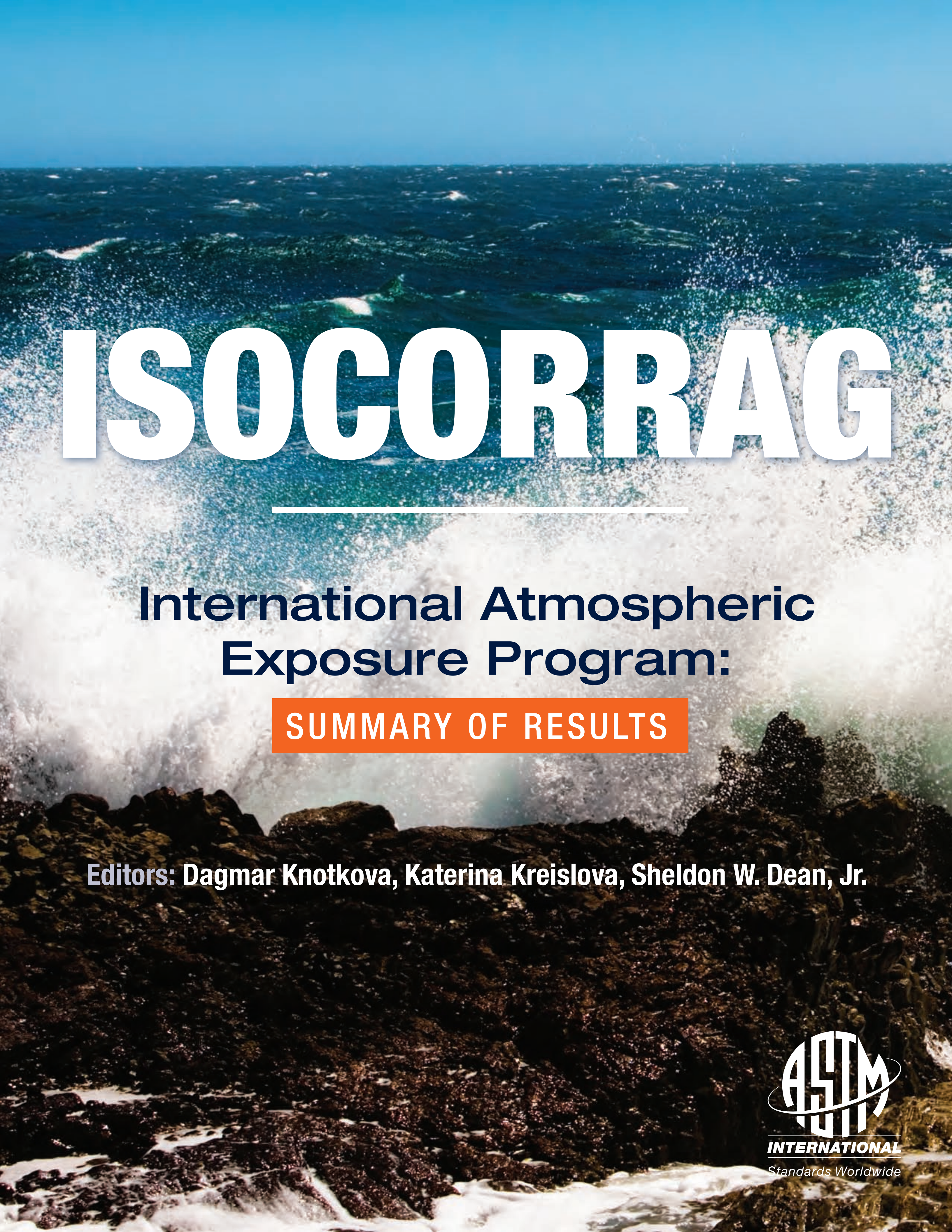

ISOCORRAG

International Atmospheric Exposure Program:

SUMMARY OF RESULTS

Editors: Dagmar Knotkova, Katerina Kreislova, Sheldon W. Dean, Jr.

ASTM
INTERNATIONAL
Standards Worldwide

ISOCORRAG

International Atmospheric Exposure Program: Summary of Results

Developed by ISO/TC 156/WG 4,
Atmospheric Corrosion Testing and Classification of Corrosivity of Atmosphere

Sponsored by ASTM Committee G01 on Corrosion of Metals

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Contents

Preface

Metals, protective coatings, and other materials deteriorate when exposed to atmospheric environments. When selecting materials for such applications, it is important to have information on the rate and type of deterioration that can occur in order to estimate the service life and economic consequences of the materials. A standardized corrosivity classification system has been developed by the International Organization for Standardization (ISO) that is used throughout the world. It has been discovered that this system is less accurate than desired in several cases, and examples both of over and underestimation have been observed. As a result, the ISOCORRAG Program was developed to provide actual exposure data to update and improve the corrosivity classification system. This program was initiated in 1986 and closed in 1998.

The improvement of the standardized corrosivity classification system was achieved by a careful evaluation and analysis of the results of the data from the ISOCORRAG Program. This program was the first worldwide atmospheric testing program carried out by many different organizations in a number of nations participating in ISO. It had a well-defined structure to obtain both short and long-term kinetics of the corrosion processes that affect several important structural metals, together with a monitoring program to record the environmental parameters that affect outdoor atmospheric corrosion. Subsequently, the MICAT Program was organized and carried out through the cooperative efforts of Spain, Portugal, and many Latin American countries. There are many similarities between the ISOCORRAG and MICAT programs, and there has been sharing of the data and results.

The analysis of the data from the ISOCORRAG Program was based on a dose-response concept to develop a relationship between the environmental parameters and the observed corrosion rates. The analyses of the results have been carried out by members of ISO/TC 156/WG 4 on Atmospheric corrosion testing and classification of corrosivity of atmosphere using statistical regression analyses methods.

Both the ISOCORRAG and MICAT programs were designed to find simple dose-response relationships between the environmental parameters and the corrosion damage. The UN ECE Convention on Long-Range Transboundary Air Pollution has also been involved in developing dose-response functions that separate wet and dry deposition of pollutants as part of their International Cooperative Program on the Effects on Materials (ICP Materials). These large-scale programs have greatly improved our understanding of atmospheric corrosion processes in the past two decades.

This book presents the results of the ISOCORRAG Program in a single document so that engineers, scientists, students, and other interested parties may have access to them. In addition, an extensive list of references has been included to assist the reader in locating these analyses of the data contained in this book.

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Acknowledgments

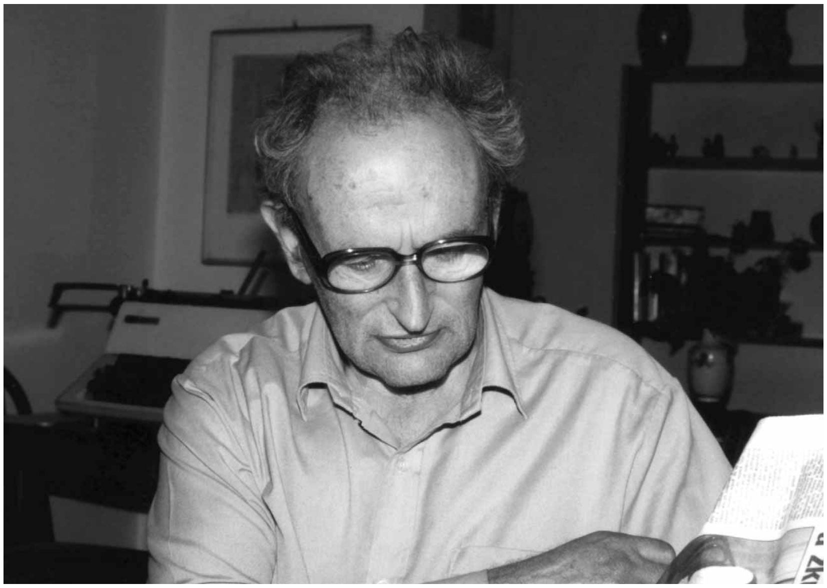
The authors acknowledge the long-term assistance of all participants of the ISOCORRAG program and all ISO/TC 156/WG 4 members who provided comments, analyses, and proposals concerned with this work. We especially appreciated the extensive cooperation among the Australian, Czech, Russian, Spanish, Swedish, and USA WG 4 members, and other colleagues in creating the data bases and protocols for handling the data. The results of these analyses have provided the technical basis for the revision of the atmospheric corrosivity classification system.

The authors gratefully acknowledge the sponsorship of ASTM Committee G01 on Corrosion of Metals that made it possible to publish this data series. In addition, support for the organization and treatment of the data in this book were provided by the R&D Project No. MSM 2579478701 Research of methods for precision of metallic materials and their protective layers service life prediction from point of view pollution in environment granted by the Ministry of Education, Youth and Sports of the Czech Republic.

Dedication

This volume is dedicated to the memory of our friend and colleague Dipl. Ing. Karel Bartoň, Ph.D., with whom we worked for decades. He was an internationally recognized expert in the field of atmospheric corrosion and corrosion protection from 1955 to 1990.

Karel Bartoň was born in 1923, in Ústí nad Labem, the Czech Republic. He spent the last years of World War II in labor camps. Thereafter, he graduated from the Institute of Chemical Technology in Prague (1950) with a degree in chemical engineering and then earned his Ph.D. in the field of physical metallurgy-corrosion from the Technical University for Mining and Metallurgy in Ostrava (1962). After receiving subsequent certificates from the Academy of Sciences of the Czechoslovak Socialist Republic, he was recognized as a leading research worker. In the course of his professional life, he worked in the fields of both corrosion science and corrosion engineering at the State Institute for the Protection of Materials (SVUOM) in Prague. He was the director from 1966 to 1970.



Karel Bartoň had many abilities and interests. He was a systematic research worker, who was able to produce a scientifically based project with complex field and laboratory tests, measurements, and monitoring. His wife worked with him in many of these activities. He always evaluated the results he obtained both in terms of their scientific contributions and in terms of their engineering applications. He was also an enthusiastic leader who stimulated his young research coworkers, and so he took part in their university education.

As a leading worker in the field of corrosion and corrosion protection he championed the concept of interdisciplinary approaches with the use of results from the fields of metallurgy, physical chemistry, climatology, statistics, and others. He worked systematically and in depth in atmospheric corrosion, where he combined the knowledge gained from laboratory tests, field testing, and practical solutions to create an integrated, theoretically supported model that was able to be widely applied.

He was a leader in standards development, and he formulated and introduced a national system of standardization in the field of corrosion and corrosion protection. This became the basis for the standardization system of the countries of the Council of Mutual Economic Assistance. Later he also influenced the approach to standardization of ISO/TC 156 “Corrosion of metals and alloys.” He formulated the basis of the classification of the corrosivity of atmospheres, and he collaborated with the WG 4 working group. He made a significant contribution in the formulation of the ISO 11303 standard, “Corrosion of metals and alloys – Guidelines for selection of protection methods against atmospheric corrosion.”

In his extensive lecturing activities, he used his ability to maintain a lively delivery with his excellent knowledge of languages. As the chairman of a regional section of the Scientific and Technical Society, field of corrosion and corrosion protection, he directed their activities in a broad sense. Although his work was accepted throughout the world, his international involvement and cooperation were negatively affected by the political situation in the decades of the 1970s and 1980s.

He was the author of many scientific and specialized publications. His book Protection Against Atmospheric Corrosion (John Wiley & Sons, 1975) combined the principles of a scientific approach with engineering solutions and was one of the primary resources for the discipline. He participated in other publications, including "Atmospheric Corrosion" (Ed. W.H. Ailor, Wiley, New York, 1982) and "Degradation of Metals in the Atmosphere" (Ed. S.W. Dean, T.S. Lee, ASTM STP 960, West Conshohocken, PA, 1988).

After he retired in 1990, he was still active as a consultant and translator.

Karel Barton was able to combine the demands of scientific research and management with a rich personal and family life. He was fond of experiencing the beauty of nature. He enjoyed participation in and following sports, and he had musical talent. He played both the violin and viola.

His energy and universal creativity set a favorable example for all of us to emulate. Dip. Ing. Karel Bartoň died in 1995, but his influence lives on with this book. A number of his ideas have been utilized by the authors of this publication, which is dedicated to his memory. Messrs. Hanus and Vitek Barton (Dr. Barton's sons) have contributed to this dedication, and one of us (DK) had worked with Dr. Barton for 35 years.

DS71-EB/May 2010

1

Introduction

THE INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, ISO, Technical Committee on Corrosion of Metals and Alloys, TC156, identified atmospheric corrosion as a priority area for the development of international standards during their organizational meeting in Riga, Latvia, in 1976. In the next meeting in Borås, Sweden, in 1978, TC 156 created Working Group 4 (WG 4) to develop standards for the classification of atmospheric corrosivity under the leadership of the Czech Republic's (formerly Czechoslovakia) delegation.

As a result of the efforts of WG 4, four International Standards were developed, ISO 9223, 9224, 9225, and 9226. These standards were based on an extensive review of atmospheric exposure programs carried out in Europe, North America, and Asia. ISO 9223 provided a general classification system for atmospheres based either on 1-year coupon exposures or on measurements of humidity parameters to estimate time of wetness, sulfur dioxide concentration or deposition rate, and sodium chloride deposition rate. ISO 9224 provided an approach to calculating the extent of corrosion damage from extended exposures for five types of engineering metals based on application of guiding corrosion values (average and steady-state corrosion rates) for the each corrosivity categories in ISO 9223. ISO 9225 provided the measurement techniques for the sulfur dioxide concentration or deposition rate, and sodium chloride deposition rate, needed as classification criteria in ISO 9223. ISO 9226 provided the procedure for obtaining 1-year atmospheric corrosion measurements on standard coupons. Two ways of determining the corrosivity category of a given location according to ISO 9223 through 9226 are presented on Figure 1.

The ISOCORRAG Program was developed subsequently to expose both flat panels and wire helix specimens to the atmosphere throughout the world to obtain a data set on atmospheric corrosion that was carried out in a uniform manner and with well-characterized samples. The goal was to eliminate testing variations that made many of the earlier studies unreliable. In addition, this program also accumulated data on the important atmospheric variables of temperature, relative humidity, sulfur dioxide, and sodium chloride deposition rates. These data would then form a point of reference to determine the accuracy of the ISSO 9223 and 9224 standards, and subsequently to provide the basis for revising these standards.

The ISOCORRAG project was initiated in 1986 as an 8-year program, but because a number of delays and problems it was not closed until 1998 in a form of the final technical report. The purpose of this Data Series Publication is to present the results obtained from this program in a single source so that future investigators have access to these important results. In addition, a partial list of publications showing conclusions from this project is provided. The goal of revising the ISO 9223, 9224, 9225, and 9226 standards has also been completed, and these new standards incorporate the information derived from this program.

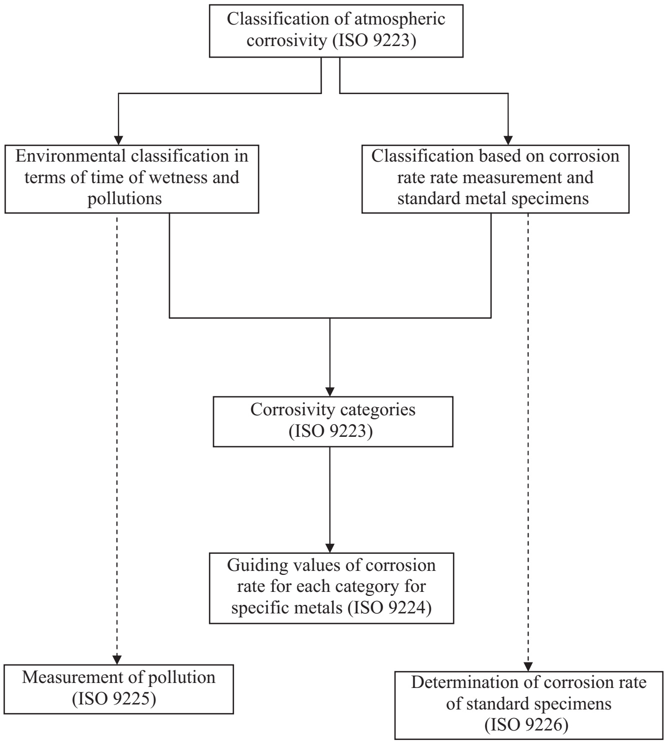


Fig. 1—Classification of atmospheric corrosivity.

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The system covers standards:

- ISO 9223:1992 Corrosion of metals and alloys. Corrosivity of atmospheres. Classification.
- ISO 9224:1992 Corrosion of metals and alloys. Corrosivity of atmospheres. Guiding values for the corrosivity categories.
- ISO 9225:1992 Corrosion of metals and alloys. Corrosivity of atmospheres. Measurement of pollution.
- ISO 9226:1992 Corrosion of metals and alloys. Determination of corrosion rate of standard specimens for the evaluation of corrosivity.

This standardized classification system is a simple system with a consistent structure, which meets the requirements for engineering use. The improvement of this classification system has been carried out. The adjustment using results of the ISOCORRAG program was performed under the leadership of ISO/TC 156/WG 4.

2

Experimental

2.1 EXPOSURE SITES

Thirteen countries participated in the exposure program with a total of 53 exposure sites. These sites included industrial, urban, rural, marine, and costal locations in temperate, tropical, and arctic zones. A list of the sites together with their designations and characterizations is given in Table 1. A world map showing the approximate location of these sites is shown in Figure 2. The organizations responsible for these sites are listed in Table 2.

2.2 MATERIALS

Four different metals were chosen for this program with the expectation that they would serve as surrogates for most of the common alloys used in exterior applications. The four metals are carbon steel, zinc, copper, and aluminum. More specific information about these metals is given in Table 3. All of the carbon steel material was taken from a single heat provided by the British Steel Corporation and corresponded to UNS G10060. The zinc material was chosen by each participant to be a commercially pure zinc alloy with sufficient alloying to be mechanically stable for the duration of the exposure, e.g., UNS Z18002. Commercially pure copper (UNS C11000, flat specimens, UNS C10200, wire specimens) and aluminum (UNS A91100) were also used because they are readily available.

2.3 SPECIMENS

Two types of specimens were chosen for these exposures, flat panels and wire helices. The flat panels were a nominal size of 100 by 150 mm and between 2 and 3 mm thick so that they would fit standard exposure racks described in ISO 8565, and ASTM G50. The wire helices were constructed of 2 to 3 mm diameter wires about 1,000 mm long and wound around a 24-mm-diameter cylindrical rod. A diagram of the completed specimen is shown in Figure 3. All wire helix specimens were prepared by the Staatliches Materialsprüfungsamt, N. W., Dortmund, Germany.

The specimens were all degreased with solvent, weighed, and measured before exposure. The flat panels were identified with an appropriate marking before exposure. The wire helices were assembled with polyamide (nylon) threaded rods and nuts, and mounted vertically at each site. The flat panels were held in racks inclined to the horizontal at an angle of 45°, except in the USA where the angle was 30°.

2.4 EXPOSURE PROGRAM

A set of specimens was initially exposed for each of 1, 2, 4, and 8-year exposures at each site. A set of specimens consisted of the four metals with both flat panels and wire helices in triplicate, for a total of 24 specimens in a set and 96 total specimens in the initial exposure. After 6 months, another set of specimens was exposed for a 1-year exposure. After 1 year, the first set of 1-year exposed specimens was removed, and another set of 1-year specimens was exposed. Every 6 months this process was repeated until a total of six sets of specimens had been exposed for 1 year. Figure 3 shows a diagram of the exposure program. The original exposure was planned to begin in the fall of 1986, but several delays occurred at various sites. It should be noted that, initially, the length of the longest exposure was not determined. The decision to terminate this exposure at 8 years occurred several years after the program was initiated. The exposure program was closed on some test sites after 6 years. It should be noted that the program was dropped after 1 year at the USA RTP site.

2.5 ENVIRONMENTAL MONITORING

The following environmental monitoring measurements were planned to be made during the entire 8-year exposure program:

- Air temperature
- Relative humidity
- Sulfur dioxide concentration or deposition
- Sodium chloride deposition

The frequency of these measurements and their reporting requirements are shown in Table 4. The sulfur dioxide deposition was to be measured either by the lead dioxide sulfation plate or the alkaline surface method. These methods are covered in ISO 9225, and the sulfation plate is also covered in ASTM G91. The sodium chloride deposition was determined by the wet candle method described in ISO 9225 and in ASTM G140.

2.6 EXPOSURE INITIATION

The initiation dates for the exposures at the various sites are shown in Table 5.

2.7 SPECIMEN EVALUATION

At the conclusion of each exposure, the specimens were retrieved and cleaned according to the procedures shown in ISO 9226. See Table 6 for a summary of these procedures. In the case of the carbon steel specimens handled by the USA, the molten sodium hydroxide with 1.5 to 2 % sodium hydride method described in ASTM G01 was used. After cleaning, the specimens were weighed and the mass losses were calculated.

The corrosion rates were calculated as follows:

$$r_{corr} = 10\Delta m / A\rho t \tag{2.1}$$

where:

r = the corrosion rate in μm/year,
Δm = the mass loss in mg,
A = the specimen area in cm^2,
ρ = the metal density in g/cm^3,
and
t = the exposure time in years.

TABLE 1—Atmospheric Corrosion Test Sites Included in the Program

	Name of		
Country	**Marking**	**Testing Site**	**Type of Atmosphere**
Argentina	ARG 1	Iguazu	semiarid, wet, rural
	ARG 2	Camet	subtropical zone, marine, wet
	ARG 3	Buenos Aires	subtropical zone, marine, wet
	ARG 4	San Juan	subtropical zone, dry, rural
	ARG 5	Yubany Base	antarctic desertic zone
Canada	CND 1	Boucherville	moderate zone, rural
Czechoslovakia	CS 1	Kašperské Hory	moderate zone, rural
	CS 2	Praha-Běchovice	moderate zone, urban
	CS 3	Kopisty	moderate zone heavy industrial
FRG	D 1	Bergisch Gladbach	moderate zone, urban
Finland	SF 1	Helsinki	moderate zone, urban
	SF 2	Otaniemi	moderate zone, “small town”
	SF 3	Ahtari	moderate zone, rural
France	F 1	Saint Denis	moderate zone, urban - semi industrial
	F 2	Ponteau Martigues	moderate zone, marine
	F 3	Picherande	moderate zone, rural
	F 4	Saint Remy, les Landes	moderate zone, marine
	F 5	Salins de Giraud	moderate zone, marine
	F 6	Ostende, Belgium	moderate zone, marine
	F 7	Paris	moderate zone, urban
	F 8	Auby	moderate zone, heavy industrial
	F 9	Biarritz	moderate zone, marine
Japan	JAP 1	Choshi	moderate zone, rural
	JAP 2	Tokyo	moderate zone, urban
	JAP 3	Okinawa	subtropics, marine
New Zealand	NZ 1	Judgeford, Wellington	moderate zone, marine - rural
Norway	N 1	Oslo	moderate zone, urban
	N 2	Borregaard	moderate zone, industrial
	N 3	Birkenes	moderate zone, rural (acid rain)
	N 4	Tannanger	moderate zone, marine splash
	N 5	Bergen	moderate zone, marine - urban
	N 6	Svanwik	cold zone, arctic
Spain	E 1	Madrid	moderate zone, urban
	E 2	El Pardo	moderate zone, urban
	E 3	Lagoas - Vigo	moderate zone, industrial
	E 4	Baracaldo, Vizcaya	moderate zone, urban
Sweden	S 1	Stockholm-Vanadis	moderate zone, urban

(*Continued*)

TABLE 1—Atmospheric Corrosion Test Sites Included in the Program (Continued)

	Name of		
Country	Marking	Testing Site	Type of Atmosphere
	S 2	Bohus Malmon, Kattesand	moderate zone, marine
	S 3	Bohus Malmon, Kvarnvik	moderate zone, marine - splash
UK	UK 1	Stratford, East London	moderate zone, industrial
	UK 2	Crowthorne, Berkshire	moderate zone, rural
	UK 3	Rye, East Sussex	moderate zone, marine
	UK 4	Fleet Hall	moderate zone, urban
USA	US 1	Kure Beach, N. Carolina	moderate zone, eastern marine
	US 2	Newark-Kerney, New Jersey	moderate zone, industrial
	US 3	Panama Fort Sherman Costal Site	tropical zone, marine - splash
	US 4	Research Triangle Park, N. Carolina	moderate zone, urban
	US 5	Point Reyes, California	moderate zone, western marine
	US 6	Los Angeles, California	moderate zone, marine - urban
USSR	SU 1	Murmansk	cold zone, marine - rural
	SU 2	Batumi	subtropical, marine - urban
	SU 3	Vladivostok	far-east, marine - urban
	SU 4	Ojmjakon	extremely cold

Geographical location of the test sites is given in Figure 2.

Fig. 2—Map showing approximate locations of sites.

TABLE 2—Organizations Participating in the ISOCORRAG Program

Country	Institution, Organization	Contact Person	Address
Argentina	Instituto Argentino de Racionalizacion de Materiales	J. Tychojkij	IRAM Chile 1192 C. Postal 1098 Buenos Aires ARGENTINA
	CITEFA Instituto de Investigaciones Cientificas y Técnicas de las Fuerzas Armadas	B.M. Rosales	Zufriategui y Varela 1633 VILLA MARTELLI Buenos Aires ARGENTINA
	INTI Instituto National de Tecnologia Industrial		Av. Gral. Paz entre Albarellos y Constituyentes Casilla de Correo 157 1650 SAN MARTIN Buenos Aires ARGENTINA
Canada	National Research Council Industrial Materials Research Institute	J.J. Hechler	75 de Mortagne Blvd. Boucherville, Quebec CANADA J4B 6Y4
Czechoslovakia	National Research Institute for Protection of Materials	D. Knotková (P. Holler 1986–90)	U měšt’an. pivovaru 934/4 170 00 Praha 7 Czech Republic
FRG	Bundesanstalt fur Strassenwesen	M. Schroder	P.O. Box 100150 W-5060 Bergisch Gladbach BRD
	Staatliches Materialprüfungsamt	C.L. Kruse (1986–88)	Marsbruchstrasse 186 D-4600 Dortmund 41
Finland	Technical Research Centre of Finland (VTT) Metallurgy Laboratory	T. Hakkarainen	Matallimiehenkuja 4 SF - 02150 Espoo FINLAND
France	EDF – DER Déparment ENA	M. Legrand	Les Renardibres Route de Seus 77250 Ecuelles FRANCE
	Cegedur Pechiney	M. Reboul	BP 27 38340 Voreppe FRANCE
	Centre Technique du Zinc	M. Piessen	34 rue Collange 92307 Levallois Perret FRANCE
	IRSID Institut de la Recherche la Sidérurgie Francaise	M. Jossio	185 rue du President Roosevelt 78105 St. Germain en Laye FRANCE
Japan	Nippon Test Panel Co.	Yasunito Togawa	2-7-10 Hatanobai Shinagawa Tokyo 142 JAPAN

(*Continued*)

TABLE 2—Organizations Participating in the ISOCORRAG Program (Continued)

Country	Institution, Organization	Contact Person	Address
New Zealand	BRANZ Building Research Association of New Zealand Building Science Group	R.J. Cordner	Private Bag Porirua NEW ZEALAND
Norway	Norwegian Institute for Air Research	J.F. Henriksen	Box 130 2001 Lillestrom NORWAY
Spain	Centro National de Investigaciones Metalurgicas	M. Morcillo	Avenida de Gregorio del Amo Ciudad Universitaria Madrid 3 ESPANA
	Escuela Tecnica Superior de Ingenieros Industriales Departemento Ingeniera Quimica	L. Espada	Vigo ESPAŇA
	LABEIN Dep. Materials and Contruction	A. Porvo	Vizcoya ESPAŇA
Sweden	Swedish Corrosion Institute	V. Kucera (J. Gullman 1986–88)	Roslagsvagen 101, hus 25 S-10405 Stockholm SWEDEN
UK	Central Electricity Research Laboratories	P. McIntyre	Kelvin Avenue Leatherhead Surrey KT 22 7 SE GREAT BRITAIN
	British Steel Swinden Laboratories	B. Lee	Moorgate Rotherham S60 A2 GREAT BRITAIN
USA	LaQue Centre for Corrosion Technology	W. Kirk	P.O. Box 656 Wrightsville Beach NC 28480 USA
	Department of Materials Science VHE 602 University of Southern California	F. Mansfeld	Los Angeles CA 90089 USA
	ASTM Committee G01	S.W. Dean Jr.	P.O. Box 538 Allentown PA 18105 USA
USSR	IFCHAN SSSR	P.V. Strekalov	Leninsky prospekt 31 117 312 Moscow RUSSIA

TABLE 3—Metals Used in the ISOCORRAG Program

- Carbon steel: unalloyed carbon steel (Cu 0.03 to 0.10 %, P < 0.07 %) (e.g., UNS G10060 British Steel composition below, EN 10130). Actual composition of British Steel used in program given below.
- Zinc: min. 98.5 % (e.g., UNS Z18002, EN 1179)
- Copper: min. 99.5 % (e.g., UNS C11000 flat panels, UNS C 10200 wire helices, EN 1652)
- Aluminum: min. 99.5 % (e.g., UNS A91100, EN 485)

Composition of unalloyed carbon steel used in the collaborative program

Alloying Element	**Percentage**
carbon	0.056
silicon	0.060
sulphur	0.012
phosphorus	0.013
chromium	0.020
molybdenum	0.010
nickel	0.040
copper	0.030
niobium	0.010
titanium	0.010
vanadium	0.010
aluminum	0.020
tin	0.005
nitrogen	0.004
manganese (X-ray fluorescence)	0.390

The following values were used for the densities of the four metals in this program: iron = 7.86, zinc = 7.20, copper = 8.96, and aluminum = 2.70.

