Atmospheric corrosion of metals
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Canada

Atmospheric Corrosion of Metals

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Please note

This publication is a part of a discontinued series and is archived here as an historical reference. Readers should consult design and regulatory experts for guidance on the applicability of the information to current construction practice.

Corrosion of metals used in buildings was discussed in a general way in **CBD 20**. Metals for exterior applications should be considered as individual cases of atmospheric corrosion, for such effects may be modified by the particular elements of a design. This Digest will offer guidelines and basic data for estimating atmospheric corrosion in given situations and is designed to assist in the selection and application of materials.

The Division of Building Research has published the results of an atmospheric corrosion test program initiated by the Associate Committee on Corrosion Research and Prevention.[1,2] The first report covers the major architectural metals and alloys of aluminum, magnesium, stainless steel, low carbon and low alloy steels, copper and zinc. The second gives the results for metal-coated steel, including cadmium and zinc electroplated, hot-dip galvanized, zinc and aluminum metallized sheet samples and metal-coated and sealed steel with organic coatings. The results are applicable in the first instance to conditions of exposure simulating those at eight corrosion exposure sites in Canada. Similar results for a large number of metals and alloys have been collected and published by committees of the American Society for Testing and Materials for exposure sites in the USA.

Fortunately, the conditions of exposure at the eight Canadian sites have been reasonably well established by measurements of temperature, time-of-wetness (or RH conditions), and extent of pollution by SO_2. It should therefore be possible to apply the results of these studies to designs where the conditions of exposure will be similar, although there remains the problem of how to predict exactly what these conditions will be.

Time-of-Wetness

In normal atmospheres containing pollutants, metals begin to corrode at an accelerated rate when the relative humidity of the air layer next to the surface exceeds about 75 per cent. This condition occurs when the air is cooled or when the surface itself is cooled, as happens when a surface radiates to a clear sky at night. The decrease in surface temperature can be as much as 5 F deg (2.8 C deg) below ambient. Such a decrease may cause the surface temperature to drop below the dew-point for an ambient relative humidity of about 85 per cent. This condition is affected by design features such as size, orientation, and surface characteristics; for example, one may observe dew formation on the rooftop of a car when there is none on its sides.

Time-of-wetness is the most important factor in atmospheric corrosion and can account for many unexplained variations in observed results. It can be measured by means of an instrument developed at DBR/NRC, and corresponds to the film of moisture on a surface that will produce a potential of over 0.2 volt between two electrodes of platinum and zinc.

Table I presents the measured values of time-of-wetness for a number of sites and the critical value of RH derived from meteorological records. The duration of the condition of relative humidity above this value corresponds to the measured time-of-wetness. It follows that the average value of time-of-wetness can be determined for any locality for which records of RH have been collected. This has been done for a 10-year period (1957-66) for the 112 meteorological stations in Canada. A plot of a selection of these data is given in Figure 1. They can be grouped in two categories: coastal and inland. Times-of-wetness, as indicated by the duration of a given range in relative humidity, show a spread of about 20 per cent, on the average, between the two types of location.
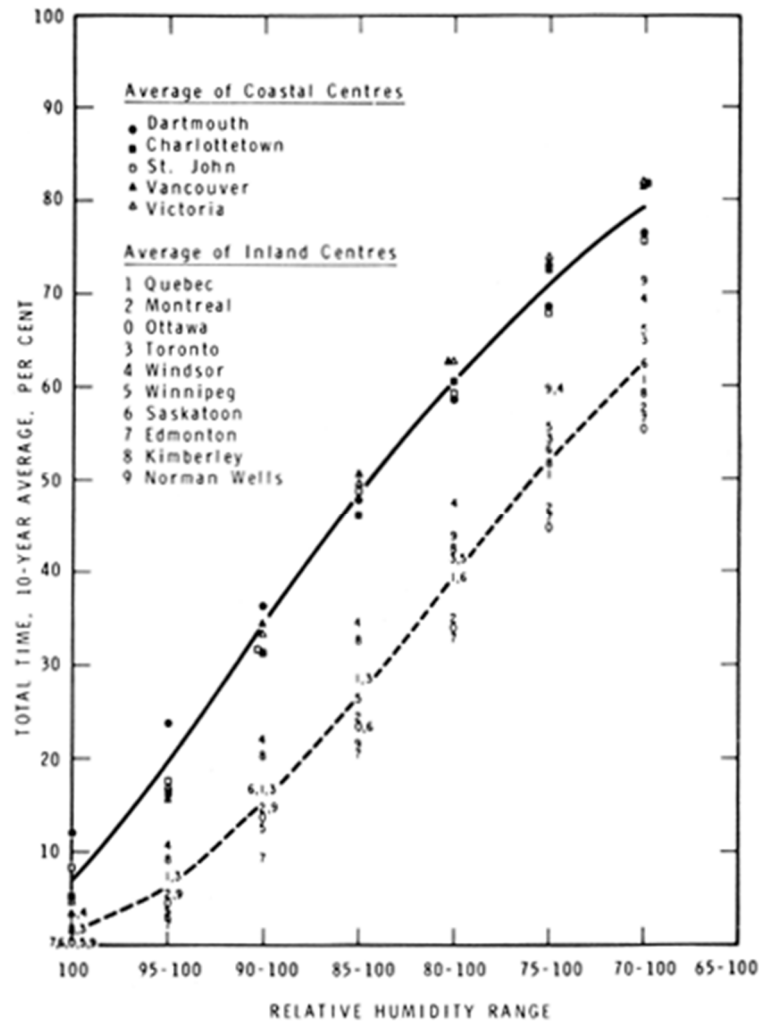

