

**European Federation  
of Corrosion  
Publications**

**Number 6**

---

**A WORKING PARTY  
REPORT**

**CORROSION  
EDUCATION  
MANUAL**

---



**Published for  
The European Federation  
of Corrosion  
by  
The Institute  
of Materials**



**Documents**

Document Sharing Hub

# Corrosion Education Manual

## EARLIER VOLUMES IN THIS SERIES

- |          |                                                                                                                                                      |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| Number 1 | <b>Corrosion in the Nuclear Industry</b><br><i>Prepared by the Working Party on Nuclear Corrosion</i>                                                |
| Number 2 | <b>Practical Corrosion Principles: a manual of corrosion experiments</b><br><i>Prepared by the Working Party on Corrosion Education</i>              |
| Number 3 | <b>General Guidelines for Corrosion Testing of Materials for Marine Applications</b><br><i>Prepared by the Working Party on Marine Corrosion</i>     |
| Number 4 | <b>Guidelines on Electrochemical Corrosion Measurements</b><br><i>Prepared by the Working Party on Physico-Chemical Methods of Corrosion Testing</i> |
| Number 5 | <b>Illustrated Case Histories of Marine Corrosion</b><br><i>Prepared by the Working Party on Marine Corrosion</i>                                    |

# European Federation of Corrosion Publications

NUMBER 6

## A Working Party Report

---

# Corrosion Education Manual

*Published for the European Federation of Corrosion  
by The Institute of Materials*

THE INSTITUTE OF MATERIALS  
1992

Book Number 544  
Published in 1992 by The Institute of Materials  
1 Carlton House Terrace, London SW1Y 5DB

Third Edition 1992  
A manual prepared by the Working Party on Corrosion Education  
for the benefit of those concerned with this subject at different  
levels

© 1992 The Institute of Materials

All rights reserved

*British Library Cataloguing in Publication Data*  
Available on request

*Library of Congress Cataloging in Publication Data*  
Available on application

ISBN 0-901716-31-6

Data processing and design by I2I Graphics, Winchester, Hampshire  
Made and printed in Great Britain by Bourne Press Ltd, Bournemouth

## Contents

|                                                             |      |
|-------------------------------------------------------------|------|
| <i>Series Introduction</i>                                  | vi   |
| <i>Preface</i>                                              | viii |
| <i>Acknowledgements</i>                                     | ix   |
| 1. Definition of corrosion - Scope of Manual                | 1    |
| 2. Classification of personnel combating corrosion          | 2    |
| 3. Outlines of courses of study                             | 3    |
| 4. Publications on corrosion education                      | 7    |
| 5. Terminology                                              | 9    |
| 6. Basic textbooks                                          | 10   |
| 7. Experiments and demonstrations                           | 18   |
| 8. Visual aids (films and videos)                           | 20   |
| 9. Books and booklets on specialised topics                 | 23   |
| 10. Handbooks providing data                                | 32   |
| 11. Journals and other periodicals                          | 34   |
| 12. Abstracts journals                                      | 36   |
| 13. Data bases                                              | 37   |
| 14. Anti-corrosion advisory services                        | 38   |
| 15. Training centres                                        | 42   |
| 16. Standards                                               | 45   |
| 17. Members of the EFC Working Party on Corrosion Education | 46   |

## European Federation of Corrosion Publications

**Series Introduction**

The EFC, incorporated in Belgium, was founded in 1955 with the purpose of promoting European co-operation in the fields of research into corrosion and corrosion prevention.

Membership is based upon participation by corrosion societies and committees in technical Working Parties. Member societies appoint delegates to Working Parties, whose membership is expanded by personal corresponding membership.

The activities of the Working Parties cover corrosion topics associated with inhibition, education, reinforcement in concrete, microbial effects, hot gases and combustion products, environment sensitive fracture, marine environments, surface science, physico-chemical methods of measurement, the nuclear industry, computer based information systems and corrosion in the oil and gas industry. Working Parties on other topics are established as required.

