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DEVELOPMENT OF EXPERTISE IN FERTILIZER PLANT OPERATIONS

DP/IND/85/006/11-03

INDIA

Technical Report: Corrosion Control in Fertilizer Industry*
Project Findings and Recommendations

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

Based on the work of J. M. Zawadzki
Expert in Corrosion Control in Chemical Process Industries

Backstopping officer: M. Derrough, Industrial Operations Technology Division

United Nations Industrial Development Organization
Vienna

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CONTENT

	Page
I. ABSTRACT	3
II. INTRODUCTION	4
A. Project Background	4
B. Phasing of the Project.....	5
III. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS...	6
Chapter 1. SHRIRAM FERTILIZERS & CHEMICALS, KOTA.	7
Chapter 2. INDIAN FARMERS FERTILIZER COOPERATIVE LTD., KANDLA	
Chapter 3. IFFCO, KALOL	
Chapter 4. MADRAS FERTILIZERS LIMITED, MADRAS	
Chapter 5. NFL Panipat	
ANNEX I-IV - Counter Partners	
ANNEX V - Steel Structures painting general guidance for IFFCO-KANDLA.	

I. ABSTRACT

Four fertilizer plants producing urea amonium phosphate and potassium chloride (NPK) situated in dry and termide/sea climatic conditions have been analysed for external (atmospheric) and internal corrosion failures.

Steel structures corrosion due to chloride ion deposition and tropical deterioration of paint systems have been stated on exposed structures. Metal surface preparation by sand blasting and water/vapour cleansing has been advised followed by two-pack synthetic resile paint systems. Heat exchangers corrosion, perforation of piping system, ccooling water treatment have been discussed.

II- INTRODUCTION

A. Project Background

Corrosion losses in India are estimated (Rajagopalan K.S.) on 4000 crores annually what amounts approximately 3 billion US dollars. In fertilizer industry, according to National Bureau of Standards and Battele Memorial Institute (1977), corrosion losses are reaching 2.1 dollars level for each 100 dollars output of produced material. Additionally very high cost for building protection and new steel structures (13.1%), maintenance of steel structures and repair due to corrosion (16.2%) have been estimated. Exploitation cost of pumps and pipelines are also very high (11.4%), what is important for fertilizers industry.

Avoidable costs for corrosion protection, selection of proper materials and procedures are estimated to be between 20% and 40% depending on the skill and technological level of industry. Taking into account 3 billion dollars corrosion losses and 20% of avoidable cost level they amounts to 600 million dollars annually for Indian economy, if technical and financial resources will be engaged to lower estimated costs.

The most important corrosion problem for fertilizer industries in India seems to be external (atmospheric and wet corrosion) of steel and concrete structures. It concerns mostly wet humid parts of the country, seaside locations and wet process installations and buildings.

To limit corrosion losses and to give the impact upon technical and financial activities as well as to upgrade existing expertise, UNIDO has defined following duties for expert.

1. To assess the corrosion problems in each of the plants and study the methods that have been used to control corrosion.
2. To study some specific corrosion problems of the plants and make recommendations.

3. To assist the fertilizer units in improving and developing newer techniques of corrosion monitoring and protection.
4. To prepare a final report, based on the findings of the mission, giving the recommendations on further action.

B. Phasing of the Project

After arrival to India, the author and his counterpart Dr.H.Ghosh of Project and Development India Ltd., visited various fertilizer plants to fulfill the requirements of UNDP Project DP/IND/85/006/11-03.

After discussions with Mr. Islam and Mr. Sat Pal from UNDP Office in New Delhi and Mr. J.K. Sondhi G.M., Projects and Development India Ltd., we have proposed a programme of work and basic activities of an expert as a preliminary action plan. The route of visits was realised in the following way:-

1. Shriram Fertilizer & Chemicals, Kota - 21st March to 26th March
2. IFFCO, Kandla - 23th March to 2nd April
3. MFL, Madras - 4th April to 9th April
4. NFL, Ranipat - 11th April to 14 April 1988

During the time of the expert's visit to different factories, Dr. H.Ghosh was assisting in discussing and analysing corrosion problems.

The plant authorities present in each plant are given in Annex.I.

The final report has been prepared, discussed and handed over to UNDP at New Delhi, at the end of the mission.

III. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

1. The technical level of plant staff in corrosion measures concerning internal failures of equipment, piping systems and process equipment is adequate to provide control, maintenance and repair.
2. Painting technology of steel structures, which are in several plants corroded, needs further development and training.
3. It is advisable to elaborate a documentary outputs concerning steel structures corrosion protection by means of paint coatings, metal coatings, duplex systems (metal-paint) for nrw structures and maintenance work.
4. Preliminary guidance for painting steel structures has been elaborated as annex to this report.
5. Sand blasting and water/vapour cleaning are the weak points in maintenance of steel structures by painting in all visited plants.
6. Baked epoxy-phenolic systems for protection heat exchangers are recommended, for replacing stainless steel by carbon steel, sand blasted and painted.
7. Reinforced plastics and poliefskylene or polipropylene should be adopted for tanks and piping systems where applicable, as well as for ducts, fans and ventilation equipment.
8. Weather resistant steel according to ISO 5952 standard should be used for wild corrosive environments and light-gauge steel structures.

1. SHRIRAM FERTILISERS & CHEMICALS : KOTA

The Fertiliser Unit of Shriram Fertilisers & Chemicals, Kota was commissioned in Feb., 1969. The installed Ammonia plant capacity was 450 T/D & Urea plant capacity of 700 T/D. During Fertiliser expansion in Oct., 1974 the plant capacities were increased to 600 T/D Ammonia & 1000 T/D Urea.

The Ammonia plant has been commissioned under the process licence of M/s Haldor Topsøe A/S Denmark with M/s Chiyoda Engineering & Construction Co. Japan as the main plant contractors.

Urea plant was commissioned under the licence of M/s Stamicarbon, The Netherlands.

Captive Power Plant : The captive thermal power generation capacity at SFC is 45 MW (Two units, of 35 MW and 10 MW).

The factory is situated in a central part of India. The climatic conditions are favourable to limit external correction of steel structures and buildings. There are practically no wet processes in production. Ammonia concentration in the air during dry season is very low. In wet season, activity of ammonia due to high humidity is influencing paint coatings of steel structures are in good condition. Aluminium alkyd paint coat is covering steel structures without metal corrosion failures. Technological process of Urea production is conducted already for last 20 years. The engineering staffs are of good technical level. The installations are maintained properly.

We have discussed following problems concerning technological process of production and some troubles existing in the plant.

Additional synthesis water cooler in ammonia plant installed in Feb.1985 after pressure testing and cleaning was perforated (July 1986). Tube material was SS 304L seamless. Chloride content was maintained at 200 ppm and after first leakages appearing the content was reduced to 50 ppm, but

it did not help. The gas temperature is 200°C at inlet and 70°C on outlet. Cooling water from closed circulation system. It was recommended to paint with epoxy-phenolic-high temperature cured sandblasted carbon steel, used as replacement material for SS 304L. Two coats of a epoxy-phenolic primer and three coats of enamel should be used. The total thickness recommended is minimum 200 mikrons. Heating of cooler by means of ammonia converter outlet gas at 200°C for 1 h. Paint supplier should give results of testing paint system durability and examination report. 5 years of coating durability is expected for this type of protection saving SS, water consumption, deposit formation and heat transfer. Microbiological tests for bacteria and fungi are recommended and is a must.

Carbon dioxide compressor cooler in ammonia plant feeded with water from open circulation system with carbon dioxide gas temperatures 150-160°C was installed in 1969. During the last two years tube leakages have occurred in SS 304 steel 2.4 mm thickness. This grade of SS should be replaced by AISI 316L or urea grade which will be better material to sustain corrosion.