In the case of the helix specimens the following formula was used:

$$r_{corr} = \Delta md/4mt \tag{2.2}$$

where:

r_{corr} = the corrosion rate in μm/year,
Δm = the mass loss in mg,
d = the wire diameter in mm,
m = the original wire mass in g,
and
t = the exposure time in years.

However, where $\Delta m/m > 50$, the following formula was used:

$$r_{corr} = 1000d[1 - (1 - \Delta m/1000m)^{1/2}]/2t \tag{2.3}$$

where the symbols above are as defined.

The corrosion rates for the triplicate specimens were averaged to produce a corrosion rate for the exposure.

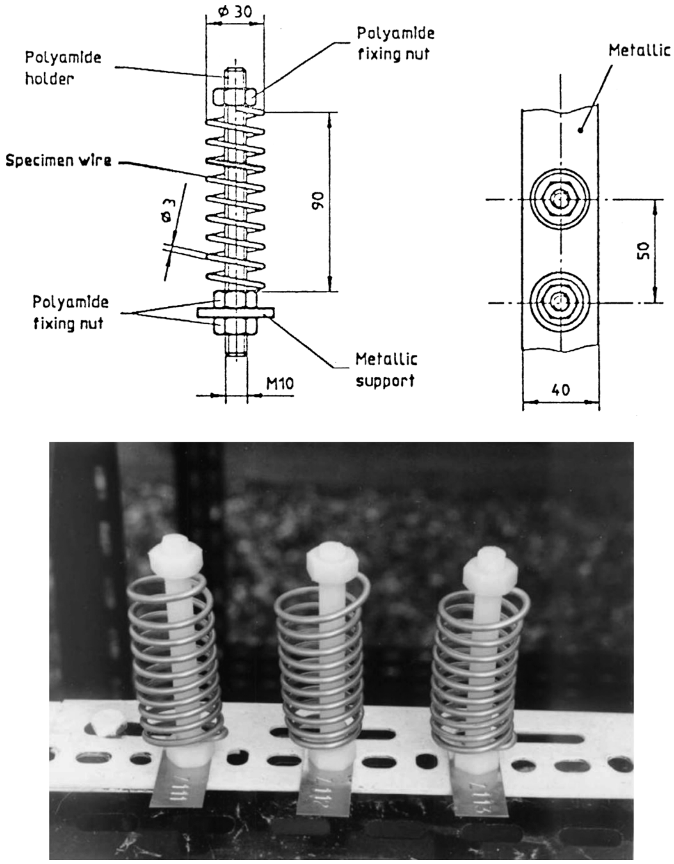

Fig. 3—Wire helix specimen assembly and installation.

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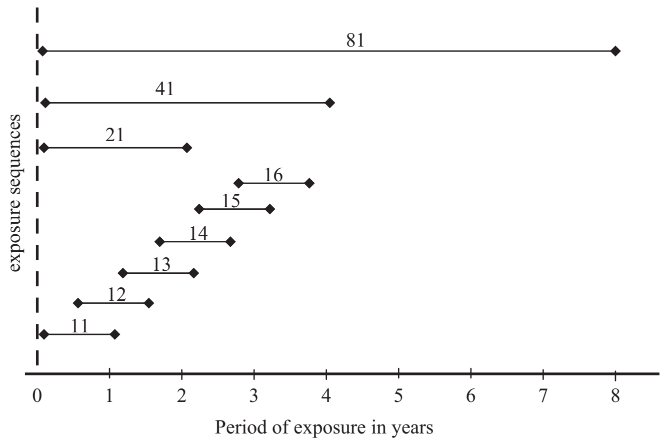

Note: The first number indicates years of exposure and the second one indicates number of repeated sequence.

Fig. 4—Diagram showing the exposure sequences.

TABLE 4—Frequency and Reporting Requirements of Environmental Condition Monitoring

Measured Value	Unit	Types and Number of Measurements	Expression of Results
Air temperature	°C	continuous or at least 3 times per day	average per month and/or per year
Relative humidity	%	continuous or at least 3 times per day	average per month and/or per year
Air Contamination			
SO_2 concentration	$\mu g.m^{-3}$	continuous - monthly	average per month
SO_2 deposition rate	$mg.m^{-2}.d^{-1}$	continuous - monthly	average per month and year
NaC1 deposition rate	$mg.m^{-2}.d^{-1}$	continuous - monthly	average per month and year

TABLE 5—Initiation Dates for the Exposure Program

Country	Atmospheric Corrosion Test Site		Date of Opening (year-month-day)
Argentina	ARG 1	Iguazu	84–10–04
	ARG 2	Camet	84–10–04
	ARG 3	Buenos Aires	84–10–04
	ARG 4	San Juan	84–10–04
	ARG 5	Yubany Base	84–12–01
Canada	CND 1	Boucherville	86–10–07
Czechoslovakia	CS 1	Kašperské Hory	86–09–08
	CS 2	Praha-Běchovice	86–09–30
	CS 3	Kopisty	86–09–26
FRG	D 1	Bergisch Gladbach	88–05–26
Finland	SF 1	Helsinki	86–11–04
	SF 2	Otaniemi	86–10–17
	SF 3	Ahtari	86–10–27
France	F 1	Saint Denis	86–12
	F 2	Ponteau Martigues	86–12
	F 3	Picherande	86–12
	F 4	Saint Remy, les Landes	86–12
	F 5	Salins de Giraud	86–12
	F 6	Ostende (Belgium)	87–02
	F 7	Paris	87–04
	F 8	Auby	86–12–10
	F 9	Biarritz	87–04
Japan	JAP 1	Choshi	86–11–01
	JAP 2	Tokyo	86–11–07
	JAP 3	Okinawa	86–11–07
New Zealand	NZ 1	Judgeford, Wellington	spring 1988
Norway	N 1	Oslo	86–11–03
	N 2	Borregaard	86–11–05
	N 3	Birkenes	86–11–06

TABLE 5—Initiation Dates for the Exposure Program (Continued)

Country	Atmospheric Corrosion Test Site		Date of Opening (year-month-day)
	N 4	Tannanger	86–11–07
	N 5	Bergen	86–11–07
	N 6	Svanwik	86–11–01
Spain	E 1	Madrid	flat 86–07 helix 87–01
	E 2	El Pardo	flat 86–07 helix 87–01
	E 3	Lagoas - Vigo	flat 86–07 helix 87–01
	E 4	Baracaldo, Vizcaya	flat 86–07 helix 87–01
Sweden	S 1	Stockholm-Vanadis	86–11–27
	S 2	Bohus Malmon, Kattesand	86–11–12
	S 3	Bohus Malmon, Kvarnvik	86–11–12
UK	UK 1	Stratford, East London	87–01–26
	UK 2	Crowthorne, Berkshire	87–01–26
	UK 3	Rye, East Sussex	87–01–22
	UK 4	Fleet Hall	87–02–10
USA	US 1	Cure Beach, N. Carolina	87–01–13
	US 2	Newark-Kerney, New Jersey	87–02–26, 27
	US 3	Panama Fort Sherman costal site	flat 87–04–30 helix 87–08–04
	US 4	Research Triangle Park, N. Carolina	87–02–15
	US 5	Point Reyes, California	87–01–15
	US 6	Los Angeles, California	87–03–02
USSR	SU 1	Murmansk	87–04–30
	SU 2	Batumi	87–05–05
	SU 3	Vladivostok	87–07–01
	SU 4	Ojmjakon	87–08–28

TABLE 6—Chemical Cleaning Solutions

Metal	Solution per Liter (5)	Time (Min.)	Temp. (°C)	Remarks
Steel	500 ml HCl (s. g. 1.19) + 3.5 g hexamethylene tetramine	10	25	(1)
Zinc	200 g CrO_3	1	80	(2)
Copper	54 ml H_2SO_4 (s. g. 1.84)	45	45	(3)
Aluminum	50 ml H_3PO_4 (s. g. 1.69) + 20 g CrO_3	10	90	(4)

Notes:

1. Molten NaOH + 1.5–2.0% sodium hydride used by USA.
2. Chloride must be removed before cleaning.
3. Deaerate solution with N_2 before using.
4. If corrosion products remain dip in HNO_3 (s. g. 1.42) 5 min. at 25°C
5. Solutions made up with purified water.

3

Results

3.1 ENVIRONMENTAL DATA

The results of the sulfur dioxide measurements are shown in Table 7. The time of wetness values were determined from the relative humidity results using the procedure shown in ISO 9223, where wetness is assumed whenever the relative humidity is above 80% and the temperature is above 0°C. The values shown in Table 8 are in hours per year. The chloride deposition rates were determined from the wet candle technique and are shown in Table 9 as mg NaCl /m^2 day.

The average values of SO_2 concentration for long-term exposure (4 and 8 years) are lower than the average values

TABLE 7—SO_2 Concentration (μg/m^3)

Code	Testing Site	s11	s12	s13	s14	s15	s16	Ave.	s21	s41	s81
ARG 1	Iugazu							12.0	12.0	12.0	12.0
ARG 2	Camet							12.0	12.0	12.0	12.0
ARG 3	Buenos Aires	12.5	12.5	12.5	11.9	11.3	10.0	11.8	12.5	12.0	12.0
ARG 4	San Juan							12.0	12.0	12.0	12.0
ARG 5	Jubay-Antarct.							1.0	1.0	1.0	1.0
CND 1	Boucherville	14.1	16.0	15.5	15.3	15.9	18.5	15.8	14.8	15.8	15.8
CS 1	Kašperské Hory	25.3	17.1	16.1	13.1	13.4	17.4	16.9	15.8	17.5	17.6
CS 2	Praha-Běchovice	89.5	65.4	70.5	65.8	59.7	53.8	67.1	87.6	68.9	56.0
CS 3	Kopisty	105.0	83.3	82.3	89.5	96.1	83.1	89.4	92.1	89.2	76.9
D 1	Bergisch Glad.	23.4	22.3	15.1	13.2	18.3	15.6	18.5	20.7	17.5	14.5
SF 1	Helsinki	21.4	21.4	20.0	18.4	16.6	15.3	18.9	20.7	18.3	13.6
SF 2	Otaniemi	20.3	16.3	19.0	14.0	10.6	11.3	15.2	18.8	15.8	13.0
SF 3	Ahtari	5.9	5.3	5.1	3.5	3.1	1.9	4.2	5.5	4.0	2.6
F 1	Saint Denis	52.8	46.3	38.8	40.0	70.3		49.6	45.7	53.9	53.9
F 2	Ponteau Mart.	151.0	96.3	76.3	80.0	73.4	44.8	87.0	113.8	100.3	100.3
F 3	Picherande	18.0	11.3	10.0	8.1	3.5	3.9	8.9	13.2	9.9	9.9
F 4	St. Remy	32.3	33.8	35.0	23.1	19.5	37.9	30.3	33.8	29.0	29.0
F 5	Salins de Gir.		40.0	39.3	42.7			39.7	39.3	39.3	39.3
F 6	Ostende (B)	10.0	30.0	32.0				24.0	21.0	21.0	21.0
F 7	Paris	53.6	53.6	53.0				53.4	53.3	53.3	53.3
F 8	Auby	214.6	184.6	167.0	146.6	127.1	117.1	159.5	190.8	190.8	190.8
F 9	Biarritz										
JAP 1	Choshi	7.3	8.1	8.3	8.1	7.5	7.1	7.7	7.8	7.6	6.1

TABLE 7—SO_2 Concentration ($\mu g/m^3$) (Continued)

Code	Testing Site	s11	s12	s13	s14	s15	s16	Ave.	s21	s41	s81
JAP 2	Tokyo	14.1	14.5	14.1	14.2	15.3	15.5	14.6	14.3	13.7	13.7
JAP 3	Okinawa	11.1	8.3	10.6	11.05	12.2	13.0	11.1	10.9	9.7	9.7
NZ 1	Judgeford										
N 1	Oslo	17.3	14.8	14.1	15.8	12.4	8.5	13.3	16.2	13.0	11.2
N 2	Borregaard	43.0	36.0	36.0	52.0	53.0	45.2	44.2	39.4	43.0	38.7
N 3	Birkenes	1.8	1.2	1.2	1.0	1.0	1.0	1.2	1.5	1.3	1.1
N 4	Tannanger	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
N 5	Bergen	9.8	9.9	9.9	7.1	6.8	8.0	8.7	9.9	6.8	6.8
N 6	Svanwik	25.8	23.5	13.1	8.9	11.0	18.1	16.7	19.5	16.7	13.8
E 1	Madrid	27.5	30.3	46.1	51.5	54.0	55.6	40.5	26.8	42.6	42.6
E 2	El Pardo	3.9	4.8	5.8	5.4	4.1	5.4	4.9	4.9	4.7	4.7
E 3	Lagoas	61.6	48.6	46.5	44.8	46.3	44.6	49.0	54.0	49.0	54.8
E 4	Baracaldo	36.8	42.8	38.8	29.4	23.5	21.0	30.7	27.8	30.1	48.1
S 1	Stockholm Vanadis	10.2	11.0	12.0	10.0	11.0	7.0	10.2	11.1	9.8	7.2
S 2	Kattesand	8.8	5.0	8.0	2.0	3.0	5.0	5.3	8.4	6.6	5.1
S 3	Kvarnvik	8.8	5.0	8.0	2.0	3.0	5.0	5.3	8.4	6.6	5.1
UK 1	Stratford	25.7	20.7	17.9	17.3	19.0	18.5	19.9	19.9	19.92	19.9
UK 2	Crowthorne	16.1						16.1	16.1	16.1	16.1
UK 3	Rye	22.9	24.5	22.4	20.1	19.7	17.6	21.2	22.3	21.1	21.1
UK 4	Fleet Hall	19.2	17.0	16.1	16.1	16.4	14.2	16.5	17.7	17.0	16.5
US 1	Kure Beach	5.4	6.2	6.6	6.1	10.5	22.8	9.6			
US 2	Newark	34.0	29.6	35.2	32.0	32.5	31.7	32.5	33.8	32.8	28.2
US 3	Panama Cz	53.0	50.0					51.5	53.0	53.0	53.0
US 4	Res. Tri. Park										
US 5	Point Reyes	4.6	4.4	4.8	7.0	8.7	7.2	6.1	5.2	6.4	5.9
US 6	Los Angeles	13.8	13.8	9.6	9.3	7.5	6.8	10.1	13.2	10.3	7.8
SU 1	Murmansk	5.0	5.0					5.0	5.0	5.0	5.0
SU 2	Batumi	25.0	28.2	25.6	26.5	26.4	26.0	26.3	25.3	25.9	26.0
SU 3	Vladivostok	13.0	15.8	34.3	41.1	25.4	27.9	26.3	26.2	24.6	23.4
SU 4	Oymyakon	5.0	5.0					5.0	5.0	5.0	5.0

TABLE 8—Time of Wetness (h/year)

Code	Testing Site	T 11	T 12	T 13	T 14	T 15	T 16	Ave.	T 21	T 41	T 81
ARG 1	Iugazu	5831	5833	5530	5273	4575	5739	5626	5681	5650	5650
ARG 2	Camet	5974	6086	6202	6354	6447	6231	6216	6088	6150	6150
ARG 3	Buenos Aires	5063	4227	4227	4795	4845	4204	4560	4645	4600	4600
ARG 4	San Juan	1002	923	847	879	865	957	912	925	920	920

(*Continued*)

TABLE 8—Time of Wetness (h/year) (Continued)

Code	Testing Site	T 11	T 12	T 13	T 14	T 15	T 16	Ave.	T 21	T 41	T 81
ARG 5	Jubay-Antarct.	2693	2535	2425	2303	2588	4204	2791	2559	2600	2600
CND 1	Boucherville	2511	2343	2087	2478	2517	2780	2453	2299	2504	2504
CS 1	Kašperské Hory	3043	3627	3579	3094	3980	4406	3622	2453	2901	2809
CS 2	Praha-Běchovice	2381	2500	2082	1978	2310	2616	2311	2559	2827	2708
CS 3	Kopisty	3107	2448	2246	2330	2375	2057	2427	2677	2415	2508
D 1	Bergisch Glad.	4773	4688	4431	4261	3746	3714	4269	4602	4253	4239
SF 1	Helsinki	2972	3456	3453	3678	3849	4062	3578	3213	3552	3483
SF 2	Otaniemi	2599	2851	3401	3051	3804	4297	3409	2766	3333	3467
SF 3	Ahtari	3315	3018	2742	3042	3129	3383	3105	3029	3131	3051
F 1	Saint Denis	4140	4784	4551	4479	3982	3670	4268	4346	4224	4224
F 2	Ponteau Mart.	3704	4273	3743	3060	3700	4410	3815	3724	3716	3716
F 3	Picherande	4320	4152	4746	4116	3550	4144	4171	4173	3965	3965
F 4	St. Remy	5628	6764	6667	6609	6250	5945	6310	6147	6181	6181
F 5	Salins de Gir.	3084	3242	3940	3942			3422	3512	3512	3512
F 6	Ostende (B)	6053	5818	6378				6084	6217	6217	6217
F 7	Paris	4326	3330	1912				3189	3190	3190	3190
F 8	Auby	4128	4618	4966				4571	4547	4547	4547
F 9	Biarritz										
JAP 1	Choshi	5732	5597	5644	5637	5642	5981	5706	5688	5699	5320
JAP 2	Tokyo	1580	1940	2412	2297	2260	2553	2173	1996	2189	2074
JAP 3	Okinawa	4715	4602	4188	3844	2964	3104	3903	4452	3831	3831
NZ 1	Judgeford										
N 1	Oslo	2616	2859	2445	2288	2605	3032	2641	2531	2591	2734
N 2	Borregaard	3139	3200	2746	3561	3709	3681	3339	2943	3314	3349
N 3	Birkenes	3679	4612	4183	4404	3972	3675	4138	3931	3991	4018
N 4	Tannanger	3876	3876	3860	4464	5442	5978	4583	3867	4833	4940
N 5	Bergen	3258	3882	4338	4878	5112	5166	4439	3498	4242	4242
N 6	Svanwik	2149	2048	2715	3119	2933	2953	2653	2432	2525	2368
E 1	Madrid	1317	1758	2641	2424	1992	2228	2060	1979	2041	2076
E 2	El Pardo	2430	2713	3660	3144	3522	3869	3223	2491	3000	3000
E 3	Lagoas	3197	3278	2715	2566	2715	2566	2840	3197	2800	2913
E 4	Baracaldo	4312	4317	4531	4474	4551	4063	4375	4422	4276	3508
S 1	Stockholm Vanadis	2540	3642	3148	3036	2959	3371	3116	2844	3206	2984
S 2	Kattesand	3914	4135	4045	3977	3936	4155	4027	3980	3850	3976

TABLE 8—Time of Wetness (h/year) (Continued)										
Code	**Testing Site**	**T 11**	**T 12**	**T 13**	**T 14**	**T 15**	**T 16**	**Ave.**	**T 21**	**T 41**	**T 81**
S 3	Kvarnvik	3914	4135	4045	3977	3936	4155	4027	3980	3850	3976
UK 1	Stratford	6176	5783	5529	4789	4088	4488	5142	5853	5100	5100
UK 2	Crowthorne	6019						6019	6019	6019	6019
UK 3	Rye										
UK 4	Fleet Hall	6195	5953	3935	4022	4778	4301	4864	5065	4812	4860
US 1	Kure Beach	4403	4200	4068	4142	4314	4609	4289	4089	4149	4081
US 2	Newark	1990	2069	1613	1937	2279	2472	2060	1622	1710	1955
US 3	Panama	7217	7157	7404	7672	8039	8097	7598	7304	7565	7500
US 4	Res. Tri. Park										
US 5	Point Reyes	3962	3874	4059	4357	4664	2511	3905	3362	3021	3852
US 6	Los Angeles	4058	3787	3664	3821	3536	3271	3690	3090	2595	3016
SU 1	Murmansk	2796	2517	2906	3503	3758	3882	3227	2734	3134	3000
SU 2	Batumi	3192	2983	3461	3379	3358	2922	3216	3327	3047	3100
SU 3	Vladivostok	4070	3805	3546	3466	4234	4402	3920	3772	3969	3930
SU 4	Oymyakon	206	281	539	436	443	344	385	373	396	385

TABLE 9—Salinity – NaCl Deposition Rate (mg/m^2/day)										
Code	**Testing Site**	**cl 11**	**cl 12**	**cl 13**	**cl 14**	**cl 15**	**cl 16**	**Ave.**	**cl 21**	**cl 41**	**cl 81**
ARG 1	Iugazu										
ARG 2	Camet	30.0	35.0	40.2	55.0	70.0	53.0	47.2	35.0	47.1	43.1
ARG 3	Buenos Aires										
ARG 4	San Juan										
ARG 5	Jubay-Antarct.	6.0	6.0	6.0	18.0	30.0	35.0	16.8	6.0	16.0	16.0
CND 1	Boucherville	55.0	70.0	55.0	61.0	58.0	56.0	59.0	46.5	52.8	52.8
CS 1	Kašperské Hory	3.8	2.7					3.3	3.3	3.3	3.3
CS 2	Praha-Běchovice	4.8	2.0					3.4	3.4	3.4	3.4
CS 3	Kopisty	3.8	1.8					2.8	2.8	2.8	2.8
D 1	Bergisch Glad.	2.5	1.8	1.8	2.3	1.7	1.0	1.9	3.9	1.6	3.8
SF 1	Helsinki	3.6	4.1	4.2	4.0			4.0	4.0	4.0	4.0
SF 2	Otaniemi	4.2	2.5	1.8				2.8	2.8	2.8	2.8
SF 3	Ahtari	3.2						3.2	3.2	3.2	3.2
F 1	Saint Denis	25.0	25.0	30.0	31.0			27.8	27.5	27.5	27.5
F 2	Ponteau Mart.	206.0	257.0	261.0	254.0		228.0	241.0			
F 3	Picherande	8.0	6.0	7.0	5.0			6.5			
F 4	St. Remy	476.0	557.0	340.0	137.0			378.0			
F 5	Salins de Gir.	138.0	247.0	168.0				184.0			
F 6	Ostende (B)	157.0	185.0	177.0				173.0			

(*Continued*)

TABLE 9—Salinity – NaCl Deposition Rate (mg/m^2/day) (Continued)

Code	Testing Site	cl 11	cl 12	cl 13	cl 14	cl 15	cl 16	Ave.	cl 21	cl 41	cl 81
F 7	Paris										
F 8	Auby	14.7	14.0	24.6				17.8	19.7	19.7	19.7
F 9	Biarritz	225.6	219.6	135.2				193.5	180.4	180.4	180.4
JAP 1	Choshi	60.0	79.0	69.0	62.0	65.0	66.0	66.8	64.5	55.3	60.0
JAP 2	Tokyo	4.3	4.1	4.7	5.5	5.2	5.1	4.8	4.5	4.8	4.8
JAP 3	Okinawa	132.0	99.0	125.0	142.0	150.0	130.0	130.0	128.5	106.7	106.7
NZ 1	Judgeford										
N 1	Oslo	2.0	3.6	2.6	1.2	1.5	1.7	2.1	2.3	2.1	2.0
N 2	Borregaard	13.2	8.6	6.6	11.3	10.0	5.3	9.1	9.9	9.0	10.0
N 3	Birkenes	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
N 4	Tannanger	212.1	209.6	214.1	418.8	367.1	385.9	301.3	213.1	297.6	313.1
N 5	Bergen	4.3	3.4	3.5	11.5	11.4	8.0	7.0	3.9	6.4	6.4
N 6	Svanwik	0.3	0.3	0.5	0.7	0.6	0.9	0.5	0.4	0.7	2.0
E 1	Madrid										
E 2	El Pardo										
E 3	Lagoas	30.0	19.0	20.0	19.0	20.0	19.0	21.2	26.7	21.6	35.3
E 4	Baracaldo	21.0	29.0	28.0	24.0	33.0	40.0	29.2	24.3	31.6	42.9
S 1	StockholmVanadis										
S 2	Kattesand	69.0	73.0	51.0	96.0	90.0	134.0	85.5	60.0	86.0	105.4
S 3	Kvarnvik	509.0	503.0	517.0	1093.0	626.0	755.0	667.0	513.0	601.8	668.5
UK 1	Stratford	18.8	21.2	9.2	8.5	12.9	19.8	15.1			
UK 2	Crowthorne	14.1									
UK 3	Rye	242.0	285.0	463.0	162.0	403.0	246.0	300.0			
UK 4	Fleet Hall	5.3	3.8	7.3	7.3	3.4	5.1	5.4	6.3	6.3	6.3
US 1	Kure Beach	133.0	112.0	148.0	194.0	248.0	266.0	184.0			
US 2	Newark										
US 3	Panama	535.0	531.0	447.0	699.0	760.0	743.0	619.0	594.6	633.2	600.0
US 4	Res. Tri. Park										
US 5	Point Reyes										
US 6	Los Angeles										
SU 1	Murmansk	12.0	16.0	24.0	24.0	19.1	24.4	19.9			
SU 2	Batumi	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.0	1.0	1.0
SU 3	Vladivostok	36.0	24.0	18.5	11.0	8.7	12.1	19.4	24.0	17.2	17.2
SU 4	Oymyakon	0.8	0.4	0.9	0.6	1.2	0.8	0.8	1.0	1.0	1.0

for shorter periods, and also the yearly averages of SO_2 concentration for latest exposures are lower than for the initial ones at some test sites. During 8 years of exposure (1986 to 1994), the significant decrease in air pollution of SO_2 occurred at some test sites, mainly at industrial ones, because of restriction laws adopted in some countries. Examples of the changes of SO_2 pollution at selected industrial, urban, rural, and marine test sites are shown in Figure 5.

Other measured environmental parameters were stable during whole exposure period.

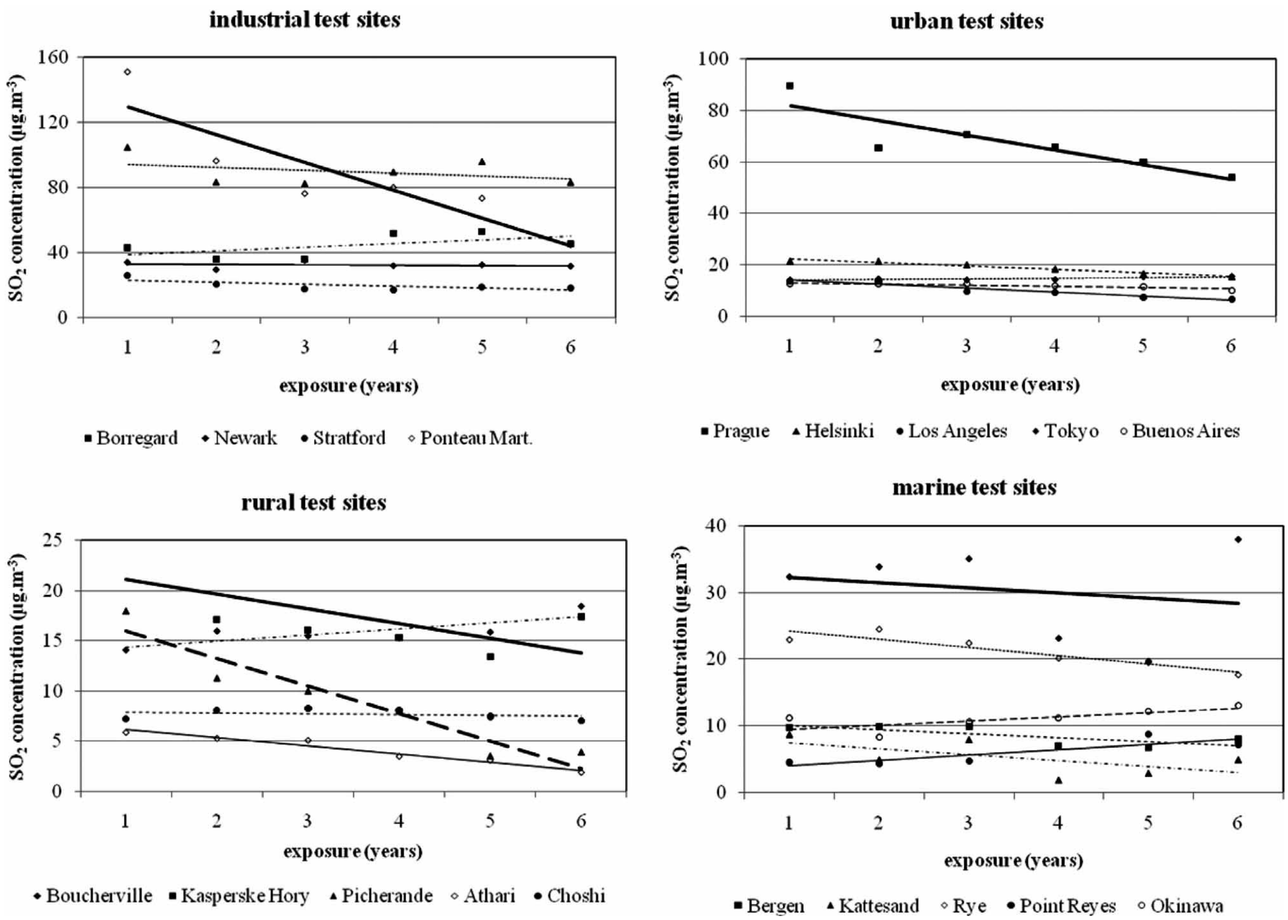

Fig. 5—Changes of SO$_2$ during exposure periods.