The Working Parties function in various ways, e.g. by preparing reports, organising symposia, conducting intensive courses and producing instructional material, including films. The activities of the Working Parties are co-ordinated, through a Science and Technology Advisory Committee, by the Scientific Secretary.

The administration of the EFC is handled by three Secretariats: DECHEMA in Germany, the Société de Chimie Industrielle in France, and The Institute of Materials in the United Kingdom. These three Secretariats meet at the Board of Administrators of the EFC. There is an annual General Assembly at which delegates from all member societies meet to determine and approve EFC policy. News of EFC activities, forthcoming conferences, courses etc. is published in a range of accredited corrosion and certain other journals throughout Europe. More detailed descriptions of activities are given in a Newsletter prepared by the Scientific Secretary.

The output of the EFC takes various forms. Papers on particular topics, for example, reviews or results of experimental work, may be published in scientific and technical journals in one or more countries in Europe. Conference proceedings are often published by the organisation responsible for the conference.

In 1987, the then, Institute of Metals was appointed as the official EFC publisher. Although the arrangement is non-exclusive and other routes for publication are still available, it is expected that the Working Parties of the EFC will use The Institute of Materials for publication of reports, proceedings etc. wherever possible.

The name of The Institute of Metals was changed to The Institute of Materials with effect from 1 January 1992. This follows the agreement upon the merger of the Institute with The Plastics and Rubber Institute and The Institute of Ceramics. The complete integration of PRI and I. Ceram. within the Institute of Materials is expected by the end of 1992, though as at January 1992, both these bodies still exist independently. The address, main telephone and fax numbers and VAT numbers are unchanged.

**A. D. Mercer**

*EFC Scientific Secretary,  
The Institute of Materials, London UK*

EFC Secretariats are located at:

Mr R Wood

European Federation of Corrosion, The Institute of Materials, 1 Carlton House Terrace,  
London, SW1Y 5DB, UK

Mr R Mas

Fédération Européenne de la Corrosion, Société de Chimie Industrielle, 28 rue Saint-Dominique,  
F-75007 Paris, FRANCE

Dr D Behrens

Europäische Föderation Korrosion

DECHEMA, Theodor-Heuss-Allee 25, P.O.B. 150104 D-6000 Frankfurt/M.15, GERMANY

## Preface

The interaction of iron and mild steel with their environments with the formation of rust and the consequent wastage of the metal provides the most common example of how metals deteriorate by corrosion; this is well illustrated by examples from everyday life such as the perforation by corrosion of silencers and exhaust systems of cars and the wastage of various kinds of structural steelwork.

The uniform corrosion of iron and steel is responsible for the conversion of large tonnage of these metals into oxide with a consequent slow deterioration in the properties of the metal. On the other hand any kind of localised attack may have serious consequences, although the amount of corroded metal may be very small, and the cost involved may be far greater than that of the component affected. Thus the failure of a heat exchanger tube by pitting attack could result in the shut down of a power station, which could leave large areas of a city without lighting or heating in midwinter. Similar considerations apply to the inconvenience caused and the cost arising from the perforation of an underground water main.

There are also other important aspects of corrosion damage. Lives can be lost through accidents arising from the failure through corrosion of mechanical components, for example the braking systems on cars. The conjoint action of stress and corrosion can result in the sudden fracture of metals at stresses well below their yield point and the consequences may be catastrophic when vital components are concerned; the explosion of boilers and pressure vessels and the disintegration of large turbogenerators by various types of stress corrosion cracking have been responsible for the loss of a number of lives. Also pollution of our environment is becoming increasingly serious and this can be decreased, for example by reducing the incidence of failures of pipes and tanks containing chemicals and fuels.

Several surveys\* have indicated that, in most industrialised countries, the cost of corrosion amounts to some 2–4.5% of the gross national product (GNP). It is further estimated that between 15 to 25% of this cost could be saved by better use of current knowledge of corrosion prevention methods, better protective systems, better design, etc.

The inconvenience and damage resulting from corrosion failures, and the consequent cost to the individual and to the economy of a nation provide important reasons for attempts to increase the knowledge of corrosion prevention. This manual has been prepared to assist in such attempts by providing information for those wishing to learn more about corrosion, for those teaching corrosion and for those whose responsibility it is to minimise the cost of corrosion to the economy of their country.