Hot potassium carbonate reboiler in ammonia plant undergoes after one year extensive corrosion behind the overlay made from SS 304L. The tubesheet from S-25-C overlaying with SUS 28 was failed. The solution composition was potassium carbonate 30%, DEA 3% and Vanadium pentoxide 0.3-0.4%. Process gas temperature 170°C, solution temperature 118°C. E-Brite 29-1 alloy with C-0.001 and Cr.26.0 was recommended and overlay of tube sheet made from 304L instead of carbon steel (galvanic corrosion).

Air water cooler in compressor compartment (Toshiba) made from copper pipes and baffles was badly perforated probably due to ammonia content in the air. Hot dip tin coating should be applied by immersing in molten tin into leakages on joining surfaces.

Ammonia plant cooling water closed system are controlled as follows: PH 6.5-8.0, total hardness - 80-140 ppm, total phosphate - 20-30 ppm, total solids- 300-600 ppm, free chlorine - not traceable, chloride ion - less than 50 ppm. Biological contaminated cooling water needs organic quarternary amines treatment.

Ammonia plant open water system is controlled as follow: pH 7.0-7.7, chloride - 25 to 35 ppm, conductivity - 700-1400, mOhm/cm .

Urea plant closed water system is controlled as follows: pH 6.5 to 8.0, total hardness 80-140 ppm, total phosphate 15-20 ppm, total solids 300 to 600 ppm, free chlorine not detectable, chloride less than 50 ppm, No corrosion problems have been observed due to water composition variations. General status of water treatment level has been referred and discussed.

Boilers for steam generation/power plant are undergoing atmospheric corrosion during the shutdown period. The reason is dew condensation during the night, accumulation of corrosive dust and water drainage. Volatile vapour phase organic inhibitors like cyclohexamine carbonate in powder form, gas or tablets are recommended. 5 gm. of inhibitor is recommended per 1 cubic meter of space. After treatment all openings should be closed by means of stoppers. Hydrazine solution in water for flushing, with nitrogen over pressure after-treatment, may also be adapted.

Standardisation of corrosion problems have been discussed, some useful standards were selected and handed over to plant personnel.

2. INDIAN FARMERS FERTILISER COOPERATIVE LTD. KANDLA

A. Findings

The Indian Farmers Fertiliser Co-operative Ltd., (IFFCO) operating Kandla Unit is manufacturing NPK and DAP fertilisers. The production amount (Install Capacity) 885 thousand tons per year or 310 thousand tons per year $P_2 O_5$.

IFFCO Kandla Unit is contributing 26% of the countries total production of NPK/DAP fertilisers. Raw materials are imported (Phosphoric Acid Concentrated and Potash), Urea and Ammonia are supplied by IFFCO KALOL Unit.

The Plant was designed and supplied by Hindustan Dorr Oliver Ltd., Ammonia Storage Tank has been designed by UHDE GmbH, Dortmund, Germany.

The Plant is located on the water front adjacent to Kandla Port Trust Oil Jetty. The plant was built at a cost of about 25 Million Dollars (30 Crores Rupees) with two streams producing 3 grades NPK based on DAP. Commercial production started in January, 1975. The capacity of the plant has been doubled at cost of 23 Million Dollars, two more streams have been added (Kandla Phase -II). The commercial production started from September, 1981.

The plant consists of four identical streams. Phosphoric Acid is pumped to a pre-neutralizer and reacted with ammonia to form a boiling slurry containing 80% solids. This slurry is pumped to the granulator where it is further ammoniated and is mixed with dry urea, potash and filler.

The dry rough material and a slurry get thoroughly mixed and granulated in the granulator. The granulated material containing about 2.5% moisture is dried in a rotary dryer and send for screening.

A number of cyclones are provided to collect and recover dust generated. Dust escaping the cyclones alongwith fumes from pre-neutralizer and granulator are scrubbed in four scrubbers with dilute phosphoric acid.

There are phosphoric acid and ammonia storage tanks and as well as urea and filler storage. The corrosive dust is present all over the factory, but the climatic conditions are favourable because of low humidity, low rainfall and long distance from the open sea. In nearby to the factory on a large area crystalline salt is processed by evaporating sea water, storage of rough salt deposit (NaCl) and purification of salt by shuffling salt crystals through out the air.

The following are the main areas of corrosion in IFFCO Plant.

- (1) Steel Structures and equipment, pipe,s ducts, chutes and instruments.
- (2) R.C.C. Structures
- (3) Insulated ammonia pipes and storage tanks
- (4) Phosphoric acid storage and hydrochloric storage tank roofs.
- (5) M.S. Water storage tank.

(1) There are a number of steel structures in the plant like roof - structures in the N.P.K Plant, Old potash storage, structures and gratings for supporting the equipments in scrubbing area, structures in screen house, structures in bagging plant etc. They are corroding due to coastal saline environment (NPK/DAP), Fertiliser dust, acid fumes at selective locations. Maintenance painting has been used to protect steel structures by plainting yearly or once in two years with one of the following plainting systems:

- (a) Surface preparation by sand blasting, application of two coats of epoxy red- oxide/zinc phosphate primer (40-50 Microne per coat) followed by two coats of coal tar epoxy paint (90-100 Microns per coat).

- (b) Wherever sand blasting is not possible the above painting system is followed after preparing the surface by mechanical cleaning and chemical cleaning. Rust convertor compound is also applied on structures before application of primer.
- (c) Surface preparation by sand blasting, application of two coats of zinc rich primer (35-40 Microns per coat) followed by two coats of polyurathane paint (35-40 Microns per coat).

The surface painted with epoxy coal tar system and polyurathane system give satisfactory protection against corrosion, but due to following factors their protection life is found to be low:-

- (a) Mechanical damage of pointed surface during handling.
- (b) Dusty environment due to which dust settles on the surfaces immediately after sand blasting and also after completion of first coat of paint.
- (c) Where ever sand blasting is not feasible, the surface preparation becomes the limitation.

Wherever new structures are erected, the surfaces are painted after fabrication and before erection at site. The problem in such cases is damage of paint during transportation and erection. Also some of the attachments are welded at site. The present practice is to clean such damaged surface mechanically and touch them with the same paints. It has been noticed that paint fails first at these places and weakens the whole structures.

- (2) The causes of corrosion of R.C.C. Structures are the same. At present there is no effective corrosion protection system for super structures and sub- soil structures but IFFCO are considering to apply suitable protective coating on R.C.C. Particularly IFFCO are not yet able to find any suitable remedial action for reducing/protecting the corrosion of sub-soil

structures such as piles/raft foundation etc. Also IFFCO are facing corrosion problem of exposed reinforcement bars in concrete structures.

3. The insulation of ammonia pipe lines and storage tanks was carried out with Thermocole - slabs and pipe-sections, which have joints and allow the moisture to reach upto the metal surface. In order to have better performance of insulation and to avoid corrosion IFFCO are planning to proceed with the PUR insulation system and needs guidelines.
4. Acid fumes come out of the phosphoric acid tank through vent pipes and cause corrosion on the tank roofs. Presently this is being solved by frequently washing of roofs and application of chlorinated painting system.
5. IFFCO are still not able to find a suitable painting system for M.S. water storage tank (drinking water) for application of M.S. surface. Presently IFFCO are applying sand blasting followed by two coats of zinc rich primer and four coats "Asphaltene" finish paint of M/s Bergar paints.

Generally the life time of paint coatings on structural steels in Phos. Acid Storage and handling area is less as compared to that on structural steels in other areas like ammonia, Bagging & Shipping, Postash Storage etc.