3.2 MASS LOSS DATA

The mass loss results for both flat panels and wire helices are shown in various tables listed below.

Table Numbers					
Specimen	**Exposure (years)**	**Fe**	**Zn**	**Cu**	**Al**
Flat panel	1	10	13	16	19
Wire helix	1	11	14	17	20
Both	2, 4, 8	12	15	18	21
Composite	1, 2, 4, 8	22	23	24	25

3.3 DATA ANALYSIS

A systematic data analysis was performed in the period from 1992 to 2005 with the goal to improve the classification system:

- statistical characterization of the ISOCORRAG and ISOCORRAG/MICAT databases,
- series of regression analyses on the 1-year corrosion measurements on flat panels and wire-helix specimens to compare the values obtained,
- series of regression analyses with the 1-year corrosion measurements to verify that the environmental data could be used to predict corrosion losses,
- derivation of dose-response functions for calculation of the corrosion attack in terms of the environmental data, and
- series of regression analyses on the multiyear corrosion losses for steel, zinc, copper, and aluminium for formulation of a model to predict the long-term corrosion kinetics.

TABLE 10—Corrosion Losses of Steel Flat Panels (μm/year), 1 Year Exposure

		Steel Flat Specimens (μm/year)						
Code	**Testing Site**	**sq11**	**sq12**	**sq13**	**sq14**	**sq15**	**sq16**	**Ave.**
ARG 1	Iugazu	5.7		5.8	6.8	5.5	5.3	5.8
ARG 2	Camet	24.9		54.8	78.2	66.0	68.3	45.2
ARG 3	Buenos Aires	16.2	14.4	12.3	15.1	15.7		14.7
ARG 4	San Juan	4.6	4.5	4.6	4.3	5.6	4.0	4.6

(*Continued*)

TABLE 10—Corrosion Losses of Steel Flat Panels (μm/year), 1 Year Exposure (Continued)

Code	Testing Site	Steel Flat Specimens (μm/year)						Ave.
		sq11	sq12	sq13	sq14	sq15	sq16	
ARG 5	Jubay-Antarct.	37.3		35.9		41.1		38.1
CND 1	Boucherville	25.5	21.5	28.3	21.3	25.5	21.6	24.0
CS 1	Kašperské Hory	27.1	23.1	26.0	23.3	30.7	25.7	26.0
CS 2	Praha-Běchovice	62.4	44.3	43.3	42.1	53.3	38.9	47.4
CS 3	Kopisty	87.9	66.1	57.7	59.1	84.1	69.2	70.7
D 1	Bergisch Glad.	38.5	40.6	35.3	37.4	31.8	33.8	36.2
SF 1	Helsinki	37.5	33.0	41.2	28.3	31.4	28.6	33.3
SF 2	Otaniemi	30.9	21.4	34.6	19.9	26.2	20.8	25.6
SF 3	Ahtari	16.7	11.0	15.7	9.7	12.5	11.3	12.8
F 1	Saint Denis	40.7	34.5	44.2	35.0	35.7	33.1	37.2
F 2	Ponteau Mart.	83.5	68.1	70.7	66.4	73.2	72.6	72.4
F 3	Picherande	19.6	15.5	19.6	12.3	15.2	14.4	16.1
F 4	St. Remy	48.1	39.2	48.2	37.4	42.3	42.7	43.1
F 5	Salins de Gir.	82.1	70.2	70.5	72.0	72.0	71.0	73.0
F 6	Ostende (B)	118.0	95.8	83.5	90.0	103.0	105.0	99.3
F 7	Paris	37.6	39.7	48.0	48.0	39.0	38.0	41.7
F 8	Auby	101.0	95.1	126.0	132.0	102.0	81.0	106.3
F 9	Biarritz	83.2	103.0	89.0	85.0	81.0	81.0	87.4
JAP 1	Choshi	44.0	40.9	45.2	39.7	48.2	42.1	43.3
JAP 2	Tokyo	38.0	28.6	48.8	32.1	55.8	33.8	39.5
JAP 3	Okinawa	118.0	138.0	54.7	57.2	44.8	39.2	75.2
NZ 1	Judgeford	20.7	18.9	19.1	19.5	18.4	17.5	19.0
N 1	Oslo	26.1	26.6	30.2	21.5	26.5	20.1	25.2
N 2	Borregaard	68.4	60.8	66.0	60.0	61.4	53.6	61.7
N 3	Birkenes	21.4	18.6	21.8	17.1	20.7	18.6	19.7
N 4	Tannanger	60.9	44.7	48.4	50.3	100.4	53.0	59.6
N 5	Bergen	27.2	22.3	27.7	25.7	38.0	26.3	27.9
N 6	Svanwik	21.5	20.0	22.5	17.3	19.7	20.1	20.2
E 1	Madrid	31.9	29.8	33.2	22.4	26.1	22.7	27.7
E 2	El Pardo	16.3	17.0	17.4	12.9	15.6	13.7	15.5
E 3	Lagoas	34.4	24.7	25.2	27.6	22.7	26.8	26.9
E 4	Baracaldo	45.9	51.1	45.0	44.3		33.3	43.9
S 1	Stockholm Vanadis	28.0	26.9	28.1	21.6	23.5	18.1	24.4
S 2	Kattesand	43.0	28.8	33.1	33.3	41.8	31.2	35.2
S 3	Kvarnvik	68.0	44.3	58.6	53.2	93.3	51.9	61.6
UK 1	Stratford	42.3	35.1	36.0	37.6	42.9	38.0	38.7
UK 2	Crowthorne	36.4	37.4	38.8	37.6	36.9		37.4
UK 3	Rye	65.9	43.9	55.8	48.7	72.8	64.3	58.5

TABLE 10—Corrosion Losses of Steel Flat Panels (μm/year), 1 Year Exposure (Continued)

Code	Testing Site	Steel Flat Specimens (μm/year)						Ave.
		sq11	sq12	sq13	sq14	sq15	sq16	
UK 4	Fleet Hall	39.6	35.4	38.1	41.7	41.8	37.7	39.0
US 1	Kure Beach	40.2	32.5	37.6	35.6	43.8		37.9
US 2	Newark	27.8	21.6	29.8				26.4
US 3	Panama	373.0						373.0
US 4	Res. Tri. Park	23.1						23.1
US 5	Point Reyes	43.2	38.7	23.4	41.2	37.4		36.8
US 6	Los Angeles	21.3	20.4	16.1	27.5			21.4
SU 1	Murmansk	26.1	26.4	29.8	28.5	35.3	41.8	31.3
SU 2	Batumi	32.2	33.6	29.4	30.2	22.5	24.2	28.7
SU 3	Vladivostok	39.0	26.4	22.4	23.9	17.4	26.3	25.9
SU 4	Oymyakon	0.8	0.4	0.9	0.6	1.2	0.8	0.8

TABLE 11—Corrosion Losses of Steel Helices (μm/year), 1-Year Exposure

Code	Testing Site	Steel Helix Specimens (μm/year)						Ave.
		sq11	sq12	sq13	sq14	sq15	sq16	
ARG 1	Iugazu	9.3	9.9	8.5	9.9	9.8	7.7	9.2
ARG 2	Camet	67.7	62.1	69.9	71.4		114.5	77.1
ARG 3	Buenos Aires	25.9	22.8	24.0	24.6	29.6	23.9	25.1
ARG 4	San Juan	9.6		6.5	6.7	7.0	6.9	7.4
ARG 5	Jubay-Antarct.	69.4		52.3		67.2		62.9
CND 1	Boucherville	28.9	24.5	27.8	23.8	30.8	24.5	26.7
CS 1	Kašperské Hory	53.9	40.5	47.7	38.8	62.3	42.9	47.6
CS 2	Praha-Běchovice	76.1	53.5	76.8	49.2	76.3	58.4	65.0
CS 3	Kopisty	125.0	93.5	113.0	90.9	124.0	102.0	108.0
D 1	Bergisch Glad.	57.5	60.2	40.4	53.4	50.6	50.5	52.1
SF 1	Helsinki	49.3	43.6	53.0	34.0	41.4	34.8	42.7
SF 2	Otaniemi	42.9	35.4	48.1	29.4	27.8	33.4	36.2
SF 3	Ahtari	19.5	14.4	20.3	11.8	16.3	14.4	16.1
F 1	Saint Denis	57.6	42.9	52.6	52.0	49.7	43.0	49.6
F 2	Ponteau Mart.	123.7	136.7	95.2	112.8	142.6	130.1	123.5
F 3	Picherande	23.7	18.8	27.6	19.4	22.7	24.4	22.8
F 4	St. Remy	102.0	91.3	95.2	95.5	98.6	85.7	94.7
F 5	Salins de Gir.	82.8	128.0	149.0	138.0	148.0	144.0	132.0

(*Continued*)

TABLE 11—Corrosion Losses of Steel Helices (µm/year), 1-Year Exposure (Continued)

		Steel Helix Specimens (µm/year)						
Code	**Testing Site**	**sq11**	**sq12**	**sq13**	**sq14**	**sq15**	**sq16**	**Ave.**
F 6	Ostende (B)		97.3	127.0	136.0	145.0	145.0	130.0
F 7	Paris		56.7	49.0	51.0	51.0	51.0	51.7
F 8	Auby	153.0	151.0	172.0	149.0	134.0	112.0	145.0
F 9	Biarritz	74.3	84.0	81.0	67.0	47.0	54.0	67.9
JAP 1	Choshi		102.0	97.8	90.4	86.6	92.1	93.7
JAP 2	Tokyo		27.4	46.6	38.8	43.8	38.5	39.1
JAP 3	Okinawa		166.0	96.0	123.0	78.6	80.9	109.0
NZ 1	Judgeford	30.5	32.6	34.9	49.3	34.4	33.3	35.8
N 1	Oslo	40.5	38.0	44.7	28.1	33.5	24.9	35.0
N 2	Borregaard	101.0	81.7	100.0	90.6	92.6	79.7	90.9
N 3	Birkenes	34.1	24.9	28.6	23.4	27.8	23.4	27.0
N 4	Tannanger	83.2	64.7	61.7	78.0	77.8	79.4	74.1
N 5	Bergen	33.5	28.9	33.1	30.1	36.2	34.9	32.8
N 6	Svanwik	32.3	25.6	30.1	26.3	30.8	28.7	29.0
E 1	Madrid		29.5	37.1	29.7	28.6	21.5	29.3
E 2	El Pardo		21.4	23.5	20.6	23.0	19.7	21.6
E 3	Lagoas		37.6	34.0	36.2			35.9
E 4	Baracaldo		70.9	56.9	59.1	48.8	44.5	56.0
S 1	Stockholm Vanadis	44.0	40.2	56.8	34.5	40.0	33.7	41.5
S 2	Kattesand	66.0	46.1	80.2	53.4	67.8	51.2	60.8
S 3	Kvarnvik	80.0	65.9	64.0	69.3	73.5	53.6	67.7
UK 1	Stratford	47.8	51.5	56.3	56.9	55.5	33.8	50.3
UK 2	Crowthorne	73.8	53.9	51.4	56.2	54.1		57.9
UK 3	Rye	91.7	98.1	90.4	89.5	92.5	92.6	92.5
UK 4	Fleet Hall	61.6	50.2	57.6	53.3	65.5	53.2	56.9
US 1	Kure Beach	63.7	72.3	67.5	112.0	93.6		81.8
US 2	Newark	28.1	26.5	27.3				27.3
US 3	Panama	224.0	369.0	311.0	283.0			297.0
US 4	Res. Tri. Park							
US 5	Point Reyes	149.0	148.0	141.0	162.0	134.0		147.0
US 6	Los Angeles	19.4	19.0					19.2
SU 1	Murmansk	65.8	47.1	47.4	49.1	50.8	49.7	51.7
SU 2	Batumi	28.9	35.7	27.2	26.9	26.6	26.9	28.7
SU 3	Vladivostok	104.0	51.5	61.6	51.1	58.3	744	66.8
SU 4	Oymyakon	2.8	1.8	1.3		1.7		1.9

TABLE 12—Corrosion Losses of Steel (μm), 2, 4, and 8 Years Exposure

		2 Years		4 Years		8 Years	
Code	**Testing Site**	**flat**	**helix**	**flat**	**helix**	**flat**	**helix**
ARG 1	Iugazu	10.1	15.4	11.2	18.0		
ARG 2	Camet	46.1	101.0	123.2	168.4		
ARG 3	Buenos Aires	26.6	29.8		51.6		
ARG 4	San Juan	6.2	7.6				
ARG 5	Jubay-Antarct.	50.0	51.2				
CND 1	Boucherville	32.7	40.9	31.1	71.2	55.2	55.2
CS 1	Kašperské Hory	35.5	71.9	51.5	110.0	65.6	107.2
CS 2	Praha-Běchovice	76.2	115.0	88.9	175.2	131.2	161.6
CS 3	Kopisty	108.0	175.0	111.0	272.0	166.4	263.2
D 1	Bergisch Glad.	50.8	74.8			98.4	122.4
SF 1	Helsinki	60.0	74.4	82.0	97.2	103.2	139.2
SF 2	Otaniemi	43.8	63.8	58.8	73.6	73.6	111.2
SF 3	Ahtari	24.8	31.8	34.8	42.4	44.8	56.8
F 1	Saint Denis	59.6	78.3	79.3	108.4	106.4	
F 2	Ponteau Mart.	121.0	192.0	179.6	219.6	284.0	
F 3	Picherande	29.4	36.8	32.7	43.6		
F 4	St. Remy	84.4	103.2	102.0	198.8	147.2	
F 5	Salins de Gir.	117.2	169.0	221.2		288.8	
F 6	Ostende (B)	187.0	181.0	304.0			
F 7	Paris	67.4	105.0	123.0	122.0	176.0	
F 8	Auby	150.0	288.0	227.2	370.0	318.0	
F 9	Biarritz	120.2	93.5	157.6	116.0		
JAP 1	Choshi	68.2	163.0	125.0	284.0	216.0	
JAP 2	Tokyo	59.8	47.0	91.2	63.6	126.4	
JAP 3	Okinawa	202.0	239.0	376.0	337.0		
NZ 1	Judgeford	28.8	45.2				
N 1	Oslo	41.2	53.2	49.2	70.0	57.6	68.4
N 2	Borregaard	103.0	135.0	134.0	227.0	170.4	271.8
N 3	Birkenes	37.8	50.4	52.8	68.4	60.6	75.6
N 4	Tannanger	84.4	103.0	121.0	161.0	148.2	160.8
N 5	Bergen	39.8	47.0	56.4	68.4	63.0	76.2
N 6	Svanwik	33.8	47.4	46.8	67.4	54.6	78.6
E 1	Madrid	42.6		44.8	59.6	53.1	64.8
E 2	El Pardo	28.2		35.6	46.0	43.2	
E 3	Lagoas	48.6		68.4	74.8	95.2	104.0
E 4	Baracaldo	66.8		77.2	107.2	103.2	147.2

(*Continued*)

TABLE 12—Corrosion Losses of Steel (µm), 2, 4, and 8 Years Exposure (Continued)

		2 Years		4 Years		8 Years	
Code	Testing Site	flat	helix	flat	helix	flat	helix
S 1	Stockholm Vanadis	40.8	77.0	54.4	101.0	66.4	172.0
S 2	Kattesand	54.0	92.4	80.3	151.0	115.2	285.6
S 3	Kvarnvik	79.4	107.0	110.0	159.0	148.0	280.0
UK 1	Stratford	62.6	94.5	82.3	132.4		
UK 2	Crowthorne	62.2	91.4	79.3	128.4		
UK 3	Rye	90.8	174.0	114.0	240.0		
UK 4	Fleet Hall	65.3	67.0	91.2	155.0		
US 1	Kure Beach					189.5	831.2
US 2	Newark					65.6	82.4
US 3	Panama		870.0				
US 4	Res. Tri. Park						
US 5	Point Reyes	55.0	244.0			126.4	
US 6	Los Angeles	24.8				57.6	
SU 1	Murmansk	44.4	71.8	80.8	104.0		
SU 2	Batumi	41.4	39.8	52.8	50.4		
SU 3	Vladivostok	48.2	153.0	82.4	244.0		
SU 4	Oymyakon	2.1	3.3	4.0	6.4		

TABLE 13—Corrosion Losses of Zinc Flat Panels (µm/year), 1 Year Exposure

		Zinc Flat Specimens (µm/year)						
Code	Testing Site	sq11	sq12	sq13	sq14	sq15	sq16	Ave.
ARG 1	Iugazu	2.39	1.31	1.17	0.56	1.19	1.53	1.36
ARG 2	Camet	1.30		1.21	2.55	2.37	4.26	1.98
ARG 3	Buenos Aires	1.12	0.87	1.05	0.88	1.42	0.65	1.00
ARG 4	San Juan	0.26	0.14	0.13	0.17	0.22	0.22	0.19
ARG 5	Jubay-Antarct.	1.26		2.48		1.22		1.65
CND 1	Boucherville	1.19	1.59	1.32	1.56	1.17	1.59	1.40
CS 1	Kašperské Hory	1.89	1.31	1.50	1.05	1.80	3.80	1.90
CS 2	Praha-Běchovice	2.18	1.49	2.00	1.41	1.70	7.90	2.80
CS 3	Kopisty	5.33	2.51	3.68	2.44	2.80	4.00	3.50
D 1	Bergisch Glad.	2.84	2.65	1.55	0.97	0.90	0.69	1.60
SF 1	Helsinki	1.55	1.29	1.40	0.90	1.20	1.30	1.30
SF 2	Otaniemi	1.08	0.89	0.90	0.50	0.80	1.10	0.90
SF 3	Ahtari	0.77	0.51	0.90	0.40	0.90	0.70	0.70
F 1	Saint Denis	1.80	1.60	1.40	1.50	1.40	1.20	1.50
F 2	Ponteau Mart.	2.10	2.50	2.50	3.40	2.80	2.50	2.65

TABLE 13—Corrosion Losses of Zinc Flat Panels (μm/year), 1 Year Exposure (Continued)

		Zinc Flat Specimens (μm/year)						
Code	Testing Site	sq11	sq12	sq13	sq14	sq15	sq16	Ave.
F 3	Picherande	1.00	1.10	1.50	0.60	0.80	0.60	0.90
F 4	St. Remy	1.70	1.80	1.70	1.30	1.50	1.10	1.50
F 5	Salins de Gir.	7.30	2.20	6.10	3.90	4.00	3.90	4.55
F 6	Ostende (B)	4.76	4.30	4.83	5.40	5.70	5.80	5.10
F 7	Paris	4.67	1.65	4.10	4.00	1.70	1.60	3.00
F 8	Auby	6.30	6.50	6.50	5.20	4.70	4.40	5.60
F 9	Biarritz	1.76	5.60		4.30	5.00	4.90	4.30
JAP 1	Choshi	1.60	1.40	1.50	1.40	1.70	1.30	1.40
JAP 2	Tokyo	1.00	1.40	1.30	1.50	1.60	1.90	1.50
JAP 3	Okinawa	6.30	4.10	3.70	3.00	1.90	1.60	3.40
NZ 1	Judgeford	0.56	0.65	0.99	0.72	0.40	0.21	0.66
N 1	Oslo	1.50	1.30	1.70	1.15	1.20	0.69	1.25
N 2	Borregaard	3.70	3.00	0.80	5.50	2.80	3.00	3.80
N 3	Birkenes	3.30	1.30	4.00	3.00	0.69	1.40	2.30
N 4	Tannanger	4.30	2.90	2.60	4.00	2.00	2.20	3.00
N 5	Bergen	3.10	1.70	1.60	2.40	1.70	2.10	2.10
N 6	Svanwik	0.70	0.80	0.90	1.30	0.58	0.72	0.80
E 1	Madrid	0.70	0.62	0.75	0.49	0.38	0.55	0.66
E 2	El Pardo	0.65	0.54	0.69	0.42	0.30	0.42	0.59
E 3	Lagoas	1.13	1.19	1.26	0.62	0.97	1.02	1.00
E 4	Baracaldo	1.23	1.20	1.23	1.51		0.98	1.20
S 1	Stockholm Vanadis	0.84	0.76	0.66	0.48	0.55	0.55	0.64
S 2	Kattesand	1.45	1.57	1.34	1.80	1.23	1.66	1.50
S 3	Kvarnvik	1.83	2.05	1.67	1.80	1.61	2.03	1.80
UK 1	Stratford	0.98	1.63	2.10	1.81	1.67	1.85	1.67
UK 2	Crowthorne	0.98	1.18	1.13	1.10	1.12		1.10
UK 3	Rye	1.85	3.64	3.01	1.39	2.70	2.62	2.54
UK 4	Fleet Hall	1.56	1.26	1.23	1.34	1.39	1.24	1.34
US 1	Kure Beach	2.24	1.57	2.44	2.07	1.90	1.83	2.01
US 2	Newark	2.25	1.79	1.96	1.79	1.85	2.09	1.96
US 3	Panama	20.00	18.00	16.90	15.20			17.50
US 4	Res. Tri. Park	0.84	0.83					0,84
US 5	Point Reyes	1.87	1.40	2.12	1.61	1.65		1.73
US 6	Los Angeles	0.88	1.19	1.32	1.25	0.96	0.95	1.09
SU 1	Murmansk	1.18	1.09	1.05	1.20	1.00	1.15	1.10
SU 2	Batumi	1.76	1.86	1.58	1.76	1.50	1.16	1.60
SU 3	Vladivostok	1.77	2.25	2.07	2.30	2.58	2.93	2.30
SU 4	Oymyakon	0.42	0.41	0.65	0.21	0.29	0.18	0.36

TABLE 14—Corrosion Losses of Zinc Helices (µm/year), 1 Year Exposure

		Zinc Helix Specimens (µm/year)						
Code	**Testing Site**	**sq11**	**sq12**	**sq13**	**sq14**	**sq15**	**sq16**	**Ave.**
ARG 1	Iugazu	1.58	1.05	3.50	1.68	2.23	1.60	1.94
ARG 2	Camet	1.71	2.38	4.52	3.34		7.01	3.79
ARG 3	Buenos Aires	1.99	1.15	0.74	1.39	2.27	1.56	1.52
ARG 4	San Juan			0.74	1.27	1.17	0.86	1.01
ARG 5	Jubay-Antarct.	3.29		1.22		4.49		3.00
CND 1	Boucherville	1.91	1.87	2.02	2.07	2.10	2.00	2.00
CS 1	Kašperské Hory	2.30	1.67	1.85	1.56	4.40	1.65	2.20
CS 2	Praha-Běchovice	3.64	3.28	2.68	2.29	5.20	2.60	3.30
CS 3	Kopisty	6.18	3.74	4.25	4.01	6.10	4.20	4.75
D 1	Bergisch Glad.	2.35	3.07	1.92	0.93	1.22	1.20	1.80
SF 1	Helsinki	3.20	2.42	2.70	1.80	2.30	1.50	2.32
SF 2	Otaniemi	1.76	1.60	2.30	1.00	1.90	2.10	1.80
SF 3	Ahtari	1.52	0.92	1.50	0.80	1.20	1.20	1.20
F 1	Saint Denis	3.70	5.70	4.00	2.66	2.55	2.42	3.51
F 2	Ponteau Mart.	16.90	8.50	22.90	12.39	16.61	9.70	14.50
F 3	Picherande	1.60	2.10	3.80	1.70	2.40	1.80	2.20
F 4	St. Remy	3.70	3.80	5.10	3.70	4.45	3.30	4.01
F 5	Salins de Gir.	5.10	5.70	5.70	6.00	5.80	5.90	5.70
F 6	Ostende (B)	8.54	11.90	9.90	11.50	11.30		10.60
F 7	Paris	2.84	2.70	2.80	2.70	2.80		2.80
F 8	Auby	8.80	9.36	9.68	9.30	7.00	6.60	8.50
F 9	Biarritz	1.93	8.38	8.90	7.84	9.34	6.37	7.13
JAP 1	Choshi		3.50	3.00	2.60	2.50	2.60	2.80
JAP 2	Tokyo		1.60	1.20	1.30	1.60	1.60	1.50
JAP 3	Okinawa		7.30	7.20	16.70	9.40	3.50	8.80
NZ 1	Judgeford	1.57	1.63	1.66	0.65	0.54	0.45	1.08
N 1	Oslo	2.50	1.70	1.90	1.45	2.00	1.49	1.80
N 2	Borregaard	6.30	5.70	4.20	7.30	5.40	5.35	5.70
N 3	Birkenes	2.90	1.30	2.80	1.13	2.00	1.70	2.00
N 4	Tannanger	3.80	3.20	2.10	2.90	3.60	4.10	3.30
N 5	Bergen	2.50	1.70	1.70	1.70	3.20	2.20	2.20
N 6	Svanwik	1.10	0.90	1.40	1.00	1.16	2.60	1.40
E 1	Madrid		1.75	1.22	1.77	1.24	1.91	1.60
E 2	El Pardo		1.54	0.82	1.26	0.80	1.41	1.20
E 3	Lagoas		2.73	2.68	2.70	9.40	3.50	4.58
E 4	Baracaldo		2.07	2.73	3.99	2.41	1.80	2.60
S 1	Stockholm Vanadis	1.40		1.99	1.21	1.57	1.26	1.50

TABLE 14—Corrosion Losses of Zinc Helices (μm/year), 1 Year Exposure (Continued)								
		Zinc Helix Specimens (μm/year)						
Code	Testing Site	sq11	sq12	sq13	sq14	sq15	sq16	Ave.
S 2	Kattesand	3.35	2.50	2.66	2.30	3.34	2.89	2.85
S 3	Kvarnvik	4.10	3.05	3.26	2.70	4.30	3.78	3.50
UK 1	Stratford	1.92	1.47	1.47	1.25	1.56	1.59	1.54
UK 2	Crowthorne	1.44	1.11	1.13	1.18	1.08		1.19
UK 3	Rye	3.17	1.73	1.90	1.68	1.78	1.88	2.02
UK 4	Fleet Hall	2.15	2.26	2.31	2.29	2.32	2.31	2.27
US 1	Kure Beach	2.55	3.30	3.58	2.86	5.30	3.67	3.55
US 2	Newark	2.14	1.80	2.32	2.09	2.37	2.17	2.15
US 3	Panama	7.58						7.58
US 4	Res. Tri. Park							
US 5	Point Reyes	3.26	3.88	3.66	4.15	2.58		3.51
US 6	Los Angeles	1.51	1.43			2.04	2.06	1.76
SU 1	Murmansk	1.82	2.23	1.94	2.14	2.30	2.01	2.10
SU 2	Batumi	2.12	1.93	2.70	2.14	1.76	1.33	2.00
SU 3	Vladivostok	2.85	3.30	3.93	3.40	2.57	2.36	3.10
SU 4	Oymyakon	0.60	0.57	0.66	0.52	0.50	0.58	0.57

TABLE 15—Corrosion Losses of Zinc (μm), 2, 4, and 8 Years Exposure							
		2 Years		4 Years		8 Years	
Code	Testing Site	flat	helix	flat	helix	flat	helix
ARG 1	Iugazu	3.48	1.70	3.64	2.68		
ARG 2	Camet	3.48	1.70	3.64	2.68		
ARG 3	Buenos Aires	1.74	2.70	3.20	4.84		
ARG 4	San Juan	0.30		1.24			
ARG 5	Jubay-Antarct.	2.14	4.94				
CND 1	Boucherville	2.48	3.12	4.96	6.48	8.88	12.72
CS 1	Kašperské Hory	2.38	3.56	3.77	4.92	6.88	9.76
CS 2	Praha-Běchovice	3.62	5.41	6.61	10.20	11.68	36.16
CS 3	Kopisty	8.38	8.93	15.60	18.30	26.88	12.88
D 1	Bergisch Glad.	2.64	3.28			7.20	10.88
SF 1	Helsinki	2.40	4.80	4.40	8.00	7.28	14.16
SF 2	Otaniemi	1.60	2.40	2.80	4.00	4.16	6.16
SF 3	Ahtari	1.20	1.80	1.60	2.00	2.64	3.04
F 1	Saint Denis	2.80	8.10	4.90	10.24	9.92	
F 2	Ponteau Mart.	4.00	20.80	7.90	28.40	16.24	
F 3	Picherande	1.80	4.10	2.40	3.80		

(*Continued*)

TABLE 15—Corrosion Losses of Zinc (μm), 2, 4, and 8 Years Exposure (Continued)