---

\* See, for example: Report of the Committee on Corrosion and Protection, (Chairman: T P Hoar), HMSO, London 1971; US National Bureau of Standards Report, Washington 1975 on the Economic effects of metallic corrosion in the United States; a report to the Congress by the National Bureau of Standards. NBS SP 511-1 - 3 (main report + two appendices). NBS, Washington 1978; Pourbaix, A : Le cout de la corrosion. Evaluation et analyses des actions permettant de la reduire, Cebelcor RT Vol. 138, No. 254, 1980, 20p, Cebelcor, Brussels.

## Acknowledgements

This manual has been prepared under the auspices of the EFC Working Party on Corrosion Education, whose membership is cited on page 46. The work started under the editorship of Professor K N Strafford and was continued under the late Professor J S Llewelyn Leach\*, the chairman of the Corrosion Education Working Party\*\*. The editors would like to thank the members of the WP for their help and guidance and especially the former Chairman, Gosta Svendenius and the former Secretary, Bengt Sundvall.

The Editors are also grateful to Ms Kaija Estrat, the librarian of the Swedish Corrosion Institute, for the preparation of the list of Journals and Periodicals (page 34 *et seq*), Abstracts Journals (page 36) and sources of Data Bases (page 37).

The Manual is a revised version of that originally produced in 1974, incorporating alterations and amendments as recommended, with up-dating as appropriate. Interest and concern in all aspects of corrosion science and engineering continues to grow, so that providing truly up-to-date sources of information within the terms of reference of even this manual is difficult. While attempting to include recent information however, the editors make no apology for incorporating earlier details. Thus, although certain corrosion monographs and publications are now out of print they are still an important source of information and no doubt are often available in libraries. It is hoped that the Manual will provide useful information and further stimulate interest in this fascinating and economically important subject.

**P. Neufeld**

*Secretary to the Working Party*

---

\*The committee are considerably indebted to Professor Leach for his work in the preparation of this Manual. Professor Leach died only a few months before publication of the Manual.

\*\* The editorial work was completed and the text prepared for publication by Mr A. D. Mercer.



# 1. DEFINITION OF CORROSION - SCOPE OF MANUAL

## *Definition of Corrosion*

Corrosion has been defined as :

“Physicochemical interaction between a metal and its environment which results in changes in the properties of the metal and which may often lead to impairment of the function of the metal, the environment, or the technical system of which these form a part”. (ISO 8044-1986)

Note that the term “corrosion” applies to the process, not to the result, which is “corrosion damage”, deterioration or effect. Implicit in the concept of corrosion as a process is the rate of corrosion reaction; implicit in the damage caused is the extent and nature of the damage in relation to the function of the systems concerned.

In a broader sense the concept “corrosion” is used also for non-metallic materials, for instance plastics. These are, however, not dealt with in this manual.

## *Scope of manual*

This manual is primarily designed to provide sources of information for all those concerned with the science and technology of the protection of metals against corrosion.

For *teachers* it provides examples of courses and information on textbooks, and other teaching aids. For *students* it provides information on textbooks, handbooks, journals and advisory services that should prove to be of value to their studies and subsequent careers. For designers, chemists, engineers and other professionals it indicates sources of advice for the avoidance and solving of corrosion problems within their industrial activities.

## 2. CLASSIFICATION OF PERSONNEL COMBATING CORROSION

The acknowledgement required by personnel involved in combating corrosion will vary according to their particular activity. In order to indicate the suitability of various teaching aids and texts for particular types of training it is convenient to define broadly the different approaches that are commonly made. Thus, in the solution of corrosion problems corrosion scientists and engineers, technologists and technicians invariably collaborate — it is recognised that there will be considerable overlap and that any person working primarily in one group will probably have interests and activities in other groups. The distinction is one of perspective, rather than level of skill.