Any type/quality of painting applied so far on Ammonia unloading Arm (Oil Jetty) tends to cake, resulting into peeling off of the coating within six months. This allows the exposure of metallic surface of the arm to the saline weather.

B. Recommendations

During the meeting held at IFFCO - KANDLA (see list of participants on ANNEX.II) the recommendations have been given for all questions presented in point)A. Findings).

Because most interested topics were connected with the steel structures protection problem, an ANNEX.III was prepared "Steel structures painting, General guidance for IFFCO - Kandla (see ANNEX.III)

R.C.C. Structures are corroded badly because of traditional design, and lack of experience in exploitation of such type of industrial buildings in chemical process industries. Not in each case the distance between concrete surface and reinforcement is adequate (50 mm). Outside protection should be used by means of epoxy coatings (also Coal tar epoxy) after cleaning of loose material and by means of pressurised washing with vapour. This washing procedure will prolong the durability of buildings after application of resistant anti-corrosive top coating (not primer). For repairing the Polymer cement concrete (PCC) in critical areas. Specialised enterprises should perform this repairs as soon as possible.

Insulated ammonia Storage tanks and pipes. should be protected by one of following systems:-

Urethane primer (2 coats -70 um) after sandblasting (see ANNEX.III) for proper sandblasting requirements), followed by urethane foam application and final coating by means of butyl cautchuck composition (e.g. ESSO - VAPALONE) in 500 um coat. Isolation thickness should be calculated (often about 40 mm of PUR foaming with $d = 35$ to 50 kg/m^3).

Another way is an aluminium metal coat sprayed in 200 um thickness onto sandblasted to 3 Grade steel surface and sealed by low viscosity (10 s. Ford No.4) urethane primer, Foam application as given before. Metal spraying should be performed by one experienced enterprise in this kind of activities, otherwise no adhesion of aluminium coat would be guaranteed.

Phosphoric Acid storage and hydrochloric acid storage tank Roofs should be protected after carefully washing with water/vapour jet, by means of alkyd or epoxy ester aluminium paint because of high temperatures of roof surfaces and dew formation in the night on this horizontally situated surfaces. Also when sand blasting is not possible, suitable penetrating primer should be advised by producer of top coat and primer suitable for hand cleaned surfaces. Two coats of primer and three coats of aluminium paint are necessary (min.150 um coat system thickness). One must take into consideration that roof temperature may be 30°C higher than air temperature during wind - free periods. Ethyl silicate zinc primer is advised when sandblasting would be possible during dismantling of the roof, followed by two aluminium pigmented urethane coatings (150 - 200 um total thickness).

M.S. Water Storage Tank. should be protected after sandblasting with zinc primer (two coats) PUR, EP (amide hardner) or ethyle silicate. The top coat should be selected from those available in India (non-toxic and tasteless) solventless epoxides are also suitable.

The solution of Ammonia Unloading Arm (Oil Jetty) Corrosion problems should be performed after testing recommended materials Phenolics, S.S. 316, PUR coatings on Al sprayed underlayer (200 up) as well as ethylsilicate zinc primer + PUR system of top coatings should be checked.

The Salt Fields surrounding the IFPCO Plant are one of the main factors influencing corrosion processes.

IFFCO : KALOL

A. Findings

The IFFCO KALOL Unit producing ammonia and urea and is experiencing some corrosion problems in different section of the plants. They are :-

1. Corrosion of CO₂ lines after the separator and coolers and corrosion of inter stage separators. (Urea Plant)
2. High pressure strippers: (urea plant)

The tubes of the stripper at the bottom portion and outlet line at the bend are getting corroded.

Shell side : Steam,
pressure 18-19 kg/cm²
Tube side : (liquid + gas)
Pressure 140 - 150 kg/cm²
temperatures - 170 - 180°C.

Material of construction - AISI 316 S.S.

3. High pressure condensor. (Urea Plant)

The AISI 316 S.S. tubes are getting corroded. The condition of the condensor are given below:

Shell side - steam (Pressure 3.5. kg)
Tube side - pressure 140-150 kg/cm²
Temperature - 165 - 170 °C.

4. Furnace side tubes of 60 ata steam boiler are getting corroded and leaked.

5. Concrete structures of prilling tower walls (top and bottom) Silo walls, bagging plant hoppers and floors are getting by urea dust.

6. In secticides plant: All vessels, columns, pumps and lines are heavily corroded.

b. Recommendation.

In all the corrosion cases mentioned are without details informations pertaining to the corrosion failure such as history of failure, material of construction, (in some cases) process parameter, process fluctuation if any, remedial measures taken and their evaluation etc. In view of this it is proposed that P-DIL should be contacted for detailed investigation of such problems. It is quite likely that some metrallurgical tests, together with scale/deposit analysis will be necessary. A general recommendation can however be given:-

High press strippere and condensors.

Material equivalent to sandivik 2 RE 69 may be tried.

Interstage coolers and separators.

The corrosion might be from cooling water side, and in case of Co2 leakage the corrosion of steel would be further aggravated.

Furnace tube failure:

Water quality is to be checked. Failed tube portion must be analysed for deposits and metrallurgical change.

Concrete structures.

The problem needs site inspection and after that suitable costing may be recommended. Insecticide plant component. It needs detailed study at site.

MADRAS FERTILIZERS LIMITED

A. FINDINGS

Madras Fertilizers Limited is a Public Sector organisation situated at Manali, Madras (Tamilnadu). The open sea is only four kilo meters from the factory. MFL have 750 tonnes per day ammonia plant and a 885 tonnes per day urea plant. MFL also have a three trains of NPK plant. MFL also have a three trains of NPK plant with a capacity of 1650 tonnes per day. The annual capacity in terms of saleable products is 153,000 tonnes of urea and 540,000 tonnes of NPK fertilizers.

The ammonia plant is of "Chemico" design using the naphtha- steam reformation route. Naphtha is obtained from the Madras Refineries Limited plant located nearby. Urea is manufactured by Chemico total recycle process. All the three units of NPK plant are designed and built by Dorr Oliver. The units are identical except that in one TVA granulation unit, while in others blunger units are used. The plant has been commissioned in 1970 with small expansion. The task force report dealing with maintenance procedures have been prepared in March 1979. Turn around inspection reports are properly documented (1980 - 1982, 1984-1985, 1986-87).

AMMONIA PLANT

1. Rust is carried over from naphtha tanks (C.S) to reformer burner causing blocking of burner nozzles.
2. L.T.bypass valve (C.S.) is undergoing corrosion cracking on the valve spindles.
3. Carbon-di-oxide absorber 1st bed is corroded on the shell side (C.S.). The incoming gas (H₂ 54%, CO₂ 20%, CO 2.3%, CH₄ 0.4%, N₂ 21% H₂O (V)) at 202 -217 Deg C and 27 Kg/cm² pressure is absorbed in "Catacarb" solution for CO₂ removal (Vanadium pentoxide and borate are used at present).
4. Carbon-di-oxide overhead condenser shell (C.S.) undergoes general corrosion.

5. Methanation heat exchanger (C.S) get corroded. This is a gas to gas heat exchanger. The incoming gas containing CO₂ and CO at 150 Deg C in the shell side is exchanged with methanator outlet gas at 343 Deg C in the tube side. Most of the failures were located at the tube to tube sheet joint.
6. External corrosion of pipings & structures (C.S) by prill dust, NPK dust, SO₂ and moisture are generally observed.

N P K PLANT

- 1 Corrosion of steel structures by NPK dust are generally observed.
- 2 Deterioration/cracking of concrete structures by NPK/prill dust is allocated in supporting structures.
- 3 Deterioration of concrete structures, conveyors and elevators in KCl handling are observed.
- 4 Fans and ducts (C.S) tubes goes erosion/corrosion by NPK dust.
5. Phosphoric acide corrosion of tanker baffles (SS 316 L) has been stated after 10 years of service.

