ATMOSPHERIC CORROSION OF METALS

A symposium
sponsored by ASTM
Committee G-1 on
Corrosion of Metals
Denver, Colo., 19–20 May 1980

ASTM SPECIAL TECHNICAL PUBLICATION 767
S. W. Dean, Jr., Air Products and
Chemicals, Inc., and
E. C. Rhea, Reynolds Metals Co.
editors

ASTM Publication Code Number (PCN)
04-767000-27

1916 Race Street, Philadelphia, Pa. 19103

Foreword

The symposium on Atmospheric Corrosion of Metals was presented at Denver, Colorado, 19–20 May 1980. The symposium was sponsored by ASTM Committee G-1 on Corrosion of Metals in cooperation with the National Association of Corrosion Engineers. S. W. Dean, Jr., Air Products and Chemicals, Inc., and E. C. Rhea, Reynolds Metals, Co., are editors of this publication.

Related ASTM Publications

Underground Corrosion, STP 741 (1981), 04-741000-27

Electrochemical Corrosion Testing, STP 727 (1981), 04-727000-27

Sampling and Analysis of Toxic Organics in the Atmosphere, STP 721 (1980), 04-721000-19

Geothermal Scaling and Corrosion, STP 717 (1980), 04-717000-27

Corrosion of Reinforcing Steel in Concrete, STP 713 (1980), 04-713000-27

Corrosion and Degradation of Implant Materials, STP 684 (1979), 04-684000-27

Stress Corrosion Cracking—The Slow Strain-Rate Technique, STP 665 (1979), 04-665000-27

Atmospheric Factors Affecting the Corrosion of Engineering Metals, STP 646 (1978), 04-646000-27

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.

ASTM Committee on Publications

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SUMMARY

Introduction

The American Society for Testing and Materials (ASTM) has been one of the most important sources of information on atmospheric corrosion technology in the 20th century. The leadership provided by ASTM has resulted from a need to develop performance data on metallic materials which are used in natural atmospheres. At the outset it was recognized that there was no satisfactory method for predicting the performance of materials in the atmosphere. Therefore it was necessary to run tests in the atmosphere to develop the data required to specify materials and design devices and structures for use in the atmosphere. As products entered the marketplace with systems designed to protect them from atmospheric corrosion, it became necessary to have standards which would accurately describe the performance of the systems. There was also a real need to understand the variables which affect atmospheric corrosion so that designers and engineers could work intelligently with the metallic materials in atmospheric service.

In the decade of the 1960's, Committee G-1 was formed for the purpose of bringing together and coordinating all standards-writing activities pertaining to metallic corrosion. As part of this work, Subcommittee GO1.04 was created to handle atmospheric corrosion. The decades of the 1960's and 1970's witnessed some subtle, but important, changes in the field of atmospheric corrosion. Environmentalists brought strong pressure to bear on society and industry in particular to minimize or eliminate pollution. This, coupled with the dramatic changes in costs of energy from various fossil fuels, has brought about a fundamental change in the types of atmosphere engineers have had to deal with. Industrial atmospheres could no longer be assumed to be heavily polluted with sulfur oxides. Another important change during this period was the development of sophisticated electronic instruments which allowed a wide variety of chemical and other types of measurements to be made. These instruments, together with digital computers, made possible a wide variety of correlations and other types of studies which heretofore were beyond the scope of laboratories involved in atmospheric corrosion work.

Earlier symposia held in 1973[1] and 1976[2] by Committee G-1 had papers

[1] *Corrosion in Natural Environments, ASTM STP 558,* American Society for Testing and Materials, 1974.

[2] *Atmospheric Factors Affecting the Corrosion of Engineering Metals, ASTM STP 646,* S. K. Coburn, Ed., American Society for Testing and Materials, 1978.

concerned with these various questions. Two Special Technical Publications (*STP*'s) have resulted from these symposia and provided a record of the earlier work on these questions. However, because atmospheric corrosion is a process requiring 10 to 20 years to become fully established, there is a real need to fortify these earlier studies with additional results as new data become available. Thus, the purpose of the 1980 symposium on atmospheric corrosion sponsored by Committee G-1 through Subcommittee GO1.04 was as follows:

1. To document how pollution control measures over the years have affected materials of construction and specifically various metallic materials used in the atmosphere.

