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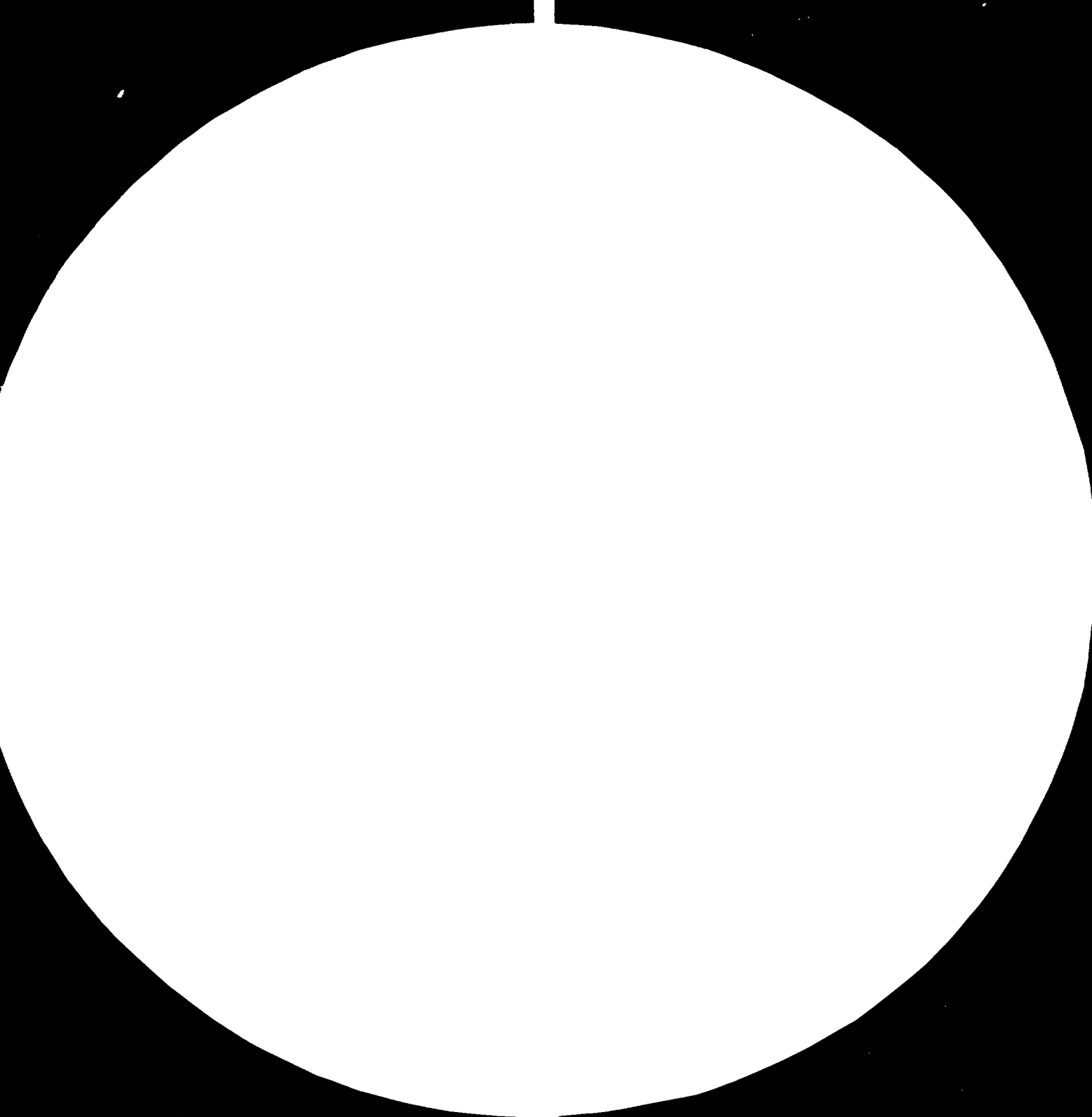
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English

ASSISTANCE IN THE DESIGN OF PREVENTIVE MAINTENANCE PRACTICE
FOR FEDERAL CHEMICAL AND CERAMICS CORPORATION LIMITED

SI/PAK/78/803

PAKISTAN

Technical report: Corrosion preventive maintenance scheme

Prepared for the Government of Pakistan
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Jerzy M. Zawadzki,
expert in corrosion

United Nations Industrial Development Organization
Vienna

V.81-26054

Explanatory notes

References to dollars (\$) are to United States dollars.

The monetary unit in Pakistan is the rupee (PRs). During the period covered by this report, the value of the rupee in relation to the dollar was PRs 9.90 = \$1.

Besides the common abbreviations, symbols and terms, the following have been used in this report:

ASTM	American Society for Testing Materials (standards)
BHC	benzene hexachloride
BS	British Standard
CP	code of practice (British Standards Institution)
CRM&R	corrosion-related maintenance and repair
DDT	dichlorodiphenyltrichloroethane
DIN	Deutsche Industrie Norm (Federal Republic of Germany standards)
FCCCL	Federal Chemical and Ceramics Corporation Limited
hdg	hot-dip galvanizing
ISO	International Organization for Standardization
M&R	maintenance and repair
m.s.	mild steel (carbon steel)
NACE	National Association of Corrosion Engineers (USA)
OSI	on-stream inspection
PVC	polyvinyl chloride
SIS	Swedish Institution for Standardization (standards)
s.s.	stainless steel
Zn/hdg	zinc coat applied by hot-dip galvanizing

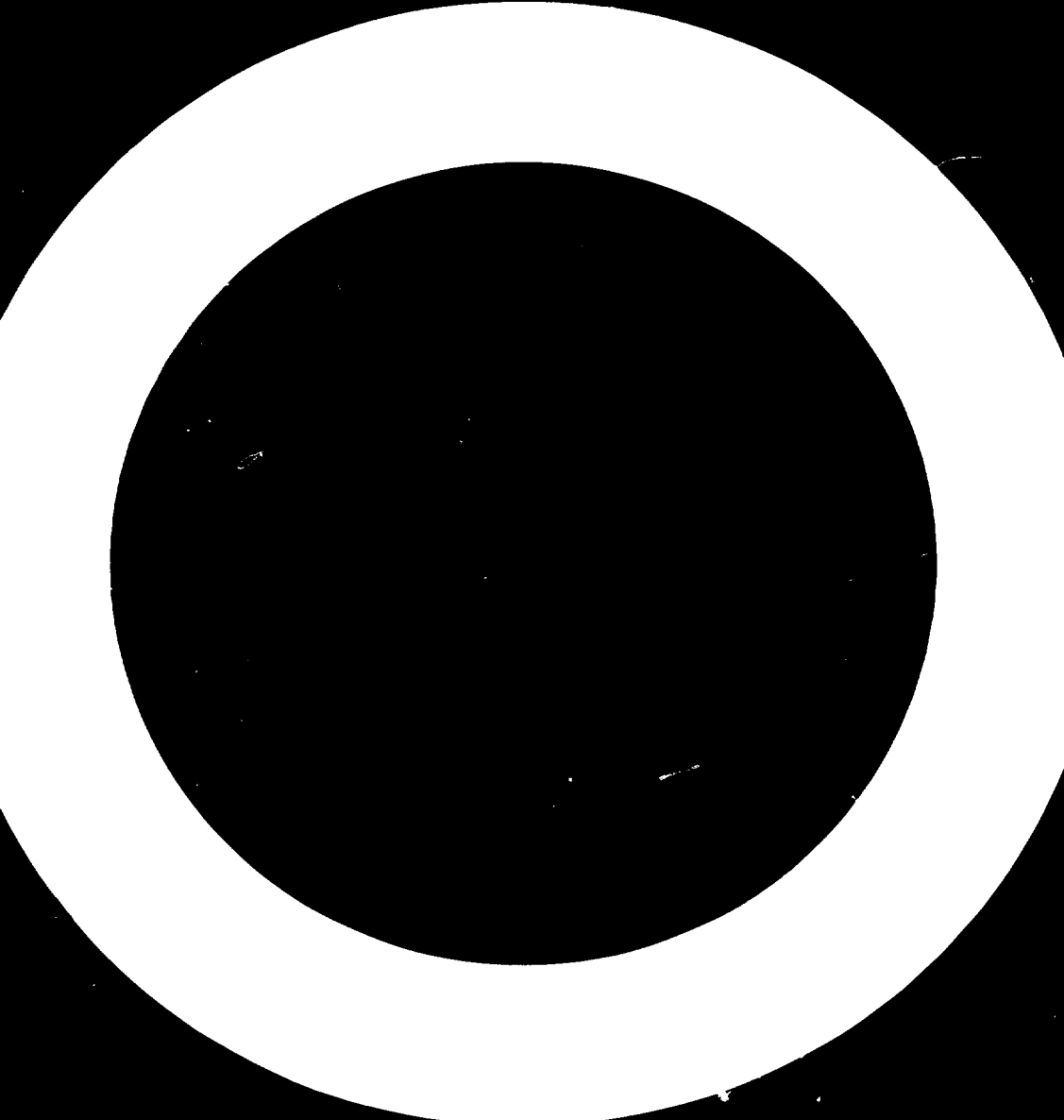
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ABSTRACT

The Government of Pakistan, wishing to develop its chemical industry, submitted a request to the United Nations Development Programme for technical assistance to the Federal Chemical and Ceramic Corporation Limited (FCCCL). Following a survey mission by the United Nations Industrial Development Organization (UNIDO) the project "Assistance in the design of preventive maintenance practice for Federal Chemical and Ceramics Corporation Limited" (SI/PAK/78/803) was approved on 30 June 1978 with UNIDO named as the executing agency, and an expert on safety, repair and maintenance started a six-month assignment in January 1980. On 1 March 1981 an expert on corrosion took up a three-month assignment, and this report describes his findings, conclusions and recommendations on corrosion-related maintenance.

Among the problems identified by the expert during his visits to FCCCL factories were poor design and protection of steel structures and a lack of standards, equipment, technology and staff training. His recommendations include advice on design, materials, maintenance and painting systems, and the organization of a corrosion laboratory, to be put into practice in Phase II of the project.



CONTENTS

<u>Chapter</u>	<u>Page</u>
INTRODUCTION.....	7
RECOMMENDATIONS.....	9
I. WORK ACCOMPLISHED.....	11
II. FINDINGS.....	12
A. The economics of corrosion protection.....	12
B. Principal observations at factories.....	14
C. Summary of findings.....	20
III. CONCLUSIONS AND RECOMMENDATIONS.....	22
A. Advice to factories.....	22
1. Corrosion and its relation to the economy.....	22
2. Design and "maintainability" of steel structures.....	23
3. Design of joints and contact areas.....	25
4. Selection of materials.....	26
5. Using low-alloy weather-resistant mild steel.....	26
6. Planning anti-corrosion maintenance.....	27
7. Planning of painting.....	28
8. On-stream inspection and corrosion testing.....	28
B. Organization of a corrosion laboratory, workshop and skilled maintenance teams.....	31

Annexes

I. Code of practice in anti-corrosion protective painting of iron and steel structures in chemical plants.....	35
II. Recommended corrosion standards for FCCCL factories.....	53
III. Recommended documentary base for FCCCL Corrosion Laboratory....	56
IV. Recommended books for training in corrosion principles.....	64
V. Equipment for corrosion related maintenance and repair.....	65
VI. Instruments for corrosion testing.....	66
VII. Recommendations for fellowships and training.....	68
VIII. Supplementary draft document for Phase II (corrosion).....	70

Page

Tables

1.	Cost of corrosion-related maintenance and repair in the FCCCL 1979-1980.....	24
2.	Corrosion-preventive paint systems for chemical environments..	36

Figures

1.	Corrosion-related maintenance and repair scheme.....	29
2.	Painting of new structures - flow sheet.....	51
3.	Repainting old structures - flow sheet.....	52

INTRODUCTION

The development of the chemical industry has been emphasized in the Government of Pakistan's development plans. The industry is controlled by the Federal Chemical and Ceramics Corporation Limited (FCCCL) established through the Ministry of Production under the Economic Reforms Order 1972.

The 14 units of the FCCCL produce a variety of products ranging from general chemicals through pharmaceuticals, plastics and ceramics to man-made fibres. At the time of the take-over the industry was in a poor way and since then the productivity of most of the former individual companies as well as that of the Corporation decreased steadily, partly because of lack of proper maintenance practices and lack of qualified maintenance engineers.

In 1975 the United Nations Industrial Development Organization (UNIDO) sent a mission under project TS/PAK/75/039 to survey the needs of the Corporation. A proposal for technical assistance followed and on 30 June 1978 the United Nations Development Programme (UNDP) responded to the Government of Pakistan's official request by approving project SI/PAK/78/803, "Assistance in the design of preventive maintenance practice for Federal Chemical and Ceramics Corporation Limited". UNIDO was named as the executing agency.

In 1979 an expert on maintenance organization assisted the FCCCL in establishing a maintenance and repair system. His appointment was for six months from 8 April 1979. It was recognized that corrosion was a major problem and an expert was appointed to advise on corrosion prevention and establish a corrosion-related maintenance and repair system. His appointment was for three months from 1 March 1981.

The corrosion expert's terms of reference were as follows:

(a) To identify the corrosion problems encountered by FCCCL, their causes and effects, and recommend remedial measures from the point of view of prevention of chemical corrosion and protection against corrosion;

(b) To give advice on laboratory methods, analytical procedures and instrumentation used for corrosion prevention and protection;

(c) To specify the equipment needed for the establishment of a specialized stationary and mobile corrosion laboratory, including non-destructive testing instruments;

(d) To give advice on the establishment of preventive and predictive maintenance system and procedures with special reference to possible failures of chemical plant equipment due to corrosion;

(e) To give advice on the safety aspects of plant operation and maintenance related to corrosion;

(f) To recommend non-destructive testing methods for on-stream preventive plant check-ups;

(g) To train the counterpart engineers of FCCCL impractical matters related to the corrosion problems frequently occurring in their day-to-day work.

The project was envisaged in two phases. Phase I has been completed. A draft project document for Phase II is included in report DP/ID/SER.A/261 by the expert on safety, repair and maintenance. A supplement to it is annexed to the present report on corrosion-related maintenance (annex VIII).

RECOMMENDATIONS

1. Direct inputs for corrosion-related maintenance and repair in FCCCL factories should be commensurate with the expected life of buildings and equipment and should be maintained at such a level as to prolong their life to between 25 and 29 years (see chapter III, section A1).
2. Care should be taken in the selection of materials to choose those whose quality is adequate to their function and which are well designed. A written specification of requirements for durability must be provided when a new factory is contracted for. Replacements should be ordered only on the written advice of the licensor (III, A4).
3. All data on materials should be obtained from the supplier of the equipment, together with an accurate and detailed description of environmental parameters (pH, temperature etc.). The user should not change environmental conditions during processing (III, A4). Low-alloy weather-resistant mild steel should be used where there are maintenance painting difficulties (III, A5).
4. All structural elements should be properly prepared before erection. Elements designed for galvanizing should be prepared by pickling in acid (III, A2). Materials should as far as possible be treated at the manufacturer's shop rather than on site, and care should be taken during transport and handling not to damage the protective cover.
5. Only continuous weld seams should be accepted in FCCCL environments and for supporting structures. Joints should be cleaned after welding and before painting and crevices between welded parts should be fully enclosed (III, A2).
6. Mild steel structures, whether new or replacements, should be of compact design and have rounded corners and edges. They should be positioned in such a way as to prevent accumulation of dirt, salts and moisture, and there should be enough space to allow access for cleaning. Elements which have to be removed for maintenance should be easily removable (III, A2).
7. Inter-material influences resulting from direct contact between dissimilar materials should be avoided. Galvanic corrosion should be avoided or reduced by various forms of isolation (III, A3).
8. The correct corrosion-related maintenance and repair scheme must be chosen according to the aggressiveness of the environment for which the structures or equipment are intended, and the scheme strictly followed (III, A6). For long-

term protection in mildly corrosive atmospheres metal coating plus painting is advised for FCCCL factories. For heavily contaminated atmospheres, only a paint-coat system can be used (III, A7).

