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SELECTED BIBLIOGRAPHY OF ATMOSPHERIC CORROSION.(U)
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FOREWORD

ABSTRACT

During an electrochemical study of atmospheric corrosion phenomena funded by the Office of Naval Research, (Contract No. N00014-75-C-0788) a number of publications related to basic aspects of atmospheric corrosion have been collected. The more important papers are enclosed in this bibliography in a chronological manner. If an abstract was provided by the authors, it is included.

This collection of papers on atmospheric corrosion is by no means complete. Many publications related to organic coatings, exposure tests, etc. have not been included since they did not contain information of basic nature.

-A063922

This bibliography is part of the Final Report (SC5030.7FR) prepared by F. Mansfeld, principal investigator, for the Office of Naval Research.

ABSTRACT

1935

"A Laboratory Study of the Atmospheric Corrosion of Metals"
W. H. J. Vernon
Trans. Faraday Soc., 31, 1668 (1935)

1936

"Uber Das Atmospharische Rosten Des Eisens"
G. Schikorr
Ztschr. Elektrochem., 42, 107 (1936)

1937

"Uber Das Atmospharische Rosten Des Eisens II"
G. Schikorr
Ztschr. Elektrochem., 43, 697 (1937)

1948

"Climatic Effects on the Corrosion of Steel"
J. Dearden
Jour. of the Iron and Steel Inst., 159, 241 (1948)

An attempt was made to correlate the corrosion of steel in a moderately industrial atmosphere with the hours of rainfall registered by a recording rain gauge. No such relation was found, as only 35-40% of the total corrosion occurred during the hours when the rainfall was sufficient to register on the gauge. A further 35-40% was due to the effects of humidity, and the balance is presumed to have occurred during periods of drizzle and when the specimens remained wet after recordable rainfall had ceased. Measurements were made of the corrosion rate of previously rusted specimens under various humidities, and a marked increase in the rate was observed when the relative humidity was over 80%. A quantitative estimate of the corrosion due to rainfall and to various ranges of humidity has been attempted. Observations were made on the effects of the weather prevailing at the start of exposure, the annual shedding of rust, the expansion when this cannot occur, and the sulphur content of rust formed under various conditions.

1949

"Effect of Weather on the Initial Corrosion Rate of Sheet Zinc"
O. B. Ellis
Proc. ASTM 49, 152 (1949)

The weight losses of 26 samples of sheet zinc exposed for periods of 28 days in a mild industrial atmosphere have been studied with relation to weather variations during the periods of exposure. There were five specimens in each sample. A multiple correlation analysis of the data has shown that the 28 day weight losses can be correlated with the number of hours of rainfall and the number of hours the relative humidity was at or near 100 per cent during the first five days of exposure. Rainfall and humidity after the first five days were much less effective in determining the corrosion rate than that during the early part of the exposure. The effect of the initial attack carries through to at least one year. Samples that had high initial corrosion rates showed higher corrosion rates after twelve months' exposure than the samples that corroded initially at low rates. The weather conditions that resulted in great variations in the initial rate of attack on sheet zinc did not have a similar effect on the initial rate of corrosion of low-copper iron.

1950

"Atmospheric Factors Affecting the Corrosion of Steel"
P. J. Sereda
Ind. Eng. Chem., 52 (2), 157 (1950)

Measurement of temperature, sulfur dioxide, and surface moisture has resulted in systematic evaluation of the atmospheric corrosion of steel and should provide a basis for the rating of inland exposure sites.

1951

"Adsorption of water vapour on solid surfaces"
F. P. Bowden, and W. R. Throssell
Proc. Roy. Soc.A., 209, 297 (1951)

> An experimental study has been made of the adsorption of water vapour on solid surfaces. Two methods are used, the first a direct weighing of the adsorbed film on a microbalance and the second an examination of polarized light reflected from the surface. Both methods agree and show that, for the surfaces examined, the adsorption of water at vapour pressures near saturation corresponds only to about two molecular layers. The experiments suggest that the heavy adsorption, which has been previously observed and which has been quoted as evidence for long-range surface effects, is due to contamination.

"Adsorption of Water Vapour on Solid Surfaces"
F. P. Bowden, W. R. Throssell
Nature, 167, 601 (1951)

1953

"The Effect on *Climate and Atmospheric Pollution on Corrosion*"
J. C. Hudson and J. F. Stanners
J. Appl. Chem., 3, 86 (1953)

> The results of routine observations on the corrosion of the small reference specimens of ingot iron and of zinc exposed at the atmospheric testing stations of the Corrosion Committee all over the world are presented and discussed. The data, which relate to more than 20 sites and to up to 20 separate annual tests at each, provide a good indication of the effect of climatic differences on atmospheric corrosion. In Great Britain, where for most of the year the climate is sufficiently humid to promote corrosion, the determining factor for its severity is the sulphur pollution of the air. Tests made in collaboration with the Fuel Research Station at 16 sites where the atmospheric pollution is measured have shown an almost perfect correlation between the amount of sulphur dioxide taken up from the atmosphere by lead peroxide pollution gauges and the rate of corrosion, both for steel and zinc. In the absence of sulphur pollution, corrosion at the sites overseas is generally slight; in dry climates it is negligible. For example, tests at Delhi indicate that the resistance of the Delhi pillar to corrosion is to be attributed to the mildness of the corrosive conditions there rather than to any superiority of the iron itself. Corrosion on surf beaches in the tropics may, however, be exceptionally severe. At Lighthouse Beach, Lagos, Nigeria and at Kure Beach, N.C., U.S.A., the rates of corrosion for steel are

about five times greater than those in the most corrosive industrial atmospheres in Great Britain. The severe corrosion at these places is associated with the salt spray from the sea, and the rate of corrosion falls off rapidly with increasing distance from the surf line. Preliminary tests on specimens exposed at different heights on the Sutton Coldfield television mast suggest that the effect of distance from the ground is secondary to the natural variations in rates of corrosion from one year to another. Some details of experimental technique are discussed. Work, in which American investigators have collaborated, has confirmed that at low copper contents variations of a few hundredths of one per cent in copper content have a marked effect on the corrosion-resistance of ingot iron. Because of the increasing difficulty in controlling the copper content of different batches of ingot iron, the small reference specimens used in the Corrosion Committee's most recent tests have been made of copper-steel instead of ingot iron. The copper-steel now in use contains about 0.3% of copper; minor deviations from this figure should not affect the corrosion rate within the experimental error. It has also been found that, although it is advisable to stir the inhibited hydrochloric acid solution (Clarke's solution) used for derusting iron or steel specimens after exposure, failure to do so does not impair the accuracy of the results, at least for ingot iron or copper-steel.

"The Problem of Atmospheric Corrosion of Metals at Relative Humidities Below 100%"
V. V. Skorchelletti and S. E. Tukachinsky
J. Appl. Chem. USSR, 26, 27 (1953)

"Corrosion Resistance of High-Strength Low-Alloy Steels As Influenced by Composition and Environment"
C. P. Larrabee
Corrosion, 9, 259 (1953)

The corrosion resistances of several high-strength low-alloy steels in various atmospheres, in natural waters and in soil are compared with those of structural copper steel and structural carbon steel in the same environments. The effects of the many variables that influence the corrosion of these steels in the different media are fully discussed.

1954

"Relative Humidity-Temperature Relationships of Some Saturated Salt Solutions in the Temperature Range 0 to 50° C"
A. Eexler and S. Hasegawa
J. of Res. of the Natl. Bur. of Stds. 53 (1), 19 (1954)

> The relative humidity-temperature relationships have been determined in air in equilibrium with saturated salt solutions of lithium chloride, $LiCl \cdot H_2O$; magnesium chloride, $MgCl_2.6H_2O$; sodium dichromate, $Na_2Cr_2O \cdot 2H_2O$; magnesium nitrate, $Mg(NO_3)_2\ 6H_2O$; sodium chloride, NaCl; ammonium sulfate, $(NH_4)_2SO_4$; potassium nitrate, KNO_3; and potassium sulfate, K_2SO_4, over a temperature range of 0° to 50° C, using the dewpoint method. The relative humidity is a continuous function of temperature, and, except for sodium chloride, is monotonic. The curve for sodium chloride increases from 74.9 percent relative humidity at 0°C to a maximum ot 75.6 percent at 30 °C and then gradually decreases to 74.7 percent. The maximum change in relative humidity with temperature, about 15-percent relative humidity as the temperature increases form 0° to 50°C, occurs with saturated salt solutions of sodium dichromate and magnesium nitrate.

1955

"Corrosion Aspects of Air Pollution"
L. Greenburg and M. B. Jacobs
Amer. Paint Journal, 39, 64, (1955)

"Atmospheric Galvanic Couple Corrosion"
K. G. Compton, A. Mendizza and W. W. Bradley
Corrosion, 35,383t (1955)

> Tests designed to provide fundamental information explaining the behavior of galvanic couples in the atmosphere are reported. The purpose is to permit prediction of their probable relative behavior. Measurements of weight losses of couples in a marine, an industrial and a severe tropical atmosphere are reported. Tests involving thin sheet electrode material separated by filter paper saturated with electrolyte are reported. Materials tested include aluminum, magnesium, stainless steel, copper, cadmium, zinc, nickel, tin, chromium, lead electroplate, silver, low carbon steel and others. Potential measurements and weight loss data are given. Specimens exposed to the atmospheres show several apparent weight loss anomalies. Measurements of corrosion currents described provide a quick means for determining probable relative corrosion behavior of couples. Differences between couples "exposed" and "sheltered" are noted. Quantitative data provided are intended to be useful to the design engineer.

1956

"The Atmospheric Corrosion of Rolled Zinc"
E. A. Anderson
ASTM STP 175, 126 (1956)

The corrosion of zinc in the atmosphere is controlled by three principal factors: (1) the frequency of rain and dewfall, (2) the acidity of the moisture, and (3) the rate of drying. The corrosion rate is a maximum in industrial locations which combine acidic atmospheric contamination with prevalance of heavy mists and dew. The composition of zinc has only a minor bearing on the corrosion rate. Corollary data are presented which explain the findings in exposure tests conducted by Subcommittee VI on Atmospheric Corrosion of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys.

"Sulfur Dioxide in New York City Atmosphere"
L. Greenburg and M. B. Jacobs
Ind. & Engrg. Chem. 48 (9), 1517 (1956)

This two-year study shows that highest concentrations of sulfur dioxide occur during temperature inversion periods. In all such instances weather conditions extending far beyond the area are the controlling factor.

"Atmospheric Corrosion by Nuclei"
R. St. J. Preston and B. Sanyal
J. Appl. Chem., 6, 26 (1956)

Bare and varnished steel contaminated by nuclei produce, in humid atmospheres, the type of corrosion characterised by filamental configuration and known as filiform. With some nuclei, corrosion takes place at relative humidities below 60%. Filiform corrosion is characteristic of, and the primary phase in, electrolytic corrosion in atmospheric conditions, but the rate of attack varies from one electrolyte to another and with the degree of humidity. In several cases, corrosion attack has been found to be greater at 70% relative humidity than at 99% relative humidity. The presence of highly hygroscopic salts in the atmosphere can initiate corrosion, even at low relative humidities. Nuclei on the outisde of a varnish film will generally start corrosion earlier than those beneath the film, especially if water is present on the surface.

1957

"Massnahmen zur Verhinderung der Korrosion durch Aufbereitung der Atmosphare"
A. Kutzelnigg
Werkstoffe und Korrosion, 4, 492 (1957)

"Uber die durch hygroskopische feste Korper verursachten Metallkorrosionen"
A. Bukowiecki
Schweizer Archiv-Annales Suisses, 23 (4), 97 (1957)

1958

"Role of Condensation in the Corrosion of Steel by Moisture & Sulphur Dioxide"
B. Sanyal, D. V. Bhadwar
J. Sci. Industr. Res., 17B, 287 (1958)

"A Polarographic Study of the Corrosion of Iron and Some Ferrous Alloys by Sulfur Dioxide"
F. J. Bowen and A. H. Gropp
Corrosion, 14, 50 (1958)

> A study was made of the manner in which sulfur dioxide attacks iron and ferrous alloys. A polarographic method was used to follow the changes in the sulfur dioxide concentration. Tests were made on one pure iron and seven low alloy steels exposed to sulfur dioxide over 12 hour periods. Etensive data are reported on the rate of consumption of sulfur dioxide by the various test samples. A corrosion mechanism involving the reduction of sulfurous acid by iron to give the sulfide is discussed.

"Measurement of Surface Moisture"
P. J. Sereda
ASTM Bulletin 228 (Feb), 53 (1958)

> 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.

1959

"The Corrosion of Metals in Synthetic Atmospheres Containing Sulphur Dioxide"
B. Sanyal & D. V. Bhadwar
J. Sci. Industr. Res. 18A, 69 (1959)

> The mechanism of atmospheric corrosion of metals has been investigated by measuring the rates of corrosion of aluminium, copper, nickel, zinc and mild steel in humid synthetic atmospheres containing sulphur dioxide. The effects of varying humidity, temperature, sulphur dioxide concentration, duration of exposure of the metals, single or in combinations, on the rates of corrosion have also been investigated. It has been observed that each metal requires a minimum humidity for the initiation of corrosion. Aluminium exhibits a critical humidity (80 per cent R.H.) at which the rate of corrosion is accelerated; mild steel exhibits critical humidities of 60 and 75 per cent R.H., and copper and zinc do not exhibit any. The rates of corrosion of the metals depend on the temperature of the atmosphere, the thickness of the moisture film on the metal surface, the nature of the corrosion products and the permeability of the films of these products to moisture and acid. Rise in temperature increases the rate of corrosion as a result of acceleration of the chemical reaction between the metal and the acid, up to a point, beyond which it falls due to lower solubility of sulphur dioxide in water vapour which does not get condensed on the metal surface.

