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ESTABLISHMENT OF PREVENTIVE MAINTENANCE SYSTEMS TO INCREASE PRODUCTIVITY OF PHILLIPI.JE INDUSTRIES

DP/PHI/87/008

PHILIPPINES

Technical report: Corrosion control and materials engineering for improving plant maintenance*

Prepared for the Government of the Philippines
by the United Nations Industrial Development Organization
acting as executive agency for
the United Nations Development Programme

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ABSTRACT

The UNDP Project "Establishment of Preventive Maintenance Systems to Increase Productivity" (DP/PHI/87/008/D/01/37) has the objective to initiate institutionalisation of preventive maintenance (PM) in Philippine industries by increasing the capabilities for consultancy, diagonostic, training and information services at the National Engineering Centre. The UNIDO short-term expert on Corrosion and Materials Engineering visited Philippines for three months in October 1989 during which number of activities, e.g. visits to different industries for study of plant problems, preparation of manuals and guidelines, listing of facilities required for field diagonostic and laboratory studies etc. were performed. Number of lectures were also delivered. It was noted that there is great awareness and demand in the Philippine industries for the consultancy in the areas of corrosion and materials provided the services are given promptly and professionally. Final success of the Project objectives will require continuous upgrading of capabilities of the NEC engineers, setting up of all recommended facilities and concentrated efforts by NEC management to ensure the acceptability of the consultants by the industries in the initial stages.

INTRODUCTION

The Medium-Term Philippine Development Plan for 1987-1992 emphasises on increased efficiency in the allocation and the use of scarce investment resources. This is to be achieved through governmental policies and direct assistance measures. The latter category includes efficiency-oriented services to be made available to Philippine industries amongst which planned maintenance has been identified as a priority area for productivity improvement in industries.

To introduce the objective of planned maintenance, specially in medium and large-scale operations, the necessity of the institutionalization of preventive maintenance (PM) was considered a must. Survey carried out by the National Engineering Centre (NEC) in 1986 identified the following areas in which assistance is required by the industries:

- maintenance management (67% of respondents)
- corrosion control (67%)
- condition monitoring (60%)
- leak prevention (60%)
- lubrication (33%)
- spare parts control and technology (27%)
- instrumentation and control (13%)
- reconditioning and salvaging (13%)

The NEC is serving as a focal point to pool engineering expertise for maintenance. To meet the industries requirements, it was deemed necessary to further expand and improve the quality of technical services rendered by the NEC with the assistance of United Nations Development Programme. The present Programme envisages:

- upgrading of NEC staff capacity
- establishment of a PM Diagonostic Laboratory
- establishment of a PM Information and Promotion Service
- introduction of PM Assistance and Consultancy services.

In persuance of the UNDP assistance provided in the Project, the first short-term UNIDO expert to join was on Corrosion and Materials Engineering. The expert reached Manila on Ist Oct 1989 and left on 29th dec '89 after completion of 3 month assignment.

During the assignment the work was carried out continuously except for 10 days break from Ist to 10th Dec '89 during the attempted coup detat.

Considering the objective of the Project and assignment period of only 3 months, a detailed work plan was drawnup in consultation with the Chief Technical Adviser and Executive Director NEC. The programme consisted of:

- Visit of selected industries to assess and discuss their corrosion and materials problems
- preparation of guidelines on specific topics of present and future use in Philippines
- preparation of training modules for consultants and technicians
- selection of instrumental facilities for inspection and field corrosion monitoring
- selection of literature for the Technical Library
- selection and specification of equipment for failure analysis and corrosion studies pertaining to industrial problems
- conducting/participating in seminars on corrosion and materials.

The work plan envisaged was completed to a great extent inspite of stoppage of work during the attempted coup detat. The latter also affected the plans to visit some of the important industries in Philippines e.g., mining, non-ferrous metallurgy etc.

The original objectives could not be fully achieved because

- the assignment period of 3 months was too short to cover the varied corrosion and materials problems experienced in different types of industries. This is primarily because environmental conditions and requirements of varied types of industries are quite different.

- no equipment were availble or could be procured during the short period to train counterpart engineers and technicians.

- in-house training of all NEC PM staff could not be completed because of their pre-occupation with other project activities

RECOMMENDATIONS

1.0 Utilisation of Services by Industries

There is great awareness and demand in the Philippine industries for consultancy in the area of corrosion and materials. It was possible during the plant visits of the expert to highlight the objective and future activities of the PM group being developed in the NEC. However, success of the Project in terms of benefits to the industries will depend on acceptance of NEC consultants by the industry and providing consultancy services promptly and professionally. This will in turn depend on the confidence created by the consultants and equipment facilities available with the NEC.

It is recommended that

a) All necessary steps should be taken to retain the presently trained engineers at least till the activities of the NEC PM group is soundly established. It is understood that the present staff has been recruited on temporary basis and this situation may lead to people looking for alternate jobs.

b) At appropriate time second line of consultants should be developed to retain continuity.

c) A senior experienced engineer, having good industrial contact, should be assigned to look into the activities of PM group and create confidence of the industries.

2.0 Field and Laboratory Testing Facilities

For services to industries for effective corrosion control and ensuring safety of equipment and plant personnel NEC would have to provide field and laboratory testing facilities. For this purpose equipment to be used more frequently will have to be kept at NEC. For the rest, assistance of other organisations like Metals Industry Research and Development Centre and Industrial Technology Development Centre in Manila can be taken.

It is recommended that urgent steps should be taken to procure the recommended facilities on priority basis. Necessary budgetary provision should be made for this.

3.0 Guidelines and Manuals

Guidelines and Manuals form the backbone of providing services, taking corrective actions and also training. Some of the important guidelines have been prepared during the assignment period.

It is recommended that

a) these guidelines should be periodically updated based on NEC's own experience and information collected from other experience published in lierature and by various technical bodies.

b) guidelines and manuals on other topics, which could not be completed due to time constraint should be prepared by NEC in future.

4.0 Assistance of UNIDO expert

Environment to which materials are exposed vary greatly depending on location and type of industries. The area to be covered to formulate corrosion control measures is therefore vast. The period of 3 months for UNDP expert envisaged in the project was short to meet the total project requirement. While the expert has tried to give maximum possible inputs, it is recommended that provision may be made in the revised project document for an additional expert on corrosion and materials engineering (1 m/m). This expert will visit before the end of the project and would give additional inputs based on the experience of NEC and will also help in the setting up of the field and laboratory facilities. It is expected that by this time most of the equipment will be procured and the new NEC building wing will be ready.

I PROJECT IMPLEMENTATION

A General

To achieve the objectives of corrosion and materials engineering within the overall objectives of the Project the expert produced various codes and guidelines, plant visit reports, organisational proposals, training programmes and also delivered number of lectures to in-house NEC staff and personnel from industries and other organisations. In addition some proposals on national corrosion test programmes, and inter institutional collaboration in the field of corrosion and materials were also prepared.

The two assigned counterpart engineers were all the time associated and they were trained in developing consultancy expertise. The Chief Technical Adviser and the Executive Director of NEC were constantly kept informed about the progress of work. The work of the expert has been positively received by all concerned.

B Counterpart Personnel

Of the total nine engineers working on the project during the assignment period, two, i.e. Mr Renato B. Golecruz and Miss Evangeline O de Guzman, were assigned to the subject of corrosion and materials. Both of them had some practical experience and specially the former who had previously worked in the industry. During the assignment, emphasis was given on training the counterpart engineers on various aspects of corrosion and materials pertaining to different industries and how to tackle technical problems taking into consideration individual client's requirements and resources. Practical aspects of problem solving and techniques of corrosion control, material selection and inspection were given due attention. This was achieved by constant interaction in the office and during the plant visit and also through lectures and discussions.

C Evaluation of Activities

As a first step, the existing situation in Philippine industries was perceived through discussion with Chief Technical Adviser, Executive Director NEC, counterpart engineers and visits to a few industries. This helped in deciding on the areas which required to be covered during the assignment period. Deterioration of a material due to corrosion depends primarily on the environment to which it is exposed. As each type of industry has its own environment the area to be covered is quite large and it was realised by all concerned that duration of 3 months is inadequate to cover all aspects. In view of the above most important areas of inputs were identified for implementation within the general framework of Project objectives.

1.0 **Industrial Visits**

A detail programme of plant visit was drawn up to cover textile, metallurgical, metalworking, mining, sugar, chemicals, refining and other industries. Of these it was possible to visit eight industries in an around Metro Manila as given in Annexure 1. Visits to industries quite far away from Manila, which were programmed for December, did not materialise. On the special request, problem of preservation of an ancient "all steel" church was also looked into and has been included in this section.

The main objectives of the plant visits were

a) to assess the type of problems on corrosion and materials being experienced in different industries,

b) to acquaint the industries of the PM activities of NEC by direct interaction

c) to train the counterpart engineers on-job in problem solving and

d) to assist the industries in few areas within the limited time of assignment.

Each visit was followed by a short report and the six of these are attached in Annexure 2. Copies of these reports were given to Chief Technical Adviser, NEC Executive Director and the PM project department.

The plant visits indicated keen demand for consultancy services in the area of corrosion and inspection. Both the management and engineers are aware of the losses due to corrosion and want some organisation to help them in a professional manner to combat corrosion problems.

2.0 Guidelines and Manuals

One of the important activity of the expert consisted of preparation of guidelines on specific topics of corrosion control, materials selection and field inspection. These were prepared keeping in view the overall requirements of Philippine industries. Number of published codes, standards and guidelines are available but these are of general nature. The guidelines prepared were comprehensive to the needs and based on expert's own experience. These will form the basis for the NEC consultants to work out the line of action in different areas.

Again the time was a constraint to cover all the areas. In all six guidelines and manuals were prepared as listed in Annexure 3. Full texts of two are attached in Annexure 4.

Guidelines on corrosion monitoring and inspection, corrosion testing procedures and cooling water corrosion control could not be completed within the present term of the expert.

3.0 Field Testing Facilities

Inspection and corrosion monitoring form the basis on which the effect of corrosion control measures, extent and nature of corrosion damge and safety and recidual life (time for replacement or repair) of equipment and facilities can be established. These form the most important tools for providing services to the industries in the area of P.M. Many of the industries do not have their own facilities and would like to have the services from an outside agency like NEC PM group for systematic inspection and monitoring. Thus direct instrumental services combined with diagonosis of the problem will have a considerable demand.

Considering the present and future requirements, list of equipment required was prepared (Annexure 5). The priorities for procuring these were also drawn up.

The importance of procuring these for effective rendering of consultancy services is emphasised as most of the industries would like to have a single point responsibility.

4.0 Diagnostic and Laboratory Facilities

In considering establishment of Laboratory facilities for diagnostic/failure analysis and corrosion test facilities it was suggested that only limited equipment which will be most frequently used, should be procured by NEC. For special types of studies, which would be required once in a while, assistance can be taken of other organisations in Manila. The suggestion was accepted by NEC and with this in view the two important testing institutions in Metro Manila, i.e. Metals Industry Research and Development Centre and Industrial Technology Development Institute were visited to have an idea about their facilities. Based on this visit a note (Annexure 6) was prepared outlining the requirements and activities of the laboratory.

For service to industries setting up of such a facility is absolutely necessary as the general impression gained from most of the industries during discussion was that prompt services in such areas is lacking in Philippines.

The expert could not provide any assistance in setting up of the laboratory as equipment were not available.

5.0 Training

The consultants at NEC in the area of corrosion and materials engineering will cater to the needs of various industries in Phillipines. They will not only provide direct services but as per the objective of the project would also require to assist the industries in training of industrial managers, front line supervisors, engineers and technicians. Considering these activities, the effectiveness of engineers and technicians in the NEC will depend not only on their qualifications but on the experience, constant updating of knowledge and techniques and interaction with personnel in related fields. This approach is also needed for plant personnels of various levels.

Based on these requirements on-job familiarisation was given the utmost importance during the plant visits to counterpart engineers. They were also involved in study of problems, report writing, discussions, etc. to give them an understanding of practical approach to problems. Lectures on some of the important topics, e.g., corrosion monitoring, inspection, material selection, stress corrosion cracking and intergranular corrosion were delivered as and when the time permitted.

PM involves numbe: of disciplines and though each individual in the PM group has his own area of activities it requires a multi-disciplinary approach to solve any problem. Attempts were therefore made to give basic idea about corrosion and materials to the whole group but this was partially successful because of pre-occupation of other members of the PM group in activities in their field and prearranged industrial training programmes.

On long term basis a well organised training and career development programme, tailored to the needs of the individual and the jobs he is expected to perform is required. These consist of on-job and in-plant training, participation in maintenance activities, attending plant shutdowns, basic and advance training on corrosion, materials, inspection and management and attending seminars and conferences in related fields. A background paper on training programme was therefore prepared and is given in Annexure 7.

For training of industry personnel seminars and special lectures were arranged. Seminar on "Industrial Corrosion Prevention and Control" was organised by NEC during the assignment period which was attended by over 25 participants. Special lectures were delivered by the consultant at the Philippine National Association of Corrosion Engineers and Philippine Oil Development Corporation. A Seminar-Workshop on "Metallography and Corrosion Failure Analysis" was planned but could not be organised because of time constraint.

6.0 Additional Activities

- The publications on corrosion and materials available in the technical library were reviewed and a list of additional books to be procured was prepared (Annexure 8).

- Details of test procedures to demonstrate the forms of corrosion durinbg training of engineers and technicians were prepared (Annexure 9).

- A proposal was made to carry out national programme on atmospheric corrosion to prepare a "Corrosion Map of Philippines" (Annexure 10).

The contents of the package of regular services offered by NEC to private industry was discussed with NEC Director. The experts opinion on the outline of such a package is given in Annexure 11.

II. UTILIZATION OF THE RESULTS OF THE ACTIVITIES

The activities have resulted in focussing the attention of the industries to possibilities of getting assistance from NEC in solving their corrosion and materials problems. Keen iterest was shown by almost all the industries visited, to get consultancy in actual problem solving and failure analysis. To a limited extent these couild be looked into by the expert during the assignment period, but the same will have to be followed up by NEC in future.

The counterpart engineers have been trained and provided technical material on the basis of which assistance to industry can be started. However, this will be more effective only after recommended inspection and laboratory equipment are procured, and proposed specialised training in selected foreign institutions is completed. These need to be considered on priority basis for due utilisation of project activities.

Successful consultancy requires not only the capability of the consultant but also his acceptance by the user. Time is therefore, an important factor in establishing the credibility of a consultancy group. Thus it will be only over a period of time that NEC can play a major role in improving productivity through technically sound PM systems tailored to the needs of the individual industries.

The following factors might therefore affect effectieve utilisation of results :

a) Absence of constant interaction with industries by a senior and experienced personnel to create confidence between the industries and young engineers/consultant in PM group. This is very much essential during the first few years.

b) Possibilities of trained personnel leaving before second line of consultants are developed.

c) Field and laboratory facilities are not procured due to budgetary constraints.

d) Services are not provided promptly, professionally and taking into consideration individual industry's capabilities.

e) Emphasis by NEC is not maintained on Systematic PM Assistance and Consultancy Services to industries.

ANNEXURE - 1

LIST OF PLANTS VISITED

1. Lucky Textiles, Meycauyan, Bulacan
2. Phiippine Steel Coating Corporation, Mayapu
3. Geo-Thermal Power Plant Complex, Mak-Ban
4. Metropolitan Water Works and Sewerage System, Balara, Metro Manila.
5. Central Azucarera de San Pedro, Batangas.
6. Philipinas Shell Petroleum Corporation, Tabangao Refinery, Batangas.
7. Armco Marsteel Alloy Corporation, Taguig, Metro Manila.
8. National Thermal Plant, Sukat Complex, Metro Manila.
9. San Sebastain Church, Quiapo, Manila.

ANNEXURE 2

PLANT VISIT REPORTS

- Lucky Textiles
- Geothermal Power Plant Complex
- Metropoliton Water Works and Sewerage System
- Central Azucarera de San Pedro
- Pilipinas Shell Tabango Refinery
- San Sebastian Church.

NO. CME/PVR/01
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SURVEY OF CORROSION PROBLEMS IN LUCKY TEXTILES

1.0 BACKGROUND

1.1. As a part of the NEC's programme the Lucky Textiles at Meycauyan, Bulacan was visitied for 3 days. The expert's counterparts were present during the visit when the vaious corrosion problems being experienced at the plan were studied at site and discussed with concerned engineers. The observations and the recommendations are outlined in this note.

1.2. The Lucky Textile was established in 1958, but during late 70's this was closed down. Later it was taken over by the present management and re-started in 1984.

1.3. The plant has mainly four sechions, i.e., spinning, weaving, finishing and utility. Of these corrosion is experienced mainly in finishing and boiler sections.

2.0. PROBLEMS

2.1. Finishing Section.

2.2. Dyeing Tanks

Dyeing tanks are made of stainless steel which contains hot solutions of various chemicals details of which are of proprietry in nature. However, it was mentioned that these are highly corrosive in nature and contain acetic acid and other salts. Dyeing is a continuous process and a number of rollers are welded at the upper and lower portions of the tanks. Corrosion is experienced near the welds, both of main tank, and welding of bearing journals to the shell. It was mentioned that whenever a leaky area is repaired by welding new leak appears near the repair weld.

The present condition was examined and at many locations slight seepage of the red dye and deposition of salt along the weld was noted. The failure of stainless steel alloy 316 in the present case is due to intergranular corrosion of the base material in the vicinity of the weld. Intergranular corrsoion is due to precipitation of chromium carbide near the weld and therefore it is recommended that instead of plain 316, AISI 316L grade of material should be used.

2.1.2. Structural Supports of Dyeing Tanks

The structural supports of stainless steel tanks are made of carbon steel channel sections. In tanks nos. 1 and 2, where the chemicals are periodically added manually, heavy corrosion of the structures is experienced. This is due to spillage of the chemicals and presence of hot and humid atmosphere.

The following remedial measures are recommended to minimize this problem:

a.) As the site of structural members is not large, these can be replaced with SS 316L as already been considered by the company.

b.) The method of addition of chemicals should be modified so that there is no spillage. A bowl with long spout/chute, mounted on a mobile trolley can be used for the purpose. The workman will positon the chute end at the centre of the tank and then add the chemical through the bowl. As the additions are made periodically, the trolley will be of help in bringing the device when additions are to be made.

c.) If the Management decides to continue the use of steel structural members then these will have to be given suitable protective coatings. In the present case the conditions are quite severe and heavy duty chemical resistant (resistant to the chemicals being used) paint system will have to be used. For this purpose reputed paint manufacturers should be consulted.(with the details of the conditions of exposure) However, in our opinion, any paint system will have limited life and periodic painting will have to be done, which at-site will be difficult. In the long-run it may be economical to change over to stainless steel as the weight of structural required is not high.

2.1.3. Deterioration of Drains

The effluent discharge drains in the vicinity of dyeing were found to be in advance state of deterioration. Concrete had been eaten away at many places. This requires immediate attention. The concrete drains will have to be lined with chemical resistant lining. The following two alternatives are suggested:

1) Acid resistant ceramic tiles will have good resistant to attack. In this case limitations will be the jointing material. Furane resin can be considered if the manufacturers guarantee that it will be suitable for the present condition of effluent composition and temperature.

2) The second alternative is to use monolithic organic coating. As the effluent contains acids polyester based coating with silica as filler material can be used. Manufacturers should be consulted for its suitability with the details of chemical composition and temperature of the effluent and its recommendations followed for application. A monolithic lining will be preferred over tile lining because joints are always points of weakness.

3) For any lining system used, the damaged drains will first have to be repaired. All care will be taken so that repaired concrete does not fail, because of improper repair procedure.

2.1.4. Bleaching Section

Bleaching is performed by hot chlorine gas in a special titanium equipment. All openings are properly sealed. However, sometimes there is leakage of chlorine which corrodes the structural supports made of carbon steel beams, angles etc. One of the affected beam has been replaced by stainless steel.

Replacement with stainless steel of the structures likely to be affected by the leaking chlorine gas is not economically justified. Further, in wet chlorine, stainless steel will also not have very good resistance to corrosion.

Use of a suitably applied heavy duty paint coating is recommended:

a.) The coating system will consist of:

(i) Brush applied 3 coat of chlorinated rubber base paint containing mineral filler resistant to wet chlorine gas.

Dry film thickness-minim 50 micron/coat

(ii) Brush applied 2 finishing coats of chlorinated rubber to required colour finish.

Dry film thickness-minim 30 micron/coat (Coating manufactured by M/S Lechler Chemie, Stuttgard; Trade name ICOSITA Heavy; other manufacturers can be contacted for similar products)

(iii)Manufacturer's guideline regarding surface preparation and other application details will be strictly followed.

b.) It will be good practice to get the work done by accrediated paint contractor of a local reputed paint manufacturer. Such a system exist in Philippines where guarantee for job is given. If the supplier has any other guaranteed paint systemn, the same should also be considered.

2.1.5. Mercirising System

Mercirising consists of subjecting the fabric to a successive treatment of caustic, stretching, washing, souring (acid), washing and drying. The treatment is carried-out in series of open tanks where the solutions/water are heated by direct injection of steam through specially designed cast iron nozzles. The 2 to $2^{1}/_{2}$" dia nozzles have number of $^{1}/_{4}$" holes.

In the two washing tanks after caustic and stretching section following problems are experienced as per the dept. engineers.

a.) The steam nozzles get choked with deposit over a period of time and requires cleaning. However, the frequency was stated to be once a year.

b.) Whitish deposits form on the rollers and require cleaning once a week, thus affecting production. Such deposits are not observed in the washing tanks downstream, whe e bath temperatures are 60°C against the 95°C.

The water used is raw water and depending on its compostion, the pH existing in the tank water and temperature deposits are likely to form. So basically the problem is to be tackled from various angles. The following line of action is suggested for a detailed study:

1) Undertake detail analysis of raw water and the tank water, as because of evaporation some degree of concentration is likely to occur.

2) Analyze the deposts formed on the rolls/jets to establish whether it is carbonate or sulphate scaling.

3) This should be followed by detail analysis of the problem to find out the remedial measure. One remedy

may be isolation of the two tanks from the main raw water supply system and use only treated water which would not leave any deposits under the operating condition. However, this would involve extra cost which would have to be economically justified.

2.2. Utility Section

2.2.1. Corrosion of Underground Pipeline

The plant originally had underground water supply piping network. These developed leaks due to soil side corrosion. The old piping network has been completely replaced with overground pipe. This has been a correct step.

2.2.2. Boiler Section

In the boiler section, the following corrosion and maintenance problems were mentioned.

a.) Corrosion and Sealing of Boiler Tubes

There are six boilers where process steam is raised. The pressure is in the range of 70-100 psi. Originally no water softener was there when lot of scaling was observed. The boiler had to be periodically chemically cleaned. Subsequently "zeolite" softener was installed in 1986. Chemical treatment, e.g. dosing of phosphate and sodium sulphite was also started. Magnetic device was also installed in one boiler but its performance in the long run was found to be inadequate. At present "softened" water with phosphate and sulphite dosing is used for all the boilers. The feed water consist of 80% make of water + 20% return condensate. The temperature of feed water is around 60°C. Of the six boilers, two are wood fired and four "bunker oil" fired.

In the past two years the boilers have been either fully or partially retubed. The tubes had experienced pitting and thinning.

The system was examined and the following comments/recommendations are made taking into considerations the long term performance of the boilers.

(i) The present method of maintaining boiler water quality needs considerable improvement. The addition of chemicals should be based on the maintenance of min amount of PO_4 and sulphite in the boiler water. At present certain norms about periodicity of addition has been fixed and no regular checks on quality of water is made. It was mentioned that this periodicity has been fixed on the basis of previous experience, the basis of which is not clear.

(ii) Similarly blowdown is also made on the basis of a fixed norm (every 4 hours) instead of T.D.S. level of boiler water.