9. The highest level of protection should be given to new structures, based on existing standards (e.g. BS, DIN, SIS) (III, A7).

10. On-stream inspection and testing for corrosion should be carried out at appropriate intervals (III, A8).

11. A corrosion laboratory should be organized at Ittehad Chemicals to carry out tests, analyses and evaluations. The laboratory should be involved in preventive maintenance for all FCCCL plants (III, B1).

12. There should be a workshop equipped to deal with testing for corrosion and cleaning (III, B2).

13. Specially skilled maintenance teams should be organized at Ravi Engineering and at Pakistan PVC. They should get short training abroad with the manufacturers of their new equipment (III, B3).

14. A senior chemical engineer should be appointed under the General Manager (Technical) of the FCCCL to control and co-ordinate activities of the corrosion laboratory and the two maintenance teams (III, B4).

15. Two persons should be trained abroad in corrosion prevention and protection (annex VII).

16. Apart from these trainees, efforts should be made at all levels to make staff maintenance-minded.

I. WORK ACCOMPLISHED

The expert visited FCCCL factories according to the programme prepared with the help of officials of the Corporation. During these visits discussions were held with staff engaged in corrosion-related maintenance and repair (CRM&R). Corrosion problems and anti-corrosion maintenance systems were analysed.

The expert also prepared the following:

- (a) A code of practice for painting in chemical factories (annex I);
- (b) A recommended corrosion standards (annex II);
- (c) A recommended documentary base for a corrosion laboratory (annex III);
- (d) A list of recommended books for training in corrosion principles (annex IV);
- (e) A list of equipment for CRM&R (annex V);
- (f) A list of instruments for corrosion testing (annex VI);
- (g) Fellowship and training recommendations (annex VII).

II. FINDINGS

A. The economics of corrosion protection

Losses due to corrosion

Corrosion losses in the world are high and are still growing because of development and industrialization processes and increasing pollution of the environment. Generally 10 to 45 per cent of corrosion costs are considered to be avoidable if the most efficient materials and corrosion control practices are used. In developing countries the value of this avoidable portion of corrosion losses would be higher and may be roughly estimated as 20 to 60 per cent.

The share of corrosion losses in chemical industries (industrial chemicals, fertilizers, pesticides, organic chemicals, petroleum refining and pulp and paper manufacture) is estimated as 10 to 15 per cent, depending on the structure of the national economy and the capital invested. Of this, 20 to 30 per cent is avoidable by means of better corrosion control practices.

A large proportion of the costs encountered in chemical plants is generally due to extensive CRM&R of equipment and structures as well as high investment costs for stainless steel (s.s.), linings and chemical-resistant protective coatings. It is estimated that 40 to 55 per cent of maintenance and repair (M&R) costs are related to corrosion in heavy chemical industries and 5 to 20 per cent in light chemical industries such as pharmaceuticals where non-corrosive materials are processed in uncontaminated atmospheres. The highest CRM&R costs and rates are observed in petroleum refineries, inorganic acids industries and fertilizer plants. In plants manufacturing alkalis and hypochlorides the maintenance costs related to corrosion are estimated at the level of about 30 per cent of all M&R costs.

The chemical industry in Pakistan

Till now no estimation of corrosion costs in Pakistan has been made and no data exist on corrosion losses. The FCCCL did not record inputs due to CRM&R either for the Corporation in general or for individual factories. As this information was lacking, rough indicators were computed by the expert in order to have some idea of the range of costs encountered in the country.

The GNP for 1979/80 was PRs 230,000,000,000.^{1/} Corrosion losses have been estimated in various countries at from 1.8 to 4.2 per cent of the GNP depending on the level of industrialization of the country, the amount of transport vehicles and cars, environmental conditions and the degree of corrosion-control practice. In the case of Pakistan and its chemical industry had on the figure for one year would therefore be between PRs 4,140 million and PRs 9,660 million (between \$4.3 million and \$9.7 million). If it is assumed that a low figure of about \$500 million is applicable, the estimated share of corrosion losses for one year amounts to \$50 million for the chemical industry in Pakistan (10 per cent of the global amount).

Material costs in Pakistan^{2/}

The cost of corrosion losses depends mainly on initial material costs and costs of manufacture. In Pakistan the costs of the raw material - mild steel (m.s.) and s.s. - are high because of import taxes and high sea-transport charges. Construction costs are also high because of "consumable" elements like imported welding electrodes and compressed gases like argon.

Mild steel

Hot rolled sheets: PRs 8,500 to 9,600 a ton depending upon availability of the required sheets and certificate prerequisites.

Cost of construction: PRs 4,500 to 5,000 a ton for tanks excluding consumables (electrodes) or PRs 6,000 a ton including consumable costs; PRs 8,000 to 8,500 a ton for vessels including consumables.

Hot rolled channels and girders: PRs 10,000 a ton for sizes up to 8 in; costs of girders above 8 in depends on availability.

Cost of construction: up to PRs 3,000.

^{1/} Pakistan Economic Survey (Islamabad, Government of Pakistan, Finance Division, 1980).

^{2/} As in April 1981, Karachi.

Hot rolled angles: PRs 7,000 to 7,500 - (local)
PRs 10,000 to 10,500 - (imported)

Cost of construction: up to PRs 4,000 including consumables.

Pipes (1 in to 6 in): PRs 50 a foot; PRs 300 a foot above 6 in.

Cost of manufacture and installation: approx. PRs 14,000 a ton.

Stainless Steel

Sheets: PRs 28,000 to 35,000 a ton depending on availability and quality (mainly A 304).

Construction costs for tanks: without consumables, PRs 7,000 a ton; with consumables, up to PRs 10,000 a ton.

Construction costs for vessels: without consumables, PRs 10,000 a ton; with consumables, PRs 12,000 a ton or more with argon welding (an argon cylinder costs: PRs 1,500 for 35 m of weld).

Piping: above PRs 40,000 a ton depending on availability.

Installation/construction charges: PRs 18,000 to 25,000 a ton.

There is a trend in FCCCL factories to use m.s. pipes because s.s. pipes of suitable dimensions are very difficult to buy and some trouble arises in manufacturing s.s. pipe-bends.

B. Principal observations at factories

Sind Alkalis Limited, Karachi

The Sind Alkalis plant is designed to produce soda ash, sodium bicarbonate and caustic soda. Corrosion problems in the plant arise from chlorides in the caustic process and the deteriorative effect on metals, mainly m.s., of an atmosphere laden with sea salt and saponification of the paint on vehicles. Sodium chloride particles, alkaline salts, dust and solar radiation are the main deteriorative factors. In some areas there is high humidity, and occasionally water may be observed splashing over equipment.

The plant constructions are about 15 years old. The design of steel structures is traditional and not adapted to corrosion protection and CRM&R. Maintenance is poor. The capacity of plant staff for proper cleaning, painting and corrosion protection is limited because of lack of

suitable equipment for sand-blasting (s-b), water cleaning and so on.

Some of the steel and concrete elements have been badly damaged and have had to be demolished. The replacement of supporting elements is difficult and carried out without improvements in design and protective systems.

Coat thickness and wall thickness are not tested. Although selection of paint according to recommendations of Imperial Chemical Industries (I.C.I.) gave better results, red lead and resinous primer are still in use.

Chlorinated rubber paints or epoxy paints are seldom used in corrosion protection. There is abnormal corrosion of painted surfaces due to poor surface cleaning before painting and because the paint coat is not thick enough. Metal spraying (MSPR) and zinc hot-dip galvanizing (Zn/hdg) are not used.

Although the expert was not expected to advise on corrosion problems in concrete structures, it must be stated that metal reinforcement in concrete pillars and floors is badly affected. This could result in serious damage and may even lead to the collapse of structures in some places. Early preventive action should be undertaken with the help of a competent civil contractor.

Pakistan PVC Limited, Karachi

The main products manufactured are caustic soda, chlorine gas and polyvinyl chloride (PVC) resin. Very severe corrosion is localized in mercury cells (covers). Tanks, pipes and other m.s. equipment are replaced often because rubber linings are not durable enough and the environment is aggressive (HCl and Cl₂ - wet gas). Steel structures are heavily corroded. Steel reinforcement in concrete pillars is partly damaged because of deterioration in the concrete.

National Fibres Limited, Karachi

As this factory was still being erected, it was suggested to the Technical General Manager that all corrosion protection be carried out according to the following standards: British Standards (BS) 5493, 1977; Deutsche Industrie Normen (DIN) 30673, March 1979; BS CP 3012, November 1972; DIN 55928, Part 6 November 1978; DIN 55928, Part 8 March 1980. There is a complete set of CRM&R standards readily available from the Pakistan Standards Institute, 39 Garden Road, Karachi.

Ittehad Chemical and Pesticides, Lahore

The plant, built in 1966, produces caustic soda and chlorine by electrolysis of NaCl brine in mercury cells and H_2SO_4 from sulphur. Some chlorine gas is compressed, bottled and sold. Ittehad Chemicals also manufactures hydrochloric acid by burning hydrogen in chlorine gas. Generally m.s. and s.s. are used in plant pipeline systems and tanks.

Steel-reinforced concrete pillars and other structures are heavily corroded because of lack of protection and the poor quality of material used by inexperienced contractors when the plant was erected. The atmosphere is variously contaminated with HCl vapours, Cl_2 gas, NaCl particles and aerosols formed during brine preparation. Generally acidic constituents are present in the air as contaminants, together with the dust of pesticides (organic chlorine compounds) at certain times and places. During NaCl brine preparation serious corrosion difficulties arise in pipes and metal settlers. In the latter, the inner and outer surfaces are protected by a coat of paint. There is no sand-blasting before painting, nor is the thickness of the paint coat checked. The plant was not supplied with cathodic protection when it was erected or subsequently.

Lining with rubber is essential to protect inner surfaces of vessels, tanks, covers, pipelines and ducts, and good craftsmanship under the experienced leadership of the rubber lining workshop could guarantee their proper maintenance.

The process of lining consists of pickling in hydrochloric acid, washing in water, drying, applying an adhesive rubber solution, preparing sheet lining material (Ittehad Chemicals Works' original formulation), applying rubber sheets, sealing and vulcanizing at high temperature. Some rubber mouldings are also formulated and produced, especially for pumps. The durability of the lining at Ittehad Chemicals is high compared with that of other factories. The DDT and BHC (benzene hexachloride) plant is stopped and some installations are being used for a new process (production of sodium hypochlorite). The supporting concrete and metal structures as well as tanks, vessels and pipelines in the DDT and BHC plant are badly corroded and are being cleaned and painted conventionally (brushed and given two protective coats). There is no washing, no neutralization, no sand-blasting, no paint selection nor thickness testing. (The painting team have no equipment for sand-blasting or instruments for testing.) After a short

time corrosion spots appear on freshly repainted surfaces.

Surface preparation grade 3 according to the Swedish Institution for Standardization (SIS) should be attained.

Ravi Rayon Limited, Lahore

The corrosive substances encountered in the chemical processing here are acetic acid, acetic anhydride, sulphuric acid, molasses, ethyl alcohol, acetone and mixtures of these chemicals with some impurities or components like ester, HCl, Cl ions and inorganic salts. There are generally no pollutants in the atmosphere but a small amount of acetic acid vapour was noticed. In the micro-climate near the plant sections, there are atmospheric contaminants due to leakages. In such circumstances the corrosiveness of the environment could be very severe, and it is increased mostly because of the solvent vapours present in the same micro-area.

All the plant's equipment was manufactured by experienced firms and up to now no catastrophic corrosion or pitting, crevice corrosion or cracking due to stress has been observed.

According to the technical staff who are well qualified in CRM&R, some difficult corrosion problems exist in the main distillation column for acetic acid. This could have a total life of about seven years, but some sections corrode faster. Pickling inhibitors are used during HCl descaling. Such inhibitors lower the dissolution effectiveness of scale present in s.s. pipes in condensers.

Heavy corrosion was observed on the outer side of underground pipes covered with a coat of bitumen. There was peeling and loss of adherence of the phenolic resin-based thermosetting coating used to protect m.s. in a methylene chloride medium. In this case HCl and water are present in the medium. All equipment made of s.s. is passivated with a solution (putty) specially formulated in Ravi Rayon to improve its resistance to corrosion.

Throughout the factory there is no cathodic protection nor preservation of concrete pillars by means of impermeable coatings according to BS and American Society for Testing Materials (ASTM) standards.

An ultrasonic thickness tester is used for wall thickness testing. On-stream corrosion testing is not monitored, except for pH. Paint-coat thickness is not checked with magnetic or electro-magnetic testers according

to ASTM standards.

Polyphosphates are used to inhibit formation of scales in water systems, but bacterial and algae growth was observed in these.

There are some books, periodicals and leaflets in the Ravi Rayon Limited library which deal with corrosion problems and CRM&R.

Baker's Yeast, Lahore

Several experienced firms and manufacturers were selected as suppliers of equipment to this plant, which is being built. Construction and installation are being carried out by a project group at the plant. Passivation of the surface of s.s. vessels (316L), passivation of welds and annealing after pipe welding are carried out well by an experienced team on the staff.

The pipe system and supports are cleaned with brushes and primed and protected with synthetic gloss enamel. The whole system is given two coats.

There is no isolation between the s.s. pipeline system and m.s. supports. All m.s. structures are painted after installation, not on the ground. Contact welds of s.s. and m.s. are not protected by a suitable coat of paint which is particularly necessary in the case of tank and vessel supports.

Concrete walls, ceilings, floors and pillars have not yet been protected against the action of the corrosive environment which is foreseen when production starts. The final product, baker's yeast, is produced from sugarcane molasses by a process of fermentation. The molasses itself as well as all intermediate and by-products is corrosive. It is also necessary not to contaminate the end product with metal ions.

On-stream control of pH was advised by the manufacturers, especially in the installation containing molasses, but no on-stream corrosion-monitoring systems; nor was it advised how to maintain and control the wall thickness of tanks and pipes by means of ultrasonic testing devices and other methods.

Ravi Engineering, Lahore

This factory, which is equipped with cold working/forming/welding sets and plate-bending machines as well as facilities necessary for the manufacture of equipment for chemical factories, is an essential element in providing a proper background to FCCCL units for corrosion control and CRM&R. An

experienced staff, especially in s.s. processing and metal working and design, should have support in cleaning and testing paint-coat quality. The use of the following equipment is necessary:

- (a) Porosity testing equipment;
- (b) Film thickness tester for paint coats and rubber linings;
- (c) Endoscope for controlling hollow sections;
- (d) Vacuum-blast equipment for shot blasting, cleaning welding joints and shot peening (4-6 m²/h).

The staff of Ravi Engineering would like more information and advice on cathodic protection. Other matters discussed included temporary corrosion protection (TCP) by hydrocarbon greases, silicone greases, graphite and molybdenum disulphide compounds.