"Design and Interpretation of Atmospheric Corrosion Tests"
H. R. Copson
Corrosion, 15 533t (1959)

> Principles under which atmospheric corrosion tests are made are much the same as those applicable to other types of testing. Considered, among other things are uses of accelerated tests, specimen size, location of test sites, differences in atmospheres, differences in metals and influence of alloying constituents. Mounting procedures, shape of specimens, drainage, influence of rainfall, influence of climatic variations, uses of shelters, reproducibility, test duration, evaluation of results.

"Reaktionsmechanismus der atmospharischen Korrosion der Metalle in feuchter und mit Schwefeldioxyd verunreinigter Luft"
K. Barton und E. Beranek
Werkstoffe und Korrosion, 10, 377 (1959)

"Report of Subgroup of Subcommittee VII, on Corrosiveness of Various Atmospheric Test Sites as Measured by Specimens of Steel and Zinc" Proc. ASTM, 59, 183 (1959)

1960

"Some Observations on the Atmospheric Corrosion Product of Steel"
J. B. Harrison and T. C. K. Tickle
Chemistry and Industry, 1383 (1960)

"Atmospheric Factors Affecting the Corrosion of Steel"
P. J. Sereda
Ind. Eng. Chem. 52 (2), 157 (1960)

Measurement of temperature, sulfur dioxide, and surface moisture has resulted in systematic evaluation of the atmospheric corrosion of steel and should provide a basis for the rating of inland exposure sites.

1961

"Die Aquivalenz der atmospharischen Korrosion von Zink und Nickel mit dem aus der Luft aufgenommenen Schwefeldioxyd"
G. Schikorr
Metall, 15 (10), 981 (1961)

"Atmospheric Corrosion Testing of Metals in Canada"
E. V. Gibbons
Corrosion, 17, 318t (1961)

The atmospheric corrosion resistance of metals is evaluated after exposure in a number of differing Canadian environments. Test sites included rural, industrial marine-industrial, marine, far northern and semi-industrial. Metals exposed include three aluminum alloys, aluminum coupled metals, carbon steel, copper-bearing low carbon steel, low alloy copper-nickel-bearing steel, low alloy copper-nickel-bearing steel, three stainless steels, two magnesium alloys, and rolled zinc. Test exposure periods varied from one to ten years.

"Atmospheric Corrosion of Metals"
I. L. Rosenfeld
1st Int. Congr. Metallic Corrosion, London (1961), Butterworth , p. 243

The paper describes the electrochemical methods of investigation that have been developed for stdying atmospheric corrosion in thin electrolyte layers. Some theoretical aspects of atmospheric corrosion, resulting from the data obtained with the aid of the methods mentioned, are considered and some new views on atmospheric corrosion mechanisms are suggested. The rate of oxygen depolarization in thin electrolyte layers beginning with $h = 3 \cdot 10^{-2}$cm increases according to the hyperbolic law. The dependence of the oxygen reduction rate on the thickness of the diffusion layer is determined by the equation $i\delta = 0{\cdot}190 \times 10\text{-}5 \text{ Acm}^{-1}$ case of many industrial metals (iron, steel, zinc, magnesium) the anodic reaction of metal ionization proceeds very slowly in thin layers. The oxygen depolarization rate increases markedly in the course of electrolyte evaporation from the metal surface.

"The Atmospheric Corrosion of Steels as Influenced by changes in Chemical Composition"
C. P. Larrabee and S. K. Coburn
1st Intl. Congr. Metallic Corrosion, London, (1961), Butterworth, p. 276

The method used for testing steels in the atmosphere is described and the types and relative corrosivity of different atmospheres compared. The results of long-time-exposure tests are plotted to show the shapes of time-corrosion curves of steels with varying corrosion resistances. The effect on corrosion resistance of steels having variations in chromium, copper, nickel, phosphorus and silcon is given for each element and when present in certain combinations. Data are taken from individual 15-year tests in industrial, semi-rural and marine atmospheres. Two hundred and seventy steels with three variations of chromium content, five of copper, two of nickel, three of phosphorus and three of silicon were tested.

1962

"Atmospheric Corrosion by Electrolyte Nuclei"
B. Sanyal and D. V. Bhadwar
J. Sci. Industr. Res., 21D, 243 (1962)

The atmospheric corrosion of mild steel, aluminium, copper, zinc, brass, tinplate, galvanized iron and lead, representing common engineering metals, by nuclei of selected electrolytes representing the corrosive constituents of metal treatment materials likely to be left as residues on metal surfaces has been investigated under controlled conditions. A new technique has been developed for inoculating the metal surfaces with the electrolyte nuclei which consists in depositing a definite quantity of the electrolyte on the metal surface by immersing metal specimens in aqueous solutions of the electrolytes for a few seconds and drying in vacuum and at 100°C. The corrosion rates of the different metals have been, in general, found to be in the following descending order: mild steel, galvanized iron, zinc, copper, brass, tinplate, lead, aluminium;

of these metals, only the first four undergo appreciable corrosion. The chlorides are more corrosive than the sulphates. Corrosion rates increase with increase in humidity, temperature, period of exposure and concentration of electrolyte onn the metal surface. Corrosion is also influenced by the pH of the solution used for inoculating the metal surfaces. In the case of mixtures of electrolytes, the corrosive effect of one electrolyte is not influenced by the presence of other electrolytes and the total effect is additive. Corrosion under immersed conditions is much lower than that due to atmospheric corrosion by nuclei of electrolytes, but aeration of the electrolyte solution under immersed condition causes rapid increase in the rate of corrosion, which finally approaches that under atmospheric exposure.

"Corrosion of Steel"
J. H. Greenblatt and R. Pearlman
Chemistry in Canada, 21 (1962)

The effects of some possible atmospheric contaminants on the corrosion of steel at three different humidities and temperatures were investigated in a series of simple laboratory tests. The trends observed confirm trends observed by different workers in outdoor exposures at different sites and indicate that there is a complex interplay between the effects of contaminants, humidity and temperature.

"Aluminium Alloys Corrosion Behaviour in an Industrial Environment,"
F. F. Booth and K. G. Latimer
Corrosion Technology, 315 (1962)

In 1948, as part of a comprehensive long-term investigation of the corrosion resistance of aluminium alloys, atmospheric exposure tests were undertaken by Aluminium Laboratories Ltd., Banbury, at a number of corrosion sites. This paper deals with the examination of strips cut at various times from sheet panels that were exposed in an industrial area at Stratford, London. The panels included most of the standard production aluminium alloys, mild steel, galvanized steel and 18/8 stainless steel.

"Effects of Air Pollution on the Atmospheric Corrosion Behavior of Some Metals and Alloys"
E. A. Tice
J.of the Air Poll. Control Assn.,12 (12), 553 (1962)

1963

"A Rapid Method for Determining the Corrosivity of the Atmosphere at any Location"
D. P. Doyle and H. P. Godard
Nature, 200, 1167 (1963)

"Bare steel structures - a new concept"
S. K. Coburn, G. W. Gilliland, J. C. Pohlman
Electr. Engr., 666 (1963)

> Certain high-strength low-alloy steels form a self-protecting oxide film that permits their exposure to the atmosphere in the bare or uncoated condition. These steels are finding applications ranging from transmission towers to distribution transformers on electric power systems. A detailed discussion is presented of how one of these steels can be used to advantage for outside structures, particularly in those areas where maintenance costs of galvanized and painted structures are high.

"Galvanic Corrosion Behavior of Aluminum in the Atmosphere"
H. P. Godard
Materials Protection, 2 (6), 38 (1963)

> Wire-on-bolt test assemblies were used to determine galvanic corrosion behavior of aluminum in contact with eight other metals when exposed to various atmospheres. Test procedure and environments at sites are given. Describes method of determining corrosion loss due to galvanic corrosion. Tabular data summarizes test results. Results also are given on crevice corrosion behavior of aluminum in the atmosphere.

"Uber den Mechanismus des atmospharischen Rostens des Eisens"
G. Schikorr
Werkstoffe und Korrosion, 14 (2), 69 (1963)

"A Rapid Method for Determining the Corrosivity of the Atmosphere at any Location"
D. P. Doyle and Hugh P. Godard
Nature, 200, 1167 (1963)

1964

"Einfluss der Korrosionsprodukte auf den langzeitigen Verlauf der atmospharischen Korrosion"
K. Barton and D. Cermakova
Werkstoffe und Korrosion, 15, 374 (1964)

"Einige Betrachtungen uber die Wirkung des Klimas auf die atmospharische Korrosion der Metalle"
J. C. Hudson
Werkstoffe und Korrosion,15,363 (1964)

"Die Bedeutung des Schwefeldioxyds fur die atmospharische Korrosion der Metalle"
G. Schikorr
Werkstoffe und Korrosion, 15, 457 (1964)

"Elektrochemische Merkmale der atmospharischen Korrosion"
H. Kaesche
Werkstoffe und Korrosion, 15, 379 (1964)

"Atmospharische Korrosion einiger wichtiger Systeme aus Grundmetallen und metallischen Uberzugen"
K. Muller
Werkstoffe und Korrosion, 15,533 (1964)

1965

"Die Abwitterungsgeschwindigkeit unlegierter Stahle in Land-, Meeres- und Industrieluft"
E. Brauns und U. Kalla
Stahl u. Eisen 85, 406 (1965)

> Corrosion rate of plain carbon steels in land, sea and industrial atmospheres. Determination of the corrosion rate of plain carbon shipbuilding steels by field tests in land, sea and industrial atmospheres over a test period of seven years. Effect of the mode of killing the steel and of treating the samples by brushing and by pickling with addition of inhibitors after weathering on the test results.

"Studies on Atmospheric Corrosion of Steels Related with Meteorological Factors in Japan. Multiple Correlation of Meteorological Factors and Atmospheric Pollution Substances on Corrosion of Steel"
K. Oma, T. Sugano and Y. Hirai
Boshoku Gijutsu, 14, 16 (1965)

"Aspects of the Atmospheric Corrosion Climate"
S. Oden
IVA:s Korrosionsnamnd, Bull. No. 45, Stockholm (1965)

"Vergleich der Ergebnisse elektrochemischer Messungen an niedriglegierten Stahlen mit ihrem Verhalten beim Rosten"
G. Becker
Archiv fur das Eisenhuttenwesen, 36, 489 (1965)

> Comparison of the results of electro-chemical measurements on low alloy steels with their behaviour in rusting. The measuring of electrochemical parameters of low alloy steels to determine a relationship with the results obtained from natural rusting tests. Relation between the degree of rust and steady and activation potential.

"Untersuchungen uber die Wirkung des Eisen (II)-sulfates beim atmospharischen Rosten und beim Unterrosten von Anstrichen, Teil I"
H. Schwarz
Werkstoffe und Korrosion, 16, 93 (1965)

"Die theoretische Deutung der Eisen (II)-sulfat-Nester im atmospharischen Rost, Teil II"
H. Schwarz
Werkstoffe und Korrision, 16, 208 (1965)

"Electrochemical Mechanism of Atmospheric Rusting"
U. R. Evans
Nature, 206, 980, (1965)

1966

"Additives prevent low carbon steel corrosion in sulfurous acid"
W. McLeod and R. R. Rogers
Mat. Prot. 5, 29 (1966)

> Mild steel in contact with an aqueous solution of sulfurous acid can be protected from corrosion by the use of an inhibitor consisting of

ammonium oxalate and hexamine. The experimental results leading to this discovery are described in this article.

"The Influence of Salts in Rusts on the Corrosion of the Underlying Steel"
K. A. Chandler
Brit. Corros. J.,1, 264 (1966)

A series of synthetic rusts was prepared with a range of sulphate and chloride contents. The samples were placed on steel specimens and after a test period of 30 days at different relative humidities, the corrosion of the underlying steel was measured. The presence of salts caused increased corrosion of thesteel and this increased with the amount of salt in the rust. Corrosion was inappreciable below a relative humidity of about 40%.

"Sulfurous Acid Corrosion of Low Carbon Steel at Ordinary Temperatures-1. Its Nature"
W. McLeod and R. R. Rogers
Corrosion,22, 143 (1966)

Corrosion rate data are presented for low carbon steel in (1) a combination of sulfur dioxide, water vapor and air, and (2) aqueous solutions of sulfurous acid in the absence of air, at ordinary temperature. Information as to the nature of the corrosion products is presented and it is shown that this depends on the place in which the corrosion takes place to an important extent.

"The Seasonal Distribution of Ferrous Sulphate Formed During the Atmospheric Rusting of Mild Steel"
T. K. Ross and B. G. Callaghan
Corrosion Science, 6, 337 (1966)

Electron probe micro-analysis was applied to specimens of rust formed by the atmospheric corrosion of mild steel sheets exposed during February 1964 in Manchester, England. The slight corrosion experienced during the succeeding four months was found to result in only a light fixation of sulphur. Continued exposure during the next eight months coincided with a marked increase in sulphur-containing formations, predominantly in the form of bands at the metal-rust interface. Further exposure for four months permitted the sulphur-containing bands found previously to move outwards through the rust to form 'nests'. Specimens exposed independently at London and Cambridge also revealed sulphur-containing includions at the interface between steel and rust.

