Measurement of surface moisture

Sereda, P. J.

Publisher's version / Version de l'éditeur:

ASTM Bulletin, 228, pp. 53-55, 1958-04-01

NATIONAL RESEARCH COUNCIL
CANADA

MEASUREMENT OF SURFACE MOISTURE
A PROGRESS REPORT

BY

P. J. SEREDA

REPRINTED FROM A.S.T.M. BULLETIN NO. 228
FEBRUARY 1958, P.53 - 55

RESEARCH PAPER NO. 54

OF THE

DIVISION OF BUILDING RESEARCH

OTTAWA

APRIL 1958

NRC 4623

PRICE 10 CENTS

Publications of the Division of Building Research may be obtained by mailing the appropriate remittance, (a Bank, Express, or Post Office Money Order or a cheque made payable at par in Ottawa, to the Receiver General of Canada, credit National Research Council) to the National Research Council, Ottawa. Stamps are not acceptable.

A coupon system has been introduced to make payments for publications relatively simple. Coupons are available in denominations of 5, 25, and 50 cents, and may be obtained by making a remittance as indicated above. These coupons may be used for the purchase of all National Research Council publications including specifications of the Canadian Government Specifications Board.

A PROGRESS REPORT—

Measurement of Surface Moisture

By P. J. SEREDA

At its meeting in 1956 the Task Group on Measurement of Atmospheric Factors of ASTM Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys decided to study surface moisture as one of the important factors in corrosion of metals. At the meeting the author volunteered to undertake to develop instrumentation to record the time-of-wetness on exposed metal samples. This paper reports the work carried out by the Division of Building Research of the National Research Council of Canada and some of the preliminary results.

LITERATURE abounds with data on the weathering of materials exposed at certain geographic locations. Without these useful data there would be no basis for the selection of engineering materials in the construction industry. The contribution of the many ASTM technical committees to this knowledge is notable.

Wide variations in corrosion rates, attributed to local climatic conditions, have been observed and efforts have been made to measure and define the factors responsible for them. Copson (1)[1] postulated from his extensive work that the corrosion rate of steel depends upon the quality and quantity of water reaching the steel surface. Dearden (2) has attempted to correlate the corrosion of steel with the hours of rainfall registered by a recording rain gage. Ellis (3) has made an important contribution to the understanding of the effect of weather upon the initial corrosion of zinc. He determined the wetness factor by means of a device that recorded the presence of moisture on a glass plate exposed with the zinc specimens. Larrabee (4) has done much work to show the effect of rain in washing contaminants such as sulfur compounds from the skyward surface of an exposed steel specimen, and the effect of precipitation such as dew on the groundward side. Compton (5) has emphasized that conditions of exposure other than geographic location may determine the rate of corrosion.

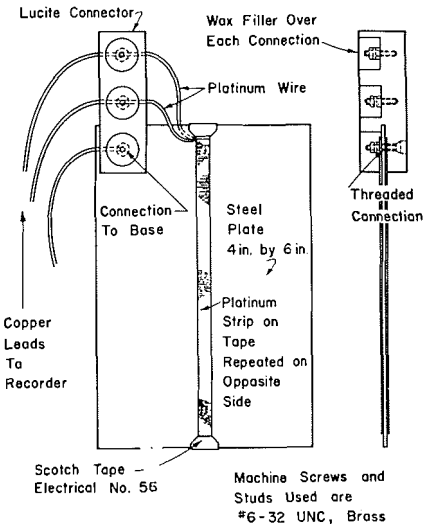


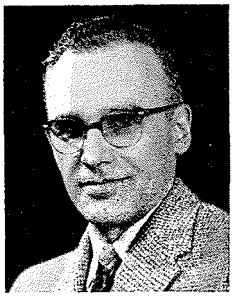
Fig. 1.—Sensing element consisting of platinum and steel.

It is an accepted fact that moisture plays an important role in all manner of deterioration and corrosion. A prime factor in the corrosion of metals is the persistence of free and even absorbed moisture, corresponding to high relative humidity, on the surface of the exposed metal specimen. Although various attempts have been made in the past to measure and record the length of time moisture persisted on the surface, the work was usually done on other than the corroding metal surface. Since the physical characteristics of the metal specimen influence the presence and persistence of moisture on its surface, it was thought that the measurement should be made on a specimen identical to the one on which corrosion is being observed. The method for measuring surface moisture presented in this report is based on a suggestion made by F. L. LaQue. It involves the measurement of the potential developed between a corroding metal specimen and an electrode of platinum placed in immediate proximity. Surface moisture serves as the electrolyte for the cell.