Code	Testing Site	2 Years		4 Years		8 Years	
		flat	helix	flat	helix	flat	helix
F 4	St. Remy	2.80	5.30	4.50	8.72	8.56	
F 5	Salins de Gir.	7.80	9.80	11.40		13.44	
F 6	Ostende (B)	5.78	11.10	10.30			
F 7	Paris	4.50	6.60	6.20	7.70	9.76	
F 8	Auby	10.72	15.24	21.88	28.00	34.40	50.72
F 9	Biarritz	6.67	11.80	12.48	31.52		
JAP 1	Choshi	2.60	4.40	5.20	8.80	9.60	
JAP 2	Tokyo	2.20	2.80	4.00	6.00	8.00	
JAP 3	Okinawa	9.00	15.80	10.00	33.20		
NZ 1	Judgeford	1.68	3.40				
N 1	Oslo	2.60	3.60	4.12	5.60		
N 2	Borregaard	7.00	10.60	13.20	19.50		
N 3	Birkenes	3.00	3.40	5.16	3.56		
N 4	Tannanger	6.60	5.20	9.80	9.84		
N 5	Bergen	1.80	2.80	8.30	5.50		
N 6	Svanwik	1.20	1.80	1.80	2.90		
E 1	Madrid	1.38		2.40	4.72	4.48	11.76
E 2	El Pardo	1.12		1.28	3.04	2.24	
E 3	Lagoas	1.84		3.33	5.52	5.84	10.72
E 4	Baracaldo	2.48		4.04	4.28	7.04	13.36
S 1	Stockholm Vanadis	1.26	3.36	2.50	5.30	4.00	8.80
S 2	Kattesand	2.58	4.58	5.50	10.00	9.60	20.80
S 3	Kvarnvik	3.02	5.38	7.20	12.90	16.80	26.40
UK 1	Stratford	3.97	2.31	7.66	3.61		
UK 2	Crowthorne	2.22	1.78	4.89	3.35		
UK 3	Rye	4.08	2.29	6.18	3.47		
UK 4	Fleet Hall	2.19	5.31	4.24	7.73		
US 1	Kure Beach	3.90	6.48	6.52	9.72	9.60	16.24
US 2	Newark	3.72					17.28
US 3	Panama	37.20				123.90	226.40
US 4	Res. Tri. Park						
US 5	Point Reyes	3.90	5.36			3.84	10.56
US 6	Los Angeles	2.38				5.84	
SU 1	Murmansk	2.08	3.62	3.90	7.40		
SU 2	Batumi	2.74	3.68	4.52	1.28		
SU 3	Vladivostok	2.30	4.48	4.12	6.80		
SU 4	Oymyakon	0.64	0.64	0.68	1.04		

TABLE 16—Corrosion Losses of Copper Flat Panels (µm/year), 1 Year Exposure

Code	Testing Site	Copper Flat Specimens (µm/year)						Ave.
		sq11	sq12	sq13	sq14	sq15	sq16	
ARG 1	Iugazu	0.99	0.61	0.81		0.76	0.62	0.76
ARG 2	Camet	2.41		2.04	2.27	2.26	2.21	2.24
ARG 3	Buenos Aires	0.81	0.47	0.63	0.69	0.93	0.58	0.68
ARG 4	San Juan	0.19	0.18	0.16	0.18	0.17	0.22	0.18
ARG 5	Jubay-Antarct.	1.98		2.10		1.97		2.02
CND 1	Boucherville	1.03	1.17	1.08	1.18	1.02	1.27	1.10
CS 1	Kašperské Hory	2.02	2.22	1.90	2.17	1.90	2.00	2.00
CS 2	Praha-Běchovice	1.51	1.40	1.46	1.11	1.20	1.20	1.30
CS 3	Kopisty	4.06	3.95	2.92	3.02	2.70	3.30	3.30
D 1	Bergisch Glad.	0.98	0.82	1.09	0.33	0.28	0.16	0.60
SF 1	Helsinki	0.63	0.70	0.70	0.60	0.70	1.00	0.70
SF 2	Otaniemi	0.57	0.67	0.90	0.90	0.90	1.00	0.80
SF 3	Ahtari	0.68	0.68	0.90	0.60	0.90	0.80	0.76
F 1	Saint Denis	1.30	1.50	1.10	1.06	1.10	1.00	1.20
F 2	Ponteau Mart.	2.60	2.60	3.40	2.70	2.40	2.60	2.70
F 3	Picherande	1.40	1.70	1.60	1.10	1.40	1.20	1.40
F 4	St. Remy	2.30	1.70	1.70	1.70	1.60	1.80	1.80
F 5	Salins de Gir.	3.30	3.50	2.90	3.20	3.20	3.00	3.20
F 6	Ostende (B)	4.30	2.50	2.60	3.00	3.00	3.00	3.10
F 7	Paris	1.60	1.50	1.00	0,90	1.60	1.50	1.40
F 8	Auby	1.30	1.80	2.10	2.20	1.80	2.00	1.90
F 9	Biarritz	2.01	4.60	4.30	3.20	3.80	4.20	3.69
JAP 1	Choshi	1.28	1.42	1.21	1.38	1.23	1.58	1.35
JAP 2	Tokyo	0.62	0.59	0.62	0.63	0.69	0.78	0.66
JAP 3	Okinawa	2.20	2.60	2.10	2.50	1.80	1.70	2.10
NZ 1	Judgeford	1.30	1.34	1.31	1.45	1.39	1.31	1.35
N 1	Oslo	0.70	0.70	0.60	0.66	0.54	0.58	0.60
N 2	Borregaard	1.50	1.20	1.40	1.30	1.50		1.40
N 3	Birkenes	1.20	1.20	1.50	1.30	1.03	1.30	1.30
N 4	Tannanger	2.00	2.00	1.60	1.80	2.10		1.90
N 5	Bergen	0.90	0.90	1.00	1.10	1.00		1.00
N 6	Svanwik	0.90	0.80	1.00	0.80	0.66		0.80
E 1	Madrid	0.51	0.59	0.61	0.42	0.30	0.39	0.53
E 2	El Pardo	1.32	1.78	0.85	1.04	0.78	1.05	1.10
E 3	Lagoas	1.32	1.21	1.02	0.75	0.67	0.96	1.00
E 4	Baracaldo	1.37	1.26	1.20	1.04		0.89	1.20
S 1	Stockholm Vanadis	0.54	0.71	0.60	0.57	0.43	0.55	0.60

(*Continued*)

TABLE 16—Corrosion Losses of Copper Flat Panels (µm/year), 1 Year Exposure (Continued)

		Copper Flat Specimens (µm/year)						
Code	**Testing Site**	**sq11**	**sq12**	**sq13**	**sq14**	**sq15**	**sq16**	**Ave.**
S 2	Kattesand	1.69	1.52	1.67	1.90	1.67	1.69	1.70
S 3	Kvarnvik	2.57	2.45	2.46	3.00	3.10	3.10	2.80
UK 1	Stratford	0.89	1.29	1.29	1.09	1.16	1.04	1.13
UK 2	Crowthorne	0.89	1.13	1.21	1.15	1.13		1.10
UK 3	Rye	1.82	1.49	2.43	1.34	1.80	2.28	1.86
UK 4	Fleet Hall	0.98	0.91	0.81	1.06	0.84	0.97	0.93
US 1	Kure Beach	2.58	3.19	2.57	2.52	3.22	3.03	2.85
US 2	Newark	1.34	1.38	1.29	1.13	1.48	1.74	1.39
US 3	Panama	6.14	4.93	4.34	4.95	7.15	5.26	5.46
US 4	Res. Tri. Park	2.43						2.43
US 5	Point Reyes	2.32	2.64	2.30	2.38	2.45	1.78	2.32
US 6	Los Angeles	1.38	1.07	1.10	1.58	0.86	0.96	1.16
SU 1	Murmansk	1.56	1.67	1.79	1.65	1.60	1.88	1.70
SU 2	Batumi	2.38	2.57	1.99	1.51	1.82	1.50	2.00
SU 3	Vladivostok	1.65	1.88	1.57	1.10	1.10	1.30	1.40
SU 4	Oymyakon	0.08	0.08	0.09		0.10		0.09

TABLE 17—Corrosion Losses of Copper Helices (µm/year), 1 Year Exposure

		Copper Helix Specimens (µm/year)						
Code	**Testing Site**	**sq11**	**sq12**	**sq13**	**sq14**	**sq15**	**sq16**	**Mean**
ARG 1	Iugazu	0.54	0.59	0.64	0.64	0.48	0.52	0.57
ARG 2	Camet	2.54	2.07	2.31	2.29		3.24	2.49
ARG 3	Buenos Aires	0.81	0.74	0.85	0.73	0.77	0.71	0.77
ARG 4	San Juan			0.32	0.29	0.33	0.61	0.39
ARG 5	Jubay-Antarct.	3.17		2.85		3.06		3.03
CND 1	Boucherville	1.08	1.12	1.36	1.34	1.40	1.41	1.30
CS 1	Kašperské Hory	3.14	2.38	2.33	2.31	2.80	2.40	2.60
CS 2	Praha-Běchovice	1.86	1.91	2.34	1.64	1.80	1.65	1.90
CS 3	Kopisty	4.66	5.16	3.61	3.53	3.40	4.60	4.20
D 1	Bergisch Glad.	1.13	1.03	1.58	0.38	0.50	0.08	0.78
SF 1	Helsinki	1.29	1.25	1.30	1.10	1.20	1.50	1.30
SF 2	Otaniemi	1.27	1.40	1.60	1.40	1.60	1.70	1.50
SF 3	Ahtari	1.19	0.70	1.30	0.80	1.10	1.60	1.10
F 1	Saint Denis	3.50	2.60	1.60	1.77	1.93	1.51	2.15
F 2	Ponteau Mart.	7.20	5.50	8.90	6.64	8.67	6.33	7.21
F 3	Picherande	1.10	1.60	1.40	1.20	2.00	1.24	1.45

TABLE 17—Corrosion Losses of Copper Helices (µm/year), 1 Year Exposure (Continued)

Code	Testing Site	Copper Helix Specimens (µm/year)						Mean
		sq11	sq12	sq13	sq14	sq15	sq16	
F 4	St. Remy	3.90	3.20	4.10	3.86	3.45	3.79	3.72
F 5	Salins de Gir.	8.90	4.50	4.70	4.80	4.70	4.70	5.30
F 6	Ostende (B)	3.00	2.90	4.40	3.50	3.60		3.50
F 7	Paris	1.83	3.20	2.60	2.80	2.70		2.60
F 8	Auby	1.60	2.10	2.70	2.90	2.70	2.50	2.40
F 9	Biarritz	4.30	5.00	4.10	3.90	5.70	4.10	4.50
JAP 1	Choshi		2.29	2.27	1.94	2.53	2.41	2.29
JAP 2	Tokyo		0.99	0.96	1.06	1.35	1.22	1.12
JAP 3	Okinawa		4.70	3.30	6.00	4.00	3.40	4.30
NZ 1	Judgeford	1.51	1.37	1.66	1.96	1.58	1.49	1.60
N 1	Oslo	1.10	1.10	0.80	0.85	0.67	0.67	0.90
N 2	Borregaard	2.60	1.90	4.60	2.35	2.40	2.30	2.70
N 3	Birkenes	1.20	1.20	1.60	1.32	1.07	1.10	1.25
N 4	Tannanger	3.80	3.10	2.50	3.20	3.60	3.20	3.20
N 5	Bergen	1.00	1.10	1.00	1.30	1.14	1.20	1.10
N 6	Svanwik	0.80	1.10	1.20	0.90	0.75	1.00	1.00
E 1	Madrid		0.93	1.04	0.76	0.58	0.70	0.80
E 2	El Pardo		1.66	1.21	1.05	0.95	0.88	1.20
E 3	Lagoas		1.40	0.99		4.00	3.40	2.92
E 4	Baracaldo		1.94	1.45	1.60	1.31	1.27	1.50
S 1	Stockholm Vanadis	1.09	1.29	1.16	0.97	0.87	0.92	1.10
S 2	Kattesand	2.20	2.27	2.48	1.90	2.50	2.63	2.30
S 3	Kvarnvik	4.10		4.99	4.60	5.30	5.45	4.90
UK 1	Stratford	1.40	1.30	1.37	1.39	1.33	1.41	1.37
UK 2	Crowthorne	1.32	1.33	1.40	1.41	1.41		1.37
UK 3	Rye	4.02	4.18	4.31	4.35	4.18	4.15	4.20
UK 4	Fleet Hall	1.44	1.61	1.66	1.59	1.57	1.62	1.58
US 1	Kure Beach	3.73	5.73	3.35	5.06	4.53	5.08	4.58
US 2	Newark	1.81	1.85	2.41	1.59	1.83	2.15	1.94
US 3	Panama	11.40	11.80	10.00	9.99	16.00	10.60	11.60
US 4	Res. Tri. Park							
US 5	Point Reyes	5.47	6.22	3.37	4.98	4.38	2.15	4.43
US 6	Los Angeles	2.17	1.94	2.08	2.28	1.75	1.99	2.04
SU 1	Murmansk	2.03	2.82	2.47	3.12	2.50	3.67	2.80
SU 2	Batumi	1.99	2.70	1.76	1.83	1.80	1.49	1.90
SU 3	Vladivostok	2.16	2.70	2.92	2.30	1.90	2.25	2.40
SU 4	Oymyakon	0.10	0.11	0.11	0.10	0.13	0.12	0.11

TABLE 18—Corrosion Losses of Copper (μm), 2, 4, and 8 Years Exposure

		2 Years		4 Years		8 Years	
Code	Testing Site	flat	helix	flat	helix	flat	helix
ARG 1	Iugazu	1.82	0.86	3.76	1.32		
ARG 2	Camet	3.30	2.88	2.60	4.68		
ARG 3	Buenos Aires	1.06	1.30	1.88	2.12		
ARG 4	San Juan	0.30		0.80			
ARG 5	Jubay-Antarct.	2.34	4.16				
CND 1	Boucherville	1.62	1.80	2.68	3.44	4.16	5.92
CS 1	Kašperské Hory	3.02	3.80	4.18	6.01	5.36	7.52
CS 2	Praha-Běchovice	2.80	4.20	4.58	6.70	6.08	8.88
CS 3	Kopisty	6.28	8.28	9.75	13.70	12.88	13.52
D 1	Bergisch Glad.	1.40	1.72			3.36	4.16
SF 1	Helsinki	1.00	2.00	2.00	3.60	3.28	5.52
SF 2	Otaniemi	1.20	2.40	2.00	3.60	2.96	5.44
SF 3	Ahtari	1.20	1.80	2.00	2.80	2.72	4.24
F 1	Saint Denis	2.10	2.60	2.90	3.90	5.68	
F 2	Ponteau Mart.	4.10	6.10	5.40	8.00	8.72	
F 3	Picherande	2.30	1.60	3.30	2.90		
F 4	St. Remy	2.90	3.40	3.70	4.60		
F 5	Salins de Gir.	4.10	9.10	7.50		8.24	
F 6	Ostende (B)	4.20	10.90	7.10			
F 7	Paris	2.00	4.70	5.10	5.80	6.88	
F 8	Auby	3.20	4.90	5.70	8.40	9.76	12.96
F 9	Biarritz	5.10	5.40	6.92	7.76		
JAP 1	Choshi	1.82	2.82	3.04	6.04	4.24	
JAP 2	Tokyo	1.10	1.82	2.24	2.96	3.92	
JAP 3	Okinawa	3.00	8.80	4.40	9.20		
NZ 1	Judgeford						
N 1	Oslo	1.20	1.60	1.88	2.16		
N 2	Borregaard	2.80	3.80	4.64	6.64		
N 3	Birkenes	2.00	1.80	3.40	2.88		
N 4	Tannanger	2.60	4.40	3.48	5.52		
N 5	Bergen	1.60	1.40	2.80	2.72		
N 6	Svanwik	1.20	0.60	1.60	0.41		
E 1	Madrid	1.02		1.64	2.16	2.64	3.60
E 2	El Pardo	2.32		3.08	3.04	4.48	
E 3	Lagoas	1.70		2.11		2.88	3.12
E 4	Baracaldo	2.32		3.44	5.92	5.28	10.40
S 1	Stockholm Vanadis	1.06	1.90	1.38	2.84	3.20	4.00

TABLE 18—Corrosion Losses of Copper (μm), 2, 4, and 8 Years Exposure (Continued)

		2 Years		**4 Years**		**8 Years**	
Code	**Testing Site**	**flat**	**helix**	**flat**	**helix**	**flat**	**helix**
S 2	Kattesand	2.60	3.60	3.76	4.60	5.60	7.20
S 3	Kvarnvik	3.32	5.42	4.28	7.16	5.60	8.80
UK 1	Stratford	1.98	2.88	3.88	5.24		
UK 2	Crowthorne	1.89	2.88	3.67	5.26		
UK 3	Rye	2.23	13.70	3.84	27.10		
UK 4	Fleet Hall	2.80	3.40	4.64	6.48		
US 1	Kure Beach	3.70	7.04	6.44	6.96	10.64	12.88
US 2	Newark		2.10	3.26		6.80	10.48
US 3	Panama	8.04	13.90	18.20	25.10	35.60	40.56
US 4	Res. Tri. Park						
US 5	Point Reyes	3.20	7.02	4.88	8.88	5.68	10.40
US 6	Los Angeles	1.62	3.04			4.24	6.80
SU 1	Murmansk	2.62	3.12	3.76	5.16		
SU 2	Batumi	4.34	4.30	6.04	6.24		
SU 3	Vladivostok	2.18	2.98	2.68	3.96		
SU 4	Oymyakon	0.11	0.12	0.20	0.24		

TABLE 19—Corrosion Losses of Aluminum Flat Panels (μm/year), 1 Year Exposure

		Aluminum Flat Specimens (μm/year)						
Code	**Testing Site**	**sq11**	**sq12**	**sq13**	**sq14**	**sq15**	**sq16**	**Ave.**
ARG 1	Iugazu	0.03	0.03	0.08	0.05	0.10	0.05	0.06
ARG 2	Camet	0.14		0.23		0.30	0.13	0.19
ARG 3	Buenos Aires	0.05	0.08	0.03	0.06	0.06	0.07	0.06
ARG 4	San Juan	0.02	0.02	0.06	0.02	0.02	0.02	0.03
ARG 5	Jubay-Antarct.	1.54		1.07		1.38		1.33
CND 1	Boucherville	0.22	0.42	0.58	0.42	0.40	0.53	0.40
CS 1	Kašperské Hory	0.51	0.47	0.36	0.89	0.58	0.16	0.50
CS 2	Praha-Běchovice	0.87	0.68	0.42	0.94	0.60	0.18	0.60
CS 3	Kopisty	0.83	0.66	0.56	0.95	0.78	0.31	0.70
D 1	Bergisch Glad.	0.18	0.13	0.48				0.26
SF 1	Helsinki	0.25	0.32	0.24	0.20	0.32	0.36	0.30
SF 2	Otaniemi	0.07	0.14	0.13	0.03	0.22	0.22	0.14
SF 3	Ahtari	0.04	0.09	0.04	0.00	0.17	0.17	0.10
F 1	Saint Denis	1.20	0.90	1.10	1.80	1.00	1.00	1.20
F 2	Ponteau Mart.	0.70	1.10	0.70	1.60	1.00	0.80	1.00
F 3	Picherande	0.20	0.40	0.20	0.50	0.20	0.20	0.30

(*Continued*)

TABLE 19—Corrosion Losses of Aluminum Flat Panels (µm/year), 1 Year Exposure (Continued)

		Aluminum Flat Specimens (µm/year)						
Code	**Testing Site**	**sq11**	**sq12**	**sq13**	**sq14**	**sq15**	**sq16**	**Ave.**
F 4	St. Remy	0.40	0.80	0.80	1.20	0.50		0.77
F 5	Salins de Gir.	1.30	0.50	0.70	0.70	0.70	0.60	0.70
F 6	Ostende (B)	1.50	1.40	1.20	1.90	1.50	1.60	1.50
F 7	Paris	1.10	0.80	1.00	0.80	0.90	1.00	0.90
F 8	Auby	1.30	1.40	2.20	1.80	1.90	1.50	1.70
F 9	Biarritz	0.50	1.30	1.40	1.40	1.20	1.30	1.20
JAP 1	Choshi	0.41	0.38	0.47	0.38	0.18	0.14	0.33
JAP 2	Tokyo	0.63	0.68	0.61	0.53	0.54	0.27	0.54
JAP 3	Okinawa	0.29	0.27	0.18	0.37	0.24	0.19	0.26
NZ 1	Judgeford	0.08	0.02	0.10	0.05	0.06		0.06
N 1	Oslo	0.30	0.20	0.20	0.06	0.09	0.05	0.15
N 2	Borregaard	0.60	0.60	0.40	0.66	0.88	0.58	0.60
N 3	Birkenes	0.20	0.10	0.20	0.04	0.04	0.04	0.10
N 4	Tannanger	1.10	0.40	0.90	0.40	0.64	0.35	0.60
N 5	Bergen	0.10	0.10	0.20	0.12	0.13	0.14	0.10
N 6	Svanwik	0.20	0.10	0.20	0.05	0.08	0.07	0.10
E 1	Madrid	0.07	0.08	0.08	0.07	0.06	0.04	0.07
E 2	El Pardo	0.05	0.06	0.06	0.03	0.04	0.07	0.05
E 3	Lagoas	0.15	0.20	0.18	0.21			0.20
E 4	Baracaldo	0.21	0.25	0.34	0.16		0.17	0.20
S 1	Stockholm Vanadis	0.20	0.25	0.22	0.16	0.12	0.15	0.20
S 2	Kattesand	0.40	0.34	0.31	0.38	0.44	0.40	0.40
S 3	Kvarnvik	0.70	0.58	0.42	0.51	0.73	0.62	0.60
UK 1	Stratford	0.93	0.29	0.34	0.25	0.32	0.27	0.40
UK 2	Crowthorne	0.93	0.11	0.11	0.13	0.12		0.28
UK 3	Rye	0.08	0.61	0.50	0.22	0.42	0.37	0.37
UK 4	Fleet Hall	0.07	0.30	0.33	0.32	0.39	0.45	0.31
US 1	Kure Beach	0.40	0.27	0.29	0.24	0.31	0.30	0.29
US 2	Newark	0.31	0.32	0.28	0.23	0.31	0.25	0.28
US 3	Panama	0.57	0.62	0.61	0.40	0.72	0.49	0.57
US 4	Res. Tri. Park	0.11						0.11
US 5	Point Reyes	0.23	0.27	0.34	0.22	0.14	0.11	0.22
US 6	Los Angeles	0.55	0.48	0.77	0.92	0.30	0.32	0.56
SU 1	Murmansk	0.61	0.72	0.56	0.79	0.96	1.19	0.80
SU 2	Batumi	0.03	0.08	0.20	0.18	0.15	0.14	0.10
SU 3	Vladivostok	0.26	0.26	0.10	0.49	0.29	0.35	0.30
SU 4	Oymyakon	0.06	0.06	0.10	0.07	0.08	0.09	0.07

TABLE 20—Corrosion Losses of Aluminum Helices (μm/year), 1 Year Exposure

Code	Testing Site	Aluminum Helix Specimens (μm/year)						Ave.
		sq11	sq12	sq13	sq14	sq15	sq16	
ARG 1	Iugazu	0.09	1.44	0.12	0.19	0.23	0.14	0.37
ARG 2	Camet	0.96	0.63	0.61	0.89		1.18	0.85
ARG 3	Buenos Aires	0.46	0.29	0.61	0.34	0.64	0.29	0.44
ARG 4	San Juan		0.12	0.11	0.17	0.22	0.16	0.16
ARG 5	Jubay-Antarct.	1.54		1.13		1.62		1.43
CND 1	Boucherville	0.61	0.30	0.36	0.34	0.62	0.42	0.44
CS 1	Kašperské Hory	0.31	0.24	0.28	0.22	0.77	0.13	0.33
CS 2	Praha-Běchovice	0.50	0.27	0.37	0.32	1.22	0.11	0.50
CS 3	Kopisty	0.84	0.44	0.47	0.62	1.34	0.61	0.70
D 1	Bergisch Glad.	0.50	0.24	1.05				0.60
SF 1	Helsinki	0.52	0.35	0.48	0.30	0.65	0.57	0.50
SF 2	Otaniemi	0.21	0.19	0.26	0.10	0.50	0.39	0.30
SF 3	Ahtari	1.71	0.10	0.14	0.10	0.32	0.33	0.45
F 1	Saint Denis	2.40	0.80	2.30	2.66	2.34	1.34	1.97
F 2	Ponteau Mart.	16.10	6.70	15.70	14.63	13.51	12.10	13.12
F 3	Picherande	0.40	0.40	0.50	0.60	0.50	0.27	0.44
F 4	St. Remy	1.50	1.10	1.50	1.40	2.00	1.60	1.50
F 5	Salins de Gir.	2.40	2.80	3.00	2.80	3.00	3.00	2.80
F 6	Ostende (B)	3.80	3.10	3.30	3.20	3.10		3.30
F 7	Paris	1.14	1.10	1.20	1.20	1.20		1.20
F 8	Auby	2.60	2.90	4.40	4.40	4.10	4.00	3.75
F 9	Biarritz	1.10	2.80	3.40	2.50	2.20	2.20	2.40
JAP 1	Choshi		0.69	0.55	0.39	1.10	0.62	0.67
JAP 2	Tokyo		0.32	0.53	0.28	0.62	0.30	0.41
JAP 3	Okinawa		0.83	0.63	1.43	1.44	0.58	0.98
NZ 1	Judgeford	0.48	0.29	0.43	0.37	0.35	1.49	0.57
N 1	Oslo	0.90	2.90	0.20	0.12	0.16	0.14	0.74
N 2	Borregaard	2.00	0.70	1.20	1.87	2.59	1.51	1.65
N 3	Birkenes	0.60	0.10	0.10	0.09	0.08	0.08	0.18
N 4	Tannanger	2.80	0.80	0.70	0.84	1.08	0.93	1.23
N 5	Bergen	0.60	0.20	0.30	0.25	0.27	0.21	0.30
N 6	Svanwik	0.30	0.20	0.30	0.14	0.23	0.13	0.20
E 1	Madrid		0.18	0.16	0.16	0.13	0.18	0.20
E 2	El Pardo		0.12	0.10	0.07	0.06	0.15	0.14
E 3	Lagoas	0.37	0.23	0.34		1.44	0.58	0.60
E 4	Baracaldo			0.32	0.33	0.37	0.34	0.35
S 1	Stockholm Vanadis	0.59	0.37	0.49	0.38	0.48	0.28	0.43

(*Continued*)

TABLE 20—Corrosion Losses of Aluminum Helices (μm/year), 1 Year Exposure (Continued)

		Aluminum Helix Specimens (μm/year)						
Code	**Testing Site**	**sq11**	**sq12**	**sq13**	**sq14**	**sq15**	**sq16**	**Ave.**
S 2	Kattesand	0.90	0.62	0.83	0.62	1.76	0.78	0.90
S 3	Kvarnvik	2.10	0.74	1.10	1.05	2.26	1.93	1.50
UK 1	Stratford		0.20	0.24	0.12	0.20	0.15	0.18
UK 2	Crowthorne		0.12	0.19	0.27	0.24		0.20
UK 3	Rye		0.51	0.63	0.43	0.59	0.46	0.52
UK 4	Fleet Hall		0.36	0.31	0.36	0.36	0.55	0.38
US 1	Kure Beach	0.69	0.73	1.04	0.99	0.85	0.89	0.87
US 2	Newark	0.60	0.75	0.60	0.46	0.51	0.64	0.59
US 3	Panama	1.19	2.30	1.47	1.72	1.97	1.23	1.65
US 4	Res. Tri. Park							
US 5	Point Reyes	1.62	1.27	1.46	1.43	1.43	0.80	1.33
US 6	Los Angeles	1.71	1.15	1.54	1.84	0.98	1.58	1.47
SU 1	Murmansk	1.59	1.88	1.47	1.81	1.87	2.07	1.80
SU 2	Batumi	0.03	0.09	0.33	0.30	0.33	0.48	0.30
SU 3	Vladivostok	0.73	0.84	0.65	0.80	0.67	0.61	0.70
SU 4	Oymyakon	0.10	0.02	0.05	0.02	0.06	0.03	0.05

TABLE 21—Corrosion Losses of Aluminum (μm), 2, 4, and 8 Years Exposure

		2 Years		4 Years		8 Years	
Code	**Testing Site**	**flat**	**helix**	**flat**	**helix**	**flat**	**helix**
ARG 1	Iugazu	0.12	0.08	0.12	0.16		
ARG 2	Camet	0.26	0.58	1.08	2.24		
ARG 3	Buenos Aires	0.04	0.70	0.16	1.12		
ARG 4	San Juan	0.04		0.08			
ARG 5	Jubay-Antarct.	2.38	2.94				
CND 1	Boucherville	0.36	0.80	0.72	1.44	1.04	2.40
CS 1	Kašperské Hory	0.61	0.40	0.71	0.41	1.28	0.80
CS 2	Praha-Běchovice	0.81	0.57	1.38	0.70	1.60	1.36
CS 3	Kopisty	1.14	0.96	2.16	1.43	2.72	2.32
D 1	Bergisch Glad.	0.08	0.44				0.32
SF 1	Helsinki	0.46	0.68	0.76	1.28	1.04	1.92
SF 2	Otaniemi	0.14	0.34	0.32	0.52	0.48	0.80
SF 3	Ahtari	0.04	0.08	0.16	0.24	0.24	0.32
F 1	Saint Denis	1.00	3.00	1.60	1.60	3.28	
F 2	Ponteau Mart.	1.20	24.40	1.70	24.30	4.16	
F 3	Picherande	0.13	0.22	0.16	0.12		
F 4	St. Remy	1.20	3.40	0.72	3.80	2.16	