2. To record information on the corrosion resistance of newer alloys and composites in the atmosphere in comparison with older, more traditional materials.

3. To discuss the mechanism of atmospheric corrosion and specifically the kinetics of atmospheric corrosion as determined by the variations of specific active species in the atmosphere.

4. To develop better systems for classifying the corrosivity of the atmospheres, including the use of electrochemical testing methods to characterize atmospheric corrosion behavior.

5. Finally, to show how laboratory tests can be used to simulate atmospheric corrosion.

The 1980 Atmospheric Corrosion of Metals Symposium met the objectives for which it was organized. A number of papers were presented on the behavior of engineering materials, including two on weathering steels, three on copper alloys, two on aluminum alloys, two on metals with metallic coatings, and one on zinc. In addition, two papers were presented on monitoring of atmospheric exposure sites using time of wetness or electrochemical corrosion monitoring systems. Two papers were also presented on laboratory tests and their correlation with atmospheric corrosion. Finally, there were papers concerned with characterizing atmospheric exposure sites and classifying the corrosivity of such sites, some work on the evaluation of microclimates and corrosion of metals, and the prediction of long-term corrosion rates of structural steels from short-term data.

This collection of papers should be very useful to engineers involved with designing and specifying materials for use in atmospheric applications, both in architectural structural and automotive applications. This publication should also be helpful to materials scientists interested in developing accelerated laboratory tests for predicting the long-term behavior of metallic materials in the atmosphere. The results herein should be useful to those planning new atmospheric corrosion exposures, both from the viewpoint of determining better monitoring methods for exposure sites and as a record of tests underway and recently completed. In addition, the data provided here should be of interest to those concerned with the economics of corrosion and how some of the newer alloy compositions behave.

In assembling the papers in this *STP* we have tried to provide a link between the past work and the future directions of ASTM in atmospheric corrosion testing, and specifically Committee G-1. There is no question that future symposia will be necessary, and we hope this volume will be an adequate progress report on the state of the art of atmospheric corrosion at the beginning of the decade of the 1980's.

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Outdoor Exposure Results

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Atmospheric Corrosion of Weathering Steels

REFERENCE: Knotková-Čermáková, D., Vlčková, J., and Honzák, J., "**Atmospheric Corrosion of Weathering Steels,**" *Atmospheric Corrosion of Metals, ASTM STP 767,* S. W. Dean, Jr., and E. C. Rhea, Eds., American Society for Testing Materials, 1982, pp. 7–44.

ABSTRACT: A general research program to study the corrosion behavior of weathering steels is being completed by the State Research Institute for Materials Protection. Three stages of research are discussed:

1. a description of the corrosion characteristics of these materials,
2. the corrosion behavior of weathering steels in structural service, and
3. the evaluation of the applicability of weathering steels for typical real structures.

The results of this program were used to formulate the corrosion section of the specification: Technical Direction for Application of Weathering Steels.

A comparison of the cost of construction using conventional paint coatings on steel versus the use of weathering steel is provided, including the protection and operation of construction.

KEY WORDS: atmospheric corrosion, weathering steel, corrosion tests on atmospheric sites, atmospheric pollution, outdoor and sheltered exposure, behavior of steel on structural elements, bolt joint, model crevice, patina rust layer, applicability on real objects, masts, industrial constructions, bridges, buildings

The corrosion of structural steels is a very serious technical problem. The volume of the steel constructions exposed to a corrosive environment is very high. The corrosivity of the atmosphere in which most steel structures are used is increasing and the application of the suitable protective systems is very complex and involved from both the raw material and energy points of view. In addition, the maintenance of the surface coatings on existing structures is laborious and expensive.

For these reasons, any system which allows the use of steel structures while minimizing cost during the service life is highly desirable. In addition, it is also desirable to obviate the need for both complex technological equipment for the production of the steel components in the structures and for labor for their maintenance in service. Thus, weathering steels which

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have an increased resistance to atmospheric corrosion and have been produced for many years under various commercial names—Cor-Ten, Mayari R, 10CHNDPŠ, Atmofix, etc.—enjoy an outstanding reputation in a wide range of applications.