In addition to those whose professional activities lie in combating corrosion it is important that engineers of all types should become more aware of the possible dangers from corrosion and of the methods used for corrosion protection. For this category the syllabus and literature proposed for groups B and C below should be taken as a guide.

The following groups may be identified:

**GROUP A : CORROSION SCIENTISTS** — those who increase the understanding of the mechanism of corrosion.

Persons such as chemists, metallurgists, physicists, engineers, etc. who are carrying out research and teaching in the field of corrosion and protection.

**GROUP B : CORROSION TECHNOLOGISTS** — those qualified by education and experience to apply available knowledge to corrosion protection in :

- (a) existing structures and processes ;
- (b) new structures and processes.

The corrosion technologist, who must collaborate with the corrosion scientist, should have a good understanding of scientific principles and should be capable of applying these to practical problems. Examples are:

- (i) corrosion engineers, corrosion protection consultants, cathodic protection specialists and
- (ii) materials engineers, chemical engineers, design engineers, maintenance and plant supervisors.

**GROUP C : CORROSION TECHNICIANS** — those whose education and training qualify them to implement decisions made by the corrosion technologists, or to carry out experimental work under supervision of a corrosion scientist.

Technicians will normally work under supervision, and will be concerned with design, surveys, inspection, commissioning plant, control, laboratory and field testing, etc.

**GROUP D : OPERATIVES** — those who carry out the actual work in the field under the supervision of the corrosion technician.

### 3. OUTLINES OF COURSES OF STUDY

The content of a course should be broadly based and should cover all the major aspects of corrosion and protection. However, it is recognised that some emphasis may be placed on the lecturer's field of interest and experience and on the specific objectives of the course. This latter point will be particularly true in the case of courses provided for groups C and D (Corrosion technicians and operatives).

For GROUP A (CORROSION SCIENTISTS) the aim has been to arrange the phenomena associated with corrosion and its prevention in a manner based upon the scientific principles involved. It will be necessary for persons belonging to this group to have taken appropriate courses in physical chemistry, electrochemistry, chemical thermodynamics, physical metallurgy etc. The depth and breadth of the course described below depend on the type and content of these other courses. Course A serves to a large extent to integrate the knowledge obtained from the other courses mentioned.

A common syllabus has been provided for GROUPS B and C (CORROSION TECHNOLOGISTS AND CORROSION TECHNICIANS), but it is apparent that the depth of approach and emphasis will not be the same. Thus, in the case of the technologist a more fundamental approach will be required, and in addition courses in physical chemistry and physical metallurgy, which should precede the course on corrosion, will be necessary to enable the technologist to appreciate the electrochemical and metallurgical aspects of the subject. On the other hand, the technician will not be required to go so deeply into theory and emphasis will be placed on the practical aspects of corrosion protection and on corrosion monitoring and testing.

For GROUP D (OPERATIVES) treatments of the principles is confined to providing only a basic knowledge relevant to the special topics being taught. These courses will be highly specialised and directed to specific jobs. Special attention will be paid to carrying out the work effectively and the training supplemented with case studies. Three examples of such courses will be given.

#### GROUP A (CORROSION SCIENTISTS)

##### *Economic and Technical Significance of Corrosion*

Discounted cash flow, present worth, investment decision, total life cycle costing.

##### *Fundamental Aspects of Corrosion*

- Thermodynamics (electrode potentials, potential-pH equilibrium diagrams)
- Kinetics (polarisation, current-potential diagrams, mixed potentials, passivity)
- Cathodic and anodic processes
- Electrochemical cells (concentration, bimetallic and active-passive cells)
- High temperature oxidation.

##### *Effects on Corrosion of Various Factors*

- Velocity, concentration and temperature
- Environment (atmosphere, aqueous solution, soil, organic solutions, biological media, fused salts, liquid metals, etc.)
- Mechanical (effects of stress, fatigue, erosion, cavitation, fretting)
- Metallurgical (composition and structure)
- Geometrical (shape, thickness, orientation).

##### *Design for Corrosion Prevention*

- Selection of materials, fabrication and construction; geometry and economics.