"Uber das Korrosionsverhalten von Salzpulvern gegenuber verschiedenen Metallen"
A. Bukowiecke und B. G. Joshi
Schweizer Archiv, 32, 42 (1966)

"Role of Ammonia in the Atmospheric Corrosion of Mild Steel"
T. K. Ross and B. G. Callaghan
Nature, 211, 25 (1966)

1967

"Atmospheric Corrosion Studies in Two Metropolitan Areas"
James B. Uphan
J. of Air Pollution Cont. Assn.17, 398 (1967)

> Atmospheric corrosion studies using established air monitoring network sites were conducted in metropolitan St. Louis and Chicago to obtain information on the quantitative relation between mean pollution levels and corrosion losses. The studies are described and data are presented showing the good correlation found between corrosion losses and sulfur-related pollutants and the insignificant effect of dustfall and suspended particulate matter.

"Study of the Influence of Different Atmospheric Factors on the Variations in the Rate of Corrosion of Mild Steel at Balasore by Regression Analysis
R. K. Tripathi, U. S. Agnihotri and G. K. Singhania
Labdev J. Sc. Tech., 5,114 (1967)

> The regression of the rate of corrosion on different atmospheric factors has been studied. The regression analysis reveals that maximum temperature and salinity accounts for 80% and 76% of the total variation observed in the rates of corrosion on the panels at 90° and 45° respectively at Balasore.

"Mechanismus der Fe-, Zn- und Cu-Korrosion in Feuchter HCI-Dampfe Enthaltender Atmosphare"
K. Barton und S. Bartonova
Collection Czechoslov. Chem. Commun., 32, 2431 (1967)

1968

"Effects of Atmospheric Factors on the Corrosion of Rolled Zinc"
Herbert Guttman
ASTM STP 435, 223 (1968)

A long term exposure program has been carried out at Birchbank, B.C., wherein rolled zinc corrosion data and certain atmospheric factor data were developed. Zinc is sensitive to variations in climatic and atmospheric pollution conditions, and as a result panels exposed on different dates for a specific period of time can corrode at different rates. An empirical equation has been developed for Birchbank which relates corrosion of zinc to the time of wetness of exposed panels and the average atmospheric sulfur dioxide content during the time panels are wet. The equation accounts for most of the observed variation in corrosion losses and is valid for exposure periods of up to 256-weeks' duration. This paper also presents information concerning the relative corrosion rates of the skyward and groundward surfaces of zinc panels, the relationship between time of panel wetness and relative humidity, and the relationship between atmospheric sulfur dioxide as measured by a Thomas autometer and by the lead peroxide method.

"Corrosion of Metals by Aqueous Solutions of the Atmospheric Pollutant Sulfurous Acid"
W. McLeod and R. R. Rogers
Electrochemical Technology, 6, 231 (1968)

It has been found here that the corrosion rate of a metal in an acid such as H_2SO_3, HNO_3, H_2SO_4 or HCl, having a normality between N/1 and N/10,000, is related to the concentration of the acid in accordance with the equation Corrosion rate = ax (Acid Normality)^b, where a and b are constant for each combination of acid and metal and where the temperature is 25°C. Having determined the values of a and b for a considerable number of these acid-metal combinations, it was possible 1 - to compare the corrosion rates of the various metals in sulfurous acid with those of the same metals in the well-known nitric, sulfuric, and hydrochloric acids, and 2 - to determine the corrosion rates of the metals in sulfurous acid of different normalities.

"Gasvolumetrische Messung der atmospharischen Korrosion"
K. Bohnenkamp
Werkstoffe und Korrosion, 19, 792 (1968)

"Survey of Corrosion and Atmospheric Pollution in and Around Sheffield"
K. A. Chandler and M. B. Kilcullen
Brit. Corros. J., 3, 80 (1968)

The nature and extent of the relationships between the corrosion of two mild steels of different copper content, and atmospheric pollution were investigated at 22 selected sites in the Sheffield area. This was part of a general investigation into atmospheric corrosion of ferrous metals. The results confirmed that there was an important relationship between the corrosion of steel and the atmospheric pollution by smoke and sulphur dioxide. However, only about 50% of the variations in corrosion rates at different sites could be attributed to sulphur dioxide, measured in this investigation by the Volumetric Method. Smoke intensity had an influence on the corrosion rate of steel similar to that of sulphur dioxide but the correlation between sulphur dioxide and smoke was high, so that their effect on the corrosion rate could not be considered as independent. Their combined effect was only slightly greater than their individual effects. The corrosion rate could not be accurately predicted from a knowledge of the quantity of these two types of atmospheric pollution present in the atmosphere.

"The Nature of Ferrous Sulphate in Rust"
D. Fyfe, C.E.A. Shanahan and L. L. Shreir
Corrosion Science, 8, 349 (1968)

The presence of $FeSO_4 . 4\,H_2O$ in rust formed on steel exposed to SO_2-containing atmospheres is unusual, since the tetrahydrate would only be expected to crystallize from acidic solutions and at 60°C. Gravimetric studies of $FeSO_4 . 7\,H_2O$ cycled between 0 and 86% r.h. at 25°C indicates that during rusting $FeSO_4 . 7\,H_2O$ crystallizes from solution and is rapidly converted into $FeSO_4 \cdot 4\,H_2O$ during periods of low humidity. This provides a simple mechanism to explain the presence of $FeSO_4 . 4\,H_2O$ in rust without postulating that acid conditions are essential.

"Rostungsgeschwindigkeit unlegierter und niedriglegierter Baustahle"
W. Schwenk und H. Ternes
Stahl u. Eisen 88, 318 (1968)

Rate of corrosion of plain carbon and low-alloy structural steels. Corrosion tests in industrial air carried out on three steels containing about 0.12%C and 0.10, 0.18 or 0.27% Cu as well as on a steel resisting to weathering with 0.09%C, 0.13%P, 0.85%Cr, 0.34%Cu and 0.32% Ni. Comprehension of the test results by mathematical equations.

1968

"A Statistical Evaluation of Atmospheric, In-Service, and Accelerated Corrosion of Stainless Steel Automotive Trim Material"
H. L. Black and L. W. Lherbier
ASTM STP 435, 3 (1968)

Stainless steel panels with various surface finishes were exposed to winter salt and ash conditions on trucks and automobiles, salt atmosphere, industrial atmosphere, and rural atmosphere for periods of one to four years. They were also evaluated by six accelerated tests either presently used by, or proposed by, the automobile industry.

Comparisons of the average results of the multiple specimens were made in an attempt to determine the relative superiority among the grades of stainless and among the surface finishes in each exposure environment. Statistical correlation coefficients were calculated to determine the degree of corrosion resistance correlation among the sites and to determine the correlation between "in-service" corrosion and the accelerated tests.

No clear superiority of any grade in all environments could be determined. With the exception of chromium flash plating, no surface finish tested was significantly superior to any other. The automobile and truck exposures showed that the varying weather conditions from one winter to another could cause unpredictable, conflicting results. The correlation between corrosion resistance and temperature, snow-fall, and de-icing agents was not clear. The statistical correlation analysis conducted showed that very limited or no correlation exists between in-service corrosion and accelerated tests. Even among the tests, the correlation was poor or not existent. This study indicates that none of the accelerated tests evaluated can be expected to predict stainless steel corrosion performance in service.

"Resistance of Titanium-Base Alloys to Atmospheric Corrosion"
M. L. Greenlee and L. F. Plock
ASTM STP 435, 33 (1968)

Eight titanium alloys were included in the 1957 ASTM Committee G-1 (formerly B-3) program to determine the atmospheric corrosion behavior of nonferrous metals and alloys. Representative alloys of the alpha, alpha-beta, and beta type were evaluated. Based upon results of weight change measurements and tension tests, two- and seven- year exposures at four prominent ASTM test sites resulted in no significant corrosion. Slight staining was observed, but there was no appreciable weight change.

"The Effect of Initial Weather conditions on the Atmospheric Corrosion of Aluminum and Its Alloys"
V. E. Carter and H. S. Campbell
ASTM STP 435, 39 (1968)

Weight losses for specimens of aluminum alloys exposed for one year to moderately severe industrial and marine atmospheres were similar for groups of specimens put out initially in winter or summer. The depth of pitting on those put out in the winter was, however, from 1½ to 2½ times as great as on those put out in the the summer. The difference is explained by the specimens exposed in winter remaining covered with a film of moisture for a greater proportion of the time during their first few weeks or months on test. It is recommended that, when comparing the atmospheric corrosion resistance of aluminum alloys, tests should be started both in summer and in winter.

"Computerized Long-Term Corrosion Data"
D. O. Spatig and W. H. Ailor, Jr.
ASTM STP 435, 43 (1968)

A program has been devised which permits computer handling of all data derived from 20-year atmospheric and marine programs. This program makes feasible the routine handling of thousands of test specimens and calculations in an accurate but rapid method. Tape records from punched cards include exposure location, duration of test, mechanical properties, density, alloy type, and panel dimensions for both control and exposed specimens. These tape records are processed on an IBM 1410 computer to calculate the effects of aging and exposure. The final machine-printed report gives the corrosion rate in mdd (milligrams per square decimeter per day) and mpy (mils per year), along with per cent changes in tensile, yield, and elongation values due to corrosion for individual specimens, and also calculates average values of these properties by alloy and exposure site.

"Atmospheric Stress Corrosion Testing of Aluminum Alloys"
H. B. Romans and H. L. Craig, Jr.
ASTM STP 435, 61 (1968)

Results are given for stress corrosion studies carried out on a number of aluminum alloys. Testing was done at Aruba, Netherlands Antilles, Kure Beach, N. C., and Richmond, Va. These sites provided environments that ranged from tropical marine to mild industrial. Failure times are compared with laboratory and service results. One aim was to study the effect of prolonged aging at ambient temperatures. In aluminum-magnesium alloys this aging may produce a metallurgical structure which makes these alloys subject to stress corrosion cracking. Specimens aged at higher temperatures do show this response in laboratory and atmospheric tests. From these accelerated data, Arrhenius plots predict these alloys should become susceptible within two to five years if aged at ambient temperatures. However, test results do not bear this out. It is possible to draw erroneous conclusions from only one type of test. For at least one alloy, the rate of failure is much more rapid in the atmosphere than in an accelerated laboratory test. This has been attributed to an interaction between specimens tested in a communal solution. In conclusion, either a laboratory or an atmospheric test is, in itself, insufficient to characterize the stress corrosion behavior of an engineering material. These two tests give data that are complimentary instead of supplementary. Both types are necessary to evaluate the potential hazards of a material having some degree of stress corrosion susceptibility.

"Corrosion Rates of Mild Steel in Coastal, Industrial, and Inland Areas of Northern California"
H. E. Thomas and H. N. Alderson
ASTM STP 435, 83 (1968)

The corrosion rate of mild steel specimens was determined at 15 sites in Northern California. Weight loss with time was measured. These sites included coastal, marine, bay, and steam-geyser areas. The methods of specimen preparation, corrosion product removal, and exposure location details are covered. The repeatability of the tests was checked and found to be good at two locations, and the agreement with ASTM results at the Point Reyes exposure test site was reasonably good.

"Atmospheric Exposure of Light Metals"
S. M. Brandt and L. H. Adam
ASTM STP 435, 95 (1968)

This paper summarizes a ten-year atmospheric corrosion test program for aluminum and magnesium base alloys sponsored by the American Society for Testing and Materials under the direction of committee B-7 on Light Metals and Alloys Subcommittee VIII on Atmospheric Exposure Tests.

The program included fourteen cast, nine wrought, and three clad aluminum alloys and five cast and four wrought magnesium alloys. The specimens, exposed at five outdoor exposure sites in the United States, were tested after exposure periods of six months, one, three, five, and ten years.

The tensile strength of the exposed specimen was compared to that of the control specimen which was stored in a sealed container. The per cent changes in tensile strength for the exposed specimens compared to the control specimens are included in the data presented.

"Atmospheric Corrosion of Copper Alloys"
D. H. Thompson
ASTM STP 435, 129 (1968)

Specimens of 18 copper metals were exposed outdoors in four locations for periods of two and seven years. Corrosion damage was assessed by measurement of loss in weight, loss in mechanical properties, and depth of pitting. Weight loss is shown to be the best measure of uniform corrosion. The mean corrosion rate was on the order of 0.05 mils per year (mpy) (1.3 mm/year). Greatest corrosion occurred at the industrial site followed by east coast marine, west coast marine, and the rural site. Nickel improved the atmospheric corrosion resistance of the copper alloys tested. Results are comparable to those obtained in other similar tests.

"Atmospheric Exposure of Nonferrous Metals and Alloys--Aluminum: Seven-Year Data"
F. L. McGeary, T. J. Summerson and W. H. Ailor, Jr.
ASTM STP 435, 141 (1968)

This report describes the results of weathering tests on 34 wrought aluminum alloys exposed seven years at four ASTM sites in the United States. Also included, for comparison, are data on three additional aluminum alloys exposed six years at five sites in England.

The British industrial atmosphere exposures at Sheffield and London were found to produce the most corrosion, particularly on the sheltered sides of these panels which were exposed at an angle of 30 deg from the horizontal. The self-limiting corrosion characteristics were observed on weather surfaces at all test sites in both countries.