UREA PLANT

- 1 Prill tower concrete is degraded by prill dust
- 2 SCC of SS piping under insulation by Cl pick up is observed

PLANT UTILITIES

- 1 SO₂ corrosion of carbon steel structures in the boiler vicinity has been stated.
- 2 I.D. fan (C.S) has a deposits/erosion problem.
- 3 Fiber reinforced plastics used for HCl handling goes on cracking.
- 4 Corrosion of C.S. structural steel from HCl fumes are observed.

- 5 Corrosion of cross country pipeline (C.S) from cooling water spray from cooling tower fan is observed.

POTASH STORAGE (KCl)

The potash storage is in very bad condition. Most of the columns have cracked exposing reinforcement. The support channels for electrical cables have collapsed. The potash storage needs extensive repair.

UREA PRILLING TOWER

Some circumferential cracks on the RCC structure on the outside were noticed. The metal structure including stairs are badly corroded (for replacement).

CROSS COUNTRY PIPELINE

CO2 Pipeline badly pitted.

The concrete or naphtha pipeline found cracked and broken at number of places. Service water pipeline was corroded badly by plate-rust 2.0 mm thick under the paint coat.

UREA/NPK STEEL STRUCTURES

During inspection of external corrosion and paint coating failures following structures have been found badly corroded and needs replacement or repainting. Vent like silencer supports, platform supports, reactor outlet line and supports, platform supports at different elevations, platform on east side, ammonia storage tank supports, main vertical supports in compressor house and cross supports, staircase structures, horizontal supports close to evaporators, leg-valve platform angle supports, vent stack supports, entry platform to lift, platform at nozzle floors, water hose supports roof supporting structures in storages areas. Engineering Inspection staff have prepared suitable documentary output (inspection report) for further action.

B. RECOMMENDATIONS

1. Heat Exchangers

It is suggested to paint carbon steel (M.S) exchanger tubes replacing S.S. tubes as well as shell side of exchangers using a epoxide-phenolic baked primer, two coats, and 2 top coats baked 180 Deg C. The system is (4 coats) of total thickness approximately 200 um. It will also control algae growth and deposit/scale formation. It is suggested to cooperate in this subject with some petroleum plant (refinery) in Madras. Sand blasting to grade 3 (SIS) is necessary. Roughness of the surface should be 40 - 60 nm. No sand dust is accepted in the abressive.

2. Tank Protection

Red oxide (Fe) epoxy primer should be used after sand blasting of new tank for naphtha feeding reformer burner. The deposits from old tank should be analysed for Zn and Fe, do to possibly of low adhesion of zinc epoxy primer and transporting deposits through filter to the burner. Cathodic protection applied by specialised firms is advised.

3. External Corrosion of piping & structures

a) Piping should be repainted after washing with water (condensate) or water/vapour jet by means of pressurized equipment. Before painting - sand blasting is necessary for synthetic paints like chlorinated rubber, epoxy, coaltar epoxy, urethane. For alkyd primers, when penetrating agent is present, mechanical surface cleaning by pressurised tools are advisable.

For long term protection Al or Zn spraying with paint sealer is recommended. Before application of thermal insulation, sand blasting is necessary with urethane primer & urethane top coat protection of steel. Corrosivity of insulation

material (mineral wool) should be checked, what is of importance not only in the case of mild steel but also S.S (ASTM). Urethane foaming insulation needs outside protection by suitable sealer paint (butyl rubber) of 0.5. mm thickness. Chloride containing insulation materials are prohibit for SS piping.

Steel structures like tanks and heavy steel girders are washed with water vapour jet. sand blasted with air and primed instantly, when painted. On next day water/vapour cleaning is advised before priming. Time of painting is 6.00 - 10.00 a.m. and 3.00 - 6.00 p.m. Surface temperature not exceeding 40 Deg C during sunny weather periods. Surface temperature is about 30 Deg C higher than air temperature between 10.00 a.m. and 3.00 p.m. Fast drying of paint coat stops paint flow and adhesion, lowering paint system durability. Water/vapour cleaning with condensate water to make all salt contamination soluble. After drying (maximum 15 minutes) priming is necessary. Steel structures made from light gauge steel profiles should be maintained by mechanical cleaning with air powered tools followed by water/vapour jet cleaning. Penetrating primer based on alkyd/phenolic resins may be used (2 coats) followed by 2 coats of alkyd or chlorinated rubber epoxy with top coat. Aluminium paints and iron oxide paints should be used.

The essential requirements is freedom of salt/acid/potash impurities on steel surface before priming and painting of steel structures when surface temperatures are below 40 Deg C. The limited temperature for exposure chlorinated rubber coats is about 70 Deg C. The radiation is limiting the use of epoxy coating as only suitable for internal environments. These 2 pack epoxy paints when exposed out doors are loosing the protective value very soon (1-2 year). The coat should be protected by means of urethane top coat when applied outside especially on roofs as the most suitable for fertilizer plant. Ethyl Silicate (2 pack) primer should be recommended with urethane inner and top coats (300 microns). Electro magnetic non destructive

thickness tester for paint coatings on blasted steel should be used.

4 Deposit of potassium compound is often causing corrosion in the installation beyond secondary reformer. Potassium compound from the primary reformer catalyst along with potassium compounds in the temperature of 300-400 Deg C are causing corrosive attack on carbon steel components towards the lower temperature limits. These compounds would lead to alkaline condition during condensation of water vapour present the gas. The highly alkaline condition at the existing gas temperature can cause stress corrosion cracking of stressed component of the valve, e.g. spindle, etc. Duplex stainless steel valve of the type Ferralium Alloy 255 or equivalent can be tried to avoid S.C.C.

5 In carbon-di-oxide removal system carbon steel is subjected to corrosion attack in presence of hot aqueous solution of CO₂ in K₂CO₃ and amine. Other absorbants present in the 'catacarb' solution and higher stream velocity would accelerate the corrosion rate. Material of the type Sandvik 2RE69 (C 0.02, Cr. 25, Ni 22, Mo 2.1, N 0.12) has solved corrosion problem in CO₂ removal system and the same may be tried in the plant.

6 The corrosion of the overhead condenser may be due to the condensation of CO₂ in water making the solution acidic to react with carbon steel. However, detailed indepth investigation is needed to solve the problem.

7 The corrosion problems faced in the methanation heat exchanger is due to the carry over of "catacarb" solution along with the gas stream (at 150 Deg C and 26 Kg/Cm² pressure) on the shell side. The tube to tube sheet joint of the methanator outlet (343 Deg C) being the most vulnerable zone is attacked by the "catacarb" solution. Suitable SS corrosion resistance material may be a probable solution, but possibility of stoppage of "catacarb" carry over at the source point would be a better proposition.

The corrosion of naphtha pipeline was originally of 5 Cr, 1/2 Mo, steel which have now been replaced by AISI 321 SS pipeline and no corrosion is observed at present.

8 Regarding preservation of exchanger/condenser tubing during shut down, it is recommended that the exchangers and condensers are to be filled up preferably with D.M. water with cyclohexylamine or hydrazine as oxygen scavenger and the system is to be plugged.

PDIL has facilities to monitor on stream corrosion rate for cooling water system.