*Methods for Corrosion Protection*

- Change of environment (inhibitors, removal of aggressive constituents)
- Electrochemical methods (cathodic and anodic protection)
- Change of metal (composition, structure or stress condition)
- Surface coatings (metallic, inorganic non-metallic and organic)
- Packaging and temporary protection in storage and transit
- Economics.

*Corrosion Testing and Monitoring*

- Service tests (field and plant tests), accelerated tests
- Standardised testing procedures and monitoring
- Statistical planning and analysis
- Economic; prediction of plant performance from laboratory tests; hazard analysis.

*Analysis and Correction of Corrosion Failures (Case Studies)**Bibliographic sources.***GROUP B (CORROSION TECHNOLOGISTS) and GROUP C (CORROSION TECHNICIANS)\****Economic and Technical Significance of Corrosion**Corrosion Processes*

- Basic concepts (electric conductance, electrode potentials, polarisation)
- Thermodynamics (potential–pH equilibrium diagrams)
- Kinetics of electrochemical corrosion (polarisation diagrams, passivity)
- Hydrogen evolution, oxygen reduction, anodic metal dissolution
- High temperature oxidation.

*Corrosion Related to Environment*

- Atmosphere
- Fresh and sea water
- Soil
- Other environments (fused salts and slags, dry gases, water-free organic liquids, molten metals).

*Metallurgical Factors*

- Composition
- Structure, grain boundaries, dislocations, stress.

**GROUP C (CORROSION TECHNICIANS)***Some Important Types of Corrosion*

Uniform corrosion, pitting corrosion, bimetallic corrosion, intergranular corrosion and fretting corrosion, corrosion fatigue and stress corrosion cracking, crevice corrosion, deposit corrosion, selective corrosion.

---

\* Note: The syllabus proposed should be of value in courses leading to qualifications in engineering, metallurgy, chemistry, etc. in which corrosion studies are important but subsidiary to the major theme, cf. chapter 2, second paragraph. The scope and depth of treatment will be dependent on the nature of the course and on the time available for teaching. The syllabus must therefore be taken as a guide to the teacher who will naturally interpret it with reference to the nature and objectives of the specific course.

*Corrosion Properties of Some Metals and Alloys*

- Unalloyed and alloyed steels, copper, aluminium, magnesium and their alloys
- Tin, lead, zinc, nickel, titanium, etc.

*Design for Corrosion Prevention*

- Corrosion prevention starts with design
- Establishment of basic prerequisites
- Choice of surface treatment or other corrosion protection
- Design principles with regard to corrosion, effects of shape and orientation
- Economics
- Monitoring facilities.

*Corrosion Protection by Change of Composition, Structure or Stress Condition of the Metal**Corrosion Protection by Modification of the Corrosive Environment*

- Removal of aggressive constituents, for example oxygen/air and water (as liquid or vapour)
- Inhibitors.

*Electrochemical Protection*

- Cathodic and anodic protection.

*Environmental Aspects*

- Effect of corrosion on the environment
- Leaching of toxic metals and chemicals into the atmosphere or potable waters.

*Corrosion Protection by Means of Coatings*

- Pretreatment of metal surfaces before the application of coatings
- Metallic coatings
- Inorganic, non-metallic coatings (anodising, chromating etc.)
- Organic coatings (paints, plastics coatings, film forming types of temporary corrosion preventives)
- Packaging and corrosion protection in storage and transit
- Economics.

*Corrosion Testing and Monitoring*

- Service tests (field and plant tests), accelerated tests
- Standardised testing procedures
- Statistical planning and analysis
- Application of results to prediction of plant performance.

*Analysis and Correction of Corrosion Failures (Case Studies)**Bibliography.***GROUP D (OPERATIVES)***Example No. 1: Protective painting of structural steel*

Source— Bayliss D A and Chandler K A: Steel work corrosion control, 1991. Elsevier Applied Science, London.

- General principles governing successful protective painting
- Surface preparation
- Paint systems
- Painting procedure
- Repainting of old steelwork

- Practical examples
- Special cases
- Relevant national standards and similar specifications.