(iii)The method of chemical additon needs improvement. A chemical dosing system shoud be introduced, if possible.

(iv) Chemicals/treatment of a reputed company like Nalco, Betz or any local company should be followed and recommendations of supplier for operations should be strictly adhered to.

b.) Tube to Tube Sheet Leaks

It was mentioned that quite often after shutdown some tube to tube sheet joints start leaking. This happens only in cases where expanded joints have been provided. This type of leakage is due to tube sheet holes developing slight ovality or increase in their diameter by repeated expansion. In future it is recommended that tube to tube sheet joint shoule be seal welded after expansion.

No: CME/PCS/02
November 1989

REVIEW OF CORROSION AND MATERIALS PROBLEMS AT MAK-BAN GEOTHERMAL POWER PLANT COMPLEX

1.0 BACKGROUND

1.1 The geothermal power plant complex of National Power Corporation at Mak-Ban was visited on 27.10.89. The materials and corrosion engineers Mr. Renato B. Golecruz and Miss Evangeline O. De Guzman were present during the visit. There are three plants A, B and C in the area with a total generating capacity of 330 MW from six 55 MW units.

1.2 The geothermal steam is piped out from deep wells varying in depth from 2150 ft. to 10,302 ft. The average depth is 5,893 ft. There are 73 wells in a total area spread over about 160,000 acres, of which 52 are production wells. The steam requirement is about 420T/hr for plants A and B and 440T/hr for plant C. The wells are drilled and maintained by the Philippine Geothtermal, Inc. and the steam supplied to National Power Corporation. The visit was made only to the NPC's power generation station C.

1.3 The flow diagram of the steam system in the plant is shown in Fig. 1 The steam of 80psi (5.65 kg/cm^2) received at the plant contains 4% non condensable gases by weight; 85% CO_2 and 15%H_2S. The steam coming out of the turbine goes into a direct contact condeser where it meets the cooling water entering the top. The condenser consists of number of trays with holes to effect good contact between the fal'ing water and rising steam.

1.4 The warm water from the well is sent to a cooling tower. While a part of the water is recirculated, the rest is sent bank to the field for reinjection in the earth. The non-condensable gases from the condensed steam is removed by means of 2-stage ejectors.

2.0 CORROSION PROBLEMS

2.1 It was mentioned that no serious problems due to corrosion are being experienced in the Complex. However, the following two were identified by them:

2.1.1. Corrosion in condensate water circulating line,

a) The condensate water line to cooling tower and back have shown considerable internal corrosion. This is inspite of the fact that as a control measure cuastic solution is injected in the water to neutralise acidity. The steel pipeline from the hot well to the cooling tower has already been replaced with fibre glass. There are plans to replace the return lines also with fibre glass.

b) The non-condensable gases contain about 85% CO_2. CO_2 dissolved in water forms carbonic acid, which makes it corrosive. Presence of H_2S further increases the corrosivity of water. Neutralisation is the most commonly used corrosion control method which has been provided in the system. However for good performance of neutralisation system two important points are are to be kept in view:

(i) Good mixing between caustic and the water for effective and quick neutralisation. For this purpose the best location for injection of caustic is the inlet of the pump. The mixing is quick and efficient when the water passes through the pumps.

(ii) Caustic Injection should be properly controlled and maintained continuously.

(iii) The pH of the water at outlet of the pumps and inlet of the cooling tower should be regularly monitored and caustic injection adjusted accordingly.

c) Even after replacement with FRP, the neutralisation should be continued because this water is also transported for injection and the pipeline outside the power plants boundary would also need protection against corrosion.

d) It may be mentioned that the water being steam condensate, it will not have any tendency for scale formation. The water is therefore expected to be corrosive even after neutralisation, specially in presence of oxygen. The pH of the water should therefore be maintained high at 10±0.2.

2.1.2. Corrosion of Steel Structure.

a) The steel structures, pipings, etc. are subjected to atmospheric corrosion specially those in the ejector section and in the vicinity of cooling tower. In these areas the paint on columns, pipings, structures does not last more than 6 months. It was mentioned that some type of epoxy coating has been used.

b) The area was found to be quite windy during the visit. Being located at high elevation it is expected that for most of the time the wind will be moderate to strong. Due to wind the equipment in the area is constantly exposed to water spray. The ejectors also release lot of steam which adds to the wetness on the structure. The water droplets have dissolved H_2S and CO_2 making the environment corrosive.

c) The paint selected for this location should be resistant to wet and damp condition in presence of CO_2 and H_2S. A suitable paint system should be selected in consultation with reputed paint manufacturers. In our opinion systems given in Table 1 will give good life. Before final selection, it is recommended that these should be tried in a few areas and performance evaluated.

d) Any paint system finally used should be applied under correct conditions, e.g., proper surface preparation, absence of surface wetness and strict supervision. Unless these are followed even best of paint will not give good life.

2.1.3. In the steam turbine, one of the blades on the low pressure section, developed crack at the root. The blade has been removed and sent for metallurgical examination. It will be appreciated if the report on the observations is sent to NEC to study cause of this failure.

3.0 GENERAL COMMENTS

3.1 Geothermal power generation consists of tapping steam from underground and generating of power from the same . During the present visit there was no discussion regarding the corrosion problems experienced in the geothermal field. However some information was available from the Head of the Mak-Ban power plant.

3.2 Tapping of steam consists of drilling hole up to the reservoir depth. The steam along with hot water comes out through a pressure reducer and control valve. Steam and water mixture are collected at gathering stations where first the steam is separated in steam/water separators. The water is drained and the steam is washed to remove any entrained water droplets and solids. Washed steam is transported to near the plant and again spray washed before sending for power generation.

3.3 It was informed that all the vessels in the gathering stations are made of stainless steel and steam pipings are of externally insulated carbon steel. Further, no corrosion problems have been experienced except for the condensate draw off pipings in the steam line.

3.4. The following corrosion problems are possible in the system, which should be kept in view for future reference problems.

3.4.1. The water coming out of the wells is hot and contains large amounts of dissolved solids. Total analysis of this water should be obtained. The water is expected to contain large amounts of chlorides and as temperatures are high, possibilities of SCC cracking of stainless steel remain. The intensity of cracking is less in the absence of oxygen. Oxygen content is therefore important.

3.4.2. The steam may have entrained chloride and as wash water contains dissolved oxygen, cracking can occur on localised conc^n of chloride, say during spray water failure.

a) Detail information on grade of stainless steel being used will be collected with regards to its resistance to SCC,IGC and pitting.

b) Shutdown should include visual inspection of welds, stagnant areas and other vulnerable points. If SCC or IGC is suscepted the area should be fluorescent dye penetrant checked along with field miscroscopy to establish the nature of corrosion.

c) In case SCC is detected, the area should be ground till all the cracks are removed. If depth of the crack is less than 25% of wall thickness and confined to 75mm dia area, the edges should be ground smooth and left as it is. If the depth is more than 25% the portion should be cut and a new plate welded.

d) In case of closely spaced pitting the above procedure should be followed.

e) In case of IGC, the material is to be changed to stabilise grade. Temporary weld repair can be done with low heat input.

3.4.3. Corrosion of Carton Steel

a) Steam,after washing contains about 4% by weight of non-condensable gases of which 85% is CO_2 and 15% H_2S. Main corrosive constituent in this system is CO_2. Corrosion of carbon steel by CO_2 is dependent on CO_2 partial pressure and temperature. In such cases mol % or vol % is more important than wt percent and this should be found out. Mol % x system pressure gives the partial pressure.

b) Corrosion rate increases with increase in CO_2 partial pressure and temperature. Above 80°C, the corrosion rate decreases because of formation of Fe-Carbonate film on steel surface. H_2S may affect this temperature.

c) Steam temperature in the present case is 160°C and that is the reason that no corrosion of C.S. piping has been observed. At condensate drain point which are not insulated, temperature comes down and corrosion took place.

d) In case of CO_2/H_2S corrosion of CS steamline, the affected portion should be u/s tested for wall thickness loss. Based on inspection results the affected portion would need replacement.

3.4.4. Wells for gettin out steam uses steel tubulars. Depending on corrosivity of soil, corrosion of well pipes can take place resulting in perforation. As in case of oil well these may require cathodic protection.

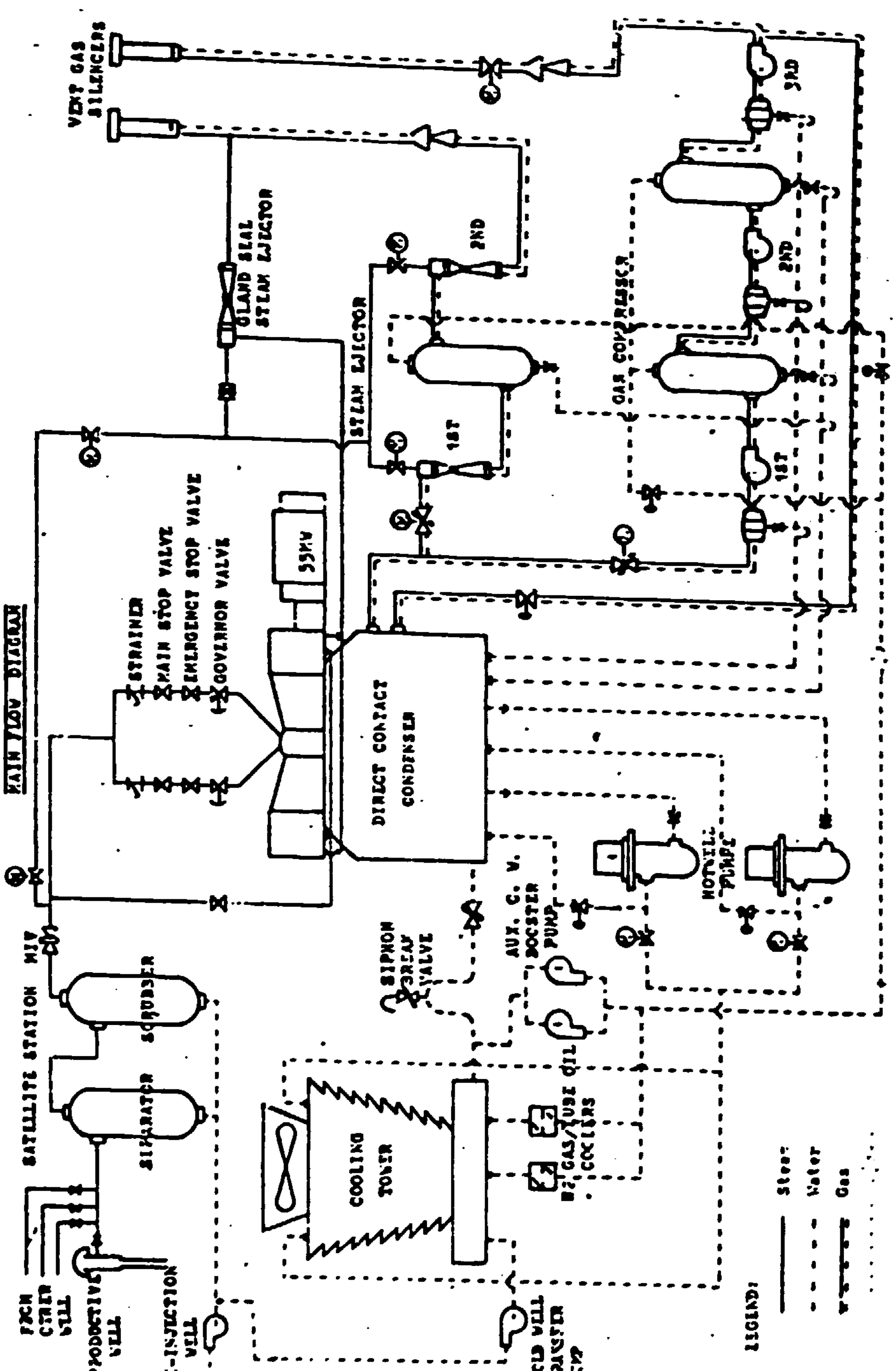

MAIN FLOW DIAGRAM
VENT GAS SILENCERS
GLAND SEAL STEAM EJECTOR
STEAM EJECTOR
1ST
2ND
GAS COMPRESSOR
3RD
STRAINER
MAIN STOP VALVE
EMERGENCY STOP VALVE
GOVERNOR VALVE
55MW
DIRECT CONTACT CONDENSER
HOTWELL PUMPS
AUX. C. W. BOOSTER PUMP
SIPHON BREAK VALVE
SATELLITE STATION
SEPARATOR
SCRUBBER
MIV
COOLING TOWER
GAS/LUBE OIL COOLERS
PRODUCTIVE WELL
RE-INJECTION WELL
COLD WELL TRANSFER PUMP
LEGEND:
Steam
Water
Gas

TABLE 1

RECOMMENDED PAINT SYSTEMS IN THE STEAM EJECTOR AREA OF MAK-BAN GEOTHERMAL POWER PLANT

CONDITION : Wet, steamy due to ejector steam and wind borne cooling water spray.

Atmosphere contains high amount of CO_2 & H_2S released in the air.

SYSTEM 1 :	Surface Preparation	Near-white metal blast (NACE No. 2 or SSPC No. SP-10)
	Primer	One coat Inorganic zinc
	Top Coats	High build vinyl
	Dry film thickness (min^m)	Primer - 3 mils Topcoat- 6 mils
SYSTEM 2 :	Surface Preparation	Same as above
	Primer	Same as above
	Top Coats	High build chlorinated rubber
	Dry film thickness	Same as above.

CME/PCS/05
November, 1989

CORROSION AND MATERIALS PROBLEMS EXPERIENCED BY METROPOLITAN WATER WORKS AND SEWERAGE SYSTEM

1.0 INTRODUCTION

1.1 The head office of the Metropolitan Waterworks and Sewerage System (MWSS) at Balara was visited on 30.10.89 along with counterpart engineer Mr. Renato B. Golecruz. The problems of materials and corrosion was discussed with Engineer Mangalabran and his other collegues. The water treatment plant at Balara was also visited. No discussion on problems in sewerage system was discussed.

1.2 The public utility water supply to Metro Manila is divided into Northern and Southern zones. Water source is from three water reservoirs known as Messa, Ipo and Bala dams. These are located at elevation of 76 meters, 101 meters and 64 meters. In addition, groundwater is tapped in same areas to augment the increase demand.

1.3 Water from Ipo and Mesa are mainly used to supply southern part of Metro Manila. The water is brought to centralised treatment plant by a 2 meter dia concrete aquaduct. Water is treated to remove suspended solids by addition of cogulant and floculant followed by filtration. The water is then chlorinated and supplied to different parts of the city. Supplys is basically by gravity flow. The distribution is not the responsibility of MWSS.

2.0 DETAILS

2.1 The following informations were supplied during discussion:

2.1.1. Quality of water

pH - 6.9 to 7.2

Total Hardness	-	44-60 mg/l as $CaCO_3$
Chloride	-	3-8 ppm.
Free Chlorine	-	0.1 ppm.

2.1.2. Material of construction

Main supply pipeline	-	steel internally and externally lined with concrete
Valves	-	C.I
Pumps	-	Casing of C.I; impeller of bronze
Chlorinator	-	
dry chlorine section	-	Steel
wet chlorine	-	Plastics
Chemical tanks	-	Stainless steel
Water	-	Plastic lined steel
Tankages	-	Concrete (mainly)

2.1.3. Corrosion problems

i. It was informed that no serious corrosion problems are being experienced by MWSS. No information of cases of pipeline leakages was available. Loss of water in distribution however is about 30%, a majority of which is considered to be due to illegal connections. Losses due to leakage are also suspected during distribution but details were not available to establish this fact.

ii. Chlorination section has considerable corrosion problem, specially due to leakage of chlorine in the enclosure. The materials for the wet chlorine handing has been changed to plastic. Problem is in dry chlorine handling pipes and other steel structures because of external corrosion.

iii. Alum and ferric chloride tanks were earlier fibre glass lined carbon steel but failed in 3-4 years. These have been changed to PVC lined and solid PVC respectively and the performance has improved.

2.2 Recommendations

2.2.1. It was mentioned that MWSS would like advice on paints to be used in the chlorination section. They also wanted to know if any alternate cheaper anode can be used in chlorine vaporiser as presently these require yearly replacement.

i. Chlorination of water is done by heating liquid chlorine supplied from storage cylinders. Liquid chlorine is heated in the vaporisers, which is contained in a hot water bath at about 160°F (70°C). The liquid chlorine from the cylinder to vaporiser and gaseous chlorine to chlorinator is handled in 3/4" dia steel pipes. When any leakage of chlorine occurs heavy corrosion of pipings near the leak takes place. The overall corrosivity of atmosphere in the room also increases leading to failure of paints.

Some of the pipes were examined. At many places leaks occured at the threaded joint. Chlorine coming in contact with moisture in air caused heavy grooving type attack. Following corrective measures are suggested:

(1) All steel pipings carrying liquid chlorine have threaded joints. All threaded joints after tightening should be seal welded. This would avoid leaky thread joints, main source of chlorine leakage.

(2) The other source of chlorine leakage is from plastic piping joints. The joints are of welded or mechanical clamping construction. All jointing should be supervised and checked for their integrity. Any leaky joints should be immediately attended to.

(3) The paint systems given in Table 1 are recommended for steel piping and structures.

(4) It is a good practice to have a well ventilated chlorination room by providing suitably located exhaust fans. As chlorine will be released to outside environment, its impact on pollution should be examined before implementation.

ii. Chlorination is done by heating in a double walled vessel, with water in the outer chamber. As chlorine should in no case become wet, the leakage of the inner shell, due to corrosion is to be avoided. This is achieved by cathodic protection. Pencil Mg anodes (four nos) are used, which are connected togehter. The alternative approaches are:

(1) Use cheaper zinc instead of Mg. This would not give desired protection as the polarity of zinc is reversed at temperatures around 65-70°C. Use of zinc above 60°C is not recommended.

(2) Second alternative is the use of aluminum alloy anodes.Aluminium is likely to develop passive oxide/hydroxide layer at high temperature, reducing its protective efficiency. However, the aluminium anode supplier can be contacted. These maybe cheaper but would also require periodic replacement.

(3) Impressed system can be used but it would require one time higher investment and greater operational control and checks. This is not a recommended alternative.

3.0 GENERAL COMMENTS

3.1 In potable water of the quality being handled by MWSS, the concrete coated line is expected to have good life as a as internal corrosion is concerned. External soil side corrosion is of importance specially in the mainlines where number of branch and subsidiary lines are connected. Taking long term performance into consideration and the fact that many of the pipes were laid more than fifty years back, a detail survey is necessary. NEC can assist MWSS in this. It is to be kept in view that though presently concrete coated water mains are being used, the old lines, specially in Manila, may be of C.I or steel coated with tar or asphalt. Some of the pipes may be even 70-80 years old.

3.2 Another area of concern is corrosion of distribution and connection lines. These are not given same attention as in case main lines, as the work is carried out in small sections and from time to time. Becasue of small volume of work the contract valve is low and therefore supervision of a large project project lacks. As MWSS suspects considerable loss of supply water due to leakages, a detail survey on distribution and supply line leaks is also necessary.

3.3 The following is the broad outline of the survey:

3.3.1. To collect all available information on:

a.) Routing of main and distribution lines in different areas.

b.) Materials of construction and protective coating system of the above lines; including supply lines.

c.) Method of connection at branch and supply lines and materials used both at present and earlier.

d.) History of failures in various sections along with their nature, wherever available.

e.) Review of all data from (a) to (d) to conclude the possible state of health of pipelines in different segments.

f.) Undertake on-the-spot joint study with MWSS as and when failure occurs in any of the lines. Thickness survey, laboratory examination on failed pipe piece (where available) and other visual examinations will be carried out during such investigation. Mostly pitting type of corrosion is expected.

g.) Areas where the incidence of leakages and corrosion rates are more, soil resistivity and soil analysis should be conducted. For soil resistivity, 4-pin or soil box method should be used. In areas where other utilities are present, the former will not give accurate readings.

h.) Based on the date collected during survey, various corrective measures can be planned for long and short term implementation.

3.3.2. It is not possible to predict the corrective measures, without detail survey of the problem. In any metropolitan area there are various underground utility lines laid near each other. So more than one methods may have to be used, depending on location and nature of problems as given below:

a.) Change of material; nodular cast iron, well coated steel, galvanised steel, plastic pipes, etc. are candidate materials depending on size, the latter for two smaller diameter distribution pipes.

b.) Recoating.

c.) Cathodic protection. Interference from other undergropund lines, foundation reinforcement of buildings, etc is to be considered.

d.) In case of (a) and (b), practibility with respect to the closure of a section of the road for a considerable time is to be taken into account. The other important point is that many water lines must be passing under the houses and buildings and opening up these areas may be difficult for any change or replacement.

3.4 Problems in sewage treatment plants and sewerage should also be discussed with MWSS and if necessary, a survey as outlined above can be taken.

Table 1

PAINT SYSTEM FOR CHLORINATION ROOM

CONDITION: Indoor with occasional leagkage of chlorine

Paint Systems:

1. (i) Brush applied 2 coats of vinyl based paint containing mineral filler resistant to wet chlorine gas.

   dft - min^{m} 50 micron/coat

   (ii) Brush applied 2 finishing coats of vinyl to required colour finish.

   dft - min_{m} 30 micron/coat

2. Alternately use FRP pipe in lieu of steel.

No. CME/PCS/06
November 1989

CORROSION AND MATERIAL PROBLEMS

AT

CENTRAL AZUCARERA DE SAN PEDRO

1.0 INRODUCTION

1.1 The Central Azucarera de San Pedro (CASP) sugar factory at Batangas was visited on 7.11.89 along with NEC engineers Renato . b. Golecruz, Primitivo B. Consunji, Evangeline O. de Guzman, and Dulce C. Bernardo. There are two basic units in the plant, i.e., sugar production and alcohol manufacturing units.

1.2 Various materials and corrosion problems were discussed along with the corrective measures already taken. The existing problems on which solutions are still to be found out were highlighted by the plant personnel and these were discussed in detail.

2.0 OUTLINE OF PROCESS AND PROBLEMS - SUGAR UNIT

2.1 Sugar Production

2.1.1. The basic raw material for production of sugar is sugar cane. The milling season is of 6-7 months duration, starting 1st or 2nd week of December. The present crushing capacity is about 8000 T/day, which is to be increased to 10,000 T/day after commissioning of the new unit.

2.1.2. The sugar cane received from field is mechanically handled, cut and crushed to produce juice. The separated raw juice is taken for further treatment to produce sugar while the solid left over, bagasse, is used as full to generated steam. It was stated that 95% bagasse is require for generating process steam requirement.

2.1.3. There are various steps involved which broadly consists of clarification, filtration follwed by concentration in quadrepel-effect evaporator system. The sugar syrup is then chemically treated with phosphoric acid and then lime. The treated syrup is heated to produec sugar crystals in vacuum pan.

2.1.4. Sugar syrup is acidic in nature and initially contains lot of solid particles which come from soil, sand, etc. The juice pH is around 5.5. The acidity of juice is neutralised but on long holding, same acidity again develops. Thus in the whole process some chances of acidity does remain and material of construction used in many equipment has been changed from original steel to stainless steel.

2.1.5. In equipment like evaporators, pans, etc., scaling develops, requiring periodic cleaning. Normally caustic cleaning is performed.

2.2 Problem Areas

2.2.1 The raw juice has both corrosive and erosive action. The original pumps made of C.I. casing and bronze impeller had short life. The impeller required change every 3-4 months. As a corrective measure it was decided to change the pump material especially the impeller to stainless steel. This is being done as and when the SS pumps are procured. At present there are only 2 pumps of all SS construction. When not available attempts have been made to use coated CS casing. The trials are still going on.