Figure 1. Duration of relative humidity ranges in the atmosphere.

Table I. Percentage Time-of-Wetness For Canadian Exposure Sites As Measured By The Dew Detector

Period	Halifax ARL*	Halifax York Redoubt	Ottawa 1961-1970	Saskatoon 1962-1970	Esquimalt 1961-1969

	1961-1972	1962-1968			
Yearly Average	39.1	44.1	35.3	30.3	42.5
SD**	4.9	3.9	4.9	4.5	4.7
Max	48.4	48.9	41.8	39.5	52.8
Min	30.7	37.3	29.6	25.4	35.7
RH Equiv***					
1955-1966	89.0	87.0	80.0	83.0	87.0
Monthly Average(Dec.)	44.4	52.0	51.6	47.5	61.5
SD	11.6	8.5	9.6	18.0	9.5
Max	72.3	67.4	71.5	74.8	71.5
Min	29.1	43.0	38.5	26.2	43.8
Monthly Average(June)	29.5	36.2	26.8	21.4	23.2
SD	6.8	7.6	11.7	7.0	7.4
Max	47.6	50.4	52.2	29.2	29.5
Min	21.6	24.4	13.7	8.6	7.0

*Atlantic Regional Laboratory, DBR/NRC.

**Standard deviation.

***RH value derived from meteorological records (Figure 1); duration of the condition for which the relative humidity is above this value corresponds to the measured time-of-wetness.

Measurements carried out on a galvanized sheet wall cladding and roof of a storage building indicated that the time-of-wetness for the roof overhang was twice that for the vertical walls. It can be expected that the rate of corrosion of the roof overhang will also be twice the rate for the walls.

The time-of-wetness in the vent space of the wall of a three-storey building, behind precast concrete exterior panels, has been found to be similar, on the average, to the time-of-wetness outside. There was a noticeable difference, however, between the values at the top and bottom of the building. The influence of moist air leaking from the building and greater wetting from rain near the top contributes to an increase of about 10 per cent in the time-of-wetness in that zone. This indicates the necessity for better corrosion protection for metal hangars, etc., in the zone near the top of the building than is required near the bottom.

It should be apparent that surfaces which trap and pond water or cool by radiation so that water vapour condenses as dew can experience a time-of-wetness two or more times the atmospheric average for the locality. It should also be apparent that they will experience an increase in corrosion rate in the same proportion. Good design practice can avoid much of this difficulty.

Pollution

Much has been said about pollution in the last few years, but in the context of atmospheric corrosion only sulphur dioxide has been shown to accelerate corrosion in a predictable way. Particulate matter such as sea salts, soot and soil has not been directly correlated with the rate of corrosion, although it has been demonstrated that particulates deposited on a metal surface can be responsible for the initiation of corrosion.

Tests of corrosion of architectural metals have been made over a 10-year period at eight exposure sites, and the corresponding levels of sulphur dioxide pollution have been measured and recorded. Since 1970 three levels of government have participated in measuring pollution by SO_2 in most large urban areas. As a result, data are available for estimating the SO_2 concentration of the environment where major structures are planned. The Federal Department of the Environment, Air Pollution Control Directorate, publishes monthly and annual National Air Pollution Surveillance Reports.