The test will be continued and again reported after twenty years, as was the case in a previous ASTM B-3 test (ASTM STP 175) on older aluminum alloys.

"Atmospheric Corrosion Behavior of Some Nickel Alloys"
D. van Rooyen and H. R. Copson
ASTM STP 435, 175 (1968)

Nickel, nickel-copper, and nickel-chromium-iron alloys were included in an atmospheric corrosion test series in industrial, marine, and rural sites. Pit depths, losses in weight, and losses in mechanical properties were extremely small after a seven-year period of exposure. The nickel-iron-chromium materials had the lowest corrosion rates, about 0.01 milligrams per square decimeter per day (about 0.002 mils per year). The corrosion rates of the nickel-iron-chromium alloys appear to have decreased substantially with exposure time, while the nickel and nickel-copper alloy specimens follow approximately linear rates. Long time durability data have also been obtained for a number of nickel-copper-iron alloys. These were boldly exposed at Bayonne, N. J. for almost

40 years. Data led to the construction of isograms connecting compositions of equal durability on the nickel-iron-copper ternary diagram. Effects of exposure under shelter are also discussed.

"Copper and Copper Alloys"
E. Mattsson and R. Holm
ASTM STP 435, 187 (1968)

In 1958 exposure tests were started in Sweden to gain knowledge of the natural patination and the corrosion behavior of copper and copper alloys when used outdoors. The investigation covered 36 alloys in sheet or rod form: 5 coppers, 20 brasses, 5 phosphor bronzes, 1 silicon bronze, 1 aluminum bronze, 1 cadmium bronze, 2 nickel-silvers, and 1 free-cutting phosphor bronze. Specimens were exposed in rural, marine, and urban atmospheres. After two- and seven-years' exposure, specimens were examined.

During the first years of atmospheric exposure the copper and copper alloys acquired a dark surface coating consisting mainly of copper oxide (Cu_2O). In urban and marine atmospheres, signs of green patina appeared on copper after about six to seven years; the basic copper salt causing the green color being sulfate in the urban, chloride and sulfate in the marine atmosphere. The average penetration as calculated from the weight loss during 7-years' exposure was: in rural atmosphere 0.2 to 0.6 μm per year, in marine atmosphere 0.6 to 1.1 μm per year, in urban atmosphere 0.9 to 2.2 μm per year. The corrosion rate decreased with the time of exposure. The losses in mechanical properties were in most cases of negligible importance.

The dezincification of brass was of significant degree only in β-brass and in certain $(\alpha + \beta)$-brasses when exposed to the urban or the marine atmosphere. Dezincification was observed also in α-brass, even with as high copper content as 92 per cent, although the depth of attack was not very great. It should also be mentioned that arsenic was consistently effective as a dezincification inhibitor for α-brass only in the marine atmosphere. This indicates that the mechanism of dezincification is different in the presence and in the absence of chloride.

The tests described here are continued and further examinations will be carried out after 20 years of exposure.

"Corrosion Test Results on Fifteen Ferrous Metals After Seven-Years Atmospheric Exposure"
G. B. Mannweiler
ASTM STP 435, 211 (1968)

This is a progress report covering findings on the removal of ferrous corrosion specimens that had been exposed for seven years to the atmospheres of five different test sites, which included rural, marine, and industrial environments. The materials employed were ten malleable and pearlitic malleable irons, two ductile irons, and three rolled steels. Previous removals of companion sets of specimens had been made after one- and three-years' exposure. A final set is scheduled for removal in 1970 after twelve-years' exposure. The appearance of the corroded plates and weight losses were evaluated.

"Hard-Rolled Aluminum Alloys"
E. Mattsson and S. Lindgren
ASTM STP 435, 240 (1968)

In 1955 exposure tests were started with the following architectural aluminum alloys in hard-rolled condition: high-purity aluminum, commercial purity aluminum (with and without 0.14 per cent copper), AlMn1.2 (with and without 0.14 per cent copper), AlMg0.65, AlMg2.5, Alclad (with core of AlMn1.2 and cladding of AlZn1). Panels of the alloys were exposed on five sites in Sweden with rural, marine, urban-marine, and industrial atmospheres.

After one-, three-, six-, and ten-years' exposure, specimens were taken in and examined with respect to pitting, layer corrosion, and change in mechanical properties.

From the results it may be concluded that the hard-rolled AlMg alloys are well suited for architectural purposes. There is no risk of blistering, and the pitting corrosion resistance is as good as for unalloyed aluminum. With hard-rolled, unalloyed aluminum of commercial purity and AlMn1.2 both without copper, the risk of blistering cannot be disregarded, at least not in a marine atmosphere. Here layer corrosion blisters were formed on the alloys mentioned in most cases already during the first year of exposure. After the initial period, however, they generally developed very slowly. One way to overcome the susceptibility to blistering apparently is to add about 0.1 to 0.2 per cent copper. Another remedy might be to use alloys in half-hard condition, which is common practice. The alclad surface developed a rather rough appearance.

It may be concluded that all the alloys tested will last for several decades in outdoor use, as far as the mechanical properties are concerned. Corrosion, however, may affect the appearance by pitting, blistering, roughening, and discoloration. Often, however, such "aging phenomena" may be regarded as an attractive patina.

"Atmospheric Corrosion of Aluminum and Its Alloys: Results of Six-Year Exposure Tests"
V. E. Carter
ASTM STP 435, 257 (1968)

Results of atmospheric corrosion tests on four aluminum alloys at five sites in Great Britain showed that corrosion, in the form of pitting, increased with atmospheric pollution. Corrosion/time curves became parallel to the time axis within two years at mild sites but at polluted industrial sites had not done so in six years. Aluminum alloys were more heavily attacked than high-purity aluminum, and a pure aluminum cladding gave considerable protection to an aluminum-copper-magnesium alloy.

"Atmospheric Corrosion of Carbon and Low Alloy Cast Steels
C. W. Briggs
ASTM STP 435, 271 (1968)

Nine carbon and low alloy cast steels cast in panel form, some machined and others unmachined, were exposed in marine and industrial atmospheres for periods of one-, three-, seven-, and 12-years and recorded as to weight loss information. The weight loss was converted to corrosion rate in terms of inches penetration per year (ipy) and milligrams lost per square decimeter per day (mdd). Comparisons were made and cast steels containing nickel, copper, or chromium as alloying elements have corrosion resistance superior to carbon cast steels or those containing manganese when exposed to atmospehric environments. Increasing the nickel and the copper contents of cast steel increases the corrosion resistance in all three atmospheric environments. Unmachined cast steel surfaces, with the casting "skin" intact, had no significant effect on the corrosion resistance of cast steels when compared to machined surfaces regardless of the atmospheric environment.

"Performance of Aluminum Alloys at Other Test Sites"
W. H. Ailor, Jr.
ASTM STP 435, 285 (1968)

The well documented pattern of corrosion behavior for aluminum alloys is confirmed for the seven-year exposures at Corpus Christi, Tex.; Richmond, Va.; McCook, Ill.; and the Kure Beach, N. C., 800-ft. site. A decrease in the corrosion rate, as determined by weight loss, was evident for all sheet alloys after about the second exposure year. Likewise, the depth of pitting decreased with time: very slight increases in depth were noted between the second and seventh years in most cases.

Results indicate that the McCook site is the most severe, with the Richmond location, the Corpus Christi exposure, and Kure Beach 800-ft site in order of decreasing severity.

The value of cladding basic alloys such as 3003 and 6061 was demonstrated again. The claddings effectively protected the core alloys from pitting and general corrosion and the clad alloys showed negligible changes in mechanical properties at all sites after seven years.

Other than the 2024 aluminum-copper alloy which showed intergranular corrosion for some hard tempers at the most severe sites, all alloys showed pitting corrosion to some extent. Maximum pit depths included 14.7 mils for the 2024-T36 alloy, 10.0 mils for the 5154-H34 aluminum-magnesium alloy, 5.2 mils for the aluminum-magnesium silicide alloy 6061-T6, and 6.3 mils for the high-purity aluminum sheet. With the exception of the 2024 metal, these deepest pits occurred at the McCook site. The deepest pit found on the Kure Beach 800-ft site panels measured 6.1 mils, and the deepest pit for most Corpus Christi panels was 5.4 mils (2024 alloy panels having some intergranular attack had measured pits as deep as 14.7 mils).

A corrosion rate of 0.175 milligrams per square decimeter per day (mdd) for 2024-T36 alloy at McCook was the highest found. If we exclude the 2024 alloys, no corrosion rate greater than the 6061-T6 rate of 0.125 mdd was found. High purity aluminum showed rates from a low of 0.004 mdd at Kure Beach to 0.004 mdd at McCook.

"Effect of One Per Cent Copper Addition on the Atmospheric Corrosion of Rolled Zinc"
S. R. Dunbar
ASTM STP 435, 308 (1968)

Atmospheric corrosion characteristics of a commercial rolled zinc alloy containing 1 per cent copper and one unalloyed grade were evaluated after two- and seven-year exposures under the Committee B-3 1957 test program on atmospheric corrosion of nonferrous metals. Comparisons were made with the behavior of three unalloyed grades included in a 20-year Committee B-3 program initiated in 1931. The usefulness of tension tests for determining corrosion rates was explored in both programs.

Weight loss determination appears to be the most reliable means of assessing corrosion rates for zinc. Good agreement among zinc corrosion rates in the two programs was obtained. Zinc composition was found not to significantly influence corrosion rates.

Pitting occurred in the copper bearing alloy most probably as a result of local galvanic action. The pit depth-total penetration ratio decreases as total penetration increases. Tensile properties of zinc were not significantly affected after seven-year exposure. Therefore, pitting is not believed to be of practical importance.

Tension tests are not useful for evaluating corrosion damage in zinc unless a means of compensating for aging effects can be found.

"Measurement of Atmospheric Factors Affecting the Corrosion of Metals"
Herbert Guttman and P. J. Sereda
ASTM STP 435, 326 (1968)

Atmospheric factors, namely, time of wetness of corroding metal panels, panel temperature, and atmospheric sulfur dioxide and atmospheric chloride content, were measured at four inland and three coastal North American test sites while corrosion data for steel, copper, and zinc were being developed. Corrosion losses experienced by panels of these metals which were exposed at different times of the year for similar periods of time showed considerable variation at all sites.

Statistical analyses show conclusively that the atmospheric factors measured completely control the rates of corrosion at all sites for at least the initial month. For longer periods of time control of the corrosion process remains with the atmospheric factors in some cases, and in others it is gradually transferred to factors related to the changing surface conditions resulting from accumulating of corrosion products and foreign agents.

At the sites where the atmospheric factors control corrosion, the emperical euqations developed enable one to predict the corrosion losses of steel, copper, and zinc from a knowledge of the atmospheric factors. They also now make it possible to account for variations in observed corrosion losses experienced by panels exposed at different times of the year.

"Corrosiveness of Various Atmospheric Test Sites as Measured by Specimens of Steel and Zinc"
ASTM STP 435, 360 (1968)

During the period 1948 to 1955, specimens of carbon steel and zinc were used to calibrate the corrosivity of the atmosphere of some 19 sites in the United States and Canada. In the period of 1960 to 1964 the study was expanded to include some 46 sites around the world.

As in the earlier study, the results at State College, Pa., were considered as unity, and the corrosivity of the other locations were ranked in terms of the corrosivity of the atmosphere at State College. Differences in corrosivity between the two exposure periods were noted in some instances, while in others the atmosphere appeared to remain constant in its action on the two test metals.

In a number of instances the corrosivity of the atmosphere toward steel was greater than its effect towards zinc. In other instances the reverse situation previaled. In a substantial number of locations the atmosphere was equally aggressive towards steel as it was towards zinc.

When the ratio of the two-year losses between steel and zinc were studied, it was evident that in characteristically industrial locations the ratio was 20 or less; whereas in a predominantly marine locations it exceeded 20 and ranged as high as 364.

In calibration test involving the corrosivity of a marine site at elevations of 60 ft, 30 ft, and ground level, there was little discrimination between elevations by the zinc specimens, but there was substantial discrimination by the steel specimens.

The current work clearly demonstrated, while corroborating the earlier work, that the corrosivity of an atmosphere varies with the metal in question, and that tests must be conducted with the metals of interest. Consecutive two-year exposure tests are more desirable than one-year tests.

1969

"Auswertung dreijahriger atmospharischer Korrosionsversuche mit Eisen, Kupfer und Zink auf tschechoslowakischen Prufstationen"
K. Barton und Z. Bartonova
Werkstoffe und Korrosion, 20, 87 (1969)

"Einfluss der chemischen Zusammensetzung auf die Kinetik der atmospharischen Korrosion von Stahlen"
P. Burda
Werkstoffe und Korrosion, 20,999 (1969)

"Mechanism of Rusting"
U. R. Evans
Corrosion Science, 9, 813 (1969)

"The Distribution of NaCl on Fe During Atmospheric Corrosion"
J. F. Henriksen
Corrosion Science, 9, 573 (1969)

The distribution of Na and Cl on iron plates during atmospheric corrosion has been determined by means of autoradiography, using the radioactive isotopes Na-24 and Cl-36. It is shown that Na and Cl are concentrated at the patches of corrosion products. Within the patches Na is located at the cathodic rim and Cl at the anodic centre.