Recommendations: Coatings may not give a sufficiently long life as the outlet end is subjected to heavy erosion/corrosion. It will be better to change the whole pump to stainless steel.

2.2.2. The CS pipes and bends of raw juice handling system are subjected to erosion/corrosion. The schedule of 10" piping has been increased to 80. Bends are affected more than the straight portion of the piping.

Recommendations: There are following approaches to solve this problem:

1. The metallurgy of bends can be upgraded to SS 321.

2. The radius of present C.S. bends cana be increased to 3D (if not already there) provided the resulting modification in piping layout can be accomodated in the present overall set up.

3. The bends can be alternately strip lined with SS 321 using 3 bead welding.

4. As regards the straight portion, present practice of periodic replacement appears to be quite adequate. Replacement with SS would however be a more permanent solution but this would cost more. This should be considered by the management before taking final decision.

2.2.2. Phosphoric acid is used along with lime for clarification of filtrate juice. Pumps and pipings for handling show sign of corrosion. The problems is more serious with piping joint leaks and deterioration of concrete floor and drains and the pump base plate.

Recommendation:

(i) The SS pipes have threaded joints. After some time due to corrosion of thread, it starts leaking, causing external corrosion of both pipes and surrounding floor. The pipes should be made of welded construction or alternately threaded joints should be seal welded. Stabilised (SS 5321) or low carbon grade (SS 3046) stainless steel should be used.

(ii) Because of acid leakage from glands, the SS pump base plate, made of C.S. gets corroded. The base plate has already been changed to SS. This is a correct step.

(iii) The leaking acid from pump and piping damage concrete flooring and drains. The present pump base concrete is in bad stape. The damaged concrete should be chipped off and the redone. After fixing the SS base plate, the concrete should be lined with ceramic tiles or base constructed of acid resistant dense silica bricks. The drain should be lined with monolithic polyster based lining, using manufacturer's recommendation for application procedure.

2.2.3. It was reported that steel tubes of multishape evaporators fail quite frequently. Failure normally occurs during and after caustic cleaning. The evaporators require cleaning bi-weekly to remove the depostis formed. Hot cleaning is practiced. It has been noted that leakage develops at junction of tube and tube sheet. No details could be obtained during the short visit but it is an interesting problem and PM group should take up failure analysis.

Recommendations:

Following lines of action are recommended:

a.) Most likely cause of failure is caustic cracking. Details of operation should be collected and the sample examined for (i) general corrosion (ii) cracking (SCC will give intergranular cracking) (iii) microscopic examination. The cracked area can also be analysed for presence of caustic on the surface.

2.2.4 Clarifier top plates show sign of corrosion and are to be replaced after about 10 years. Filtered juice is heated to about 216-222°F (102°C - 10°C) and lime added to bring up the pH to 6.8 - 7.2. After floculator, the juice is fed to clarifiers, where the solids are removed to get clarified juice.

Sugar juice is basically acidic and if the pH control is not proper it is likely to cause corrosion, specially during the period when pH is low. On the top of the plates, deposits form and underneath the deposti corrosion can occur either due to development of acidity or under deposit corrosion.

Recommendations:

(i) To carryout a thorough inspection of the plates to see the nature of attack, i.e., localised or uniform. Uniform attack would indicate more of an acid attack.

(ii) To collect the deposti and find out pH of the water extract. The pH of the deposit may not be same as that of the bulk solution.

(iii) To have a greater control ever pH. Possibilities of increasing the pH range to 7-5-8.0 should be examined from the process point of view.

(iv) It is likely that a life of 10 years for the plates made of C.S. is quite adequate.

3.0 OUTLINE OF PROCESS AND PROBLEMS - ALCOHOL UNIT

3.1 Molasses, a by-product of sugar production is fermented in closed stainless steel tanks to produce raw alcohol. The CO_2 is collected, washed, compressed and sold as CO_2 gas. The raw alcohol is distilled in copper columns to produce industrial and over quality alcohol. Except for atmospheric corrosion of structures, there are very few material and corrosion problems in the alcohol unit.

3.2 Most of the equipment in production of alcohol are made of either S.S. or copper. It was mentioned that some corrosion of copper trays has been experienced in the beer rectifying column. The problem is confined mainly in the beer middle section where 10 Bau. caustic solution is introduced. The area just below the downcomer pipes thin faster resulting in perforation.

Caustic is added to control pH and remove deposits which form on the plates. Though the problem was not studied in detail it appears to be a case of erosion/corrosion. Corrosion of copper is quite low in this environment but falling liquid disrupts the protective film and probably causes comparatively accelerated corrosion.

Recommendations:

Detail study of problem should be taken up by PM to establish the causes of corrosion.

4.0 ATMOSPHERIC CORROSION

4.1 Normal corrosivity of atmosphere in and around the plant is quite high. The plant is located at higher altitudes with lot of trees and water streams around making the R.H. quite high all the year around. Further, H_2S and CO_2 and probably other gaseous chemicals are emitted in the atmosphere and formed in lagoons of waste water from the sugar plant due to degradation of organic matters. Further there are member of open tanks containing hot liquors thus making the area inside the plant hot and humid. Consequently the structural steels are heavily affected with corrosion.

It was mentioned that galvanised roofing has only a few years life and many of the roof structural members were found in advance stage of deterioration.

Recommendations:

Same protective system will not be suitable in all areas. Before selection of protective systems, field trials on panels with some selected coating systems should be exposed and the most economical ones should be selected. It should be kept in view that repainting period should preferably be high for structures inside the plant than those outside.

As regards roofing, painted galvanised iron sheet should be used. Further, the zinc coating thickness should be higher (50-100%) than normally being produced in the Philippines. The paint system used on galvanised sheet should be resistant to the chemicals inside the plant.

No. CME/PCS/07
December 1989

CORROSION AND MATERIAL PROBLEMS IN TABANGAO REFINERY

1.0 INTRODUCTION

1.1 The Tabangao Refinery of Pilipinas Shell Petroleum Corporation in Batangas was visited on 24.11.89 along with NEC engineers Mr. Renato B. Golecruz and Miss Evangeline O. de Guzman. Initially discussions were held with Mr.Joseph Holden, who gave a broad outline of the problem and also the system for problem solvings in the area of materials and maintenance. He stated that the problems are studied in-house and where necessary sent to their head office in The Hague where a centralised service group exists to help various Shell organizations throughout the world.

1.2 It was explained by NEC team that the purpose of the present visit was more to learn about various corrosion problems being experienced and how these are being solved.

1.3 Subsequently a visit was made to the plant and detail discussions were held. The objectives of the PM group being established in NEC was explained to the plant personnel.

2.0 DETAILS OF PLANT CORROSION AND MATERIALS PROBLEMS

2.1 The Tabangao Refinery having total throughput of about 2 MT/year was commisioned in 1965 and consists of the following units:

- Crude distillation - 2 (1 of about 1.3 MT/year and 2nd of about 0.7 MT/year capacity
- Platformer - 2
- Merox - 1

- Hydrofiner - 1
  (for naphtha)

- Hydrodesulp - 1
  uriser (for diesel)

- Utilities

- Port for water pumping andloading
  and unloading facilities

- Propane/Butane

High sulphur middle east crude is being processed. The refinery has got its owen captive power plant.

2.2 Crude Distillation Unit

2.2.1. Distillation column of the 1st unit is made of carbon steel with SS 410 trays and valves. Opposite the entry nozzle, impingement plate has been provided. The original impingement plate has been replaced with SS 316, because heavy attack of CS was experienced due to suspected presence of naphthenic acid in some of the imported crude. Further, to reduce the high temperature sulphur attack the inlet temperature of the column is restricted to 360°C max^{m}.

The distillation column of 2nd unit has its bottom portion made of SS 410 clad C.S. (up to diesel draw off) to take care of sulphur attack. The top portion is made of C.S. The crude inlet temperature is 380-390°C. Internals are of SS 410. Due to corrosion over long period of time a portion beyond original cladding has been strip lined with SS 410. The last lining job was done using plate lining technique.

Comments: Most probably the 1st unit was originally designed to process low sulphur "sweet crude" (Indonesian?) but subsequently high sulphur crude was processed. In such a situation there are two approaches.

- reduce crude inlet temperatuer within a managable corrosion rate and carry out maintenance, job as and when necessary. The product pattern will change in case of low temperature.

- Strip line the bottom portion with SS 410 and use normal operating condition. This would involve considerable welding job, which is to be carried out very carefully after proper cleaning of corroded surface. Any carbon or sulphur pick-up from oil and sulphide scale would affect integrity of weld. The striplining is carried using 3 bead technique with SS 309 welding electrodes. In extreme cases underbead cracking have lead to cracking of main column, where the lining was not done properly.

2.2.2. The crude heater to column transfer line in both the units are of 5Cr - 0.5 Mo. This material is suitable for both low and high sulphur crudes.

2.2.3. It was mentioned that to take care of crudes (received from time to time) having neutralisation number of more than 0.5 (due to presence of naphthenic acid) two steps are being followed:

- Mixing of crudes having low and high naphthanic acid contents to bring down the neutralisation number of the mix below 0.5.

- Upgrading of metallurgy of trays and valves to SS 316 from the present SS 410. The upgrading is being done in stages and recently in one of the columns all the trays have been replaced with SS 316.

Comments: In the presence of naphthanic acid there is no marked difference in corrosion rates between plain C.S. and Cr-Mo alloys. SS 316 is most commonly used. However, in such a case not only the trays and valves, but main column, transfer line and also heater tubes will be affected and may have to be changed in future.

Further, SS 316 is liable to chloride SCC in column tops, where water condensation occurs. Even in high temperature areas cracking can occur during start ups and shutdowns, in case pockets of high chloride concentrations exist. Chloride can come from the crude, steam (when steaming is done before opening the column) and water (used for washing the column prior to maintenance jobs).

Careful periodic inspection is necessary whenever SS 316 is used.

Polythionic acid SCC is also possible.

2.2.4. Overhead Corrosion Control.

Overhead corrosion occurs due to decomposition of chloride salts into HCl at high temperatures. The reactions are

$$MgCl_2 \cdot H_2O \quad - \quad MgO + HCl$$
$$CaCl_2 \cdot H_2O \quad - \quad CaO + HCl$$

The HCl goes to the top of the column being gaseous and dissolves in condensing water, thus causing acid attack. Condenser tubes, accumelators, column top and pipings are affected. Injection of caustic is being praciticed. Caustic injection point is after the last heat exchanger and before the heater inlet. The caustic reacts with $MgCl_2$ and $CaCl_2$ to form NaCl, which does not decompose and thus binds the HCl. NaCl remains in the column bottom crude. The amount of caustic is adjusted to maintain the condensed water pH to 6.5. In case of decrease in pH, the final control is made by injecting ammonia at the column top outlet.

a.) The refinery had earlier experienced caustic cracking of piping, specially in the furnace header, where unreacted caustic tried to collect at dead ends. This has been taken care of by modifying the header and nearby piping design. If opportunity arises, NEC should try to study the modification because during the short visit it was not possible to go into details.

<u>Comments</u>: In injection of caustic following additional steps need condideration:

i. Injection point to be located up-stream of the present position, where the crude temperature is in the region of 120°C.

ii. Good performance of vortex mixer should be properly monitored.

iii. Attempt should be made to add sufficient caustic to reduce 80% of HCl and final neutralisation carried out by adding NH_3. This may requi'e periodic 'Petreco Steam Distillation test' to determine HCl potential of crudes being processed. The procedure is available in Petrolite Testing Procedures publication.

b.) The overhead condenser and other coolers and condensers are made of AL-brass, the cooling water used being once-through sea water. The O/H condenser tube have average life of 4 years. This is due to process side corrosion, specially due to acidic or alkaline conditions prevailing due to improper control of overhead pH to round about 6.5. High pH results in NH_3 attack and low pH acidic attack. Tubes at the inlet end of shell are affected more because of impingement action of corrosive condensed water droplets inspite of provision of impingement plate. The plant is proposing to change the tube material to Sanicro 28. This has UNS number N08028 and contains 26-28Cr, 29.5-32.5Ni, 3-4Mo, 0.6-1.4Cu and o.03C max^m. This material has very good resistance to both pitting and SCC.

Comments: The other possible material; used in sea water service successfully, is UNS N08366 (AL-6X) containing 20-22Cr-23.5-25.5., 6-7Mo and 0.035C max^m. Before deciding on the material cost difference and SCC resistance of AL-6X should be got confirmed. If retubing is to be done, effect of the new material on existing tube sheet and sea water side material should be got checked by consulting the tube manufacture.

c.) Condensate Accumulator

Condensate accumulator bottom section is subjected to corrosion by water which is separated from naphtha. Periodically this is sanblasted and painted with epoxy coating.

Comments: The other alternative is to gunnite line the bottom section with acid resistance cement. The water boot is also to be gunnite lined.

d.) Deasalter

There is no desalter and therefore no control in amount of salt coming from the crude tanks.

Comments: Provision of a desalter would not only improve O/H corrosion control but also operation of unit.

e.) Corrosion rate monitoring.

There is no provision for corrosion monitoring of overhead corrosion which makes the operation of neutralising system difficult leading to pH excursions.

Comments: Monitoring system should be introduced. The probe should be placed in water-boot. Over and above a closer check of pH should be made (at site every four hours and in laboratory once every shift). The chloride content of O/H water should also be analysed once evry shift. All the records should be maintained analysed and changes in caustic and NH_3 injection made. The recommended parameters for O/H condensed water are

pH = 6.5±0.2 in case of copper alloy tube materials

= 7.2±0.2 in case of SS tube material

Chloride = 20ppm max*

2.3 Platformer Unit

2.3.1. There are two platformer units. During the present visit corrosion problems connected with HCl attack during regeneration step only could be discussed. During regeneration of catalyst after completion of a run, chloride is injected to activate the catalyst. In the process HCl is formed at high temperature which condenses on cooling of recirculating gas causing corrosion of steel piping and equipment in the cooler sections. Earlier caustic solution was added to neutralise the acid but it is being planned to switch over to inhibitor injection.

Comments: Injection of caustic requires great care as it may cause SCC if there is localised concentration and temperatures are high. Normally soda ash or Na_2CO_3 is preferred in such cases. Na_2CO_3 leaves behind NaCl, which is to be removed because even if neutralisation is proper chloride will accelerate normal corrosion rate. Water injection upstream of cooler is helpful in this connection.

Injection of inhibitor is a good alternative and success of the new system will be worth watching.

2.4 Port and Water Intake Pier

2.4.1. Sea water is used as a cooling medium in the refinery. Sea water is pumped by four pumps from the pier in cement lined steel pipings. The standby pump is steam driven while the others are operated on electricity. Chlorine is injected directly in sea water at intake point to control organic growth.

The sea water distribution lines in the plant are also internally cement lined up to 3" dia pipes. Smaller diameter pipes are galvanised or carbon steel and replaced periodically. The experience is not bad with small dia C.S. pipes and their use is economically justified.

Comments: Cement lines CS pipes are in use for decades for sea water service. If lining is of good quality (dense and sulphate resistant cement) and pipes laid and joined properly no problem is expected.

Smaller diameter pipes used may be of copper alloys like AL-bronze, though these have also limited life but better than C.S. Other alloy is 90Cu-10Ni-1.4Ni, which is being extensively used, specially in off-shore platforms, where higher reliability and lower weight are important considerations. In on-shore Cu-Ni is justified mainly for smaller dia pipes, instrument lines and exchanger tubings. If proper cement lining facilities are not available, for larger dia pipes alternate materials, costlier but not as good, are use of epoxy lined nodular cast iron and Ni-resist in increasing order of their resistance to corrosion.

2.4.2. Jetty and the approach road piles for intake pumping stations are of steel, which are cathodically protected. The C.P. system is not working for the last one year, and is planned to be replaced. The area of piles in the splash zone and above M.S.L. are affected due to corrosion though these are periodically painted using coal tar. From the visual observations, the condition of the coating was not found to be good.

Comments: The splash zone and area above M.S.L. are affected max* by corrosion. Because this area is not continuously immersed in water, CP is not effective. In the severe corrosive condition most of the coatings fail. The following points need to be taken into consideration in such cases:

a.) Provide Monel alloy 400 sheathing. This has a long history of successful use since 1949 and is adopted for long service life. 1.5mm thick Monel sheet is rolled in two halves and then welded to circular pipes. A 1967 NACE survey showed that more than, 700 offshore platforms and riser pipes is USA were sheathed with Monel alloy 400. International Nickel Co (INCO) has developed technique for Monel sheathing of H-piles also. They have also developed a technique to fix the sheathing by "nailing" instead of welding. It is claimed that this has as good a performance as welding. In this procedure monel nails are fixed using an air-gun to give sufficient force to penetrate the sheath and the steel. Details should be obtained from International Nickel Co., New York.

b.) Where Monel sheathing is not possible or for spot maintenance repair two pack epoxy type splash zone compound has given excellent result. There is a long experience of successful use of "Cooke Splash Compound" manufactured by "Cooke Paint and Varnish Company" (PO Box 389, Kansas City, Missoiri 64141). It is a polymide cured, 100% solid epoxy and can be applied on materials made of steel, wood or conrete, both over and underwater. Similar product by other companies can be used but its properties and performance history should be verified. Enclosed sheet gives the technical data of the product.

2.4.3. The jetty and approach road for product loading and unloading are made of concrete. Estensive concrete and reinforcement damage led to a massive restoration job. The work was carried out by Concrete Repair Incorporated of U.K. about 2 years back. Performance of repair work is under observation.

Comments: It will be interesting to get details of repair procedure and also observe how it lasts. Normally repair of concrete, contaminated with chloride does not give a long trouble free life.

No. E-12

TECHNICAL DATA

INFORMATION SHEET

1. DESCRIPTION:

Cook's Splash Zone Compound is a polyamide cured, 100% solids epoxy designed especially for application to wet and submerged surfaces. Its unique properties enable it to displace water on the surface and cure under water regardless of wave action.

Although intended primarily for use on splash zone areas of offshore drilling equipment, it is recommended in several other areas such as:

a. Coating of underwater pilings and bridge abutments made of steel, wood, or concrete.

b. Patching of pipes in wet or underwater locations.

c. Patching of cracks in concrete lined ditches, sluices, etc.

d. Equipment which must be coated while wet or submerged.

2. SURFACE PREPARATION:

2.1 The area to be cleaned should extend from approximately 24 inches below the low tide water level, to the top of the splash zone. Sandblasting is the recommended method of preparing the surface. This can be successfully accomplished underwater as the initial blast of air clears a path for the sand – air mixture.

Where blast cleaning is impossible, all loose rust, slime, and barnacles must be removed by scraping. Such surface is definitely inferior to a blast cleaned surface.

Splash Zone Compound can be used over tight rust to give temporary repair service.

DO NOT use on galvanized surfaces.

2.2 WOOD

Remove all slime, barnacles, and marine growth. Splash Zone Compound protects effectively against Teredos and other types of marine worms.

2.3 CONCRETE

Remove all slime, barnacles, and marine growth by blast cleaning or other methods.

3. MIXING:

Component A, 920-L-922, is a dark blue color.

Component B, 920-Y-921, is a light yellow color.

Mix components A and B together ...... 1:1 by volume. We do not recommend mixing more than 2 gallons total in a batch.

Mixing must be thorough ...... with a bright green color resulting. DO NOT OVERMIX as this merely shortens the pot life. (See chart below.)

Any streaks of yellow or blue color denotes improper mixing. A slow air driven or heavy duty electric mixer is recommended for use.

POT LIFE is as follows:

Temperature	Pot Life
100° F.	15 minutes
90° F.	20 minutes
80° F.	25 minutes
70° F.	35 – 40 minutes

Do not mix more material than can be used in this time!!!

4. APPLICATION:

Being a very viscous compound, this product must be applied with the hands (protected with rubber gloves) ...... or with a trowel, depending on the surface.

Be sure that the rubber gloves are wet before using as this material will stick to dry rubber gloves.

5. COVERAGE:

One gallon of Splash Zone Compound mixed as recommended will cover 16 square feet at a 100 mil thickness.

Recommended application is 60 to 100 mils.

When estimating requirements, allow an extra 10 – 15% for irregular surfaces and wastage.

6. CURING PROPERTIES:

The film will be tough and elastic in 16 hours.

Complete cure requires 7 days

7. CLEANING OF EQUIPMENT:

Clean equipment at the completion of EACH operation ...... while material is still UNCURED, using Methyl Ethyl Ketone or Cook's 255-C-5 Reducer.

8. SAFETY:

DANGER!! Strong sensitizer. Avoid contact with the skin. Use rubber gloves during application.

9. PHYSICAL DATA:

Total solids by volume	100%
Viscosity	Heavy Paste

10. PRODUCT AVAILABILITY:

PRODUCT	CODE	PACKAGE SIZE
Component A, Blue	920-L-922	One gallon
Component B, Yellow	920-Y-921	One gallon

Splash Zone Compound, consisting of the above 2 components, is available in 2-gallon kits only.

11. ORDERING INSTRUCTIONS:

For each 32 square feet of surface to be coated to the recommended film thickness of 100 mils, one 2-gallon kit is required. This does not include an allowance for irregular surfaces and wastage.

No. CHE/FCS/08
December 1989

PRESERVATION OF SAN SEBASTIAN CHURCH

1.0 BACKGROUND

1.1 The National Historical Institute (NHI) is charged with the responsibility of restoring and preserving the historical-cultural legacies in the Philippines. The all-steel San Sebastian Church in Quiapo, Manila is one of the unique churches being maintained by the NHI. The church was built in 1891 and was constructed from steel brought from Belgium in parts and built at the site.

Restoration of this church has been taken up. Recently its interior walls were restored with the help of Italian expertise. NHI is however finding prevention and control of corrosion quite a problem.

1.2 NHI approached NEC for its help in extending technical expertise to prevent slow and steady deterioration of the historic-cultural property. NEC indicated that preservation of historical items is highly specialised in nature, but agreed to have a look at the problem, considering its national inportance. Accordingly the UNIDO expert on Materials and Corrosion, along with NEC engineers Mr. Renato B. Golecruz and Evangeline O. de Guzman visited the San Sebastian Church on 15.12.898.

2.0 OBSERVATIONS AND RECOMMENDATIONS

2.1 On the basis of observations made and discussions and study of photographic records, the following salient features of the problem can be were highlighted.

2.1.1. The four walls and pillars of the church are of double wall, all steel construction. The main construction features, as explained, are shown in Fig. 1 and 2. From some of the holes drilled in the plates, the side walls appeared to be about 3.5 - 4 mm thick. It was not possible to have an idea about the internal conditions, but it was stated that, from windows cut, the internal space was found to have considerable deposit of rust.

2.1.2. The important aspects, from the point of view of corrosion control measures, as understood during the visit were:

a.) <u>External Wall</u>: The church was painted externally about 3 years back. As sand blasting was not considered practical in a crowded location from the point of view of large volume of dust formed during the process, the surface preparation consisted of wire brushing only. This was followed by application of rust converter and then subsequent paint coatings. (Details of paint system was not available).

Within this short period of 3 years, paint failure has started, specially at the edges and corners. The paint was found to peel off along with earlier rust easily. The surface was also rough with patches of high points indicating that earlier rusting had been quite heavy. Though no records are available it was stated that the church has been repainted 3-4 times earlier.

It was also observed that at some locations wall plates have been replaced because of excessive thinning due to corrosion.