TABLE 21—Corrosion Losses of Aluminum (μm), 2, 4, and 8 Years Exposure (Continued)							
		2 Years		4 Years		8 Years	
Code	**Testing Site**	**flat**	**helix**	**flat**	**helix**	**flat**	**helix**
F 5	Salins de Gir.	1.20	4.90	2.40		4.08	
F 6	Ostende (B)	1.90	5.66	3.36			
F 7	Paris	1.70	2.80	3.32	3.52	3.76	
F 8	Auby	3.44	7.10	6.16	11.50	11.68	21.44
F 9	Biarritz	1.46	2.90	2.88	8.36		
JAP 1	Choshi	0.32	0.88	0.64	1.92	0.96	
JAP 2	Tokyo	0.62	0.44	1.64	1.04	4.32	
JAP 3	Okinawa	0.38	1.86	0.52	2.12		
NZ 1	Judgeford	0.12	0.84				
N 1	Oslo	0.40	0.60	0.68	0.76		
N 2	Borregaard	1.00	2.40	2.90	5.00		
N 3	Birkenes	0.20	0.20	0.48	0.32		
N 4	Tannanger	1.20	3.40	1.80	4.40		
N 5	Bergen	0.40	0.40	0.76	0.78		
N 6	Svanwik	0.20	0.20	0.11	0.12		
E 1	Madrid	0.12		0.20	0.28	0.16	0.88
E 2	El Pardo	0.06		0.12	0.24	0.40	
E 3	Lagoas	0.22		0.41	0.38	0.64	1.84
E 4	Baracaldo	0.22		0.36	0.84	0.64	1.60
S 1	Stockholm Vanadis	0.32	0.80	0.44	1.12	0.80	1.60
S 2	Kattesand	0.56	1.36	1.04	1.40	1.60	4.80
S 3	Kvarnvik	0.90	2.80	1.44	4.72	2.40	9.60
UK 1	Stratford	0.64	0.30	0.97	0.56		
UK 2	Crowthorne	0.51	0.10	0.99	0.20		
UK 3	Rye	0.64	0.28	1.42	0.60		
UK 4	Fleet Hall	0.86	0.22	1.72	0.52		
US 1	Kure Beach	0.34	0.53	0.65	1.66		
US 2	Newark	0.44	0.91				
US 3	Panama	1.02	2.68	1.64	3.04		
US 4	Res. Tri. Park						
US 5	Point Reyes	0.28	2.80	0.40	7.44		
US 6	Los Angeles	1.02	2.78	1.81	4.40		
SU 1	Murmansk	1.74	3.66	1.16	6.96		
SU 2	Batumi	0.24	0.37	0.32	0.44		
SU 3	Vladivostok	0.40	1.20	0.56	2.28		
SU 4	Oymyakon	0.11	0.10	0.08	0.12		

TABLE 22—Corrosion Losses of Steel (μm), 1, 2, 4, and 8 Years Exposure

		Flat Specimens				Helix Specimens			
Code	**Testing Site**	**1 year**	**2 years**	**4 years**	**8 years**	**1 year**	**2 years**	**4 years**	**8 years**
ARG 1	Iugazu	5.8	10.1	11.2		9.2	15.4	18.0	
ARG 2	Camet	45.2	46.1	123.2		77.1	101.0	168.4	
ARG 3	Buenos Aires	14.7	26.6			25.1	29.8	51.6	
ARG 4	San Juan	4.6	6.2			7.4	7.6		
ARG 5	Jubay-Antarct.	38.1	50.0			62.9	51.2		
CND 1	Boucherville	24.0	32.7	31.1	55.2	26.7	40.9	71.2	55.2
CS 1	Kašperské Hory	26.0	35.5	51.5	65.6	47.6	71.9	110.0	107.2
CS 2	Praha-Běchovice	47.4	76.2	88.9	131.2	65.0	115.0	175.2	161.6
CS 3	Kopisty	70.7	108.0	111.0	166.4	108.0	175.0	272.0	263.2
D 1	Bergisch Glad.	36.2	50.8		98.4	52.1	74.8		122.4
SF 1	Helsinki	33.3	60.0	82.0	103.2	42.7	74.4	97.2	139.2
SF 2	Otaniemi	25.6	43.8	58.8	73.6	36.2	63.8	73.6	111.2
SF 3	Ahtari	12.8	24.8	34.8	44.8	16.1	31.8	42.4	56.8
F 1	Saint Denis	37.2	59.6	79.3	106.4	49.6	78.3	108.4	
F 2	Ponteau Mart.	72.4	121.0	179.6	284.0	123.5	192.0	219.6	
F 3	Picherande	16.1	29.4	32.7		22.8	36.8	43.6	
F 4	St. Remy	43.1	84.4	102.0	147.2	94.7	103.2	198.8	
F 5	Salins de Gir.	73.0	117.2	221.2	288.8	132.0	169.0		
F 6	Ostende (B)	99.3	187.0	304.0		130.0	181.0		
F 7	Paris	41.7	67.4	123.0	176.0	51.7	105.0	122.0	
F 8	Auby	106.3	150.0	227.2	318.0	145.0	288.0	370.0	
F 9	Biarritz	87.4	120.2	157.6		67.9	93.5	116.0	
JAP 1	Choshi	43.3	68.2	125.0	216.0	93.7	163.0	284.0	
JAP 2	Tokyo	39.5	59.8	91.2	126.4	39.1	47.0	63.6	
JAP 3	Okinawa	75.2	202.0	376.0		109.0	239.0	337.0	
NZ 1	Judgeford	19.0	28.8			35.8	45.2		
N 1	Oslo	25.2	41.2	49.2	57.6	35.0	53.2	70.0	68.4
N 2	Borregaard	61.7	103.0	134.0	170.4	90.9	135.0	227.0	271.8
N 3	Birkenes	19.7	37.8	52.8	60.6	27.0	50.4	68.4	75.6
N 4	Tannanger	59.6	84.4	121.0	148.2	74.1	103.0	161.0	160.8
N 5	Bergen	27.9	39.8	56.4	63.0	32.8	47.0	68.4	76.2
N 6	Svanwik	20.2	33.8	46.8	54.6	29.0	47.4	67.4	78.6
E 1	Madrid	27.7	42.6	44.8	53.1	29.3		59.6	64.8
E 2	El Pardo	15.5	28.2	35.6	43.2	21.6		46.0	
E 3	Lagoas	26.9	48.6	68.4	95.2	35.9		74.8	104.0

TABLE 22—Corrosion Losses of Steel (μm), 1, 2, 4, and 8 Years Exposure (Continued)

		Flat Specimens				**Helix Specimens**			
Code	**Testing Site**	**1 year**	**2 years**	**4 years**	**8 years**	**1 year**	**2 years**	**4 years**	**8 years**
E 4	Baracaldo	43.9	66.8	77.2	103.2	56.0		107.2	147.2
S 1	Stockholm Vanadis	24.4	40.8	54.4	66.4	41.5	77.0	101.0	172.0
S 2	Kattesand	35.2	54.0	80.3	115.2	60.8	92.4	151.0	285.6
S 3	Kvarnvik	61.6	79.4	110.0	148.0	67.7	107.0	159.0	280.0
UK 1	Stratford	38.7	62.6	82.3		50.3	94.5	132.4	
UK 2	Crowthorne	37.4	62.2	79.3		57.9	91.4	128.4	
UK 3	Rye	58.5	90.8	114.0		92.5	174.0	240.0	
UK 4	Fleet Hall	39.0	65.3	91.2		56.9	67.0	155.0	
US 1	Kure Beach	37.9			189.5	81.8			831.2
US 2	Newark	26.4			65.6	27.3			82.4
US 3	Panama	373.0				297.0	870.0		
US 4	Res. Tri. Park	23.1							
US 5	Point Reyes	36.8	55.0		126.4	147.0	244.0		
US 6	Los Angeles	21.4	24.8		57.6	19.2			
SU 1	Murmansk	31.3	44.4	80.8		51.7	71.8	104.0	
SU 2	Batumi	28.7	41.4	52.8		28.7	39.8	50.4	
SU 3	Vladivostok	25.9	48.2	82.4		66.8	153.0	244.0	
SU 4	Oymyakon	0.8	2.1	4.0		1.9	3.3	6.4	

TABLE 23—Corrosion Losses of Zinc (μm), 1, 2, 4, and 8 Years Exposure

		Flat Specimens				**Helix Specimens**			
Code	**Testing Site**	**1 year**	**2 years**	**4 years**	**8 years**	**1 year**	**2 years**	**4 years**	**8 years**
ARG 1	Iugazu	1.36	3.48	3.64		1.94	1.70	2.68	
ARG 2	Camet	1.98	3.48	3.64		3.79	1.70	2.68	
ARG 3	Buenos Aires	1.00	1.74	3.20		1.52	2.70	4.84	
ARG 4	San Juan	0.19	0.30	1.24		1.01			
ARG 5	Jubay-Antarct.	1.65	2.14			3.00	4.94		
CND 1	Boucherville	1.40	2.48	4.96	8.88	2.00	3.12	6.48	12.72
CS 1	Kašperské Hory	1.90	2.38	3.77	6.88	2.20	3.56	4.92	9.76
CS 2	Praha-Běchovice	2.80	3.62	6.61	11.68	3.30	5.41	10.20	36.16
CS 3	Kopisty	3.50	8.38	15.60	26.88	4.75	8.93	18.30	12.88
D 1	Bergisch Glad.	1.60	2.64		7.20	1.80	3.28		10.88
SF 1	Helsinki	1.30	2.40	4.40	7.28	2.32	4.80	8.00	14.16

(*Continued*)

TABLE 23—Corrosion Losses of Zinc (μm), 1, 2, 4, and 8 Years Exposure (Continued)

		Flat Specimens				**Helix Specimens**			
Code	**Testing Site**	**1 year**	**2 years**	**4 years**	**8 years**	**1 year**	**2 years**	**4 years**	**8 years**
SF 2	Otaniemi	0.90	1.60	2.80	4.16	1.80	2.40	4.00	6.16
SF 3	Ahtari	0.70	1.20	1.60	2.64	1.20	1.80	2.00	3.04
F 1	Saint Denis	1.50	2.80	4.90	9.92	3.51	8.10	10.24	
F 2	Ponteau Mart.	2.65	4.00	7.90	16.24	14.50	20.80	28.40	
F 3	Picherande	0.90	1.80	2.40		2.20	4.10	3.80	
F 4	St. Remy	1.50	2.80	4.50	8.56	4.01	5.30	8.72	
F 5	Salins de Gir.	4.55	7.80	11.40	13.44	5.70	9.80		
F 6	Ostende (B)	5.10	5.78	10.30		10.60	11.10		
F 7	Paris	3.00	4.50	6.20	9.76	2.80	6.60	7.70	
F 8	Auby	5.60	10.72	21.88	34.40	8.50	15.24	28.00	50.72
F 9	Biarritz	4.30	6.67	12.48		7.13	11.80	31.52	
JAP 1	Choshi	1.40	2.60	5.20	9.60	2.80	4.40	8.80	
JAP 2	Tokyo	1.50	2.20	4.00	8.00	1.50	2.80	6.00	
JAP 3	Okinawa	3.40	9.00	10.00		8.80	15.80	33.20	
NZ 1	Judgeford	0.66	1.68			1.08	3.40		
N 1	Oslo	1.25	2.60	4.12		1.80	3.60	5.60	
N 2	Borregaard	3.80	7.00	13.20		5.70	10.60	19.50	
N 3	Birkenes	2.30	3.00	5.16		2.00	3.40	3.56	
N 4	Tannanger	3.00	6.60	9.80		3.30	5.20	9.84	
N 5	Bergen	2.10	1.80	8.30		2.20	2.80	5.50	
N 6	Svanwik	0.80	1.20	1.80		1.40	1.80	2.90	
E 1	Madrid	0.66	1.38	2.40	4.48	1.60		4.72	11.76
E 2	El Pardo	0.59	1.12	1.28	2.24	1.20		3.04	
E 3	Lagoas	1.00	1.84	3.33	5.84	4.58		5.52	10.72
E 4	Baracaldo	1.20	2.48	4.04	7.04	2.60		4.28	13.36
S 1	Stockholm Vanadis	0.64	1.26	2.50	4.00	1.50	3.36	5.30	8.80
S 2	Kattesand	1.50	2.58	5.50	9.60	2.85	4.58	10.00	20.80
S 3	Kvarnvik	1.80	3.02	7.20	16.80	3.50	5.38	12.90	26.40
UK 1	Stratford	1.67	3.97	7.66		1.54	2.31	3.61	
UK 2	Crowthorne	1.10	2.22	4.89		1.19	1.78	3.35	
UK 3	Rye	2.54	4.08	6.18		2.02	2.29	3.47	
UK 4	Fleet Hall	1.34	2.19	4.24		2.27	5.31	7.73	
US 1	Kure Beach	2.01	3.90	6.52	9.60	3.55	6.48	9.72	16.24
US 2	Newark	1.96	3.72			2.15			17.28
US 3	Panama	17.50	37.20		123.90	7.58			226.40
US 4	Res. Tri. Park	0.84							
US 5	Point Reyes	1.73	3.90		3.84	3.51	5.36		10.56

TABLE 23—Corrosion Losses of Zinc (μm), 1, 2, 4, and 8 Years Exposure (Continued)

		Flat Specimens				Helix Specimens			
Code	Testing Site	1 year	2 years	4 years	8 years	1 year	2 years	4 years	8 years
US 6	Los Angeles	1.09	2.38		5.84	1.76			
SU 1	Murmansk	1.10	2.08	3.90		2.10	3.62	7.40	
SU 2	Batumi	1.60	2.74	4.52		2.00	3.68	1.28	
SU 3	Vladivostok	2.30	2.30	4.12		3.10	4.48	6.80	
SU 4	Oymyakon	0.36	0.64	0.68		0.57	0.64	1.04	

TABLE 24—Corrosion Losses of Copper (μm), 1, 2, 4, and 8 Years of Exposure

		Flat Specimens				Helix Specimens			
Code	Testing Site	1 year	2 years	4 years	8 years	1 year	2 years	4 years	8 years
ARG 1	Iugazu	0.76	1.82	3.76		0.57	0.86	1.32	
ARG 2	Camet	2.24	3.30	2.60		2.49	2.88	4.68	
ARG 3	Buenos Aires	0.68	1.06	1.88		0.77	1.30	2.12	
ARG 4	San Juan	0.18	0.30	0.80		0.39			
ARG 5	Jubay-Antarct.	2.02	2.34			3.03	4.16		
CND 1	Boucherville	1.10	1.62	2.68	4.16	1.30	1.80	3.44	5.92
CS 1	Kašperské Hory	2.00	3.02	4.18	5.36	2.60	3.80	6.01	7.52
CS 2	Praha-Běchovice	1.30	2.80	4.58	6.08	1.90	4.20	6.70	8.88
CS 3	Kopisty	3.30	6.28	9.75	12.88	4.20	8.28	13.70	13.52
D 1	Bergisch Glad.	0.60	1.40		3.36	0.78	1.72		4.16
SF 1	Helsinki	0.70	1.00	2.00	3.28	1.30	2.00	3.60	5.52
SF 2	Otaniemi	0.80	1.20	2.00	2.96	1.50	2.40	3.60	5.44
SF 3	Ahtari	0.76	1.20	2.00	2.72	1.10	1.80	2.80	4.24
F 1	Saint Denis	1.20	2.10	2.90	5.68	2.15	2.60	3.90	
F 2	Ponteau Mart.	2.70	4.10	5.40	8.72	7.21	6.10	8.00	
F 3	Picherande	1.40	2.30	3.30		1.45	1.60	2.90	
F 4	St. Remy	1.80	2.90	3.70		3.72	3.40	4.60	
F 5	Salins de Gir.	3.20	4.10	7.50	8.24	5.30	9.10		
F 6	Ostende (B)	3.10	4.20	7.10		3.50	10.90		
F 7	Paris	1.40	2.00	5.10	6.88	2.60	4.70	5.80	
F 8	Auby	1.90	3.20	5.70	9.76	2.40	4.90	8.40	12.96
F 9	Biarritz	3.69	5.10	6.92		4.50	5.40	7.76	
JAP 1	Choshi	1.35	1.82	3.04	4.24	2.29	2.82	6.04	
JAP 2	Tokyo	0.66	1.10	2.24	3.92	1.12	1.82	2.96	
JAP 3	Okinawa	2.10	3.00	4.40		4.30	8.80	9.20	

(*Continued*)

TABLE 24—Corrosion Losses of Copper (µm), 1, 2, 4, and 8 Years of Exposure (Continued)

		Flat Specimens				Helix Specimens			
Code	Testing Site	1 year	2 years	4 years	8 years	1 year	2 years	4 years	8 years
NZ 1	Judgeford	1.35				1.60			
N 1	Oslo	0.60	1.20	1.88		0.90	1.60	2.16	
N 2	Borregaard	1.40	2.80	4.64		2.70	3.80	6.64	
N 3	Birkenes	1.30	2.00	3.40		1.25	1.80	2.88	
N 4	Tannanger	1.90	2.60	3.48		3.20	4.40	5.52	
N 5	Bergen	1.00	1.60	2.80		1.10	1.40	2.72	
N 6	Svanwik	0.80	1.20	1.60		1.00	0.60	0.41	
E 1	Madrid	0.53	1.02	1.64	2.64	0.80		2.16	3.60
E 2	El Pardo	1.10	2.32	3.08	4.48	1.20		3.04	
E 3	Lagoas	1.00	1.70	2.11	2.88	2.92			3.12
E 4	Baracaldo	1.20	2.32	3.44	5.28	1.50		5.92	10.40
S 1	Stockholm Vanadis	0.60	1.06	1.38	3.20	1.10	1.90	2.84	4.00
S 2	Kattesand	1.70	2.60	3.76	5.60	2.30	3.60	4.60	7.20
S 3	Kvarnvik	2.80	3.32	4.28	5.60	4.90	5.42	7.16	8.80
UK 1	Stratford	1.13	1.98	3.88		1.37	2.88	5.24	
UK 2	Crowthorne	1.10	1.89	3.67		1.37	2.88	5.26	
UK 3	Rye	1.86	2.23	3.84		4.20	13.70	27.10	
UK 4	Fleet Hall	0.93	2.80	4.64		1.58	3.40	6.48	
US 1	Kure Beach	2.85	3.70	6.44	10.64	4.58	7.04	6.96	12.88
US 2	Newark	1.39		3.26	6.80	1.94	2.10		10.48
US 3	Panama	5.46	8.04	18.20	35.60	11.60	13.90	25.10	40.56
US 4	Res. Tri. Park	2.43							
US 5	Point Reyes	2.32	3.20	4.88	5.68	4.43	7.02	8.88	10.40
US 6	Los Angeles	1.16	1.62		4.24	2.04	3.04		6.80
SU 1	Murmansk	1.70	2.62	3.76		2.80	3.12	5.16	
SU 2	Batumi	2.00	4.34	6.04		1.90	4.30	6.24	
SU 3	Vladivostok	1.40	2.18	2.68		2.40	2.98	3.96	
SU 4	Oymyakon	0.09	0.11	0.20		0.11	0.12	0.24	

TABLE 25—Corrosion Losses of Aluminum (µm), 1, 2, 4, and 8 Years of Exposure

		Flat Specimens				Helix Specimens			
Code	Testing Site	1 year	2 years	4 years	8 years	1 year	2 years	4 years	8 years
ARG 1	Iugazu	0.06	0.12	0.12		0.37	0.12	0.16	
ARG 2	Camet	0.19	0.26	1.08		0.85	1.08	2.24	
ARG 3	Buenos Aires	0.06	0.04	0.16		0.44	0.16	1.12	
ARG 4	San Juan	0.03	0.04	0.08		0.16	0.08		

TABLE 25—Corrosion Losses of Aluminum (μm), 1, 2, 4, and 8 Years of Exposure (Continued)									
		Flat Specimens				**Helix Specimens**			
Code	**Testing Site**	**1 year**	**2 years**	**4 years**	**8 years**	**1 year**	**2 years**	**4 years**	**8 years**
ARG 5	Jubay-Antarct.	1.33	2.38			1.43			
CND 1	Boucherville	0.40	0.36	0.72	1.04	0.44	0.72	1.44	2.40
CS 1	Kašperské Hory	0.50	0.61	0.71	1.28	0.33	0.71	0.41	0.80
CS 2	Praha-Běchovice	0.60	0.81	1.38	1.60	0.50	1.38	0.70	1.36
CS 3	Kopisty	0.70	1.14	2.16	2.72	0.70	2.16	1.43	2.32
D 1	Bergisch Glad.	0.26	0.08			0.60			0.32
SF 1	Helsinki	0.30	0.46	0.76	1.04	0.50	0.76	1.28	1.92
SF 2	Otaniemi	0.14	0.14	0.32	0.48	0.30	0.32	0.52	0.80
SF 3	Ahtari	0.10	0.04	0.16	0.24	0.45	0.16	0.24	0.32
F 1	Saint Denis	1.20	1.00	1.60	3.28	1.97	1.60	1.60	
F 2	Ponteau Mart.	1.00	1.20	1.70	4.16	13.12	1.70	24.30	
F 3	Picherande	0.30	0.13	0.16		0.44	0.16	0.12	
F 4	St. Remy	0.77	1.20	0.72	2.16	1.50	0.72	3.80	
F 5	Salins de Gir.	0.70	1.20	2.40	4.08	2.80	2.40		
F 6	Ostende (B)	1.50	1.90	3.36		3.30	3.36		
F 7	Paris	0.90	1.70	3.32	3.76	1.20	3.32	3.52	
F 8	Auby	1.70	3.44	6.16	11.68	3.75	6.16	11.50	21.44
F 9	Biarritz	1.20	1.46	2.88		2.40	2.88	8.36	
JAP 1	Choshi	0.33	0.32	0.64	0.96	0.67	0.64	1.92	
JAP 2	Tokyo	0.54	0.62	1.64	4.32	0.41	1.64	1.04	
JAP 3	Okinawa	0.26	0.38	0.52		0.98	0.52	2.12	
NZ 1	Judgeford	0.06	0.12			0.57			
N 1	Oslo	0.15	0.40	0.68		0.74	0.68	0.76	
N 2	Borregaard	0.60	1.00	2.90		1.65	2.90	5.00	
N 3	Birkenes	0.10	0.20	0.48		0.18	0.48	0.32	
N 4	Tannanger	0.60	1.20	1.80		1.23	1.80	4.40	
N 5	Bergen	0.10	0.40	0.76		0.30	0.76	0.78	
N 6	Svanwik	0.10	0.20	0.11		0.20	0.11	0.12	
E 1	Madrid	0.07	0.12	0.20	0.16	0.20	0.20	0.28	0.88
E 2	El Pardo	0.05	0.06	0.12	0.40	0.14	0.12	0.24	
E 3	Lagoas	0.20	0.22	0.41	0.64	0.60	0.41	0.38	1.84
E 4	Baracaldo	0.20	0.22	0.36	0.64	0.35	0.36	0.84	1.60
S 1	Stockholm Vanadis	0.20	0.32	0.44	0.80	0.43	0.44	1.12	1.60
S 2	Kattesand	0.40	0.56	1.04	1.60	0.90	1.04	1.40	4.80

(*Continued*)

TABLE 25—Corrosion Losses of Aluminum (μm), 1, 2, 4, and 8 Years of Exposure (Continued)

		Flat Specimens				Helix Specimens			
Code	Testing Site	1 year	2 years	4 years	8 years	1 year	2 years	4 years	8 years
S 3	Kvarnvik	0.60	0.90	1.44	2.40	1.50	1.44	4.72	9.60
UK 1	Stratford	0.40	0.64	0.97		0.18	0.97	0.56	
UK 2	Crowthorne	0.28	0.51	0.99		0.20	0.99	0.20	
UK 3	Rye	0.37	0.64	1.42		0.52	1.42	0.60	
UK 4	Fleet Hall	0.31	0.86	1.72		0.38	1.72	0.52	
US 1	Kure Beach	0.29	0.34	0.65		0.87	0.65	1.66	
US 2	Newark	0.28	0.44			0.59			
US 3	Panama	0.57	1.02	1.64		1.65	1.64	3.04	
US 4	Res. Tri. Park	0.11							
US 5	Point Reyes	0.22	0.28	0.40		1.33	0.40	7.44	
US 6	Los Angeles	0.56	1.02	1.81		1.47	1.81	4.40	
SU 1	Murmansk	0.80	1.74	1.16		1.80	1.16	6.96	
SU 2	Batumi	0.10	0.24	0.32		0.30	0.32	0.44	
SU 3	Vladivostok	0.30	0.40	0.56		0.70	0.56	2.28	
SU 4	Oymyakon	0.07	0.11	0.08		0.05	0.08	0.12	

3.4 CORROSIVITY CLASSIFICATION

The environmental results were used to determine corrosivity classification of the various sites according to the ISO 9223 procedure. The sulfur dioxide, chloride, and time of wetness classification criteria together with the estimated corrosivity categories for the various sites are shown in Table 26. The corrosivity categories for the various sites based on 1-year mass loss results are shown in Table 27 for flat panels and in Table 28 for the wire helices. The corrosivity classification is summarized for flat panels, helices, and environmental data for steel in Table 29, for zinc in Table 30, for copper in Table 31, and for aluminum in Table 32. Table 33 and Figure 6 provide a summary for all materials and environmental data.