C. REPAINTING OF BADLY CORRODED STEEL ELEMENTS

In case areas and buildings light gauge steel elements are corroded in a very large extent. Rusting is observed with crevices and plate rust. There is a danger of hydrogen embrittlement and stress corrosion cracking, when the girder is under the stress (generally horizontally situated profiles). After hammering and scrapping followed lby brushing, the designer should decide if inspected part is recommended for replacement or repainting. Generally badly corroded elements are not easily cleaned up, even by sand blasting, and needs replacement. Paint coat durability will not be achieved, lasting only 2 to 3 years. Support rails, barriers, steps and gratings should be replaced with new, zinc coated hot dip galvanised and polyurethane paints, from safety point of view. Bolts and nuts should be replaced with hot dip galvanized and epoxy coal tar painted before installation.

Atmospheric corrosion of carbon steel structural quality is highly increased by chloride ions (from potassium chloride, sodium chloride and magnesium chloride) occuring in MFL as fog, powder or mist. Chloride ions are responsible for beta-FeOOH formation leading to magnetite formation, crevice corrosion and plate rust. Embrittlement of steel and loss of their ductility are the main contributing factors of failures during windy periods of the year.

Inspecting steel elements only by measuring thickness is not adequate, because of hydrogen embrittlement of M.S. when exposed to certain environment e.g. acidic. Complete metallurgical testing should be performed for estimating important steel parameters in laboratory conditions. Steel elements must be cleaned by sand blasting (not pickling). Yield strength of steel and hardness are important parameters for further decisions (repainting or replacement).

NATIONAL FERTILIZERS LIMITED
PANIPAT.

A. FINDINGS.

Ammonia Plant is designed to produce 900 Tc/Day ammonia based on partial oxidation of Residual fuel oil/LSHS by SHELL GASIFICATION process at a pressure of $55\text{kg}/\text{cm}^2\text{G}$. The Plant is laid out in single stream except for the three gasification units. The unreacted carbon from gasification section equivalent to 1.5% of feed-stock is obtained as carbon water and treated in Carbon Recovery Section. Carbon is recycled back alongwith feed stock and the rest is burnt as fuel in Auxiliary boilers. Waste heat from gasification section is utilised in generating $105\text{kg}/\text{cm}^2\text{G}$ steam in Waste Heat Boilers.

The raw synthesis gas is further processed for H_2S and CO_2 removal in the different stages by low temperature RECTISOL PROCESS. Before CO_2 removal shift conversion is employed using HT catalyst. The waste heat from shift conversion is used partly in absorption refrigeration unit for Rectisol Section and partly for generating low pressure steam. The CO_2 removed in this section is sent to Urea Plant.

After CO_2 removal, decarbonated gas is sent to Nitrogen wash unit where it is scrubbed with liquid nitrogen at (-190°C) and $38\text{ kg}/\text{cm}^2\text{G}$ pressure to remove carbon monoxide and methane as tail gas.

After purification in nitrogen wash unit, the synthesis gas is compressed to $230\text{kg}/\text{cm}^2\text{G}$ and ammonia synthesis is carried out in HALDOR TOPSOE loop employing radial flow convertor.

The Oxygen requirement for partial oxidation in gasification process, nitrogen requirement for synthesis gas and utility nitrogen, liquid nitrogen are produced in an air separation plant having a capacity to process $1,34,400\text{ Nm}^3/\text{hr}$. of feed air. Air separation and nitrogen wash unit are supplied by M/s BHPV, India with collaboration of M/s Air Liquide, France.

Urea Plant is designed to produce 1550 tonnes/day urea, based on MITSUI-TOASU TOTAL RECYCLE "C" IMPROVED PROCESS. Ammonia and CO_2 are compressed to a pressure of 250 atmosphere and allowed to react inside a Titanium lined reactor at about 200°C . 30% Urea is produced at the exit of the reactor. The unreacted ammonia and CO_2 are removed in the down stream purification section. The 30% urea solution obtained is further concentrated in three stages; the last being at - 660mm Hg Vacuum in the crystallizer. In the crystallizer about 70% crystals are formed. The crystals are centrifuged and conveyed to the prilling tower top at a height of about 68 meters. The urea crystals are melted and sprayed in the prilling tower.

Following questions are to be discussed:

1. How to protect RCC surface in dust chamber of prilling tower from urea solution? At present, solution free epoxy coating is done every year. This is a time consuming job and due to limited period available during annual turn around, the job is not executed as per standard specifications. We would like you to suggest a system which can be executed in shorter period.
2. How to protect floor in the prilling tower from urea solution attack? Is there any protective coating material which can be executed on wet surface?
3. Is there any additive which can make the concrete while casting, resistance to urea solution?
4. How to protect asbestos sheets from the urea dust attack on economical cost? Is replacement the only solution?
5. How to protect floors of bagging plant when urea is stored.
6. In D.M. Plant the drains carrying regenerated effluents containing dilute sulphuric acid and caustic solution get cracked/damaged with the result the foundations and floors are getting damaged or corroded. Is there any material for coating the drains for their protection from dilute sulphuric acid and caustic solution? After damage to the drains we have laid HOP pipelines in the trenches alongwith the troughs

made of PVC sheets, but again due to the leakages from the PVC, Acid and Alkali is getting into the floor.

7. Is there any moist chlorine resistant paint for steel structure and the equipments?

8. Erosion/corrosion is occurring in the pipes and pipe-fittings in the ash disposal system. The material of piping and pipe fittings is mild steel, is there any alternate material which can be used in place of existing nickel hard cast iron/M.S. material.

9. In Gasification section pipes thickness down stream of Waste Heat Boiler got reduced from 12 mm to 3 mm in a period of about 10 years plant operation. The material of piping is 0.5 Mo. Is there any other alternate material which can replace the existing material? The gas contains carbon particles, H_2S etc. The temperature varies from $318^{\circ}C$ - $144^{\circ}C$. The gas analysis is as under:

CO_2 5.52%, CO 48.12%, H_2 44.22%, CH_4 0.50%, N_2 0.28%,
 A_2 0.55%, H_2S 0.7%, COS 0.04%.

10. There is corrosion in Methanol-water rectifier. This tower is part of the Rectisol absorber. The distillation of about $3M^3/hr$. methanol is carried out to maintain methanol purity. Besides water-methanol also contains H_2S and HCN in small quantities. The pH of the bottom product² is around 5. The tower, shell and trays are of carbon steel. Heavy corrosion has been observed at the lower portion of the tower.

11. Fouling and corrosion in lean/semi-lean methanol heat exchangers has been observed. There are six number of heat exchangers in series, the process parameters are as under:

	<u>Shell side.</u>	<u>Tube side.</u>
Process Fluid.	Lean Methanol.	Loaded methanol.
Analysis:	Methanol 98% H_2S \angle 5mg/L.	Methanol 98% H_2S \angle 10gms/L.
	Total sulphur. \angle 1 gm/L.	HCN 1ppm.
	Rest Water.	Rest water.
Operating Temps.in/out- $^{\circ}C$.	96/-20	-33.5/88
Operating Pr.in/ H^2G	25	28

Materials of construction are carbon steel.

<u>Design Temp.</u>	<u>Shell.</u>	<u>Tube.</u>
H.Exch.A	-30°C	-45°C.
H.Exch.B	150°C	-11°C.
H.Exch.C,D,E,F.	150°C	120°C.

Tube leakages have been observed in the exchangers C,E,F after about 4 years of operation.

12. Corrosion in Air Compressor inter-cooler.

Heavy fouling and corrosion has been observed in the Air Compressor inter-cooler, on air side. The pressure drop has increased from 0.1k/Cm² to 0.7k/Cm² within an operation of about 24 months. Both shell and tubes are of carbon steel. The fouling is mostly on the cold ends where the water in the air gets condensed.

13. Is there any anti-corrosive paint which can be used for the pipings and valves in order to avoid a corrosion due to atmosphere containing H₂S? The temperature in the pipelines and pipe fittings is as low as - 70°C.