<u>Recommendations</u>: The church is located in densely populated area of Manila, with heavy traffic all around. The atmosphere is corrosive and a good painting system should be applied to preserve the church. The surface should be grit blasted to white or near white finish, followed by one coat of inorganic zinc primer (3 mils min" dft). The primer should be top coated with 2-coats of high build vinyl (6 mils min" dft). For grit blasting vacuum shot blasting will be used to avoid emission of dust. If properly executed such a system is expected to last for more than 15-20 years before repainting becomes necessary.

b.) <u>Interior Walls</u>: Interior walls require to be maintained in original condition and restoration work has already been completed by specialists who came from Italy. It is understood that the internal surface has been given a coating of micro-crystalline wax.

c.) <u>Windows</u>: Windows are of ornamental design and are of cast iron. Cast iron normally has higher resistant to atmospheric corrosion. These were informed to be in comparatively good condition. The joint between steel plate and window frames have shown gaps. These areas have been filled with putty to avoid leakage of rain water in the space between double wall.

Recommendations: No recommendations can be given for windows as the design aspects were not seen. Anyhow, because of tinted-glass art design, any work on this would require quite different considerations. Except local light touching no other method is recommended at present.

d.) Circular Stairways: These are reported to be comparatively in better condition, probably because these are not directly exposed to rains and external pollution. However, because of enclose condition these are exposed to relatively higher humidity conditions, specially the top sections where the air circulations is restricted. Material of construction of these were not enquired. These will be of steel or cast iron.

Recommendations: If made of steel these will be mechanically cleaned of rust (with power tool if sections are thicker). This will be followed by a system consisting of rust converter, primer and finishing coats.

A long lasting system cannot be applied because the items cannot be blast cleaned at site.

However, if these can be brought outside in sections, painted and reassembled then the recommended system will be the same as (a). The vinyl top coats can be replaced with 2 coats of chlorinated rubber (min" 4 mils dft) or other chemical resistant paints..

For cast iron the systems will be decided in consultation with manufacturer. The main requirement, good adhesion and long life of paint on cast iron. For surface preparation no power tool will be used the job will be done in-situ (preferably) because of brittle nature of cast iron.

e.) Roofing: Original roofing galvanised steel sheets, are still in good condition. This is because of thicker gauge of steel and zinc coating used. At some locations white rust has formed.

Recommendations: The roofs should be painted internally also as white rusting has started at some locations.

f.) Steel Structural: Of greater importance is the preservation of strength of main load bearing structural members, e.g., pillars, bracings, etc. Integrity of these will finally determine the life of this unique all-steel church. Unforturnately design is such that, (i) all of the angles and channel bracings are inside the double walls and (ii) vertical H channels of the pillars are covered all around with circular and rectangular plates of various design. The space between the two, it was stated gets filled with water during rains, due to leakage. Attempts have been made to seal these leakages (specially between the window frame and the wall) but the leaks have not completely stopped. Holes have also been drilled at some locations to drain out the water.

It was mentioned during discussion that at whenever it has been necessary to cut a window in the outer plate, considerable collection of rust has been found inside. This indicates that the steel is corroding internally also.

Recommendations: Once the San Sebastian Church has been declared as a historical monument, we have to consider its preservation not form tens of years but hundreds of years. The first priority is therefore to establish integrity of main structural members and arrest their further deterioration. The following steps are suggested:

(i) Open small, say 1' wide x 2' high windows at locations both horizontally and at different elevations. Lower areas are more important because water tends to collect at the bottom. By using flood lights, the condition of structural members and also internal surface of outer plates, can be visually observed. Use of mirror rotated at different angles can make a comparatively larger area available for observation. If necessary boroscope can be used for the purpose. It may be mentioned that pillars inside the church chamber may be in good condition compared to those of four outer walls because these are not exposed to external source of rain water (unless there is any leakage from the roof).

(ii) Approachable sections of the structural members can then be thickness gauged using calipers or any other suitable devices. The data collected should be reviewed, analysed and compared with original thickness. This should be followed by analysis of structural integrity, (a) as of present, and (b) max™ additional thickness available for further reduction in wall thickness in future, i.e., to find out min™ thickness required for the structure to be safe.

(iii) Corrosion is due to moist and high R.M. conditions prevailing inside due to presence of water. Rust formed under such conditión is normally not adherent and has a tendency to flake off. The flaked off rust falls down and collects at the bottom. The area packed with rust retains water collected for a long period and thus the wet rust further accelerates corrosion.

(iv) For long term preservation of internal surface:

1. It will be necessary to remove the collected rust. This can be done mechanically by opening windows at the bottom. Once the step (i) above is completed, it will be possible to get an idea about the extent of rust collected and the amount of work involved.

2. All points from which water is likely to leak should be identified and sealed. Possibility of using pressure test to find out points of leak can be examined. The details of original design was not studied and we are not aware if; (A) Walls are totally sealed or openings have been provided to take care of thermal expansion of air in the enclosed space and steel members, (B) The double walls and columns of outer walls are connected or isolated from inside.

The pressure test is therefore only a suggestion for examination. All visible leaks including drilled holes will be closed (air tight) and the double walled interior will be pressurised to say 0.5 to 1 psi. Points of leaks can then be checked using soap bubble or halogen test. In case of larger openings or gaps escaping air can be detected by feel or sound.Though considerable efforts and time will be needed, once it is found practicable, the results will be of considerable importance in controlling future corrosion.

3. Once leakage points are closed, use of VPI (vapor phase inhibitor) will have to be made to reduce further corrosion. VPI in liquid form can be sprayed inside the space. Periodic spraying say once or twice in a year, if the space is not completely closed, may be required. This aspect will be known only after a complete study is made.

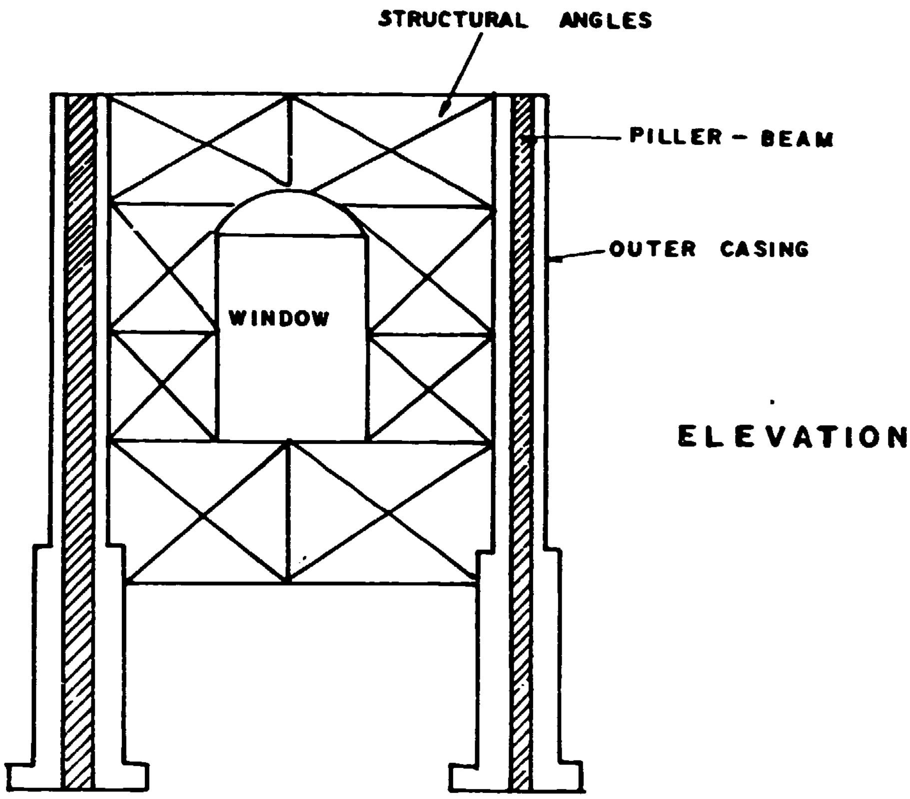
3.0 RECOMMENDATIONS

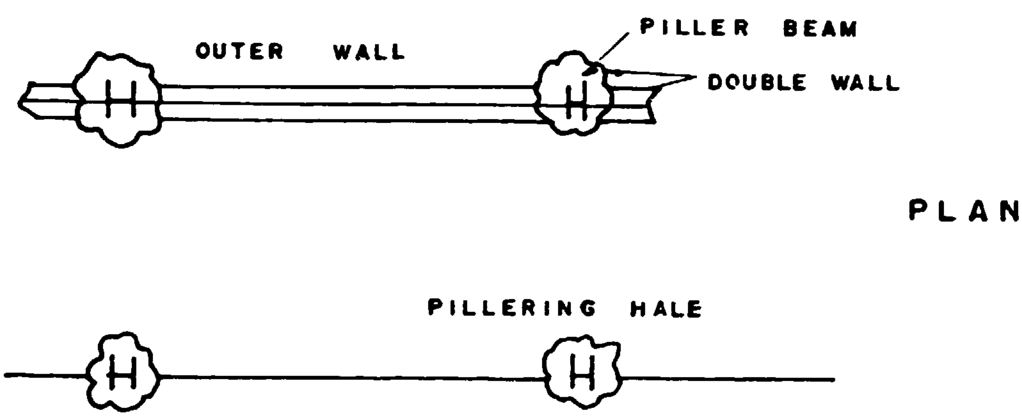
3.1 Carry out detail ultrasonic thickness survey at different levels to find out the remaining thickness of outer steel plates and compare with the original thickness.

3.2 Open windows and examine the condition of internal structural members.

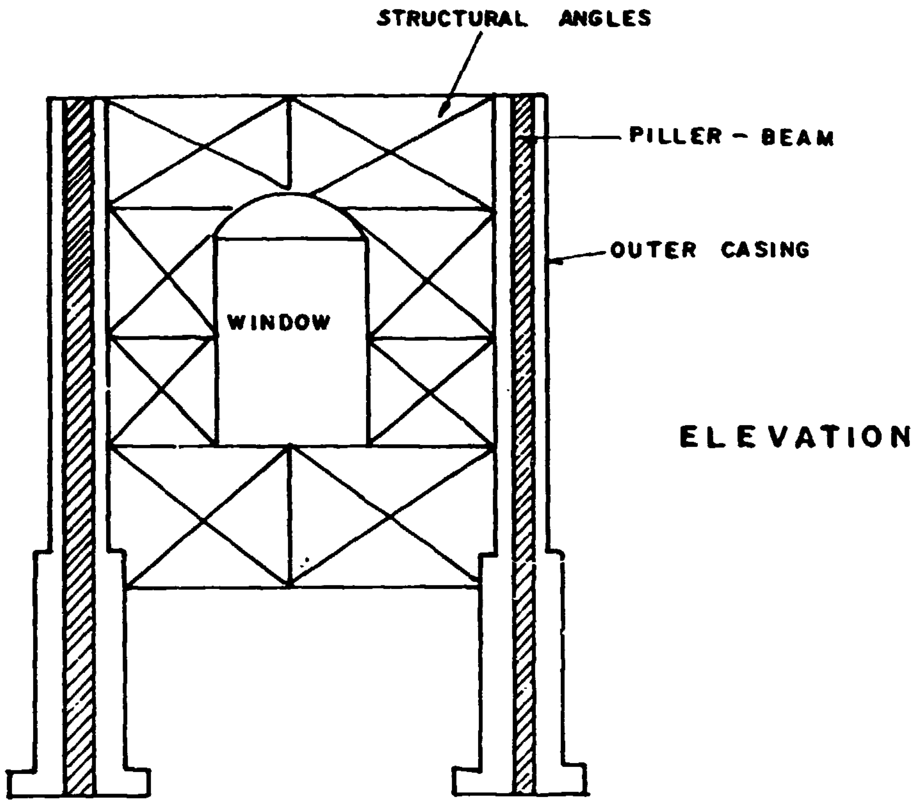
3.3 If study indicates corrosion control necessary remove collected rust, locate and seal leakages and use VPI for protection.

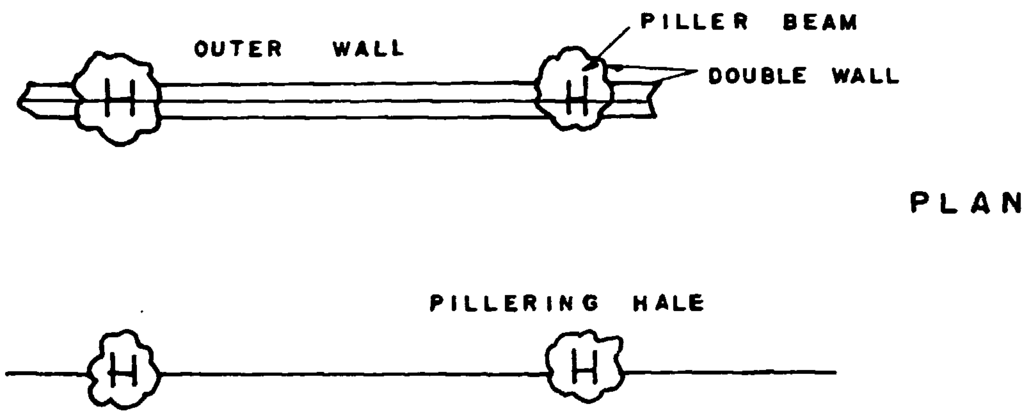
3.4 Apply good paint system outside and also inside as outlined earlier.





SCHEMATIC ARRANGEMENT OF DOUBLEWALL
PILLER AND OUTER WALL
(NOT TO SCALE)





SCHEMATIC ARRANGEMENT OF DOUBLEWALL PILLER AND OUTER WALL

(NOT TO SCALE)

ANNEXURE - 3

LIST OF MANUALS AND GUIDELINES

1. Manual on Precommissioning Chemical Cleaning of Industrial Boilers, Suction Piping of Compressors and Lube Oil Piping System of Tubro-Generators.

2. Guidelines on Survey and Study of Plant Corrosion and Failures Problem.

3. Guidelines on Industrial Painting.

4. Guidelines in Prevention of Corrosion and Deterioration of Reinfored Concrete.

5. Consideration in Selection of Materials for Chemical Process and Power Industries.

6. Outlines on Identification of Material Damage by Field Metallography.

ANNEXURE 4

MANUALS AND GUIDELINES

- Identification of Material Damage by Field Microscopy
- Guidelines on Industrial Painting

No. CME/0/01
October, 1989

OUTLINES ON
IDENTIFICATION OF MATERIAL DAMAGE
BY FIELD METALLOGRAPHY

1.0 INTRODUCTION

1.1 Metallography is one of the most important tool to identify the type and extent of material damage both due to corrosion and metallurgical changes occuring during high temperature service.

1.2 Normal method is to carry out this test in laboratory which involves cutting a sample under commonly known "destructive test" and therefore can be carried out only on a damaged equipment which need partial or full replacement or where it is possible to replace the part after cutting.

1.3 For cases where taking out of sample is not possible, methods have been developed by which on-site metallographic examinations can be carried out in the field.

2.0 AVAILABLE FIELD METALLOGRAPHY METHODS

2.1 Field Microscope

2.1.1 The first approach had been to develop portable microscope of low weights which can be easily carried to the field along with portable polishing and etching kits.

2.1.2 The microscope is mounted on a tripod for positioning on the desired area. To increase the stability of the system in some cases the legs are provided with sufficiently strong magnetic device. These are suitable for ferrouos materials.

2.1.3 The field microscope has many disadvantages, chief amongst which are:

(i) it cannot be placed properly on any surface other than in horizontal downward facing position.

(ii) the microstructure in many cases is not sharp because of lack of level when the microscope is placed on a corroded uneven surface.

(iii) microphotographs taken generally out of focus or lack clar

2.1.4 Due to the above disadvantages, microscope did not find much favour wi corrosion and inspection engineers.

2.2 Replica Microscopy

2.2.1 The advent of electron-microscopy saw rapid growth in replica technology, where the structured details of the surface is transferred on a thin film which is then viewed under electron-microscope. The plastic tape films used in elctron microscopy was further modified and made suitable for field replica.

2.2.2 In replica microscopy, instead of viewing the structure in-situ, the structure is transferred on a tape, specially made for the purpose. The tape is then taken to the laboratory and then obse.ve under the microscope for details. Shadowing similar to electron microscopy can also be done to get good contrast.

3.0 METHODOLOGY

3.1 Surface Preparation

3.1.1 The area to be examined is first ground with abrasive wheels driven by either electrical or pneumatic machines. Pneumatic machines are required where the safety requirements do not allow the use of electric driven machines. Small size (.75 - 50 m m dia) of different grits are used to have a reasonably finished surface.

3.1.2 After grinding the area is polished with rotating wheels having different grades of emery papers to a finish to "000" grade.

3.1.3 Where necessary this can be followed by final polishing with Al_2 O_3 polishing powder using felt wheels or electro polishing.

3.2 Etching

3.2.1 Etching is the most critical part of the whole process. Eteching is preferably done electrolytically for which a portable kit and normal etchants used for metallographic study of various metals and alloys are used.

3.2.2 It has been found from practical experience that to get good structural details and clarity the area may have to be alternately etched and polished two or three times. For different cases the techniques is to be finalized by a few trials.

3.3 Microscopic Examination

3.3.1 Field Microscope

a) In case of field microscope the method followed is similar to labortaroy examination. The microscope is placed over the surface and then viewed under the microscope at various magnific- ations. It is a good practice to start with a magnification of 25 to 50 and then raise it further.

b) At lower magnifications the overall structure, cracks, etc. are noted and then specific details examined at higher magnifications. Field constraints limit its use to very low magnifications. Normally, a magnifications up to 250 can be tried.

3.3.2 Replica Microscope

a) After polishing, a small length of tape is taken, one side of which is softened with a suitable solvent, placed lightly on the surface and then pressed (starting from one side) as per the instructions of the tape suppliers.

b) The tape is then slowly lifted, preserved properly and then carried in the laboratory for examination under the microscope.

4.0 DISADVANTAGES OF FIELD MICROSCOPY

4.1 Field microscopy gives structural details of surface only. No indications of variations with depth can be ascertained by this method.

4.2 In case of cracking, while the mode of cracking can be established, its other details, e.g. depth and morphology cannot be determined.

4.3 Inspite of these limitations field microscopy is an important tool to identify the nature of material damage, especially when used with other inspection data e.g. hardness, ultrasonic, radiography, known behavior of the material under the exposed condition and over and above the experience of the concerned engineers.

5.0 SOME CASE STUDIES

5.1 Cracking of Ammonia Horton Sphere

5.1.1 One ammonia Horton sphere made of Japanese steel of Min 60 kg/mm2 strength was inspected after 16 years of operation. The ammonia was stored at about 4kg./cm2 and zero degrees Celsius.

5.1.2 Inspection carried out using wet fluorescent magnetic particle inspection (WFMPI) on and 6 inches on both sides of the welds showed extensive cracking.

5.1.3 When originally designed and fabricated in 1967-68 it was not recognized that this material is susceptible to stress corrosion cracking (SCC) in ammonia. Subsequent experience worldwide showed the strong SCC susceptibility of this material.

5.1.4 In the present case it was decided to establish whether the cracking is due to SCC or any other reason. Replica technique was used for the study. Due to the working constraints inside the sphere it was not possible to get structural details of very good quality. However, the observations clearly indicated the presence of transgranular cracks, from which it was concluded that crackingis due to SCC.

5.1.5 The cracks were repaired, hydrotested and reinspected using WFMPI. Additional cracks were detected. Considering the toxity of NH3 and related safety hazards the sphere was decommissioned.

5.2. Residual life of Fluid Catalytic Cracker (FCC) Reactor

5.2.1. All high temperature, high pressure equipment are designed for a service life of 100,000 hrs. However, in normal practice these are used for much longer period. In the present case the carbon steel FCC reactor had been in operation for about 32 years. The decision to run the reactor for such a long period was taken because the operating temperature for most of the period was between 480 degrees Celcius-490 degrees Celcius, against the design temperature of 524 degrees Celcius. Further a large part of original corrosion allowance still remained, making the operating hoop stress also lower than the design.

5.2.2 However to ascertain whether any deterioration in material properties has taken place, it was decided to carry-out detailed examination. While the main studies were carried out on a sample plate cut from the reactor, in-situ metallography was also carried out for the non-destructive examination. Replica technique was used to examine the parent metal and heat affected zone (HAZ).

5.2.3 Using alternate etching and polishing three times it was possible to get very good structural details. Microstructure showed absence of graphitisation and partial spherodisation of the pearlite No grain boundary voids, which are observed in case of considerable degree of creep was not detected. From in-situ metallography no significant structural deterioration was observed indicating that the material is still under good condition.

5.2.4 The above conclusions were confirmed from destructive tests, e.g. hot tensile R.T. mechanical properties and accelerated creep rupture tests.

5.3 <u>Cracking of LPG Storage Sphere</u>

5.3.1 LPG Storage sphere made of carbon steel material showed number of transverse and longitudinal weld cracks after 12 years operation. The inspection tool used was WFMPI and cracks were found on second circumperential welds, HAZ and cleat and arc strike marks.

5.3.2 Replica technique used to identify the nature of cracking confirmed the crack to be due to H_2S . The scale collected from the metal surface showed presence of about 12% sulphur. The structure in the cracked area was martensitic or upper bainitic. H_2S entered the system due to maloperation of Merox Unit.

5.3.3 As other welds were free of cracking it was decided to change the bottom portion which was successfully done. The sphere was stress relieved at 610 degrees Celsius plus or minus 10 degrees Celsius using gas burners. WFMP1 after stress relieving showed absence of any crack and the sphere suitable for use.

CME/0/05
December 1989

GUIDELINES ON INDUSTRIAL PAINTING

1.0 GENERAL

1.1 The outline describes the painting system, method of application and other details for protection of industrial steel structures, pipings, equipment, machinery, etc., against atmospheric corrosion. The protection of immersed structures and structures subjected to tidal and splash action in marine environment are not included in this outline.

1.2 A total paint system includes: surface preparation; pretreatment (if needed); application techniques, coating system and inspection. Various standards and code of practices are available and these should be consulted for detail procedures and requirments. Some of the important ones are:

- Steel Structures Painting Council, USA
- British Standards (BS 5493), U.K.
- National Association of Corrosion Engineers, USA

2.0 PAINT APPLICATION

2.1 Surface Preparation

2.1.1. Depending on particular requirement surface preparation prior to painting will be by:

- hand tool or power tool cleaning
- blast cleaning

SSPC surface preparation specifications is given in Table 1.

2.1.2. For total repainting job or new jobs only blast cleaning will be used. For localised maintenance repair of failed paint coating or items which have been supplied with shop primer coating, whose condition in general is good, mechanical cleaning can be used. Mechanical cleaning can also be used in areas where the blast cleaning is not permitted. Life of coating on mechanical cleaned surface is lower than that on blast cleaned surface and therefore where heavy duty or long life paints are used blast cleaning is preferred.

2.1.3. Mechanical cleaning

For mechanical cleaning striking tools, chipping hammers or rotating steel wire brush will be used. Excessive burnishing of surface shall be avoided as it can reduce paint adhesion. On completion of cleaning, the, loose material shall be removed from the surface by clean rags and blown off with compressed air. If absolutely necessary, water or steam washing will be done but the surface will be immediately dried with compressed air before any superficial rusting develops.

2.1.4. Blast cleaning

The surface shall be blast cleaned at 7 kg/cm^2 pressure using sand or chilled iron abrassives. Use of sand for blast cleaning should be followed only in case where the total dft (dry film thickness) is below 200 micron (8 mils) or where grit blasting is not economically feasible. For heavier coatings grit blasting should be specified to get the best life out of paints.

A uniform anchor pattern without peak and valleys is vitally important to adhesion of paint. Thus a clean well graded and sized abrasive should be used.

On completion of blast cleaning, all loose material from the surface will be removed by wiping and use of compressed air. Vacuum cleaning can also be used. Use of water to clean the surface after blasting will be avoided.

2.1.5. Temperature and humidity

Surface cleaning will not be done during rains, mist and where temperature and relative humidity are such as to cause dew to form on the surface. For practical puposes the limit can be taken as 80% RH.