TABLE 26—Classification of Test Sites According to ISO 9223 Environmental Criteria

SO_2 Pollution			Pollution by Airborne Salinity			Time of Wetness		
test site	average value	category	test site	average value	category	test site	average value	category
Birkenes	1.2	P0	Svanwik	1.0	S0	Oymyakon	381	T3
Tannanger	4.0	P0	Batumi	1.0	S0	San Juan	855	T3
Ahtari	4.1	P0	Oslo	2.1	S0	Boucherville	1396	T3
El Pardo	4.9	P0	Otaniemi	2.5	S0	Madrid	2060	T3
Kattesand	5.0	P0	Helsinki	3.7	S0	Tokyo	2173	T3
Kvarnvik	5.0	P0	Tokyo	4.4	S0	Kopisty	2444	T3
Murmansk	5.0	P0	Picherande	6.5	S1	Svanwik	2605	T4
Oymyakon	5.0	P0	Bergen	7.1	S1	Oslo	2641	T4
Choshi	7.7	P0	Borregaard	8.2	S1	Jubay-Antarct.	2693	T4
Bergen	8.6	P0	Stratford	15.1	S1	Lagoas	2840	T4
Picherande	9.1	P0	Auby	16.0	S1	Praha	2991	T4

TABLE 26—Classification of Test Sites According to ISO 9223 Environmental Criteria (Continued)

SO_2 Pollution			Pollution by Airborne Salinity			Time of Wetness		
test site	**average value**	**category**	**test site**	**average value**	**category**	**test site**	**average value**	**category**
Kure Beach	9.6	P0	Vladivostok	18.4	S1	Ahtari	3105	T4
Stockholm V.	9.8	P0	Murmansk	19.9	S1	Paris	3189	T4
Okinawa	11.1	P0	Lagoas	21.2	S1	Kašperské H.	3206	T4
Oslo	13.8	P1	Saint Denis	27.8	S1	Batumi	3216	T4
Tokyo	14.6	P1	Baracaldo	29.2	S1	El Pardo	3223	T4
Otaniemi	15.3	P1	Boucherville	59.0	S1	Murmansk	3227	T4
Boucherville	15.9	P1	Choshi	66.8	S1	Otaniemi	3256	T4
Svanwik	16.7	P1	Kattesand	85.5	S1	Salins de Gir.	3310	T4
Kašperské H.	17.1	P1	Okinawa	130.0	S2	Borregaard	3339	T4
Bergisch G.	18.0	P1	Ostende (B)	173.0	S2	Helsinki	3578	T4
Helsinki	18.9	P1	Salins de Gir.	184.0	S2	Ponteau M.	3846	T4
Stratford	19.9	P1	Kure Beach	184.0	S2	Okinawa	3852	T4
Salins de Gir.	20.0	P1	Biarritz	193.0	S2	Vladivostok	3920	T4
Los Angeles	20.0	P1	Ponteau Mart.	241.0	S2	Los Angeles	4003	T4
Rye	21.2	P1	Rye	300.0	S2	Birkenes	4138	T4
Ostende (B)	24.0	P1	Tannanger	321.0	S2	Picherande	4171	T4
Batumi	25.8	P1	St. Remy	378.0	S2	Bergisch G.	4267	T4
Vladivostok	28.6	P1	Panama	619.0	S3	Saint Denis	4268	T4
St. Remy	30.3	P1	Kvarnvik	667.0	S3	Kure Beach	4289	T4
Baracaldo	32.1	P1	Iugazu	no data		Baracaldo	4375	T4
Borregaard	44.2	P2	Camet	no data		Bergen	4439	T4
Madrid	44.2	P2	Buenos Aires	no data		Auby	4571	T4
Lagoas	48.7	P2	San Juan	no data		Tannanger	4583	T4
Saint Denis	49.6	P2	Jubay-Antarct.	no data		Buenos Aires	4645	T4
Panama	51.5	P2	Kašperské H.	no data		Iugazu	5680	T5
Paris	53.4	P2	Praha	no data		Choshi	5704	T5
Praha	67.5	P2	Kopisty	no data		Stratford	5783	T5
Ponteau M.	87.0	P2	Bergisch G.	no data		Ostende (B)	6083	T5
Kopisty	89.9	P2	Ahtari	no data		Camet	6088	T5
Auby	188.0	P3	Paris	no data		St. Remy	6310	T5
Biarritz	no data		Judgeford	no data		Panama	7598	T5
Buenos Aires	no data		Birkenes	no data		Biarritz	no data	

(*Continued*)

TABLE 26—Classification of Test Sites According to ISO 9223 Environmental Criteria (Continued)

SO_2 Pollution			Pollution by Airborne Salinity			Time of Wetness		
test site	average value	category	test site	average value	category	test site	average value	category
Camet	no data		Madrid	no data		Judgeford	no data	
Crowthorne	no data		El Pardo	no data		Stockholm V.	no data	
Fleet Hall	no data		Stockholm V.	no data		Kattesand	no data	
Iugazu	no data		Crowthorne	no data		Kvarnvik	no data	
Judgeford	no data		Fleet Hall	no data		Crowthorne	no data	
Newark	no data		Newark	no data		Rye	no data	
Point Reyes	no data		Res. Tri. Park	no data		Fleet Hall	no data	
Res. Tri. Park	no data		Point Reyes	no data		Newark	no data	
San Juan	no data		Los Angeles	no data		Res. Tri. Park	no data	
Jubay-Antarct.	no data		Oymyakon	no data		Point Reyes	no data	

TABLE 27—Test Sites Categories Based on 1-Year Corrosion Losses of Flat Panels (μm/year)

Unalloyed Steel	A	B	Zinc	A	B	Copper	A	B	Aluminum	A	B
Panama	373.0	C5	Panama	17.50	C5	Panama	5.46	C5	Auby	1.70	C3
Auby	106.0	C5	Auby	5.60	C5	Biarritz	3.69	C5	Ostende (B)	1.50	C3
Ostende (B)	99.3	C5	Ostende (B)	5.10	C5	Kopisty	3.30	C5	Yubany B.	1.31	C3
Biarritz	87.2	C5	Salins de Gir.	4.60	C5	Salins de Gir.	3.20	C5	Saint Denis	1.20	C3
Okinawa	75.2	C4	Biarritz	4.30	C5	Ostende (B)	3.10	C5	Biarritz	1.20	C3
Salins de Gir.	73.0	C4	Borregaard	3.80	C4	Kure Beach	2.85	C5	Ponteau M.	1.00	C3
Ponteau M.	72.4	C4	Kopisty	3.50	C4	Kvarnvik	2.80	C5	Paris	0.90	C3
Kopisty	70.7	C4	Okinawa	3.40	C4	Ponteau M.	2.70	C4	Murmansk	0.80	C3
Borregaard	61.7	C4	Paris	3.00	C4	Res. Tri. Park	2.43	C4	St. Remy	0.77	C3
Kvarnvik	61.6	C4	Tannanger	3.00	C4	Point Reyes	2.42	C4	Kopisty	0.70	C3
Tannanger	59.6	C4	Praha	2.80	C4	Camet	2.23	C4	Salins de G.	0.70	C3
Rye	58.5	C4	Ponteau Mart.	2.60	C4	Okinawa	2.10	C4	Madrid	0.70	C3
Praha	47.4	C3	Rye	2.54	C4	Jubay-Antarct.	2.04	C4	Praha	0.60	C3
St. Remy	44.1	C3	Birkenes	2.30	C4	Kašperské H.	2.00	C4	Borregaard	0.60	C3
Baracaldo	43.9	C3	Vladivostok	2.30	C4	Batumi	2.00	C4	Tannanger	0.60	C3

TABLE 27—Test Sites Categories Based on 1-Year Corrosion Losses of Flat Panels (µm/year) (Continued)

Unalloyed Steel	A	B	Zinc	A	B	Copper	A	B	Aluminum	A	B
Choshi	43.3	C3	Bergen	2.10	C4	Auby	1.90	C4	Kvarnvik	0.60	C3
Paris	41.7	C3	Kure Beach	2.01	C3	Tannanger	1.90	C4	Panama	0.57	C2
Point Reyes	40.1	C3	Newark	1.96	C3	Rye	1.86	C4	Los Angeles	0.56	C2
Tokyo	39.5	C3	Kašperské H.	1.90	C3	St. Remy	1.80	C4	Tokyo	0.54	C2
Fleet Hall	39.0	C3	Jubay-Antarct.	1.87	C3	Kattesand	1.70	C4	Kašperské H.	0.50	C2
Stratford	38.7	C3	Kvarnvik	1.80	C3	Murmansk	1.70	C4	Rye	0.42	C2
Kure Beach	37.9	C3	Point Reyes	1.73	C3	Picherande	1.40	C4	Boucherville	0.40	C2
Crowthorne	37.4	C3	Stratford	1.67	C3	Paris	1.40	C4	Kattesand	0.40	C2
Saint Denis	37.2	C3	Iugazu	1.62	C3	Borregaard	1.40	C4	Fleet Hall	0.36	C2
Camet	36.8	C3	Bergisch G.	1.60	C3	Vladivostok	1.40	C4	Choshi	0.33	C2
Jubay-Antarct.	36.6	C3	Batumi	1.60	C3	Newark	1.39	C4	Bergisch G.	0.30	C2
Bergisch G.	36.2	C3	Saint Denis	1.50	C3	Judgeford	1.36	C4	Helsinki	0.30	C2
Kattesand	35.2	C3	St. Remy	1.50	C3	Choshi	1.35	C4	Picherande	0.30	C2
Helsinki	33.3	C3	Tokyo	1.50	C3	Praha	1.30	C4	Vladivostok	0.30	C2
Murmansk	30.8	C3	Kattesand	1.50	C3	Birkenes	1.30	C4	Stratford	0.29	C2
Batumi	28.7	C3	Boucherville	1.40	C3	Saint Denis	1.20	C3	Kure Beach	0.29	C2
Bergen	27.9	C3	Choshi	1.40	C3	Baracaldo	1.20	C3	Newark	0.28	C2
Madrid	27.7	C3	Fleet Hall	1.34	C3	Los Angeles	1.16	C3	Okinawa	0.26	C2
Lagoas	26.9	C3	Helsinki	1.30	C3	Stratford	1.13	C3	Point Reyes	0.22	C2
Newark	26.4	C3	Oslo	1.30	C3	Boucherville	1.10	C3	Oslo	0.20	C2
Kašperské H.	26.0	C3	Camet	1.26	C3	El Pardo	1.10	C3	Lagoas	0.20	C2
Vladivostok	25.9	C3	Baracaldo	1.20	C3	Crowthorne	1.10	C3	Baracaldo	0.20	C2
Otaniemi	25.6	C3	Crowthorne	1.10	C3	Bergen	1.00	C3	Stockholm V.	0.20	C2
Oslo	25.2	C3	Murmansk	1.10	C3	Lagoas	1.00	C3	Camet	0.19	C2
Stockholm V.	24.4	C2	Los Angeles	1.09	C3	Fleet Hall	0.93	C3	Crowthorne	0.12	C2
Boucherville	23.2	C2	Buenos Aires	1.01	C3	Iugazu	0.80	C3	Res. Tri. Park	0.11	C2
Res. Tri. Park	23.1	C2	Lagoas	1.00	C3	Otaniemi	0.80	C3	Otaniemi	0.10	C1
Los Angeles	21.4	C2	Otaniemi	0.90	C3	Svanwik	0.80	C3	Ahtari	0.10	C1
Svanwik	20.2	C2	Picherande	0.90	C3	Helsinki	0.70	C3	Birkenes	0.10	C1
Birkenes	19.7	C2	Res. Tri. Park	0.84	C3	Ahtari	0.70	C3	Bergen	0.10	C1
Judgeford	19.3	C2	Svanwik	0.80	C3	Tokyo	0.66	C3	Svanwik	0.10	C1
Buenos Aires	16.2	C2	Ahtari	0.70	C2	Buenos Aires	0.64	C3	Batumi	0.10	C1

(*Continued*)

TABLE 27—Test Sites Categories Based on 1-Year Corrosion Losses of Flat Panels (μm/year) (Continued)

Unalloyed Steel	A	B	Zinc	A	B	Copper	A	B	Aluminum	A	B
Picherande	16.1	C2	Judgeford	066	C2	Bergisch Glad.	0.60	C2	Oymyakon	0.07	C1
El Pardo	15.5	C2	Madrid	0.60	C2	Oslo	0.60	C2	Judgeford	0.06	C1
Ahtari	12.8	C2	Stockholm V.	0.60	C2	Stockholm V.	0.60	C2	Iugazu	0.05	C1
Iugazu	5.8	C2	El Pardo	0.50	C2	Madrid	0.50	C2	Buenos Aires	0.05	C1
San Juan	4.6	C2	Oymyakon	0.40	C2	San Juan	0.18	C2	El Pardo	0.05	C1
Oymyakon	0.8	C1	San Juan	0.18	C2	Oymyakon	0.09	C1	San Juan	0.03	C1

TABLE 28—Test Sites Categories Based on 1-Year Corrosion Losses of Helices (μm/year)

Unalloyed Steel	A	B	Zinc	A	B	Copper	A	B	Aluminum	A	B
Panama	297.0	C5	Ponteau M.	13.40	C5	Panama	11.60	C5	Ponteau M.	13.50	C5
Point Reyes	147.0	C5	Ostende (B)	10.60	C5	Ponteau M.	9.70	C5	Auby	3.80	C4
Auby	145.0	C5	Okinawa	8.80	C5	St. Remy	5.30	C5	Ostende (B)	3.30	C4
Salins de Gir.	132.0	C5	Auby	8.50	C5	Salins de Gir.	5.30	C5	Salins de Gir.	2.80	C4
Ostende (B)	130.0	C5	Biarritz	8.20	C5	Kvarnvik	4.90	C5	Biarritz	2.40	C4
Ponteau M.	126.0	C5	Panama	7.58	C5	Kure Beach	4.58	C5	Saint Denis	2.10	C4
Okinawa	109.0	C5	Borregaard	5.70	C5	Biarritz	4.50	C5	Murmansk	1.80	C3
Kopisty	108.0	C5	Salins de Gir.	5.70	C5	Point Reyes	4.43	C5	Borregaard	1.70	C3
St. Remy	94.7	C5	Kopisty	4.80	C5	Okinawa	4.30	C5	Panama	1.65	C3
Choshi	93.7	C5	St. Remy	4.20	C4	Kopisty	4.20	C5	St. Remy	1.50	C3
Rye	92.5	C5	Kure Beach	3.88	C4	Rye	4.20	C5	Kvarnvik	1.50	C3
Borregaard	90.9	C5	Saint Denis	3.60	C4	Ostende (B)	3.50	C5	Los Angeles	1.47	C3
Kure Beach	81.8	C5	Point Reyes	3.51	C4	Tannanger	3.20	C5	Point Reyes	1.33	C3
Tannanger	74.1	C4	Kvarnvik	3.50	C4	Saint Denis	2.80	C4	Paris	1.20	C3
Praha	68.4	C4	Praha	3.30	C4	Murmansk	2.80	C4	Okinawa	0.98	C3
Biarritz	67.9	C4	Tannanger	3.30	C4	Borregaard	2.70	C4	Tannanger	0.90	C3
Kvarnvik	67.7	C4	Vladivostok	3.10	C4	Kašperské H.	2.60	C4	Kattesand	0.90	C3
Vladivostok	66.8	C4	Choshi	2.80	C4	Paris	2.60	C4	Kure Beach	0.87	C3
Kattesand	60.8	C4	Kattesand	2.80	C4	Auby	2.40	C4	Kopisty	0.70	C3
Crowthorne	57.9	C4	Paris	2.80	C4	Vladivostok	2.40	C4	Vladivostok	0.70	C3

TABLE 28—Test Sites Categories Based on 1-Year Corrosion Losses of Helices (μm/year) (Continued)

Unalloyed Steel	A	B	Zinc	A	B	Copper	A	B	Aluminum	A	B
Fleet Hall	56.9	C4	Baracaldo	2.60	C4	Kattesand	2.30	C4	Choshi	0.67	C3
Baracaldo	56.0	C4	Helsinki	2.60	C4	Choshi	2.29	C4	Bergisch G.	0.60	C2
Bergisch G.	52.1	C4	Lagoas	2.50	C4	Los Angeles	2.04	C4	Newark	0.59	C2
Paris	51.7	C4	Fleet Hall	2.27	C4	Picherande	2.00	C4	Rye	0.52	C2
Murmansk	51.7	C4	Bergen	2.20	C4	Newark	1.94	C4	Praha	0.50	C2
Stratford	50.3	C4	Kašperské H.	2.20	C4	Praha	1.90	C4	Helsinki	0.50	C2
Saint Denis	49.6	C3	Picherande	2.20	C4	Batumi	1.90	C4	Ahtari	0.50	C2
Kašperské H.	47.6	C3	Newark	2.15	C4	Judgeford	1.62	C4	Picherande	0.50	C2
Helsinki	42.7	C3	Murmansk	2.10	C3	Fleet Hall	1.58	C4	Tokyo	0.41	C2
Stockholm V.	41.5	C3	Rye	2.02	C3	Otaniemi	1.50	C4	Boucherville	0.40	C2
Tokyo	39.1	C3	Batumi	2.00	C3	Baracaldo	1.50	C4	Judgeford	0.40	C2
Otaniemi	37.8	C3	Birkenes	2.00	C3	Stratford	1.37	C4	Stockholm V.	0.40	C2
Judgeford	36.3	C3	Boucherville	2.00	C3	Crowthorne	1.37	C4	Fleet Hall	0.38	C2
Lagoas	35.9	C3	Bergisch G.	1.80	C3	Boucherville	1.30	C3	Kašperské H.	0.30	C2
Oslo	35.0	C3	Oslo	1.80	C3	Helsinki	1.30	C3	Otaniemi	0.30	C2
Bergen	32.8	C3	Otaniemi	1.80	C3	Birkenes	1.30	C3	Bergen	0.30	C2
Madrid	29.3	C3	Los Angeles	1.76	C3	El Pardo	1.20	C3	Lagoas	0.30	C2
Svanwik	29.0	C3	Madrid	1.60	C3	Lagoas	1.20	C3	Baracaldo	0.30	C2
Batumi	28.7	C3	Stratford	1.54	C3	Tokyo	1.12	C3	Batumi	0.30	C2
Boucherville	27.5	C3	Stockholm V.	1.50	C3	Ahtari	1.10	C3	Oslo	0.20	C2
Newark	27.3	C3	Tokyo	1.50	C3	Bergen	1.10	C3	Svanwik	0.20	C2
Birkenes	27.0	C3	Svanwik	1.40	C3	Stockholm V.	1.10	C3	Madrid	0.20	C2
Picherande	22.8	C2	Judgeford	1.21	C3	Svanwik	1.00	C3	Crowthorne	0.20	C2
El Pardo	21.6	C2	Ahtari	1.20	C3	Oslo	0.90	C3	Stratford	0.18	C2
Los Angeles	19.2	C2	El Pardo	1.20	C3	Madrid	0.80	C3	Birkenes	0.10	C2
Ahtari	16.1	C2	Crowthorne	1.19	C3	Bergisch G.	0.78	C3	El Pardo	0.10	C2
Oymyakon	1.9	C2	Oymyakon	0.60	C2	Oymyakon	0.10	C1	Oymyakon	0.06	C1
Buenos Aires	no data		Buenos Aires	no data		Buenos Aires	no data		Buenos Aires	no data	
Camet	no data		Camet	no data		Camet	no data		Camet	no data	
Iugazu	no data		Iugazu	no data		Iugazu	no data		Iugazu	no data	
Res. Tri. Park	no data		Res. Tri. Park	no data		Res. Tri. Park	no data		Res. Tri. Park	no data	
San Juan	no data		San Juan	no data		San Juan	no data		San Juan	no data	
Jubay-Antarct.	no data		Jubay-Antarct.	no data		Jubay-Antarct.	no data		Jubay-Antarct.	no data	

TABLE 29—Steel Corrosivity Classification

Test Site	Corrosivity Classification Based on Corrosion Rate Measurement (μm/a)														Corrosivity Classification in Terms of Wetness and Pollution
	flat							helix							
	sq11	sq12	sq13	sq14	sq15	sq16	avg	sq11	sq12	sq13	sq14	sq15	sq16	avg	
Oymyakon	1	1	1		1		1	2	2	2		2		2	2
Ahtari	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Birkenes	2	2	2	2	2	2	2	3	2	3	2	3	2	3	3
Boucherville	3	2	2	2	3	2	2	3	2	3	3	3	2	3	3
Buenos Aires	2						2								
El Pardo	2	2	2	2	2	2	2		2	2	2	2	2	2	3
Iugazu	2		2				2	3	3	4	3	3	3	3	3
Judgeford	2	2	2	2	2		2	3	3	3	3	3		3	
Los Angeles	2	2	2	3			2	2	2					2	2
Picherande	2	2	2	2	2	2	2	2	2	3	2	2	2	2	3
Res. Tri. Park	2						2								
San Juan	2	2	2				2								2
Stockholm V.	3	3	3	2	2	2	2	3	3	4	3	3	3	3	3
Svanwik	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3
Baracaldo	3	4	3	3		3	3		4	4	4	3	3	4	
Batumi	3	3	3	3	2	2	3	3	3	3	3	3	3	3	3
Bergen	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3
Bergisch G.	3	3	3	3	3	3	3	4	4	3	4	3	3	4	3
Camet	2		4				3								
Crowthorne	3	3	3	3	3		3	4	4	4	4	4		4	
Kure Beach	3	3	3	3	3		3	4	4	4	5	5		4	4
Fleet Hall	3	3	3	3	3	3	3	4	3	4	4	4	4	4	
Helsinki	3	3	3	3	3	3	3	3	3	4	3	3	3	3	3
Choshi	3		3	3	3	3	3		5	5	5	5	5	5	4
Kašperské H.	3	2	3	2	3	3	3	4	3	3	3	4	3	3	3
Kattesand	3	3	3	3	3	3	3	4	3	4	4	4	4	4	3

Lagoas	3	2	3	3	2	3	3		3	3	3			3	4
Madrid	3	3	3	2	3	2	3		3	3	3	2	3	3	3
Murmansk	3	3	3	3	3	3	3	4	3	3	3	3	3	4	3
Newark	3	2	3				3	3	3	3				3	
Oslo	3	3	3	2	3	2	3	3	3	3	3	3	2	3	3
Otaniemi	3	2	3	2	3	2	3	3	3	3	3	3	3	3	3
Paris	3	3	3	3	3	3	3	4	3	4	4	4		4	4
Point Reyes	3	3		3	3		3	5	5	5	5	5		5	
Praha	4	3	3	3	4	3	3	4	4	4	3	4	4	4	4
Saint Denis	3	3	3	3	3	3	3	4	3	4	4	3	3	3	4
St. Remy	4	3	3	3	3	3	3	5	5	5	5	5	5	5	5
Stratford	3	3	3	3	3	3	3	3	4	4	4	4	3	4	4
Tokyo	3	3	3	4	3	3	3		3	3	3	3	3	3	3
Vladivostok	3	3	2	2	2	3	3	5	4	4	4	4	4	4	3
Jubay-A.	3		3				3								
Borregaard	4	4	4	4	4	4	4	5	4	5	5	5	4	5	4
Kopisty	5	4	4	4	5	4	4	5	5	5	5	5	5	5	4
Kvarnvik	4	3	4	4	5	4	4	4	4	4	4	4	4	4	4
Okinawa	5	5	4	4	3	3	4		5	5	5	4	4	5	4
Ponteau M.	5	4	4	4	4	4	4	5	5	5	5	5	5	5	4
Rye	4	3	4	3	4	4	4	5	5	5	5	5	5	5	5
Salins de Gir.	4	4	4	4	4	4	4	4	5	5	5	5	5	5	4
Tannanger	4	3	3	3	5	4	4	5	4	4	4	4	4	4	4
Auby	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Biarritz	5	5	5	5	5	5	5	4	5	4	4	3	4	4	
Ostende (B)	5	5	5	5	5	5	5	5	5	5	5	5		5	5
Panama	5						5	5	5	5	5			5	5

TABLE 30—Zinc Corrosivity Classification

Test Site	Corrosivity Classification Based on Corrosion Rate Measurement (μm/a)														Corrosivity Classification in Terms of Wetness and Pollution
	flat							helix							
	sq11	sq12	sq13	sq14	sq15	sq16	avg	sq11	sq12	sq13	sq14	sq15	sq16	avg	
El Pardo	2	2	2	2	2	2	2		3	3	3	3	3	3	3
Judgeford	2	2	3	3	2		2	3	3	3	2	2		3	
Madrid	3	2	3	2	2	2	2		3	3	3	3	3	3	3
Oymyakon	2	2	2		2		2	2	2	2		2		2	3
San Juan	2	2	2				2								3
Stockholm V.	3	3	2	2	2	2	2	3		3	3	3	3	3	3
Ahtari	3	2	3	2	3	3	3	3	3	3	3	3	3	3	3
Baracaldo	3	3	3	3		3	3		4	4	4	4	3	4	3
Batumi	3	3	3	3	3	3	3	4	3	4	4	3	3	4	3
Bergisch G.	4	4	3	3	3	2	3	4	4	3	3	3	3	3	3
Boucherville	3	3	3	3	3	3	3	3	3	4	4	4	2	4	3
Buenos Aires	3	3	3				3								
Camet	3		3				3								
Crowthorne	3	3	3	3	3		3	3	3	3	3	3		3	
Fleet Hall	3	3	3	3	3	3	3	4	4	4	4	4	4	4	
Helsinki	3	3	3	3	3	3	3	4	4	4	4	4	4	4	3
Choshi	3	3	3	3	3	3	3		4	4	4	4	4	4	4
Iugazu	4	3	3				3								4
Jubay-Antarct.	3		4				3								
Kašperské H.	3	3	3	3	3	4	3	4	3	3	3	5	3	4	3
Kattesand	3	3	3	3	3	3	3	4	4	4	4	4	4	4	3
Kvarnvik	3	4	3	3	3	4	3	4	4	4	4	5	4	4	5
Lagoas	3	3	3	2	3	3	3		4	4	4			4	3
Los Angeles	3	3	3	3			3	3	3					3	3
Murmansk	3	3	3	3	3	3	3	3	4	3	4	4	4	4	3
Oslo	3	3	3	3	3	2	3	4	3	3	3	4	3	3	3

Otaniemi	3	3	3	2	3	3	3	3	3	4	3	3	4	3	3
Picherande	3	3	3	2	3	2	3	3	4	4	3	4	3	4	3
Point Reyes	3	3	4	3	3		3	4	4	4	4	4		4	
Res. Tri. Park	3	3					3								
Saint Denis	3	3	3	3	3	3	3	4	5	4	4	4	4	4	3
St. Remy	3	3	3	3	3	3	3	4	4	5	4	5	4	5	5
Stratford	3	3	4	3	3	3	3	3	3	3	3	3	3	3	4
Svanwik	3	3	3	3	2	3	3	3	3	3	3	3	4	3	3
Tokyo	3	3	3	3	3	3	3		3	3	3	3	3	3	3
Bergen	4	3	3	4	3	4	4	4	3	3	3	4	4	4	3
Birkenes	4	3	4	4	2	3	4	4	3	4	3	4	3	4	3
Borregaard	4	4	5	5	4	4	4	5	5	5	5	5	5	5	3
Kure Beach	4	3	4	4	3		4	4	4	4	5	5		4	4
Kopisty	5	4	4	4	4	4	4	5	4	5	4	5	5	5	3
Newark	4	3	3				4	4	3	4				4	
Okinawa	5	4	4	4	3	3	4		5	5	5	5	4	5	4
Paris	5	3	4	4	3	3	4	4	4	4	4	4		4	3
Ponteau M.	4	4	4	4	4	4	4	5	5		5	5	5	5	4
Praha	4	3	2	3	3	5	4	4	4	4	4	5	4	4	3
Rye	3	4	4	3	4	4	4	4	3	3	3	3	3	3	5
Tannanger	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Vladivostok	3	4	4	4	4	4	4	4	4	4	4	4	4	4	3
Auby	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4
Biarritz	3	5		5	5	5	5		5	5	5	5	5	5	
Ostende (B)	5	5	5	5	5	5	5	5	5	5	5	5		5	5
Panama	5	5	5	5			5	5						5	5
Salins de Gir.	5	4	5	4	4	4	5	5	5	5	5	5	5	5	4

TABLE 31—Copper Corrosivity Classification

Test Site	Corrosivity Classification Based on Corrosion Rate Measurement (μm/a)														Corrosivity Classification in Terms of Wetness and Pollution
	flat							helix							
	sq11	sq12	sq13	sq14	sq15	sq16	avg	sq11	sq12	sq13	sq14	sq15	sq16	avg	
Oymyakon	1	1	1		2		1	2	2	2		2	2	2	3
Madrid	2	2	3	2	2	2	2		3	3	3	2	3	3	3
San Juan	2	2	2				2								3
Ahtari	3	3	3	3	3	3	3	3	3	4	3	3	4	3	3
Baracaldo	4	3	3	3		3	3		4	4	4	4	3	4	3
Bergen	3	3	3	3	3		3	3	3	3	4	3	3	3	3
Bergisch G.	3	3	3	2	2	2	3	3	3	4	2	2	1	3	3
Boucherville	3	3	3	3	3	3	3	3	3	4	4	4	4	4	3
Buenos Aires	3	2	3				3								
Crowthorne	3	3	3	3	3		3	4	4	4	4	4		4	
El Pardo	4	4	3	3	3	3	3		4	3	3	3	3	3	3
Fleet Hall	3	3	3	3	3	3	3	4	4	4	4	4	4	4	
Helsinki	3	3	3	3	3	3	3	3	3	4	3	3	4	4	3
Iugazu	3	3	3				3								4
Lagoas	4	3	3	3	3	3	3		4	3				3	3
Los Angeles	4	3	3	4	3	3	3	4	4	4	4	4	4	4	3
Oslo	3	3	3	3	2	2	3	3	3	3	3	3	3	3	3
Otaniemi	2	3	3	3	3	3	3	3	4	4	4	4	4	4	3
Saint Denis	4	4	3	3	3	3	3	5	4	4	4	4	5	4	3
Stockholm V.	2	3	3	2	2	2	3	3	3	3	3	3	3	3	3
Stratford	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4
Svanwik	3	3	3	3	3		3	3	3	3	3	3	3	3	3
Tokyo	3	2	3	3	3	3	3		3	3	3	3	3	3	3
Auby	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Batumi	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3
Birkenes	3	3	4	4	3	4	4	3	3	4	4	3	3	3	3

Borregaard	4	3	4	4	4		4	4	4	5	4	4	4	4	3
Camet	4						4								
Choshi	3	4	3	4	3	4	4		4	4	4	4	4	4	4
Jubay-Antarct.	4		4				4								
Judgeford	4	4	4	4	4		4	4	4	4	4	4		4	
Kašperské H.	4	4	4	4	4	4	4	5	4	4	4	5	4	4	3
Kattesand	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3
Murmansk	4	4	4	4	4	4	4	4	5	4	5	4	5	5	3
Newark	4	4	3	3	4	4	4	4	4	4	4	4	4	4	
Okinawa	4	4	4	4	4	4	4		5	5	5	5	5	5	4
Paris	4	4	3	3	4	4	4	4	5	4	4	4		4	3
Picherande	4	4	4	3	4	3	4	3	4	4	3	4	5	4	3
Point Reyes	4	4	4	4	4		4	5	5		5	5		5	
Ponteau M.	4	4	5	4	4	4	4	5	5	5	5	5	5	5	4
Praha	4	4	4	3	3	3	4	4	4	4	4	4	4	4	3
Res. Tri. Park	4						4								
Rye	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5
St. Remy	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5
Tannanger	4	4	4	4	4		4	5	5	4	5	5	5	5	4
Vladivostok	4	4	4	3	3	4	4	4	4	5	4	4	4	4	3
Biarritz	4	5	5	5	5	5	5	5	5	5	5	5	5	5	
Kure Beach	4	5	4	4	5	5	5	5	5	5	5	5	5	5	4
Kopisty	5	5	5	5	4	5	5	5	5	5	5	5	5	5	3
Kvarnvik	4	4	4	5	5	5	5	5		5	5	5	5	5	5
Ostende (B)	5	4	4	5	5	5	5	5	5	5	5	5		5	5
Panama	5	5	5	5			5	5	5	5	5			5	5
Salins de Gir.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4

