AN OBJECTIVE OBSERVATION TECHNIQUE FOR FREEZING PRECIPITATION

EWTE 73T1001

Perhaps you may have a similar interest in this problem. Be glad to discuss it some time.

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LABORATORY REPORT NO. 7-73

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AN OBJECTIVE OBSERVATION TECHNIQUE FOR FREEZING PRECIPITATION

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STERLING, VA. 22170

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MANAGEMENT SUMMARY

AN OBJECTIVE OBSERVATION TECHNIQUE FOR FREEZING PRECIPITATION

Summary of Accomplishments.

We have developed several objective techniques of observing and reporting freezing precipitation. The techniques proposed here are suitable for use in applications ranging from the simplest "yes/no" answer to precision research requiring refined quantitative data. Any of the proposed techniques can be used in current and projected automatic weather stations.

We have found commercially available sensors which are usable and "off the shelf." It may be necessary to make relatively minor design changes in these sensors or to provide logic circuits to massage the output. Costs are estimated to vary from about $800 for the simplest system to about $1,600 for the system with the maximum resolution.

Why We Looked at This Problem.

Some areas served by the National Weather Service experience numerous freezing precipitation events each year. This may vary from the light, and often very beautiful, "silver thaw" of the mid-latitude states to very heavily damaging and dangerous "ice storms" experienced in the North Central and Northeastern states. Flying is made dangerous. Highway traffic may be brought to a standstill. These things are often taken somewhat for granted, but NWS still does not have a usable objective observation technique for freezing precipitation - until now.

Among techniques tried by other workers have been capitance precipitation detectors depending upon changes in capacitance caused by differences in dielectric constants of air and water; changes in resonant frequency of a driven tuning fork; sonic impact detectors; and a magnetostriction vibrating cylinder of a design closely similar to the one we propose now.

What Happened.

At the time we searched journals, catalogs, and commercial literature, we were unaware of a Canadian project using a magnetostrictive sensor. We did, however, select a sensor from the same family of detectors built by Rosemount Engineering Co. as the one used by Atmospheric Environment Service (AES) (Canada). One major difference being that our sensor was not radio frequency interference (r.f.i.) protected. In this series of detectors a driven-oscillator forces a small, closed cylinder to vibrate longitudinally, parallel to its axis, by the magnetostriction principle. Driven at its resonant frequency, when dry, the cylinder will become heavier with accretion of ice. This increased weight will cause a shift in resonance. This shift can be calibrated to read out in ice accretion.

Our ice accretion detector was operated continuously at Mount Washington Observatory, N. H.(MWO), from mid-January to the end of April 1973. Initial installation had been made in October 1972, but r.f.i. and other problems caused us much delay. The sensor was almost completely rebuilt before useful data was taken. After the sensor had been rebuilt, it would work frequently, apparently successfully, in the r.f. field at MWO. At MWO there is a very intense r.f. field which caused changes in the characteristics of this sensor to such a degree as to convince us that r.f.i. protection must be used, at least there.

In the 3-1/2 months of operation at MWO, we got approximately 350 hours of apparently successful operation. We also got icing data taken by the MWO staff by a technique known as rotating multicylinders. This is a technique developed by Langmuir and successors during World War II. In the 3-1/2 months of operation, we had no further mechanical or electrical failures of the sensor.

Data analysis.

Data analysis was based on the assumptions: (1) the ice formed on a flat surface normal to the wind during freezing rain or freezing drizzle events can be equated or correlated to the ice formed on a rod exposed to the identical conditions; and (2) the performance of the sensor probe (rod) is exactly equatable to that of the rotating multicylinders. The first assumption is well supported in the literature. The second assumption is reasonable in view of the comparative sizes of the diameters of the cylinder used and the probe.

Data selection rules required that only icing periods (one hour long) taken within one-half hour of a rotating, multicylinder icing observation reduced the number of usable periods from 350 to 52. Of those, approximately 40% were taken during low r.f.i. (after the TV and FM stations left the air). Events occurring at rates as great as 3.6 inches per hour were measured.

We would like to be able to say that the test sensor actually measured icing exactly equal to the amount of available icing computed from the multicylinder data. That is, the

$$\text{Ratio} = T_o/T = 1 \qquad \text{where } T_o = \text{measured icing}$$

$$T = \text{available icing.}$$

For the 52 total cases, the mean ratio was in fact 1.082 — or, that is to say the ice accretion detector measured 8.2% high. During the periods of low r.f.i., the mean ratio was 1.096. The coefficients of correlation between T_o and T computed were:

For the total data - 0.901

For low r.f.i. data - 0.930

Since the sensor used responds to change in the mass of the probe, the density of ice used in establishing the calibration is critical. Calibrations are usually made with glaze. Formation of rime on the same probe will give an erroneous icing measurement. Climatologically speaking, glaze does not form frequently below 20°F. Differentiating between glaze and rime events by ambient temperatures may be used to improve the quality of the reading, to a degree. Using lower cut-off temperatures would reduce the chance of misclassifying glaze events while increasing the chance of misclassification of more rime events. Operational need would then be the deciding factor.

Summaries of Proposed Observation Techniques

Technique I - Freezing Precipitation Yes/No:

This will provide only a statement of whether or not freezing precipitation of any kind is detected.

Technique IA - Freezing Precipitation Yes/No with Type Discrimination:

A simple extension of this basic technique based on whether or not the ambient temperature is above an assumed critical temperature for the deposition of rime.

Technique II - Quantitative Freezing Precipitation Observation:

This is a straightforward counting of deicing cycles during a unit of time. The count is then converted to depth by multiplying a conversion factor.

Technique IIA - Quantitative Freezing Precipitation Observation with Type Discrimination:

An extension of Technique II by use of the critical temperature mentioned earlier to discriminate between rime and glaze.

Technique III - Quantitative Freezing Precipitation Observation with Analog Voltage:

This is the most complex of the proposed techniques. In addition to counting deicing pulses as in Technique II, the analog voltage level of the unfinished cycle at the read signal is proportioned to provide the maximum precision of reading.

Technique IIIA - Quantitative Freezing Precipitation with Analog Voltage and Type Discrimination:

This is an extension of Technique III by use of the critical temperature approach to discriminate between rime and glaze.

Our Recommendations:

We believe an observation technique providing a simple yes/no indication of icing (Technique I, above) will answer a large number of requirements. To this end, a suitable, r.f.i.-protected icing detector system should be developed or selected from commercially available models. A system of this type is expected to cost about $800 for sensor and power supply.

For a general purpose, across-the-board observation technique which is directly applicable to existing and planned automatic weather stations, we recommend the use of a quantitative technique which will also indicate the type of icing (Technique IIA, above). This technique, when coupled with a detector which has been calibrated for deicing at low accretion thickness (say, 0.02 inch), will provide a precision and accuracy of measurement which will meet aviation and forecast requirements. It promises to be more dependable than subjective observations resulting from FMH-1 instructions. A system of this kind is estimated to cost about $1,400 for sensor, power supply and logic.

Whatever technique, be it one proposed in this study, a modified version, a combination, or another completely different, ultimately selected, the sensor should be selected, or designed, and several of the provisional systems installed in typical exposures for use experience. Before final usage in a network, a thorough test and evaluation of the candidate system would be necessary.

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PREFACE

The principal investigator was A. N. Hill. Paul I. Chinn assisted in the data reduction and preparation of illustrations.

Note: The National Weather Service of the National Oceanic and Atmospheric Administration does not approve, recommend, or endorse any product except for its own use, and naming an item is for the purpose of identification only and shall not be used in advertising, sales promotion, or to indicate in any manner, either implicitly or explicitly, endorsement by the National Weather Service.

AN OBJECTIVE OBSERVATION TECHNIQUE FOR FREEZING PRECIPITATION

What We Have Shown

We have developed several objective techniques of observing and reporting freezing precipitation. We have found commercially available sensors which are directly usable for this program. The resolution in the output data can be geared to the user's need by easily-made design changes in the sensor and/or the associated logic. The costs are estimated to vary from about $800 for the simplest system to about $1,600 for the system with maximum resolution.

Why We Looked at This Problem

Freezing rain, freezing drizzle, and hoar frost occur in many parts of the U.S. during late fall, winter, and spring. The buildup of ice on communication lines, power lines, and antennae often becomes great enough to cause them to break. Ice on buildings and other structures may become heavy enough to cause failure. Ice accumulation on runways, taxiways, and highways may make them unsafe. Icing, including hoar frost, may cause changes in the aerodynamics of an aircraft sufficiently to cause an accident.

The Federal Meteorological Handbook No. 1 (FMH-1) gives criteria for reporting the occurrence and the intensity of freezing rain and freezing drizzle. However, we believe the observations resulting from these instructions are very subjective and are not adaptable to automatic observation techniques. There is a rather casual reference to making a depth measurement of glaze, but no technique for this is actually discussed. Hoar frost is defined but there is no provision for either measuring or reporting this phenomenon. (Since there is no provision for reporting hoar frost, we will not continue to separate it out from rime in this report.)

Some techniques others looked at.

An intensive literature search showed that several techniques have been tried in the past. Few withstood rigorous testing. Some of these techniques will be described briefly.

1) Peck capacitance detector. Several years ago, the Equipment Development Laboratory (EDL) and the Test and Evaluation Laboratory (T&EL) of the National Weather Service (NWS) set up a joint task to provide Mr. Richard Peck (now retired) an opportunity to build a more refined version of a capacitance precipitation detector. This detector was

supposed to have provided a binary output coded to various liquid precipitation forms and rates occurring. However, if some heating were provided, it could further discriminate between some forms of solid precipitation (including freezing rain) and liquid forms. This heating was provided by heaters in response to a thermostat. Basically, the individual detector sections were capacitors (either parallel wires, plates, or annular rings) introduced to an a.c. bridge. Normally, the dielectric was dry air, but when precipitation fell on the capacitor, the dielectric strength was altered by the water then introduced. For solid precipitation some heating was provided to melt it into water. Logic circuits provided various outputs corresponding to the form of precipitation occurring. A bench test program at EDL indicated that the system was less than satisfactory. No further work was done on it.

2) Tuning fork detector. This detector is simple enough in theory. A tuning fork is driven at its resonant frequency. If one tine is loaded by a small mass of ice, the resonant frequency changes. This change in frequency is sensed and related to the amount of ice accreted on that tine. This has been used in laboratory situations but has not been rugged or durable enough for field application.

3) Sonic impact detectors. About 10 years ago, the Instrument Engineering Division (predecessor to the Equipment Development Laboratory), contracted for the development and construction of a Present Weather Detector System for use with the AMOS-IV. This system was to detect and differentiate between hydrometeors which may be of importance in automatic reporting. Component detectors and the method of proposed usage are briefly outlined below:

> Liquid Hydrometeors - Detected by sound of impact by sensitive microphones mounted as diagonally-opposed pairs under thin metal quadrant squares.
>
> Frozen Hydrometeors - Detected by sound of impact by sensitive microphones mounted back of each of the four exposed faces of a tetrahedron.
>
> Snow - Detected by light source and photocell across diameter of cylindrical, vertical chimney.
>
> Freezing Rain - Icing (freezing rain) was detected by the change in resonant frequency of a driven tuning fork as ice accreted upon one tine of the fork.

The IED did not find the delivered system workable, and nothing further was done with it.

4) Canadian Experiment, 1971-1972. During the winter of 1971-1972, the Instrument Division, Atmospheric Environment Service (Canada) (AES), conducted an ice accretion study at two coastal stations known to have frequent icing events during the winter - Gander, Labrador, and St. John's, Newfoundland. ("Measurements of Ice Accretion Progress Report, Winter 1971-1972," P. M. Cahiné, Atmospheric Environment Service (Toronto), 1972.) Mr. P. M. Chainé was the engineer in charge. A Rosemount Engineering Co. Model 871CB1 Ice Accretion Detector was installed at each station along with horizontal test plates and vertical cylinders (Model 871CB1 was calibrated for 0.02" accumulation before triggering). The correlation of this data against accumulations on the horizontal plates and vertical cylinder was hoped for.

He found that the detector was in generally good agreement except at high accumulation values where there were excessive numbers of detections (deicing cycles in our terms). Chainé attributed many of their problems to aerodynamics of the detector. He said that these detectors offered much promise as network instruments, and that further work should be done using instruments with better aerodynamic characteristics.

