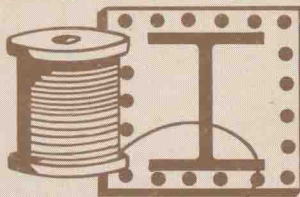


ATMOSPHERIC FACTORS AFFECTING THE CORROSION OF ENGINEERING METALS



S. K. Coburn, *editor*



STP 646

AMERICAN SOCIETY FOR TESTING AND MATERIALS

ATMOSPHERIC FACTORS AFFECTING THE CORROSION OF ENGINEERING METALS

Proceedings of the
Golden Anniversary Symposium
Commemorating 50 Years'
Atmospheric Exposure Testing

A symposium sponsored by
Committee A-5 on
Metallic-Coated Iron and Steel Products
and Committee G-1 on
Corrosion of Metals
AMERICAN SOCIETY FOR TESTING
AND MATERIALS
Pennsylvania State University
State College, Pa., 18–19 May 1976

ASTM SPECIAL TECHNICAL PUBLICATION 646
S. K. Coburn, editor
United States Steel Corporation

04-646000-27



AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race Street, Philadelphia, Pa. 19103

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Library of Congress Catalog Card Number: 77-93113
ISBN 0-8031-0286-0

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Printed in Baltimore, Md.
June 1978
Second Printing, Mars, Pa.
March 1985

Dedication



Vincent Paul Pearson
12 April 1916 to 15 October 1977

This volume, recording the activities of the Golden Anniversary Symposium, and serving as a permanent record of contributions to the field of atmospheric corrosion, is hereby dedicated as a living memorial to our professional colleague and close personal friend—Vincent Paul Pearson, Senior Research Engineer, Research Department, Inland Steel Company, East Chicago, Indiana, who passed away on 15 October 1977, at the age of 61 years.

Vince was born in Chicago, Illinois, and attended its public schools and the University of Illinois. He completed the requirements for the B.S. degree at Roosevelt University in 1940. He began his career in the Research Laboratory of the Inland Steel Company in 1940 in the field of steel pickling inhibitors. He spent the period 1942 to 1945, during World War II, in the United States Army Armored Artillery where he achieved the rank of Colonel.

Upon his return to Inland Steel, he became engaged in corrosion activities beginning in 1948 and continuing to 1968. He had responsibilities in the area of corrosion control. During this period, he was granted three patents in the field of tinplating. Beginning in 1968, he supervised programs in atmospheric corrosion and accelerated testing in the field of metallic-coated sheets.

Vince was a resident of Chesterton, Indiana for 30 years. He was married to Clare Breckenridge on 15 April 1939, and leaves a married son, John, and married daughters, Ann Donahue and Dottie Johnson, and a mother, Dagmar Johansen, a sister, Mrs. Samuel Bond, and five grandchildren. He was a precinct committeeman, served on the Board of Zoning Appeals for many years, and was a Cub Master.

Vince came into ASTM activity when the giants of another era were completing their work. He learned well and soon picked up the reigns of Subcommittee XIV on Sheet Tests. When Committee G-1 was activated, it was Vince who was called upon to coordinate the effort to gain membership. His organizing ability, his enthusiasm, and thoroughness in these tasks made him a giant of sorts in his own right. He left us with several viable committee structures in which we and future members can function effectively. Vince prepared the tabulation forms for the annual sheet inspection of A05.15 and G01.4.2. He prepared all subcommittee and section reports. He photographed all specimens and presented thoroughly documented photographic reports at the annual meetings which will serve as a model of effectiveness. He conducted the 50th Annual Inspection by rededicating the State College rural test site in a ribbon-cutting ceremony. Vince was equally active in atmospheric corrosion affairs in the National Association of Corrosion Engineers where he was the chairman of the newly formed Unit Committee on Atmospheric Corrosion. He became a corrosion specialist in 1971.

It can truly be said of Vincent Paul Pearson—who faithfully served his country, was a successful investigative corrosion engineer, inventor, author, organizer, parent, loving husband, and a dedicated citizen—that he was man for all seasons.

Foreword

This publication contains papers presented at the Golden Anniversary Symposium Commemorating 50 Years' Atmospheric Exposure Testing at the State College Rural Test Site held at Pennsylvania State University, State College, Pa., 18-19 May 1976. The symposium was sponsored by the American Society for Testing and Materials Committees A-5 on Metallic-Coated Iron and Steel Products and G-1 on Corrosion of Metals. D. C. Pearce, American Smelting and Refining Company, and S. K. Coburn, United States Steel Corporation, presided as symposium co-chairmen. Mr. Coburn is editor of this publication.