"Uber den beschleunigenden Einfluss von Schwefeldioxid und Wasser auf die atmospharische Korrosion von verrosteten Eisen"
K. Barton and Z. Bartonova
Werkstoffe und Korrosion, 20, 216 (1969)

"Atmospheric Corrosion of Metals Part VI-Corrosion of Metals at Jodhpur"
M. L. Prajapat, G. K. Singhania and B. Sanyal
Labdev J. Sci. Tech., 7-A, 34 1969

Corrosion rates of mild steel and nonferrous metals have been determined at Jodhpur representing semi-arid or subtropical type of climate. It is observed that mild steel specimens exposed during non aggressive months show lower yearly corrosion rates than specimens exposed in more aggressive months. Statistical analysis shows that corrosion rate depends upon wind velocity and number of rainy days. The metals studied in the atmospheric conditions of Jodhpur could be arranged in the following order as regards their proneness to corrosion-mild steel > zinc > galvanized iron > copper > brass > aluminum.

1970

"The Kinetics of Corrosion of Iron and Zinc in a Moist Environment,"
A. M. Zinevich, E. I. Sergeeva, Yu. N. Mikhailovskii, and V. B. Serafimovich,
Protection of Metals, 6, 310 (1970)

"Electrochemical Kinetics of Zinc and Iron Self-Dissolution Under Thin Films of Electrolytes,"
Yu. P. Gladkikh, Yu. N. Mikhailovskii, L. A. Shuvakhina, and R. I. Nazarova,
Protection of Metals, 6, 1456 (1970)

> A study has been made of the corrosion kinetics of zinc and iron under thin films of electrolytes (30-500μm in thickness) containing various concentrations of chloride ions, and of the effect of a periodic moistening of the metal on its self-dissolution rate.

"Effects of Atmospheric Sulfur Dioxide on the Corrosion of Zinc,"
F. H. Haynie and J. B. Uphan,
Materials Protection, 9 (8),35 (1970)

> The amount of sulfur dioxide in the air is the major factor in determining the rate of corrosion of zinc. Because little, if any, zinc corrosion would occur in a nonmarine environment if SO_2 were not present, the reduced life of galvanized products can be directly attributed to air pollution.

"Der Begriff "kritische Feuchtigkeit" beim Atmospharischen Rosten von Stahl"
K. Barton and Z. Bartonova,
Werkstoffe and Korrosion, 21, 85 (1970)

"Penetration of Sulfur Dioxide into an Alkyd Paint Film,"
M. Svoboda, G. Klichova, and B. Knapek,
Protection of Metals, 6, 586 (1970)

> This article presents a survey of the annual accounts of the Institute of the SVUOM, published articles, and reports, supplemented by new refined data on the rate of penetration of sulfur dioxide into an alkyd paint film.

"Environmental Protection in the City of New York,"
M. Eisenbud,
Science, 170 (13), 706 (1970)

"Eigenschaften von Elektrolyt-Filmen bei der atomspharischen Korrosion,"
D. Knotkova-Cermakova und J. Vlckova,
Werkstoffe und Korrosion, 21, 16 (1970)

1970

"Une Méthode Électrochimique Rapide de Prédétermination de la Corrosion
Atmosphérique"
M. Pourbaix
Z. Phys. Chem. 244, (1970)

On décrit une méthode originale de prédétermination d comportement de métaux ou alliages à la corrosion atmosphérique, caractérisée par le fait que des échantillons de ces métaux ou alliages sont soumis à des actions alternées d'humidification et de sechage avec mesure de l'evolution de leur potentiel d'électrode lors des humidifications. Une patine parfaitement protectrice est obtenue lorsque le potentiel d'électrode s'est stabilisé a des valeurs élevées.

Cette méthode permet une étude scientifique rapide de l'influence de nombreux facteurs que interviennent en corrosion atmosphérique, ainse que dans d'autres cas de corrosion lors d'humidifications et séchages alternés. On mentionne quelques exemples d'application de cette méthode à des études relatives à des aciers patinables: discrimination entre aciers patinables et aciers non patinables; formation accélérée de patines protectrices, etc. ...

1971

"Effects of Atmospheric Pollutants on Corrosion Behavior of Steels"
F. H. Haynie and J. B. Upham
Materials Protection and Performance, 10 (11), 18 (1971)

The following discussion is a companion article to "Effects of Atmospheric Sulfur Dioxide on the Corrosion of Zinc" published in the August, 1970 issue of Materials Protection and Performance. The corrosion behavior of three types of steels exposed to air pollution at urban and rural sites was measured by weight loss and found to be nonlinear with time and a function of both sulfur dioxide and photochemical oxidant concentrations.

1971

"Method for Investigating the Effect of Climatic Parameters on the Rate of Atmospheric Corrosion of Metals,"
Yu. N. Mikhailovskii, L. A. Shuvalkhina, H. B. Klark, and V. V. Agafonov,
Protection of Metals, 7, 125 (1971)

The authors propose a method for the continuous recording of the rate of atmospheric corrosion of metals. It is based on the measurement of the electric resistance of a thin metal layer (a vacuum condensate or a thin foil) during the corrosion process.

"Calculation of the Atmospheric Corrosion Rate for Zinc and Cadmium in Various Climatic Regions,"
Yu. N. Mikhailovskii, G. B. Klark, L. A. Shuvakhina, A. P. San'ko,
Yu P. Gladkikh, and V. V. Agafonov,
Protection of Metals, 7, 466 (1971)

The authors developed a method for determining the atmospheric corrosion rate of metals from climatic data for various regions, taking into account the corrosion processes caused by the formation of adsorption and phase moisture films on metal surfaces.

"The Spreading of Sulphate Nests on Steel in Atmospheric Corrosion,"
K. Barton, D. Kuchynka, Z. Bartonova, and E. Beranek,
Corrosion Science, 11, 937 (1971)

Radiochemical and microscopial investigations of the behaviour of sulphate nests in the course of atmospheric corrosion as well as dissolution characteristics of sulphate from nests containing rusted steel lead to a description of the spreading of sulphate nests as a discontinuous process. Periodical cracking of a membrane surrounding the nest causes concentrated $FeSO_4$ solution or solid crystal to be expelled and results in the formation of new corrosion centres. The mechanism of this process is explained with the assumption of anion permeability of the membrane.

"Use of a Quartz Resonator to Study Atmospheric Corrosion Processes,"
P. V. Strekalov and Yu. N. Mikhailovskii,
Protection of Metals, 7, 120 (1971)

A unit has been developed for using a quartz resonator to study corrosion processes in metals beneath adsorbed films of electrolytes. A quartz resonator can be used to evaluate the thickness of adsorbed layers of moisture, arising on the surface of the metal being investigated. It has been established that the true surface of ground quartz, upon which there has been deposited a film of aluminum with a thickness on the order of tens of Angstrom units, is approximately 30 times greater than the visible geometric surface. In a pure moist atmosphere(93% relative humidity) the thickness of the oxide film formed on magnesium during the course of the first hour is about 5-7 A. From this point on, the growth of the thickness of the film is strongly inhibited.

"On the Protective Nature of Atmospheric Rust on Low-Alloy Steel"
I. Matsushima and T. Ueno
Corrosion Science, 11, 129 (1971)

The essential nature of protective rust films formed on low-alloy, weathering steels by atmospheric exposure has been clarified as to (1) the electrochemical behavior, (2) catalytic ability to form sulphate from SO_2 in the atmosphere, and (3) distribution of active corrosion sites on rusted steel surfaces. Autoradiographs show that active corrosion sites are less on a more corrosion resistant steel and decrease with exposure time. The more continuous nature of the rust coating on such a steel is also obvious from greater anodic polarization. Furthermore, a more resistant steel forms less suphate in polluted atomspheres due to the favourable nature of the rust.

"The Mechanism of Atmospheric Rusting and the Effect of Cu and P on the Rust Formation of Low Alloy Steels"
T. Misawa, T. Kyuno, W. Suetaka and S Shimodaira
Corrosion Science, 11, 35 (1971)

The oxidation processes of Fe(II) hydroxo-complexes to α, β, γ, and δ -FeOOH and Fe_3O_4, which are important atmospheric products of steels, and the effect of Cu^{2+}, PO_4^{3-} ion on the oxidation of the Fe(II) hydroxo-complexes in aqueous solutions have been investigated. The mechanism of atmospheric rusting deduced from the results obtained in the present investigation has been used to explain the difference in behaviour between ordinary mild steels and low alloy steels during atomospheric exposure. It is concluded that Fe(II) complexes are transformed to amorphous δ-FeOOH by the catalytic effect of Cu and P present in steels. The amorphous δ-FeOOH forms a compact rust layer that enhances corrosion resistance of the steel.

"The Nature of the Electrolytes on Surfaces in Atmospheric Corrosion"
D. Knotkova-Chermakova and Ya. Vlchkova
Protection of Metals 7, 323 (1971)

Results are given of a study of the composition of the electrolytes in the film of moisture formed on metal surfaces exposed under different atmospheric conditions.

"Use of Infrared Spectroscopy to Investigate the Corrosion Products of Copper"
I. A. Efimov, B. N. Rybakov, L. A. Knizhenko, G. V. Maslova, and
Yu. Ya Kharitonov
Protection of Metals, 7, 382 (1971)

1972

"Composition of the Atmospheric Corrosion Products of Aluminum"
I. A. Efimov, B. N. Rybakov, L. A. Knizhenko, G. V. Maslova, and
Yu. Ya. Kharitonov
Protection of Metals, 8, 524 (1972)

"A Microscopic Study of Steel Surfaces Exposed to a Humid SO_2-Containing Atmosphere"
B Heimler and N.-G. Vannerberg
Corrosion Science, 12, 579 (1972)

Electropolished and etched steel samples have been exposed to a humid, sulphur dioxide-containing atmosphere under controlled conditions. The surface structure of the samples and the distributionn of the points of attack after exposure have been studied with a scanning electron microscope.

"Mechanism of Atmospheric Rusting"
U. R. Evans and C. A. J. Taylor
Corrosion Science, 12, 227 (1972)

The present paper describes a research on Atmospheric Rusting, which has been in progress for 5 y in the Department of Metallurgy at Cambridge University. The discussion is designed to present the connection between the electrochemical mechanism of atmospheric corrosion with that of corrosion under immersed conditions.

"Mechanism of Rusting under Different Conditions
U. R. Evans
Brit. Corros. J., 7, 10 (1972)

"Beitrage zur Erforschung des Mechanismus' der atmospharischen Korrosion
A. Bukowiecki,
Oberflache-Surface, 13,219 (1972)

"The Influence of the Relative Humidity and Corrosion Products on the Adsorption of Sulfur Dioxide on Metal Surfaces"
T. Sydberger and N.-G. Vannerberg
Corrosion Science, 12, 775 (1972)

> The adsorption of sulfur dioxide on metal surfaces has been followed using an S-35 isotope. Experiments have been performed with $1.0 \cdot 10^{-5}$ per cent SO_2 (0.10 ppm) at r.h. between 50 and 98 per cent. The adsorption properties of polished iron, zinc, copper and aluminium samples have been compared with those of pre-exposed samples of these metals. Measurements have shown a pronounced dependence of the adsorption rate on the humidity. Almost quantitative adsorption of sulfur dioxide has been obtained on pre-exposed iron samples at r.h. $\geq$ 80 per cent. Remarkably low adsorption capacities at humidites $<$ 90 per cent have been found for the corrosion products of copper and aluminium. Changes in the adsorption rate with time have been used to study the corrosion initiation on polished iron surfaces.

"Effect of Weathering on the Electrochemical Behaviour of Steels"
R. Bruno, G. Agbio and G. Bombara
Brit. Corros. J., 7, 122 (1972)

> The potentiodynamic anodic behaviour of some low-alloy steels was investigated in 0.1 M Na_2SO_4 in relation to weathering. The set of materials tested included an ordinary carbon steel, a Cu-bearing steel, a Cu-P steel and a Corten-type steel. The weathering was affected by short-duration exposures either in an industrial atmosphere or in a sulphate spray, and also by anodic dissolution through repeated potential sweeps. In every case the potentiodynamic anodic behavior clearly differentiated the steels, giving satisfactory correlation with the type and content of alloying elements, and was consistent with the weight-loss behaviour in extended atmospheric tests.

"Les relations entre la pollution de l'environement et la corrosion du zinc et de l'acier galvanise"
N. Dreulle, P. Dreulle
Corrosion, Traitements,
Protection, Finition, 114 (1972).

"Chemical Attack and Economic Assessment of Air Pollutants on Exterior Paints"
J. W. Spence, F. H. Haynie
T. Paint Tech., 44, 70 (1972)

> This preliminary report investigates the deterioration of exterior paints by sulfur dioxide and particulate matter, and the associated potential economic loss to manufacturers and consumers. Crucial dose-response data are lacking in the published studies surveyed for these pollutants. The potential cost to the consumer due to pollutant attack of four classes of exterior paints is estimated at $700 million annually, and pollutant damage to household paints represents over 75% of that total. A new study involving field and laboratory exposures has been initiated to determine dose-response data from which the economic loss for certain paint classes may be better formulated.