What Happened:

The system we chose.

We thoroughly searched journals, catalogs, and commercial literature for candidate systems. The one appearing to be the most promising was a family of ice accretion detectors available "off the shelf" from the Rosemount Engineering Company, Minneapolis, Minn. These detectors are of the variety using a cylindrical probe oscillating in a magnetostrictive mode discussed briefly above in the AES study. A driver oscillator forces the cylinder to vibrate longitudinally, parallel to the cylinder axis, at its resonant frequency. An added mass on the cylinder will change its resonant frequency. This change in frequency is sensed by suitable circuitry to a predetermined (calibrated) maximum excursion. At that point, a relay is caused to close, initiating a deicing, or heating, cycle simultaneously with a near zero-resistance closure signal. This contact closure can be used to activate an alarm, or, in our case, a counting circuit. Since we anticipated the desirability of an analog-voltage output for study purposes, a model providing a linear d.c. voltage proportional to ice accretion was selected. This system, specifically the Rosemount Model 871BR1 Ice Accretion Detector (see figure 1) was ordered.

Since we expected to use the instrument at a coastal location, we ordered the detector without radio frequency interference (r.f.i.) protection. That model was very appreciably cheaper and task funds were low. During the data-taking period, this "economy" proved to be very false. (This system was ultimately installed at Mount Washington Observatory, N. H., in a very intense r.f. field!) By a factory calibration the detector provides the following signal or commands:

1) An analog output of 0 to 5 VDC corresponding, linearly, with ice accretion of 0 to 0.150 inch.

2) An icing signal output of a 28 VDC pulse of approximately 5 seconds duration.

3) A switch closure to activate the internal deicing heaters to deice the sensor within approximately 7 seconds. After that the sensor returns to its normal mode of operation, ready to repeat the cycle.

System check at Sterling Research and Development Center (SR&DC)

The ice accretion detector was checked in facilities at SR&DC. Necessary improvisions made were not entirely adequate for best testing, but they were at least adequate for testing the basic functioning. During the first round of tests, several apparently anomalous events occurred. These were discussed frequently with Rosemount engineers by telephone. (It should be pointed out that, throughout the entire test, installation, and data-taking periods, we received only the finest, most willing cooperation from Rosemount engineers.) After several days' testing, we were certain that something was wrong. By agreement with Mr. John Kowles, Rosemount Engineering Co. (REC) project engineer, the detector was returned to the factory. We also sent them our recorder charts which illustrated certain apparent malfunctions. The detector was returned to us very promptly, and we began a new series of tests. Many of the effects noted originally no longer existed or were much reduced after the factory repair. We decided that the detector was satisfactory for our field installation.

Site selection:

We experience only a limited number of freezing rain events in any year in the Sterling area. Because of this, we decided very early in the program to seek out a suitable coastal site in the Northeast U. S. We also considered Mount Washington Observatory, N. H.(MWO) Most persons associated with meteorology have heard stories of the ice, the cold, and the wind atop Mt. Washington. Climatological and semi-scientific literature verified this impression (see Table 1). It was decided to make our installation at Mt. Washington if suitable arrangements could be made there.

A visit was made to MWO to make a more thorough investigation of the desirability and feasibility of a test there. Discussions with Mr. Guy Gosselin and Mr. John Howe indicated that our space requirements could be accommodated. The Mount Washington Observatory was to test an ice detector for deicing a radome for the U. S. Army Cold Region Research and Engineering Laboratory (CRREL), also. Mount Washington Observatory also has facilities for making routine, multiple rotating cylinder icing measurements. Icing rates as great as 12 inches/hour could be expected. However, Mr. Howe emphasized the very strong r.f. field at the station. (It measures between 10-20 volts/meter.)

The question of operation in a strong r.f. field was referred to REC. After careful consideration, they said that even though this detector was not r.f.i. protected, they thought it would be alright. Similar, nonprotected detectors had been successfully operated in fields as great as 10 volts/meter. We decided: that MWO would be a suitable test site; the staff there was most interested in doing the project; space and power were available at the Observatory; and we would take the risk of operating in a strong r.f. field as being a recognized one.

Projected program at MWO:

1) Installation: To be made during the week of October 1, 1972.

   a. The sensor would be remoted to parapet of the top level of the instrument tower (see figure 2). Cabling to be provided would permit removal of the detector to inside the tower during manual deicing periods. (Heavy icing occasionally needs to be chopped off the tower and instrument mountings.)

   b. Well-shielded power and signal cables to be used for interconnections.

   c. The control cabinet and the strip-chart recorder to be located as requested by Director, MWO.

2) Operating periods: Operation was to be continuous unless forecasts indicate at least 24 hours before next probable icing period.

3) Multi-cylinder measurements: A multi-cylinder ice-accretion determination was to be made soon after the onset of icing and repeated each six hours after that (workload permitting). (For basic discussion of the theory behind use of multi-cylinder ice-accretion determinations, see "Mathematical Investigation of Water Droplet Trajectories," Irving Langmuir and Katherine B. Flodgett, General Electric Research Laboratory, Report RL-225, December 1944-July 1945, reissued June 1949.)

4) Microfilm (35 mm) copies of the daily Form WSB-16, "Daily Weather Observations," were to be provided at the end of each month.

5) In addition to the multi-cylinder icing data, visual observations during icing events to observe the condition of the sensor and objects about it were to be made. Significant information was to be logged for later transmittal to NWS. If anything especially notable was observed, photographs were to be taken.

We had problems early.

No particular problems were encountered in the routine of system installation. However, when the system was tested using the internal test methods, it did not perform as expected. All checks seemed to point toward strong r.f.i. - both radiated and conducted. Even when tested after the TV and FM stations were off the air, erratic performance was experienced.

In spite of the on-site efforts of Mr. John Kowles, REC project engineer, the sensor continued to malfunction. It was returned to the factory where it was rebuilt and recalibrated. The rebuilt detector was installed in early January 1973. It worked quite well, both day and night - for about 10 days. Gradually, it became more r.f.i. susceptible. It worked very well after the TV and FM stations went off the air. The CRREL detector (hermetically sealed and MIL-spec. r.f.i. protected but otherwise very similar) was located less than two feet away from the NWS detector and worked beautifully. At night, the two detectors tracked each other almost perfectly. In all, we decided that the radiated r.f. was getting into our detector and causing shifts in operating characteristics.

The MWO staff were instructed to operate only during the post-midnight hours before the stations returned to the air. It was our belief that sufficient data would be gotten to evaluate the technique even on such a reduced basis. In actuality, the system was left on continuously, and some apparently normal recordings during daytime events were made. Operation was continued through April 1973. A large number of icing events were recorded - some of very intense nature (see figure 3 for a typical section of the recorder chart). In later weeks, the recorder was turned off during periods of low probability of icing.

Analysis of our data.

In the sensor selection, data-taking, and observation techniques development, at least two very basic assumptions were necessary: (1) the ice formed on a flat surface normal to the wind during freezing rain or freezing drizzle events can be equated or correlated to the ice formed on a rod exposed to identical conditions; and (2) the performance of the sensor probe (rod) is exactly equatable to that of the rotating multicylinders. In developing the rotating multicylinder ice accretion measurement technique, Langmuir, Howell, Lewis and others in the mid-to-late 1950's demonstrated mathematically and experimentally that the cylinder surface tangential to the circumference and normal to the air flow past the cylinder was essentially equivalent to a plane surface of small dimension. By rotating the cylinder, a uniform, measurable coating of ice could be formed.

It was, therefore, the objective of our data analysis to determine whether or not the ice accretion detector actually measured an amount of ice equal to that calculated from the rotating multicylinder data which we would accept as being the standard. This appeared to be reasonable since the multicylinder data were based on a cylinder whose diameter was not greatly different than the diameter of the sensing probe.

For the purpose of data analysis, all the recorder charts were examined for periods of operation which looked to be usable. It was found that no icing events occurred in which the ice buildup was too fast for the recorder to follow. In general the charts were very readable and easy to work up. During periods that the ice detector was operating correctly very clean analog recordings resulted. There were cases of deicing signals less than 2-1/2 minutes apart (24 deicings an hour would represent 3.6 inches of ice). Usable periods were marked without regard to time of day. This resulted in a very large number of events (over 350 hours). This number was quite drastically reduced by requiring that a rotating multicylinder observation be taken within a half-hour preceding the beginning or following the end of an hour's operation. This was done in an effort to improve the comparability of the observed cases to the measured data. We recognized, of course, that the characteristics of the icing event could change drastically in a very short time. There were still over 50 hours of observation available.

It was a relatively simple procedure to determine the amount of icing reported as measured by the ice accretion detector. All that one needs to do is count the deicing signals during a unit time (we used one hour as the unit for this report). This number multiplied by the factory preset calibration of the detector will equal the quantity we have called the measured icing (T_o). Of considerable importance is the fact that the preset calibration was based on the density of glaze (clear ice) which was taken as 0.8 grams per cubic meter.

We would like to believe this measured icing is precisely the amount of icing the detector could report if all the available liquid water in the air were captured and frozen on the probe (called "available icing (T)" in this report). By starting with a computation of the available liquid water contained in the volume of air swept past the ice accretion detector probe in a unit of time, we may derive the following conversion formula:

$$T = \frac{E_m \, w \, U}{\rho_i}$$

where T = available icing

E_m = the collection efficiency of the probe. (We assumed earlier that the collection efficiency of the sensor probe is exactly equal to that of the rotating multicylinders.)

w = the available liquid water content of the air

U = the wind speed

ρ_i = density of ice

The density of ice (ρ_i) may vary in meteorological cases from that of dense glaze (0.8 to 0.9 grams/cm^3) down to rime ice which may vary from a low of 0.2 or 0.3 grams/cm^3 to as much as 0.5 grams/cm^3. Since it is known that most of the icing at Mount Washington Observatory falls in the rime classification, a mean value of 0.4 grams/cm^3 was used for computational purposes whenever the ambient temperature was below 22°F (-5.6°C). For ambient temperatures between 22°F and 32°F, the glaze ice density of 0.8 grams/cm^3 was used. When the value of ρ_i (rime) is introduced and all units are expressed in the system of measurement in which they are reported by the Observatory, we have:

$$T = 0.1267 \quad E \quad w \, U \qquad \text{inches/hour}$$

But, since our data and computations indicate that T_o and T were consistently not equal, the ratio of the measured icing to the available icing was determined:

$$\text{Ratio} = T_o/T$$

When the mean of this ratio was taken for all 52 observation hours, it was 1.082 — or, that is to say the ice accretion detector measured 8.2% too much ice compared to the computed available icing. When only those hours for which it was deemed that there was no probable effect from the r.f. field, the ratio was 1.096 — very close to the value in the total case. If the periods during which the TV and FM stations were in operation were considered as a group, alone, the mean ratio was 1.072. While it appears to be a degradation of the data to omit the high r.f.i. cases, actually this is a statistical fluke. Among the high r.f.i. cases, several observations with quite low ratios were included (the sensor indicated an inordinately small amount of ice). These influenced the total case and the high r.f.i. case means unduly.

Table 2 (and figures 5 through 7) shows the correlations between the ratio T_o/T and the factors for computing the available icing (T). By examining this series of figures and those immediately following, you can get a feel for the interrelations between the ratio T_o/T and available icing (T) and the factors in the equation for computing the available icing T from observed data. The confidence limits drawn in each figure will give you information about the overall quality of the data as related to the two parameters treated in each case.

Table 3 (and figures 8 through 11) shows the coefficients of correlation between the measured icing and the factors of this equation. It is of special value to note the strong degree of correlation between the measured icing (T) and the experimentally determined available icing (T) shown in the fourth row of this table and in figure 11. (Ideally, we would like to have a 1:1 relationship between the measured and the available icing which would result in a 45° slope in the regression line of figure 11.)

Failure of probe to deice on some occasions

One problem which plagued this detector throughout its season of exposure was its failure to completely deice. This was observed to a small degree during the pre-installation testing at Sterling, but Rosemount was unable to duplicate the effect in their icing wind tunnel. Figure 4 is a photograph taken by MWO personnel of a typical occurrence. From this picutre it is apparent that the probe would be sheltered from the icing by the buildup in front of it. It appears possible in cases of heavy icing that while the heating cycle for deicing purposes puts a great amount of heat into the airfoil (strut) on which the probe is mounted (it is estimated that this airfoil has approximately 20 watts per square inch heating applied), not all the ice is actually removed.

