 5. A layer of aluminum foil (in lieu of Nichrome) as a vapor barrier and detector.
- Item 6. A layer of Fiberglas 126 to act as the water catching agent between detectors.
- Item 7. A winding of Nichrome V #26 wire to act as a detector.

The purpose of model 9 is to incorporate a temperature control in an attempt to provide rapid unloading with relatively large amounts of power.

For rapid unloading a relatively large amount of power is required for a short time. This power must be controlled to prevent damage to the detector. A variable resistance type of temperature control was developed for this purpose. It consists of a nickel wire wound integral with the heater winding, but not touching it. By use of an electronic circuit, controlling the power to keep the nickel wire at a constant resistance, the temperature of the detector is maintained constant.

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PROGRAM FOR NEXT INTERVAL

An evaluation of the Bureau of Reclamation gage, designed for use in snow measurement in isolated regions, will be made upon receipt of plans and specifications for the gage. It is hoped that this gage will provide a better solution to the problem than the known gages evaluated in this report.

Except for the preceding evaluation, no further work on precipitation gages is contemplated during the remainder of this contract period unless the Signal Corps technical personnel have some further recommendations. Fabrication of a field model of the precipitation detector will be made for field trials, and a report on results of the research will be prepared.

Work will start on a literature survey concerning the measurement of dust deposited per unit area.

PERSONNEL

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