Further, the surface once cleaned will be applied with the 1st coat as soon as possible. Thus the area to be cleaned at any time shall be preplanned in conjunction with painting schedule. As a rule of thumb surface preparation time can be taken as 3-4 times that of painting.

2.1.6. Shop coated surface

In case of shop coated surfaces, surface preparation shall consist of rubbing down thoroughly with emery paper to remove all foreign matters, washing with degreasing solvent (white spirit) to completely remove grease, etc., followed by cleaning with warm fresh water and then air dried. In case degreasing with white spirit is not fully effective, the surface should be finally wiped clean with an aromatic solvent like xylol or light naphtha. If alkaline detergents are used in the cleaning process, it should be followed by clear steam rinse. The distilled water should be applied on surface and suitable pH paper brought into contact with the distilled water. If this paper indicates that surface is alkaline, the steam rinsing should be repeated till the surface is free of alkalinity. Where the shop coat has peeled off or damaged, the affected area will in addition be cleaned and coated with the original paint.

2.1.7. Equipment, e.g., pumps, valves, etc., supplied with primer and finishing coat will not be repainted unless the paint is damaged. The procedure in this case will be same as given under 2.1.6.

3.0 PROTECTIVE SCHEMES

3.1 Selection of protective scheme is the 1st step in corrosion control of any structures, pipings, etc., and due attention is to be given to this aspect at the beginning of any project. In selection of appropriate scheme the important points are: nature of environment, severity of exposure conditions, nature of the structure and its critically, expected life and maintenance schedule or repainting interval. In general the following three criteria based on time to first maintenance should be used:

Grade A scheme: This will consist of an initial protective scheme to last for a period of 10 years or more before first maintenance becomes necessary.

Grade B scheme: This consists of the initial coating to last for a minimum period of 5 years, before repainting becomes due.

Grade C scheme: This consists of an initial protective scheme applied to last for less than 5 years but not less than 3 years.

For industrial painting the present practice is to prefer Grade A and B schemes because of cost of repainting and difficulties in carrying out a good job in an operating plant. Grade A scheme can be used under some conditions where either the conditions are very severe or frequent repainting is difficult, e.g., inside a plant.

3.2 It is rather difficult to predict the performance of a protective scheme and accumulated experience plays an important part in the selection. Periodic inspection, field trials, etc., from the basis of accumulating the experience. Systematically recorded data are not always available and at this stage standardisation of the system can be based primarily on life expectancy under more or less similar conditions. While this outline will form for NEC the basis of selection at this stage, the same should be modified and made more specific in future as field experience is collected and reviewed.

3.3 Industrial paint systems are exposed to varied environments in a plant and have to perform under specific conditions. The paint system should therefore be resistant to industrial atmosphere, marine and industrial atmosphere, various acidic and alkaline chemical fumes and spillages, solvents, humid and continuously wet conditions, etc. depending on the location and type of industry.

A plant system consists of primer, intermediate and finishing coats and among the best and most widely used are vinyl, vinylesters, phenolic epoxies, chlorinated rubber, epoxies, coaltars, silicone and inorganic and organic zincs. In addition there are special paints based on neoprene, saran, etc. for specific end use (especially corrosive chemicals).

3.3.1 Before selecting a coating the first step is to survey the environmental conditions for humidity, temperature, sunlight, chemical constituents, presence of dust or solids in air, spillage conditions, etc. Various generic paints have different resistance as given in Table 2 and 3. The most important criteria to be considered in a particular case will decide the candidate formulations.

3.3.2. For large jobs, the economics of systems should be compared before selection of schemes to get, the predetermined min^{m} life of various grades given under 3.1. Basically vinyl, chlorinated rubber and epoxy based paints and organic and inorganic zinc primers should be considered for painting in various industries, specially those in the vicinity or inside the working areas. For those outside the working area and quite away for the atmosphere to be heavily polluted, other systems based on coal tar, alkyd and phenolics should be considered.

3.3.3. BS 5493 of UK and SSPC of USA have recommended various systems to be used under different environmental conditions. Of these, BS 5493 is considered as a monumental guide. In Section Two of this code of practice series of tables provide information for typical periods to first maintenance for a wide range of protective systems. Systems are tabulated for ten main environments and notes are provided for a further nine. Table 4 BS indicates how these tables are compiled. For comparison some typical recommendations of SSPC is given in Table 6 CE.

3.3.4. In practice one will come across many cases where paint systems tried earlier have not performed well. In such cases details of the systems, application, inspection, etc. should be studied. If one or more system is thought to be necessary, it is better to 1st conduct field trials with candidate systems by exposing painted panels or painting parts of structure and evaluating their performance for about a year before finalisation.

3.3.5. Table 6 gives the repainting guidelines.

4.0 INSPECTION AND SUPERVISION

4.1 It is said that any paint system is as good as it is "applied". Unless proper steps are taken and recommended procedures followed. even best of paint will fail miserably. Proper supervision and inspection are therefore necessary. Improper surface preparation, mixing or stirring of paint, addition of more thinner to increase speed of application, application of below min^{m} paint thickness, less than recommended time gap in between different coatings, adverse weather conditions during application, etc. affect the performance of paint.

4.2. Inspection

4.2.1. For surface preparation, there are three important factors to be considered:

a.) Cleanliness: Swedish Standards Institution in Stockholm originally developed cleanliness standards which is now more or less universally accepted. These are available as photographic standards from SSPC. NACEsells plastic encapsulated blast cleaned metal coupons cleaned to white, near-white, commercial and brush-off degree of cleanliness.

b.) Surface profile: Surface profile is also important from the point of view of achoring of paint. Three methods are available:

(i) Depth micrometers which uses a penetrating needle dial micrometer with a flat base. The micrometer is placed at different locations where it rests on the peaks. The depth penetration below the plane of the base is recorded on the dial face of the instrument. The study of all readings give the range of depth.

(ii) Surface-profile comparator consists of blast cleaned surface discs or coupons with a known profile depth. Three discs of sand, shot and grit abrasives are available. The KeaneTator (KTA-Tator Association Inc., Coraopolis, Penn., USA) surface profile comporators disc has been accurately measured by SSPC and who can be contacted for advice. The other is the Clemtex Anchor Pattern Standards (CAPS) marketted by Clemtex Ltd., Houston, Texas. The comparator is placed on the blasted surface and a visual comparison is made.

(iii) Replica tape method determines the anchor pattern profile by compressing a foam like tape into the blast cleaned surface. The replica of the anchor pattern is used to measure the profile height using a spring micrometer.

The method (ii) is more popular as it can be easily used.

c.) Freedom from oil/grease: In case where it is necessary to remove oil and grease freedom from their presence shall be determined by letting water flow overs the surface. The water should completely wet the steel without beading, crawling or breaking.

If alkali detergents are used for degreasing, freedom from left over alkalinity should be checked using a pH or litums paper after applying distilled water to the surface.

4.2.2. For paint system, the thickness of each coat and total film thickness are very important. Finally it is dry film thickness which determines the life of the paint but it is to be ascertained that each coat of primer, intermediate and finishing coats are of specified thickness. Two methods being followed during paint inspection are:

a.) Wet-film thickness measurements: Standard gages are available which are used after completion of each coat. The desired dry film thickness is obtained by multiplying wet-film thickness with % solids by volume in the paint.

b.) Dry-film thickness measurements: Dry film thickness is measured after the drying of the paint. For steel surfaces the instruments are of magnetic type and the most popular ones are "Elcometers". For non-ferrous substrate instruments based on eddy-current principle are available.

4.3 Supervision

4.3.1. Supervision during painting is the most important part of assuring that correct procedure has been followed during painting. The responsibility of supervision may either be with the inspection or maintenance personnel depending on the organisational responsibility in the respective organisations.

4.3.2. Surface preparation:

- All weld spatter, slivers, sharp or rough edges are removed and/or ground smooth

- In case of brush or other mechanical cleaning, all loose rust, oil, grease and, dirt and damaged paint are properly removed to make the surface suitable to receive the paint.

- For blast cleaning proper air pressure and size of abrasives is being used as per the recommendation. The operation of oil/water separator in the air line will be ensured.

- Once the blast cleaned surface is approved for painting, it must be ensured that it is coated before any rust visible under a 5x magnification forms on the surface. As a guide the following may be considered for the total elapsed time from start of blast cleaning to application of coatings.

Max^m time elapsed (hrs.)	Relative Humidity Range (%)
4	73.1 - 80
8	67.1 - 73
12	60.1 - 70
18	55.1 - 60
20	50.1 - 55
24	42.1 - 50

Thus the blast cleaning and painting should be planned depending on the climatic condition.

b.) Paint Application

- To ensure that specified paints are being used by the contractor.
- To ensure that clean brushes or spray guns or rollers are being used.
- To ensure the paints are properly stirred and/or mixed in proper proportion for more than one pack systems.

- Manufacturer's recommended time in between the coats are followed.

- Proper safety precautions are taken against solvent fumes, e.g., use of mask, maintaining ventilation in close space.

TABLE I
TYPICAL SURFACE PREPARATION SPECIFICATIONS

CLEANING METHOD	Quality** BS 4232	SSPC*** Spec	Photo References SIS 05 59 00 * INITIAL CONDITIONS A Intact Millscale	B Rusting Millscale	C Rusted	D Rusted & Pitted
Solvent cleaning		SP 1				
Hand tool cleaning		SP 2		B St 2	C St 2	D St 2
Power tool cleaning		SP 3		B St 3	C St 3	D St 3
Blast cleaning						
Brush-off		SP 7		B Sa 1	C Sa 1	D Sa 1
Commercial	3rd	SP 6		B Sa 2	C Sa 2	D Sa 2
Near-white	2nd	SP 10	A Sa 2 1/2	B Sa 2 1/2	C Sa 2 1/2	D Sa 2 1/2
White metal	1st	SP 5	A Sa 3	B Sa 3	C Sa 3	D Sa 3
Pickling		SP 8				

* Same as SSPC - Vis 1 "Pictorial Surface Preparation Standards for Painting Steel Surfaces"

** Approximate equivalent in British Standard 4232 "Surface Finish of Blast-Cleaned Steel for Painting"

*** Surface Preparation Specifications of the Steel Structures Painting Council

TABLE 1
COMPARATIVE RESISTANCE VALUE OF TYPICAL COMMERCIAL COATING FORMULATIONS

Condition	Generic type										
	Neo-prene	Vinyl	Saran	Epoxy	Chlori-nated rubber	Styrene copolymer blends	Furan	Phenolic	Alkyd	Asphalt	Oil based
Sunlight and water	8	10	7	9	7	6	8	9	10	7	10
Stress and impact	10	8	7	3	7	6	1	2	4	5	4
Abrasion	10	7	7	6	7	7	5	5	6	3	4
Heat	10	7	7	9	5	6	9	10	8	4	7
Water	10	10	10	10	10	10	10	10	8	10	7
Salts	10	10	10	10	10	10	10	10	8	10	6
Solvents	4	5	5	8	3	4	10	10	4	2	2
Alkalies	10	10	8	9	10	10	10	2	6	7	1
Acids	10	10	10	10	10	10	10	10	6	10	1
Oxidation	6	10	10	6	9	8	2	7	3	2	1
Total	88	87	81	80	78	77	75	75	63	60	43

TABLE 3
OUTLINE OF SSPC PAINT SYSTEMS

No.	SSPC SYSTEMS	GENERIC	USES
1	PS 1.00-1.05	Oil base	For weather-exposed wire-brushed steel
2	PS 2.00-1.05	Alkyd	For weather exposure
3	PS 3.00	Phenolic	For high humidity, condensation or fresh water immersion
4	PS 4.00-4.05	Vinyl	For immersion, industrial or chemical exposure
6	PS 6.00-6.03	For vessels	Bottoms, bootopping, topside, superstructures
7	PS 7.00-7.01	Shop paints	For non-corrosive interior or short-term exterior
8	PS 8.01	Rust Prev. compounds	For temporary protection or sheltered locations
9	PS 9.01	Asphalt	For weather and corrosive atmospheres
10	PS 10.00-10.01	Coal tar	For underwater, underground or corrosive environments
11	PS 11.01	Coal tar epoxy	For fresh or salt water, chemicals, underground
12	PS 12.00-12.01	Zinc-rich	For marine, abrasion, immersion, chemicals
13	PS 13.00-13.01	Epoxy	For water immersion, chemical, industrial, or marine use
14	PS 14.01	Alkyd or asphalt	For steel joints, for interior use
15	PS 15.01	Chlorinated rubber	For chemical, marine, moisture
16	PS 16.01	Silicone-alkyd	For gloss and color retention, chalk resistance
17	PS 17.01	Water-base	For air pollution control areas; weather-exposed
18	PS 18.00	Urethane	For weathering, chemical resistance, low temperature curing, high-build

TABLE 4

Exterior exposed non-polluted coastal atmosphere

Typical time to first maintenance (years)	General description	System reference (table 4)	Total nominal thickness (μm)	Notes (see the end of this table)
Very long (20 or more)	Galvanize	SB2	140	a, b, c, d
	Unsealed sprayed aluminium	SC2A	150	a, f
	Unsealed sprayed zinc	SC3Z	250	a, c, d, f
	Sealed sprayed aluminium	SC6A	150	d, e, f
	Sealed sprayed zinc	SC6Z	150	d, e, f
Long (10 to 20)	Galvanize	SB1	(85 min.)	a, b, c, d
	Galvanize plus paint	SB9	(85 min. +60 min)	h, i
	Unsealed sprayed zinc	SC2Z	150	a, c, d, f
	Sealed sprayed aluminium	SC5A	100	d, e, f
	Sealed sprayed zinc	SC5Z	100	d, e, f
	Sprayed aluminium plus paint	SC9A	100 +(30to100)	e, i
	Sprayed zinc plus paint	SC9Z	100 +(30to100)	e, i
	Organic zinc-rich	SD3	100	g
	Inorganic zinc-rich	SE2	100	g
	Drying oil-type	SF8	190 to 230	
	Silicone alkyd over two-pack chemical resistant	SG1	245	
	One-pack chemical-resistant	SH6	270	
	One-pack chemical-resistant over two-pack chemical resistant	SL3	295	

Typical time to first maintenance (years)	General description	System reference (table 4)	Total nominal thickness (pm)	Notes (see the end of this table)
Medium (5 to 10)	Unsealed sprayed zinc	SC1Z	100	a, c, d, f
	Organic zinc-rich	SD2	75	g
	Inorganic zinc-rich	SE1	75	[illegible]
	Drying-oil type	SF7	165 to 190	
	One-pack chemical-resistant	SH3	150	
Short (less than 5)	Organic zinc-rich	SD1	50	g
	Drying-oil type	SF2	120 to 150	j
	Drying-oil type	SF5	85 to 105	
	One-pack chemical resistaot	SH1	160	j

NOTE: Treatments listed for the longer lives will always protect for shorter-period requirements and are frequently economical also for these shorter lives.

TABLE 5

SOME TYPICAL RECOMMENDATIONS FOR COATING STRUCTURAL STEEL

Zone #	Environment	Preferred system	Alternates
1A	Interior, normally dry (or temporary protection) Unusual in hwy. work, very mild (oil base paints would last 10 yrs or more)	One coat of fast-drying shop paint (example: SSPC Paint 13) over nominally hand-cleaned steel. Finish coat optional (see SSPC-PS 7.01)	(1) Other one-coat primers (example: TT-P-636) (2) Rust proofing (SSPC-PS 8.01) or (3) More durable systems as per Zone 1B, or (4) Approved proprietary paint
1B	Exterior, normally dry (includes most highway areas where oil base paints now last 6 yrs or more)	Apply 2 coats of oil base (example: SSPC-Paint 14) over wire-brushed steel. 1-2 finish coats of long oil alkyd (SSPC-Paint 101 aluminum or SSPC-Paint 104 white, gray or green) 4.0 mils or more thickness (5.0 mils for 4 coats) (See SSPC-PS 1.01, 1.02 or 1.03)	(1) Blast clean (SSPC-SP 6) and use same paints or shorter oil alkyds. (2) Alternate primers (SSPC-Paint 2; TT-P-57, Type I; AASHO M72-57, Type I or II; or TT-P-615, Type V) or (3) Alternate intermediate TT-P-86, Type II or non-leafing aluminum, or (4) Equivalent state system, or (5) Same systems as Zone 2A or 2B, or (6) Proven proprietary system.
2A	Frequently wet by fresh water involves condensation, splash, spray, or frequent immersion. (Oil base paints now last 5 yrs or less)	Near white blast clean surface; 4 coats (4.5 mils) of vinyl (example: SSPC-Paints 8 or 9) (See SSPC-PS 4.04 or 4.02)	(1) Pickle (SSPC-SP 8) instead of blast cleaning. (2) Alternate vinyls are VR 3 or approved propietaries

TABLE 5 (Continuation ......)

Zone #	Environment	Preferred system	Alternates
2B	Frequently wet by salt water involves condensation, splash, spray, or frequent immersion. (Oil base now last) 3 yrs or less)	Near white blast clean surface; apply zinc-rich primer (example: SSPC-PS 12.00 or MYL-P-23236 or California Highway Spec. 66-G-55) followed by approved wash primer and finish coat. (Example: SSPC-PT 3 plus SSPC-Vinyl Paint 8 or 9, 3+ mils.) Assure satisfactory adhesion of finish coats.	(1) Use finish coats with same vehicle as zinc-rich primer (inorganic, epoxy, chlorinated rubber, vinyl, etc). (2) Use vinyl paint system with wash coat and inhibitive primer (example: SSPC-PS 4.01 OR 4.03) (3) Use as alternate finish coats or by themselves, coal tar epoxy (SSPC-PS 11.01), epoxy (guide SSPC-PS 13.00), or approved chlorinated rubber system, or other proven proprietary sytem.
3	Chemical exposures (Acidic, alkaline, oxidizing, solvents, etc)	Same as for Zone 2B, but with chemically resistant finish coat system specially chosen to protect primer and base metal against specific chemical agent. (Zinc-rich unsatisfactory for very acid or very alkaline conditions) Assure satisfactory adhesion of finish coats.	Same choices as for Zone 2B but with special finish coats. (1) Coal tar epoxy (SSPC-PS 11.01) (at least 16 mils). (2) Straight vinyls for acid and alkali (SSPC-PS 4.01 or 4.03) (3) Epoxies for alkalies, salts, aliphatics, acid splash, not for strong solvents.

TABLE 5 (Continuation ......)

Zone #	Environment	Preferred system	Alternates
			(4) Neoprenes and other proven proprietary systems to resist specific conditions.
4	SPECIAL CONDITIONS		
	Painting galvanized steel	Solvent clean to remove oil and grease. Wire brush to remove any rust. Apply zinc dust-zinc oxide paint TT-P-641 (Type II for new steel, Type I for old, as per SSPC-PS 2.05 and 1.04). Somewhat better adhesion if surface is weathered before painting.	(1) Chemical pre-treatment of new work by commercial hot phosphate or wash primer. (2) Zinc-rich prime (example: Guide SSPC-PS 12.00). (3) Prime with SSPC-Paint 5.
	Mildew	After surface preparation wash mildewed surface with trisodium phosphate and dry. Add mildewcide to each coat of paint (example: B-quinolinoleate). Vinyl, chlorinated rubber resins, and baxton metaborate and zinc-rich pigmentations tend to resist mildew.	Alternate mildewcides and fungicides include copper naphthenate, chlorinated phenols, phenyl mercuric dodecylsuelnate, proprietary agents. Add in amount recommended by the manufacturer.
	Temporary protection and rust-proofing	See system on Zone 1\. Also see SSPC, PS 8.01 "Rust Preventive Compounds" (thick non-hardening films over minimum surface surface preparation	Soft, heavy or hard film compounds as per 52-MA-602 Type B, C, or D, or use proprietary rust-proofing compounds.

TABLE 5 (Continuation ......)

Zone *	Environment	Preferred system	Alternates
	Painting welds	Before welding, do not paint within some 1" of edges. Blast clean after welding, See SSPC-PA 1 Sections 3.5.2.4	Chip and wire brush weld thoroughly. Wash with 5% phosphoric acid and rinse. See SSPC-SP-1, Section 3.1.6

* These are intended as specific exposure zones of the portion of the structure under consideration rather than geograpic zones. Severity of exposure can change sharply over very short distances due to such factors as wind, spray, condensation, and use of de-icing chemicals.

TABLE 6

REPAINTING GUIDELINE

PRIORITY NO. 1 IMMEDIATE RECOAT:

(A) Areas showing ASTM Rust 1-4
(B) Areas with underfilm corrosion with loss in adhesion.

PRIORITY NO. 2 RECOAT WITH 12 TO 24 MONTHS

(A) Areas showing ASTM Rust 6-8
(B) Localized rusting
(C) Delamination of top coat

PRIORITY NO. 3 RECOAT MAY BE DELAYED OVER 24 MONTHS

(A) Areas showing ASTM Rust 9-10
(B) Minor local spot rusting
(C) Chalking or erosion of coating

REFER ASTM D610-68/SSPC-Vis FOR RUST GRADING

ANNEXURE - 5

No. CME/CIE/01
October 1989

CORROSION MONITORING AND INSPECTION FACILITIES

To tackel the problem of maintenance on a national basis, a centralised group to assist the Philippine Industry is being set up at National Engineering Centre with the assistance of UNIDO. The role of corrosion, corrosion monitoring, materials and inspection specialists in the group has been recognised.

Corrosion and inspection both assess the state of health and reliability of any equipment, structure, piping, etc. based on which preventive maintenance activities are planned. The Centre should therefore have corrosion monitoring and inspection aids which will be necessary to assist the Philippine industry. Some of the larger industries, e.g. refineries, power plants etc. may have their own in-house facilities or can afford to take the assistance of outside contractors. However there will be many others who would need the help of the Centre's equipment. The following inspection and corrosion monitoring equipments are being recommended for procurement. The items requiring immediate procurement have been marked(*)

*1. Portable Digital type Ultrasonic/thickness gauge 'D' meter with minimum accuracy of +/- 0.1mm and range of up to 100mm in multiple scales. The instrument must be battery operated (Facility of having a built in data storage will have an added advantage)

Manufacturers :

a.) M/s. Kraut Krammer Branson
250, Long Beach Boulevard
Strafford, Connecticut 06487
U.S.A.

b.) Wells Kraut Kramer
Black Horse Road
Letchworth
Herts, SG6 1HF
U.K.

2* Portable Hardness Tester Based on Ultrasonic principle Kraut Kramer Model BHV-10, direct reading, digital type.

Manufacturer:

M/s Kraut Krammer Branson
U.S.A.

3. Yoke type fluorescent Magnetic Particle Tester,

- Hand beld Yoke type electromagnet conforming to ASYM E 70. Magnet Model M.26 of Pony Industries, Japan or equivalent.
- Black light suitable for above alongwith 3 spare bulbs
- Trasformer 200V/100V preferably with variable magnetic field indicator

Manufacturers:

a.) M/s Magnaflux
U.S.A.

b.) M/s Pony Industries
Japan

*4 Dye-penetrant kit consisting of cleaner, developer and dye.

*5 Fluorescent Dye Penetrant test kit with cleaner, fluorescent dye, black lamp and associated accessories.

*6 Portable Alloy Analyser, for in-situ non-destructive chemical composition Metallurgist-XR & Alloy Analyser Direct reading type along with standard sample

Manufacturer:

Texas Nuclear
P.O. Box 9267
Austin, Texas 78766, USA

*7 Portable Crackdepth meter Kraut Krammer Model X-RT 705 or equivalent. Crackdepth range 0.1 to 120mm. Battery operated.

Manufacturer:

M/s Kraut Krammer Branson
U.S

*8 Ultrasonic Flaw Detector. Programmable and facilities for storage of data and digital display. Frequency range 1 - 35 MHZ Power supply Ni Cd cells. Straight and angular probes of diameter 8mm to 25mm. Kraut Krammer Model USD - 10 or equivalent.