Kurram Chemical Company Limited, Rawalpindi

The products marketed by this factory are pharmaceuticals like essential oils, artimesia oil and santonin which is an extract from the buds and leaves of a plant. These are manufactured by extraction with hydrocarbons and are also chemically purified. The purification process uses hydrochloric acid, a highly corrosive agent. In the extraction process with hydrocarbons the pH of the medium is sometimes lower than 4. This is the reason why s.s. extractors are used. It is not clear why the pH of the solution is so low, but it was suggested in discussion with the manager of the factory that only organic acids might be present in the dry herbs. This could be proved by chemical analysis.

Steel structures which are primed with paint undergo corrosion when in contact with wood surfaces or an acidic extract from wood.

Heavy corrosion was observed in m.s. tanks in the acidification room. There are altogether 14 tanks in this room. The capacity of each tank is 2,000 gallons. It should be pointed out that the corrosion of tanks is a long-lasting process. The wall thickness when new was estimated at 10 - 12 mm. Now crevice corrosion may at any time cause failure.

In the tablet-making and processing department no corrosion losses were reported.

Swat Ceramics Company Limited, Shaidu

This new factory producing ceramic articles has generally no corrosion problems. There is no high-temperature corrosion in the furnaces because

of the good quality of materials used for the furnaces themselves, and the uncontaminated gas (no sulphur compounds). During pipe transport of slip/slurry the rate of abrasion and corrosion is very low because of the inhibitors in the slurry (sodium hexametaphosphate).

Nowshera DDT Factory, Nowshera

Production has been stopped for two years in this 25-year-old factory which is very badly corroded. Corrosion has affected steel structures as well as concrete ceilings and supports, floors, etc. Pipelines and electrical installations have practically terminated their life of 25 years.

C. Summary of findings

(a) Plant corrosion in the FCCCL is caused mainly by poor design and protection of steel structures and supporting concrete pillars both at the erection stage and when equipment is assembled.

(b) There are no accidental failures in s.s. equipment, but low durability of plant sections in very corrosive environments like chlorine gas, brine and hydrochloric acid.

(c) Some rubber linings are of good quality, but sometimes the lining technology leaves room for improvement.

(d) On-stream corrosion inspection (OSI) does not take place because of a lack of instruments, experience and training abroad.

(e) No standards, e.g. BS, ASTM, Deutsche Industrie Norm (DIN), are used in the testing and evaluation of corrosion, nor in the application of anti-corrosion protective measures.

(f) Only one factory has an organized library with some books and information leaflets relating to corrosion.

(g) Painting of new and repainting of old structures is not properly performed, especially as regards surface preparation and the selection of paint systems.

(h) Paint-work on steel structures is not checked during painting and the final results of repainting are poor, causing failures of m.s. structural parts due to corrosion.

(i) CRM&R staff in the FCCCL and factories are intelligent, interested and enthusiastic, but they need training.

(j) There is a lack of equipment for mechanical steam-cleaning and blast-cleaning of metal surfaces before M&R painting and for quality control of paint coats and linings.

(k) There is a lack of instruments and probes for corrosion testing in the laboratory and during production.

(l) Corrosion losses in Pakistan are estimated at about \$500 million a year (2 per cent of the GNP), and the share due to the Pakistani chemical industry is at the level of \$50 million a year.

(m) With proper painting technology, O.S.I. and corrosion control measures, 20 to 40 per cent of corrosion losses encountered now in FCCCL factories is estimated to be avoidable.

(n) The high costs of material (m.s. and s.s.) in Pakistan are the most important reason for introducing effective corrosion protection and CRM&R in FCCCL plants.

III. CONCLUSIONS AND RECOMMENDATIONS

A. Advice to factories

1. Corrosion and its relation to the economy

Corrosion losses in industrial chemicals factories grow when inputs for CRM&R are not commensurate with the expected lifetime of equipment and with capital growth due to prolonged exploitation of a factory. Direct inputs for CRM&R in FCCCL chemical factories should be maintained at such a level as to prolong the life of constructions and equipment to 25-29 years.

The service lifetimes (and therefore replacement times) of structures and equipment in FCCCL factories, which are in several cases lower than in other countries are as follows:

	<u>Years</u>
Supporting structures (steel):	
heavily polluted humid atmospheres.....	5 - 8
chemical atmospheres.....	10 - 15
Supporting concrete structures (reinforcement):	
heavily polluted humid atmospheres.....	5 - 6
chemical atmospheres.....	8 - 10
Equipment (m.s.):	
chemical reaction tanks.....	5 - 10
storage tanks.....	3 - 5
pipes.....	5 - 10
Pumps.....	3 - 5
Valves.....	3 - 5
Chemical reaction tanks and columns (s.s.).....	7 - 12
Rubber-lined covers and vessels.....	2 - 5
Heating equipment and exchangers.....	5 - 8
Process control instruments.....	3 - 5

Depreciation rates in a one-year period must be generally high. This should be changed by means of proper CRM&R schemes and reduction of those corrosion and replacement costs which are avoidable. Preventive schemes should include long-lasting chemical-resistant paint systems, durable rubber linings, and improvements in design.

Corrosion is not only a technical, but also an economic problem associated with a loss of capital, business profits and outputs. Corrosion protection measures obviate or reduce such losses. An optimum economic situation may be achieved by selecting a suitable combination of material and techniques, after considering their cost and appraising the benefits realistically. Conservation of national resources by means of suitable CRM&R technology makes it possible to prolong their lifetime and delay depreciation. (see table 1). The depreciation time of plant differs from its lifetime and is usually shorter.

Depreciation rates of plant steel work and equipment in the FCCCL are based on a 10-year span and on initial costs of steelwork when erected. Replacement costs and the value of replaced items are increasing because the market prices of m.s. and s.s., as well as transport, electrodes and energy, are rising. When steelwork which is corroded after, say, 15 years is replaced, the costs now are often three times higher compared with those at the time of plant erection (in capital value). Existing and partly worn out steelwork has a higher capital value now than when it was erected. Depreciation rates are lower in comparison with the capital growth. Prices of materials and energy are still rising as well as CRM&R cost, but CRM&R is a major factor supporting the capital growth of steelwork and plant equipment. Corrosion-related inputs should be treated as low capital investment costs and are profitable for the FCCCL economy.

2. Design and "maintainability" of steel structures

When m.s. structures are erected or used to replace an old or corroded element they should have a compact design and be shaped (with rounded corners and edges) and positioned in such a way as to prevent the accumulation of corrosive salts and dirt. Water and moisture collection and sedimentation should be avoided, especially on horizontal planes, crevices and roofs. Good run-off and drip-off is essential for painted surfaces in order to keep them dry as long as possible.

Only continuous weld seams should be accepted in FCCCL chemical environments and for supporting structures. Welding in pockets and corners which are not accessible for sand-blasting should be avoided. Butt-welded joints are easier to clean before painting than lap joints. It is important that joints are cleaned after welding and before painting to remove bits of

Table 1. Cost of corrosion-related maintenance and repair in the FCCCL 1979 - 1980

Factory	Maintenance and repair costs PRs/year			CRM&R cost annual share, in PRs/year	Plant and machinery, original costs at erection in PRs	Book value of plant machinery in 1980, PRs ^{b/}	Ratio of CRM&R to book value ^{c/}	Value of manufactured products PRs/year	Ratio of M&R to product value
	1979	1980	(%) ^{a/}						
Antibiotics	20 476	24 012	(10)	2 401	6 380 000	550 000	0.4	13 790 000	0.2
Ittehad Chem.	1 718 236	2 315 753	(60)	1 389 452	38 430 000	8 510 000	16.3	128 520 000	1.1
Ittehad Pest.	347 424	204 253	(40)	81 701	14 480 000	9 850 000	0.3	22 900 000	0.9
Kurrham Chem.	61 967	33 728	(20)	6 745	2 060 000	820 000	0.8	2 440 000	1.4
Nowshera DDT	133 866	402	(--)	<u>a/</u>	3 900 000	990 000	-	160 000	0.3
Pakistan Dyes	not avail.	253 574	(30)	76 072	4 870 000	670 000	11.4	5 920 000	4.3
Pakistan PVC	977 726	202 726	(60)	600 000 ^{e/}	107 330 000	59 180 000	1.0	72 950 000	1.3
Ravi Rayon	6 171 025	7 770 650	(30)	2 331 119	189 720 000	70 640 000	3.3	115 140 000	6.7
Ravi Engng.	88 405	157 386	(10)	15 738	3 340 000	1 170 000	1.3	16 450 000	0.9
Sind Alkalis	172 786	485 285	(60)	291 171	92 730 000	40 740 000	0.7	55 250 000	0.9
Swat Ceramics	355 152	568 784	(10)	56 878	76 780 000	55 590 000	0.1	26 900 000	2.1
Swat Elutrit.	160 261	278 871	(20)	55 774	7 020 000	4 190 000	1.3	4 420 000	6.3
Total	10 207 184	12 295 424		4 907 051	547 040 000	252 900 000		464 840 000	
Averages							1.9		2.6

a/ Supposed % share for CRM&R cost.

b/ Depreciation rate at the level of 10% a year.

c/ Corrosion-related annual replacement rate.

d/ Plant shut down.

e/ Estimated annual mean value on 1979 basis.

flux (alkaline or acidic contaminants). Crevices between welded parts should be fully enclosed by continuous welds.

All structural elements designed for Zn-hdg should be prepared beforehand by pickling in acids. Such elements should be designed according to BS (see annexes II and III). It is generally advisable to use metal spraying equipment to apply coats of zinc and aluminium to m.s. structures, which should be appropriately designed for this purpose.

Access should be provided for cleaning and painting of all surfaces which have to be protected. These include the backs of pipes, ventilation ducts, lockers and supports. Elements which have to be removed for maintenance, cleaning and repainting should be readily and easily removable.

All parts which are exposed to heavily contaminated atmospheres and water vapour, as well as to the splashing and draining of corrosive liquids, should be able to be separately dismantled for proper cleaning and protection.

3. Design of joints and contact areas

Joints and contact areas of items made from m.s., s.s. or other materials are danger points from the corrosion point of view and should be especially carefully treated when they are being designed and during maintenance. Inter-material influences resulting from direct contact between dissimilar metals should be avoided. Compatible materials should be used to obtain entity in the project.

Galvanic corrosion can be avoided or reduced even in a highly corrosive environment by means of dielectric separation; high-grade insulating materials, gaskets, tapes, sealant and fillers applied on faying surfaces should give a reduction of potential sufficient to lower the corrosion rate and to avoid the formation of crevices. Less noble components should be made larger and thicker than cathodic elements. Anodic elements should have a sufficient allowance and should be easily removable for replacement when necessary. Both anodic and cathodic elements should be isolated at a distance of not less than 50 mm. Cathodic metals should be used for critical components and should be protected sacrificially by means of large metal parts which are anodic. The unfavourable effects of small anodic areas, highly corrosive environments, corrosive deposits and condensation of moisture on galvanic cells (e.g. m.s./s.s.), should be avoided. Lead washers, painting with epoxy two-pack systems, teflon isolation and other

methods should be used for m.s./s.s. separation.

4. Selection of materials

Basic considerations in design should be the presumed life of equipment and optimal durability coupled with economy of corrosion prevention. Failures occur generally when inadequate material was used and the design was defective. The two go together.

A written specification of requirements for durability, lifetime and CRM&R must be provided when a new factory is contracted for. It would concern equipment and the separate installation parts which are prone to corrosion.

It is no longer possible to select suitable materials (s.s.) in Pakistan according to laboratory tests on corrosion resistance; only general data from existing standards and guidebooks are available. Metals and alloys for replacements should be ordered only on the written advice of a licenser. The same applies to welding electrodes and heat treatment. The best materials should be used so that the required length of service is obtained and at a reasonable cost for CRM&R. The manufacturers of equipment are responsible for selection of material according to its functional suitability.

It is imperative that the user should not change the environmental conditions during processing, as this can be detrimental to the durability and life of equipment. All data on materials should be obtained from the supplier of the equipment together with an accurate and detailed description of environmental parameters (e.g. pH, temperature, critical concentrations of impurities).

5. Using low-alloy weather-resistant mild steel

This type of steel should be used where there are maintenance painting difficulties, for mildly corrosive conditions and light structures, supporting beams, and so on. M.s. of this quality has not been used in Pakistan till now. Because of low maintenance costs of such steelwork it is advised that it be used without painting in FCCCL plants for structures not exposed to highly corrosive gases and vapours.

It is not necessary to paint weather-resistant m.s. where decorative effects are a secondary consideration and corrosiveness of the environment

is estimated to be low. In such cases copper containing low-alloy weather-resistant steel is naturally covered by an impervious layer of black-brown products protecting it against crevice corrosion.

To evaluate the usefulness of this material in FCCCL plants, a testing programme starting in Phase II of the project should be carried out after selection of places to expose steel plates. It is important for the FCCCL corrosion-protection economy to make this arrangement at that time and to reduce anti-corrosion maintenance costs in FCCCL plants in the future.

Anti-corrosion maintenance schemes for steelwork should be based on programmed inputs for each year of plant exploitation, depending on the aggressiveness of the environment and presumed durability of paint coatings on m.s. or of weather-resistant m.s. alloy. An important question which arose during discussions with FCCCL managers and factory managers concerned the economies of protecting old structures. The question was: at what level should the maintenance input be, in relation to the value of steelwork and its life time? This question should be analysed during the projected Phase II of the project after collection of the necessary data which are partly included in table 2 and should be supplemented in the second phase.

6. Planning anti-corrosion maintenance

(Comprehensive data on planning and maintenance organization are included in the UNIDO Technical Report DP/ID/SER.A/261, 8 January 1980, based on the work of the project's expert on safety, repair and maintenance).

CRM&R should be based on a planned maintenance programme, and this should be compatible with corrosion phenomena which sometimes occur rapidly and unexpectedly. Often abnormal corrosion may be discovered in inaccessible places, joints and crevices, when instant action is necessary to avoid further damage. This is often the case when wall thickness is not measured with nondestructive testing instruments and no OSI is made. Fast-corroding critical parts require rapid dismantling and replacement. Major impediments to maintenance should be avoided at corrosion-affected weak points and all CRM&R operations should be foolproof even in the critical situations which can arise.

The incidence of corrosion-related failures is rising in old factories where deterioration and even catastrophic accidents may occur. As long as equipment and constructions are new and useful, their "maintainability" must

be ensured; maintenance should be regular and according to a proper scheme and standardized technology. OSI for corrosion, testing and monitoring allow a low level of unexpected failures to be maintained. Failure analysis should be made for serious corrosion breakdowns. The CRM&R scheme given in figure 1 should be implemented in Phase II of the project.

7. Planning of painting

Paint protects 70 to 80 per cent of corroded metal surfaces. The highest level of protection should be given to new structures when erected, based on existing standards, e.g. BS, DIN and the Swedish Institution for Standardization (SIS). It will delay repainting and induce lower maintenance costs. The protection of steelwork should start in the design stage of a project and should be performed according to figures 2 and 3 in annex I.

The choice must be made between painting, metallization, galvanizing and metal coating plus painting. For long-term protection in mildly corrosive industrial atmospheres, metal coating plus painting is advised for FCCCL factories, to obtain a 15-year span between the initial painting and the first maintenance repainting.