"Phase Composition and Thermal Stability of Products from Atmospheric Corrosion of Lead"
I. A. Efimov, B. N. Rybakov, G. V. Maslova, and Yu. Ya. Kharitonov
Protection of Metals, 8, 644 (1972)

"Effect of Temperature on the Adsorption of Moisture and the Corrosion Rate of Zinc Under Atmospheric Conditions"
P. V. Strekalov, V. V. Agafonov, and Yu. N. Mikhailovskii
Protection of Metals, 8, 521 (1972)

"Prediction of the Severity of Atmospheric Corrosion by Discriminant Analysis of Local Meterological Factors"
R. K. Tripathi, U. S. Agnihotri and J. N. Nanda
Brit. Corros, J., 7, 212 (1972)

> Discriminant function analysis has been used to enable the corrosiveness of an environment to be classified into one of several broad categories, knowing the values of specified atmospheric factors. Of various combinations of meteorological factors that were tried, the following combination proved to be the most discriminating: average of daily maximum temperature in ^{0}C, average daily maximum relative humidity, number of rainy days in a month, total rainfall in mm in a month, and average pollution (SO_2 + NaCl in mg/cm^2 per day over a month). These

criteria were used to classify stations at Delhi, Bombay and Tezpur, giving results that agreed well with those obtained in exposure trials.

"Mechanism of Rusting under Different Conditions"
U. R. Evans
Brit. Corros. J., 7 , 10 (1972)

Rust formed from iron immersed in a salt solution is a secondary product precipated where the soluble anodic and cathodic products meet; being mainly produced at a distance from the metallic surface, it cannot protect, and the corrosion proceeds at a nearly uniform rate; only if either anodic or cathodic product is sparingly soluble will corrosion be slowed down-the two cases being known as anodic and cathodic inhyibition. The currents passing between anodic and cathodic areas have been measured and are found to correspond to the corrosion-rate in the sense of Faraday's law. During corrosion by drops of salt solution placed on a horizontal surface, the current passing between the central anode and the peripheral cathode has been shown up by a magnetic method due to Blaha. In these cases the electrochemical mechanism is not in doubt. Atmospheric corrosion set up by saline dust-particles can be explained by a mechanism like that of drop-corrosion. That set up by moist air containing sulphur dioxide is found to be connected with the formation of ferrous sulphate; when once this has been produced, the presence of sulphur dioxide in the gas phase is not needed for the continuation of rusting. Here again there is evidence of an electrochemical mechanism. The anodic reaction is $Fe = Fe^2 + 2e$, whilst the cathodic reaction is the reduction of FeOOH to Fe_3O_4, which is then oxidised by air to give a larger quantity of FeOOH than previously existed. Since the fresh rust is formed at a sensible distance from the site of anodic attach, the rust, although adherent, is not protective. This action will continue only if an electrochemical conducting limb ($FeSO_4$ solution) and an electronically conducting limb (Fe_3O_4) are provided. If the humidity is so low that the $FeSO_4$ solution dries up, rust-formation by this mechanism will cease-explaining the principle of critical humidity, as developed by Vernon and Buckowiecki. If the metal does not form an electronically conducting intermediate oxide, a mechanism providing rapid atmospheric attach will be impossible; this explains why zinc, which under immersed conditions is corroded more quickly than iron, suffers atmospheric attack more slowly; indeed a zinc coating is commonly used to protect iron under atmospheric conditions.

"Kinetic Study of the Uptake of Sulphur Dioxide by Aluminium"
D. J. Spedding
Brit. Corros. J., 7, 281 (1972)

The sorption by aluminium of sulphur dioxide at atmospheric concentrations has been envestigated using sulphur-35 sulphur dioxide. For the sulphur dioxide dosages used the uptake was always linear and strongly dependent on humidity. The humidity dependence was probably related to the equilibrium between gas-phase water and aluminium surface water. The fraction of sorbed sulphur dioxide desorbed when the partial pressure of sulphur dioxide was reduced was found to increase with decreasing humidity. The results are discussed in relation to a proposed mechanism for the corrosion of aluminium by sulphur dioxide.

1973

"Predicting the Atmospheric Corrosion Behavior of Steel in an Industrial Environment"
R. A. Legault, S. Mori and H. P. Leckie
Corrosion, 29, 169 (1973)

A rapid and reliable laboratory method of predicting the industrial atmospheric corrosion behavior of steel has long been sought. The determination of this behavior in an actual atmospheric exposure can require several years. A method has been devised which allows predictions of such behavior to be made from laboratory measurements which can be obtained in a few days.

"Accelerated Testing of Zinc and Cadmium for Atmospheric Corrosion in Climatic Chambers"
Yu. N. Mikhailovskii, L. A. Shuvakhina, and Chin T'chi Hong Wang
Protection of Metals, 9, 135 (1973)

This article describes a method of determining corrosion constants by testing the metals in artificial-climate chambers; results of a forecast of the corrosion of zinc and cadmium in various climatic regions are presented.

"The Effect of Relative Humidity on Adsorption of Sulphur Dioxide on to Metal Surfaces"
J. R. Duncan and D. J. Spedding
Corrosion Science, 13, 993 (1973)

Previous studies of the influence of relative humidity on $^{35}SO_2$adsorption on to iron and zinc surfaces are supplemented by using a continuous flow exposure method. This gives results which agree closely with those from the previously reported interrupted-flow method for most areas studies. It is found that sample preparation before exposure has a considerable effect on the results achieved. A desorption process from the zinc-zinc oxide-SO_2 surface system has been found, with a pseudo-first order half-life of the reaction of approx 7.2 ks. Desorption from some iron samples was also observed, but could not be quantified.

"Calculation of Atmospheric Corrosion Rate of Aluminum and its Alloys in Various Climatic Zones According to Meteorological Parameters"
Yu. N. Mikhailovskii, G. B. Klark, L. A. Shuvakhina, V. V. Agafonov, and N. I Zhuravleva
Protection of Metals, 9, 240 (1973)

The purpose of the work was to investigate the effect of meteorological factors (humidity and air temperature, wetting time of metal surface by phase layers of moisture, chemical composition of atmosphere) on the corrosion rate of aluminum and its alloys under natural conditions and to develop engineering methods for calculating the corrosion effects expected on these materials in any climatic zone.

"Behaviour of Rust and Rusted Steel Surfaces"
G. K. Singhania and B. Sanyal
Brit. Corros. J., 8, 224 (1973)

The effect of the presence of rust on steel on its further corrosion during outdoor and laboratory exposure to SO_2 has been examined. More aggressive initial conditions favour the formation of non-protective, loose rust which flakes off from the metal surface and increases the subsequent yearly corrosion values. The initial rust present increases the rate of attack during the first 2-3 months, but there is then a general falling off of the corrosion rate with time. SO_2-contaminated rust is able to promote corrosion on clean (rust-free) steel, but the amount of corrosion is not dependent on the amount of SO_2 adsorbed by the rust. The order of severity of attack on steel by different electrolytes differs from that caused by rust produced by the same electrolytes. Rust contaminated with $FeSO_4$ or $Fe\ Cl_3$ enhances the rusting of steel, whereas rust converters (such as phosphates) have beneficial effects. In the further rusting in SO_2 of pre-rusted steel specimens it was found that the duration of the pre-rusting period determines the subsequent rate of rusting, but the 'age' of the rust, rather than its thickness, determines its protective effect. In interrupted SO_2 exposure, in which the pre-rusted specimens were first exposed to SO_2 and then to humid SO_2-free air, it was found that a temperature (18°C) and humidity (50% R.H.) which are too low to initiate the formation of incipient reaction product ($FeSO_4 \cdot 4H_2O$) on clean metal, allow sufficient formation of these products on rusted specimens to enable rusting to continue in moist SO_2-free air. Increase in the duration of outdoor exposure of steel produces a more positive final potential and increased anodic polarisation, corresponding to the improvement in the protective property of the rust during exposure.

"Untersuchungen zur Ausbildung von Deckschichten auf niedriglegierten Stahlen und Baustahl mit einem Wechseltauchverfahren"
W. Forker, G. Reinhard and E. Dix
Neue Hutte, 18, 235 (1973)

"Macroscopic Structure of the Rust Layer formed in the Atmospheric Corrosion of Steel"
J. Honzak
Brit. Corros, J., 8, 162 (1973)

> The paper deals with the structure of the rust layer formed on steel under various conditions of atmospheric corrosion. The various stages of the corrosion process proceed at different rates depending on the total effect of a variety of climatic factors. These factors also affect the nature of the corrosion products in the various layers. At certain subcritical rates of corrosion the amount of rust in the layer next to and bonded to the metal remains approximately constant. But if this critical velocity is exceeded a cylical disturbance with restructuring of the layer will take place. The final structure of the rust layer depends on the strength of the mechanical bonds between the various layers, these bonds differing according to the conditions under which the rust layers are formed.

"Investigations of the Atmospheric Corrosion of Plain Carbon and Low-Alloy Steels in Industry, Country, and See Air"
K. Bohnenkamp, G. Burgmann and W. Schwenk
Stahl und Eisen, 93,1054 (1973)

> Investigations of natural corrosion of three steels with 0.10, 0.18 and 0.27%Cu in industry air, of a high-strength and a weather-resistant steel and various unalloyed and low-alloy steels in sea air, country air, and industry air on the test stands of the Verein Deutscher Eisenhuttenleute. Mathematical evaluation of the results by means of regression analysis. Discussion of the influences of the investigational procedure and the corrosion processes.

"Apparatus for Studying Atmospheric Degradation of Materials"
K. E. Johnson and A. F. Bromley
Anti-Corrosion, 17,(1973)

> A simple, flexible test facility has been devised which is suitable for examining the effects of trace gases on the degradation of materials under conditions approximating to those of free atmospheric exposure.

"Initial Reactions of SO_2 After Adsorption on to Metals"

J. R. Duncan and D. J. Spedding
Corrosion Science, 13, 881 (1973)

> An electrophoretic method for separation of labelled corrosion products from metals exposed to atmospheres containing natural concentrations of $^{35}SO_2$ has been developed. Using this method, it was found that on iron and zinc such products are exclusively sulphur (IV) species and sulphate. The conversion of S(IV)→S(VI) on both iron and zinc was found to have a half-life of approx. 24 h. The implications of these results are discussed with respect to a different chemistry of surface electrolyte layers from that of bulk solutions.

"Die Beziehung zwischen Umweltverschmutzung und Korrosion von Zink und feuerverzinktem Stahl"
N. Dreulle und P. Dreulle
Metall, 27,626 (1973)

"The influence of carbon particles on the corrosion of iron in a humid, sulphur dioxide-containing atmosphere"
R. Ericsson, B. Heimler and N.-G. Vannerberg
Werkst. und Korrosion, 24, 207 (1973)

> Iron samples covered with a thin layer of activated carbon have been exposed to humid atmospheres containing sulphur dioxide under controlled conditions. The increase in weight has been determined as a function of the time of exposure. An increased rate of corrosion of samples covered with a thin layer of activated carbon has been observed compared with samples without carbon, at low relative humidities only.

"Kristalline und amorphe Primarbildungen beim Rosten von metallischem Eisen in SO_2-haltiger Atmosphare bei verschiedenen Feuchtigkeitsgraden"
E. D. Franz
Werkstoffe und Korrosion, 24, 598 (1973)

"Aspects scientifiques des relations entre la pollution et la corrosion metallique"
Jean Talbot
Corrosion, Traitements, Protection, 21, 97 (1973)

1974

"Corrosion Aggressivity of Model Regions of Czechoslovakia"

D. Knotkova-Cermakova, B. Bosek, and J. Vlckova
ASTM STP 558, 52 (1974)

A comprehensive research program was started in Czechoslovakia five years ago for a systematic investigation of the corrosion aggressivity of selected industrial regions. The corrosion tests were performed on 19 corrosion stations in the North-Bohemian model region. Principal technical metals were tested. The characteristics of climate and air pollution and also the combined index of the corrosion aggressivity were suggested and numerically expressed. The hyperbolic function has most closely approximated the law of the time-dependent course of the corrosion process of metals. The regression analysis was performed with the use of various forms of the climate characteristics, and the most favorable function was expressed. The cybernetic model of the atmospheric corrosion process was suggested.

"Electrochemical Technique for Determination of the Instantaneous Rate of Atmospheric Corrosion"
V. Kucera and E. Mattsson
ASTM STP 558, 239 (1974)

The aim of this investigation was to develop a technique and equipment for the measurement of the instantaneous rate of atmospheric corrosion of metals. An electrochemical method was chosen for this purpose and a technique was developed for continuous measurement and recording of the currents generated in models of the electrochemical corrosion cells which occur on the metal surface when exposed to the atmosphere. Two types of cells were used, galvanic cells consisting of steel and copper electrodes and electrolytic cells consisting of only one type of electrode, namely, steel, zinc or copper. In the latter type of cell an external emf was applied. The cell current was found to vary between 10^{-10} and 10^{-3}A in accordance with changes in climatic conditions the changes being at least in qualitative agreement with changes in the rate of atmospheric corrosion as earlier reported in the literature. An inexpensive electronic integrator was developed for estimation of the accumulated quantity of cell current over a certain period of time. This device integrates separately on two counters the amount of current during periods with low current and during periods with high current. A time counter also records the exposure time during which the current exceedfs a chosen value. This time counter can be used to measure the time of surface wetness, that is, that part of the period of exposure when the corrosion current is of practical importance. Efforts are now being made to find the quantitative relation between the cell current and the atmospheric corrosion rate. It is believed that the technique will prove to be a useful tool for the investigation of atmospheric corrosion in the laboratory as well as on test sites out of doors and in industrial applications.