The Measuring Device

Since Subcommittee VII has used mild steel and zinc as calibrating materials for rating the corrosivity at the various exposure sites, these two metals were the immediate choice for the base metal in the sensing element.

The sensing element finally developed for this purpose is shown in Fig. 1. It consisted of two platinum foil electrodes 0.004 in. thick, $\frac{1}{4}$ in. wide, and $5\frac{1}{2}$ in. long, mounted on 4 by 6-in. steel or zinc panels. One electrode was mounted on each side to record the skyward as well as the groundward exposure. Scotch electrical tape No. 56 consisting of 0.002-in. film of thermosetting polyester was used to insulate the electrode from the base. This tape, $\frac{1}{4}$ in. wide, was applied on the platinum foil and similar tape, $\frac{1}{2}$ in. wide, was ap-



P. J. SEREDA, associate research officer, Division of Building Research, National Research Council, Ottawa, has been engaged since 1950 in the study of the behavior of water in porous systems including methods of detecting and measuring the presence of water on surfaces of materials.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

Authorized Reprint from the Copyrighted ASTM BULLETIN No. 228, February, 1958
American Society for Testing Materials, Philadelphia 3, Pa.

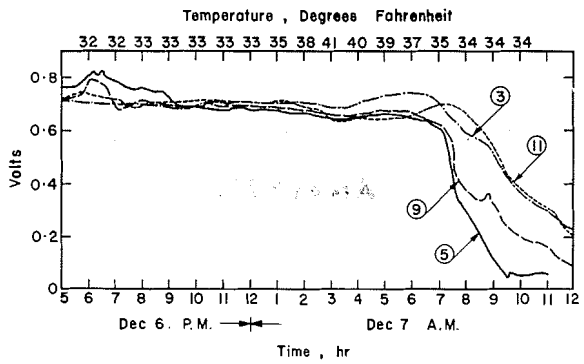


Fig. 2.—Record of potential from four platinum and steel cells during a fog at Ottawa.

5 Skyward element No. 2
9 Skyward element No. 3
3 Groundward element No. 2
11 Groundward element No. 3
Shunt Resistance 100 megohms

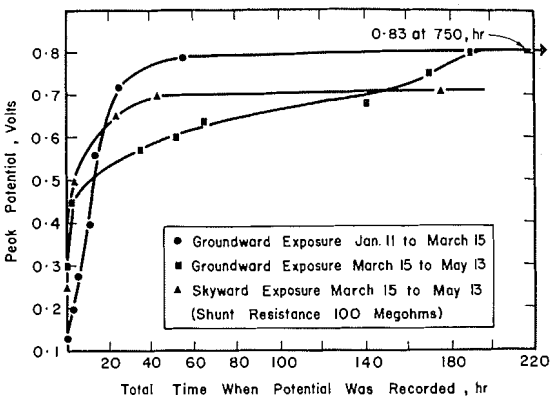


Fig. 3.—Peak potential developed by platinum and steel cell while exposed at Ottawa.

plied on the steel or zinc base. The tape on the foil was cemented to the tape on the base by means of cement E. C. 1022 (Minnesota Mining and Manufacturing Co.). Excess tape was trimmed flush with the edges of the foil with a scalpel. Connection to the platinum foil was made with 20-gage platinum wire which in turn was connected to copper leads at the special Lucite connector shown in the drawing. This connection was sealed from the weather by wax.

A Speedomax 12 point recorder, calibrated to record −0.2 to +1.8 v, registered the potential. A by-pass circuit consisting of a shunt resistance returned the recorder to zero when the element was dry. Since the value of this resistance affected the sensitivity of this device to various climatic conditions, the recorder was altered to sense the potential developed by each cell across a series of shunt resistances of 1, 5, 25, and 100 megohms. This was achieved by introducing a bank of 12 relays to work in conjunction with the 12 relays already in the recorder. The coils of the relays were coupled and were energized through the selector switch of the recorder.

Principle of Operation

The detecting element described here when covered by water, constitutes a galvanic cell. The electromotive force of such a cell can be defined in terms of the metals used for the electrodes and the type and concentration of the active ions which enter into the chemical reactions.

The electromotive force of this cell can be measured by means of a potentiometer under reversible conditions when no current is drawn from the cell. Under these conditions the electromotive force would be independent of the size of electrodes and the extent to which the electrodes were covered by the acting electrolyte. This corresponds with the maximum sensitivity for detecting moisture on the surface of this element because the cell potential is independent of the amount of moisture that is present.

Since it was desirable to measure the degree of wetness of the element, the cell was shorted externally through a shunt resistance resulting in a flow of current through this by-pass circuit. The potentiometer recorder was connected across the shunt resistance so that it measured the IR_e drop. This IR_e drop is the measured potential discussed in this paper.