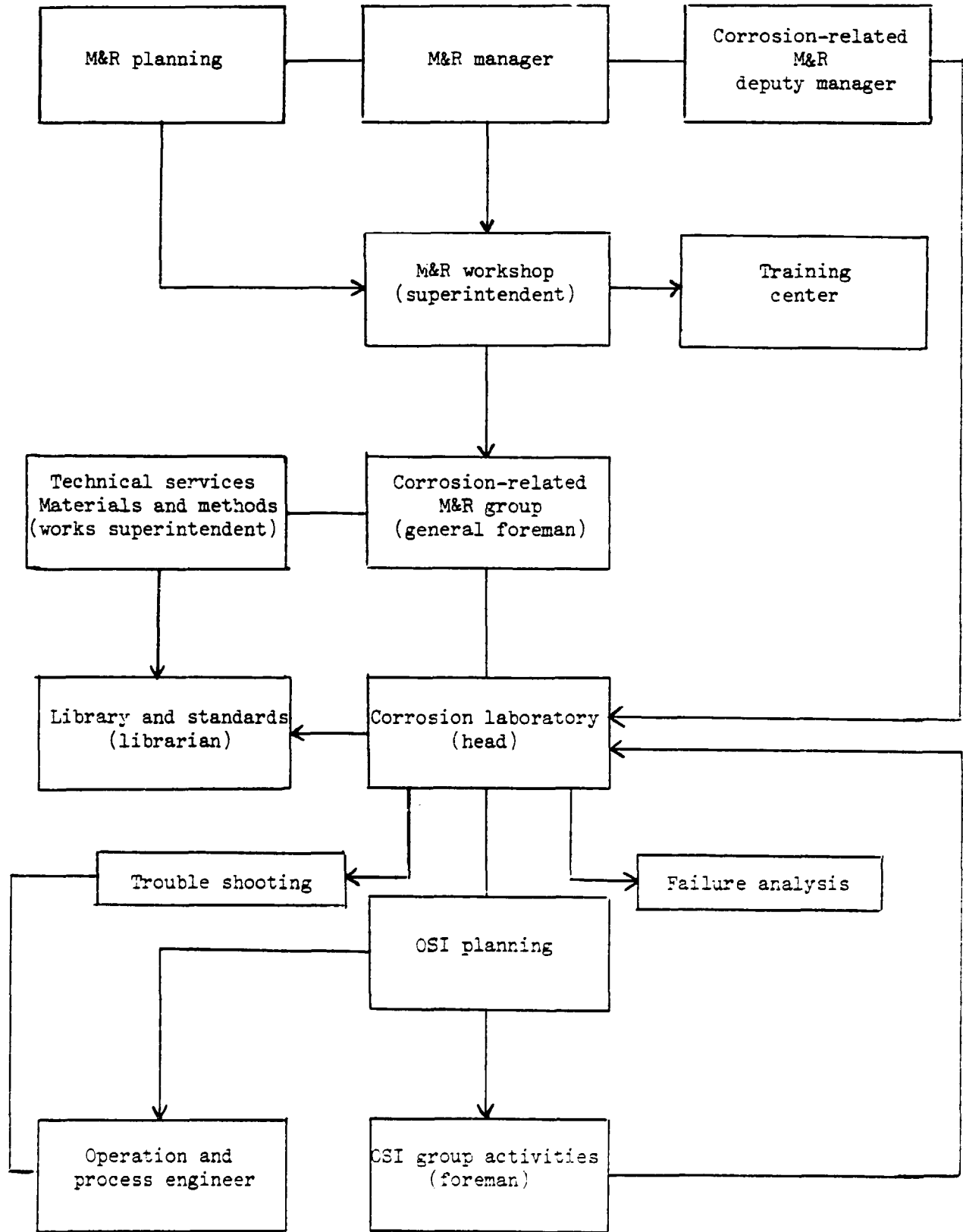
For heavily contaminated atmospheres only a paint-coat system (annex I, table 3) can be used, giving 5 to 10 years before painting. When a decorative appearance is not important, galvanized or metalized structures are recommended for outside atmospheres contaminated only with trace amounts of corrosive gases. Metal coatings have until now been used to only a very limited degree in Pakistan because of technical difficulties with them.

Maintenance painting should be done by the painting staff of each factory according to the flow chart given in annex I (figure 3). Existing equipment for cleaning in FCCCL factories makes it impossible to perform the job well and obtain adequate paint coat durabilities with low investment in the paint itself.

8. On-stream inspection and corrosion testing

OSI involves, as well as wall-thickness ultrasonic testing, surface temperature testing, and X-ray monitoring, the use of retractable samples and electrochemical probes located at critical points of the installation. These are essential for checking and for predicting CRM&R time and intervals of breakdown. This is the only means of determining the rate and type of corrosion.

Figure 1. Corrosion-related maintenance and repair scheme



The exposure scheme which should be based on knowledge and experience, depends on the type of environment, velocity of flow and temperatures. Operating techniques and installation of probes used for periodic or continuous testing should be carried out in close co-operation with the supplier of the probes/equipment.

The probes should be placed in strategically important places for monitoring corrosion, to check the aggressiveness of the environment and any changes. Periodic monitoring of wall thickness by means of ultrasonic methods does not exclude monitoring inside pipes and vessels. The samples and probes determine the effectiveness of anti-corrosion measures (e.g. inhibitors), the selection of appropriate materials and the controlling velocity of flow and their influence upon the corrosion rate and forms of corrosion. They should be positioned so as to provide measurements reproducible for other application. Probes are important also for evaluating changes in the aggressiveness of the medium and also for assessing the relative corrosion rates.

OSI makes it possible to check the environment and the state of the metal without interrupting the chemical process, and to obtain valuable data to estimate the durability of installations and forecast the approximate date of maintenance and replacement. Priorities may be established for maintenance when the data are carefully analysed.

In the initial stages the number of control and check points are generally overestimated (150 to 200). For high corrosion rates one- to six-month intervals for inspection are sufficient; for low rates six to twelve months; and for very low corroding media two to three years. It is important to remember that the overestimation of the number of checking points holds good for the first year only. After four years only 25 per cent of the points initially selected are checked. This reduction takes place after zero-estimation losses at "safe" points of the plant installation. Weak points chosen during the initial period of OSI are sometimes checked very often, depending on corrosion rates and losses observed or presumed.

OSI is not advised to test stress corrosion, or to estimate the time when stress-corrosion cracking will appear. In a long-term scheme it can diminish corrosion losses in danger areas and eliminate weak points of the installation through selection of the right materials and their thicknesses. OSI makes the need for maintenance work less frequent and

permits the prediction of corrosion in order to plan CRM&R.

In the FCCCL PVC and Ravi Rayon factories it is particularly advised that OSI is adopted for the following: pipelines, pipe bends and loops, blind pipes and pipes in contact with flanges, temperature-measuring instrument covers, reactors, valves, bends and lines where liquid velocities change, or condensation or evaporation occur, where hot-cold points are situated, and where sedimentation is common.

It is also important to carry out OSI on sections near welds, on thin wall-pipes welded with flanges, on multiconnection lines, at pump outlets and at non-compatible metal connections. Pipes, pumps and valves should be monitored by X-ray at the erection stage of a factory and monitoring should continue during processing and when items are replaced.

The FCCCL factories have to be advised on this type of action for Phase II of the project.

B. Organization of a corrosion laboratory, workshop
and skilled maintenance teams

1. Laboratory

A chemical laboratory for corrosion testing should be organized at Ittehad Chemicals. Its objectives should be to carry out the following:

- (a) Corrosion testing (gravimetric and gauging) in liquid media on a laboratory scale;
- (b) OSI, probe evaluation by weight and optical methods;
- (c) Wall-thickness testing by means of ultrasonic instruments, surface temperature measurements;
- (d) Chemical and physico-chemical analyses and evaluation of liquid environments;
- (e) Co-operation with Ravi Engineering in preparation of samples and racks for OSI.

The laboratory should be involved in preventive maintenance for all FCCCL plants as necessary and have some mobility. It is presumed that the duties of this laboratory would be extended to pilot and loop testing as well as to elaborating inhibitor control systems. Two engineers and two technical assistants should be appointed at the beginning.

The laboratory should be set up in the existing chemical laboratory and should be equipped with the following:

- (a) Electric balance
- (b) Glass containers
- (c) Stereo microscope and optical equipment (lenses)
- (d) Measuring gauges (needle micrometers)
- (e) Cleaning and pickling chemicals/surface active agents, acids, pickling inhibitors
- (f) pH meter
- (g) Ultrasonic wall-thickness gauge
- (h) Instruments to measure surface temperature
- (i) A set of corrosion meters and probes.

These instruments should be complemented later with instruments for electrochemical testing, a loop for testing on-stream corrosion and non-destructive X-ray wall-thickness meters.

(The documentary base for laboratory activities is given in annex III.)

2. Workshop

The expert on safety, maintenance and repair designed a workshop at Ravi Engineering for Phase II of the project. A complementary design for CRM&R should contain the following:

- (a) Blast equipment (one open, one closed)
- (b) Impact (pneumatic) tools for cleaning welds and old paint coats
- (c) Multipurpose porosity tester
- (d) Paint and rubber lining thickness tester

3. Skilled maintenance teams

These should be organized at Ravi Engineering to provide the necessary activities at the Kalashah Kaku complex, and at the PVC Karachi rubber-lining workshop. These two teams which are intended for pilot activities in CRM&R at the Kala Shah Kaku and Karachi factories should each possess the following:

- (a) Open blasting equipment
- (b) Impact (pneumatic) tools
- (c) Mobile high-pressure steam washing equipment
- (d) Paint-coat thickness gauges.

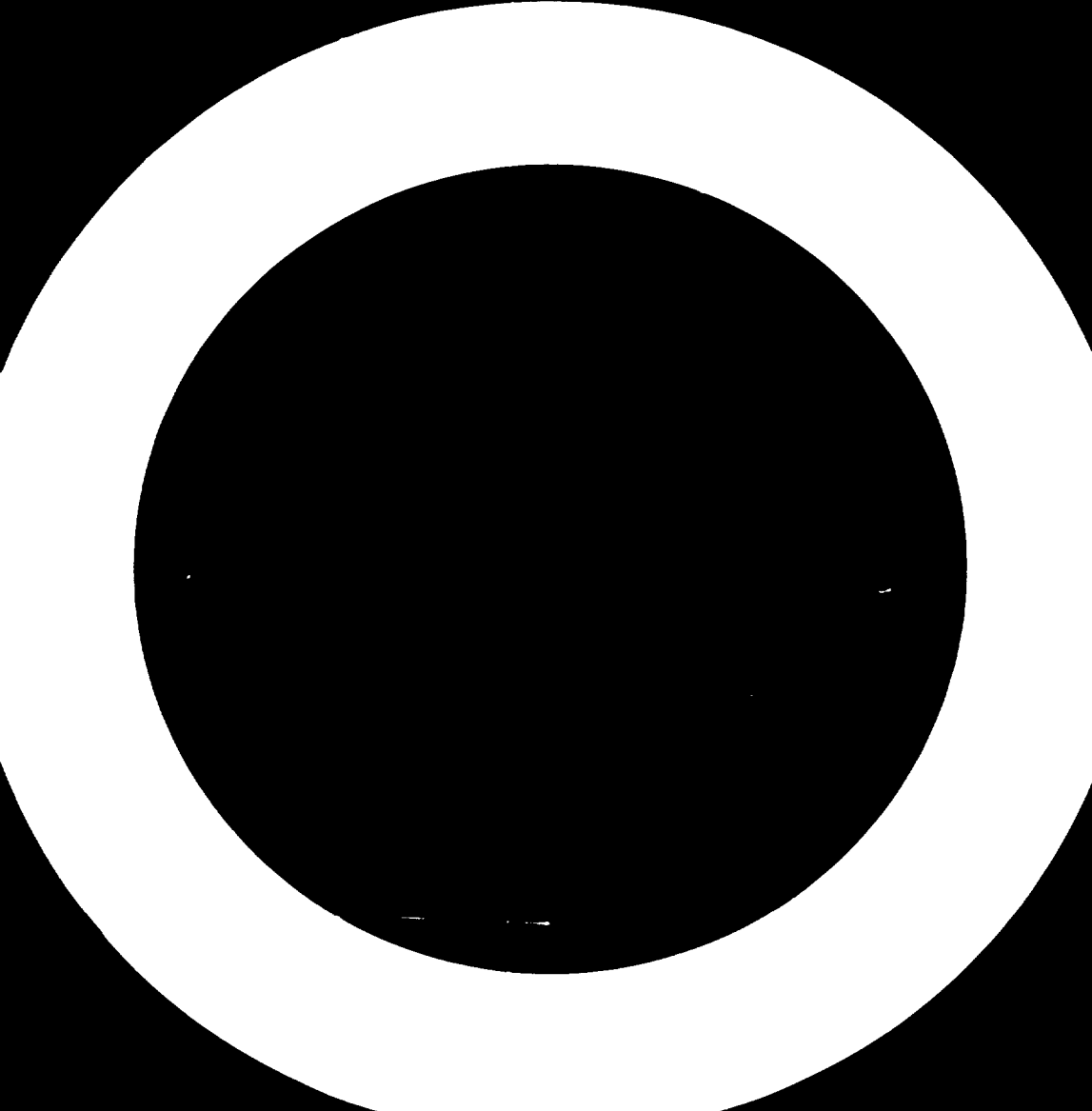
Both groups of staff members should obtain theoretical and practical training in Phase II of the project. All equipment for cleaning (blast and steam) should be bought with the necessary replacement parts and

accessories. The staff should get short training abroad with the equipment manufacturer.

4. Senior chemical engineer

He should be appointed under the General Manager (Technical) of the FCCCL to control and co-ordinate activities of the corrosion laboratory and the two maintenance teams.

Note: Lists of equipment and instruments are attached as annexes V and VI.



Annex I

CODE OF PRACTICE IN ANTI-CORROSION PROTECTIVE PAINTING
OF IRON AND STEEL STRUCTURES IN CHEMICAL PLANTS

Paints

Requirements

Paints of the quality required for chemical factories should have the following properties:

- (a) ease of application by brush;
- (b) freedom from thickening, settlement or evaporation of solvent during storage;
- (c) good drying properties (within 24 hours).

For external use four coats of paint are generally necessary. If the types recommended in table 2 are used, the average total thickness of dry paint film over the complete paint system lies between 100 and 150 μm .

Although thicknesses of 100 μm can be achieved in a single coat with some types of paint, for example, coal tar epoxy paints, most paint systems consist of several coats. A multicoat system helps to reduce the porosity of the paint film and to eliminate the risk of holidays and discontinuities.

Selection of paint

It is advisable to get all the paints from the same supplier, from whom assurances should be obtained on their satisfactory intercoat adhesion and durability.

The properties of the priming paint are most important. It should 'wet' the surface readily and in addition it should contain an inhibitive pigment. For chemically resistant paint such pigments are chromates and red lead. The anti-corrosive pigments used in priming paints are toxic and the necessary precautions should be taken during their application.

Finishing coats should be highly impermeable to moisture and gases, and should have good resistance to the chemical environment. Lamellar pigments such as micaceous iron oxide and aluminium leafing pigment reduce the permeability of the film and retard chemical degradation by sunlight. Red iron oxide and titanium dioxide are generally suitable for finishing coats in chemical environments; zinc oxide pigment is less so.