Manufacturer:

M/s Kraut Krammer Branson
USA

*9 Portable Corrosion Rate Monitoring Instrument for industrial use.

Based on polarisation resistance principle. Multi range selection switch with corrosion rate measuring range varying from 0.05 to 200 miles per year.

Battery operated.

Probes of mild steel and admirality brass-6 each.

*10. Portable Corrosion Rate Instrument.

Based on electrical resistance principle. Multirange with facilities to measure corrosion rate from .1 mils to 200 mils per year.

Carbon Steel Probe - 6 nos

Manufacturers for items 9 and 10

a.) Petrolite Equipment and Instruments
P.O. Box 2546, Houston, Tx 77252

b.) Cormon Ltd., Cormon House, South Street, Lancing, West Sussex BN15, BAJ, U.K.

c.) Rohrback Cossasco 4669, S-uthwest Freeway Suite #250, Honston, Tx - 27, USA.

(Note : Instrument 10 is very useful for oil and gas Industries. For clean solutions, e.g. cooling water, boiler water, etc. instrument (9) will be suitable and this is an immediate requirements.)

*11. Visual Inspection Kit to be carried by engineers consisting of :

- Small Permanent Magnet	1
- Magnifying Lens x10	1
- Caliper	1
- Measuring Tape, 2 meters	1
- Knife, 3" long blade	1

(These can be purchased separately)

* * * * * *

No. CME/CIE/01-A1
November 1989

CORROSION MONITORING AND INSPECTION FACILITIES

Additional information on note No. CME/CIE/01, October,1989.

1.) Item No. 6 (of CME/CIE/01) Portable Alloy Analyzer Model B-366, Texas Nuclear, Series 9266.

Source: M/S Ramsey Engineering Pvt. Ltd.
20 Base Road, Taren Point
N.S.W., Australia

Price : US$25,000. (December '81)

2.) Set up for Replica Microscopy along with Accessories

a.) Portable Microscope - 1
b.) Reflective Replica Set - 2
(containing 100 Replicas)
c.) Portable Grinder - 1
(with grinding wheels - 3 of each grade)
d.) Portable Electrolyte Polisher and Etcher - 1

Source: M/S Struers A/S
Valhojs Alle 176
DK - 2610, Rodovre
Kobenharm, Denmark

Price : a.) 6,850 DKr (Sept.'89)
b.) 250 DKr per set (June'84)
c.) 14,140 DKr (June'86)
d.) 11,100 DKr (June'84)

ANNEXURE 6

No. CME/TP/03
December 1989

LABORATORY CORROSION AND MATERIALS TESTING FACILITIES AT NATIONAL ENGINEERING CENTRE

1.0 BACKGROUND

1.1 The PM Group in the National Engineering Centre at University of the Philippines is being set up with UNDP assistance to assist Philippines in increasing productivity through a well organised preventive maintenance system. Preventive Maintenance's primary objective is to avoid breakdowns of equipment both static and rotating and it requires a multi-disciplinary approach is getting the desired results.

1.2 Materials and corrosion engineering form important part of preventive maintenance and these have been given due importance in drawing the programme. During the 3 months stay of UNIDO Corrosion & Materials Engineering Consultant, it was noticed that in the above area some other organisations in the Philippines have built up testing facilities to assisst the industry, in their requirements. In any consultancy job it is absolutely necessary that adviced is given in shortest possible time. Therefore, where testing is to be performed the same is to be carried out quickly as possible. To assess how the facilities of various organisations can be utilised with advantage, the two main organisations, i.e., Materials Industrila Research and Development Centre and Industrial and Technological Development Centre were visited. Annexures A and B give the list of facilities available with these organisations.

2.0 AVAILABLE FACILITIES

2.1 To give consultancy to industries in the field of materials and corrosion, two main areas of studies required will be:

a.) Field testing and inspection

b.) Laboratory testing

Field testing facilities are already being built up in the NEC, because that will form a part of the day to day activities of the consultant. For this a list has already been drawn up and action is being taken on the same. In this report the requirements for laboratory studies at the NEC have been detailed:

2.2 The laboratory facilities are needed in the following areas:

1. Chemical Analysis of Materials and Corrosion Products

2. Metallurgical Properties

   a.) Mechanical properties

   b.) Micro-structural analysis

   c.) Crystallinity of material

3. Corrosion Studies

2.2.1. <u>Chemical Analysis</u>

The quantum of both qualitative and quantitative chemical analysis to be carried out will be considerable. However, building up of total facilities at NEC is not justified and assistance of outside organisations will become necessary. MIDC will be the best organisation to have an organisation for this purpose. However, MIDC is already loaded with routine chemical analysis services to the industries though not from the point of view of corrosion and materials failure. Therefore its services will be used only as and when necessary.

At NEC analysis of metallic elements in metals and alloys can be carried out using the recommended field testing equipment. For carbon and more precise analysis of metals (specially where alloying element % is quite small) or water and quantitative analysis of corrosion or scaling products, the samples can be sent to MIDC.

Qualitative analysis facilities, which would require min^m facilities, can be built up at the centre. This would require some chemicals, glass wares, heaters, filtering arrangements, etc. Theses are parts of the list given in Annexure C. Procedures for qualitative analysis are available in standard analytical books.

2.2.2. Metallurgical Examination

a.) Mechanical Properties

The quantum of mechanical testing jobs will not be large,m except perhaps the hardness testing. These tests can be carried out at the Metallurgy Department of UP (situated in NEC building itself) failing which facilities of MIDC will have to be used. For preparation of standard test samples on a priority basis, which takes the max^m time, NEC will have to have a contract with one or more private workshops in Manila.

b.) Micro-structural Analysis

Micro-structural study will form an important part of failure analysis, both corrosion and mechanical. The followings are the requirements for micro-structural studies:

1.) Opticl Microscopy - The NEC will have to have its own optical microscope, because it is one of the most important tool of investigation. One bench microscope along with specimen cutting and polishing facilities will be required for the purpose. The particulars are given in Annexure D. It is possible that the microscope ordered as a part of "field micrsocopy" requirements will serve the immediate purpose.

For more detail observations facilities at MIDC or ITDC can be used.

2.) Scanning-Electron Microscope

For some special studies it may become necessary to carry out SEM & EDAX studies. SEM is avialable at Metallurgy Dept., MIDC and ITDI. EDAX arrangement is however, only available eith ITDI. Facilities at any of these institutes can be used, when required depending on availability.

3.) X-ray Diffraction

X-ray diffraction analysis will be required when it becomes necessary to establish the phases present in a material or to identify the type of corrosion product. Both MIDC & ITDI have these facilities, which can be used as and when required. Requirement for such study will be quite rare.

2.2.3. Corrosion Studies

a.) Facilities for testing corrosion resistance coatings, paints. etc. are avialable with MIDC. But in none of the organisations laboratory corrosion testing facilities are available. The PM group will therefore have to be provided with those corrosion testing facilities for which will be required to be used more frequently for the local industries.

b.) The following testing facilities are recommended as min^m requirment:

1.) Facilities to carry out electro-chemical measurements, e.g., potentiodynamic polarisation plots, tafel plots,polarisation resistance plots, potentiostatic measurements, galvanic corrosion measurements, sensitisation tests, pitting scans, etc. For this purpose micro-processor based system Model 350-1, manufactured by EG & G Princeton Applied Research (P.O. Box 2565, Princeton, NJ 08540, USA) is most suited.

2.) Six 1 litre pyrex glass conical flask with reflex condenser arrangement to carry out intergranular, stress corrosion cracking and high temperature chemical corrosion tests on stainless and other steels.

3.) Facilities to carry out immersion tests on various materials, using beakers, hot water bath and other glass equipment. Static test for inhibitor evaluation can also be carried out with this arrangement.

4.) Laboratory evaluation of cooling water treatment chemicals by setting up a circulating system using pumps, jars, glass tubings, metallic tubings and also electrical resistance and polarisation resistance probes. This set up should be considered at a future date if projects are sponsored by the industries. NACE and ASTM have standards for carrying out these tests.

5.) For accelerated tests on metallic and paint coatings facilities available at MIDC should be used.

ANNEXURE A

FACILITIES AVAILABLE IN MIRDC FOR LABORATORY TESTS

1. Physical and Mechanical Metallurgy

   - Metallography
   - Scanning Electron Microscopy (without EDAX facility)
   - Tensile Test
   - Bend Test
   - Hardness Test
   - Impact Test (charpy)

2. Chemical Analysis

   - Instrumental and wet analysis for various metallic elements
   - Water Analysis
   - Carbon Analysis

3. Corrosion Tests

   - Salt spray test for metallic and non-metallic coating evaluation
   - CASS Test for above
   - Thickness and uniformity of zinc, tin and other coatings.

4. Non-destructive Testing

   - Radiography
   - Magnetic Particle Inspection
   - Liquid Penetrant Testing (or DP Test)
   - Ultrasonic Testing

ANNEXURE B

LABORATORY FACILITIES AVAILABLE AT ITDI
(Most of these are under installation)

1. Physical and Mechanical Metallurgy

   - Scanning Electron Microscopy (with EDAX)
   - X-ray Deffractometer
   - Metallurgical Microscope

2. Chemical Analysis

   - UV-VIS Spectrophotometer
   - FT-IR Spectrophotometer
   - Ion-Chromoatograph

3. Corrosion Testing

   - Combined Cyclic Corrosion Tester
   - Surface Roughness Tester (for blast cleaned surface)
   - Atmospheric Corrosion Testing Facilities
   - Automatic Polarisation System for Corrosion Study
   - Impedence Testing for Organic Coatings
   - Paint Adhesion Testing Facilities

ANNEXURE C

LABORATORY FACILITIES AT NEC

1. Metallurgical Evaluation

- Metallurgical Microscope; (1 No) Bench typoe with magnification range of 50 to 1200 along with arrangements for taking microphotographs.

- Sample cutting machine along with cutting wheels (1 No)

  To cut samples from round rectangular or any other shape upto a thickness of 100mm max*. Suitable for operation at 220V, 60 cycles.

- Sample mounting machine along with press and cylindrical heaters of size 12.5mm to 37.5

- Wheel grinding machine for rough polishing (1 No). Motor driven. To be operated at 220V, 60 cycles.

- 1 No Polishing machine with two horizontal wheels. Adjustable multispeed drive. Motor to be operated at 220V, 60 cycles.

- Stereo Microscope for macro examination along with photographic arrangement.

- Alumina powder for polishing.

2. Working bench with ceramic or other corrosion resistant lining top. 4 Nos

- One for electrochemical corrosion studies

- One for immersion corrosion studies

- One for chemical analysis

- Oner for Metallurgical studies

3. Laboratory Facilities

- 1 No Water Bath with heating and temperature control arrangement and a stirrer. Size of the bath -

24"x16"x16" deep. For immersion test. To be operated at 220V, 60 cycles.

- 1 No Water Bath as above but of size 18"x12"x12" deep for electrochemical studies

- Hot plate 18"x12" with temperature control arrangement. 2 Nos

- Glass wares:

  o Pyrex Beakers

    250 cc - 6 Nos

    500 cc - 12 Nos

    1000 cc - 12 Nos

    2000 cc - 6 Nos

  o Conical Flasks (Pyrex)

    250 cc - 12 Nos

    500 cc - 12 Nos

    1000 cc - 12 Nos

  o Test Tubes (Pyrex)

    25 cc - 24 Nos

    50 cc - 24 Nos

    100 cc - 24 Nos

  o Other glass accessories like tubings, pippets, standard glass joints, 2 and 3 ways stop cocks, etc.

- Gas burners with tripods, wire gauge, etc. 6 Nos.

- Electric Hot Oven, Temp range 100 - 1200°C. Complete with temp controller, temp indicator. Oven heating chamber size 8"x4"x18" depth. To be used for heat treatment, loss on ignition, etc.

ANNEXURE 7

No. CHE/TP/01
October, 1989

TRAINING PROGRAMME FOR CORROSION AND MATERIALS ENGINEERS AND TECHNICIANS

1.0. INTRODUCTION

1.1. The PM Consultancy Group in NEC, being set up to assist the Philippine Industries, will have a strong team for corrosion control materials and inspection. The effectiveness of this group will depend not only on the qualifications of the personnel, but also on their experience, constant updating of knowledge and techniques and interaction with personnel in related fields.

1.2. The group dealing with corrosion and inspection would include engineers and technicians, having different levels of expertise and would therefore require different types of inputs. Well organized training will form an important part of the constant development.

1.3. While the final training programme will depend on the overall needs of the PM group, for the corrosion and inspection engineers and technicians an outline of the same is recommended. This takes into account future growth of the group by way of induction of new staff members and growing activities.

2.0. TYPE OF TRAINING

2.1. Type of training is to be tailored to the needs of the persons of various levels and experience. The activities of corrosion and inspection consultants and technicians wuold include investigation of problems, failure analysis, preparation of standards and codes, corrosion monitoring and laboratory stuies, etc. Each individual in his own area would require a multi-disciplinary approach and for this training will play an important role. For example, a technician may have to perform duties connected with laboratory tests, corrosion monitoring and plant inspection. Similarly an engineer will have to guide the technician in his duties and over and above plan, implement and interpret test data.

2.2. Considering the above, the training has to be broadly divided into following categories:

1. For Senior Engineers

i) Persons with more than two years experience and having speicialisation in corrosion and inspection.

a.) Attending advance and refresher courses on corrosion, inspection and maintenance.

b.) Attending seminars and conferences related to corrosion and inspection.

c.) In plant training in different industries and reputed corrosion laboratories outside and inside the country.

d.) Visiting various fabricators, material manufacturers and corrosion control and inspection equipment manufacturers for technica; discussions.

ii) For the fresh engineers having no specialisation in corrosion and inspection.

a.) Attending in-house corrosion, inspection and monitoring courses.

b.) Attending basic corrosion and inspection courses conducted by reputed organisations.

c.) Participating in plant shutdowns.

2. <u>For technician</u>

i) For experienced technicians (min. 3 years experience)

a.) In-plant training on corrosion monitoring and inspection.

b.) Participating in plant shutdowns.

c.) Attending basic technical courses on corrosion, monitoring and inspection.

d.) Attending advance in-house corrosion, inspection and monitorign courses.

ii) For fresh technicians

a.) Attending in-house corrosion and inspection courses.

b.) Participating in plant shutdowns.

3.0. TRAINING PROGRAMME

3.1. Training will be of continuing nature and every year an outline of programme for training will be drawn up. Where there are posssibilities of arranging group training programme, consultations will be held with other organisations in the Philippines.

It is essential that training programme is primarily drawn up taking into account the immediate and future activities of the group.

3.2. Except for in-house training, planning would require contacting organisations outside the NEC. For in-plant training the assistance of industries in the Philippines will have to be taken. The programme for particiaption in shutdown will have to be drawn depending on planned shutdowns in different industries. In-plant training outside the Philippines can be arranged in important industries through UNIDO or under other Official Exchange Programmes.

Short visits to operating industries, manufacturers and laboratories outside Philippines for engineers will have to be arranged by direct contacts. Such visits can be arranged during participation in seminars and conferences abroad to minimise travel costs.

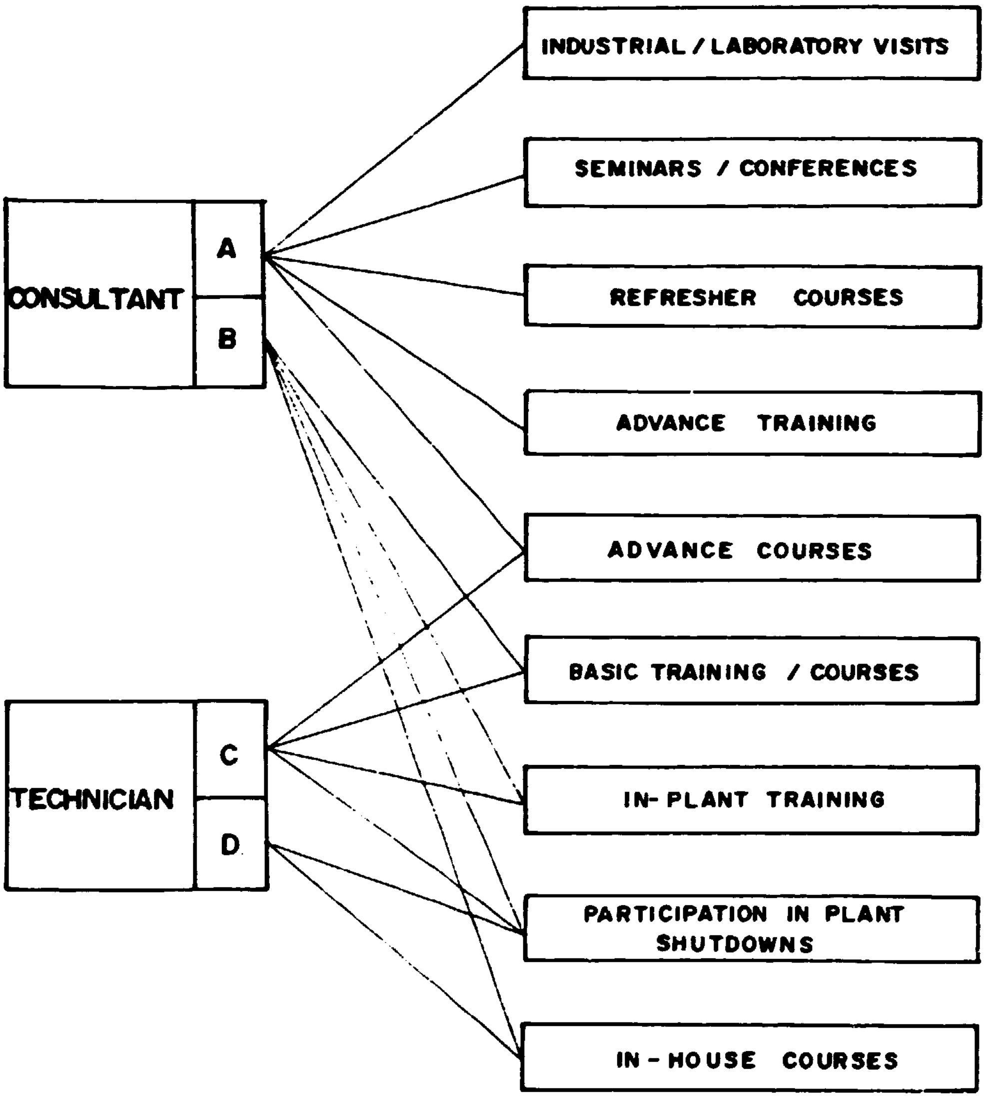
Training in the use of various instruments can be organised through the equipment suppliers either in the Centre or in the manufacturers' organisations. Such training can also be organised in Philippines as group training in consultation with other organisations. For advance training of this nature training at specialised institutions is prefereed.

Specialised courses on corrosion and inspection are provided by many organisations and institutions. Both short (up to 1 week) and medium terms (3-4 months) courses are available. There are different courses tailored to the needs of the engineers and technicians.

In-house training (both basic and advance) will form an important part of the overall training programme. In addition to lectures this will involve series of corrosion experiments and use of monitoring and inspection equipment. Suitable text will be prepared by the engineers assigned for the particular presentation. The engineers will first practice them in "dry runs" in which they will take turns in "teaching" the other lecturers. This will give an opportunity to each lecturer to modify the text and to make the presentation more practical oriented. The content of the lecture will vary with level of participants. For example to fresh technicians the presentation will be less theoritical so that their interest and attention would be aroused and maintained.

Seminars and conferences will form an important forum for exchange of ideas, specially for senior staff. Participation in gatherings organised by important organisations in topics of group's interest will be encouraged.

TRAINING CHART FOR CORROSION AND MATERIALS TEAM IN NEC



A – Engineers with specialisation and minimum 3 years experience in Corrosion, Materials and Inspection.

B – Fresh Engineers

C – Technicians with minimum 3 years experience in corrosion monitoring and inspection.

D – Fresh Technicians.

SEMINARS AND CONFERENCES

Important Institutions and Organisations arranging seminars and conferences related to corrosion and inspection.

- National Association of Corrosion Engineers, P.O. Box 218340, Houston, 77218, (U.S.A.)

- American Society of Testing Materials, 1916 Race Street, Philadelphia, PA 19103, (U.S.A.)

- Society of Chemical Industry, 14 Belgrave Sq., London SWIX 8PS

- European Federation of Corrosion, Society de Chimie Industrielle, 80 Route de St-Cloud, 92 Rueit-Malmaisen, Paris

- Centre Francais de la Corrosion (Cefracor), 28 rue Saint-Dominique, Paris (7 eme)

- Institute of Corrosion Science and Technology, 14 Belgrave Square, London SWIX 8 PS

- Central Electrochemical Research Institute, Karaikudi, India

- Kerrsionscentralen ATV, Park Alle, 345, DK 2600, Clostrup, Denmark

- Centre Belge d'Etude de la Corrosion (CE BELCOR), Avenue Paul Heger, Grille 2, B-1050, Brussels

- Singapore Institute of Standards and Industrial Research, 179 River Valley Road, P.O. Box 2611, Singapore 0617
- Swedish Corrosion Institute, Box 43037, S10072, Stockholm 43.

- Dechema - Institute, Frankfurt on Meine, W. Germany

- Japan Association of Corrosion Central, Kikai - Shinki-Kaikan, Rm 204, 21-1-5 Shiba-Koon, Minate-Ku, Tokyo.

STUDY AND TRAINING COURSES

SUBJECT	COURSE	ORGANISERS/VENUE	PARTICIPANTS/ LANGUAGE	DURATION
Corrosion	Corrosion and corrosion control	Centre Belge d'Etude la corrosion, CEBELCOR, Avenue Paul Rogar, Grille 2, B-1050 Brussels, (Belgium).	Engineers, with 2 years experience. English.	2 semester of 3 mos.
	Corrosion science and technology	Corrosion Study Centre, "A Dacce" Faculty of Science, University of Ferrara, Via L Borsari 46, I-44100 Ferrara, (Italy)	Engineers. Italian.	45 days
	NACE Basic and Advance Course	National Association of Corrosion Engineers, P.O. Box 218-340, Houston Texas 77218 (U.S.A.)	Engineers & technicians with minm. 3 yrs. experience English.	5 days
	Corrosion Prevention by cathodic protection	- do -	Engineers & technicians with basic corrosion course. English.	5 days
	Corrosion control in oil & gas production	- do -	- do -	5 days
	Corrosion prevention by coatings	- do -	- do -	5 days
	Cathodic protection	Institution of Corrosion Science and Technology, 14 Belgrave Sq., London SWIX 8PS. (Also arranges courses in collaboration with NACE).	- do -	7 days

SUBJECT	COURSE	ORGANISER/VENUE	PARTICIPANTS/ LANGUAGE	DURATION
	Corrosion monitoring and measurement	Corrosion Monitoring Consultancy, 'ST Pirans, Donchworth Road, Wantage Oxan, OX12 9AU, (U.K.)	Engineers & technicians with minm. 3 years experience. English.	4 days (Course tailored to clients needs Training is provided at client premises.)
	Corrosion protection	Corr Ocean Engineering A.S P.O. Box No. E16, N. 7001 Trondheim (Norway)	- do -	7 days - do -
Inspection	Ultrasonics	Automation Industries, Inc. Sperry School of NDT, 4000 Lockbourne Road, Columbus. Ohio 43207	Engineers & technician with minm. 3 years experience. English.	15 days
	Non-destructive	- do -	- do -	4 days
	Radiography	- do -	- do -	15 days
	Radiation Safety	- do -	- do -	5 days
	Eddy current inspection	- do -	- do -	3 days
	Ultrasonic Testing of Materials	Singapore Institue of Standards and Industrial Research, 179 River Valley Road, P.O.Box 2611, Singapore 0617	- do -	30 days
	Industrial Radiography	- do -	- do -	30 days
	Painting Inspector Certification	Institution of Corrosion Science and Technology, 14 Belgrave Sq., London SWIX 8PS	Technicians with minm. 3 years experience. English.	5 days
	Cathodic Protection, Inspector Certification	- do -	- do -	5 days

SUBJECT	COURSE	ORGANISER/VENUE	PARTICIPANTS/ LANGUAGE	DURATION
	Non Destructive Testing	Scottish School of N.D.T. Paisley College, High Street, Paisley, PA1 2BE U.K.	Engineers & technicians minm. 3 years experience. English.	Various courses are available.
	International coating, inspector training and certification	National Association of Corrosion Engineers, P.O.Box 21840, Houston, Tx 77218 b)	- do -	3 courses i.e. basic intermediate & advanced programmed of 7 days each.
	Non-Destructive Testing	Kingston Polytechnic, Penrhyn Road, Kingston-Upon-Thames KT 1 2EE (U.K.)	Engineers. English	Short and medium term.
	Radiography	Kodak Marketing Education Dept., Godebridge Lane, Hempstead, Herts (U.K.)	Engineers & technicians with minm. 3 years experience. English.	5 to 7 day
	Non-Destructive Testing	Whitford Internation Ltd. Whitford House, Clayton wood Close, West Park, Leeds, West Yorkshire LS 166 QE (U.K.)	- do -	- do -
	Non-Destructive Testing	The Unit Inspection Company Sketty Hall, Swansea, SA2 8[illegible] (U.K.)	Engineers	26 weeks

*Note:

a.) Includes materials engineering topics

b.) Corrosion Engineering Association
174 High Street, Guildford, Surrey
GU1 3HW (U.K.)