TABLE 32—Aluminum Corrosivity Classification

	Corrosivity Classification Based on Corrosion Rate Measurement (μm/a)														Corrosivity Classification in Terms of Wetness and Pollution
	flat							helix							
Test Site	sq11	sq12	sq13	sq14	sq15	sq16	avg	sq11	sq12	sq13	sq14	sq15	sq16	avg	
Ahtari	2	2	2	2	2	2	2	4	2	2	2	3	3	3	3
Baracaldo	2	3	3	2		2	2			3	3	3	3	3	3
Batumi	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3
Bergen	2	2	2	2	2	2	2		2	3	3	3	2	3	3
Bergisch G.	2	2	3				2	3	3	4				3	3
Birkenes	2	2	2	2	2	2	2		2	2	2	2	2	2	3
Buenos Aires	2	2	2				2								
Crowthorne		2	2	2	2		2		2	2	3	3		3	
El Pardo	2	2	2	2	2	2	2		2	2	2	2	2	2	3
Iugazu	2	2	2				2								
Judgeford	2	2	2	2	2		2	3	3	3	3	3		3	
Lagoas	2	2	2	2			2	3	3	3				3	3
Madrid	2	2	2	2	2	2	2		2	2	2	2	2	2	3
Oslo	3	2	2	2	2	2	2		3	2	2	2	2	2	3
Otaniemi	2	2	2	2	3	3	2	2	2	3	2	3	3	3	3
Oymyakon	2	2	2		2		2	2	2	2		2		2	3
Picherande	2	3	2	3	2	2	2	3	3	3	3	3	3	3	3
Res. Tri. Park	2						2								
San Juan	2	2	2				2								
Stockholm V.	2	3	3	2	2	2	2	3	3	3	3	3	3	3	
Svanwik	2	2	2	2	2	2	2	3	2	3	2	3	2	3	3
Borregaard	3	3	3	3	4	3	3	5	3	4	5	5	4	4	4
Boucherville	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Camet	2		3				3								
Kure Beach	3	3	3	3	3	3	3	3	3	4	4	4	4	4	3
Fleet Hall		3	3	3	3	3	3		3	3	3	3	3	3	

Helsinki	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3
Choshi	3	3	3	3	2	2	3		3	3	3	4	3	3	4
Kašperské H.	3	3	3	4	3	2	3	3	3	3	3	4	2	3	3
Kattesand	3	3	3	3	3	3	3	4	3	4	3	4	4	4	
Kvarnvik	3	3	3	3	3	3	3	5	4	4	4	5	5	5	
Los Angeles	3	3	4	4	3	3	3	4	4	4	4	4	4	4	3
Newark	3	3	3	3	3	3	3	3	4	3	3	3	3	3	
Okinawa	3	3	2	3	3	2	3		4	3	4	4	3	4	4
Panama	3	3	3	3	3	3	3	4	5	4	4	5	4	4	5
Point Reyes	3	3	3	3	2	2	3	4	4	4	4	4	4	4	
Praha	4	3	3	4	3	2	3	3	3	3	3	4	2	3	3
Rye		3	3	3	3	3	3		3	3	3	3	3	3	
Salins de Gir.	4	3	3	3	3	3	3	5	5	5	5	5	5	5	4
Stratford		3	3	3	3	3	3		2	3	2	2	2	2	4
Tannanger	4	3	4	3	3	3	3		4	3	4	4	4	4	3
Tokyo	3	3	3	3	3	3	3		3	3	3	3	3	3	3
Vladivostok	3	3	2	3	3	3	3	3	4	3	4	3	3	3	4
Auby	4	4	5	4	5	4	4	5	5	5	5	5	5	5	5
Biarritz	3	4	4	4	4	4	4	4	5	5	5	5	5	5	
Jubay-Antarct.	4		4				4								
Kopisty	4	3	3	4	4	3	4	4	3	3	3	4	3	3	3
Murmansk	3	3	3	4	4	4	4	4	5	4	4	5	5	5	3
Ostende (B)	4	4	4	5	4	4	4	5	5	5	5	5		5	5
Paris	4	4	4	4	4	4	4	4	4	4	4	4		4	4
Ponteau M.	3	4	3	4	4	4	4	5	5	5	5	5	5	5	4
Saint Denis	4	4	4	4	4	4	4	5	4	5	5	5	4	5	4
St. Remy	3	4	4	4	3		4	4	4	4	4	5	4	4	5

TABLE 33—Comparison of Corrosivity Categories for Metals in ISOCORRAG Program

	Corrosivity Classification Based on Corrosion Rate Measurement (µm/yr)								Corrosivity Classification in Terms of Wetness and Pollution			
	flat				helix							
Test Site	**Fe**	**Zn**	**Cu**	**Al**	**Fe**	**Zn**	**Cu**	**Al**	**Fe**	**Zn**	**Cu**	**Al**
Oymyakon	1	2	1	2	2	2	2	2	2	3	3	3
Ahtari	2	3	3	2	2	3	3	3	2	3	3	3
Birkenes	2	4	4	2	3	4	3	2	3	3	3	3
Boucherville	2	3	3	3	3	4	4	3	3	3	3	3
Buenos Aires	2	3	3	2								
El Pardo	2	2	3	2	2	3	3	2	3	3	3	3
Iugazu	2	3	3	2	3				3	4	4	4
Judgeford	2	2	4	2	3	3	4	3				
Los Angeles	2	3	3	3	2	3	4	4	2	3	3	3
Picherande	2	3	4	2	2	4	4	3	3	3	3	3
Res. Tri. Park	2	3	4	2								
San Juan	2	2	2	2					2	3	3	3
Stockholm V.	2	2	3	2	3	3	3	3	3	3	3	3
Svanwik	2	3	3	2	3	3	3	3	3	3	3	3
Baracaldo	3	3	3	2	4	4	4	3	3	3	3	3
Batumi	3	3	4	2	3	4	4	3	3	3	3	3
Bergen	3	4	3	2	3	4	3	3	3	3	3	3
Bergisch G.	3	3	3	2	4	3	3	3	3	3	3	3
Camet	3	3	4	3								
Crowthorne	3	3	3	2	4	3	4	3				
Kure Beach	3	4	5	3	4	4	5	4	4	4	4	3
Fleet Hall	3	3	3	3	4	4	4	3				
Helsinki	3	3	3	3	3	4	4	3	3	3	3	3
Choshi	3	3	4	3	5	4	4	3	4	4	4	4
Jubay-Antarct.	3	3	4	4								
Kašperské H.	3	3	4	3	3	4	4	3	3	3	3	3

Kattesand	3	3	4	3	4	4	4	4	3	3	3	3
Lagoas	3	3	3	2	3	4	3	3	4	3	3	3
Madrid	3	2	2	2	3	3	3	2	3	3	3	3
Murmansk	3	3	4	4	4	4	5	5	3	3	3	3
Newark	3	4	4	3	3	4	4	3				
Oslo	3	3	3	2	3	3	3	2	3	3	3	3
Otaniemi	3	3	3	2	3	3	4	3	3	3	3	3
Paris	3	4	4	4	4	4	4	4	4	3	3	4
Point Reyes	3	3	4	3	5	4	5	4				
Praha	3	4	4	3	4	4	4	3	4	3	3	3
Saint Denis	3	3	3	4	3	4	4	5	4	3	3	4
St. Remy	3	3	4	4	5	5	5	4	5	5	5	5
Stratford	3	3	3	3	4	3	4	2	4	4	4	4
Tokyo	3	3	3	3	3	3	3	3	3	3	3	3
Vladivostok	3	4	4	3	4	4	4	3	3	3	3	4
Borregaard	4	4	4	3	5	5	4	4	4	3	3	4
Kopisty	4	4	5	4	5	5	5	3	4	3	3	3
Kvarnvik	4	3	5	3	4	4	5	5	4	5	5	5
Okinawa	4	4	4	3	5	5	5	4	4	4	4	4
Ponteau M.	4	4	4	4	5	5	5	5	4	4	4	4
Rye	4	4	4	3	5	3	5	3	5	5	5	5
Salins de Gir.	4	5	5	3	5	5	5	5	4	4	4	4
Tannanger	4	4	4	3	4	4	5	4	4	4	4	3
Auby	5	5	4	4	5	5	4	5	5	4	4	5
Biarritz	5	5	5	4	4	5	5	5				
Ostende (B)	5	5	5	4	5	5	5	5	5	5	5	5
Panama	5	5	5	3	5	5	5	4	5	5	5	5

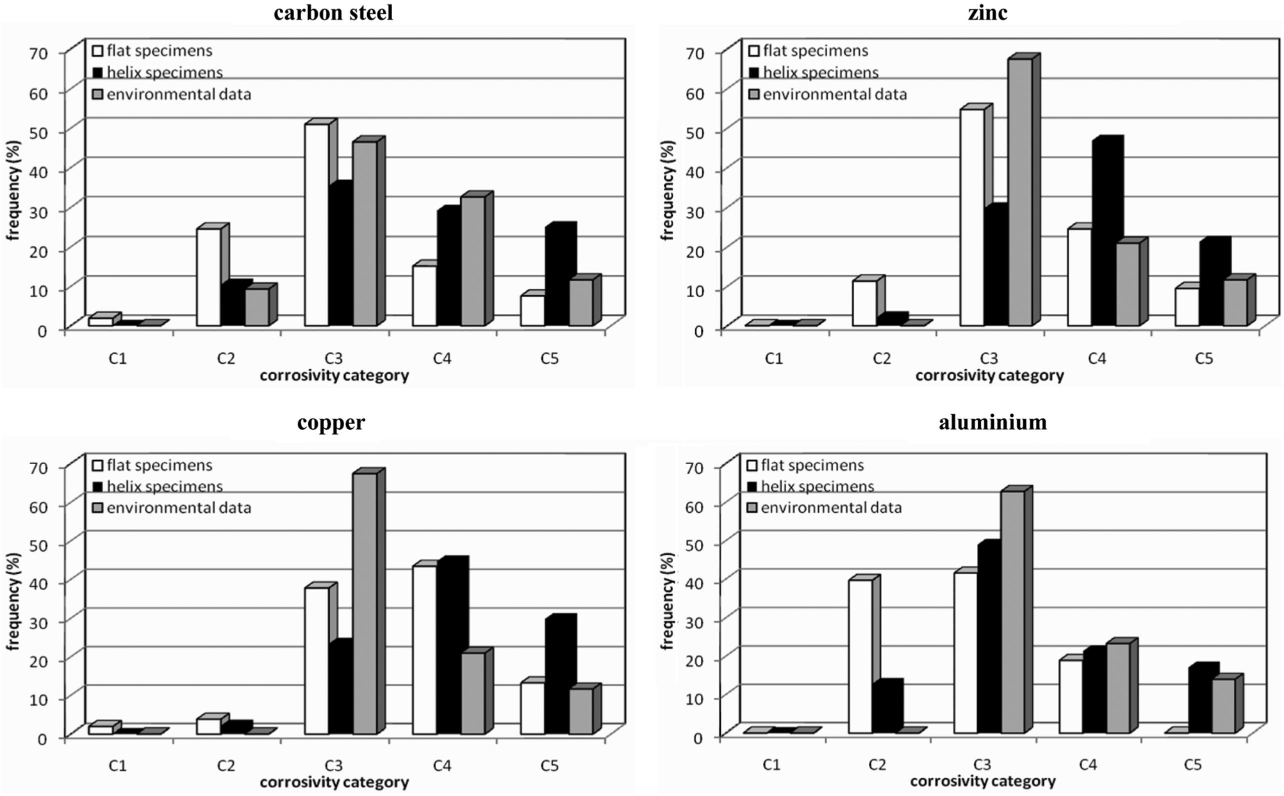

Fig. 6—Applications of different methods for atmospheric corrosivity evaluation.

3.5 LONG-TERM KINETICS

The multiyear data were used to determine the kinetics of the atmospheric corrosion processes. The well-known relationship for these processes is the power law expression:

$$ML = At^B \tag{3.1}$$

where:

ML = the mass loss per unit area,

t = the exposure time in years,

A = the mass loss per unit area in the first year of exposure,

and

B = the power law exponent, a value usually less than 1.0.

This expression may be converted to a logarithmic form as follows:

$$\mathrm{Log}(ML) = A' + B\mathrm{Log}\ t \tag{3.2}$$

where:

A′ = logA.

4

Analyses of Results and Summary

THE PRIMARY METHODS OF THE DATA ANALYSES performed were introduced in the Experimental chapter of this book. The results of this program have been used in many publications covering specific issues that arose from this study. A partial list of these papers is given below to assist researchers in locating these publications.

For general information, some conclusions and informative tables are included.

4.1 CHARACTERISTICS OF THE DATABASE

The basic ISOCORRAG program descriptive statistics were determined for the final completed 1-year exposure data:

- corrosion losses of flat specimens of steel, zinc, copper and aluminum from 51 test sites,
- environmental parameters SO_2, salinity (SAL), and time of wetness (TOW),
- n = 304 for 1-year corrosion losses and environmental data.

Limit values for quartiles and frequency of occurance in the corrosivity categories are given in Tables 34 and 35.

Based on agreement of the Czech and Spanish coordinators of the ISOCORRAG and MICAT programs, an integrated database of both programs was developed with the goal to bettter cover all climatic zones of the Earth and have more classified environmental and pollution levels. The structure and methodology of both programs were fully comparable.

The Wilcoxon two samples rank test was used to determine if there were significant differences between the ISOCORRAG and MICAT data sets with respect to the variable tested. This test verifies the correspondence or difference in distribution of the compared sets and is an appropriate statistical procedure for handling sets with nonsymmetrical distributions. The basic descriptive statistics and sorting of the results according to the classification criteria for the integrated database are presented in Tables 36, 37, and 38.

Conclusions:

- MICAT data cover more classified categories of TOW.
- ISOCORRAG data cover more classified categories of pollution (P and S).
- Categories TOW_1, P_4, and S_4 are not covered (exceptions are the Panama and Kvarvik sites).
- Variability of data is higher in the integrated database.
- Significant differences in mean temperature correspond with differences in climatic zones covered by these programs.
- There are significant differences in distribution of values for salinity, higher for ISOCORRAG data than for MICAT data.
- Significant differences in corrosion losses for aluminum are caused by asymmetrical distribution of these values in the ISOCORRAG program.
- Integrated database includes more information.

This summary is based on papers [1, 2, 3, 4] and WG 4 documents [N 260, N 275, N 329].

4.2 COMPARISON OF THE ATMOSPHERIC CORROSION RATES OF FLAT AND WIRE-HELIX SPECIMENS

A comprehensive review of the ISOCORRAG data confirmed that the helices showed significantly higher corrosion rates than the flat panels for all four metals included in the program, and smaller diameter wires showed proportionately higher rates than the larger diameter wires. This study also showed that sulfur dioxide accelerated the corrosion rate of zinc wires more than flat panels and chloride deposition accelerated the corrosion rate of copper wires more than flat panels, while both of these environmental factors accelerated the corrosion rate of aluminium wires as compared to flat specimens. This effect is related to the fact that the wires are more effective at collecting the gaseous and particulate pollutants. Because of the fact that the wire-helix specimens have systematically

TABLE 34—Basic Descriptive Statistics and Limit Values for the Single Quartiles

VAR	N	MIN	Q1	Q2	Q3	MAX	MEAN	SD	COEFF OF VAR
TOW	304	206	2938	3769	4533	8097	3820	1415	0.37
SO2	304	0.9	9.4	15.3	32.4	214.6	25.1	28.9	1.15
SAL	283	0.3	3.0	7.3	69.0	1093	76.2	157.0	2.06
Fe_F	282	0.40	23.00	35.5	48.4	373.50	41.2	31.9	0.77
Zn_F	289	0.13	1. 10	1.56	2.38	19.98	2.15	2.30	1.07
Cu_F	288	0.07	0.90	1.33	2.03	7.15	1.59	1.05	0.66
Al_F	291	0.00	0.14	0.31	0.62	2.20	0.45	0.42	0.94

TABLE 35—Distribution of Variables in Standardized Corrosivity and Environmental Categories According to ISO 9223:1992 (Frequency and Percentage Frequency)

Fe_F	C1	C2	C3	C4	C5	TOT
F	6	71	138	40	27	282
%	2.1	25.2	48.9	14.2	9.6	100
Zn_F	C1	C2	C3	C4	C5	TOT
F	0	37	169	53	30	289
%	0.0	12.8	58.5	18.3	10.4	100
Cu_F	C1	C2	C3	C4	C5	TOT
F	6	26	109	114	33	288
%	2.1	9.0	37.8	39.6	11.5	100
Al_F	C1	C2	C3	C4	C5	TOT
F	58	155	77	1	0	291
%	19.9	53.3	26.5	0.3	0.0	100
TOW	TOW$_1$	TOW$_2$	TOW$_3$	TOW$_4$	TOW$_5$	TOT
F	0	1	48	210	45	304
%	0.0	0.3	15.8	69.1	14.8	100
SO$_2$	P$_0$	P$_1$	P$_2$	P$_3$		TOTAL
F	127	123	43	11		304
%	41.8	40.5	14.1	3.6		100
SALIN	S$_0$	S$_1$	S$_2$	S$_3$		TOTAL
F	87	119	57	20		283
%	30.7	42.0	20.1	7.1		100

TABLE 36—ISOCORAG-MICAT Integrated Database Characterization

VAR	Sample	Min	Max	Median	Mean	Stand. Dev.	Z WILCOXON
T	MICAT	−2.9	27.8	20.0	19.6	6.6	
	ISOCORAG	−14.9	26.3	11.2	10.6	7.1	6.99 + +
RH	MICAT	34.0	90.3	76.0	74.0	9.9	
	ISOCORAG	50.7	88.6	77.0	75.9	7.1	−1.14 + +
TOW	MICAT	0.03	1.00	0.49	0.49	0.20	
	ISOCORAG	0.04	0.87	0.44	0.43	0.17	1.69
Rain	MICAT	5	4015	933	1004	708	
	ISOCORAG	–	–	–	–	–	–
SO$_2$	MICAT	0.7	69.2	7.9	15.1	16.3	
	ISOCORAG	1.0	150.4	13.5	21.6	26.3	−1.64
SALIN	MICAT	0.4	228.2	8.7	23.6	43.4	
	ISOCORAG	1.0	667.0	21.0	110.0	169.0	−3.98 + +
Steel	MICAT	1.6	388.0	23.4	46.4	67.7	
	ISOCORAG	1.5	373.0	35.7	44.7	53.0	0.15
Zinc	MICAT	0.11	8.0	1.23	2.04	2.11	
	ISOCORAG	0.18	17.5	1.50	2.15	2.50	−0.26

TABLE 36—ISOCORAG-MICAT Integrated Database Characterization (Continued)

VAR	Sample	Min	Max	Median	Mean	Stand. Dev.	Z WILCOXON
Copper	MICAT	0.10	8.22	1.23	1.92	1.79	
	ISOCORAG	0.05	5.46	1.32	1.54	1.05	1.33
Alum	MICAT	0.01	4.07	0.37	0.80	1.03	
	ISOCORAG	0.03	1.70	0.32	0.46	0.40	2.19 +

Significance level: + – 5 %
++ – 1 %

TABLE 37—Cases of Different Combinations of Levels for TOW, P, and S Classification Characteristics

TOW Classified Interval	Number of Cases	Combination of P and S Classified Interval	
TOW_1	0	P_0S_0	–
TOW_2	1	P_0S_0	1
TOW_3	21	P_0S_0	10
		P_0S_1	3
		P_1S_0	3
		P_1S_1	3
		P_2S_0	1
		P_3S_0	1
TOW_4	71	P_0S_0	12
		P_0S_1	11
		P_1S_0	8
		P_1S_1	14
		P_2S_0	2
		P_3S_1	6
		P_2S_2	1
		P_3S_1	1
		P_0S_3	3
		P_1S_3	1
TOW_5	22	P_0S_0	4
		P_0S_1	5
		P_0S_2	1
		P_1S_1	4
		P_1S_2	1
		P_2S_0	1
		P_2S_1	3
		P_0S_3	1
		P_1S_3	1
		P_2S_3	1

higher corrosion losses, and this effect was greater for smaller wire diameters, it was decided to exclude this type of specimens in the revised atmospheric classification standard.

This summary is based on paper [5] and WG 4 documents [N 330, N 355].

4.3 ENVIRONMENTAL EFFECTS: 1 YEAR CORROSION RATES

The work on adjustment of the corrosivity classification system included a series of regression analyses performed on the 1-year experimental data to obtain more extensive information on the single and combined environmental effects. In this step of cooperative work, the aim was to apply simple regression functions with and without logarithmic transformation of quantities. This transformation increased normality of distribution and made it possible to formulate linear regression models. It was not an aim of this work to formulate dose-response functions for the standard corrosivity catagories based either on the ISOCORRAG or MICAT data or a combination of them. Examples of correlation analyses and regression analyses are given in Tables 39 and 40 and Figures 7 and 8.

Environmental effects on 1-year corrosion rates are characteritzed in more detail in papers [6, 7] and WG 4 documents [N 329, N 349].

In Table 40, the results of regression analysis for the following models are given:

$$\ln \text{Corr} = a + b1 * SO_2 + b2 * \ln SAl + b3 * \ln TOW \quad (4.1)$$

$$\ln \text{Corr} = a + b1 * SO_2 + b2 * \ln SAl + b3 * \ln TOW + b4 * Temp \quad (4.2)$$

4.4 DERIVATION OF DOSE-RESPONSE FUNCTIONS FOR THE NORMATIVE CORROSIVITY CATEGORY DERIVATION

For this purpose, the database included the integrated ISOCORRAG/MICAT results and was extended to include data from Russian sites in frigid regions in order to increase the number of sites with low temperatures. The dose-response functions all are based on data after 1 year of exposure and can be used for the corrosivity category derivation and not for assessing lifetimes of structural metals in different atmospheric environments.

The functions all include the effects of SO_2, Cl, TOW, and T. The R^2 values are between 0.8 and 0.9 except for aluminum, where it is substantially lower. Aluminum experiences localized corrosion, but the corrosion attack is calculated as uniform corrosion.

Parameters of dose-response functions are defined in Table 41.

TABLE 38—Average Values of Metal Corrosion Loss of Series of 1 Year of Exposure in Both Programs

		ISOCORRAG Database				MICAT Database			
ISO Category	Metal	Number	Max	Min	Ave	Number	Max	Min	Ave
S_0P_0	Carbon steel	5	19.7	4.6	12.2	20	28.1	1.4	13.2
	Zinc	5	2.29	0.19	1.09	19	3.31	0.11	1.12
	Copper	5	1.25	0.18	0.82	20	1.94	0.09	0.72
	Aluminum	5	0.27	0.08	0.17	18	0.27	0.01	0.12
S_0P_1	Carbon steel	6	36.2	25.2	28.6	2	31.1	9.7	20.4
	Zinc	6	1.96	0.66	1.33	2	1.77	0.82	1.30
	Copper	6	1.39	0.53	0.89	2	0.64	0.53	0.59
	Aluminum	6	0.76	0.16	0.41	2	0.54	0.12	0.33
S_1P_0	Carbon steel	5	45.2	12.8	26.8	17	69.3	11.1	28.6
	Zinc	5	2.11	0.70	1.37	11	2.53	0.19	1.08
	Copper	5	2.24	0.76	1.42	16	3.19	0.35	1.66
	Aluminum	5	2.19	0.24	0.83	15	1.93	0.06	0.54
S_1P_1	Carbon steel	9	43.8	24.0	34.2	11	49.4	17.4	32.0
	Zinc	9	2.30	1.10	1.52	9	2.46	0.56	1.35
	Copper	9	2.04	0.66	1.14	10	1.98	0.71	1.30
	Aluminum	9	1.46	0.62	0.97	10	3.56	0.27	1.11
S_1P_2	Carbon steel	4	61.7	27.9	43.5	3	158.9	28.2	98.4
	Zinc	4	3.80	0.94	2.26	2	1.25	0.45	0.85
	Copper	4	1.38	0.93	1.20	2	2.86	1.23	2.05
	Aluminum	4	3.16	0.46	1.74	2	0.78	0.33	0.56
S_2P_0	Carbon steel	4	87.4	35.2	60.3	5	371.5	29.3	184.2
	Zinc	4	4.29	1.40	2.65	3	7.07	2.89	4.94
	Copper	4	3.66	1.35	2.20	5	5.80	2.51	3.88
	Aluminum	4	3.24	0.70	1.47	4	1.68	0.86	1.35
S_2P_1	Carbon steel	4	99.4	37.9	63.4	3	365.0	33.5	197.6
	Zinc	4	5.13	1.52	3.30	3	7.47	4.03	5.80
	Copper	4	3.19	1.80	2.73	3	4.85	3.61	4.39
	Aluminum	4	4.13	0.78	2.23	3	3.79	1.67	2.80

Corrosion losses of carbon steel, zinc, and copper are expressed in μm.
Corrosion losses of aluminum are expressed in $g \cdot m^{-2}$.

The dose-response functions are as follows for structural metals:

Carbon steel

$$C_{St} = 0.085 * SO_2^{0.56} * TOW^{0.53} * \exp(f_{St}) + 0.24 * Cl^{0.47} * TOW^{0.25} * \exp(0.049T) \qquad (4.3)$$

$f_{St}\,(T) = 0.098(T - 10)$ when $T \leq 10°C$, othewise

$f_{St}\,(T) = -0.087(T - 10)$

$N = 119, R^2 = 0.87$

Zinc

$$C_{Zn} = 0.0053 * SO_2^{0.43} * TOW^{0.53} * \exp(f_{Zn}) + 0.00071 * Cl^{0.68} * TOW^{0.30} * \exp(0.11T) \qquad (4.4)$$

$f_{Zn}(T) = 0$ when $T \leq 10°C$, othewise

$f_{Zn}\,(T) = -0.032(T - 10)$

$N = 116, R^2 = 0.78$

TABLE 39—Correlation and Regression Analysis

		MICAT	ISOCORRAG	Integrated	
Metal	**Environmental Parameter**	**N = 66**	**N = 49**	**N = 115**	**Test Dif. R(ISO)-R(MIC)**
Carbon steel	TOW	0.165	0.477 + +	0.261 + +	$p < 0.10$ (Z = 1.82)
	SO_2	0.355 + +	0.351 + +	0.330 + +	n.s.
	Salinity	0.773 + +	0.645 + +	0.526 + +	n.s.
Zinc	TOW	0.389 + +	0.448 + +	0.399 + +	n.s.
	SO_2	0.214	0.365 + +	0.305 + +	n.s.
	Salinity	0.484 + +	0.574 + +	0.498 + +	n.s.
Copper	TOW	0.289 +	0.411 + +	0.330 + +	n.s.
	SO_2	0.282 +	0.263 +	0.219 +	n.s.
	Salinity	0.458 + +	0.263 +	0.371 + +	n.s.
Aluminum	TOW	0.087	0.209	0.129	n.s.
	SO_2	0.333 +	0.559 + +	0.279 + +	n.s.
	Salinity	0.684 + +	0.254 +	0.219 +	n.s.

Significance level: + − 5%
\+ + − 1%

TABLE 40—Comparisons of Two Models of Regression Analysis

	Partial Regression Coefficients					**β-Weights**				
ln Corr	**a**	**SO_2**	**ln SAL**	**ln TOW**	**TEMP**	**SO_2**	**ln SAL**	**ln TOW**	**TEMP**	**R^2**
$Fe_{(F)}$ (1)	3.65	0.11	0.14	0.88		*0.37*	*0.31*	*0.51*		0.63
(2)	3.58	0.11	0.14	0.87	0.005	*0.36*	*0.30*	*0.50*	0.04	0.64
$Fe_{(H)}$ (1)	3.93	0.11	0.15	0.86		*0.38*	*0.34*	*0.50*		0.68
(2)	4.02	0.11	0.16	0.89	−0.006	*0.39*	*0.35*	*0.52*	−0.05	0.68
$Zn_{(F)}$ (1)	0.39	0.10	0.13	0.55		*0.37*	*0.32*	*0.36*		0.49
(2)	0.49	0.10	0.13	0.61	−0.006	*0.38*	*0.33*	*0.40*	−0.06	0.51
$Zn_{(H)}$ (1)	0.45	0.11	0.17	0.27		*0.48*	*0.47*	*0.19*		0.59
(2)	0.34	0.11	0.17	0.22	0.007	*0.48*	*0.47*	*0.16*	0.07	0.59
$Cu_{(F)}$ (1)	0.35	0.05	0.15	0.70		*0.21*	*0.37*	*0.47*		0.58
(2)	0.33	0.05	0.15	0.72	0.002	*0.21*	*0.38*	*0.48*	0.02	0.60
$Cu_{(H)}$ (1)	0.38	0.07	0.22	0.55		*0.24*	*0.50*	*0.33*		0.58
(2)	0.35	0.07	0.22	0.56	0.003	*0.23*	*0.50*	*0.34*	0.02	0.59
$Al_{(F)}$ (1)	−1.97	0.14	0.23	0.22		*0.39*	*0.41*	<u>0.11</u>		0.39
(2)	−1.39	0.15	0.25	0.46	−0.042	*0.42*	*0.44*	*0.22*	−0.28	0.45
$Al_{(H)}$ (1)	−1.43	0.15	0.27	0.29		*0.36*	*0.40*	<u>0.12</u>		0.36
(2)	−1.41	0.15	0.27	0.32	−0.001	*0.36*	*0.40*	<u>0.13</u>	−0.00	0.37

For technical reasons, the values of SO_2 concentration are divided by 10 and the time of wetness is expressed in terms of relative wetness per year. Naturally, these transformations do not affect the β-weights expressing the relative proportions of the environmental effects on corrosion. Significance of β-weights (stand. regr. coeff.): <u>underlined</u>. . . .5% level of significance, *italics*. . . . . . . .1% level of significance.