*Example No. 2 : The protection of steel by metal coatings*

Source — The Protection of Steel by Metal Coatings. No. 5 of a series of Corrosion Prevention Booklets. Steel Users Advisory Service, British Steel Technical, Rotherham, UK.

**Metal coatings used for the protection of steel**

- Zinc
- Aluminium
- Cadmium.

**Methods of application**

- Hot-dipping
- Metal spraying
- Electroplating
- Diffusion coating
- Cladding.

**Choice of coating and coating method**

- Painting of metal coatings.
- Relevant national standards.

*Example No. 3 : The corrosion of steel and its prevention*

Source — A Background to the Corrosion of Steel and its Prevention. No. 3 of a series of Corrosion Prevention Booklets, as example 2 above.

- Introduction
- The electrochemical nature of corrosion
- Electrode potentials
- Corrosion of two metals joined together
- Corrosion of iron and steel
- Factors affecting corrosion rates in natural environments
- Preventive measures
- Appendix — Note on acidity and alkalinity.

#### 4. PUBLICATIONS ON CORROSION EDUCATION

Sources of Corrosion Information and other Guides to practice in Corrosion Control. National Corrosion Service, National Physical Laboratory, Teddington, Middlesex, TW11 0LW, UK.

Papers on 'Corrosion Education' at EUROCORR '87, Karlsruhe, 1987, Preprints, p375-421, DECHEMA, Frankfurt.

Costa J M and Vilarrasa M: Microcomputer Programs for Corrosion Education. UK Corrosion '88 and EUROCORR 88, Brighton, 1988, Preprints, Vol. III, p99-109. Institute of Corrosion, Leighton Buzzard, UK.

Fischer W and Schmitt G: The Iserlohn Model of Corrosion Education. EUROCORR '87, Karlsruhe, 1987, Preprints, p381-383. DECHEMA, Frankfurt.

Galland J, Jerome M and Wenger F: Education through Research: Use of Pedagogic Tool of "Corrosion Education" Related to Industrial Preoccupations. EUROCORR '87, Karlsruhe, 1987, Preprints, p395-401. DECHEMA, Frankfurt.

Galland J: Action de Rénovation Pédagogique: Sensibilisation de la Jeunesse aux Problèmes de la Lutte contre la Corrosion: Concours Photographique du Jeune Corrosionniste. Ecole Centrale des Arts et Manufactures, 1985.

Galland J: L'Enseignement de la Corrosion auprès d'Etudiants en Génie Mécanique dans un Institut Universitaire de Technologie: un Problème Pédagogique, European Journal of Engineering Education, France 1983, 9, 273.

Hammersley E J: Training for Anti-Corrosion Maintenance of Naval Aircraft. British Corrosion Journal, 1969, 4, 231-235.

Heitz E, Henkhaus R and Rahmel A: 23 years Experience with DECHEMA Continuing Education Courses on Corrosion and Corrosion Protection — Conception of a Two Week Experimental Course for Scientists and Engineers from Industry. EUROCORR '87, Karlsruhe, 1987, Preprints, p417-421. DECHEMA, Frankfurt.

Heitz E and v Meysenbugh C M: Seminare und Kurse über Korrosion und Korrosionsschutz bei der DECHEMA. Galvanotechnik + Oberflächenschutz 6, 1965, 10, 240-243.

Leach J S Ll: Education and Training in Corrosion: the contribution of the government of the UK, 8th Internat. Congr. Met. Corros, Mainz, 1981, Proc., Vol. II, p1941-1946. DECHEMA, Frankfurt 1981.

Leach J S Ll: The Future Needs of Corrosion Education. EUROCORR '87, Karlsruhe, 1987, Preprints, p375-380. DECHEMA, Frankfurt.

Ministère de l'Education Nationale, Centre Français de la Corrosion, Ecole Centrale des Arts et Manufactures (1983): Actes du colloque: Rénovation pédagogique de l'enseignement de la lutte contre la corrosion.

Papers presented at the Conference on Education, Training and Communication in Corrosion Control in Engineering at the University of Sheffield, April 1969. Inst. of Corrosion, Leighton Buzzard, UK.