"Weathering resistance of iron and steels"
J. A. Vaccari
Materials Engineering 4, 60 (1974)

"Korrosion durch die Atmosphare"
H. Laub
Galvanotechnik, 65, 209 (1974)

"The Corrosivity of the Atmosphere
J. B. Mohler
Plating, 61,62 (1974)

"The Economics of Clean Air in Perspective"
F. H. Haynie
Materials Protection, 13 (4),33 (1974)

This paper places the economics of providing cleaner air in perspective by emphasizing some of the tangible benefits to be received. The Materials Branch, National Environmental Research Center, Research Triangle Park, N.C., has determined damage functions for air pollution effects on materials and estimated the resulting economic loss to the nation.

"Bimetallic Corrosion Effects on Mild Steel in Natural Environments"
K. E. Johnson and J. S. Abbott
Brit. Corros. J. 9, 171 (1974)

"The Rust Preventing Mechanism of Zinc Dust Paints"
F. Theiler
Corrosion Science, 14, 405 (1974)

In atmospheric weathering the rust preventing mechanism of zinc dust paints is dominated by the sealing action of the zinc corrosion products on the paint surface. Under immersed conditions the time of cathodic protection of bare steel is dependent on the zinc content of the paints. An optimum zinc content has been found for all of the tested binders: polystyrene, vinyl copolymer and chlorinated rubber. Differences in the optimum zinc content arise mainly due to the different wetting of the pigment by the binders.

"Corrosion atmospherique de l'acier doux. Exposition de [illegible]ier aux intemperies"
K. Bohnenkamp, G. Burgmann and W. Schwenk
Corrosion-Anticorrosion, 43, 587 (1974)

"Procede electrochimique rapide pour la mesure de la resistance contre la corrosion atmospherique des metaux"
E. Erdos
Galvano-Organo, 43, 382 (1974)

"Analyses of Some Suggested Mechanisms for Atmospheric Corrosion of Iron in Presence of SO_2"
J. R. Duncan
Werkstoffe und Korrosion 25, 420 (1974)

"Die Kinetik des Rostens von Eisen in der Atmosphare"
K. Barton, S. Bartonova und E. Beranek
Werkstoffe und Korrosion 25, 659 (1974)

"Effect of Sodium Chloride on the Adsorption of Waver Vapor and the Kinetics of the Atmospheric Corrosion of Zinc"
P. V. Strekalov, Yu. N. Mikhailovskii, and T. S. Balandina
Protection of Metals, 10, 264 (1974)

1975

"Die Korrosionsbestandigkeit der nichtrostenden Stahle an der Atmosphare - Auswertung von Versuchen bis zu 10jahriger Auslagerung-"
R. Ergang und M. B. Rockel
Werkstoffe und Korrosion 26, 36 (1975)

"Neues Modell zum Mechanismus der Oxydation des Eisens
C. G. Nestler
Technik, 30, 456 (1975)

"Red de estaciones de ensayos de corrosion atmosferica del CENIM en Espana"
M. Morcillo
Rev. Metal. CENIM, 11, 82 (1975)

"Summator of the Action of the Temperature-Moisture Complex on Metals with Tests Under ATM Atmospheric Conditions"
Yu. N. Mikhailovskii and V. A. San'ko
Zashchita Metallov, 11 (5), 644 (1975)

"A Study Concerning the Properties of Rust on Weatherproof Steel After Life Tests and Accelerated Tests"
A. M. Shlyafirner, G. P. Yakubova, A. I. Golubev, and N. I. Sotskov
Protection of Metals, 11 (2) 200 (1975)

"Corrosion of Coated Metals"
J. B. Mohler
Metal Finishing, 33 (1975)

"Eine universelle Einrichtung fur die Prufung der atmospharischen Korrosion von Metallen und Schutzuberzugen"
D. Knotkova-Cermakova, J. Kosobud, J. Vlckova and J. Honzak
Werkstoffe und Korrosion 26, 118 (1975)

1976

"Electrochemical Monitoring of Atmospheric Corrosion Phenomena"
F. Mansfeld and J. V. Kenkel
Corrosion Science, 16, 111 (1976)

> An atmospheric corrosion monitor (ACM) which consists of Cu/Zn or Cu/steel couples, has been used to study various aspects of atmospheric corrosion. Calibration of ACM's is carried out under 1 ml of distilled water. Measurements under 10^{-5}-10^{-1} N KCl show that the conductivity of the electrolyte is not an important parameter in determining the amount of current flow. A detailed study was related to the effect of salt particles on atmospheric corrosion. While no current flow and no corrosion occurred on clean surfaces up to r.h.≈95%, large increases of galvanic current were observed when salt particles were placed on the ACM surface provided that the relative humidity in the test cell was higher than the r. h. value of a saturated solution of the salt particle applied. The ACM has also been used to monitor changes in the composition of gaseous atmospheres (air, N_2, N_2 plus SO_2). Outdoor exposure of the Cu/Zn and Cu/steel ACM suggests that this instrument can be used not only to monitor time-of-wetness, but also the corrosivity of a test environment.

"Automated Apparatus for Investigating the Corrosion Effects and the Adsorption of Moisture During Atmospheric Corrosion of Metals"
P. V. Strekalov, M. V. Danilova, and Yu. N. Mikhailovskii
Protection of Metals, 12, 226 (1976)

"Beitrag zur quantitativen Rontgenphasenanalyse an Rosten"
H. Baum
Neue Hutte 21, 568 (1976)

"Möglichkeiten der Bestimmung des Zustandes der Betauung und Befeuchtung der Oberflache"
I. Jirovsky, I. Kokoska und J. Prusek
Werkstoffe und Korrosion 27, 16 (1976)

"Corrosion of Carbon Steel Through a Thin Film of Solution"
Z. Takehara, A. Saito and S. Yoshizawa
Corrosion Science, 16, 91 (1976)

> The corrosion phenomena of carbon steel covered with a thin film of solution were examined by using a vertical rotating disk electrode dipped partially in the corroding solution. The diffusion rate of oxygen through the thin film of solution, obtained from the cathodic polarization curve, was the rate-determining step of the corrosion process. This rate was much larger than that through the bulk solution. The effect of carbon content in the steel on the corrosion is discussed and the corrosion of the steel containing copper is also discussed.

"Studying the Atmospheric Corrosion of Metals by the Polarization-Resistance Method"
V. A. Kuznetsov, S. G. Polyakov, Yu. S. Gerasimenko, and Yu. G. Kotlov
Protection of Metals, 12, 109 (1976)

"Electrochemical Method for Investigation of Protective Properties of Operational/Preservative Oils and Greases Under Conditions of Cyclic Dew Formation"
L. N. Shelchkova, S. S. Savel'ev, A. G. Mokhov, V. S. Luneva, and M. R. Gileva
Protection of Metals, 12, 109 (1976)

"Behavior of Metallic and Oxide Coatings During Development of Microbiological Corrosion in the Atmosphere"
A. A. Gerasimenko
Protection of Metals, 12, 96 (1976)

"Electrolytes for Studying Electrode Processes in Thin Films with Atmospheric Corrosion Tests"
G. Kh. Dzhincharadze, V. S. Kemkhadze, S. N. Mandzhgaladze, and E. V. Glonti
Protection of Metals, 12, 112 (1976)

"Screening Properties of Packaging in Protecting Metal Articles From Atmospheric Corrosion"
B. G. Balashov and E. I. Kozlova
Protection of Metals, 12, 114 (1976)

"Acid Precipitation"
G. E. Likens
Chem. Eng. News, 54, 29 (1976)

"Corrosion Resistance of Aluminum Alloys in the Atmosphere of Industrial Plants"
T. G. Kravchenko and I. A. Efimov
Protection of Metals, 12, 373 (1976)

"Corrosion of High-Alloy Aluminum Grades Under Atmospheric Conditions"
V. D. Kalinin, G. M. Budov, and V. S. Sinyavskii
Protection of Metals, 12, 501 (1976)

"Initial Stages During Atmospheric Corrosion of Metals at Below-Zero and Above-Zero Temperatures in Humid Air"
Yu. N. Mikhailovskii, P. V. Strekalov, and T. S. Balandina
Protection of Metals, 12, 451 (1976)

"Effects of Sulfur Dioxide and Acid Precipitation on Metals and Anti-Rust Painted Steel"
V. Kucera
Ambio, 5, 243 (1976)

> The corrosion rate of several metals and of painted surfaces is significantly higher in polluted urban atmospheres than in rural atmospheres. This is ascribed chiefly to the high concentrations of airborne sulfur pollutants in urbanized areas. The increased corrosion rate causes substantial economic losses.

"Kennwerte zur Klassifizierung der Aggressivität der Atmosphäre
Von Wolfgang Köhler and Wilfried Heider
Korrosion, 7 (4), 3 (1976)

1977

"Electrochemical Measurements of Time-of-Wetness and Atmospheric Corrosion Rates"
F. Mansfeld and J. V. Kenkel
Corrosion, 33, 13 (1977)

An atmospheric corrosion monitor has been developed which allows monitoring of time-of-wetness and corrosion behavior in outdoor exposure. This device is being used in exposure studies in Southern California and has also been applied to laboratory studies of atmospheric corrosion, in which the effects of salt particles, gaseous pollutants, impurities in rust, temperature, and relative humidity are evaluated.

"Saturated Vapor Pressures of Volatile Corrosion Inhibitors"
O. I. Golyanitskii
Protection of Metals 13, 451 (1977)

"Behaviour of a Galvanic Cell Simulating the Atmospheric Corrosion Conditions of Gold Plated Bronzes"
B. Mazza, P. Pedeferri, G. Re and D. Sinigaglia
Corrosion Science, 17, 535 (1977)

"Short-Term Atmospheric Corrosion of Mild Steel at Two Weather and Pollution Monitored Sites"
J. B. Johnson, P. Elliott, M. A. Winterbottom and G. C. Wood
Corrosion Science, 17, 691 (1977)

Results are recorded of topographical details, weight loss and corrosion product analysis for short-term atmospheric exposure of mild steel, in relation to weather and pollutant factors. Various structured corrosion features, e.g. doughnut-like, were noted. The major corrosion product found was γ-$Fe_2O \cdot 3H_2O$, with some α-$Fe_2O \cdot 3H_2O$ and α-FeOOH. Wet initial conditions of exposure and subsequent high levels of humidity were found to have the dominant overriding effect in promoting corrosion losses. Smoke was shown to be capable of exerting a very strong influence upon the effective corrosivity of atmospheric sulphur dioxide.

"Air Quality Reference Data for Corrosion Assessment"
T. E. Graedel and N. Schwartz
Materials Protection, 16 (8), 17 (1977)

Graphical summaries of the concentrations of atmospheric contaminants are presented for over 3700 sites at which one or more of the contaminants are monitored. Also included are data on ambient humidities and temperatures. The data provide a comparison base for design and test results calibration. Atmospheric upper limit values (the maximum average values sustained over field exposures of 10 to 30 years) are defined for the following: temperature, humidity, aldehydes, ammonia, ammonium ion, benzene-soluble organics, chloride ion, gaseous chlorine, fluoride ion, hydrogen sulfide, nitrate ion, nitric oxide, nitrogen dioxide, nonmethane hydrocarbons, ozone, sulfate ion, sulfur dioxide, and total particulate matter. Indoor and outdoor concentrations as a function of time and site are also discussed.

"Simulating Metal Atmospheric Corrosion in Artificial Climate Chambers and Accelerating it by Raising the Temperature"
L. A. Shuvakhina, Yu. N. Mikhailovskii, N. F. Sharonova, and V. S. Sedova
Protection of Metals, 13, 130 (1977)

This paper gives the results of studying the effect of temperature upon corrosion speed in iron, zinc, cadmium, and copper in a pure moist atmosphere and in the presence of thin phase layer of water on the metal. The coefficients of corrosion acceleration with increased temperature were defined. The extent to which the corrosion process in the metals studied can be accelerated relative to actual conditions by conducting the tests in artificial climate chambers at 40-60^{0} was shown.

"The Application of Potentiostatic Polarization Techniques to Corrosion Under Thin Condensed Moisture Layers"
S. G. Fishman and C. R. Crowe
Corrosion Science, 17, 27 (1977)

An electrochemical cell was constructed with which potentiostatic corrosion techniques were applied to the thin film of electrolyte. The resultant corrosion rates are consistent with those reported from long time weight loss measurements.

"X-Ray-Electronic Investigation of Inhibitors of Atmospheric Corrosion at Metallic Surfaces"
A. N. Novitskii, Ya. V. Salyn', and V. I. Nefedov
Protection of Metals, 13, 174 (1977)

"Untersuchungen zur atmospharischen Korrosion mit einer elektrochemischen zelle"
W. Friehe and W. Schwenk
Stahl und Eisen, 97, 685 (1977)

"A Comparison of the Mass and Resistance Change Techniques for Investigating Thin Film Corrosion Kinetics"
Wen-Yaung Lee, H. C. Siegmann, and J. M. Eldridge
J. Electrochem. Soc. **124**, 1744 (1977)

In situ quartz oscillator microbalance (QCM) and electrical resistance change (RC) measurements were carried out simultaneously on identically prepared Permalloy films in order to establish the sensitivity and reproducibility of each technique for investigating atmospheric corrosion. Both techniques were found to be highly sensitive to thickness changes (better than 1A) resulting from corrosion in a high humidity atmosphere containing trace quantities of acid-forming, gaseous pollutants. However, the QCM results were found to be an order of magnitude more reproducible than the RC data. Moreover, it was established from the QCM findings that the average mass increase due to corrosion was quite closely proportional to the square root of exposure time in the test chamber. Thus complex thin film corrosion kinetics can be determined with considerable accuracy provided reasonable experimental procedures are employed. The results of both measurements were compared also in an isochronal plot where it was found that the resistance change was proportional to the ssquare of the mass increase arising from the formation of corrosion products. The origin of this relationship was investigated by carrying out simulated corrosion studies involving punching out holes in an aluminized Mylar structure while determining the effects of material loss on electrical resistance.