Table 2. Corrosion-preventive paint systems for chemical environments

Paint system	Coating thickness(mm)	Grade of surface preparation according to BS	Application on/for
1. Two coats of red lead alkyd primer, one coat of alkyd enamel grey, one coat of aluminium/micaceous iron oxide top coat	120	2 1/2	General steelwork in chemical plant not exposed to highly contaminated environment
2. One coat red iron oxide/zinc chromate chlorinated rubber primer, one undercoat of thixotropic chlorinated rubber-based filler, one top coat of chlorinated rubber enamel	120	2 1/2	General steelwork in chemical plant exposed to salts, alkalis, brine
3. One coat of zinc-rich epoxy two-pack primer, three to four coats of chemical-resistant two-pack epoxide top coats (depending on the aggressiveness of environment)	120-150	1 - 2	Indoor or undershed structures exposed to atmosphere containing heavy solvents/chloride
4. Two coats of two-pack epoxy primer, three epoxy top coats	150-200	1 - 2	Indoor or undershed structures exposed to atmospheres containing alkaline salts or acid vapours
5. Three coats of coal tar epoxy paint	300	2 1/2	Underwater or underground pipes and structures; the roof of tanks, atmospheres contaminated with chloride and chlorine gas
6. One coat of vinyl two-pack zinc chromate etch primer, one coat of thixotropic chlorinated rubber-based undercoat, one top coat of chlorinated rubber enamel		Zn-MSPR	Long-lasting protection of general steelwork in chemical plant not exposed to highly contaminated atmospheres
7. One coat of vinyl two-pack zinc chromate etch primer, two chlorinated rubber paint top coats	60	Zn-hdg	Long-lasting protection of general steel work inside and outside buildings

Chlorinated rubber and epoxide paints are recommended (table 2) for heavily corrosive atmospheres. Near chemical plant sections, alkyd paints may be used, but when exposed directly these are chemically attacked and lose their protective value, generally because of pollution of the air with alkalis, chlorine gas, salts or other chemicals. Where spillage of acids, alkalis or solvents is observed, it is essential to use chlorinated rubber or epoxy coatings, which are resistant and impermeable to the chemicals. A high standard of surface preparation by blast-cleaning is essential to get the best performance from these paints.

Three types of chemical-resistant paints are recommended:

Cold-cured epoxides

These paints consist of two separate components: epoxide resin and curing agent.

Cold-cured epoxide paints have good acid and alkali resistance and are highly resistant to solvents. They stand up to abrasion and wear. They should not be confused with one-pack epoxy-ester paints.

Chlorinated rubber

Chlorinated rubber paints show good resistance to alkalis, weak acids, brine and salt water but they are less solvent-resistant than epoxide paints and are more affected by exposure to high temperatures (above 80°C). High-build chlorinated rubber paints contain thixotropic agents and yield dry films 50 to 80 µm thick in one coat. After brush-application their drying time is normally not less than 12 hours.

Coal tar-epoxy

These yield films 100 to 150 µm thick per coat. The dry film develops considerable hardness and some resistance to solvents. The black colour of these paints can be lightened by means of other light-coloured chemical-resistant paint e.g. aluminium chlorinated rubber paint.

Exposure conditions

The corrosive conditions surrounding steelwork in chemical plants fall into three broad categories:

(a) Highly corrosive conditions. The atmosphere is very humid and polluted by dust and chemicals (Cl_2 , HCl , NaCl , Na_2CO_3 , acetone);

(b) Industrial conditions (only air impurities);

(c) Mildly corrosive conditions. Administrative buildings and mechanical workshops are usually located in areas belonging to this category.

(a) Highly corrosive conditions

In heavily polluted atmospheres the general structural layout and design of details are especially important. Faulty design leads to the trapping of corrosive substances; it may be impossible to protect the steelwork at some exposed points. In locations where corrosion is exceptionally severe, e.g. where some surfaces are subject to acid spray or chlorine brine, chemical-resistant paints should be chosen. It is preferable to apply most of the paint in the protective scheme in the shop and under cover, before dispatch to the site. Blast-cleaning is essential for this environment.

Metal coating (zinc spraying or Zn-hdg) beneath the paint system should be used on surfaces where paint alone is unlikely to be affective over 15 to 20 years and on relatively inaccessible surfaces that cannot conveniently be repainted except at long intervals.

(b) Industrial conditions

The choices given in table 2 for industrial environments should prove satisfactory for m.s. structures. These call for surface preparation by blast-cleaning.

(c) Mildly corrosive conditions

Somewhat lower thicknesses of protective schemes may be acceptable for parts of m.s. structures that are not exposed to the worst conditions. Brush-cleaning is generally acceptable for this environment.

Long-life protective systems

Long-life protection is necessary on m.s. parts of installations where uninterrupted production or service over long periods is essential. In these circumstances the initial cost of the structure, including the necessary protective system, is of little value as compared with the magnitude of the losses incurred during breakdown.

The protective scheme should be applied under the most favourable conditions, preferably under cover before dispatch to the site, and special arrangements should also be made for handling the parts and transporting

them to the site without damage to the protective system. Suitable protective systems for these structures are as follows:

(a) In only slightly polluted environments, metal coatings (Zn) with a life equal to the maintenance interval;

(b) Metal coatings (Zn, Al) with a paint system of two priming coats and two finishing coats. The paint system should have a life equal to the maintenance interval whereas the metal coating should last about 10 years.

In chemically corrosive conditions it is advisable to use Zn-hdg sheets having one of the heavier Zn coating weights, in conjunction with a protective organic coating.

The selection of protective systems of high durability such as metal coating/painting schemes is economically appropriate where conditions are severe and maintenance is difficult because of heavy indirect expenses through loss of production or interruption of important services. If the difficult maintenance and environmental conditions are only localized it is advisable to use such systems only in exposed parts of the structures.

Badly corroded material is difficult to paint satisfactorily and (unless blast-cleaned) should not be used where a high standard of protection is required.

For temperatures between 90°C and 200°C aluminium heat-resistant paints should be used to obtain good life-times after surface preparation by blast-cleaning. Two or three coats of the paints should be applied. A special heat-resisting primer is required (two coats), before the aluminium paint (two coats) is applied. For temperatures between 170°C and 250°C, zinc dust/graphite paints are recommended. This paint is applied in a single heavy coat immediately after blast-cleaning. Heat may be applied only 12 hours after painting. Temperatures above 250°C and up to about 350°C may be withstood only by silicone paints. Exposure to wet weather before the coat is completely cured should be avoided. Sprayed aluminium coatings may also be used at these high temperatures, as well as inorganic zinc primer and a silicone resin based aluminium paint as a finishing coat to give a system with an optimal life.

Because of differences in the aggressiveness of the atmosphere at different places at chemical works, no precise advice can be given on the durability of any of the recommended protective systems.

The life of a protective coating will seldom be the same all over a structure, because of local variations in corrosiveness and exposure. There may be differences between the sunny and shady sides, or between parts exposed horizontally and those that are not. Wind direction is important when aggressiveness of environments is evaluated (sea air, acid fumes, salt fog).

Planning of work

All aspects of the work involved in the protection of steel structures against corrosion must be considered at an early stage in the development and planning of project flow-charts. These include all the steps from the delivery of the materials to the fabricating shop to the completion of the work on site, together with subsequent inspection and maintenance (figures 2 and 3).

In tender notices and contracts the protective system should be specified in full at the time of inquiry, and the contractors should nominate, preferably from approved lists, both the painting subcontractor and the supplier of the paints covered in the tender. The requirement to complete work by a specified date frequently makes it necessary for the final painting to be done outside under conditions that lead to early failures of the paint system. To overcome this difficulty, the specification should ensure that enough time is allocated for the proper application of the complete protective system.

Preliminary planning should also include the preparation of the scheme of work and arrangements for the following:

- Blast-cleaning at or near the site
- Applying all or most of the protective system
- Organization, inspection and control of the work
- Surface preparation and suitable shop-applied coating of the steelwork
- Receiving, stacking and handling of fabricated material in a holding area at the site
- Maintenance of the protective coating before erection
- Preparatory treatment and painting during fabrication and erection

Metal surface preparation

Proper surface preparation contributes more than any other single factor to the success of a protective scheme, and BS 5493:1977 recommendations should

be closely followed. It is essential that application of the first coat of primer should follow without delay after cleaning.

Blast-cleaning is recommended for all paint systems applied to important steel structures and to structures whose location or function makes access difficult. It should also be used for steelwork subjected to heavily corrosive atmospheres, sudden variations of temperature, alternating stresses and continuous vibration. Blast-cleaning roughens steel and it is essential that an adequate thickness of priming paint be applied to cover the peaks on the surface (especially where metal spraying is concerned.)

Only for steelwork inside some plant and administration buildings where the conditions are not corrosive, and for internal surfaces of box sections and enclosed spaces, is hand cleaning suitable for alkyd paints.

Faster work can be expected and an improved degree of cleanness achieved with mechanical methods (impact tools) over hand-cleaning.

Surface preparation should be thorough and the bare metal surface should be primed as soon as possible after preparation, in any case within four hours under non-corrosive atmospheric conditions. Under corrosive conditions a bare, clean metal surface must be coated immediately. When prepared surfaces have to be left uncoated for a long period, e.g. overnight, they should be inspected before priming and, if necessary, prepared again.

Sprayed metal coatings are porous and when they are to be painted they should preferably be sealed immediately after application, with an etch primer. This should be followed as soon as possible by a coat of priming paint and by painting on site with a top coat.

Special measures are necessary to remove welding slag, spatter and flux residues (which are often alkaline and damaging to paint) before steel in the vicinity of welds is painted. This can be done by washing with fresh water, followed by chipping or blast-cleaning.

It is good practice to apply by brush and extra stripe coat of paint to edges, corners, crevices, bolt heads and rivet heads. This stripe coat is best applied soon after the first priming coat has dried.

Both contact surfaces between steel and timber exposed to wet or corrosive conditions should be coated with hot tar or bitumen bedding compound immediately before being brought together, and the nuts, bolts and

washers used in the joints should be similarly treated.

In structures in exposed positions or highly corrosive conditions, the surfaces to be permanently in contact should each after cleaning be given a coat of priming paint before assembly and they should be brought together while this is still wet. Special care should be taken after assembly to paint all edges and corners near the joints, together with the bolt heads, nuts and washers, so as to prevent the ingress of water.

In welded constructions, contact surfaces that will be completely sealed can be left unpainted. If they will not be completely sealed, no paint other than a prefabrication primer should be applied within 50 mm of the edges that are to be welded. The remainder of each contact surface should be given a coat of priming paint which should be allowed to dry before the surfaces are brought together.

Immediately before paint is applied all dust, loose paint or other loose material should be cleaned from the surface by brushing including washing down with fresh water and a bristle brush where necessary. Washing down painted surfaces should be done with clean fresh water and scrubbing brushes followed by a final rinsing or hosing with clean water.

Washing down is specially recommended for surfaces that have been exposed to polluted atmospheres at any time before or during the painting process. All washed surfaces should be allowed to dry before being painted.

Surfaces that have been contaminated by cement should be thoroughly cleaned with fresh water before the grout has set. White corrosion products on zinc coatings may cause failure of paint systems applied over them. Surfaces in this condition should be thoroughly cleaned by wire-brushing and washed with clean fresh water before being painted.

The use of white spirit for cleaning steel before painting is not recommended in FCCCL plants.

Paint application

Where the site conditions are unfavourable to painting because of salt spray, smoke, chemical pollution or heavy condensation, the full protective system should be applied before the work is dispatched to the site.

The work should be carefully planned and timed. Where local conditions vary throughout the year and there is a rainy season, painting in the wet

season should be avoided. Painting should not begin while there is dew on the surface, and should be discontinued if the steelwork is wetted by rain or condensation.

If the full protective system on erected steel elements cannot be completed according to programme, the exposure period of the shop-applied coating should not exceed the appropriate recommendation before application of the scheme (three months). Precautions should be taken to prevent damage to and minimize contamination of the painted surface. In the event of damage, such areas should be cleaned and touched up with primer.

The best course is to apply all or most of the protective system (metal coating and paint) at the manufacturer's works, leaving only the final coat of paint to be done at the site. Precautions are necessary to prevent damage to the protective system in transit.

Paint cannot be applied to warm surfaces. Paint manufacturers experienced in tropical conditions are familiar with the necessary modifications to ensure satisfactory results, but chlorinated rubber paints should be applied with particular care. Prolonged storage of paint in the tropics should be avoided.

Painting technology

Supporting steelwork and bridges

The protective schemes recommended in table 3 apply to bridgeworks but need extension where the steelwork is located over corrosive areas. The intensity of corrosion in supporting bridges varies throughout the structure, but is generally most severe near joints. Local protection with additional coatings and sealing at such places is recommended. Where practicable, the full protective scheme should be applied to the steelwork before erection and special arrangements should be made to prevent damage to the protective coating during transport and erection. When the steelwork is assembled care should be taken to provide adequate access for maintenance.

Supporting pillars

Particular attention should be paid to treatment of the foot of supports. Steelwork and concrete surfaces should be protected by epoxy tar paint for a distance of 150 mm above and below the column base. Three coats should be applied on blast-cleaned metal surface. Welded or riveted site joints

should be protected to the same standard as the remainder of the structure. Where the contact surfaces of site joints are not hot-dip galvanized, special precautions should be taken to ensure that water does not penetrate, e.g. by painting the contact faces immediately before they are brought together, or by sealing them with caulking compound. The most satisfactory arrangement may be to make all the joints with electroplated bolts fitted with washers under the head and the nut. These washers and the contact faces should be painted with epoxy tar paint before the joints are made. The electroplated nut and bolt heads should be painted with epoxy or chlorinated rubber primer after the bolts have been tightened.

Internal surfaces of industrial water tanks

Attention should be paid to safety precautions, particularly as regards ventilation where solvents are used when the inside of tanks is painted.

(a) Tanks should be designed with internal surfaces that are accessible at all points; brackets, stays, flanges and other fittings should be reduced to a minimum;

(b) Until all the inlets have been fitted to the tank, it should not be cleaned;

(c) Before it is painted care should be taken to remove all dust, grit, cuttings or chippings from the bottom of the tank;

(d) The steel surface should be blast-cleaned to grade 2 of the SIS immediately before painting;

(e) All paints should be applied to dry surfaces. Sometimes electric blowers may be required.

For many waters which are not particularly corrosive, Zn-hdg is adequate. For more corrosive waters, it is necessary to apply an additional coating of, for example, a high-build epoxy tar paint, using three to four coats, sufficient to give a dry-film thickness of 500 μm .

For acid waters, hdg is not recommended and the epoxy or chlorinated rubber system alone should be used (300 μm). Blast-cleaning is essential before high-build chlorinated rubber or cold-cured epoxide resin paint is applied.

For effective protection against very corrosive waters, blast-cleaning, red lead alkyd primer, and then a hot coal-tar pitch or bitumen coating to a total thickness of at least 2.5 mm should be applied. The undersides of roofs of water tanks should be painted with high-build epoxy tar paint.

Buried structures

The quality of the coating should be appropriate to the expected severity of the corrosive conditions. If necessary these should be ascertained by a preliminary soil survey.

External coating for steel pipelines should consist of bitumen or coal-tar epoxy paint that contains a fine inert mineral filler. Reinforcement with a wrapping of fibreglass felt, woven glass fabric or similar material is sometimes advisable. Blast-cleaning is necessary for external surfaces and weldings.

The coating procedure is as follows:

- (a) The pipe is cleaned by abrasive blasting, down to the bare metal (SIS grade 2 1/2);
- (b) A thin zinc-rich epoxy two-pack coat is applied and allowed to dry thoroughly, in order to provide a satisfactory bond between the steel and the coatings;
- (c) Three coats of coal-tar epoxy paint are applied;
- (d) The pipe is given an outer wrapping of impregnated asbestos or fibreglass felt to protect the paint coat against mechanical damage and soil stresses when buried.

The ends of individual lengths of pipe should be left uncoated or covered by zinc-rich epoxy paint to a maximum 25- μ m thickness so that joints can be made. Joints, and any couplings, should be coated on site using a system (epoxy primer) of equal protective value to that on the pipe. Wax-coated tapes may be used to protect buried pipes, but generally these are more suitable for pipelines above ground exposed to salt mist or to heavily polluted atmospheres. Large-diameter pipelines can also be protected by surrounding them with Portland-cement concrete 100 mm to 150 mm thick.