In a circuit of the galvanic cell having an internal resistance, R_i, connected through an external shunt resistance R_e a current, I, will flow depending on the values of the resistances. The equation relating the electromotive force of the cell to the measured potential can be written as follows:

$$\text{Electromotive force} = IR_i + IR_e$$

The internal resistance of the cell was about 5000 megohms when dry and about 2000 ohms when completely wet. This resistance depends upon the area of the electrodes that is wetted by the electrolyte and the concentration of active ions present. For any given value of the shunt resistance the current varied as the electrodes became wetted by the electrolyte and this registered in the measured potential. As the shunt resistance was increased, the sensitivity of the element was also increased and for any given condition the measured potential was the highest when the shunt resistance was 100 megohms. When the shunt resistance was 1 megohm the sensitivity was decreased to the point that only the condition of complete wetness on the surface of the element was recorded.

When the element consisting of the cell of platinum and steel was immersed in distilled water the measured potential across the 100 megohm shunt reached a maximum of 0.6 to 0.7 v. This potential was not affected when solutions of KCL and NaCl of various concentrations were used. Addition of sulfate ion in the form of a saturated solution of sodium sulfate increased the measured potential to about 0.8 v.

Results and Discussion

Most of the work to date has been done with an element consisting of platinum and steel. Therefore, only the results obtained with this element are reported here, although the element consisting of platinum and zinc shows considerable promise. The data were obtained with the elements exposed at an angle of 30 deg to the horizontal at Ottawa, Ont., and at Halifax, N. S.

First, the reproducibility of the measured potential obtained from two separate elements was determined by observing the record during a period of fog—a very constant condition of wetness (Fig. 2). It is apparent that reproducibility was good and subsequent data have confirmed this finding without exception.

The potential measured from these cells varied from zero to a maximum of about 0.85 v under various conditions of exposure and depending on the value of the shunt resistance. It was found that a maximum potential of 0.6 to 0.7 v was recorded from the cell of platinum and steel when immersed in distilled water and connected through a 100 megohm shunt. This potential was reproduced when the cell was exposed to a heavy rainfall. After outdoor exposure for a certain time, the maximum potential increased to about 0.85 v. This rise was attributed to contaminating salts from the atmosphere. During a prolonged rainfall, this maximum decreased to a lower value on the skyward side. This decrease was attributed to leaching of the salts.

Laboratory experiments indicated

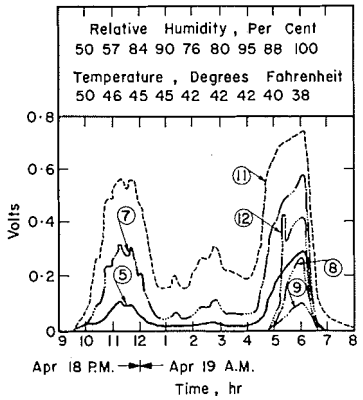


Fig. 4.—Record of potential from platinum and steel cell during light dew at Ottawa.

Element No.	Shunt Resistance	Exposure
5	1 megohm	groundward
7	5 megohms	groundward
11	100 megohms	groundward
6	1 megohm	skyward
8	5 megohms	skyward
12	100 megohms	skyward

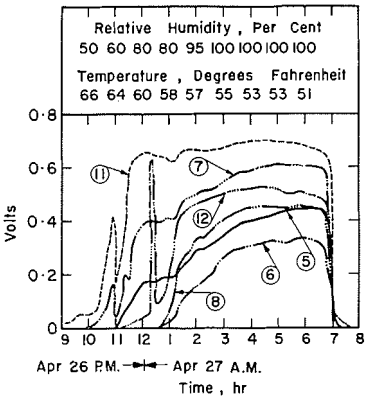


Fig. 5.—Record of potential from platinum and steel cell during moderate dew at Ottawa.

Element No.	Shunt Resistance	Exposure
5	1 megohm	groundward
7	5 megohms	groundward
11	100 megohms	groundward
6	1 megohm	skyward
8	5 megohms	skyward
12	100 megohms	skyward

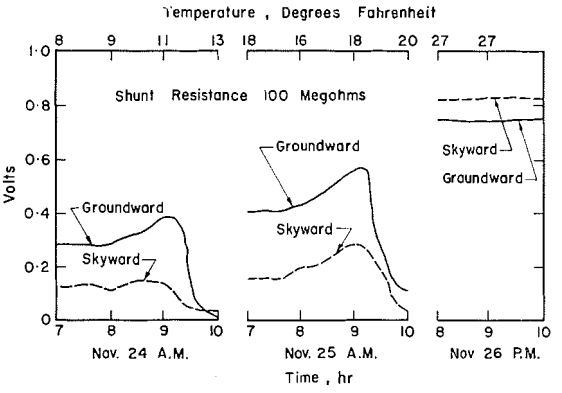


Fig. 6.—Record of potential from platinum and steel cell during snowfall at various temperatures.