Some of the data collected by air pollution agencies are given as parts per million (ppm), parts per 100 million, or $\mu g/m^3$, when the method involves a continuous sampling of the air to obtain an hourly value. These can be converted to units of MDD (Milligrams $SO_3/dm^2/day$) by the following conversions:

1 MDD = 0.028 ppm
1 MDD = 80 $\mu g/m^3$

It should be remembered that whereas pollution varies hourly, daily and seasonally, corrosion is a long-term process and only average, monthly, or yearly values should be used for predicting it. For this reason it is best to obtain yearly values from measurements taken monthly of total sulphation. Such data are now available for some major cities (Figure 2).
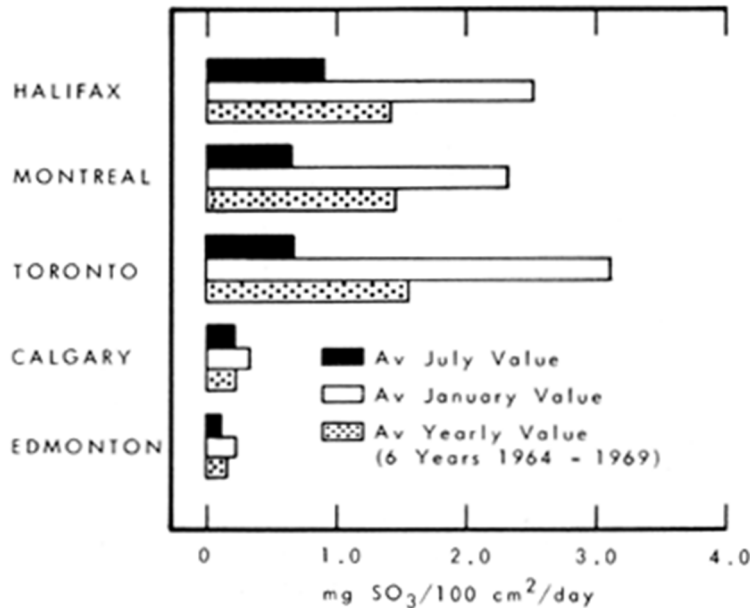

Figure 2. Levels of pollution by SO_2 in some major cities in Canada.

Finally, SO_2 levels can be greatly influenced by local pollution whose source can even be the chimney of the building under consideration. Roof flashings, gutters, metal roofs and metal cladding can be greatly influenced by SO_2 released close to the top of the building. Any prediction of corrosion rate must take such situations into account.

Sea Salts

Atmospheric corrosion of metals in an environment defined as marine is greatly accelerated, but this condition exists only where the exposure is subject to direct sea spray. It has been found that the corrosivity of a marine atmosphere is reduced several fold only 1 to 2 km (1/2

to 1 mile) inland. At one exposure site in Kure Beach, N.C., the corrosion rate of steel at the 80-ft site is about 10 times higher than that at the 800-ft site, showing that chloride concentration decays rapidly with distance from the coast.

Temperature

There is evidence that temperature is a factor in atmospheric corrosion. In Canada, however, most of the densely populated section of the country lies in a narrow belt of nearly constant latitude and the mean annual temperature varies by no more than about 10 F deg (5.5 C deg). In view of this, temperature as a factor in corrosion need be considered only for the Far North. The very low corrosion rate observed for Norman Wells is partly attributable to the low average temperature as well as to low pollution.

How To Use Available Information

When the question of corrosion of a metal proposed for use in a certain location is to be considered, the over-all or average environmental conditions of time-of-wetness, temperature, and concentration of SO_2 and chlorides should first be established. In the second phase of the detailed design, an assessment should be made of the corrosion rate of each metal to be exposed by identifying test data from a site where the conditions of time-of-wetness and pollution are similar. If available data do not correspond because the conditions of exposure are different, then estimates can be made by assuming a linear relation of corrosion and time-of-wetness. For some metals such as Alcan 57S alloy and zinc the linear relation seems to extend to SO_2 pollution also, but unfortunately there does not seem to be a simple correlation for most others.

Correlations to date are applicable for short-term corrosion, especially for the first month or even year, but not for the long term. In most instances long-term corrosion is greatly affected by corrosion products, but their influence has not yet been determined sufficiently to enable a quantitative prediction. Of all the metals tested only zinc was found to have a constant rate of corrosion, independent of length of exposure, at three of the sites (Ottawa, Montreal, Trail). Thus, its long-term performance is predictable from short-term tests. For other sites its rate of corrosion decreased with time of exposure, so that the 10-year value was about half the one-year value.

If the corrosion rates of two metals are known at one location and the rate for one of them is known at another location, it will not be possible to predict the corrosion rate of the second metal from the ratio of the two rates at the original site because this ratio does not remain constant. It must be concluded that the designer has to rely heavily on experience in estimating atmospheric corrosion of metals. This Digest should provide guidance in making judgements; and further information is available in a more detailed publication.[3]

References

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