Related ASTM Publications

**Galvanic and Pitting Corrosion—Field and Laboratory Studies, STP 576
(1976),04-576000-27**

Stress Corrosion—New Approaches, STP 610 (1976), 04-610000-27

Chloride Corrosion of Steel in Concrete, STP 629 (1977),04-629000-27

A Note of Appreciation to Reviewers

This publication is made possible by the authors and, also, the unheralded efforts of the reviewers. This body of technical experts whose dedication, sacrifice of time and effort, and collective wisdom in reviewing the papers must be acknowledged. The quality level of ASTM publications is a direct function of their respected opinions. On behalf of ASTM we acknowledge with appreciation their contribution.

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Introduction

In the February 1958 issue of the ASTM Bulletin, H. F. Hormann, Chairman of Committee A-5 on Corrosion of Iron and Steel, authored a brief history covering its first 50 years' activity. On 18-19 May 1976, the 50th annual spring inspection at the State College, Pennsylvania, Rural Exposure Test Site, was performed by the members of Subcommittees XIV, XV, and XVI on Sheets, Wire, and Hardware, respectively. To mark the occasion, a Golden Anniversary Symposium on Atmospheric Corrosion was held simultaneously at the Keller Conference Center on the campus of the Pennsylvania State University at University Park, Pennsylvania, in conjunction with the more recently formed Committee G-1 on Corrosion of Metals, under whose jurisdiction all future atmospheric exposure tests for ASTM are being conducted.

To properly appreciate the significance of this event one must note that during the Ninth Annual ASTM meeting held in June 1906, Edgar Marburg, Secretary-Treasurer, after listening to all the heat generated by the papers and the discussion on the corrosion of iron and steel, made the following motion: "In view of the importance of this subject and the lack of knowledge concerning the same, it would seem to be eminently proper for the Society to appoint a standing committee on the general subject of the corrosion of iron and steel." The motion carried and it was announced at the 1907 Annual Meeting that Committee U on the Corrosion of Iron and Steel had been formed. In 1910 the designation was changed to Committee A-5.

One can appreciate that wrought iron, being the oldest form of commercial ferrous material, held a tactical advantage over the comparative newcomer—steel—because of the inconsistent performance of some of the available compositions. Today wrought iron is no longer produced. Differences of opinion concerning the variation in corrosion rates of iron and steel not only caused heated debates during this period, but led to the starting of several lawsuits. Obviously, comparative exposure data were lacking and the effects of differences in the environment were not generally recognized as influencing performance.

Among reasons offered for these inconsistencies in performance were too high manganese, too low phosphorus, protection offered by slag, electrolysis due to sulfurous acid in the air, and failure to carry tests through to destruction. Because of the sulfurous atmospheres, the committee believed that immersion of specimens in 20 percent sulfuric acid would provide performance differences which were sufficient to furnish a basis for con-

cluding that metal manufactured by one process was superior to that manufactured by another. The results, however, indicated that such differences did not furnish a basis for discrimination between products.

The early work of the committee thus was devoted to conducting field tests to fulfill the need for generating comparative performance data for different materials under identical conditions of exposure. The first test was put out in 1908, and dealt with segregation within the ingot, as well as the influence of concentration levels of carbon and manganese. Billets were taken from the top, middle, and bottom of selected ingots, and rods and wire were drawn, galvanized, woven into fence, and exposed around the campus of the old Carnegie Institute of Technology (now Carnegie-Mellon University) in Pittsburgh, Pennsylvania.

In 1910, work commenced on the evaluation of the Preece Test using a solution of copper sulphate as a means for determining the zinc coating weight on sheets and wire. It was not until 1915 that work was initiated to investigate the corrosion rates of iron and steel as influenced by different levels of copper. Between 1916 and 1917 specimens were exposed at the Naval Academy at Annapolis, Maryland, at the military installations at Fort Pitt in Pittsburgh, Pennsylvania, and at Fort Sheridan, Illinois. The tests were terminated in 1923 at Pittsburgh, in 1928 at Fort Sheridan, and in 1954 at Annapolis because of the need for the property in these respective locations.