These steels were manufactured in Czechoslovakia as early as before World War II, but a systematic regulation of their use occurred only in the late 1960's. At this time, extensive research programs were undertaken. The work started at that time had to yield, as quickly as possible, technical results sufficient for the state-aided application of these steels in practice. The research was, therefore, carried out as an extensive team effort which involved the collaboration of a number of the research institutes, for example, the Research Institute of Ferrous Metallurgy, Technically-Economic Research Institute of Metallurgy, the Research Institute of Steel Constructions, and the Welding Research Institute. This extensive research project was aimed at developing information concerning the metallurgy, corrosion resistance, fabrication techniques, and economics of weathering steels. The results of this research were used in the preparation of the very extensive and specific standard: "Czechoslovak Directions for the Application of Weathering Steels," published in December 1978 [*1*].[2]

The extent of the work carried out and the knowledge gained are much wider than reported earlier, and it is impossible to condense it in even one extensive publication. For this reason, only a section of our information on the atmospheric corrosion of weathering steels is discussed herein on the following three topics:

1. Description of the atmospheric corrosion characteristics.
2. Corrosion behavior of weathering steels on structural members in typical atmospheres.
3. Evaluation of the usability of weathering steels for real typical structures.

Atmospheric Corrosion Tests of Weathering Steels

Aim, Extent, and Method of Tests

The results of corrosion tests from the network of atmospheric testing stations forms a basis for establishing the corrosion performance of various materials. Such tests are carried out in a standardized mode and in well-defined conditions, and so the results for a particular material are comparable to results from other sources. However, the application of these results to an actual structure is neither simple nor unambiguous.

In the present study, three types have been used:

1. Tests at atmospheric exposure stations where the atmospheric condi-

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

tions are well known and the test technique has been standardized. Specifically, Location 1 involved in outdoor atmospheric exposure with specimens on stands, inclined 45 deg to the horizontal and facing south. Location 2 involved vertical specimens using a standard Stevenson screen.[3]

Most of the tests were carried out in the SVÚOM main atmospheric testing stations where conditions were monitored regularly and the corrosivity of the station atmosphere was measured periodically. The results of these corrosivity measurements are reported in Table 1. These tests were carried out over a 15-year period.

Tests also were performed, to a lesser extent, at single-purpose sites selected so that they could provide more detailed data on the corrosion behavior of selected steels in atmospheres having smaller variations in sulfur dioxide (SO_2) content for 5-year testing periods.

2. Tests at the single-purpose test stations, which are located in rural, urban, and industrial atmospheres in Category 2 exposures, that is, in sheds. Category 3 exposures involving indoor tests were also carried out. The present study required information on the effect of sheltering on the corrosion of these materials because most structural applications have some portions of the steel surface exposed in this mode. However, conventional station tests do not provide this information. These tests were carried out for 5 years on simple Novodur stands with actual construction geometries in exploitation microclimates.

3. Atmospheric exposures were carried out at test stations in specific locations to evaluate unusual and extreme effects. Three- to five-year exposures were made in various production plants to determine the corrosion behavior of these steels in specific industrial atmospheres. Such test results are not usually applicable to other environments.

4. Atmospheric exposures were carried out at test stations to evaluate special arrangements of the specimen, including the effect of orientation of the corroding surface, effect of specimen mass, and the individual corrosion rates of top and bottom sides of the specimens. The duration of these tests was 8–10 years.

Seven test programs of the type described under No. 1 of the foregoing have been initiated. Sixty different types of steels have been included in these tests.

Table 2 gives the compositions of the Atmofix type of Czechoslovakian commercial steels together with the composition of the comparison steel. The compositions of the other steels in these programs will be provided only when specific results are reported.

Only two types of steels were subjected to the tests described in Nos. 2 through 4 of the foregoing. These steels were the low-alloy Atmofix 52A steel

[3] The Stevenson screen is a louvered cabinet which shields specimens from direct exposure to the elements.