These failures have been discussed with Rosemount engineers. One recommendation made was to calibrate the sensor to deice with a much thinner ice coating. It would be quite feasible to deice at 0.05-inch (or even smaller) increments. This would fit in well with our possible observation techniques as well or better than the present 0.15-inch increment. It was also recommended to use a hemispherical probe-mount to encourage the runoff of water from ice melting and leave a smaller chance of bridging. From the experience of Mr. Howe, MWO engineer, the heating in such a dome would need to be a minimum of 5 watts per square inch. The heating in the present airfoil (or strut) upon which the probe is mounted is a nominal 20 watts per square inch.

Comments from Mount Washington Observatory

The following are comments extracted from an April 20, 1973, letter from John Howe, MWO staff engineer.

"1) RF interference from adjacent commercial FM and TV transmitters was serious. Valid tests could be performed only when these transmitters were off the air. The following comments to apply (to) performance without RF interference.

"2) Ability of the instrument to detect the onset of icing was excellent. Response of the analog output to variations in icing rate and to cessation of icing also appeared to be excellent, except for the fault described in Paragraph 3. No false indications of icing were noted, either in fog or in clear air.

"3) Shedding of ice from the sensor strut (the airfoil cross-section member which supports the cylindrical probe) was frequently incomplete. The resulting ice formation would then shield the probe partially or completely (see figure 4) We feel that a longer heating duration and redesign of the probe support would solve this problem.

"4) The sensor appears to be adequately rugged, and suffered no visible harm, although it was exposed in winds up to 130 mph and must at times have been hit by flying chunks of ice. (The few small scratches on the strut were probably inflicted during manual removal of heavy ice accumulations from the flange.)

"5) Ice had occasionally to be manually cleared from the unheated mount and flange. Although in less severe environments this would seldom be a problem, we suggest that thought be given to providing a somewhat greater extent of deiced area below the probe (say three to four inches)."

As can be seen from these notes which summarize his impressions over the six-month span of testing at Mount Washington, the primary problem to Mr. Howe's view is the partial deicing which has been previously mentioned. The Rosemount representatives have indicated that several new or modified designs are available. The ice-massing on the unheated areas has not been directly addressed, however.

What Can Be Done

In Chapter A-7, "Atmospheric Phenomena," in FMH-1, definitions and observation criteria for these phenomena are given. When freezing drizzle, freezing rain, hoar frost, etc. are discussed, the instructions reference the use of liquid precipitation and/or snow criteria (particularly Tables A7-1, -2, -3, and -5). The net result is a set of observation techniques which lead to essentially subjective data. In using the rate of-fall or visibility as criteria, there may be serious question of the direct applicability of them to freezing drizzle or freezing rain (see Tables A7-2, A7-3, and A7-5, FMH-1). However, these tables were intended to be used to describe the rate of fall of liquid precipitation, not the actual accumulation of ice.With an objective technique, users can be more assured of the quality of icing which may affect their operations. Empirical data to support possible re-examination and revision of the present intensity criteria will become available. This, then, should prove to be a usable guidance to the forecaster.

To date, this task has by necessity been largely one of data taking to provide some basis for possible observation techniques which may be recommended. We believe that this has been accomplished. These data, when reduced and objectively compared, lead us to the proposed observation techniques presented in detail in Appendix A.

Summaries of proposed techniques

Technique I – Freezing Precipitation Yes/No:

This will provide only a statement of whether or not freezing precipitation of any kind is detected.

Technique IA - Freezing Precipitation Yes/No with Type Discrimination:

A simple extension of this basic technique based on whether or not the ambient temperature is above an assumed critical temperature for the deposition of rime.

Technique II - Quantitative Freezing Precipitation Observation:

This is a straightforward counting of deicing cycles during a unit of time. The count is then converted to depth by multiplying by a conversion factor.

Technique IIA - Quantitative Freezing Precipitation Observation with Type Discrimination:

An extension of Technique II by use of the critical temperature mentioned earlier to discriminate between rime and glaze.

Technique III - Quantitative Freezing Precipitation Observation with Analog Voltage:

This is the most complex of the proposed techniques. In addition to counting deicing pulses as in Technique II, the analog voltage level of the unfinished cycle at the read signal is proportioned to provide the maximum precision of reading.

Technique IIIA - Quantitative Freezing Precipitation with Analog Voltage and Type Discrimination:

This is an extension of Technique III by use of the critical temperature approach to discriminate between rime and glaze.

Some pitfalls.

We have already pointed out that r.f.i. is a potential problem with these sensors. However, the MIL-spec r.f.i. protection provided the CRREL sensor at MWO, appears to us to be proof-positive of the viability of that system. We would not recommend that any system be procured without r.f.i. protection unless it is done on a site-by-site selection basis. That does not appear to be a desirable way to go in general.

A possible area of concern which does not show up in our data, but which was visually observed by MWO personnel is involved with the angle of attack. By this we mean how the wind passes the sensor. Optimumly, it should be normal to the axis of the probe. Due to orographic effects or nearby obstructions, the resultant incident wind may be anything but normal to the axis. No ready solution suggests itself to us, but this should be recognized as an inherent source of error.

Although we have postulated a way to discriminate between rime and glaze, we recognize that this still will leave an area of unresolved differences. We do, however, recommend this refinement in discrimination for use in observation techniques be used for quantitative observations.

Possible Choices

We fully believe that the potential of an objective technique for making freezing precipitation observations has been demonstrated. Therefore the adoption of one of the proposed techniques is indicated. With such a decision, the choosing of an "off-the-shelf" sensor or design of a new one to fit that technique would be necessary. It is our sincere belief that no new sensor development will be necessary, however.

The selection of one or more of the proposed techniques will hinge largely upon the needs of the end user. If he needs only to know if frozen precipitation is or is not occurring at this particular time, then Technique I (or IA) is for him. If, however, he needs to know the intensity, also, then either Technique II or III is indicated. Our experience indicates that for all but the most exacting requirements, Technique II (or IIA) will give sufficient, practical precision.

We do not believe it necessary to proceed to take more data of the sort gotten last winter. However, we do recommend the developing or selecting of a provisional sensor and putting several out in typical sites for use experience before going into a large network. Test and evaluation of the final system configuration would be required before network usage, also. For use in developing the candidate system we have included in Appendix B two functional specifications.

Whom to Contact

For additional information and data in reference to this task, contact A. N. Hill, Observation Techniques Development and Test Branch, T&EL, IDS 1235-8242.

Table 1

Mt. Washington Observatory Weather Summary for December 1971

Average Daily Maximum Temperature	- 8.7°C
Average Daily Minimum Temperature	-17.2°C
Number of Days, Maximum 0°C	27
Number of Days, Minimum -18°C	24
Lowest Temperature on Record	-43.3°C
Average Wind Speed	20 m/s (45 mph)
Absolute Maximum Wind Speed	78 m/s (174 mph)
Average Relative Humidity	Approx. 85%
Precipitation on	19 days
Cloudiness	6 - 7 octas
Precipitation (Water Equivalent)	160 mm (6.29 inches)

Table 2

Coefficients of Correlation Between T_o/T and E , w, and U*

Factor	All Data	Low r.f.i.
E_m	-0.467	-0.580
w	-0.515	-0.513
U	-0.135	-0.023

Table 3

Coefficients of Correlation Between T_o and E_m, w, U, and T*

Factor	All Data	Low r.f.i.
E_m	0.683	0.601
w	0.834	0.732
U	0.345	0.262
T	0.901	0.930

*The notation is as used in the text:

T_o = the measured icing
E_m = the collection efficiency of the probe
w = the available liquid water content of the air
U = the wind speed
T = the available icing
T_o/T = the ratio of the measured icing to the available icing

SPECIFICATIONS

1. SCOPE. The Model **871BR1** is a Type I ice detector which provides an analog output voltage as ice forms on the sensing element. In addition, an icing signal is also provided by the closure of a relay when the ice accretion on the sensing element reaches a preset level. Relay closure occurs when full scale analog output is reached. The thickness of the ice accretion is dependent on a combination of airspeed, temperature, and water content.

The sensing element of the Model is an ultrasonic axially vibrating tube whose natural frequency of vibration decreases with an added mass of ice (correlated to ice thickness).

Because of the unique principle of operation, the Model **871BR1** is not affected by coatings of water, oil, grease, dust and dirt, insects, etc.

2. DESIGN AND PERFORMANCE CHARACTERISTICS.

2.1. Accuracy. Calibration with fixed icing conditions is within ±10% of set ice thickness under combined effects of vibration, acceleration and ambient temperature.

2.2. Environment. The Model is hermetically sealed.

2.2.1. Operation Temperature. The Model **871BR1** is designed to operate from -54°C to +71°C.

2.2.2. Vibration. Meets conditions of MIL-E-5272, Procedure **XIII**

2.2.3. Acceleration. Designed to withstand 15 g's steady acceleration.

2.2.4. Deicing. Self-contained heaters in the sensing element and housing are internally controlled to deice the sensing element within **12** seconds after an icing signal is given.

2.3. Input Power.

Detector, +28 VDC, 100 ma nominal.
Deice, 115 VAC at 225 Watts.

2.4. Switching Level. An internal adjustment is made during final calibration to provide an icing signal at the desired ice accretion level.

2.5. Outputs.

2.5.1. Icing Signal Output. The signal output provided by the Model **871BR1** is a +28 volt signal capable of providing 1 amp. The icing signal will remain on for seconds after each icing encounter.

2.5.2. Analog Output. An analog output voltage is provided which is proportional to the amount of ice on the sensing element. Standard calibration is:

0 ±0.3 VDC - No Ice
6 ±0.3 VDC 0.150" of Ice.

End point tolerances include effects of temperature over range of -54°C to 50°C.

2.5.2.1. Linearity. The relationship between output voltage and time in a constant icing condition is within 5% of full scale from a straight line drawn between end points.

2.5.2.2. Output Impedance. Less than 100 ohms output impedance. Suggested load impedance greater than 5 K ohms.

2.6. Self-Test. By grounding pin E for approximately 1 second, an icing signal and an analog output voltage are produced.

2.7. Dielectric Strength. The heaters shall be tested as a sub-assembly. A one-minute application of 550 volts rms shall not cause dielectric breakdown between the heater element and the case.

2.8. Mounting. Position as shown with respect to air flow, using 100° flathead screws for mounting.

2.9. Finish. All external parts are stainless steel or electroless nickel plated.

2.10. Connector. MS3114-12-10P or equivalent.

2.11. Weight. Less than 24 ounces.

2.12. Nomenclature. The following minimum information shall be included on the nameplate.

Ice Detector
REC Model **871BR1**. S N______
Rosemount Engineering Company
Minneapolis, Minnesota
Patent Number 3,341,835

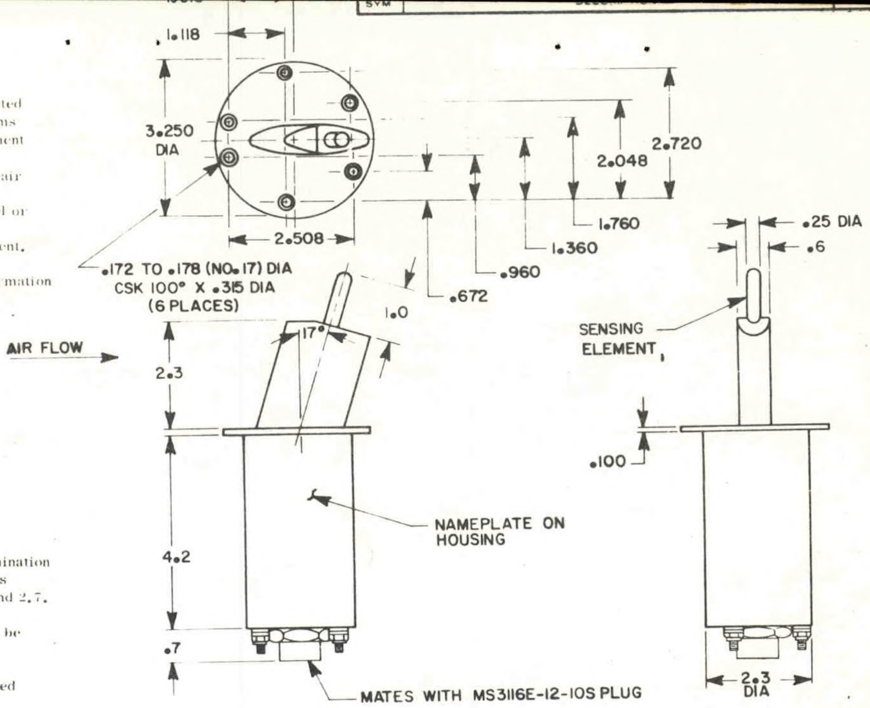
Pin Designation

A.	+28 VDC	F.	Test Point 2
B.	DC Return	G.	Spare
C.	Case Ground	H.	AC Common
D.	Switch Output	J.	115 VAC
E.	Test Point 1	K.	Analog Output

3. INDIVIDUAL TESTS. These shall include examination for good workmanship, conformance to this drawing and tests implied or defined by Sections 2.2.4, 2.3, 2.4, 2.5, 2.6, and 2.7.