14. Steel structures coming in contact with urea dust are painted with epoxy base paints, but the paints get spoiled within 6 months. Is there any better paint or protective method which can keep the steel structure in good condition?

15. The atmosphere in the cooling tower is always humid and carry lot of water vapours. Is there any paint which can be used on the steel structures and equipments under wet conditions?

16. Corrosion of carbon steel jacket of first-stage Kobe Compressor in Urea Plant for carbon dioxide. The steel plates get corroded by cooling water after one year of service. The gas temperature is 140°C.

17. Thrust-shoe (white metal) of Kobe Compressor gets corroded after one year service.

B--RECOMMENDATIONS.

1. Solventless epoxy is suitable only after water/steam high pressure cleaning and drying of intact concrete surface. Fluorosilicate treatment is advised for sealing.
2. The floor should be made by specialised firm. The ceramic material should be bounded and sealed at surface. The floor must be resistant to external mechanical damage.
3. Good results have been obtained by means of Fluorosilicate treatment or oxalic acid(10%) sealing after washing with water/steam with high pressure jet cleaning equipment.
4. Asbestos sheets should be replaced by corrugated sheets covered with Zn/acrylic coating.
5. Ceramic material sealed with synthetic putty (Habenite type) should be applied by specialized firms.
6. The main problem in protecting floors and foundations is not only acid resistant material but sealing compound (Habenite type) resistant against both alkali and acid. In some cases hot applied asphaltic mastics with inert pigment and PVC sheets are suitable.
7. Vinyl coatings(250 μ m) are resistant against chlorine and water on steel structures.
8. Failure mechanism should be studied on piping material before replacement. The recommendations from the supplier of the material may be adopted.
9. ^{Ten years} ~~Five~~ operating period should be generally accepted under aggressive corrosive environment. Duplex steel for such services can be tried.
10. The corrosion is due to the acidic conditions in the Methanol/water rectifier. Injection of some alkaline media is recommended to improve the pH. Morpholine or imidazole can be tried.
11. The corrosion of carbon steel tubes in lean/semi-lean Methanol heat exchangers is due to the corrosive ingredients such as H_2S , HCN , COS etc. alongwith moisture present in the gas. Some corrosion resistant stainless steel can be tried as a suitable material.

12. The deposit analysis should be made to estimate if the dust contains Fe and organic material (fouling). Air filtration should be checked. Application of baked phenolic epoxy paint (Sakaphene type) 200 μm at 180°C (baking temperature during one hour for each coat) reduce wet corrosion accelerated by Sulphur Dioxide.

13. Urethane paints baked or two-pack, after metal preparation by sand blasting are recommended. Aluminium sprayed metal coating of 200 μm thickness with sealer compounds is also suitable for valves working in low temperatures.

14. Painting technology should be improved according to the supplier's recommendations and standards (DIN, ISI).

15. Shields should be applied during painting. Water emulsion paints are sometimes suitable when properly used.

16. Aluminium metal spray coat thickness 200 microns after sand blasting followed by epoxide two-pack sealer of low viscosity (10 Sec. on Ford cup No.4) will be suitable.

17. The corrosion of thrust shoe appears to be fretting type or selective corrosion. However, further study is advised. Metallographical analysis, lubricating oil analysis should be carried out. Replacement of oil should be performed after shorter duration. Possibly Cd electro-plating (12 microns) on the thrust shoe may reduce corrosion.

NDT lab. at Panipat is adequately equipped to tackle all the inspection jobs of the plant. However, inspection by Fibroscope should have camera attachment. Chemical Lab. is doing analysis by corrosion test coupons which is not sufficient for determining the type of corrosion. It is recommended that surface profile testing method to be adopted for detecting the rate and type of corrosion. Instrument like Profilemeter (Taylor-Bobson) would serve the purpose.

COUNTER PARTNERS

1. Projects & Development India Ltd.

- Mr. J.K. Sondhi - General Manager
- Dr. H. Ghosh - Dy. Superintendent (R & D)
- Dr. B.N. Singh - M.Sc.D.PHIL., Asstt. Manager

2. Shriram Fertilisers & Chemicals, Kota

- Mr. I. Ghosh - A.G.M. (Fert.)
- Dr. A.C. Mathew - Works Manager
- Mr. Chaman Lal Gupta - Sr. Development Engineer (Tech.)
- Mr. S.N. Aeri - Plant Manager (Ammonia)
- Mr. K.K. Kaul - Jt. Manager (Ammonia)
- Dr. N.J. Singh - Addl. Plant Supdt. (Pollution Control)
- Dr. A.M. Komarwar - Addl. Plant Supdt. (Pollution Control)
- Mr. S. Sainoni - Asstt. Plant Supdt. (R & D)
- Mr. Vikram Singh - Asstt. Engineer (R & D)
- Mr. B. Krishnan - Asstt. Engineer (R & D)
- Mr. B.K. Agarwal - Mech. Engr. (C.E.(F))
- Mr. R. Bhatia - Asstt. Engineer (C.E.(F))
- Mr. S.K. Sharma - Asstt. Lab. Supdt. (Ammonia/Urea Lab.)

IFFCO - KALOL

Following Officers participated in the meetings

1.	Mr. J.P. Singh	General Manager
2.	Mr. J.M. Saxena	Manager(Technical)
3.	Mr. Y.L. Mehta	Manager(Production)
4.	Mr. B.M. Sonani	Manager(Maintenance)
5.	Mr. A.S. Parmar	Supdt.(Offsites)
6.	Mr. R.R. Kartha	Supdt.(Dredging)
7.	Mr. S.K. Mishra	Supdt.(Mech.)
8.	Mr. J.M. Patel	Supdt.(IPM)
9.	Mr. J.S. Pachter	Supdt.(Civil)
10.	Mr. S. Sampati Rao	Supdt.(Elect.)
11.	Mr. S.P. Yadav	Supdt.(Gen.Engg.)
12.	Mr. D.M. Seetharaman	Sr.Shift Engineer
13.	Mr. K. Ramachandran	Supdt.(Laboratory)
14.	Mr. P.P. Shaunkani	Asstt. Manager(Transportation)
15.	Mr. R.P. Dubey	Civil Engineer
16.	Mr. S.H. Chaudhary	Sr.Training Officer.
17.	Mr. R.M. Mankodi	Mechanical Engineer
18.	Mr. Y.P. Vansia	Supdt.(P & S)
19.	Mr. H.S. Ladkani	Civil Engineer
20.	Mr. A.J. Margabandhu	Process Engineer
21.	Mr. D. Prasad	Asstt. Engineer

IFFCO : KALOL

1.	Mr. H.D. Desai	Shift Engineer (Jrea)
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ANNEX III

LIST OF PARTICIPANTS FROM MADRAS FERTILIZERS LIMITED,
MANALI, MADRAS 600 068

L VASUDEV	CHAIRMAN & MANAGING DIRECTOR
K R KRISHNASWAMI	GENERAL MANAGER
K KASTHURI RANGAN	DY GENERAL MANAGER (PROJECTS)
K M RAO	DY GENERAL MANAGER (MAT. MGT)
T C PITCHAPPAN	DY GENERAL MANAGER (TECH)
V NAMDIRAYAN	DY GENERAL MANAGER (MECH)
JACOB EAPEN	DY GENERAL MANAGER (OPTN)
K V RAJAGOPALAN	MANAGER - ENGG & INSPN
B RANGAIAH	MANAGER - FIELD MAINTENANCE
K P SUBRAMANIAN	PLANT MAINTENANCE MANAGER - PLANNING
S RANGANATHAN	PLANT INSPECTION MANAGER
P P SUBRAMANIAN	ASST MANAGER - INSPECTION
N E SRIDHARAN	ASST MANAGER - INSPECTION
S KARTHIKEYAN	ASST MANAGER - PROCESS
D RAGHU	SR INSPECTION ENGINEER
P HARAN	SR INSPECTION ENGINEER

NATIONAL FERTILIZERS LIMITED
RAIPUR UNIT.