ANNEXURE 8

No. CME/L/01
October,1989

Number of books dealing with corrosion and materials have been received in the Centre or are under order. The list has been received and found to be quite comprehensive. The following additional books are recommended for procurement:

1. Corrosion Handbook by H.H. Unlig,
   Published by John Wiley and Sons, London

2. Corrosion and Prevention in Waters by G. Butler and H C K Ison.
   Published by Leonard Hill Books, 8-10 King Street London W.G.

3. Corrosion Resistance of Metals & Alloys by F.L. Laque & H. R. Copson.
   Published by Reinhold Publishing Corporation, New York.

4. Corrosion Prevention by Practising Engineers by J. Bosich
   Published by Barnes & Nobles, New York

5. Protection of Iron & Steel Structures from Corrosion , B S I 12008
   Published by British Standard Institutions, London

6. Steel Structures Painting Manual Vol. I & II
   Published by Steel Structures Painting Council, Pittsburgh, Pa, U.S.A.

7. Chloride Corrosion of Steel in Concrete ASTM STP 629. Edited by D.E. Tonini and S.W. Dean
   Published by American Society for Testing Materials, 1916 Race Street, Philadelphia, Pa 19103, U.S.A.

8. Following publications by National Association of Corrosion Engineers.

   8.1. Cooling Water Treatment Manual

   8.2. NACE Coatings and Linings Handbook

   8.3. Electrochemical Techiniques for Corrosion

   8.4. Atmospheric Corrosion of Metals

8.5. Stress Corrosion Cracking Control Measures

8.6. Corrosion Data Survey, Metals and Non-metals

8.7. Control of Internal Corrosion in Steel Pipe Lines and Piping System

8.8. High Voltage Electrical Inspection of Pipeline Coatings Prior to Installation

8.9. Forms of Corrosion, Recognition and Prevention

8.10. Corrosion Inhibition

9. Ultrasonic Testing of Materials - English Edition by J.U.H. Krautkramer
Published by Krautkramer GMBH, Robert Bosch - Strasse 3, 5030 Hurth 5, West Germany

10. Handbook on the Non-destructive Testing of Materials - English Edition by E A W Muller
Published by Verdag Oldenbourg, Munchen, West Germany

11. Stress Corrosion of Metals by Logan
Published by John Willey & Sons

12. Failure Analysis and Metallography - Micro-Structural Science Vol. 15, by Mitchel E. Blum
Published by American Society of Metals International Park Ohio 44073, U.S.A.

13. Pipeline Corrosion & Cathodic Protection by Marshall E. Parkers.
Published by Gulf Publishing, U.S.A.

14. Application Manual for Paint and Protective Coating by W.F. Gross
Published by McGraw Hill

15. Corrosion Vol. 1 & 2 by Shreir.
Published by Newnes Butterworths, London

16. Dewpoint Corrosion by D.R. Holmes
Published by Ellis Henevard

17. Defects and Failures in Pressure Vessels and Pipings by Thielsch
Published by Reinhold Publishing Company

18. Failure Analysis - Case Histories and Methodology by Naumann
Published by A S M, U.S.A.

19. ASME Section VIII Div 1 and 2 (Pressure Vessle Code), ASME Section II A and B (Material Code). Published by American Society of Mechanical Engineers, U.S.A.

ANNEXURE 9

No. CME/TP/02
October 1989

TEST PROGRAMME FOR

BASIC TRAINING ON CORROSION

1.0. INTRODUCTION

1.1. Training of engineers and technicians at the National Engineering Centre and also from industries in the field of corrosion will be an important activity of the PM Group developed at NEC. The training programme of consultants and technicians is detailed in report No. CME/TP/01. The programme includes "basic training on corrosion" for fresh engineers and technicians. The same programme can also be used for training and in workshop programmes for plant personnel in future.

1.2. The basic training programme would include series of corrosion lectures, video programmes and simple laboratory tests to demonstrate various corrosion phenomenon. The present report gives details of demonstration tests.

2.0. FIRST SERIES OF TESTS - ELECTRO-CHEMICAL ASPECTS

2.1. Electrode Potential

Whenever a metal is immersed in an electrolyte it develops a potential with respect to the medium. The potential developed depends on the environment and tne metal concerned.

2.1.1. Test No. 2 (1)

Take a mild steel sample of 50mm x 50mm size and immerse in distilled water after polishing to a finish by "0" size emery paper and degreasing. The sample will be weighed before test. Place th luggin capillary near the specimen with connection to saturated calomel electrode. Make electrical connection to a potential measuring device as shown if Fig. 1. Measure potential initally at intervals of 5 minutes till the potential stabilises and subsequently once every day till 10 days. After 10 days clean the specimen and determine loss in weight and corrosion rate. (Note: If luggin capillary is not available dip the electrode in the beaker for initial experiments).

2.1.2. Test No. 2 (2)

Repeat the test No. 2 (1) with Sea Water.

2.1.3. Test No. 2 (3)

Repeat the test No. 2 (1) with N/1000 HCl. Time of test will be 6 Hrs.

The above test 2 (1) to 2 (3) will indicate how the potential changes with the environment.

2.1.4. Test No. 2 (4)

Repeat test 1 (2) with Stainless Steel.

2.1.5. Test No. 2 (5)

Repeat test 2 (3) with Stainless Steel. Time of test will be 24 Hrs.

2.1.6. Test No. 2 (6)

Repeat test 2 (2) with Aluminum.

2.1.7. Test No. 2 (7)

Repeat test 2 (3) with Aluminum.

2.1.8. Test No. 2 (8)

Repeat test 2 (2) with Cu-Ni Alloy. (Use smaller size specimen , 25mm x 25mm, if necessary).

2.1.9. Test No. 2 (9)

Repeat test 2 (2) with Zinc (use smaller size specimen, 25mm x 25mm, if necessary).

2.1.10. Test No. 2 (10)

Repeat test 2 (3) with Zinc (use smaller size specimen, if necessary).

Above test, 2 (4) to 2 (10), would establish that corrosion potential and rate vary with material and environment. Compare potential with standard electrode potential series.

2.2. Galvanic Effect

Previous tests indicate that metals develop potential in an electrolyte and the potential developed depends on material and medium.

Corrosion being an electrochemical process the corrosion rate or kinetics of corrosion is governed by the amount of current flowing between anode and cathode. The flow of current would, as in any electrical circuit, depend on:

(i) Difference in potential, i.e. ΔV

(II) Resistance of the circuit, R

$$\Delta V/I = R \quad \text{or} \quad I = \Delta V/R$$

In addition to the above two factors, in the corrosion process, the polarisation characteristics of anodes and cathodes also play important role.

2.2.1. Difference in Potential

a.) Test No. 2 (11)

Put a weighed mild steel and brass specimen of 50 x 50mm in a beaker containing 3% NaCl water. The specimens will be polished and degreased. Place capillaries facing both the specimens as shown in Fig. 2. If luggin capillary is not available pl e the calomel electrode in the centre of the two specimens). Measure the potential of individual specimen periodically till the potential stabilises.

Now connect the two specimens externally through a multi-range ammeter of zero resistance. Measure the current at periodic intervals and also potential of both brass and steel once every day. Note change in direction of potential in both electrodes. Continue the test for 10 days. Weigh the specimen after removing all corrosion product. Only steel will show weight loss.

Determine corrosion rate in mils per year from weight loss and corrosion current and compare the results. The test will show that in the above system steel is anode and brass cathode. It will also show that corrosion is dependent on the flow of current.

b.) Test No. 2 (12)

Repeat test No. 2 (11) with brass and stainless steel samples.

The test will show that corrosion rate is small because of low difference in potential between stainless steel and brass and the inherent low corrosion rates of two alloys.

c.) Test No. 2 (13)

Repeat test 2 (11) with mild steel and zinc.

The test will show that zinc is corroded and acts as anode while mild steel fully protected, if the potential of the system is more negative than-850 mV.

2.2.2. Electrical Resistance of Circuit

a.) Test No. 2 (14)

Repeat the test No. 2 (11), but by placing a variable resistance in the circuit. (arrangement is shown in Fig. 3).

3.0. SECOND SERIES OF TESTS - FORMS OF CORROSION

3.1. Corrosion causes deterioration and there are many forms in which effect of corrosion is observed. These have been explained in short. Forms of corrosion which can be reproduced by simple experiments have been given.

3.2. General Corrosion

The corrosion causes uniform loss of metal all around. The resulting surface is for all practical purposes smooth. In such a situation it is easier to predict life once the corrosion rate is established.

3.2.1. Test No. 3 (1)

Repeat tests 2 (1), 2 (2) & 2 (3) with mild steel and 2 (7) with aluminum. Examine the samples after test. These were found to have uniform corrosion.

3.3. Pitting Corrosion

Localised high corrosion at some points compared to overall surface results in piting type of corrosion. Pits may be broad and shallow or small and deep. Greater the penetration rate of pits lower the life of equipment specially those which contain liquid or gases. Pitting rate is higher in metals and alloys which show active/passive behaviour.

3.3.1. Test No. 3 (2)

Take 2.5 x 2.5 cm AISI 304 stainless steel sample and polish to a finish by '00' emery paper (fine finish) degrease and weigh. Prepare 250 c.c. of 10.8% $FeCl_3$, $6H_2O$ solution in 0.05 N HCl. Dip the sample for four hours. Test temperature will be 40°C.

After test wash the sample carefully and weigh. Count number of pits and measure pit depth using a sharp pin needle (e.g. dental probe).

3.3.2. Test No. 3 (3)

Repeat the test 3 (2) with AISI 410 stainless steel.

3.3.3. Test No. 3 (4)

Repeat test 3 (2) with AISI 316 stainless steel.

The above tests, 3 (2) to 3 (4) will show that the three stainless steels have the following decreasing order of pitting susceptibiltiy. ss 410, ss 304 and ss 316.

3.3.4. Test No. 3 (5)

Repeat test 3 (2) with mild steel.

Mild steel will corrode uniformly without pitting.

3.3.5. Test No. 3 (6)

Take a sample of 100 x 50 cm AISI 304 stainless steel and polish to a finish by '00' emery paper and degrease. Dip the sample in sea water for 5 minutes, withdraw it and allow the film of water to dry by placing the sample flat on a filter paper. The top surface of the sample will have randomly distributed salt crystals.

Place the specimen on the dessicator plate with a layer of water in the bottom of the dessicator and cover. Run the test for 15 days, remove the sample and clean under running water. Examine the surface.

3.3.6. Test No. 3 (7)

Repeat the test 3 (6) with mild steel.

3.3.7. Test No. 3 (8)

Repeat the test 3 (6) with aluminum.

The tests 3 (6), 3 (7) and 3 (8) will show that stainless steel and aluminum are more likely to pit them mild steel.

3.3.8. Test No. (9)

Repeat test No. 3 (6) with 10% solution of Na_2SO_4 in distilled water.

After the potentials of the two electrodes stabilise (still not electrically connected) connect the two electrodes through a multi range zero resistance ammeter. In between the ammeter and one of the electrode the variable resistance will be at '0' position to start with. After the current stabilises (few hrs to 24 hrs generally) increase the resistance so that the current is reduced by half. Continue the test for 10 days with daily measurements of potentials of two electrodes.

Determine loss in weight and calculate corrosion rate from weight loss and current and compare.

b.) Test No. 2 (15)

Repeat test No. 2 (13) with same arrangement as in test No. 2 (14). Compare the results of test Nos. 2 (11), 2 (13), 2 (14) and 2 (15).

Compare with test 3 (6), 3 (7) and 3 (8). The test will show that chloride is a much more stronger pitting promoter than sulphate.

3.4. Intergranular Corrosion

Some alloys like stainless steels and aluminum alloys are susceptible to intergranular corrosion. In intergranular corrosion the grain boundaries of alloys are attacked in preference to the grains. Though extent of weight loss and apparent attack are less, the alloy looses strength and leaks where intergranular attack occurs (generally near the welds in what is known as heat affected zone - HAZ).

3.4.1. Test No. 3 (10)

Take one 10 mm x 50 mm sample from AISI 304 stainless steel sheet (preferably about 2-3 mm thick) polish to 'OO' emery finish, degrease and weigh. Before polishing the sample will be heated at 650°C for 1 hour.

Take a solution containing 47 cc per litre of concentrated sulphuric acid and 13 gms/litre of $CuSO_4.5H_2O$ in a pyrex flask fitted with a reflux condenser. Immerse the stainless steel specimen in the above boiling solution for 72 hours. Take out the specimen and subject to a bend of 180°C over a radius of 5 mm.

Appearance of crack on the surface would indicate intergranular corrosion. Mount the bent portion of specimen and examine for the nature of attack along the cross section under optical microscope both before and after etching.

Note: If no cracks are visible on bending repeat with three consecutive test of 72 hours period each on a fresh sample before bending.

3.4.2. Test No. 3 (11)

Repeat test 3 (10) but with AISI 304 L or 321 stainless steel. No or little intergranular cracking would be observed.

The tests No. 3 (10) and (11) would show that while 304 is susceptible to intergranular attack, 304 L or 321 are not.

3.5. Cavitation Erosion

Whenever in a moving liquid fluid there is creation of low pressure areas, the material is subjected to conjoint action of corrosion and impact resulting in cavitation erosion. Pump impellers and ship propellers are generally subjected to this type of attack. The affected area has a mottled appearance with closely spaced pits.

No simple tests are available to reproduce this phenomenon. Some failed pump impeller can be collected from industry as an exhibit.

3.6. Stress Corrosion Cracking

Some alloys are susceptible to cracking when subjected to tensile stress in a specific environment. Some common instances are:

- mild steel in caustic and nitrate
- stainless steel in chloride
- copper alloys in ammonia
- Aluminum alloys in chloride

Cracking is either intergranular or transgranular, depending on the type of alloy and environment.

3.6.1. Test No. 3 (12)

Take a 2 cm wide and 10 cm long 1.5 to 2 mm thick annealed brass sample with 3 mm dia holes at two ends along the lenght.

Polish to a finish by '00' emery paper. Bend at the centre around 2 cm rod to form 'U'. Put a steel nut and bolt through the hole and tighten with nut till the two legs of 'U' are parallel.

Prepare similar specimens from pure copper and AISI 304 or 316 stainless steel.

Put 5% NH_4OH solution at the bottom of a dessicator. Place the bent brass, copper and stainless steel specimens over the dessicator plate and cover the dessicator.

Take out the three specimens every 2 hours for first six hours and examine outer bend for surface, crack under a low powe microscope or with a magnifying lens. Note for number and length of cracks. Continue the test for 24 hours with copper and brass specimens and 10 days with stainless steel. Mount the specimen and examine microscopically after polishing, with and without etching.

The test 3 (12) would show that while brass cracks in ammonia atmosphere, copper does not. The test would also show that brass cracks intergranularly. (Note: If brass is in cold rolled condition there will be mixed mode of cracking, i.e., both inter and transgranular). Stainless steel would also show no cracking.

3.6.2. Test No. 3 (13)

Prepare AISI 304 stainless steel as above. Take 42% solution of $MgCl_2.6H_2O$ in a 500 cc. flask fitted with a reflux condensor. Hang the U bent specimen in the boiling solution. Examing the outer bend of the specimen every 2 hours for first 6 hours under low magnification for number and length of cracks. Continue test for 48 hours.

Mount the specimen and examine microscopically after polishing, with and without etching.

The test no. 3 (13) would show that stainless steel is susceptible to cracking in chloride solution and that cracking is branching type and transgranular.

No cracks will be starting from the indise surface of U-bend which is under compression.

3.7. Fatigue Corrosion

Metals and alloys are susceptible to cracking under alternate stresses due to phenomenon known as fatigue cracking. In presence of corrosive environment the susceptibility to cracking is increased.

Pump shafts, piston rods, etc, fail due to corrosion fatigue.

There are no simple tests to reproduce these failures. Some failed pump shaft can be collected from industry as an exhibit.

3.8. Impingement Corrosion

When high velocity liquid fluid containing entrained air bubbles strikes against a metal surface, highly localised corrosion takes place at the point of impingement leading to perforation. Similar effect is observed when at any point during change in the direction the fluid directly impinges on the metal surface.

Failure of copper alloy exchanger tubes at tube inlet, failure at bends, etc., are instances of impingement corrosion.

Reproduction of impingement corrosion in laboratoru requires elaborate arrangement bur for explaining some failed copper alloy exchanger tubes can be collected from industry.

3.9. De-alloying

Alloys which are mixture of two or more metals, sometimes fail due to corrosion of one metal in the alloy in preference to the other (generally major). The phenomenon is known as de-alloying and examples are desincification, dealuminification and denickelification. These occur under ceratin specific conditions of alloy and environment.

3.9.1. Test No. 3 (14)

Take a 20 mm wide and 100 mm long brass (preferably 60% Cu - 40% Zn) specimen. Polish to a finish by '00 emery paper.

Take 500 cc of solution containing 10 gms of cupric chloride per litre to which 5 drops of concentrated HCl have been added. Continue the test at room temperature for six weeks. Take out the sample and bend it. Note for surface colour and any cracks. Observe the cross section microscopically. Spongy coppery red layer will be visible on outer surface. Determine depth of this layer.

Test 3 (14) would show that brass is susceptible to dezincification.

4.0. THIRD SERIES OF TESTS - CORROSION PROTECTION

4.1. Corrosion can be controlled by various methods, e.g., painting, inhibition and cathodic protection. The effectiveness of the various methods are given in the next series of tests.

4.2. Corrosion Inhibition

4.2.1. Test No. 4 (1)

Take two 500 cc beakers, one containing 400 cc of tap water and the other 400 cc of tap water with 0.1% of sodium chromate. Take two 50 mm x 100 mm of mild steel specimen polished to a finishe by 'O' size emery paper and degrease. Weigh the specimens and place one specimen in each beaker. Observe the surface condition of the two specimens for 3 days, take them out, remove the rust by scrubbing with handbrush and reweigh. From the loss in weight and area (both sides) calculate corrosion rate in mgm/dm^2/day (*mdd*).

The test will show that chromate inhibits corrosion of mild steel in water.

4.3. Painting

4.3.1. Test No. 4 (2)

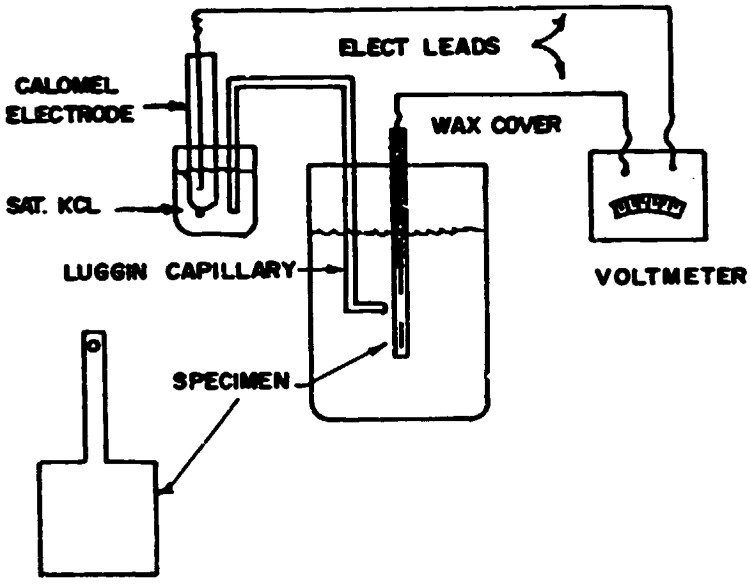
Take two 100 mm x 100 mm mild steel plate and pickle them in acid to remove all the mill scle. Take one plate and expose it to atmosphere for a few weeks till it develops a sufficient thick coating of rust. Lightly clean the loose rust with a brush (so as not to remove all the rust). Paint the rusted sample with one coat each, of primer (red lead or chromate) and compatible finishing coat. Put a 50 mm long scribe mark (scratch) at the centre of the plate so as to expose the steel below the paint. Spray the surface with 3% NaCl solution droplets and put the sample in a dessicator containing a layer of water. Repeat the same painting and exposure procedure with pickled mild steel without rust.

Observe the specimens for 1-2 weeks. It will be demonstrated that the paint on pickled surface gives better life than rusted surface. If a grit or said blasted plate is also included in the test, superiority of it over the other two will be evident. The degree of protective property will be judged on the basis of rust spots and rusting on both sides of the scratch mark.

4.3. Cathodic Protection

4.3.1. Test No. 4 (3)

Repeat Test No. 2 (13) to show that zinc protects steel cathodically.



ELECT LEADS
CALOMEL ELECTRODE
WAX COVER
SAT. KCL
LUGGIN CAPILLARY
VOLTMETER
SPECIMEN
SIDE VIEW

FIGURE: I

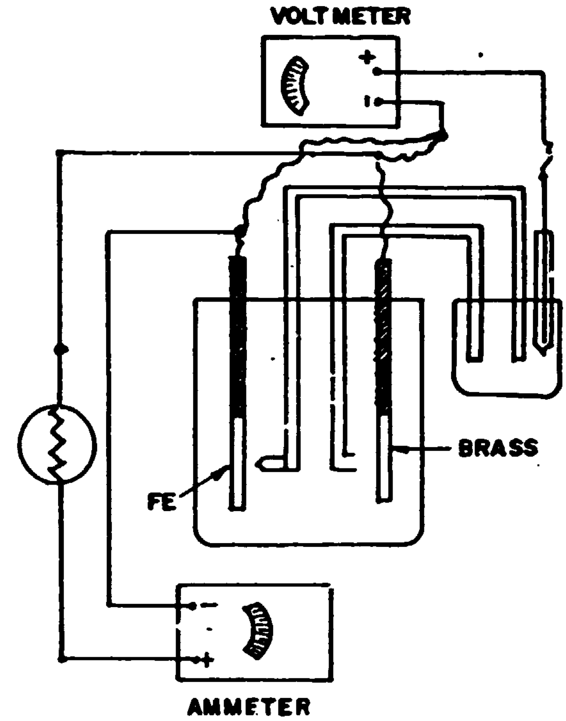


FIGURE - 2

FIGURE-3

(SAME AS FIGURE-2 BUT WITH A VARIABLE RESISTANCE IN CIRCUIT AT CIRCLE IN FIG.2

ANNEXURE 10

ATMOSPHERIC CORROSION STUDIES IN THE PHILIPPINES

1.0 INTRODUCTION

The metallic structures and outdoor equipment , roofing and facilities in industries and human dwellings are exposed to the local atmospheric environment and need protection against external corrosion. Steel, the most commonly used material, is protected by paint, metallic coating like galvanising or both. The protective system used for any particualr case depends on

- corrosivity of environment
- periodicity of repainting
- economics

In addition to the above, in the long run it is desirable to standardise the paint systems to reduce inventory and make the procuremnt easy.