Hdg pipes

Hdg steel pipes should have a zinc surface coating of not less than 600 g/m². The protection given by the zinc should be augmented by means of two coats of zinc-epoxy paint.

Water-sealed gas holders

The steelwork, or at least the crown and side plates, should be blast-cleaned at the manufacturer's shop, and coated while still warm with an alkyd red lead primer. This should be omitted from a 50 mm-wide margin

adjacent to the edges of the plates that are to be welded. Alternatively, steel plates may be blast-cleaned and immediately afterwards completely coated with a zinc-rich prefabrication primer (welding primer).

Rising lifts

A coat of red lead alkyd primer should be applied on the surface of the lift after erection. The work should be completed by two further coats of alkyd paint, applied to the fully erected holder from cradles or bosun's chairs. One coat of micaceous iron oxide paint is applied, followed by a coat of aluminium paint, both in oleoresinous media.

Bottom lift

Conventional paints are unsuitable for the bottom lift, which is immersed in water for prolonged periods. Cold-cured epoxide paints, applied to blast-cleaned surfaces, should be used.

Inner surfaces

The insides of holders used for storing gas, and steel outer tanks require protection with two priming coats of red lead alkyd paint.

Cup and grip areas

The cup and grip areas of gas holders should be coated with zinc by metal spraying. The sprayed zinc coating should have a mean thickness of 200 μm . The metal coating should be further protected by chemical rubber paint applied over a vinyl etch primer which is a sealer.

Storage and transport

Before erection, manufactured materials should be laid out or stacked clear of the ground in an orderly manner to ensure that no pools of water can accumulate on the surfaces.

For temporary corrosion protection blast-cleaned steel should be given at least two coats of priming paints or a single coat of zinc-rich paint before being put into store. The dry-film thickness of the zinc-rich primer should not exceed 25 μm .

Stored material should be inspected from time to time and if maintenance painting proves necessary, the defective paintwork should be fully repainted

Special slings or lifting points, or both, for handling and loading or unloading at the manufacturer's shop, during transit, and at the site should be provided. Special supports, packings and lashings on vehicles or trucks are necessary to prevent chafing.

Particular care should be taken in the storage of coated pipes. There should be cushioning between layers, and the ends of internally coated pipes should be plugged.

Maintenance painting

General

After several years, when it is observed that some supporting steelwork elements and important girders are corroded, it will be necessary to replace them or to carry out maintenance painting.

M.s. structures are sometimes not designed with sufficient space left to clean and prepare surfaces and to meet the requirements of anti-corrosion protection by painting. When important structural elements are replaced, the first step is to use a good new design and to protect them by means of painting or Zn-hdg.

All construction parts to be repainted should be prepared before welding as well as immediately after it (seams) by means of sand-blasting. New structural elements prepared for painting in the shop should also be sand-blasted.

Surface cleaning

When the surface of plant sections is prepared, the old paint coat as well as corroded surfaces should be worked over first with water, preferably a high-pressure steam/water mixture, but a jet of water from a nozzle may be efficient.

After cleaning and drying the main and plain surfaces should be sand-blasted or cleaned with scrapers and steel brushes. Scraping and brushing is not suitable for general surface preparation and is not comparable to sand-blasting. It should be used only in cases where it is difficult to reach some small areas and as a supplement when sand-blasting in deep holes and on joints is not possible.

After sand-blasting the pH of the surface should be determined by means of wet pH indicator paper. In cases where the pH value of a surface is not between 6.5 and 7.5, it should be neutralized with diluted phosphoric acid wash (0.5 per cent by volume) or Na_2HPO_4 (0.1 per cent by weight). After that the surface should be dried and air-cleaned especially at joints and slots.

Structures should be repainted before the protective coating shows any sign of serious breakdown. Maintenance will be made easier if its requirements are taken into account at the design stage. The aim should be to keep the steelwork free from repair, while retaining an acceptable appearance (only 5 per cent corroded surfaces). This can be achieved by repainting upon inspection, which should be made at regular intervals (6 - 12 months).

Maintenance work may involve repainting the whole structure, or alternatively patch-painting to make good local breakdowns, followed later by complete repainting when general deterioration of the old paint has become evident.

In industrial environments there are many places where steam, solution-splash, exhaust gases and fumes are present. Sometimes repainting should be undertaken very often; it will vary with the age of the structure. The decision to repaint may be complicated by the fact that breakdown is seldom uniform over all the surface, so that some parts may need instant renewal and others not. If heavy rusting develops on joints, repainting should be undertaken at once. Flaked paint systems or systems with generally weak adhesion do not provide a suitable basis for repainting, and should be stripped to the bare metal as soon as possible.

Hdg surfaces originally left unpainted should be painted before the useful life of the zinc coating nears its end. Slight rust-staining and discoloration of Zn-hdg surfaces are often due to corrosion of the iron-zinc alloys and not to attack on the basic steel. The safest course, however, is to paint as soon as marked discoloration is observed after the surface is washed with water.

All removable parts and pipes should be dismantled and replaced after the repainting is completed. Particular attention should be paid to the cleaning-out of crevices and hollow sections where dust and dirt have collected. Filling crevices with mastic paste (putty) should be considered.

Washing down with fresh water will be necessary and should be regarded as normal procedure to remove the deposits of salts on structures. Salts may lead to rapid failure of paint applied to them. The cleaning should be completed by rinsing with clean fresh water, taking care to remove residues from folds and crevices. Steam pressure jets are effective for removing non-adherent paint coats and corrosion, but care is needed to avoid damage to the coat itself.

Non-ionic emulsion cleaners may also be used but the residues should be thoroughly removed by rinsing with water. The quality of the surface preparation should conform to the specified standard (BS, SIS) when blast-cleaning.

Sharp edges, faying surfaces and other specially vulnerable areas should be treated by hand.

Welding slag or spatter from the runs of welds and adjacent steelwork should be cleaned off and the affected areas treated.

No prepared area should be left unpainted for longer than the specified time. A time schedule should previously have been agreed between the inspector and the contractor so as to ensure this.

Application of paint system

Paint systems and recommendations for their application are given in table 3 and figure 2. The protective system of coats of paint used for maintenance painting will be governed to some extent by the condition of the old paint, which may not be uniform over all the structure. Broadly, three kinds of surface can be distinguished:

(a) Areas of intact adherent paint where deterioration is accompanied by slight checking and unbroken blisters. These areas should be washed down and dried, and then given one or more coats of finishing alkyd paint;

(b) Areas where appreciable but not excessive paint breakdown has occurred and where there is some blistering and rusting. These areas should be washed down or neutralized, scraped, wire-brushed, washed with water and dried. One or two coats of chlorinated rubber priming paint followed by two coats of the finishing paint should be applied;

(c) Areas where the paint has deteriorated badly and has lost its adhesion, and where the steel has rusted appreciably. These areas should be neutralized and cleaned to the bare metal, preferably by blast-cleaning. In such cases in chemical plants, two coats of epoxy primer or chlorinated rubber primer (see table 3) are applied followed by two to three coats of top paint.

The optimum performance of a coat of paint depends on getting the correct thickness. Checking by means of a magnetic or electro-magnetic

thickness gauge is essential. In the case of very corrosive environments the porosity of the coat should also be checked.

During painting the affected areas should be protected or shielded by means of a shelter or a tent to avoid air and surface contamination with dust and they should be electrically neutral. This should be checked before application of a top coat. Horizontal surfaces should be carefully checked for dust. Contaminated surfaces should be cleaned with a water-soaked rag or cotton waste. After the surface is cleaned and dried the first coat of paint should be applied to give a uniform protective layer.

A suitable thickness for a coating system is 120-150 μ depending on aggressiveness of the environment, the possibility of water condensation, and difficulty of access and maintenance. If the surface is inaccessible or difficult to reach, a thicker coat or an additional coat is recommended to improve durability and to lower painting costs in the long term. Three coats of epoxy tar paint should be 0.3 mm thick, according to the manufacturers' advice.

Where different cleaning treatments are given to different areas of a structure, planned co-ordination of the work is important (see figure 2). Where the paint is removed entirely, the area of clean bare metal should extend for at least 25 mm all round the boundary of the defect. The first priming coat should be applied immediately after the surface has been prepared for patch-painting.

No two-pack paint (epoxide) should be used after the expiration of its stipulated shelf life under the current conditions, of which the paint manufacturers should have been informed.

The prolongation of the intervals between repainting resulting from the use of more coats of a costly paint should be balanced against the increased cost of materials and labour, the comparisons being made on a cost per annum basis.

Painting should be planned for the season during which the best ambient conditions may be expected. Where painting under adverse conditions is unavoidable, temporary shelters may be useful. The temperature of the steel at the time of painting should not exceed 38°C.

Figure 2. Painting of new structures - flow sheet

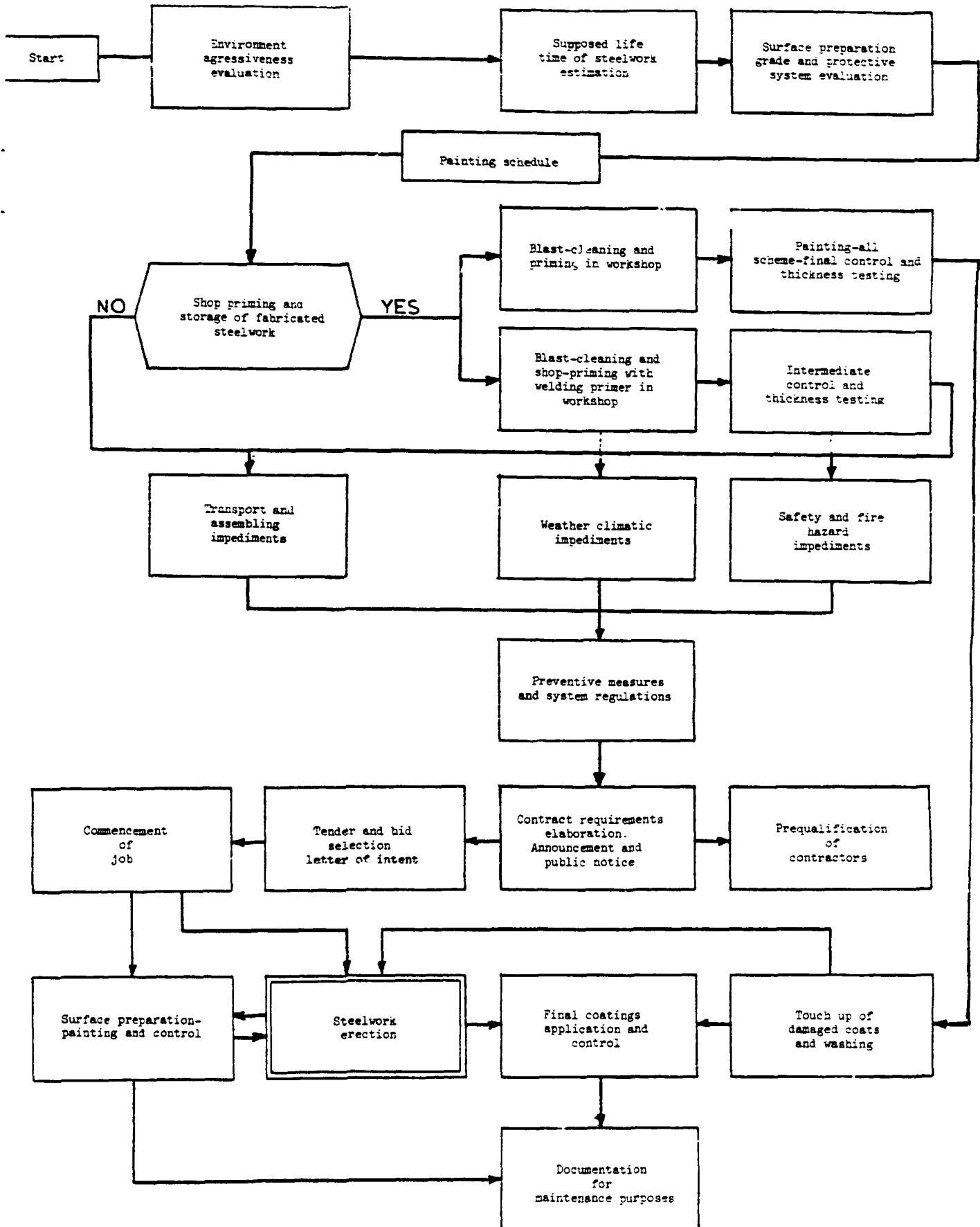
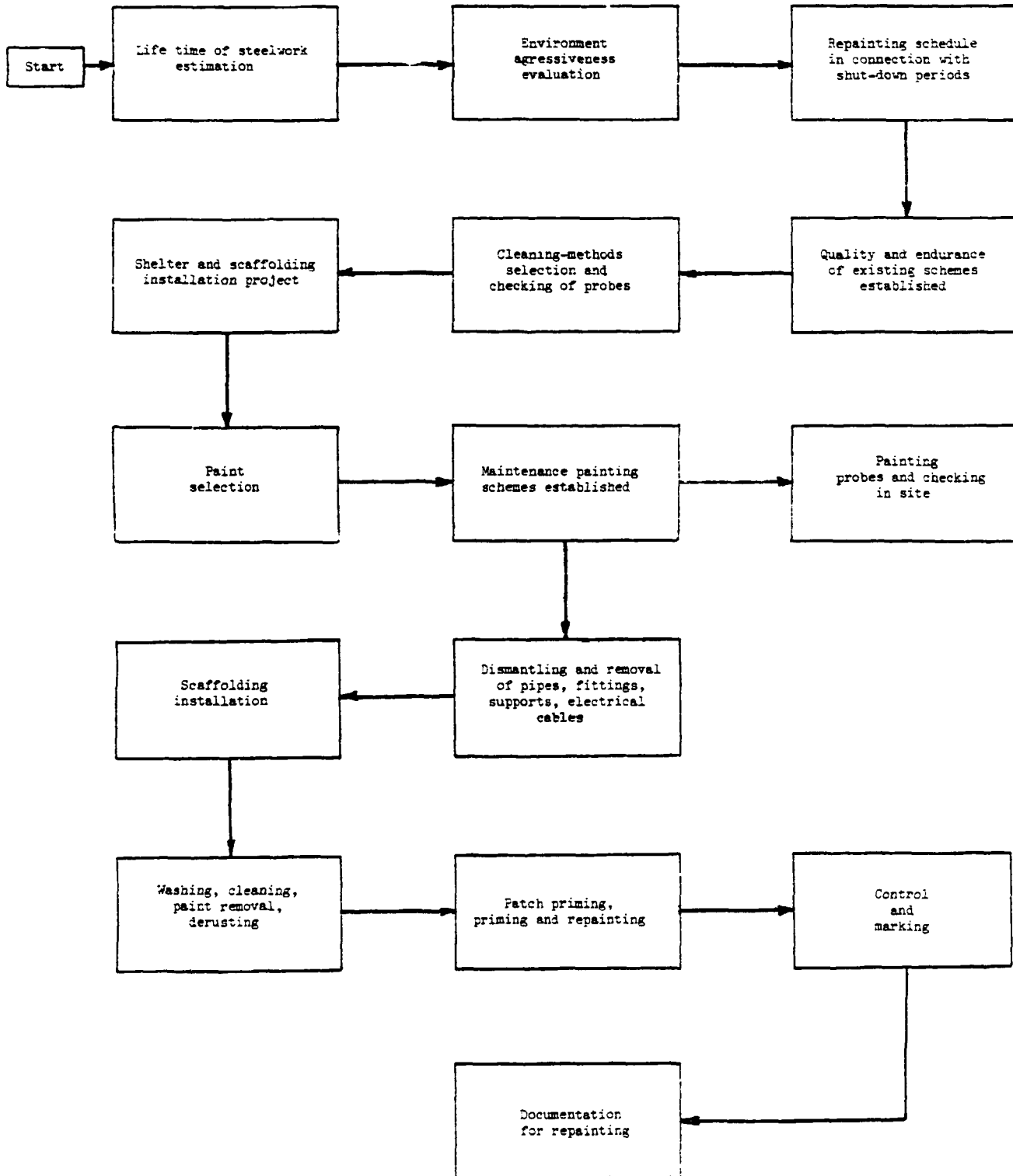