The following officers participated in the discussions:

- | | | |
|-----|-------------------|----------------------|
| 1. | Mr. Y.K.Talwar. | General Manager. |
| 2. | Mr.N.J.Dudhe. | Manager (T.S). |
| 3. | Mr.S.C.Kashyap. | Manager (Prod.). |
| 4. | Mr.V.M.V.Muthu. | Manager (Projects). |
| 5. | Mr. M.K.Varshney. | Adcl.Mgr. (Mech). |
| 6. | Mr.S.L.Bhargwaj. | Dy.Manager (PE). |
| 7. | Mr.S.N.Soneja. | Dy.Manager (GE). |
| 8. | Mr.Dilbag Singh. | Chief Chemist. |
| 9. | Mr. P.K.Bansal. | Dy. Manager (Civil). |
| 10. | Mr.N.S.Mothshara. | Asstt.Manager (GE). |
| 11. | Mr. S.K.Goel. | Asstt.Manager (PE). |
| 12. | Mr.M.L.Dua. | Asstt.Chief Chemist. |
| 13. | Mr. A.D.Arya. | Engr. (Civil). |

Mr. I.K.Suri, G.M.(Tech) has provided all the informations pertaining to corrosion control practice and other inspection (NIT) method which are in practice in NFL Units. He also highlighted the inter unit technical exchange programme which benefits the process and maintenance personnels.

STEEL STRUCTURES PART 3
GENERAL GUIDANCE FOR DESIGN - CORROSION.

1. PLANNING OF WORK.

One of the prerequisites for efficient use of equipment and steel work is systematic planning of corrosion related maintenance and repair.

The first and most important is maintenance prevention starting at the design and purchase stages through change of design and material.

Predictive maintenance is essential to understand the functioning of production equipment under local conditions leading sooner or later to the need for repair and replacement. The problem does not lie only in the actual repair operations, but also in the planning and managerial activities.

Long - term planning is a mean of over - coming maintenance difficulties and avoiding corrosion related emergency repairs. Maintenance planning and prevention eliminates the maintenance work as much as possible.

All aspects of the work involved in the protection of steel structures against corrosion must be considered at an early stage in the development and planning on a project sheet flow - charts. This includes all the steps from the delivery of the materials to the fabricating shop to the completion of the work on site, together with subsequent inspection and maintenance (table 1 and 2).

In tender notices and contracts the protective system should be specified in full at the time of enquiry, and the contractors should be nominated, preferably from approved lists, both the painting subcontractor and the supplier of the paints covered in the tender.

2. EXPOSURE CONDITIONS.

The corrosive conditions surrounding steel work in fertilizer plant fall into three broad categories :-

- (1) Highly corrosive conditions. The atmosphere is polluted by dust and chemicals as NaCl , H_3PO_4 , $(\text{NH}_4)_2\text{HPO}_4$, KCl , Ammonia gas.
- (2) Industrial conditions.
- (3) Mildly corrosive conditions. Administrative buildings and mechanical workshops are usually located in area belonging to this category.

The sun radiation is one of more aggressive deterioration agents due temperatures involved, decomposition and oxidation of paint coat vehicle and pigments.

Dew formation at early morning on flat, horizontally situated painted metal surfaces leads to solubilization of corrosive deposits and electrolyte formation. Thin and concentrated electrolyte film penetrates paint system at temperatures $20 - 60^\circ\text{C}$. during morning hours. The pH of this film estimated by means of indicator paper may be alkaline (7-12) or acidic (3-7). Both are harmful for paint coat and metal.

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The life of a protective coating will seldom be the same all over a structure, because of local variations in corrosivity and exposed conditions. There may be differences between the sunny and shady sides, or between parts exposed horizontally and those that are not. Wind direction is important when evaluating aggressivity of environment (sea - side , acid fumes source, water - fog).

5. PAINT SELECTION.

It is advisable to obtain all the paints from the same supplier, from whom assurances should be obtained. Finishing coats should be highly impermeable to moisture and gases, and should have good resistance to the chemical environment.

Lamellar pigments such as micaceous iron oxide, and aluminium leafing pigment reduces the permeability of the film and retarding chemical degradation by sunlight. Red iron oxide and titanium dioxide are generally accepted for chemical environment paints but zinc oxide pigment is less suitable for use in chemical environments. Zinc - pigment is prone to acids.

Guide values for drying time and temperature resistance in table - 3.

Epoxides Cold - Cured (two pack)

These paints consist of two separate components :-

- (1) Epoxide resin,
- (2) Curing agent.

Cold - cured epoxide paints have good acid and alkali (amide - cured) resistance and are highly resistant to solvents. They

They are resistant to abrasion and wear but not to sun radiation. Hardener and paint should be carefully mixed by means of a stirrer in recommended portions. Pot life is limited by supplied.

Chlorinated rubber .

Chlorinated rubber paints show good resistance to alkalies, and salt solutions but they are less solvent-resistant than epoxide paints and are more affected by exposure to elevated temperatures (only upto 70°C). High - build chlorinated rubber paints contain thixotropic agents and yields dry films of thickness 50 to 80 micrometers in one coat. After brush - application their drying - time is normally not less than 12 hours.

Coal tar - epoxy.

They are yielding films 100 to 150 um thick per coat. The dry film develops considerable hardness and water resistance. The black colour of these paints can be shielded by means of other light- coloured chemical - resistant paint e.g. aluminium chlorinated rubber paint.

Urethane paints.

They are similar to epoxides, but are evaluated as more resistant to sun - radiation, mechanical damage and low temperature adhesion. The durability of urethane paint system is very ~~high~~ high (upto 15 years) in outdoor conditions.

Ethylsilicate zinc primers (two-pack)

They are recommended as the best primers for all top coats for tropical environment with excellent adhesion and abrasion resistance.

Silicone paints.

For temperatures between 90°C and 200°C aluminium heat resistant silicone paints should be used to obtain good life times after surface preparation by blast cleaning. Two or three coats of the paints should be applied. A special heat - resisting primer is required (2 coats), before applying the aluminium paint (2 coats). For temperatures between 170°C and 250°C , Zinc dust/graphite paints are recommended. This paint is applied in single heavy coat immediately after blast cleaning.

4. METAL SURFACE PREPARATION.

Blast - cleaning is recommended for all paint systems applied to important steel structures and to structures whose location or function renders access difficult. It should also be used for steel work subjected to heavy corrosive atmospheres, sudden variations of temperature, alternating stresses and continuous vibration. Blast - cleaning roughens steel and it is essential that an adequate thickness of priming paint be applied to cover the peaks on the surface. Advised steel surface profiles are given in table - 4 . Sand particles size should be between 1 - 0.5 mm and no dust should be present. Sand from the Sea must not be used. A higher rate of working can be expected and an improved degree of cleanliness can be achieved with mechanical method (by means of high pressure impact tools) than with hand - cleaning. After sand blasting and blowing the surface with compressed air cleaning with tap water or condensed water should be performed. After 10-15 minutes of drying, primer coat is applied. Under corrosive conditions a bare clean metal surface must be coated immediately. When prepared surfaces have to be left uncoated for a long period, e.g. over night, they should be inspected before priming and, if necessary , prepared again.

The use of high pressure water vapour equipment is recommended for cleaning before and after sand blasting.