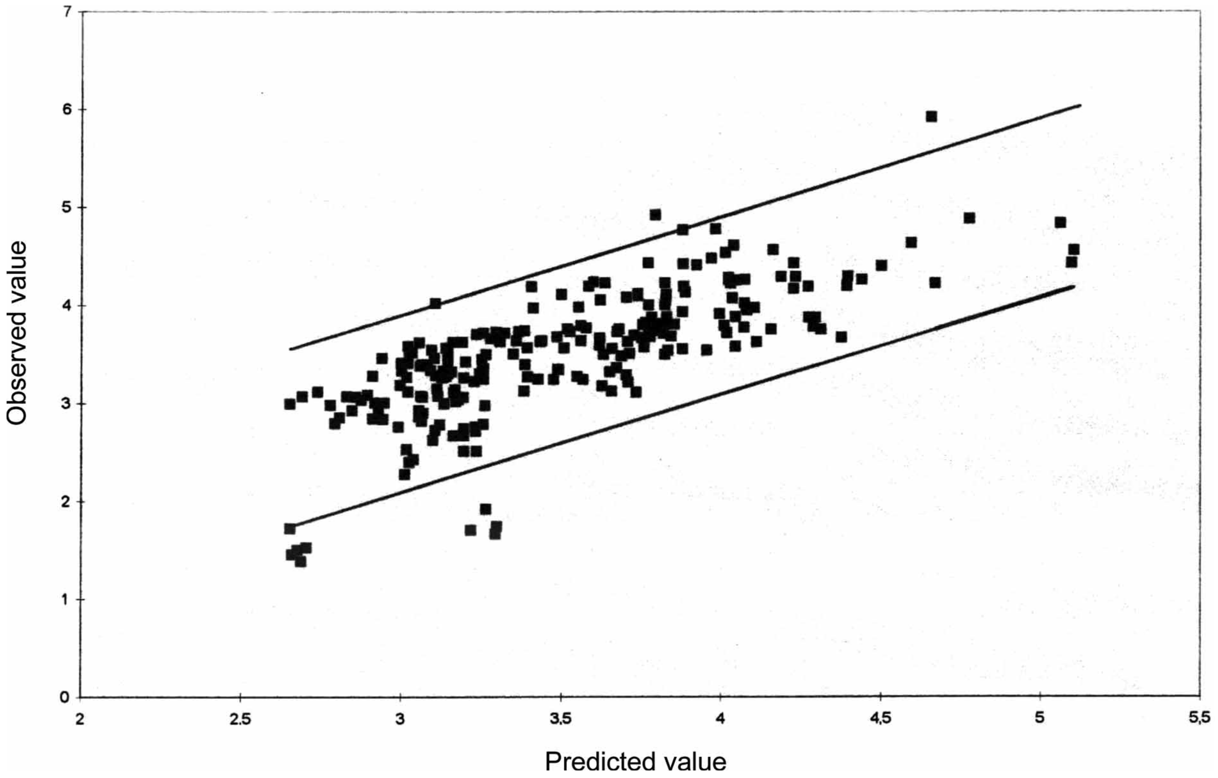

Fig. 7—Analysis of residual and standard error of prediction for carbon steel using Equation 4.1.

Copper

$$C_{Cu} = 0.00013 * SO_2^{0.55} * TOW^{0.84} * \exp(f_{Cu}) + 0.0024 * Cl^{0.31} * TOW^{0.57} * \exp(0.030T) \quad (4.5)$$

$f_{Cu}(T) = 0.047(T - 10)$ when $T \leq 10°C$, othewise

$f_{Cu}(T) = -0.029(T - 10)$

$N = 114, \ R^2 = 0.81$

Aluminum

$$C_{Al} = 0.00068 * SO_2{}^{0.87} * TOW^{0.38} * \exp(f_{Al}) + 0.00098 * Cl^{0.49} * TOW^{0.38} * \exp(0.057T) \quad (4.6)$$

$f_{Al}(T) = 0$ when $T \leq 10°C$, othewise

$f_{Al}(T) = -0.031(T-10)$

$N = 108, R^2 = 0.61$

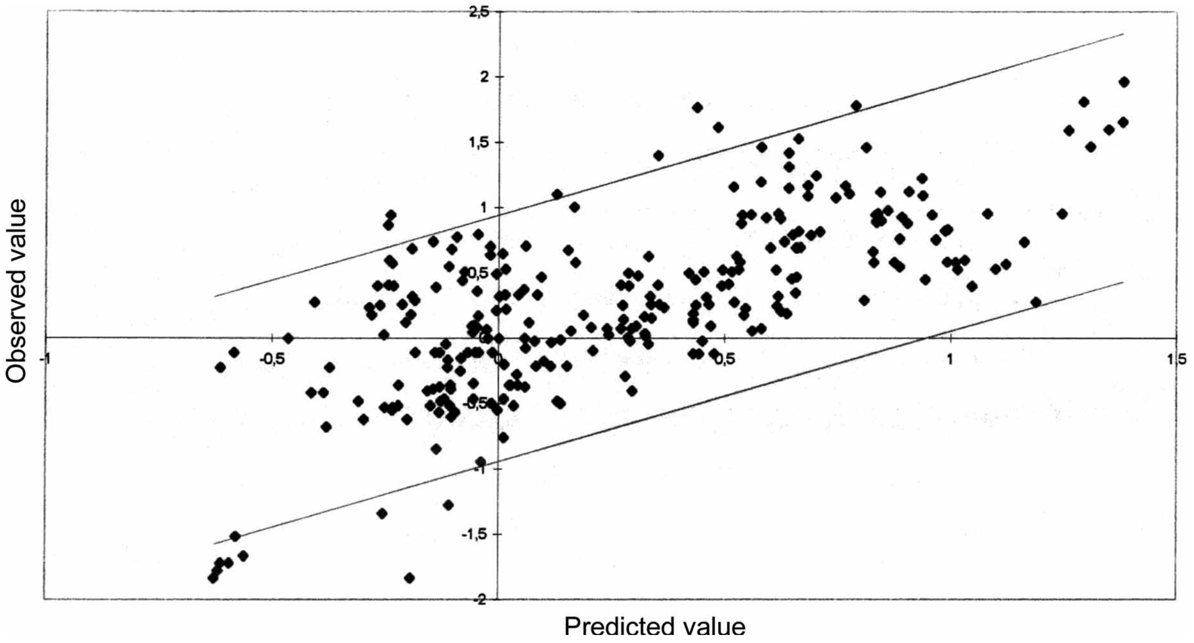

Fig. 8—Analysis of residual and standard error of prediction for copper using Equation 4.1.

TABLE 41—Parameters Used in Dose-Response Functions Including Symbol, Description, Annual Averages of Interval Measured, and Units

Symbol	Description	Interval	Unit
T	Temperature	−17.1 – 28.7	°C
TOW	Time of wetness	206 – 8760	h.year^{-1}
SO_2	SO_2 deposition	0.7 – 150.4	mg·m^{-2}day^{-1}
Cl	Cl^- deposition	0.4 – 699.6	mg·m^{-2}day^{-1}

where C_{Me} = corrosion attack after 1 year of exposure in μm of metal Me.

The predicted and observed values for the derived functions are presented in Figure 9.

This summary is based on paper [8] and WG 4 documents [N 393, N 396, N 406, N 410].

4.5 LONG-TERM KINETICS OF STRUCTURAL METALS

The approach used was to employ the kinetic model that has been widely used for atmospheric corrosion, and was discussed in Chapter 3, Equations 3.1 and 3.2.

$$ML = At^B \tag{3.1}$$

or

$$Log(ML) = A' + BLog\ t \tag{3.2}$$

where:

ML = mass loss per unit area,

t = exposure duration (years),

A = mass loss per unit area in 1 year (A′ = log A), and

B = time exponent, usually less than 1.

The values for A or A′ have been measured, and by means of a variety of dose-response functions, it is possible to estimate these values with reasonable accuracy for steel, zinc, and copper. The results for aluminum show much larger variations, probably because the mechanism of aluminum corrosion is a pitting mechanism rather than general corrosion.

Regression analyses of the B values versus climatic and air pollution component levels showed much less variation. In the case of steel, only time of wetness and, to a much smaller extent, chloride, affected the B value. Both parameters increased the B value, indicating that they made the rust layer less protective. Sulfur dioxide and chloride affected the B value for copper, but chloride tended to reduce the B value whereas sulphur dioxide increased it. This suprising result is in contrast to the effect chloride deposition has on the initial rate of attack, the *a* value, where it increased the initial rate. As a result, the initially higher rate decreases faster and, ultimately, the mass loss falls below where it would be without any chloride deposition. This can require 3 to 10 years to occur with higher chloride deposition rates requiring longer times. In the case of both zinc and aluminum, the B values are not dependent on the atmospheric variables.

If one uses Equation 3.2 to estimate intermediate or long-term corrosion losses, much greater accuracy can be achieved than with a less specific corrosion category estimation. The best results are obtained in cases where 1-year corrosion losses are measured. In that case, it is necessary only to estimate the B value and obtain the corrosion loss at any subsequent time. By adding two standard deviations to the estimated B value, an upper bound that incorporates 97.5 % of the uncertainty

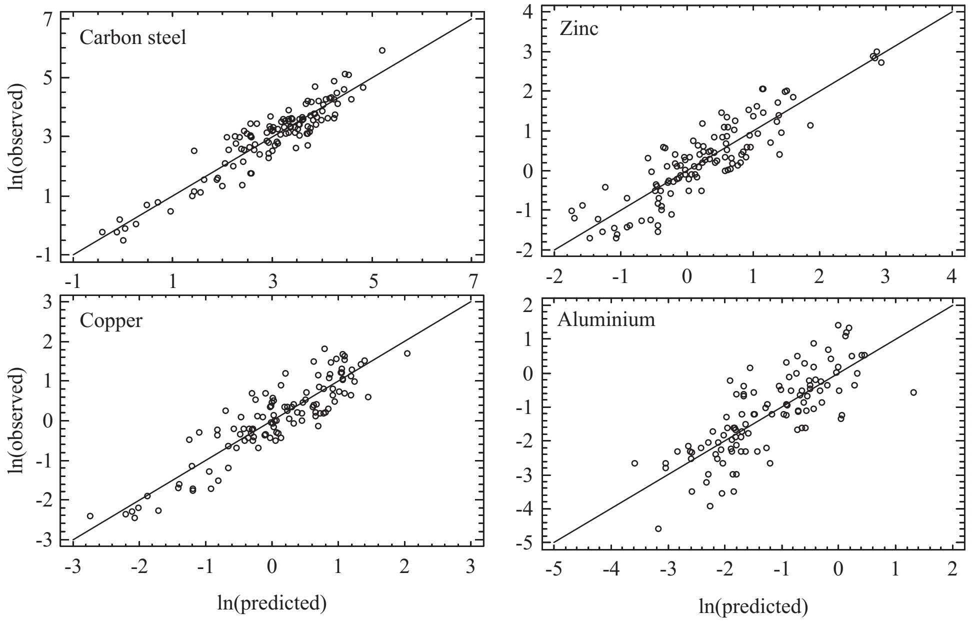

Fig. 9—Observed vs. predicted values (logarithmic) for carbon steel, zinc, copper, and aluminum (Equation 4.3–4.6).

can be determined. Where it is necessary to estimate both the A and B values, the errors become significantly larger. In most cases, however, it is possible to predict to within a factor of 2 the corrosion losses for long-term exposures. These approaches are covered in the new ISO 9224 revised standard, and they should make the calculations more accurate in predicting the performance of metals in outdoor service.

Figure 9 shows a comparison between the 8-year predictions for structural metals and the measured corrosion losses in the ISOCORRAG Program. The values for the ISO

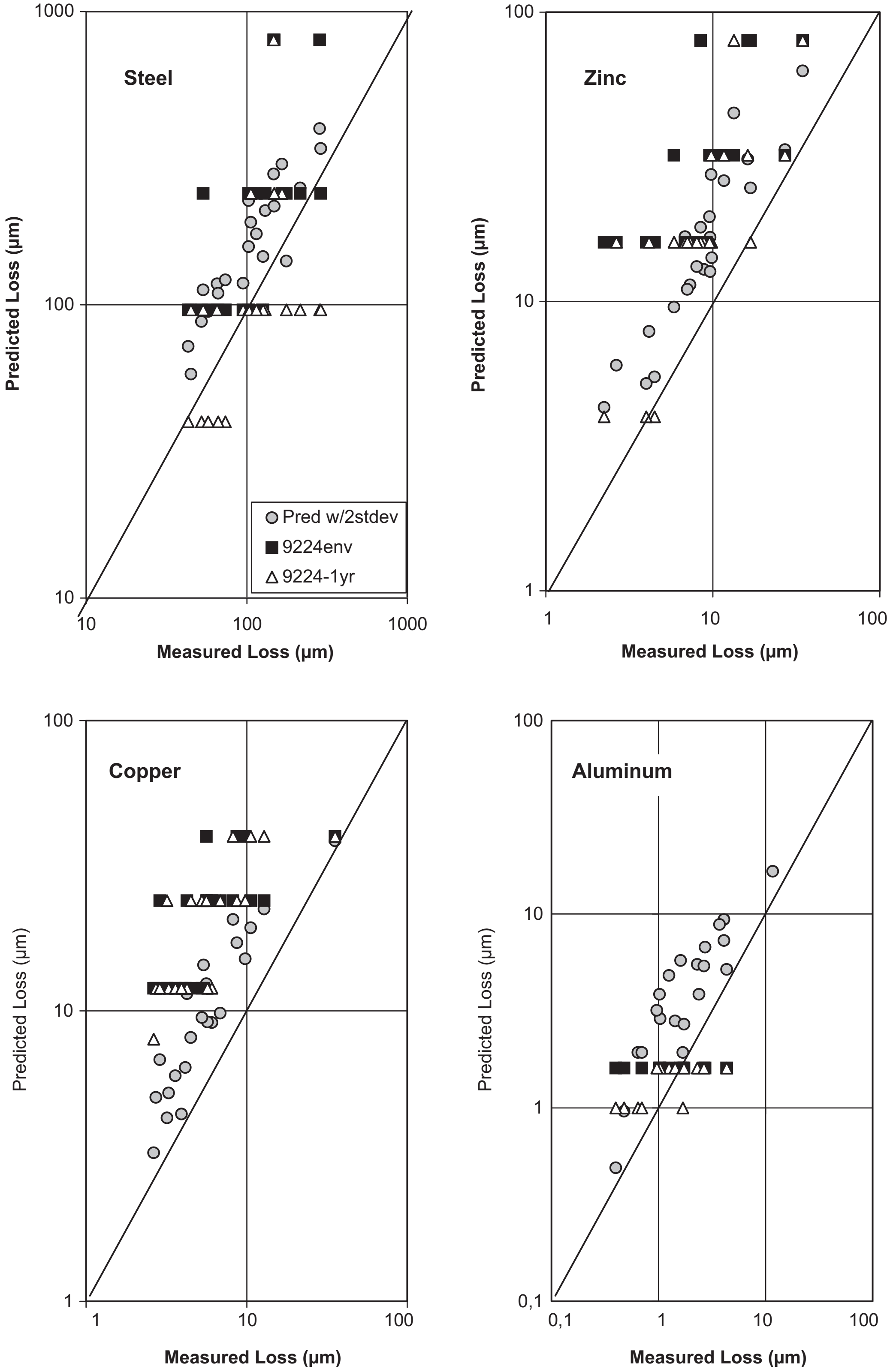

Fig. 10—Comparison between the 8-year predictions for four metals and the measured corrosion losses in the ISOCORRAG program

TABLE 42—Guiding Corrosion Values for Corrosion Rates (r_{av}, r_{lin}) of Carbon Steel, Zinc, and Copper in Atmospheres of Classified Corrosivity Categories (values in μm per year)

	Average Corrosion Rate (r_{av}) During the First 10 Years					
Metal	**C1**	**C2**	**C3**	**C4**	**C5**	**CX**
Carbon steel	$r_{av} \leq 0.4$	$0.4 < r_{av} \leq 8.3$	$8.3 < r_{av} \leq 17$	$17 < r_{av} \leq 27$	$27 < r_{av} \leq 67$	$67 < r_{av} \leq 233$
Zinc	$r_{av} \leq 0.07$	$0.07 < r_{av} \leq 0.5$	$0.5 < r_{av} \leq 1.4$	$1.4 < r_{av} \leq 2.7$	$2.7 < r_{av} \leq 5.5$	$5.5 < r_{av} \leq 16$
Copper	$r_{av} \leq 0.05$	$0.05 < r_{av} \leq 0.3$	$0.3 < r_{av} \leq 0.6$	$0.6 < r_{av} \leq 1.3$	$1.3 < r_{av} \leq 2.6$	$2.6 < r_{av} \leq 4.6$
	Steady-State Corrosion Rate (r_{lin}) Estimated as the Average Corrosion Rate During the First 30 Years					
Metal	**C1**	**C2**	**C3**	**C4**	**C5**	**CX**
Carbon steel	$r_{lin} \leq 0.3$	$0.3 < r_{lin} \leq 4.9$	$4.9 < r_{lin} \leq 10$	$10 < r_{lin} \leq 16$	$16 < r_{lin} \leq 39$	$39 < r_{lin} \leq 138$
Zinc	$r_{lin} \leq 0.05$	$0.05 < r_{lin} \leq 0.4$	$0.4 < r_{lin} \leq 1.1$	$1.1 < r_{lin} \leq 2.2$	$2.2 < r_{lin} \leq 4.4$	$4.4 < r_{lin} \leq 13$
Copper	$r_{lin} \leq 0.03$	$0.03 < r_{lin} \leq 0.2$	$0.2 < r_{lin} \leq 0.4$	$0.4 < r_{lin} \leq 0.9$	$0.9 < r_{lin} \leq 1.8$	$1.8 < r_{lin} \leq 3.2$

9224 predictions were based on the maximum rates for the predicted corrosion category. The categories were estimated either from the environmental information or from the 1-year corrosion losses as described in ISO 9223. The projections from Equation 3.2 include a two standard error increment to make the results conservative. The results shown in Figure 10 clearly demonstrate the greater fidelity and smaller tendency to underestimate the corrosion damage of Equation 3.2 approach. The large scatter in the predicted results may be caused by the fact that many atmospheric variables were not included in the prediction equations, including the temperature of the environment.

For some engineering applications, more general guiding corrosion values defined in intervals of average corrosion rates for corrosivity categories may be used (Table 42). Average corrosion rates for up to 10 years are considered corresponding to an initial period of exposure. Average corrosion rates for periods longer than 10 years are considered steady-state corrosion rates. The uncertainty level for guiding corrosion values defined as averages for initial and steady-state periods is high.

The calculated ranges of average corrosion rates are based on calculation procedures according to the revised version of ISO 9224 [WG 4 document N506], and they are derived from 1-year corrosion rates for six corrosivity categories according to ISO 9223 [WG 4 document N 505]. Other results are presented in paper [9] and WG 4 document [N 392].

5

Application of Results

THE COMPLETION OF THE ISOCORRAG PROGRAM, together with the extensive analyses that have been carried out on the results, has closed some of the gaps in our knowledge in the field of atmospheric corrosion. This was accomplished by having a large-scale and well-defined program that covered both corrosion results and environmental data for a major portion of the Earth's surface. The primary goal of the ISOCORRAG Program was to have such a data set for the revision of the ISO atmospheric corrosivity classification system.

The results of the ISOCORRAG Program have been used to create models for predicting both short and long-term corrosion damage. These models, together with updated measurement techniques for atmospheric variables, were incorporated in the proposals to revise the ISO atmospheric corrosion classification standards: ISO 9223 [WG document 505], 9224 [WG document 506], 9225 [WG document 507], and 9226 [WG document 508]. A diagram showing how these standards fit together for the purpose of estimating atmospheric corrosion damage is shown in Figure 11.

This corrosivity classification system:

- defines corrosivity categories for the atmospheric environments by the 1-year corrosion losses of standard specimens (corrosivity determination),
- gives dose-response functions for normative estimation of the corrosivity category based on calculated 1-year corrosion loss of standard metals,

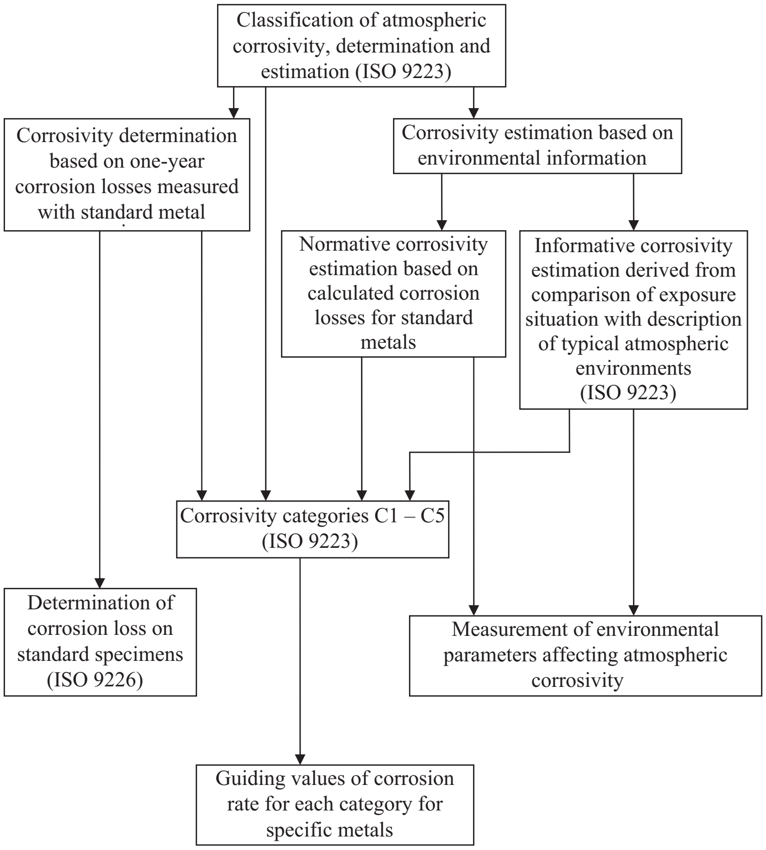

Fig. 11—Classification of atmospheric corrosivity: revised approach.

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- uses simplified environmental data for informative estimating the corrosivity catagories,
- gives calculation model and guiding corrosion values for standard structural metals after extended exposure,
- introduces methods for measurement of environmental parameters for the purpose of estimating corrosivity category according to ISO 9223, and
- specifies methods of evaluation of the 1-year corrosion loss of standard metals for atmospheric corrosivity determination.

The work on and revision of the corrosivity classification standards have been carried out by ISO technical committee working group ISO/TC 156/WG 4 Atmospheric corrosion testing and atmospheric corrosivity classification.

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EXAMPLES OF ISOCORRAG ATMOSPHERIC TEST SITES

Fig. 12—Examples of ISOCORRAG marine atmospheric test sites.

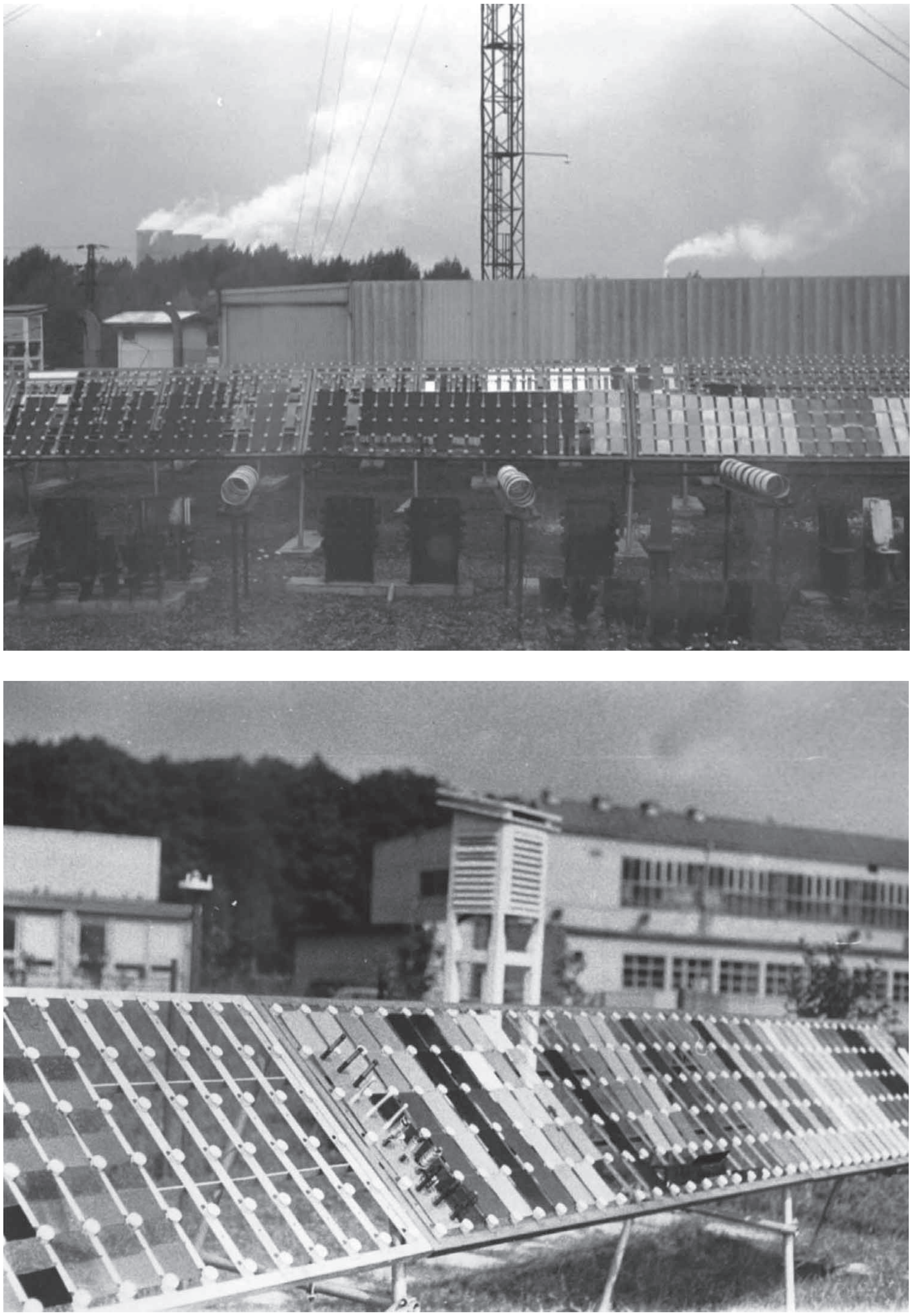

Fig. 13—Examples of ISOCORRAG industrial and urban atmospheric test sites.

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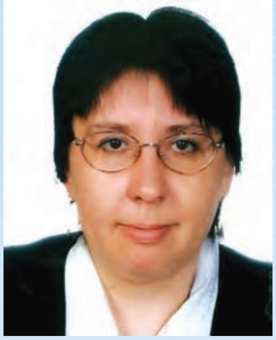
Dr. Knotkova is a world-renowned scientist who has worked for more than 40 years in the Czech Republic on the atmospheric corrosion of metals. She has served as chair of ISO/TC 156/WG 4 and has published extensively in Europe and the USA. She has led the ISO efforts to develop standards on using atmospheric and pollution data to estimate atmospheric corrosion rates and to use this information to select appropriate protection systems for coping with atmospheric corrosion. She developed and led the ISO effort to conduct a worldwide atmospheric exposure program to understand the variables that affect the atmospheric corrosion of engineering metals. She has won the NACE International Frank Newman Speller Award for excellence in corrosion engineering based on her work in the atmospheric corrosion area.



Mrs. Katerina Kreislova has worked with Dr. Knotkova for many years and is quite familiar with the ISO CORRAG Program. She is a member of the UN ECE ICP Coordination Group and has been involved with the analysis of atmospheric corrosion data extensively.

Dr. Dean has been active in the field of atmospheric corrosion since 1962, and has been a member of ASTM International Committee G01 on Corrosion of Metals since 1965. He chaired ASTM Subcommittee G01.04 on Atmospheric Corrosion for several years and also the NACE International Unit Committee T3-R on Atmospheric Corrosion. He has represented the USA in ISO/TC 156/WG 3 and 4 from their creation in 1978 to the present and led the USA participation in the ISO CORRAG Program. He has published 29 papers on various aspects of atmospheric corrosion, and chaired three ASTM symposia on atmospheric corrosion and related topics and co-edited the STP books of collected papers resulting from these symposia. He has won the ASTM Award of Merit, the ASTM Sam Tour Award, the ASTM Charles Dudley Award, the ASTM Committee G01 Francis L. Laque Award, the ASTM William T. Cavanaugh Award, and the NACE Frank Newman Speller Award. He is a fellow of ASTM International, NACE International, American Institute of Chemical Engineers, and the Materials Technology Institute.

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