Figure 3. Repainting old structures - flow sheet



Annex II

RECOMMENDED CORROSION STANDARDS FOR FCCCL FACTORIES

Sind Alkalis Limited

- CP 3012, 1972 - Code of practice for cleaning and preparation of metal surfaces
- BS 5493, 1977 - Code of practice for protective coating of iron and steel structures against corrosion

Pakistan PVC Limited

- CP 3012, 1972 - Code of practice for cleaning and preparation of metal surfaces
- BS 5493, 1977 - Code of practice for protective coatings of iron and steel structures against corrosion
- BS 729, 1971 - Hot dip galvanised coatings on iron and steel articles
- BS 1822, 1952 - Nickel clad steel plate
- BS 4164, 1967 - Coal tar based hot applied material components
- CP 231, 1966 - Painting of buildings
- CP 3003, 1970 - Lining of vessels and equipment for chemical processes, Part 1 (Rubber), Part 7 (Corrosion and heat resistant metals), Part 6 (Phenolic resins)

National Fibres Limited

- BS 5493, 1977 - Code of practice for protective coating of iron and steel structures against corrosion
- BS 729, 1971 - Hot dip galvanised coatings on iron and steel articles
- CP 231, 1966 - Painting of buildings
- BS 4769, 1971 - Sprayed and unfused metal coatings for engineering purposes
- BS 4959, 1974 - Recommendations for corrosion and scale prevention in engine cooling systems
- CP 1021, 1973 - Cathodic protection

Ittehad Chemicals and Pesticides

- BS 5493, 1977 - Code of practice for protective coatings of iron and steel structures against corrosion
- BS 729, 1971 - Hot dip galvanised coatings

- BS 4761, 1971 - Sprayed unfused metal coatings for engineering purposes
- CP 231, 1966 - Painting of buildings
- CP 3003, 1970 - Lining of vessels and equipment for chemical processes.
Part 1 (Rubber), Part 3 (Lead), Part 6 (Phenolic resins),
Part 7 (Corrosion-and heat-resistant metals)
- BS 4959, 1974 - Recommendations for corrosion and scale prevention in
engine cooling systems
- CP 1021, 1973 - Cathodic protection
- BS 1822, 1952 - Nickel clad steel plate

Ravi Rayon Limited

- CP 3003, 1970 - Lining of vessels and equipment for chemical processing.
Part 1 (Rubber), Part 5 (Epoxide resins), Part 6
(Phenolic resins), Part 7 (Corrosion-and heat-resistant
metals)
- CP 1021, 1973 - Cathodic protection
- BS 4761, 1971 - Sprayed unfused metal coatings for engineering purposes
- BS 3740, 1964 - Steel plate clad with corrosion resisting steel
- BS 1821, 1952 - Nickel clad steel plate
- BS 5493, 1977 - Code of practice for protective coatings of iron and
steel structures against corrosion
- CP 3012, 1972 - Cleaning and preparation of metal surfaces

Baker's Yeast

- BS 5493, 1977 - Code of practice for protective coatings of iron and
steel structures against corrosion
- CP 3012, 1972 - Cleaning and preparation of metal surfaces
- CP 231, 1966 - Painting of buildings
- BS 1170, 1968 - Method for treatment of water for marine boilers

Ravi Engineering Limited

- CP 3003, 1970 - Lining of vessels and equipment for chemical processes,
Part 1 (Rubber), Part 3 (Lead), Part 5 (Epoxide resins),
Part 6 (Phenolic resins), Part 7 (Corrosion-and
heat-resistant metal), Part 9 (Titanium)
- CP 3012, 1972 - Cleaning and preparation of metal surfaces
- CP 1021, 1973 - Cathodic protection
- BS 4761, 1971 - Sprayed unfused metal coatings for engineering purposes

- BS 4950, 1973 - Sprayed fused metal coatings for engineering purposes
- BS 4479, 1969 - Recommendations for the design of metal articles that are to be coated
- BS 1822, 1952 - Nickel clad steel plate
- BS 729, 1971 - Hot dip galvanised coating on iron and steel articles

Ravi Engineering Lahore

- BS 3382 - Electroplated coatings on threaded components, Part 1 (Cadmium), Part 2 (Zinc), Part 7 (Thicker platings for threaded components)
- BS 534, 1966 - Steel pipes, fittings and specials for water, gas and sewage
- BS 4164 - Specification for coal-tar based hot applied coating materials for protecting iron and steel including suitable primers where required
- BS 5624 - Code of practice for the lining of vessels and equipment for chemical processes: copper and copper alloys
- BS 3740 - Steel plate clad with corrosion-resisting steel
- BS 3072 - Nickel and nickel alloys. Sheet and plate
- BS 2554 - Vertical steel welded storage tanks with butt-welded shells for the petroleum industry
- BS 2594 - Horizontal mild steel welded storage tanks
- BS 4652 - Metallic zinc-rich priming paint/organic media
- CP 117 - Composite construction in structural steel and concrete
- CP 114 - Standard use of reinforced concrete in buildings
- BS 2451 - Chilled iron shot and grit
- BS 4604 - The use of high strength friction grip bolts in structural steelwork
- CP 2010 - Pipelines, Part 2 (Design and construction of steel pipelines on land), Part 3 (Design and construction of iron pipelines on land)
- BS 903 - Methods of testing vulcanised rubber. Determination of hardness (microtest)
- SIS 055900 - Pictorial steel surface preparation standards for painting

Annex III

RECOMMENDED DOCUMENTARY BASE (STANDARDS) FOR FCCCL
CORROSION LABORATORY

<u>Number</u>	<u>Title</u>
1. ANSI/ASTM G 50-76	Standard recommended practice for conducting atmospheric corrosion tests on metals
2. ANSI/ASTM G 51-77	Standard test method for pH of soil for use in corrosion testing
3. ANSI/ASTM D 2485-68	Standard test method for coatings designed to be resistant to elevated temperatures during their service life
4. ASTM G 46-76	Standard recommended practice for examination and evaluation of pitting corrosion
5. ANSI/ASTM G 48-76	Standard test method for pitting and crevice corrosion resistance of stainless steels and related alloys by the use of ferric chloride solution
6. ANSI/ASTM G 49-76	Standard recommended practice for preparation and use of direct tension stress corrosion test specimens
7. ASTM A 262	Detecting susceptibility to intergranular attack in stainless steel specimens
8. ASTM A 279	Total immersion corrosion testing of stainless steels
9. ASTM A 393	Conducting acidified copper sulphate test for intergranular attack in austenitic stainless steel
10. ASTM C 464	Corrosion effect of thermal insulating cement on base metal
11. ASTM D 130	Copper corrosion by petroleum products

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| 12. ASTM D 801 | Dipentene, sampling and testing |
| 13. ASTM D 849 | Copper corrosion of industrial aromatic hydrocarbons |
| 14. ASTM D 1838 | Copper strip corrosion by liquefied petroleum (LP) gases |
| 15. ASTM D 2251 | Metal corrosion by halogenated organic solvents and their admixtures |
| 16. ASTM D 2649 | Determining corrosive characteristics of solid film lubricants |
| 17. BS 534, 1966 | Steel pipes, fittings and specials for water, gas and sewage |
| 18. BS 729, 1971 | Hot-dip galvanised coatings on iron and steel articles |
| 19. BS 1822, 1952 | Nickel-clad steel plate |
| 20. BS 3382, Part 7, 1966 | Thicker platings for threaded components |
| 21. BS 3416, 1961 | Black bitumen coating solutions for cold application |
| 22. BS 3740, 1964 | Steel plate clad with corrosion-resisting steel |
| 23. BS 4164, 1967 | Coal tar based hot applied coating material for protecting iron and steel, including suitable primers where required |
| 24. BS 4479, 1969 | Recommendations for the design of metal articles that are to be coated |
| 25. BS 4761, 1971 | Sprayed unfused metal coatings for engineering purposes |
| 26. BS CP 231, 1966 | Painting of buildings |
| 27. BS CP 3003, 1970 Part 1, 1967 | Lining of vessels and equipment for chemical process |
| | Part 2 Glass enamel |
| | Part 3, 1965 Lead |

	Part 4, 1965	Plasticised PVC sheet
	Part 5	Epoxide resins
	Part 6	Phenolic resins
	Part 7, 1970	Corrosion-and heat-resistant metals
28.	BS CP 3012, 1972	Cleaning and preparation of metal surfaces
29.	BS 1170, 1968	Methods for treatment of water for marine boilers
30.	BS 4959, 1974	Recommendations for corrosion and scale prevention in engine cooling systems.
31.	BS CP 1021, 1973	Cathodic protection
32.	DIS 4287/1-79	Surface roughness, terminology, Part 1: Surface and its parameters
33.	DP 4287/11-78	Surface roughness, terminology, Part 11: Measurement of surface roughness parameters
34.	ISO 3950 - 79	Continuous electrolytic tin-coated cold-reduced carbon steel of commercial and drawing qualities
35.	ISO 4499 - 78	Hard metals; metallographic determination of micro-structures
36.	ISO 4505 - 78	Hard metals; metallographic determination of porosity and uncombined carbon
37.	ISO 4545 - 75	Micro hardness test, Knoop and Vickers
38.	DIS 4968 - 78	Steel macrographic examination by sapphire print (Beumann method)
39.	DIS 4567 - 79	Steel macrographic examination by etching with strong mineral acid
40.	DP 6506 - 78	Metallic materials; hardness test, Brinell
41.	DP 6507 - 78	Metallic materials; hardness test, Vickers

42. DP 6508 - 78
Metallic materials; hardness test,
Rockwell
43. ISO 1459 - 73
Metallic coatings; protection against
corrosion by hot-dip galvanizing,
guiding principles
44. ISO 1461 - 73
Metallic coatings; hot-dip galvanized
coatings on fabricated ferrous products,
requirements
45. ISO 2063 - 73
Metallic coatings; protection of iron
and steel against corrosion. Metal
spraying of zinc and aluminium
46. DIS 2079 - 79
Surface treatment and metallic coatings;
general classification of terms
47. DIS 4042 - 78
Threaded components; electroplated
coatings
48. DIN 4998 - 77
Continuous hot-dip zinc-coated carbon
steel sheet of structural quality
49. ISO 813 - 74
Vulcanized rubber; determination of
adhesion to metals, one plate method
50. DIS 1513 - 79
Paints and varnishes; examination and
preparation of samples for testing
51. ISO 2724 - 73
Vitreous and porcelain enamels for
cast iron; production of specimens
for testing
52. ISO 2746 - 73
Vitreous and porcelain enamels;
enamelled articles for service under
highly corrosive conditions. High-
voltage test.
53. DP 4528 - 75
Vitreous and porcelain enamelled
articles; guide to the selection of
test methods
54. DIS 2064 - 79
Metallic and other non-organic coatings.
Definitions and conventions concerning
the measurement of the thickness.

55. ASTM A 384(3), 1972
Safeguarding against warping and distortion during hot-dip galvanizing of steel assemblies, recommended practice for
56. ASTM G 1 (31), 1972
Recommended practice for preparing, cleaning and evaluating corrosion test specimens
57. ASTM A 143(3), 1972
Safeguarding against embrittlement of hot-dip galvanised structural steel products and procedure for detecting embrittlement, recommended practice for
58. ASTM A 262(3), 1970
Detecting susceptibility to intergranular attack in stainless steels, recommended practice for
59. ASTM A 393(3), 1963
Recommended practice for conducting acidified copper sulphate test for intergranular attack in austenitic stainless steel
60. ASTM E 243 (5,31), 1971
Recommended practice for electromagnetic (Eddy current) testing of stainless steel, copper and copper alloy heat exchanger and condenser tubes
61. ASTM G 4(3,31), 1968
Conducting plant corrosion tests, recommended practice for
62. G ASTM G 5(31), 1972
Recommended practice for standard reference method for making potentiostatic and potentiodynamic anodic polarization measurements
63. ASTM G 21(26,30), 1970
Recommended practice for determining resistance of synthetic polymeric materials to fungi
64. ASTM G 30(31), 1972
Making and using U-bend stress corrosion test specimen, recommended practice for

65. ASTM G 31(31), 1972 Recommended practice for laboratory immersion corrosion test specimen
66. ASTM B 154(5), 1971 Standard method for mercurous nitrate test for copper and copper alloys (stress corrosion cracking)
67. ASTM B 487(7), 1973 Measurements of metal and oxide coating thickness by microscopical examination of a cross-section
68. ASTM G 35(31), 1973 Susceptibility of stainless and related Ni-Cr-Fe alloys to stress corrosion cracking in polythionic acids, recommended practice for
69. ASTM A 13, 1956 Scheme for the identification of a piping system
70. ASTM G 36(31), 1973 Recommended practice for performing stress corrosion cracking tests in boiling magnesium chloride solution
71. ASTM G 37(31), 1973 Mattson's solution of pH 7-2 to evaluate the stress-corrosion cracking susceptibility of Cu-Zn alloys, recommended practice for the use of
72. ASTM A 90(3), 1969 Weight of coating on zinc-coated (galvanised) iron or steel articles, test for
- ASTM A 279(3), 1963 Total immersion corrosion test of stainless steels
73. ASTM B 117(7,21,31), 1973 Salt-spray (fog) testing, test for (Method is intended for ferrous and non-ferrous metals with or without inorganic or organic coatings)
74. ASTM C 464(14), 1964(1970) Corrosion effect of thermal insulating cements on base metals, test for

- 75. ASTM D 2251(22), 1967(1972) Metal corrosion of halogenated organic solvents and their admixtures, test for
- 76. ASTM D 2688(23), 1970 Corrosiveness of water in the absence of heat transfer (weight loss methods), test for
- 77. ASTM D 2776(23), 1972 Corrosiveness of water in the absence of heat transfer (electrical methods), test for
- 78. ASTM D 2803(21), 1970 Filiform corrosion resistance of organic coatings of metal, test for
- 79. ASTM F 64(28), 1969 Corrosive and adhesive effect of gasket materials on metal surfaces, test for
- 80. ASTM G 3(31), 1968 Conventions applicable to electro-chemical measurements in corrosion testing
- 81. ASTM G 6(21,30), 1972 Abrasion resistance of pipeline coatings, test for
- 82. ASTM G 9(21,30), 1972 Water penetration into pipeline coating, test for
- 83. ASTM G 11(21,30), 1972 Test for effects of outdoor weathering on pipeline coatings
- 84. ASTM G 12(21,30), 1972 Non-destructive measurement of film thickness of pipeline coatings on steel
- 85. ASTM G 13(21,30), 1972 Impact resistance of pipeline coatings (limestone drop test), test for
- 86. ASTM G 14(21,30), 1972 Impact resistance of pipeline coatings, test for
- 87. ASTM G 15(31), 1971 Corrosion and corrosion testing, definition of terms relating to
- 88. ASTM G 17(21,30), 1972 Penetration resistance of pipeline coatings, test for
- 89. ASTM G 18(21,30), 1972 Joints, fittings and patches in coated pipelines, test for