In 1924, Committee A-5 decided to begin a new series of tests involving the atmospheric exposure of bare and galvanized steel sheets and wire of the same steel with different coating weights, and pole line hardware with a variety of coatings. The sheet tests commenced at State College, Altoona, and Brunot Island in Pittsburgh, Pennsylvania, in the fall of 1925, and at Key West, Florida and Sandy Hook, New Jersey, in the winter of 1926. The first inspection at State College was performed in the spring of 1926. The time to the first appearance of rust was used to evaluate the galvanized steel sheets while the time to perforation was the criterion for judging the resistance of the uncoated steel sheets. The coated hardware specimens were placed in test in 1929, and the coated wire tests were underway by 1936.

Despite the massive increase in population and industrial growth in isolated centers throughout the country since 1926, the self-purifying ability of the atmosphere permitted the State College site to retain its rural aspect. Although all of the specimens at nearby industrial Altoona have deteriorated, the slow deterioration rate of specimens at State College permitted the discrimination necessary to fulfill the purposes of Edgar Marburg's motion in 1906.

As a result of the installation of high-speed, continuous galvanizing lines in the 1950s, a critical need developed for information concerning the relative performance of this new product as it related to the known performance of the earlier product obtained from the galvanizing pot in the hot dip

process. Accordingly, Subcommittee XIV on Sheet Tests secured representative specimens from several producers of the continuous galvanized product. Similar specimens, in the same range of coating weights of zinc, were obtained from producers supplying material from the same equipment used to produce the hot-dip galvanized specimens exposed in the initial test of 1926. The new test commenced in 1960, and annual inspection reports have been filed together with the reports of the remaining 1926 test at State College. The results of these two long term investigations can be obtained by an inspection of the reports of Committee A-5 in the yearly *Proceedings* of ASTM.

For many years there had been a growing interest in ASTM for the formation of a committee devoted exclusively to the corrosion of metals. During the existence of ASTM, Committee A-5 increasingly concentrated its efforts towards specifications for coated steel products; in 1967 its title and scope changed to Metallic Coated Iron and Steel to properly reflect this activity. Likewise, Committee B-3 on Corrosion of Nonferrous Metals and Alloys was limited in its scope in dealing with the corrosion of other metals. The earliest discussions towards this end, however, began in 1941. By 1963, recommendations were made by an ad hoc committee headed by K. G. Compton to dissolve Committee B-3 and create a committee whose scope was expanded as follows: "The promotion and stimulation of research, the collection of engineering data, and the development of methods of tests and nomenclature relating to corrosion of metals." This recommendation was accepted by the Board of Directors of the Society on 21 January 1964. Thus, a new entity, entitled Committee G-1 on Corrosion of Metals, came on the scene with its first chairman, F. L. LaQue. At the same time the name of the Advisory Committee on Corrosion was changed to the more precise Advisory Committee on Exposure Test Facilities.

On 9 February 1965, with the writer as chairman, Subcommittee IV of G-1 on Atmospheric Corrosion held its initial meeting. By 1966, Subcommittee IV defined four areas of responsibility: Section 1 on Weather, Section 2 on Metal Coatings on Steel, Section 3 on Ferrous Metals and Alloys, and Section 4 on Nonferrous Metals. It was agreed that no new tests would be initiated by Subcommittees XIV, XV, and XVI of the newly termed Committee A-5, and that Committee A-5 members would hold dual membership in Committees A-5 and G-1 so as to continue existing field testing programs. Accordingly, the completion of the worldwide calibration tests in 44 locations, initiated in Committee A-5 were reported in Committee G-1.

In 1967, Committee G-1 conducted a symposium entitled Metal Corrosion in the Atmosphere. The papers, including the aforementioned calibration test data, were published in STP 435, by the same title, emphasizing the testing aspects of corrosion technology. In 1956, Committee A-5 cooperated with the American Welding Society in the inspection aspects of the elaborate exposure tests they established utilizing thermally sprayed steel panels.

The study was designed to evaluate the protection afforded by sealed and unsealed panels of sprayed zinc and aluminum exposed in various industrial, rural and marine ASTM test sites.

In 1968, another test was begun with galvanized steel sheets to compare the performance of products whose coating thickness was controlled either by exit rolls or by an air knife.