4. PRODUCTION SAMPLING TESTS. These will be proposed and quoted upon request.

5. QUALIFICATION TESTS. These will be proposed and quoted upon request.



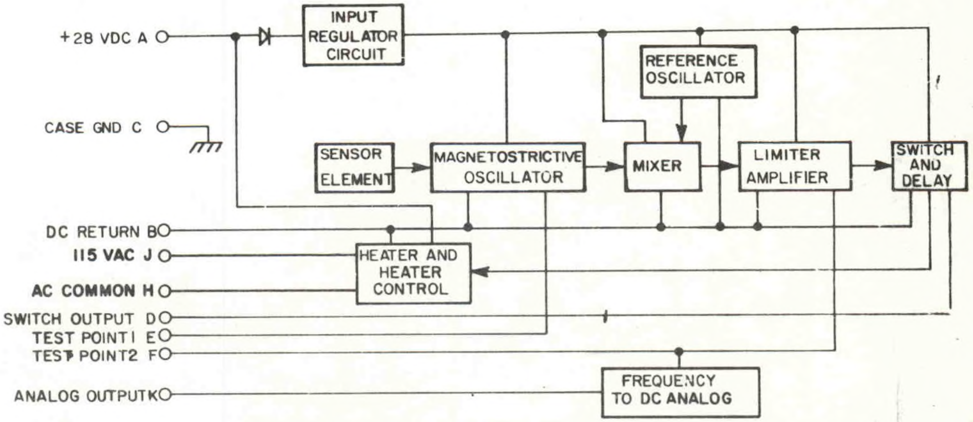


Figure 1. Schematic Diagram of Model 871BR1 Ice Detector

QUANTITY REQD	PART NO	ITEM NO	DESCRIPTION
		LIST OF MATERIAL	

UNLESS OTHERWISE SPECIFIED
REMOVE ALL BURRS AND SHARP EDGES
MACHINE SURFACE FINISH 125✓
-TOLERANCES-

DECIMALS	HOLES	
X ± 1	0135 to 125	+004 -001
XX ± 02		
XXX ± 0'0	126 to 250	+005 -001
FRACTIONS ± 1/32	251 to 500	+006 -001
ANGLES ± 2°		

DO NOT SCALE PRINT

ROSEMOUNT ENGINEERING COMPANY
MINNEAPOLIS, MINN.

TITLE SPECIFICATION DRAWING

ICE DETECTOR

* PROPRIETARY INFORMATION IS CONTAINED HEREIN AND MUST BE HANDLED ACCORDINGLY
BY ________ DATE ________
* THIS DRAWING DOES NOT CONTAIN PROPRIETARY INFORMATION
BY GD DATE 8-14-70
(IF NO SIGNATURE APPEARS THE UPPER STATEMENT APPLIES)

		DATE
DR. BY	Griffin	8-14-70
CHKD	N. Wahlstrom	8-14-70
APPD	G. Dormegaard	8-14-70

CODE IDENT NO	SIZE	DRAWING & PART NO	REV.
04274	C	871BR1	
SCALE 1/2	WT ______	SHEET 1 OF 1	

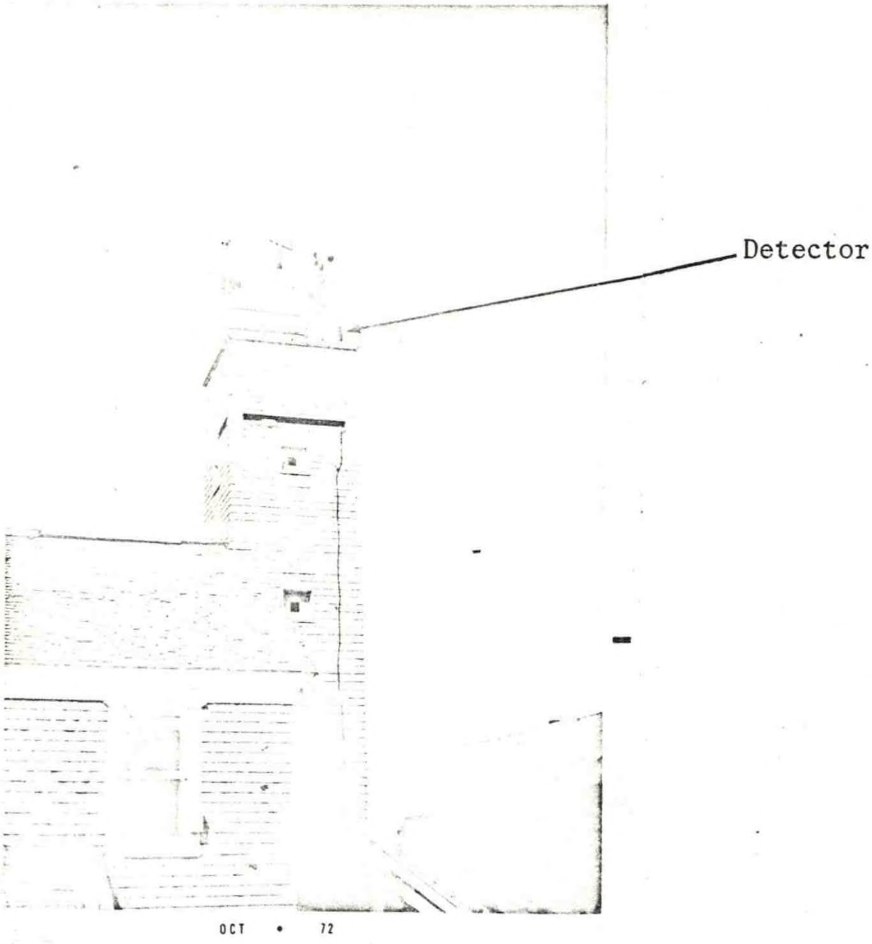


Figure 2. Instrument tower at Mount Washington Observatory (arrow points to the ice accretion detector)

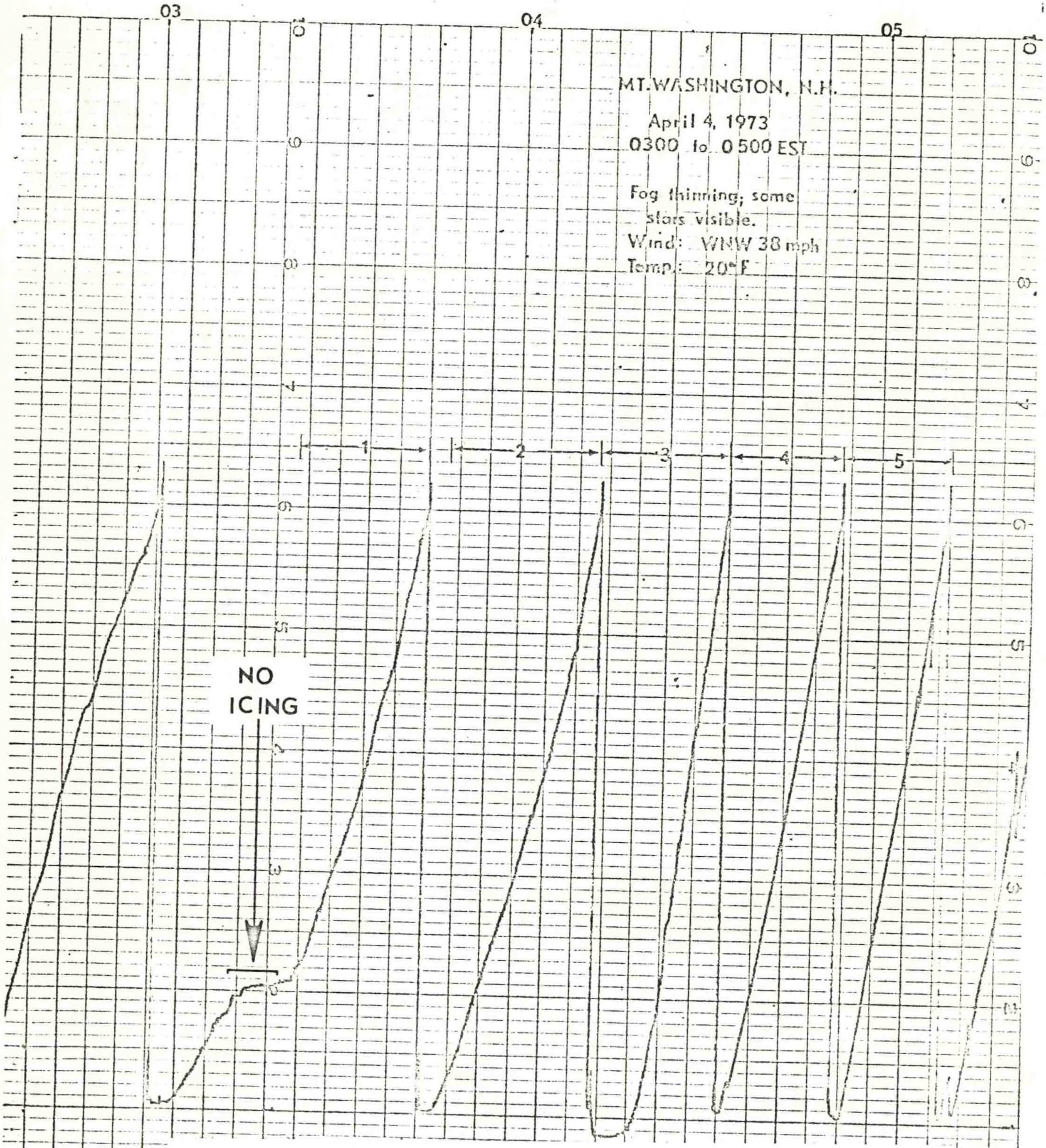


Figure 3. Typical Section of Recorder Chart. Successive icing events are indicated by the numbered intervals. Note the period of no icing preceding Interval 1.