that the sulfate ion caused an increase in the measured potential whereas chloride ion had no effect. Figure 3 shows that when a new element was exposed in the winter to conditions producing wetness on the surface, the measured potential increased to a higher value in a shorter total time of wetness than when the element was exposed in the spring. This finding is consistent with the fact that the SO_2 content of the air was twice as high in the month of January as in the months of March and April. The graph also shows that to record a value of 0.5 v a new element had to be exposed for only a couple of hours to conditions of wetness in the spring whereas it had to be exposed for over ten hours in the winter. This can be explained on the basis that the rate of corrosion reactions which supply the active ions for the galvanic cell, is lower when the temperature is lower. It follows, therefore, that a certain amount of corrosion products is necessary to give the cell its maximum sensitivity. On the other hand, excess scale had the opposite effect by bridging the electrodes with a low-resistance path so that loose scale, formed on the groundward side of the steel panel, had to be scraped off from the vicinity of the platinum electrode every two or three months.

In certain localities the period of wetness caused by dew represents a substantial fraction of the total period of wetness from all manner of precipitation. The records of the measured potential developed by the cells during the formation of dew were varied depending on the dew point of the air, air temperature, wind velocity, etc. A typical record is shown in Figs. 4 and 5. Light dew occurred first on the groundward side, presumably because of its proximity to the moisture coming from the ground. These records also show the effect of the shunt resistance. It is significant that the potential was recorded long before the air reached 100 per cent relative humidity. This is accounted for by the fact that the panel was cooled to a temperature below the dew point of the air by radiation loss to the sky. Laboratory experiments have shown that a potential will be recorded when the element is cooled to a temperature corresponding to the dew point of the air. This potential is very low at first because only traces of moisture are on the surface, and will reach a high value only after the element is held for over an hour at a temperature several degrees below the dew point of the air. Air currents have a considerable influence on the value of the potential measured under these conditions.

Figure 6 shows that snowfall at temperatures below and above freezing was recorded as a potential which increased with increasing temperature.

Summary and Conclusions

A method has been developed which can detect the presence of surface moisture on metal panels exposed to outdoor conditions. Sensitivity of the element can be varied so that traces of moisture on the surface as in the case of dew or snow at low temperature can be differentiated from gross moisture as during a period of rain. Finally, it is quite certain that the presence of SO_2 in the atmosphere can be detected by an increased maximum potential.

It has yet to be shown how the measured potential developed by surface moisture relates to the rate of corrosion of the metal. Work is now under way to determine whether any relationship exists between the area under the potential-*versus*-time curves and the rate of corrosion of the metal.

It is hoped that the areas under the potential-*versus*-time curves for any two periods will have the same ratio as the hours of wetness as indicated by the element having the same sensitivity. If this turns out to be the case, then an attempt will be made to develop a simple recorder to give merely the hours of wetness using these sensing elements.

The record of hours of wetness resulting from all manner of precipitation should be of great assistance not only to those studying the corrosion of metals but also in the evaluation of results of deterioration of coatings, and especially the correlation of results from accelerated aging tests with actual service performance.

Acknowledgment:

The author gratefully acknowledges the invaluable assistance of H. F. Slade and S. E. Dods in setting up the apparatus and collecting the data.

References

(1) H. R. Copson, "A Theory of the Mechanism of Rusting of Low Alloy Steel in the Atmosphere," *Proceedings*, Am. Soc. Testing Mats., Vol. 45, p. 554 (1945).

(2) J. Dearden, "Climatic Effects on the Corrosion of Steel," *Journal*, Iron and Steel Inst., Vol. 159, No. II, p. 241 (1948).

(3) O. B. Ellis, "Effect of Weather on the Initial Corrosion of Sheet Zinc," *Proceedings*, Am. Soc. Testing Mats., Vol. 49, p. 152 (1949).

(4) C. P. Larrabee, "The Effect of Specimen Position on Atmospheric Corrosion Testing of Steel," *Transactions*, Electrochemical Soc., Vol. 85, p. 297 (1944).

(5) K. G. Compton, "Outdoor Exposure Testing on Racks and Test Fences," Symposium on Conditioning and Weathering, p. 87, Am. Soc. Testing Mats. (1952). (Issued as separate publication, *ASTM STP No. 133.*)

A list of all publications of the Division of Building Research is available and may be obtained from the Publications Section, Division of Building Research, National Research Council, Ottawa, Canada.