"Application de L'électrochimie en Couche Mince à L'étude de la Corrosion Atmosphérique"
C. Fiaud and F. Tirbonod
Metaux-Corrosion-Industrie **51**, 388 (1977)

"Physicomathematical Simulation of Steel Corrosion Under Atmospheric Conditions"
Yu. N. Mikhailovskii, V. V. Agafonov and V. A. San'ko
Prot. Metals **13** (5) 429 (1977)

1978

"Corrosion of Decorative Plating Systems in Various Localities in the USA"
R. L. Saur
Plating and Surface Finishing, 65, 48 (1978)

Decoratively plated specimens were exposed in several widely separated localities in the U.S.A. to obtain data on the variation in effect of geographic, environmental and climatic influences on corrosion. Of all these influences, exposure to sunlight appeared to be most effective and tended to reduce the amount of corrosion.

"An Instrumental Gravimetric Method for Indexing Materials, Contaminants, and Corrosion Products According to Their Hygroscopicity"
J. D. Sinclair
J. Electrochem. Soc., 125, 734 (1978)

The moisture pickup characteristics of selected dusts, contaminants, corrosion products, and aged insulation and substrate materials have beenn determined in a dynamic humid environment by instrumental gravimetric analysis. These are compared with pure salts and other standard materials to categorize their relative hygroscopicities during the initial adsorption stage and subsequent stages of moisture pickup. In addition, the minimum relative humidities at which some pure salts and a variety of other substances will pick up moisture are reported.

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"Determination of the Instantaneous Rate of Atmospheric Corrosion"
J. A. Gonzalez
Werkstoffe and Korrosion, 29, 456 (1978)

An attempt has been made to determine the applicability of Stern's (or polarisation resistance) method for obtaining a reliable evaluation of the instantaneous rate of atmospheric corrosion.

The tests carried out so far have revealed a good agreement between electrochemically obtained information on the influence of various corrosion factors and their real effect on the attack of metals when exposed to the atmosphere.

"Investigation of Atmospheric Exposure Factors that Determine Time-of-Wetness of Outdoor Structures"
P. R. Grossman
ASTM STP 646, 5 (1978)

Wetness of outdoor structures is caused partly by condensation of water form 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.

"Final Report on the ASTM Study: Atmospheric Galvanic Corrosion of Magnesium Coupled to Other Metals"
Robert Baboian
ASTM STP 646, 17 (1978)

In 1949 a study was initiated by H. O. Teeple sponsored by Subcommittee VIII on Galvanic and Electrolytic Corrosion of the American Society for Testing and Materials (ASTM) Committee B-3 on Corrosion of Nonferrous Metals and Alloys. This study covered the atmospheric galvanic corrosion of magnesium coupled to a number of dissimilar metals and alloys. Previously, results were reported for two and one half years exposure at State College and Kure Beach. This report, sponsored by Subcommitee VII on Galvanic Corrosion of ASTM Committee G-1 on Corrosion of Metals, presents the final data from this study after an approximate 22-year exposure at these test sites.

"Effects of Air Pollutants on Weathering Steel and Galvanized Steel: A Chamber Study"
F. H. Haynie, J. W. Spence and J. B. Upham
ASTM STP 646, 30 (1978)

A statistically designed laboratory study of the effects of gaseous air pollutants on materials was completed. Weathering steel and galvanized steel were among materials exposed in controlled environment chambers. The direct and synergistic effects of relative humidity, sulfur dioxide, nitrogen dioxide, and ozone in a programmed dew/light cycle were studied. For weathering steel, sulfur dioxide, relative humidity, and interaction between the two were the important corrosion rate factors. For galvanized steel, only the direct effects of sulfur dioxide and relative humidity were important. The remainder of the fifteen possible direct and synergistic effects were statistically insignificant.

"Metallic Barriers for Protection of Contacts in Electronic Circuits from Atmospheric Corrosion"
D. R. Marx, W. R. Bitler and H. W. Pickering
ASTM STP 646, 48 (1978)

The effectiveness of a variety of 1 to 2-μm-thick barriers in preventing the interdiffusion of copper substrates with gold overplates was investigated. These studies were carried out at both elevated (400 and 500°C) and low temperatures (100 and 175°C). In the high temperature range, of the materials studied, only the cobalt and cobalt-5 weight percent phosphorous were found to be effective barriers. Their effectiveness was comparable to that of the nickel-8 weight percent phosphorous barrier reported by Turn.

The low temperature results were anomalous in that the specimens annealed at 100°C show greater penetration than those annealed at 175°C. It is proposed that this temperature effect is related to the concurrent recrystallization of the gold overplate taking place to a larger degree during the higher temperature diffusion anneal. Thus, at the lower temperature the high density of grain boundaries characteristic of as-plated structures is better preserved and leads to a larger overall (grain-boundary) diffusive flux.

"Corrosion Investigations at Panama Canal Zone"
M. A. Pelensky, J. J. Jaworski and A. Gallaccio
ASTM STP 646, 58 (1978)

This paper reports on the progress of investigations being conducted at Panama Canal Zone, relative to corrosion of dissimilar metal couples exposed in the atmosphere, in the soil, and in seawater. Machined specimens of aluminum, brass, magnesium, Monel, steel, stainless steel, and titanium alloys are included in this study.

Exposure of dissimilar and similar (control) metal couples was initiated over 2 years ago for a planned maximum 5-year exposure. Couple replicates (four of each metal) are removed from exposure periodically and returned to the laboratory for visual examination and weight loss determinations to evaluate the corrosion effects of each of the environments on the various couples. A total of seven removals from each environmental exposure is planned during the course of the corrosion investigations. To date, five removals of atmospheric specimens, five removals of seawater immersion specimens, and four removals of soil burial specimens, have been completed over a 2-year period and evaluated by this laboratory. Results of findings to date are presented in this paper.

"Behavior of Zinc-Coated Steel in Highway Environments"
G. German
ASTM STP 646, 74 (1978)

Results of 3 to 7-year exposure periods of galvanized steel specimens in Ontario and Quebec highway environments are reported. Continuous hot-dip, batch hot-dip, and electrogalvanized materials were used. Results indicated that a coating life of five years per mil of coating can be expected in urban environments, and 10 to 20 percent longer protection in rural environments. The method of zinc application appeared to have no significant influence.

"Kinetics of the Atmospheric Corrosion of Galvanized Steel"
R. A. Legault and V. P. Pearson
ASTM STP 646, 83 (1978)

Atmospheric corrosion behavior was evaluated separately on skyward and groundward surfaces of galvanized steel test panels exposed in both industrial and marine environments. The behavior in every case can be accurately described by the same general kinetic relationship, $\Delta W = kt^N$, where the empirically determined coefficients, K and N, can be used to separate the tendency for a corrosion product to form from the effect of that corrosion product on the subsequent reaction. The specific kinetic equations which apply in each case can be used to reliably predict long-term atmospheric corrosion behavior.

"Corrosion Prevention with Termal-Sprayed Zinc and Aluminum Coatings"
F. N. Longo and G. J. Durmann
ASTM STP 646, 97 (1978)

This paper presents the results of 19 years' testing, undertaken by the American Welding Society, to evaluate the flame-sprayed zinc and aluminum coatings, sealed and unsealed, applied to low-carbon steel.

Panels were exposed to seawater at mean tide and below low tide levels at two different locations. Panels were also exposed to atmospheric conditions at six different locations including rural, industrial, salt air, and salt spray environments.

The results indicate that low-carbon steel can be protected from the corrosive effects of these environments for 19 years or more by the application of flame-sprayed zinc or aluminum coatings.

"Atmospheric Corrosion of Electroplated Zinc Alloy Die Castings"
J. H. Payer and W. H. Safranek
ASTM STP 646, 115 (1978)

The effect of electroplating variables on atmospheric corrosion of copper, nickel, and chromium electroplates on zinc alloy die castings was investigated at mobile and stationary test sites. Most than 3000 electroplated die castings were exposed on Detriot, Michigan, trucks; Youngstown, Ohio, trucks; New York City tugboats; Detriot, Michigan, roof tops; and Kure Beach, North Caroline, 245-m (800-ft) lot, for periods of up to 10 years. Exposure to mobile test sites provided a valuable supplement to the more conventional stationary test site. The application of microdiscontinuous chromium proved to be the most influential factor for improved corrosion resistance.

"ASTM Atmospheric Corrosion Testing: 1906 to 1976"
W. H. Ailor
ASTM STP 646, 129 (1978)

In the early fall of 1976 ASTM Committee G-1 on Corrosion Metals exposed more than 40 ferrous and nonferrous sheet materials at five test locations. These exposures are a part of the third 20-year atmospheric test program generated by ASTM corrosion groups since 1932. Metals include new alloys, tempers, and coatings developed since the initiation of the last program.

Exposures have triplicate exposed panels for removal periods of 2, 5, 10, and 20 years at test sites at Kure Beach, North Carolina, 24-m(80-ft) lot; Newark-Kearny, New Jersey; Point Reyes, California; State College, Pennsylvania; and Panama Canal Zone.

Ten metal suppliers are participating in this new long-term test program. Among the metals exposed are aluminum, copper, lead, magnesium, nickel, stainless steel, titanium, and zinc alloys. Aluminized and galvanized coated steels are also being tested.

Evaluation of these materials includes weight loss (corrosion rates), pitting depth, and changes in mechanical properties.

One task group is monitoring weather conditions at the sites and another group is calibrating the site corrosivities through periodical short-term (1 and 2 year) exposures of steel and zinc panels during the course of the 20-year tests.

"Protection of Copper Metals from Atmospheric Corrosion"
L. D. Fitzgerald
ASTM STP 646, 152 (1978)

The development of a synthetic patina process for copper metals is described. The chemistry of the process essentially parallels the natural atmospheric corrosion of copper. Various stages of the patination system are illustrated via scanning electron microscopy (SEM) photographs.

The development of organix resin-based coating systems are described, including passivation systems, solvent selection and resin screening techniques. An accelerated weathering test program for evaluation of clear coatings is detailed. Field evaluation at various test sites are correlated with coating properties. The illustrate the effect of atmospheric contaminants, sea spray contamination, and high ultraviolet intensity exposure effects as they pertain to coating life.

Field tests of the inorganic patina and of both an organic lacquer and a shop-applied film coating system are described indicating the potential durability of the system.

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"An Accelerated Atmospheric Corrosion Test (AACT)"
R. D. Smith
ASTM STP <u>646</u>, 160 (1978)

A laboratory test method for accelerated atmospheric corrosion testing has been developed. Copper alloys were the main subject of testing, and the principal atmospheric simulation was urban-industrial. The test method has been very useful in ranking experimental copper alloys relative to commercial alloys and is believed to be adaptable to other alloy systems and environments. Representative reproducible oxide films can be generated for film study work and kinetics of film formation can be followed easily.

"Atmospheric Corrosion Behavior of Aluminum-Zinc Alloy Coated Steel"
J. C. Zoccola, H. E. Townsend, A. R. Borzillo, and J. B. Horton
ASTM STP <u>646</u>, 165 (1978)

The influence of the aluminum content of hot-dip aluminum zinc alloy coatings on their corrosion behavior was studied by means of salt-spray and atmospheric corrosion tests. The objective was to develop an improved aluminum-zinc alloy coating on steel that would be more durable than galvanized coatings and that would be more protective to cut edges and areas of mechanical damage than hot-dip aluminum coatings. The optimum alloy was found to be 55 weight percent aluminum-zinc. This new alloy coating is two to four times as corrosion-resistant as a galvanized coating of similar thickness. Furthermore, for the galvanic protection of cut edges of sheet in some environments, this coating proved to be superior to aluminum coatings.

"Atmospheric Corrosion of Laminar Composites Consisting of Copper on Stainless Steel"
Robert Baboian, Gardner Haynes and Peter Sexton
ASTM STP 646, 185 (1978)

Atmospheric corrosion of laminar composites consisting of copper on stainless steels has been studied through direct exposure of copper-clad ferritic and austenitic stainless steels to provide information on galvanic effects at cut edges and pores in the copper cladding. Qualitative and quantitative results after exposure for 7.5 years are presented and environmental effects are considered. Application of electrochemical techniques for predicting galvanically induced localized corrosion are discussed and related to environmental conditions and alloy composition. Mechanisms for galvanic pitting and crevice corrosion are correlated with service performance of the copper-stainless steel couples.

"Corrosion Map of the British Isles"
T. R. Shaw
ASTM STP 646, 204 (1978)

This paper describes a simple and reliable methodology by which the effects of atmospheric corrosion can be measured, and developed into a corrosion map. The use to which such information can be applied to provide savings in design, materials, selection of protective finishings, and maintenance expenditures of such finishings is discussed.