This Golden Anniversary Symposium marks the completion of the hopes of those members who, in 1941, believed there should be a committee devoted to all of the common construction metals. You will note herein that there are several papers devoted to each of the metals: steel, zinc, aluminum, and copper, and that the testing aspect has been duly recognized.

S. K. Coburn

Corrosion engineer, Special Technical Service,
Metallurgy, United States Steel Corporation,
Pittsburgh, Pa.; symposium chairman and editor.

Investigation of Atmospheric Exposure Factors that Determine Time-of-Wetness of Outdoor Structures*

REFERENCE: Grossman, P. R., "Investigation of Atmospheric Exposure Factors that Determine Time-of-Wetness of Outdoor Structures," *Atmospheric Factors Affecting the Corrosion of Engineering Metals*, ASTM STP 646, S. K. Coburn, Ed., American Society for Testing and Materials, 1978, pp. 5-16.

ABSTRACT: Wetness of outdoor structures is caused partly by condensation of water from the atmosphere, which we recognize as dew. Rain is the source of part of the wetness. The condensation process means that heat must be removed from air at the surface where condensation occurs. This heat exchange process by radiation from the exposed surface to the cold sky is examined in detail. Temperature differences between an insulated black surface, facing skyward, and ambient air conditions were observed to be as high as 8°C (15° F). Effects of wind velocity, orientation, and surface characteristics are given. Time-of-wetness measurements for test panels exposed at Miami, Florida are reported, including the "black box" exposure method used for coated panels. Comparisons of time-of-wetness investigations reported by Guttman and Sereda are given.

KEY WORDS: atmospheric corrosion, environments, test panels, corrosion rates, panel radiation, sky radiation

Outdoor test sites for observing the performance of materials all have a common problem of defining the characteristics of the environment at that particular location. There are many factors involved, including moisture levels, duration of the moisture condition, air pollution, temperatures, and surface characteristics. Organic materials have additional factors inherent in sunlight degradation processes. We now use computers to segregate the most important and pertinent information, so that useful development

*Original experimental data were measured in U.S. customary units.

¹Vice president, Q-Panel Co., Cleveland, Ohio 44135.

work can proceed and materials can be developed to achieve a greater resistance to the deteriorating forces of weather.

Even when the magnitude of the problem is reduced to a study of the deteriorating forces of wetness, as is done in the field of corrosion, there are still many variables involved with many complex interactions. We get around the problem by measuring the degradation process, such as corrosion, at a Site A, such as Penn State, and then expose the same material at a Site B, such as at Kearney, N.J., the result being a relative degradation at the two sites. Large amounts of data are collected, and one can go a long way in explaining just why Site B is more aggressive than Site A. However, there remains a continuing need to better define the factors which contribute to the observed corrosion or deterioration at a given location.

A new measuring tool came on the scene some twelve years ago, and it was called a time-of-wetness meter, a device which measured just how much of the time a test panel is wet. Technical activity was conducted by people working together in ASTM, and results of measurements made and correlation with corrosion of metals in the atmosphere were reported [1].² The initial work came out of the National Research Council of Canada, and P. J. Sereda was a leader and a prolific writer in this work [1-4].

For background information, we should first review just what is a time-of-wetness meter. Fig. 1 shows the principles involved. A zinc plate has a

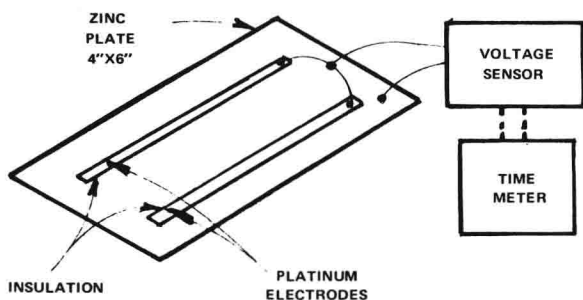


FIG. 1—The time-of-wetness meter.

platinum electrode glued to its face, with platinum spaced about 0.1 mm (4/1000 in.) from the zinc with an insulating adhesive. Electrical leads are attached to the two dissimilar metals. When wetness bridges the space between the two metals, we have a battery that generates about 1 V. When the voltage goes over 0.2 V, a running time meter is activated to record wetness time. The platinum zinc interface is 53 cm (21 in.) in length, and the electrical circuitry is such that 1/50 of a μA is the current flow once the wetness time interval has started.

²The italic numbers in brackets refer to the list of references appended to this paper.