As discussed above, corrosivity of environment plays a major role in the selection of protective system and as the former is primarily dependent on the environmental factors, it is essential that aggresiveness of the atmospheric environment is known. While in a micro-scale environment varies from location to location, for general purpose the overall corrosivity of geographic locations in a country on a macro scale becomes important.

Taking long term perspective it is therefore essential that a well planned study on atmospheric corrosion is initiated in the Philippines based on which a corrosion map can be drawn, as has been done in many countries.

2.0 CONTROLLING FACTORS

2.1 Factors affecting atmospheric corrosion are:

i. Climatic - temperature, humidity, wetting and drying period, rainfall, etc.

ii. Chemical - presence of SO_2, acidic gases, chlorides and other salts in the air.

iii. Physical - erosive action of sand and solid particles in the air.

2.2 The climatic conditions in the Philippines varies to some extent in different regions. Further, Philippines has a long coastal line and most of the regions are subjected to high winds which tend to increase the chloride level in the atmosphere and thus its aggresiveness. In areas where industries are also located the atmosphere is further polluted with gases emitted by these industries. Urban areas, on the other hand are polluted from exhaust of vehicular traffic and domestic fuels.

3.0 OBJECTIVE OF STUDY

3.1 The atmospheric corrosion basically involves the following steps.

a.) Formation of a thin layer of moisture on the metal surface either due to condensation during change in ambient temperature and humidity or rains. In case of hygroscopic solids deposited on the surface, as in case of marine and industrial environment, condensation occurs more readily.

b.) The thin film of moisture absorbs the water soluble gases or solids in the air or dissolves the soluble solids deposited on the metal surface forming a thin layer of corrosive electrolyte.

c.) The corrosion occurs due to this film of electrolyte forming solid corrosion products.

d.) Once a layer of rust is formed further corrosion takes place by the electrolyte reaching the metal surface through the pores or gaps in the layer. In such a case the corrosion rate diminishes with time.

3.2 Due to number of factors involved in controlling atmospheric corrosion and the interaction of many of them being more complex it has been found difficult to predict the corrosivity of a given area by accelerated laboratory tests. In development of protective systems, atmospheric corrosion studies have therefore played a major role in all the countries and such a study is felt essential in the Philippines also.

3.3 The objectives of the study will be:

First Phase: Establish corrosivity of atmosphere in different areas and corelate with atmospheric pollution and climatic conditions. For the studies mild steel and zinc as reference will be used and exposed at some selected centres decided on the basis of location and facilities for conducting the tests. Effect of proximity to sea and also the splash zone will be included in the study which will be important for the harbour installations and other dwellings and industries along the cost.

In selection of location meteoroligical and climatic conditions throughout the Philippines will be reviewed. Urban, rural, marine, industrial and industrial + marine areas will be identified. And finally typical 15-20 sites will be selected. As the project would require exposure and removal of panels, collection of climatic and pollution data, more than one organizations will have to be involved in the study. The selection of test sites would therefore have to be based on local organizations who are agreeable to be associated with the project.

Second Phase: Once the corrosivity in different areas are established studies will be undertaken to evaluate some selected coating systems in consultation and association with local paint manufacturers.

4.0 TEST PROCEDURE

4.1 For atmospheric corrosion studies it is essential to carryout field test as it is difficult to simulate the variables in laboratory.

4.2 The tests on mild steel will be conducted by exposing 150 x 100 x 2.5mm mild steel sheet panels and at the end of the test period, the loss in weight and nature of attack will be determined. The loss in weight will be corelated with changes in humidity, temperature, level of pollutant e.g. SO_2, Cl_2, H_2S, chloride, NO_2 dust particles, etc.

Two series of samples will be exposed, one in the beginning of summer i.e. May/June and the second in the beginning of winter, i.e. October/November. The test periods will be of 3 months, 6 months and 1 year for bare metals. The panels will be facing NW direction except in case of sea shore, where it will be facing the coast.

The details of the procedure to be followed for the tests are given in Annexure 'A'.

4.3 The tests on protective coatings will be carried out for two years on galvanized and painted panels. The size of the panels will be 150 x 100 x 2.5mm. The evaluation of painting will be by visual observation.

The detail procedure is given in Annexure 'B'

5.0 FACILITIES REQUIRED

The following facilities will be required.

- Monel, galvanized or wooden racks for fixing specimens.
- Specimens for exposure.
- Weighing balance of 2.0 Kg. capacity with accuracy up to 1.0 mg.
- Arrangement for chemical cleaning (details are in Annexures).
- Arrangement for collecting meteorological and pollution data, e.g. continuous RH and temperature recorder, rainfall gauge, wind direction and velocity recorder, SO_2 and chloride candles, etc.

Annexure 'A'

PROCEDURE FOR CONDUCTING STUDIES ON ATMOSPHERIC CORROSION OF METALS

1.0 Introduction.

1.1 This procedure gives details for conducting studies on atmospheric corrosion of metals. The objective of the tests is to establish the effects of various pollutants in the air and variations in climatic condition on corrosion of different metals. It is envisaged that these tests will help in preparing Corrosion Map of the Philippines.

2.0 Test Specimens.

2.1 The test specimens to be exposed shall be mild steel and zinc for determining corrosivity of atmosphere. Mild steel and zinc will conform to ASTM specifications A-7 and B-69 Type I or II respectively.

2.2 Size of mild steel and zinc specimens will be 150 x 100 x 2.5mm and 150 x 100 x 1.5mm respectively.

2.3 Numbering for identification of specimens shall be made by drilling holes on left and bottom horizontal sides of specimens as specified for the master plate, the sketch of which is given in Fig. 1. The station number will similarly be identified by drilling holes on right hand vertical side of the specimens. The reference hole at top centre will be partly drilled.

3.0 Preparation and Cleaning of Test Specimens.

3.1 The test specimens shall be free from surface scale and surface contaminants like grease and oily matter. The surface will also be given uniform finish for reproducable results.

3.2 Mild steel specimens shall be grit blasted or pickled in inhibited acid for removal of mill scale. After pickling, the surface shall be finished with emery paper No. 0 and degreased with suitable solvent.

3.3 The zinc specimens shall be finished with emery paper No.00 and then degreased with suitable solvent. Light rubbing will be used to avoid deep scratching or embedding of grit on the metal surface.

3.4 All specimens shall be stored in dissicator and weighed before the exposure. Weighing up to an accuracy of 10 mg. for mild steel and 1 mg. for zinc shall be sufficient.

4.0 Exposure of Test Specimens.

4.1 Specimens shall be exposed in racks fitted at suitable locations within e meter of the ground level. While exposure, it is to be ensured that corrosion product of mild steel does not fall on zinc or vice versa. Further the specimens shall be electrically insulated from each other.

4.2 The test racks shall be as per the sketch given in Fig. 2.

4.3 Three sets of samples in duplicate or triplicate will be exposed, one seried in May/June and the second in October/November.

5.0 Assessment of Corrosion.

5.1 The specimens shall be visually examined once every month for nature of corrosion, i.e. nature, distribution and colour of corrosion product. The observations will be recorded.

5.2 One set of specimens from each series will be removed after three, six and twelve months of exposure.

5.3 The specimens after removal will be examined for nature of corrosion product and weighed to determine the change in weight with the corrosion product intact.

5.4 Mild steel specimens shall be cleaned in inhibited 5% sulphuric acid at 60°C with periodic scrubbing under running water with stiff steel wire brush.

Zinc specimens shall be cleaned in 20% chromic acid solution at 80°C or in a 10% trisodium phosphate solution at 85°C. The specimens during cleaning will be periodically taken out and scrubbed under running water with cotton swab.

5.5 After removal of corrosion products, the test specimens shall be weighed and loss in weigh recorded. The rate of corrosion of various samples shall be calculated in m.m. penetration per year as given below:

Original weight (before test)	=	W_1 in gms.
Final weight (after cleaning)	=	W_2 in gms.
Loss in weight, W_3	=	$W_1 - W_2$ in gms.
Area of sample	=	A in cm^2
Period of test	=	p in days
Density of sample	=	d

Corrosion rate in mm penetration per year (mm) =

$$\frac{W_3 \times 365}{A \times p \times d} \times 10$$

Note: d for Zinc = 7.87
d for mild steel = 7.14

5.6 Specimens will also be examined for any localised corrosion i.e., pitting and the number of large pits and maximum pit depths shall be recorded. The pit depth measurement shall be carried out with the help of travelling microscope or a micrometer with a least count of 0.025mm or a pit depth gauge.

6.0 Environmental Records

6.1 For the period of the test, climatic conditions, e.g. daily relative humidity (maximum and minimum), temperature (maximum and minimum) and average wind direction and monthly rainfall will be recorded in the area. Any storms in each month will also be recorded.

6.2 The pollution data recorded at each site will be for level of chloride, SO_2, H_2S, NH_3 and any other chemicals suspected to be present due to the type of industries in any particualr locality.

Annexure 'B'

PROCEDURE FOR CONDUCTING STUDIES ON PERFORMANCE OF PAINT AGAINST ATMOSPHERIC CORROSION

1.0 Introduction.

1.1 This procedure gives details for conducting studies on protective systems to prevent deterioration of metals due to atmospheric corrosion. The objective of the tests is to evaluate performance of different protective systems to help in the selection of paints.

2.0 Test Specimens.

2.1 The test specimens to be exposed shall be painted mild steel panels. Any other metal or alloy will be used only in special cases where such evaluations are needed. In this procedure details of mild steel have been given. For other materials the same procedure will in general be applicable except for some special steps, particular for that system and recommended by the paint manufacturer.

2.2 Size of mild steel, specimens shall be 150 x 100 x 2.5mm.

2.3 Numbering for identification of specimens shall be made by drilling holes on left and bottom horizontal side of specimens as specified for master plate (Fig. 1 in Annexure 1). The station number shall similarly be identified by drilling holes on right hand vertical side of the specimens. All holes will be partially drilled.

3.0 Preparation of Test Specimens.

3.1 The test specimens shall be free from surface scale and surface contaminants like grease and oily matter. The surface will be given a uniform coating with specimen edges well covered up to avoid initiation of failure at these points.

3.2 Specimens shall be grit/sand blasted as a minimum to NACE No. 2 finish, unless otherwise recommended by the coating manufacturer in which case manufacturer's recommendation will be followed.

The NACE Standard is designated as TM-01-70.

3.3 After sand blasting the specimens shall be blown with air (without entrained water droplets) and rubbed with cotton swab to remove any adhering solid particles.

3.4 The specimens shall then be given primer and finishing coats as per manufacturer's recommendations, which will be strictly followed.

3.5 The dry thickness of primer and total paint system will be recorded using elcometer.

3.6 Paint coatings on specimens will be locally damaged using a scriber to determine their passivation characteristic or resistance to underfilm attack. The scribe will be in the form of two 50mm. long scratches to expose the base metal. The position are shown in Fig.B1.

3.7 Half the numbers of specimens will be scribed at the beginning of the test and rest after 6 months exposure.

3.8 All specimens shall be stored in shelter (i.e. in a room) and weighed before exposure. Weighing up to an accuracy of 10 mg. shall be sufficient.

4.0 Exposure of Test Specimens.

4.1 Specimens shall exposed in racks fitted at suitable locations within a meters of the ground level. While exposing it is to ensured that corrosion product of one does not fall on the other. Further the specimens shall be electrically insulated from each other.

4.2 The test racks shall be as per the sketch given in Fig.2 of Annexure A.

4.3 Two sets of samples in quadriplicate will be exposed, one series in May/June and the second in October/November.

5.0 Assessment of Corrosion.

5.1 The specimens shall be visually examined once every month for condition of paint, i.e. degree of rusting, blistering and chalking using guidelines given in ASTM D610, D714 and D1654 respectively.

5.2 One set of specimens from each series will be removed after one and two years of exposure.

5.3 The specimens will then be examined for the following:

a.) Degree of rusting (ASTM D610)

b.) Degree of blistering (ASTM D 714)

c.) Degree of chalking (ASTM D1654)

d.) Extent of underfilm attack

e.) Condition of finishing/primer paint.

f.) Adhesion of paint film around scribe mark.

Note: Any rusting within 1 cm. of edges will be ignored.

5.4 The specimenes shall then be washed under running water and wiped with cotton swab and weighed to determine change in weight.

6.0 Environmental Records.

6.1 For the period of the test, climatic conditions, e.g. daily relative humidity (maximum and minimum) temperature (maximum and minimum) and average wind direction and monthly rainfall will be recorded in the Area. Any storms in each month will also be recorded.

6.2 The pollution data recorded at each site will be level of Chloride, SO_2, H_2S, NH_3, etc.

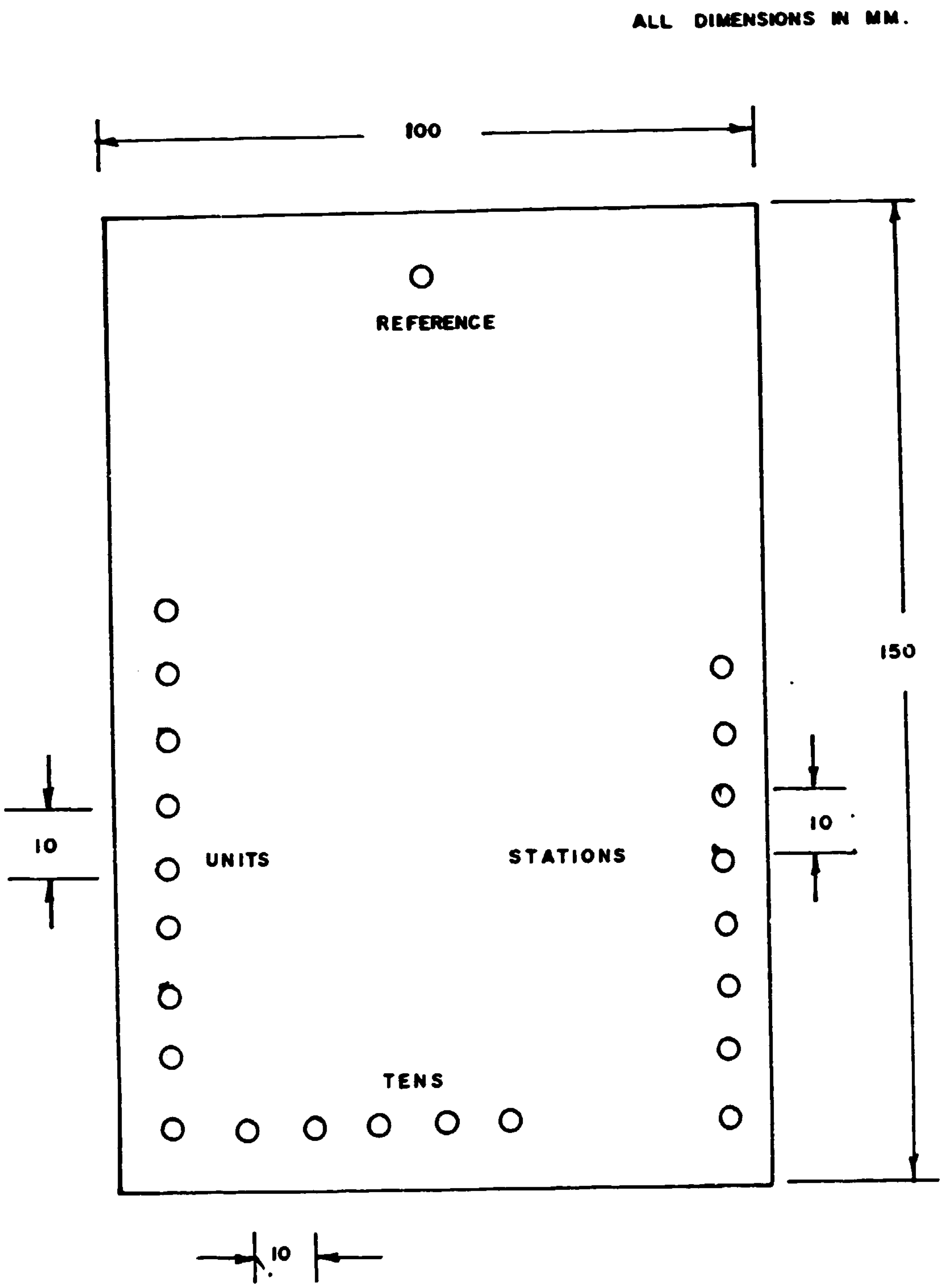


Fig. A1. ATMOSPHERIC CORROSION TEST PANEL (BARE)

All dimensions in mm.

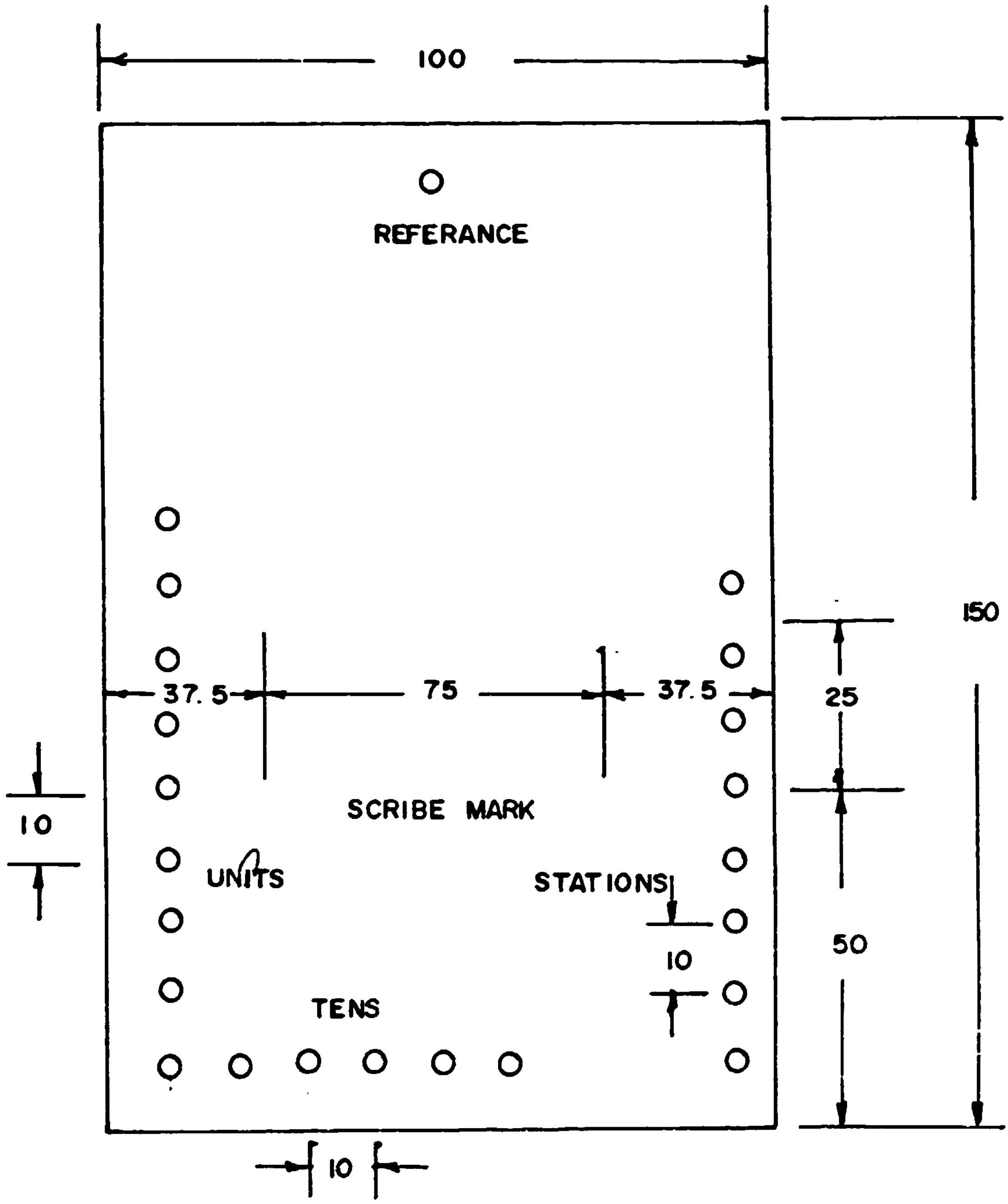


FIG. B1. ATMOSPHERIC CORROSION TEST PANEL (PAINTED)

ANNEXURE 11

OUTLINE OF SCOPE OF SERVICES OF PM GROUP

1.0 PREAMBLE

1.1 The Preventive Maintenance group of the National Engineering Centre of University of the Philippines has been set up with UNDP aid to give consultancy services to the Philippines industries in various aspects of plant maintenance. The objectives of the services are:

- optimizing maintenance cost
- increasing on-stream efficiency
- ensuring continuous improvement in maintenance practices

Maintenance has many facets and include areas like tribology, materials and corrosion, repair and welding techniques, vibration analysis, mechanical design, plant operation, system and organizational approach, etc. Many of the problems are inter-related and the uniqueness of the services provided by NEC is its multidisciplinary and multipersonnel approach through group of consultants having specialization in different areas.

1.2 To make the services practical oriented and to meet the requirements of the industries, the PM group has been equipped with its own field equipment in the areas of inspection, corrosion monitoring, field metallography, vibration analysis, laboratory testing facilities, etc.. NEC is also planning to establish cooperative linkages with ITDI and MIRDC to utilized their facilities as and when required.

1.3 The consultants have undergone extensive training in local industries and abroad and have worked with local and overseas specialists under UNDP assistance. By blending specialist knowledge and experience and through continuous interaction amongst themselves, attending scientific and technical institutions and various in-house groups, the PM group has developed the necessary expertise on maintenance technology to provide intergrated services to Philippine industries.

2.0 SCOPE OF SERVICES

The scope of services will be the following but not necessarily limited to it only.

2.1 Failure Analysis

2.2 Selection and upgrading of construction materials, metallic and non-metallic, to meet the special requirements of the environment.

2.3 Providing details of heat treatment, welding and repair techniques for stationary equipment

2.4 Corrosion control and prevention in

* Industrial cooling water treatment
* Boiler water treatment
* Corrosion inhibition
* Painting coating and linings
* Cathodic and anodic protection
* Corrosion monitoring

2.5 Inspection

* NDT services
* Plant inspection
* Inspection system and organization

2.6 Mechanical Maintenance

* System and organization
* Preventive and predictive maintenance
* Vibration and stress analysis
* Repair techniques
* Spare parts standardization and inventory control procedures
* Tribology

2.7 Training of plant personnel in the various areas of material maintenance

2.8 Undertake long term development projects in association with other organizations in the field of materials maintenance as and when required by the clients

2.9 Build up data bank in the area of materials maintenance

3.0 MANNER OF RENDERING SERVICES

3.1 The PM group provides consultancy services either (i) through a long term contract or (ii) through a specific job contract

3.2 Under long term contract, the PM group will visit the plant on a planned basis-once in 3 months for 2-3 days for a periodic review of problems and give recommendations. For any immediate problems, the clients can approach the group by telephone or letter with the description of the problem. The consultants will be sent at the earliest as receiving the information.

3.3. The specific job contract will be taken up after the problem is referred and the scope of work and financial terms and conditions are approved.