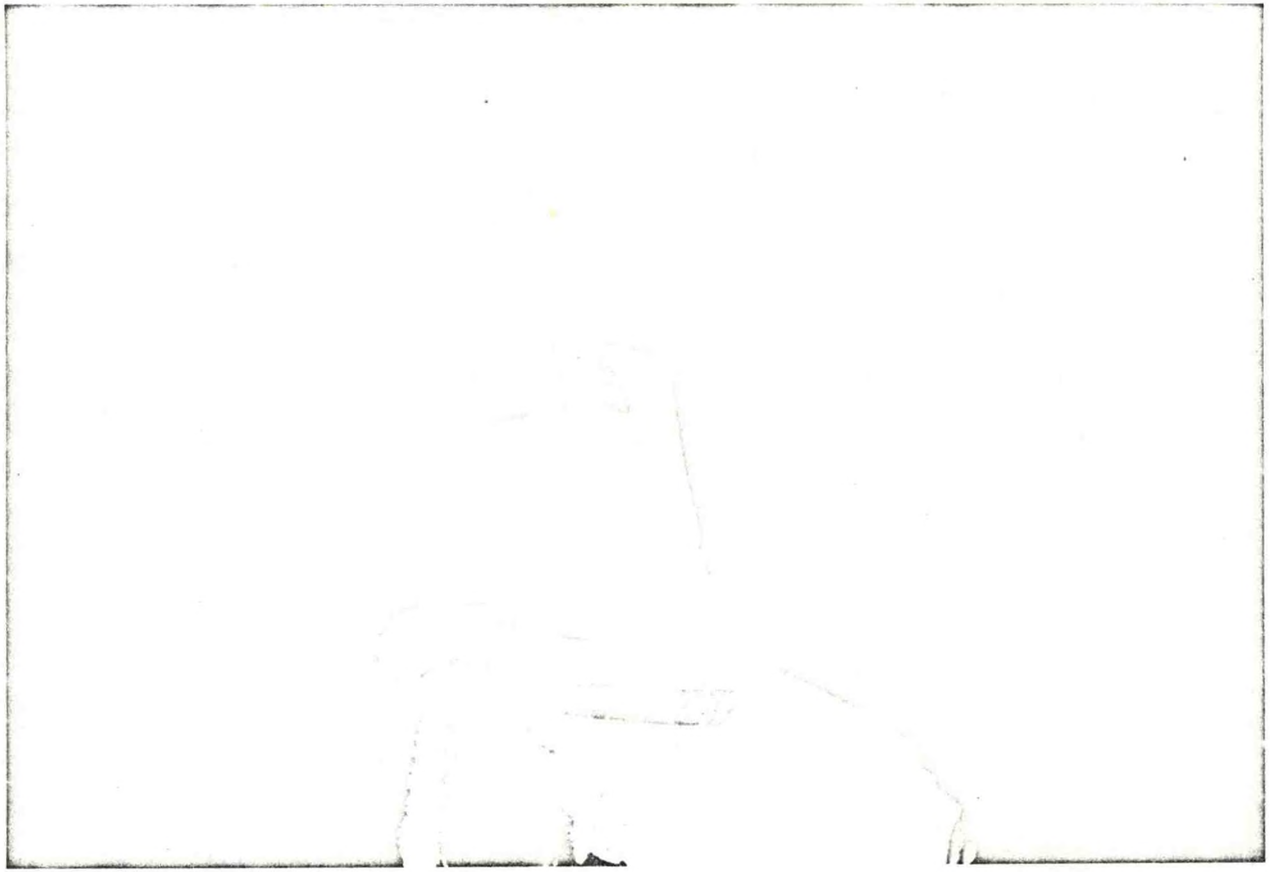


Figure 4. Ice Shield on Ice Accretion Detector at Mount Washington Observatory on April 11, 1973 at 2:45 a.m. (Wind: West 73 mph; Temperature: 6°F; Liquid Water Content: 0.78 g/cm^3; Efficiency of Catch: 0.617)

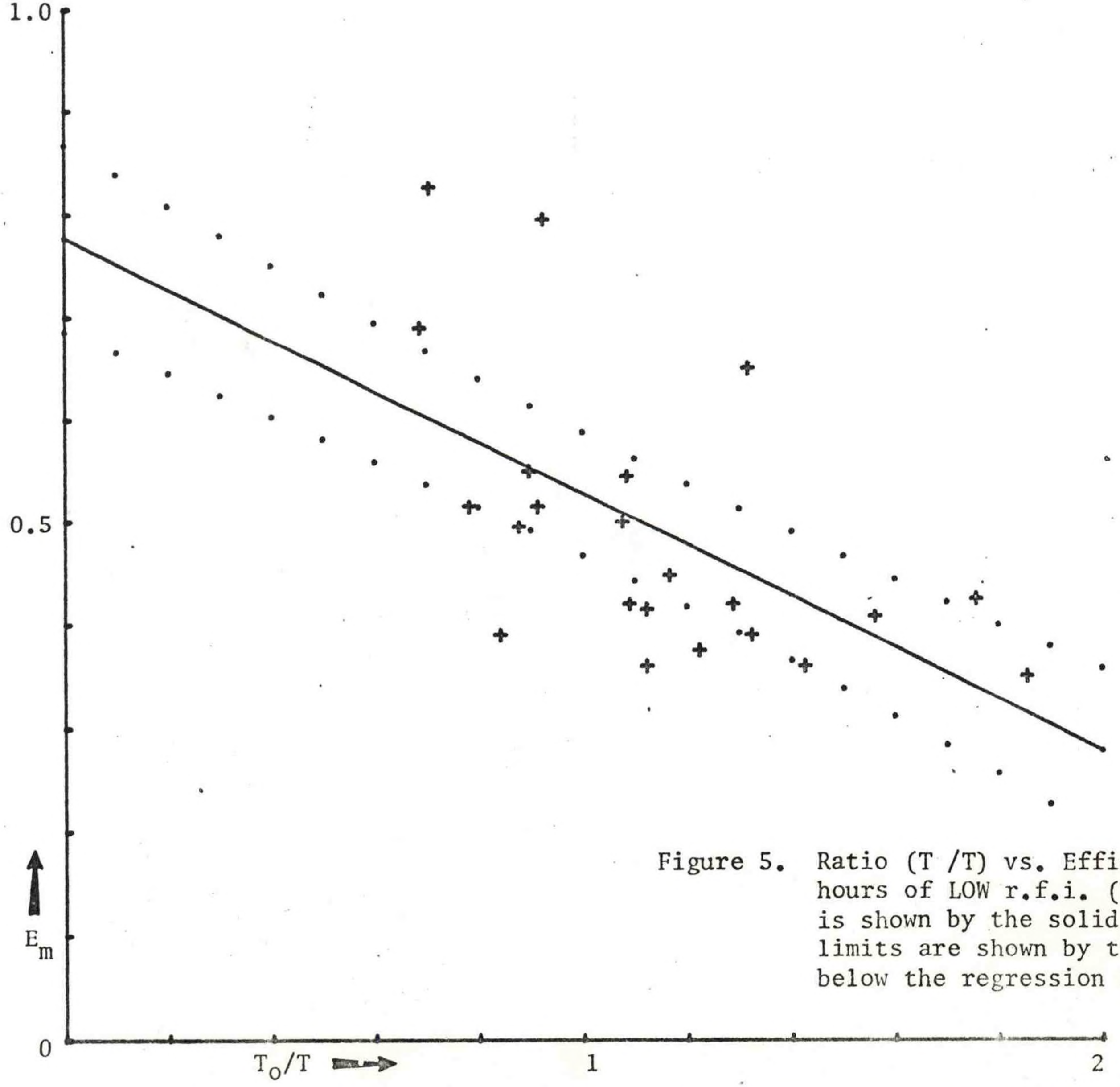


Figure 5. Ratio (T /T) vs. Efficiency of Catch (E) for hours of LOW r.f.i. (The linear regression line is shown by the solid line. The 75% confidence limits are shown by the dotted lines above and below the regression line.)

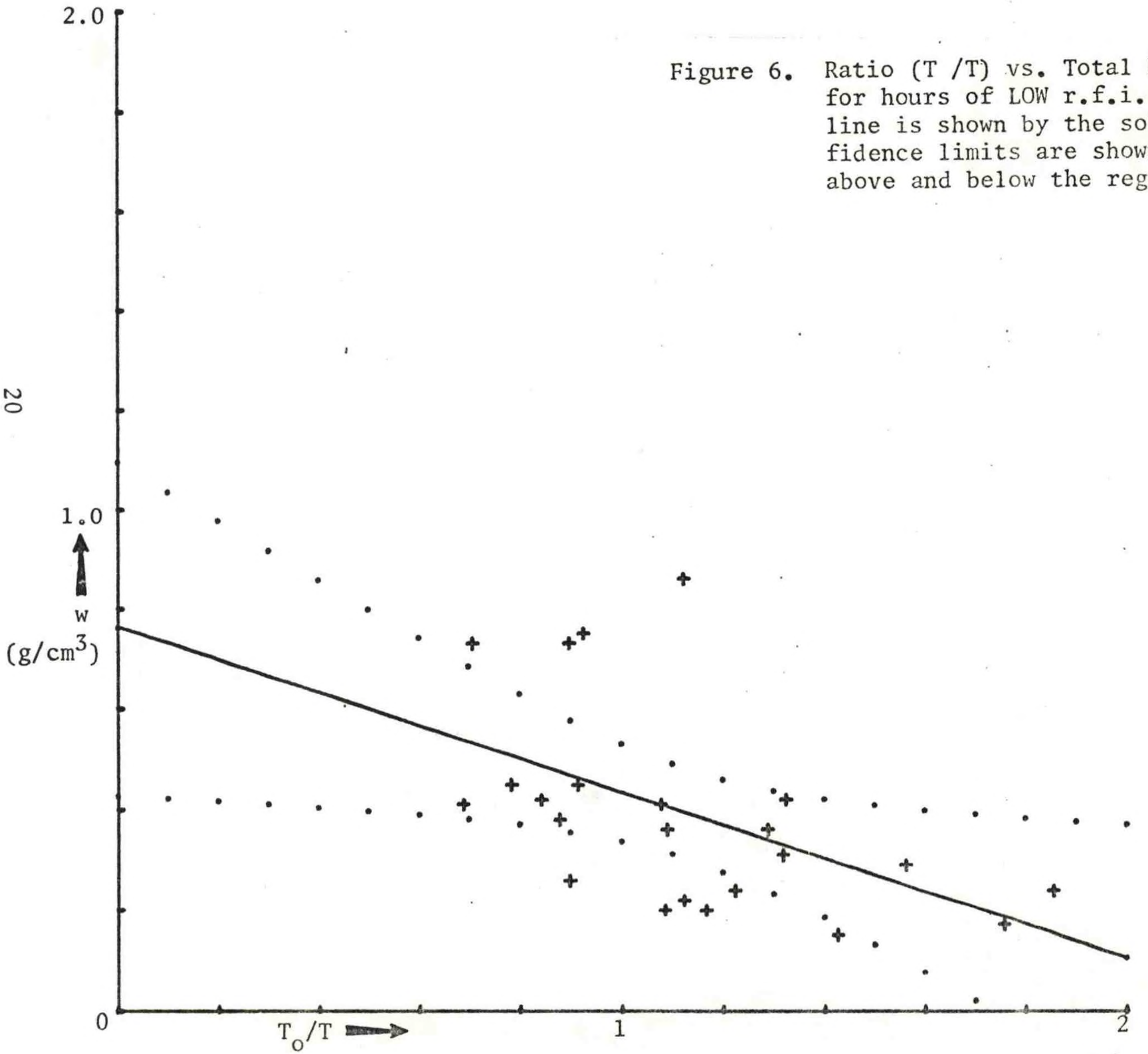


Figure 6. Ratio (T /T) vs. Total Precipitable Water (w) for hours of LOW r.f.i. (The linear regression line is shown by the solid line. The 75% confidence limits are shown by the dotted lines above and below the regression line.)