90. ASTM G 19(21,30), 1972 Disbonding characteristics of pipeline coatings by direct soil burial, test for
91. ASTM G 20(21,30), 1972 Chemical resistance of pipeline coatings, test for
92. ASTM G 28(31), 1972 Detecting susceptibility of intergranular attack in wrought nickel rich chromium bearing alloys
93. ASTM G 32(31), 1972 Vibratory cavitation and erosion test
94. BS 1427, 1962 Routine control methods of testing water used in industry
95. BS 2690 Methods of testing water used in industry
- Part 5, 1967 Alkalinity, acidity, pH value and carbon dioxide
- Part 6, 1968 Chlorine and sulphate
- Part 7, 1968 Nitrite, nitrate and ammonia (free, saline and albuminoid)
- Part 9, 1970 Appearance (colour and turbidity) odour, suspended and dissolved solids and electrical conductivity
- Part 13, 1972 Dichromate value (chemical oxygen demand), non-volatile organic carbon, tannins and chlorine
96. BS 4232, 1967 Surface finish of blast-cleaned steel for painting
97. ASTM G 35(31), 1973 Susceptibility of stainless steels and related Ni-Cr-Fe alloys to stress-corrosion cracking in polythionic acids, recommended practice for
98. ASTM G (36), 1973 (31) Performing stress-corrosion cracking tests in a boiling magnesium chloride solution, recommended practice for
99. ASTM G (37), 1973 (31) Mattson's solution of pH 7-2 to evaluate the stress-corrosion cracking susceptibility of Cu-Zn alloys, recommended practice for use of

Annex IV

RECOMMENDED BOOKS FOR TRAINING IN CORROSION PRINCIPLES

- Ailor, W.H. Handbook on corrosion testing and evaluation. New York, John Wiley.
- Balalayev, G.A. Corrosion prevention practice. New York, Beekman.
- Bosich, J.F. Corrosion prevention for practicing engineers. New York, Cahuers.
- Burns-Bradley, C. Protective coatings for metals. New York, Interscience.
- Champion, F.A. Corrosion testing procedures. New York, John Wiley.
- Clifton, R.H. Principles of planned maintenance. London, E. Arnold.
- Dettner, H.W. Dictionary of metal finishing and corrosion. New York, Elsevier.
- Diamant, R.M.F. The prevention of corrosion. London, Business Books.
- Evans, U.R. An introduction to metal corrosion. London, E. Arnold.
- Fontana, M. and N. Green. Corrosion engineering. New York, McGraw-Hill.
- LaQue, F.L. and H.R. Copson. Corrosion resistance of metals and alloys. New York, Reinhold.
- Mellan, I. Corrosion resistant materials handbook, part I. Park Ridge, New Jersey, Noyes Development Corporation.
- NACE. Corrosion in chemical processing. Houston, Texas.
- _____ Survey for selection of materials. Houston, Texas.
- Plaster, H.J. Blast cleaning and allied processes. London, Garden City Press.
- Floudek, V.R. Design and corrosion control. Canada, Editor M.
- Ross, E.B. Handbook of metal treatment and testing. New York, John Wiley.
- Shreir, L.L. Corrosion. London, G. Newnes.
- Speller, F.N. Corrosion: causes and prevention. New York, McGraw-Hill.
- Uhlig, H.H. Corrosion and corrosion control. New York, John Wiley.
- Wilson, C.I. and S.A. Oates. Corrosion and the maintenance engineer. New York, Hart.
- Wormwell, F. and E. Evans. Corrosion of metals in chemical engineering practice. London, Butterworths.

Annex V

EQUIPMENT FOR CORROSION-RELATED MAINTENANCE AND REPAIR

Equipment	Specification	Approximate price (\$)
Blast-cleaning equipment	Open type with accessories e.g. Type AP 600 by Techma, Warsaw	2,000
Vacuum blast-cleaning equipment	With accessories, iron grid and chilled iron shot 500 kg e.g. Type SB-4 by Techma, Warsaw	10,000
Impact tools	For cleaning welds and paint coats, with accessories e.g. as made by Atlas Copco AB, Sweden	8,000
Washing equipment	High-pressure steam, mobile, with accessories e.g. as made by Electrolux AB, Sweden	10,000

Annex VI

INSTRUMENTS FOR CORROSION TESTING

Equipment	Specification	Approximate price (\$)
Wall-thickness gauge	Portable, digital, ultrasonic, with battery power supply, battery charger and probes (1-30 μm wall thickness) e.g. as made by Krautkramer GmbH (FRG)	3,000
Ferritescope	Set with accessories e.g. Type FE8d3, Fischer GmbH (FRG)	4,000
Poroscope	DC type with a set of electrodes for paint coat and rubber linings e.g. Type H3d2-15, Fischer GmbH (FRG)	3,700
Thickness tester	Portable, digital, for paint coats and rubber linings on steel. Ranges 0-50, 20-200, 50-500 and 250-4000 μm , with accessories e.g. as made by Fischer GmbH (FRG)	1,000
Workshop thickness gauge	For Microtest III F, Microtest III S 3 and Microtest III S 10, with accessories e.g. as made by Electro-Physik Hans Nix (FRG)	2,000
Endoscope	Flexible, 8mm diameter with fibre bundle e.g. Type 10.160, Classen and Co (FRG)	6,500
Stereomicroscope	Type 2338 with accessories 2307, 2331, 2308, 2334, 2337, 2306, 2309, 1415, 1419, 1413, with a set of accessories e.g. Classen and Co (FRG)	1,800
Rigid endoscope multiscope	12mm dia. with variable direction of view and illuminated visual angle 115 $^{\circ}$; working length 540mm, set with accessories e.g. as made by Comeg GmbH, (FRG)	2,000

Equipment	Specification	Approximate price (\$)
Surface temperature digital thermometer	For metal surface temperature testing up to 700°C with accessories and probes e.g. Minitherm d, Keller (FRG) or Ultrakust (FRG)	1,000
On-stream corrosion testing probes and measuring devices	Set with accessories and retractable valves e.g. as made by Magna-Flux Co, USA	15,000

Annex VII

RECOMMENDATIONS FOR FELLOWSHIPS AND TRAINING

Budgeting

It is proposed that two persons (six man-months) be trained in corrosion prevention and protection, with an estimated budget of \$9,000 which might be sought from outside agencies, and PRs 60,000 from the Government.

Fellowship

One person should be trained over four months, taking fee-paying courses and workshop training in corrosion at the following institutions in the United Kingdom:

- (a) University of Manchester Institute of Science and Technology. Corrosion and Protection Centre (corrosion courses);
- (b) British Council of Maintenance Association;
- (c) Centre for Training on Preventive Maintenance Welding, Feltham, Middlesex;
- (d) British Chemical Plant Manufacturers' Association (in the workshop);
- (e) British Mechanical Rubber Manufacturers' Association (in the workshop);
- (f) Federation of British Rubber and Allied Manufacturers (in the workshop);
- (g) Engineering Equipment Users' Association (in the workshop);
- (h) Rubber and Plastics Research Association of Great Britain (in the workshop);
- (i) Stainless Steel Fabricators' Association of Great Britain (in the workshop);
- (j) Tank and Industrial Plant Association (in the workshop);
- (k) The Welding Institute (visits);
- (l) Stainless Steel Development Association (visits).

Training

Two months' training should be given to one person at suppliers of equipment and instruments in Sweden, Poland and West Germany (see annexes V and VI for possible firms).

Candidates

Corrosion-related courses in welding, cladding and lining. The trainee should be a mechanical engineer with workshop experience in maintenance,

stainless steel welding, preventive maintenance techniques, lining with organic materials, cladding, sealing and heat treatment. Metallurgical experience is essential.

Course on corrosion-control instruments and chemical and mechanical cleaning equipment. The trainee should be a chemical engineer with industrial practice in chemical testing methods, the chemical processes of cleaning and corrosion testing. The candidate should have some experience in metal surface preparation before painting and painting technology.

Annex VIII

SUPPLEMENTARY DRAFT DOCUMENT FOR PHASE II
(CORROSION)

United Nations Development Programme
Project of the Government of Pakistan
Project data sheet

Title: Assistance in Design of Preventive Maintenance Practice for Federal
Chemical and Ceramics Corporation Limited - Phase II - Corrosion
Activities

Number: DP/PAK/zz/zzz

Duration: Six months (three plus three)

Sector: Industry

Sub-sector: Establishment and expansion of industries

Government co-operating agency: Federal Chemical and Ceramics Corporation Ltd.
through the Ministry of Production

Executing agency: United Nations Industrial Development
Organization (UNIDO)

Date of submission:

Starting date: January 1982

Government contribution: PRs 220,000

UNDP/UNIDO contribution: \$119,000

Approved:

on behalf of UNIDO

Date

on behalf of UNDP

Date

I. BACKGROUND AND JUSTIFICATION

Phase I of Project SI/PAK/78/803 dealing with assistance in the design of a preventive maintenance scheme for the Federal Chemical and Ceramics Corporation Limited (FCCCL) was started in April 1979 by an expert on safety, maintenance and repair, whose assignment ended in September 1979. (See report DP/ID/SER.A/261). Another expert in corrosion-related maintenance and repair started an assignment to the FCCCL on 1 March 1981 and completed his work at the end of May 1981. Both experts' reports describe maintenance procedures, schemes, economic evaluations and codes of practice and advise on the setting up of the second phase of the project. This annex concerns only the subject of corrosion in the projected Phase II.

II. OBJECTIVES OF PROJECT PHASE II (CORROSION)

Immediate objective

The immediate objective is to train engineers, managers and supervisors of the FCCCL factories in corrosion principles, the technology of corrosion protection, testing and maintenance systems. Such training would enable them to carry out these activities in their factories and to act on the recommendations given at the completion of Phase I (recommendations on standards, on protective painting of steel structures, and on the implementation of design and corrosion-control measures in chemical processing). Corrosion losses in the Pakistan chemical industry estimated in Phase I would be controlled by means of the correct technology. This is an important factor in saving national resources, reducing the import of steel, improving the durability of FCCCL plant, reducing depreciation rates and prolonging the exploitation period of the factories.

Long-term objectives

The long-term objectives are improved productivity and reduced maintenance costs and downtime due to breakdown of steel structures and plant segments.

III. PROJECT OUTPUTS OF PHASE II (CORROSION)

- (a) Increasing productivity in FCCCL factories;
- (b) Reduction of corrosion and metal losses;
- (c) Protection of national resources and FCCCL plant substance;

(d) Reduction of imports of steel, paints, electrodes and isolating materials;

(e) Improvement in the technical level of FCCCL staff.

IV. WORKPLAN (CORROSION)

A. Description of corrosion expert's activities

(First three-month period)

1. Technical assistance and advice to the maintenance managers on implementing the preventive maintenance scheme designed during Phase I, dealing with cleaning, repainting, design improvements and isolation of heavily corroded plant sections in Pakistan PVC, Sind Alkalis, Ittehad Chemicals, Ittehad Pesticides and Ravi Rayon;
2. Organization in Ittehad Chemicals and procuring principal chemicals and tools for corrosion laboratory (50m²) based on Pakistan market sources (Government contribution);
3. Assistance in procuring imported equipment and instruments according to technical leaflets collected in Phase I (UNIDO contribution) as well as procuring books and standards (Government contribution);
4. Preparing probes of different kinds to determine environmental corrosiveness at the Ittehad Chemicals laboratory, using new protective coats, linings and weather-resistant mild steel probes;
5. Designing and conducting at the Kala Shah Kaku group of factories the basic corrosion training programme for selected participants, dealing with corrosion-related maintenance of steel structures and based on the code of practice elaborated during Phase I of the project;

(Second three-month period)

6. Organizing at Ittehad Chemicals the corrosion testing laboratory and implementation of principal testing methods based on standards and purchased instruments and probes (UNIDO contribution);
7. Training repainting staff in new cleaning technology (blast-cleaning and steam-cleaning) for repainting work and corrosion maintenance using the new equipment purchased (UNIDO contribution);
8. Planning on-stream corrosion inspection scheme for essential plant elements in two FCCCL factories. Placing of probes and samples (UNIDO contribution);

9. Acquiring weather-resistant low-alloy steel for plant sections to reduce maintenance and painting costs.

B. Training and fellowships programme

Between the two three-month periods it is envisaged that a training and fellowship programme would be carried out abroad for selected FCCCL staff members in the field of corrosion, testing, painting, cleaning, lining and welding stainless steel, according to annex VII.

C. Timing of the project

1. Procurement and delivery of chemicals and equipment for the laboratory (Government of Pakistan contribution) starting January 1982. Procurement of instruments in July 1982 (UNIDO contribution);
2. Training of selected participants and staff in CRM&R, cleaning, painting and design (August 1982);
3. Maintenance assistance and advice in factories at Karachi and Lahore for cleaning and repainting, selection of materials and design (July - August 1982).

Training and fellowships (January 1982 - January 1983)

4. Training on courses at Manchester Institute of Technology with consultations in welding of s.s., lining and cladding in different associations in the United Kingdom (four months) (see annex VII);
5. Training with suppliers of instruments and equipment (two months, starting in August 1982);
6. Final organization of corrosion laboratory (starting January 1983);
7. Training of equipped repainting staff (February 1983);
8. Planning of on-stream inspection and positioning of coupons and probes (January - March 1983);
9. Acquisition of weather-resistant low-alloy steel (January - March 1983);
10. Final report (March 1983).

D. Corrosion expert's activities

July - August 1982

1. Briefing UNIDO, Vienna
2. Procurement of instruments and equipment
3. Activities at FCCCL factories in Pakistan

January - March 1983

4. Briefing UNIDO, Vienna
5. Activities at FCCCL factories in Pakistan
6. Debriefing UNIDO, Vienna

Government contribution, PRs. (Corrosion)

Code	Total (PRs)	1982 (PRs)	1983 (PRs)
40	Equipment		
41	Expendable (books, standards)	30,000	30,000
42	Non-expendable (laboratory glassware, chemicals and auxiliary equipment)	55,000	55,000
43	Buildings (renovation of old lab.)	25,000	25,000
49	Component total	<u>110,000</u>	<u>110,000</u>
50	Miscellaneous		
51	Operation/maintenance equipment	50,000	30,000
54	Travel on fellowships and training (regional and abroad)	60,000	30,000
59	Component total	<u>110,000</u>	<u>50,000</u>
99	GRAND TOTAL	<u>220,000</u>	<u>50,000</u>

E. Project budgeting (corrosion)

UNIDO/UNDP contribution

Code	<u>Total</u>		<u>1982</u>		<u>1983</u>	
	<u>m/m</u>	<u>\$</u>	<u>m/m</u>	<u>\$</u>	<u>m/m</u>	<u>\$</u>
10 Project personnel						
11 Experts						
11-4 Corrosion expert	6	36,000	3	18,000	3	18,000
19 Component total		<u>36,000</u>		<u>18,000</u>		<u>18,000</u>
30 Training	6	<u>9,000</u>	6	<u>9,000</u>		
40 Equipment ^{a/}						
Instruments for corrosion testing		40,000		40,000		
Equipment for cleaning		30,000		30,000		
49 Component total		<u>70,000</u>		<u>70,000</u>		
54 Duty travel		4,000		3,000		1,000
59 Component total		<u>4,000</u>		<u>3,000</u>		<u>1,000</u>
99 GRAND TOTAL		<u>119,000</u>		<u>100,000</u>		<u>19,000</u>

a/ Based on prices and lists given in annexes V and VI of this report.