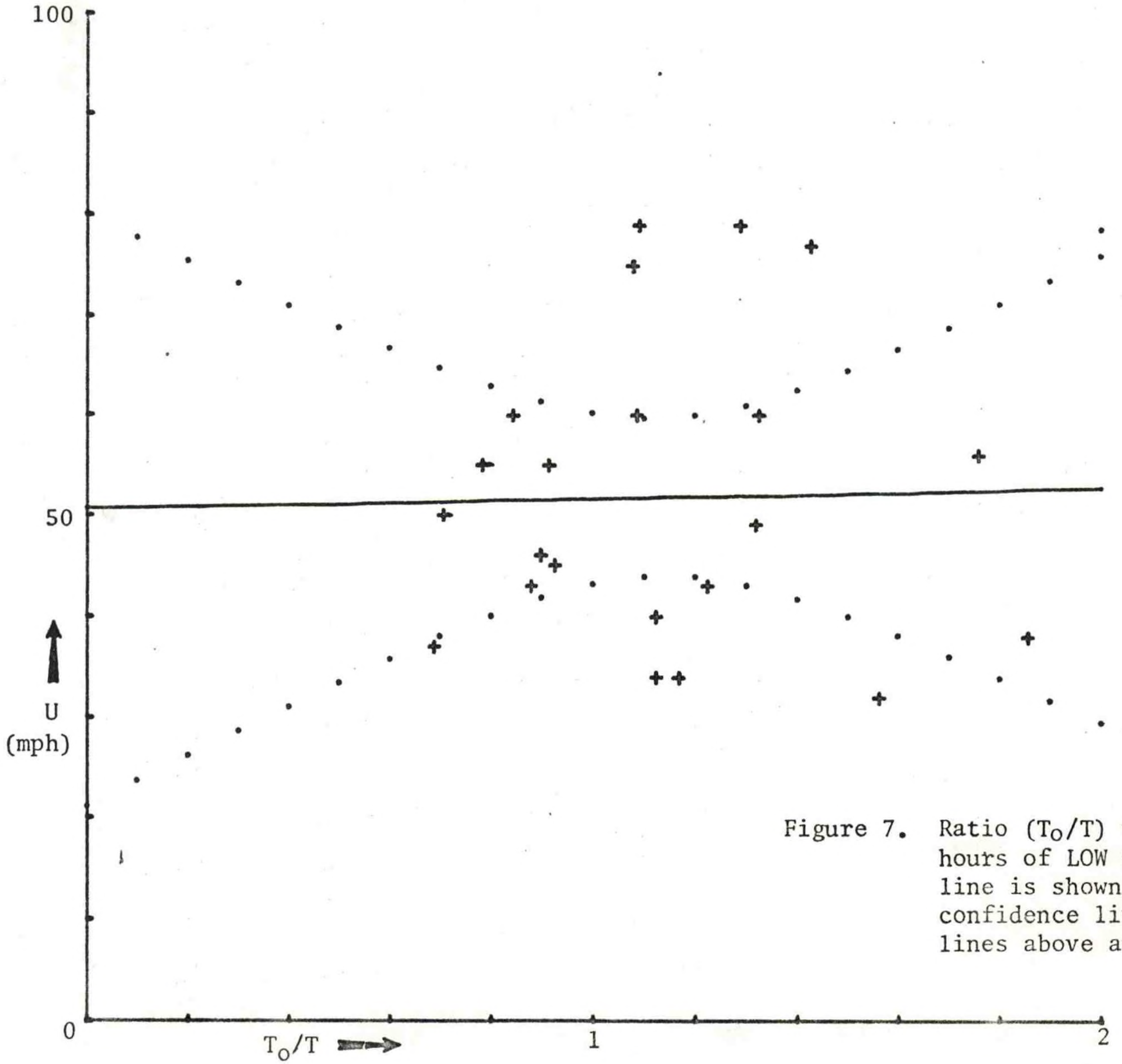


Figure 7. Ratio (T_O/T) vs. Wind Speed (U) for hours of LOW r.f.i. (The linear regression line is shown by the solid line. The 75% confidence limits are shown by the dotted lines above and below the regression line.)

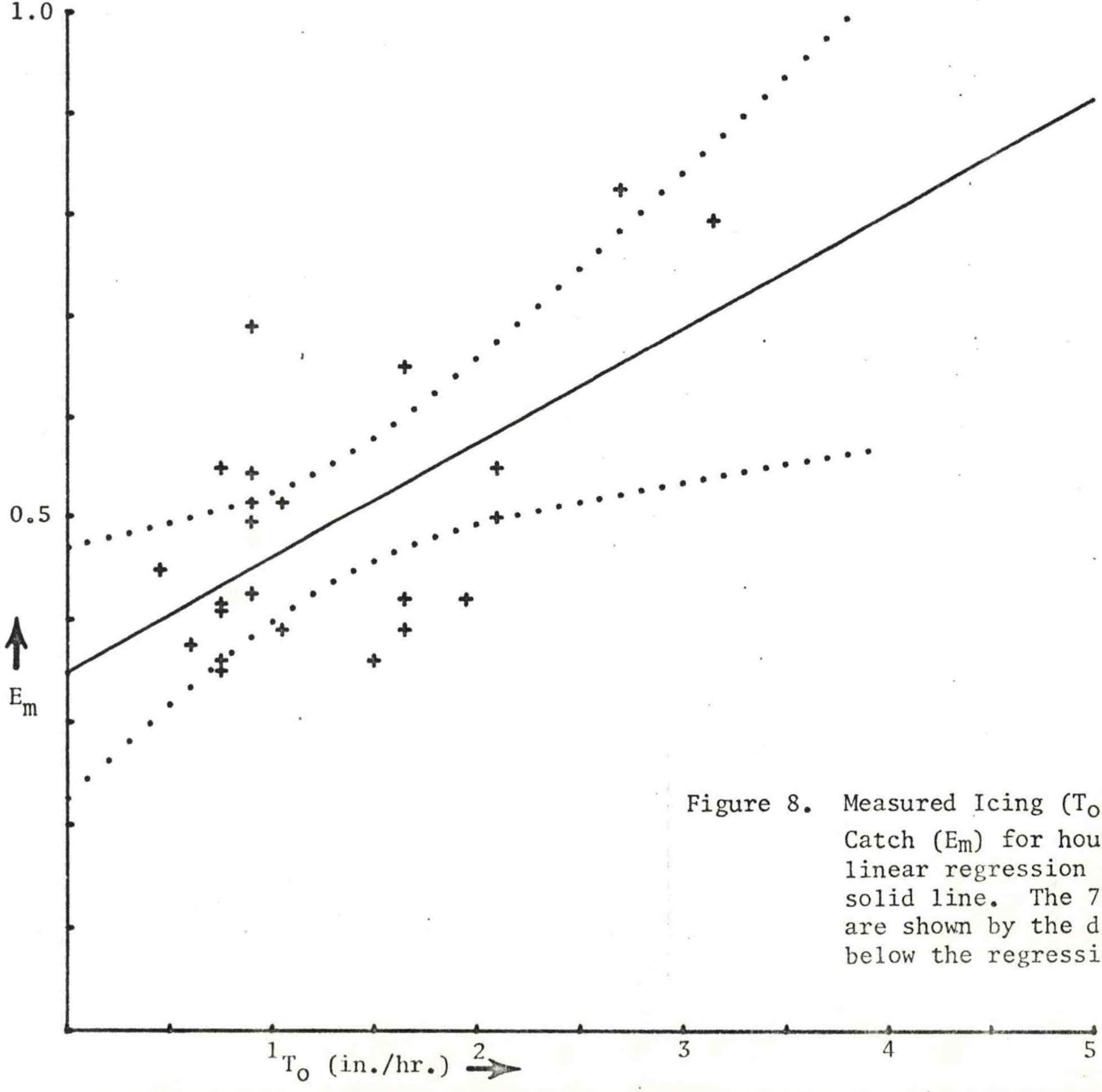


Figure 8. Measured Icing (T_o) vs. Efficiency of Catch (E_m) for hours of LOW r.f.i. (The linear regression line is shown by the solid line. The 75% confidence limits are shown by the dotted lines above and below the regression line.)

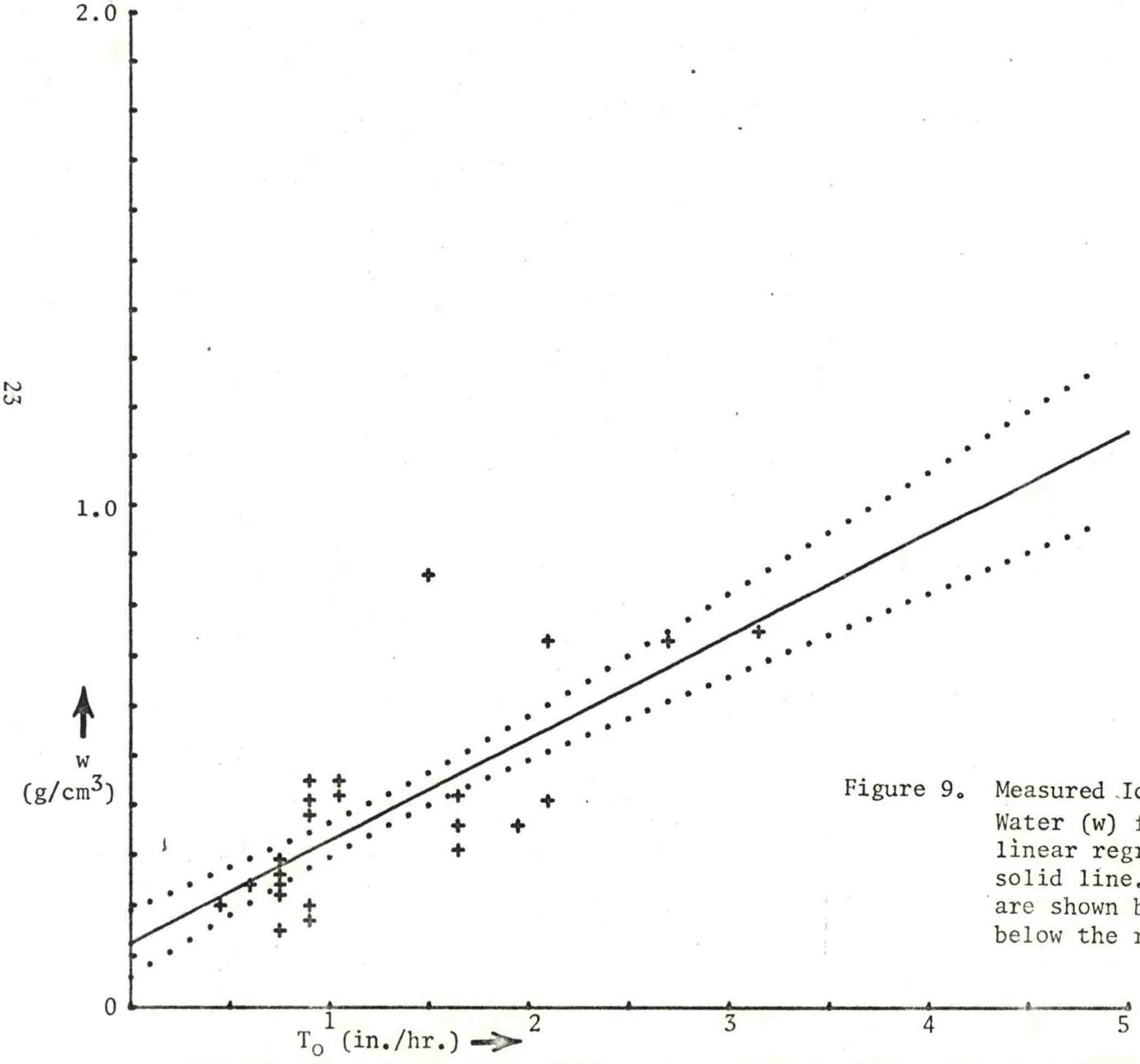


Figure 9. Measured Icing (T_o) vs. Total Precipitable Water (w) for hours of LOW r.f.i. (The linear regression line is shown by the solid line. The 75% confidence limits are shown by the dotted lines above and below the regression line.)

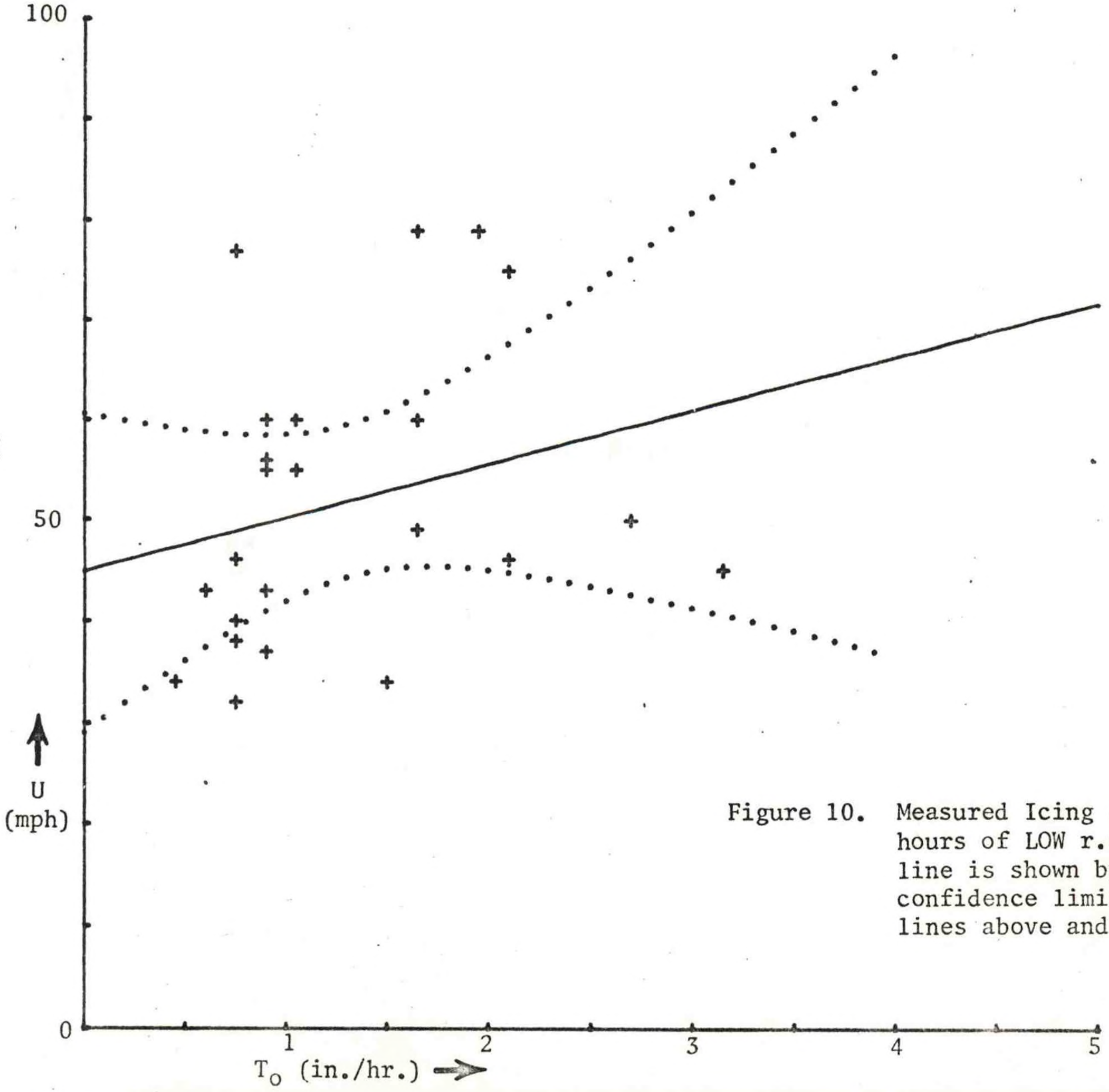


Figure 10. Measured Icing (T_O) vs. Wind Speed (U) for hours of LOW r.f.i. (The linear regression line is shown by the solid line. The 75% confidence limits are shown by the dotted lines above and below the regression line.)

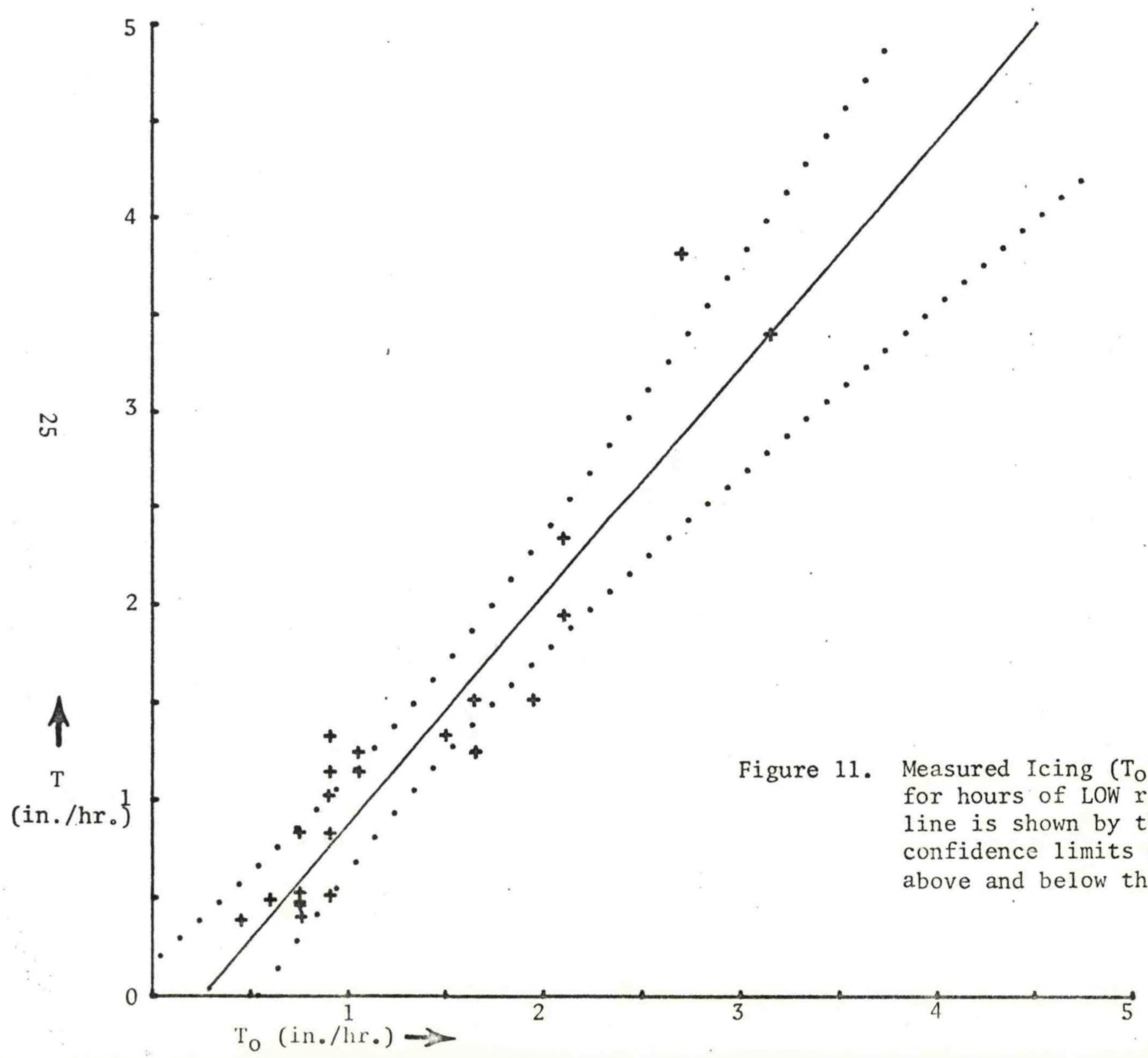


Figure 11. Measured Icing (T_O) vs. Available Icing (T) for hours of LOW r.f.i. (The linear regression line is shown by the solid line. The 75% confidence limits are shown by the dotted lines above and below the regression line.)

APPENDIX A

SOME PROPOSED OBJECTIVE OBSERVATION TECHNIQUES OF FREEZING PRECIPITATION

Proposed observation techniques.

Technique I - Freezing Precipitation Yes/No:

This is a technique which keeps circuitry to a minimum and will provide a Yes/No statement to an automatic meteorological observing station (AMOS).

a. Detector: Rosemount Series 871 Ice Detector or equal; r.f.i. protected; d.c. deicing signal of not more than 10 seconds duration; calibrated to deice after 0.02-inch ice accumulated; thermostat to turn detector on when ambient temperature is below 40°F.

b. Associated Circuitry: latching relay to lock in:

(1) any deicing signal pulse within preceding hour; or

(2) any pulse within last 10 minutes of hour preceding AMOS query as commanded by the automatic station.

c. Mode of operation:

1) Ice detector to be installed as required with 360° clear-azimuth.

2) Power supply to detector to be 115 volts, 60 Hertz, or 28 volts d.c. according to local need and detector model to be used.

3) AMOS issue query command at proper time to assure latching relay closure (or opening) is read out at proper time.

4) AMOS provide a release command to clear the latching relay after scan is completed.

5) AMOS to format response into outgoing message as required.

d. Discussion: This appears to be a minimum capability and will fulfill the original objective of providing a simple yes/no answer to the question of occurrence of frozen precipitation. It will not differentiate between freezing rain and freezing drizzle, however. Since the type of sensor postulated is not affected by water (liquid), by grease, or most other non-solid matter, it is safe to say that if it is activated at all, there is frozen precipitation present.

A sensor of this type would probably cost in the order of $800 each.

Technique IA - Freezing Precipitation Yes/No with Type Discrimination:

A forecaster may increase the amount of intelligence gotten from this sensor by noting the ambient temperature. Several references reviewed indicate that rime typically forms at temperatures above an arbitrary cutoff point. It would not be safe to assume *absolutely* that glaze forms above that temperature and *only* rime below it, but such a cutoff temperature appears to be a good assumption from a probability aspect. To allow for station or regional climatology, an assortment of selectable cutoff temperatures centered about -10°C(15°F) is recommended. It would be reasonable to accomplish this differentiation between glaze and rime automatically after the local cutoff point has been set in the logic provided. It should be noted that the suggested cut-off temperature is based on climatological frequencies. If the operational need is sufficient to demand greater surety of classifying the maximum number of glaze events with the risk of misclassifying some rime events as glaze, the cuf-off temperature can be made low enough to do so.

a. Detector: Same as in subparagraph *a*, Technique I, with the addition of a temperature modifying network to be effective at a temperature of 25°F, 20°F, 15°F, 10°F, or 5°F as selected based on the station climatology.

b. Associated Circuitry:

1) Latching relay to accomplish function outlined in subparagraph *b*, Technique I.

2) Temperature network to accept the ambient temperature signal and operate in one of two modes: ambient temperature above the local set point or ambient temperature below the local set point.

c. Mode of Operation:

1) The first four steps of subparagraph *c*, Technique I, remain the same.

2) As the scan of the system's output is completed, the AMOS would encode the response as "freezing rain,ZR" when the ambient temperature is above the local set point. When the ambient temperature is below the local set point, the response would be encoded as "freezing drizzle, ZL." In neither case would an intensity indication be available. No differentiation between freezing drizzle and hoar frost will be made.

3) AMOS to format this coded response into the outgoing message as required.

d. Discussion: A system as modified here from that presented in Technique I would cost about $800 for the sensor and an additional $250 for the required logic - making a system total of about $1,050.

Technique II - Quantitative Freezing Precipitation Observation

a. Detector: Rosemount Series 871 Ice Detector or equal; r.f.i. protected; d.c. deicing signal of not more than 10 seconds duration; calibrated to deice after 0.02 inch ice accumulated; thermostat to turn detector on when ambient temperature is below 40°F.

b. Associated Circuitry: Register to store deicing signal pulses for one hour; logic to convert pulse count to inches of accretion at end of hour (or other selected interval); logic to encode and make ready to insert in message format (it would also be possible to go from pulse count to encoded form directly); circuit to provide for register clearance after reading. (Alternatively, rather than store for an hour, any discrete portion of an hour could be selected, and the output encoded accordingly.)

c. Mode of Operation:

1) Ice detector to be installed as required with 360° clear-azimuth.

2) Power supply to detector to be 115 volts, 60 Hertz, or 28 volts d.c. according to local need and detector model used.

3) AMOS scan output of logic board(s) in subparagraph b, above, as necessary for formatting into the outgoing message as required.

4) AMOS provide clearing command to register after scan is completed.

d. Discussion: This technique appears to be a logical progression upward from the previous one. It gives an estimate of degree of icing taking place — if a deicing pulse is called for during the sampling period used. In the data from Mt. Washington there were occasions when a single cycle took in the order of 50 minutes (0.15 — 50 = 0.003 inches per minute - "moderate" freezing rain if the tables in FMH-1 are used). Using a calibration rate of 0.02-inch per cycle, we could expect 0.15 — 0.02 or 7-1/2 cycles in that time.

A sensor of this type would cost about $800. To this add the cost of a logic card - say, $500, for a total cost of about $1,300.

Technique IIA - Quantitative Freezing Precipitation with Type Discrimination:

The remarks made in the leading paragraph of Technique IA in regard to added intelligence from the data would be applicable here, too. Actually, since we are considering some logic in this system, it is possible that with slight additional cost, this distinction could be performed for the forecaster with a reasonable degree of success. Either the actual rate of precipitation or the coded letter-designations could be transmitted.

a. Detector: Same as in subparagraph a, Technique II, with the addition of a temperature modifying network to be effective at ambient temperatures determined by the local set point.

b. Associated Circuitry:

(1) A register to store deicing signal pulses for one hour.

(2) Logic to convert this pulse count to inches of accretion at the end of the hour (or other selected interval).

(3) When ambient temperature is below the local point, this conversion is to be adjusted to a mean density of rime.

(4) Logic to encode and make ready to insert in message format (it would also be possible to go directly from pulse count to the encoded form).

(5) Circuit to provide for register clearance after reading.

(6) Alternatively, rather than store for an hour, any discrete portion of an hour could be selected, and the output coded accordingly.

c. Mode of Operation: Same as in subparagraph c, Technique II.

d. Discussion: The discussion of subparagraph d, Technique II, is applicable here, also, basically. Since we have already called for a logic card and we do not feel that adding enough logic to perform this function will unduly complicate it, a modest additional cost of $100 would be adequate. Thus, the sensor system would cost about $800 and the logic card about $600 to make a total of about $1,400 (estimated).

Technique III - Quantitative Freezing Precipitation Observation with Analog Voltage:

a. Detector: Same as in subparagraph a, Technique I, with the addition of a voltage analog output linearly proportional to ice accretion (output to be 0 volts to 5 volts d.c. at 0.02-inch accretion).

b. Associated Circuitry: Register to store completed deicing signal pulses for one hour (or other selected interval); voltage-sensing logic to measure analog voltage level of incomplete pulse; logic to convert pulses in register and partial pulse into inches of accretion; logic to encode icing quantity and make ready to insert it into message format; circuit to provide for clearance of register and the residual analog voltage ramp. (Alternatively, rather than store for one hour, any discrete portion of an hour could be selected and the output encoded accordingly.)

c. Mode of Operation:

1) Ice detector to be installed as required with 360° clear-azimuth.

2) Power supply to detector to be 115 volts, 60 Hertz, or 28 volts d.c. according to local need and detector model used.

3) AMOS scan output of logic board(s) in subparagraph b, above, as necessary for formatting into the outgoing message as required.

4) AMOS provide clearing command to remove old data from register.

d. Discussion: This sensor would be close to the one used at Mount Washington (r.f.i. protection has been added and a finer calibration range used). The data resulting from it would be as refined as we think it could be, with the possible exception of using the temperature discrimination technique.

It is estimated that the cost of this sensor would be about $1,000 plus $500 for the logic card - a total of about $1,500.

Technique IIIA - Quantitative Freezing Precipitation Observation With Type Discrimination:

a. Detector: Same as in subparagraph a, Technique III, with the addition of a temperature modifying network to be effective at ambient temperatures determined by the local set point.

b. Associated Circuitry: Same as in subparagraph b, Technique III, with added provision to adjust the analog voltages to inches of accretion for density of rime when ambient temperature is below the local set point.

c. Mode of Operation: Same as in subparagraph c, Technique III.

d. Discussion: The data from this system would be as refined as it would appear possible with this sensor type. It is believed that changes to the logic originally required in subparagraph d, Technique III, would add not more than $100 to the cost of the system - for a total of about $1,600.

APPENDIX B

Proposed Functional Specifications

Part I - Functional Specification for a Freezing Precipitation Detection System

Part II - Functional Specification for a Freezing Precipitation Detection System with an Analog Voltage Output

PART I

Functional Specification
For
Freezing Precipitation Detection System

1.0 INTRODUCTION

The purpose of this specification is to provide the necessary functional requirements for the design of a Freezing Precipitation Detection System. Freezing rain and freezing drizzle occur in the northern latitude of the continental U.S. and in Alaska during late fall, winter, and early spring. The buildup of ice on communication lines, power lines, and antennae on occasion becomes great enough to cause them to break. Ice on buildings and other structures may become heavy enough to cause failure. Icing on aircraft may cause modification of the aerodynamics of the aircraft sufficiently to cause an accident. Ice accumulation on runways, taxiways, and highways may make them unsafe. Hoar frost accumulation on parked aircraft may dangerously alter airfoil characteristics. It is the intent of this specification to provide for a freezing precipitation detection system which will provide only a "yes/no" answer to an automatic weather station.

2.0 SERVICE CONDITIONS

2.1 Meteorological - operating

Temperature: -62°C to +55°C (-80°F to +130°F)

Humidity: 0 to 100% R.H.

Combined Temperature/Humidity: 30°C at 100% R.H.

Wind: 0 to 125 knots

Pressure: 670 to 1050 mbs

Altitude: to 10,000 ft.

Solar Radiation (maximum): 104 langleys/hour

Icing: 0 to 4.5 inches/hour

Rain: 12 inches/hour at 40 knots

Dust/Sand: Exposure to dust and sand-laden atmosphere

Salt Spray Exposure: Yes

2.2 Meteorological - storage and shipping

Temperature: -62°C to +65°C (-80°F to +149°F)

Humidity: 0 to 100% R.H.

Combined Temperature/Humidity: 55°C at 100% R.H.

Pressure: 550 to 1060 mbs.

Altitude: To 14,000 ft.

Rain: 4 inches/hour (in shipping container)

Transportation vibration: To 60 cycles/sec (in shipping container)

Transit drop: 16 inches to 22 inches drop (in shipping container)

Bench Handling: 4-inch drop

2.3 Power

The equipment shall be capable of operating from a primary power source of 115±10 volts, 60±5 Hertz.

2.4 Electromagnetic Interference

The equipment shall be so designed that it will perform as specified in the presence of electromagnetic interference from commercial TV and FM transmitters sufficient to create an electric field equal to or greater than 10 volts/meter. For purposes of testing, this equipment will be considered as Class ID of MIL-STD-461A. Satisfactory performance under the following test methods of MIL-STD-462 is the minimum requirement: CE01, CE02, CE04, CS01, CS02, CS06, RS02 and RS03 with a limiting field strength of 10 volts/meter (both radiated and conducted).

3.0 DESIGN REQUIREMENTS

3.1 Electrical

a. The ice accretion detector shall be capable of automatically measuring freezing precipitation up to a rate equivalent to 4.5 inches/hour with an accuracy of at least ±10% over the specified range of operating temperatures, winds and humidity.

b. An output pulse, or zero-resistance contact closure, shall be given for each 0.02-inch ice accretion.

c. In order to maintain sensitivity to change, the ice accretion detector shall be "deiced" at frequent intervals. Deicing at the time of the pulse in subparagraph b immediately above would be preferred. Any other interval must be supported by full documentation to prove that neither the overall sensitivity nor the resulting data will be adversely affected.

d. A latching relay circuit is to be provided to be activated by any icing signal during the observation period. The relay will remain closed until released by a command from the automatic weather station. The observation period will last one hour or less, as necessary to meet the needs of the observation programs. All timing pulses, clearing commands, and scans of the output shall be originated by the automatic weather station.

e. The output of the ice accretion detection system will be encoded and/or formatted for transmission by the automatic weather station.

f. The ice accretion detection system shall consume not more than 300 watts of power during deicing cycles. During the periods between deicing cycles, no more than five (5) watts of power shall be required.

3.2 Physical

a. The ice accretion detector shall be designed to be non-directional in sensitivity.

b. All ice shall be melted from the sensing probe and mounting areas adjacent to it each "deicing" cycle. The thoroughness of this ice removal shall be independent of the wind speed from 0 to 125 knots (150 mph).

c. The overall size of the detector body shall be kept to the minimum to accomplish the necessary functions. The sensing probe shall be so mounted on the body that no part of the body will constitute a shield to the probe, thus rendering it less accurate.

d. Mounting hardware must be such that the sensing probe will be within 5° of the vertical when installation is complete.

PART II

Functional Specification
For
Freezing Precipitation Detection System
With an Analog Voltage Output

1.0 INTRODUCTION

The purpose of this specification is to provide the necessary functional requirements for the design of a Freezing Precipitation Detection System which provides an analog voltage output for precise data reduction. Freezing rain and freezing drizzle occur in the northern latitudes of the continental U.S. and Alaska during late fall, winter, and early spring. The buildup of ice on communication lines, power lines and antennae on occasion becomes great enough to cause them to break. Ice on buildings and other structures may become heavy enough to cause failure. Icing on aircraft may cause modification of the aerodynamics of the aircraft to cause an accident. Ice accumulation on runways, taxiways, and highways may make them unsafe. Hoar frost accumulation on parked aircraft may dangerously alter airfoil characteristics. It is the intent of this specification to provide for a freezing precipitation detection system which will provide both a qualitative and a quantitative output to an automatic weather station.

2.0 SERVICE CONDITIONS

2.1 Meteorological - operating

Temperature: -62°C to +55°C (-80°F to +130°F)

Humidity: 0 to 100% R.H.

Combined Temperature/Humidity: 30°C at 100% R.H.

Wind: 0 to 125 knots

Pressure: 670 to 1050 mbs

Altitude: to 10,000 ft.

Solar Radiation (maximum): 104 langleys/hour

Icing: 0 to 4.5 inches/hour

Rain: 12 inches/hour at 40 knots

Dust/Sand: Exposure to dust and sand-laden atmosphere

Salt Spray Exposure: Yes

2.2 Meteorological - storage and shipping

Temperature: -62°C to +65°C (-80°F to +149°F)

Humidity: 0 to 100% R. H.

Combined Temperature/Humidity: 55°C at 100% R.H.

Pressure: 550 to 1060 mbs

Altitude: to 14,000 ft.

Rain: 4 inches/hour (in shipping container)

Transportation Vibration: to 60 cycles/sec (in shipping container)

Transit Drop: 16 inches to 22 inches drop (in shipping container)

Bench Handling: 4-inch drop

2.3 Power

The equipment shall be capable of operating from a primary power source of 115±10 volts, 60+5 Hertz.

2.4 Electromagnetic Interference

The equipment shall be so designed that it will perform as specified in the presence of electromagnetic interference from commercial TV and FM transmitters sufficient to create an electric field equal to or greater than 10 volts/meter. For purposes of testing, this equipment will be considered as Class ID of MIL-STD-461A. Satisfactory performance under the following test methods of MIL-STD-462 is the minimum requirement: CE01, CE02, CE04, CS01, CS02, CS06, RS02 and RS03 with a limiting field strength of 10 volts/meter (both radiated and conducted).

3.0 DESIGN REQUIREMENTS

3.1 Electrical

a. The ice accretion detector shall be capable of automatically measuring freezing precipitation at a rate equivalent to 4.5 inches/hour with an accuracy of at least ±10% over the specified range of operating temperatures, winds and humidity.

b. An output pulse, or zero-resistance contact closure, shall be given for each 0.02-inch ice accretion. Simultaneously, an analog voltage proportional to the accreted ice between 0 and 0.02 inch shall be generated. The analog signal will be between 0 and +5 volts d.c. This signal will be linear with the ice accretion.

c. In order to maintain sensitivity to change, the ice accretion detector shall be "deiced" at frequent intervals. Deicing at the time of the pulse in subparagraph b immediately above would be preferred. Any other interval must be supported by full documentation to prove that neither the overall sensitivity nor the resulting data will be adversely affected.

d. Provision shall be made of a register to store one count for each deicing signal pulse at a maximum rate of 4.5-inches per hour, or 225 deicing pulses per hour at 0.02 inch per pulse.

e. If at the end of the observation period (10 minutes, 1 hour, etc.) there is an analog signal not equal to either 0 volts or 5 volts (incomplete cycle), the voltage level of the end point of the ramp generated will be sensed. This voltage divided by the full icing event voltage (5 volts d.c.) will give a proportion of pulse height.

f. The total number of events plus the partial pulse of subparagraph e, above, will be multiplied by 0.02 inch per pulse to give a precise measure of the ice accreted during the observation period.

g. The output of the ice accretion detection system will be encoded and/or formatted for transmission by the automatic weather station.

h. The ice accretion detection system shall consume not more than 300 watts of power during deicing cycles. During the periods between deicing cycles, no more than five (5) watts of power shall be required.

3.2 Physical

a. The ice accretion detector shall be designed to be non-directional in sensitivity.

b. All ice shall be melted from the sensing probe and mounting areas adjacent to it each "deicing" cycle. The thoroughness of this ice removal shall be independent of the wind speed from 0 to 125 knots (150 mph).

c. The overall size of the detector body shall be kept to the minimum to accomplish the necessary functions. The sensing probe shall be so mounted on the body that no part of the body will constitute a shield to the probe, thus rendering it less accurate.

d. Mounting hardware must be such that the sensing probe will be within 5° of the vertical when installation is complete.