Special measures are necessary to remove welding slag, spatter and flux residues (which are often alkaline and dangerous to paint), before painting steel in the vicinity of welds. This can be done by washing with fresh water, followed by chipping or blast-cleaning. Vacuum - blast equipment is recommended for this purposes with continuous abrasive transport (grit). After sand blasting the pH of the surface should be determined by means of wet pH indicator paper. In the case when the pH of a surface has the value different then 6,5 - 7,5 - it should be neutralised with diluted phosphoric acid wash (0,5 % by volume) or Na_2HPO_4 (0,1 % by weight). After that the surface should be dried and blown out especially at joints and slots.

When only mechanical cleaning is possible, immediately before paint is applied, all dust, loose paint or other loose material should be cleaned from the surface by brushing including washing down with fresh water and a bristle brush, where necessary. Washing down painted surfaces should be done with clean fresh water and scrubbing brushes followed by a final rinsing or hosing with clean water and or water/vapour mixture by means of high - pressure equipment.

Washing down is specially recommended for surfaces that have been exposed to polluted atmosphere at any time before or during the painting process. All washed surfaces should be allowed to dry before being painted after blasting not longer than 10 - 15 minutes because of corrosion). The use of white spirit for cleaning steel before painting is not recommended.

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Metal coating Zn or Al beneath the paint system, as a preparation should be used on surfaces where paint alone is unlikely to be effective during 15-20 years period and on relatively inaccessible surfaces that cannot conveniently be repainted except at long intervals.

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

Metal coatings(Zn , Al) with a paint system of two priming coats and two finishing coats should be used. The system will have a life equal to the maintenance interval without allowing for damage to the metal coating, generally 10 years. Repainting is very easy.

5. REPAINTING.

In Industrial environments there are many places where steam, solution - splash, exhaust gases and fumes are present. Repainting should be undertaken some times very often or will vary with the age of the structure. The decision if to repaint may also be complicated by the fact that breakdown is seldom uniform all over the surface, so that some parts may need instant renewal and others not. If heavy rusting develops on joints, repainting should be undertaken at once.

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

Flaked paint or systems with generally weak adhesion do not provide a suitable basis for repainting, and should be stripped as soon as possible to bare metal.

Before repainting surface quality should be checked by painter. Sharp edges, faying surfaces and other specially vulnerable areas should be properly treated by hand scrapers, needles and wire brushes. The removal of welding slag or spatter from the runs of welds and adjacent steelwork, is necessary.

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

Broadly, two kinds of surface can be distinguished :-

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

- Areas where the paint has deteriorated badly and has lost its adhesion, and where the steel has rusted appreciably. These areas should be neutralised, washed with water and cleaned to bare metal, preferably by blast-cleaning. In this case, for chemical plants, two coats of primer are applied with sufficient drying time according to the advice of paint manufacturer following by 2-5 coats of top paint (generally 250 - 300 um) checked by nondestructive measuring instrument.

Paint can not be applied to warm surfaces (no higher than 40°C). Paint manufacturers experienced in tropical applications are familiar with the necessary modifications to ensure satisfactory results, but chlorinated rubber paints should be applied with care.

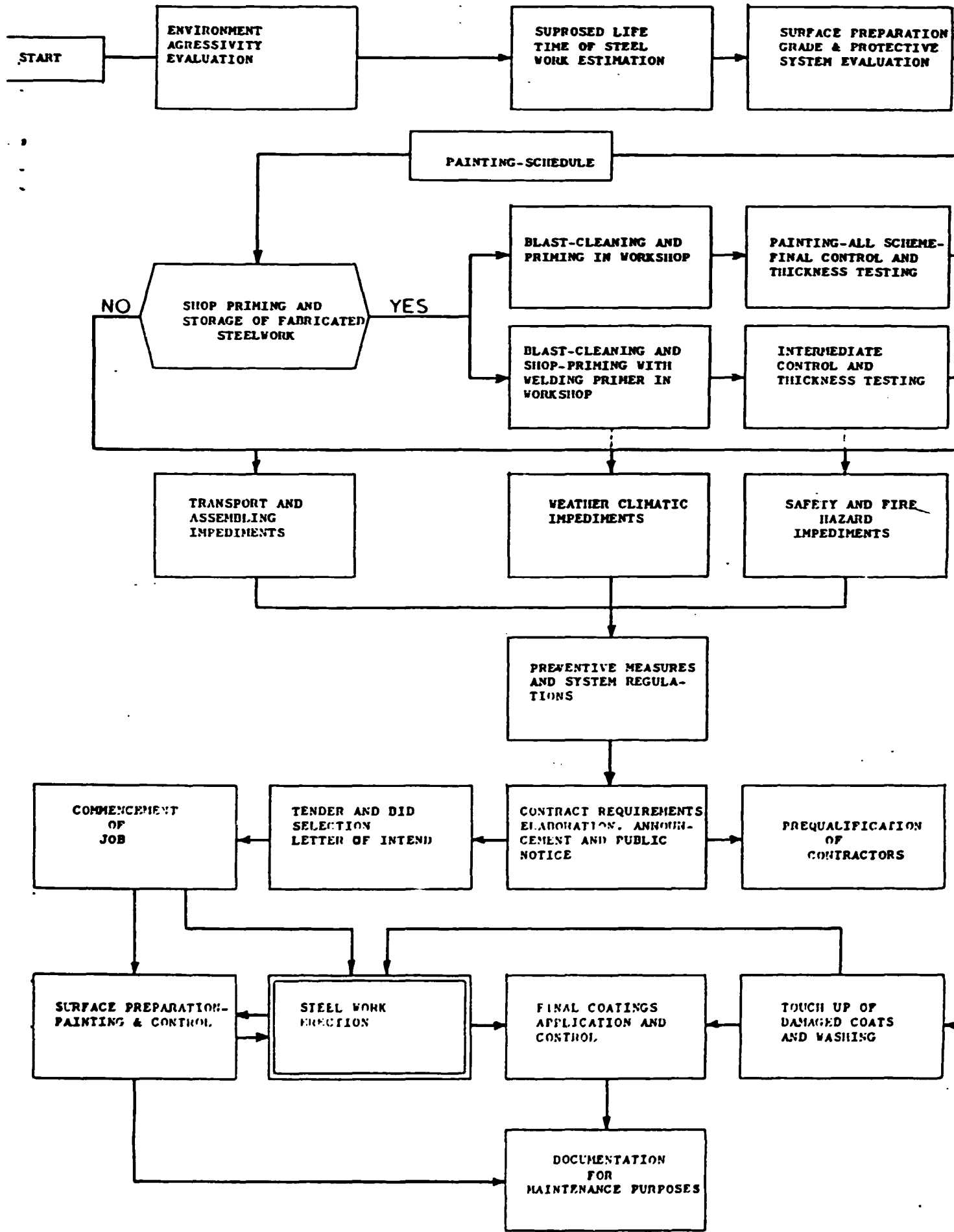
Prolonged storage of paints in the tropics should be avoided. It is good practice to apply an extra stripe coat of paint by brush to edges, corners, crevices, bolt heads, and rivet heads. This stripe coat is best applied soon after the first priming coat has dried.

During painting the affected areas should be protected or shielded by means of a shelter or a tent to avoid surface contaminating with dust, and should be neutral. This must be checked before application of a top coat. Dust should be especially checked on horizontally situated surfaces. Contaminated surface should be cleaned with a water soaked rag/cotton waste.

The suitable thickness of a coating system should be 150-300 micrometer depending on aggressivity of environment, water condensation possibilities, difficulty to access and maintenance.

PAINTING OF NEW STRUCTURES -FLOW SHEET

TABLE 1



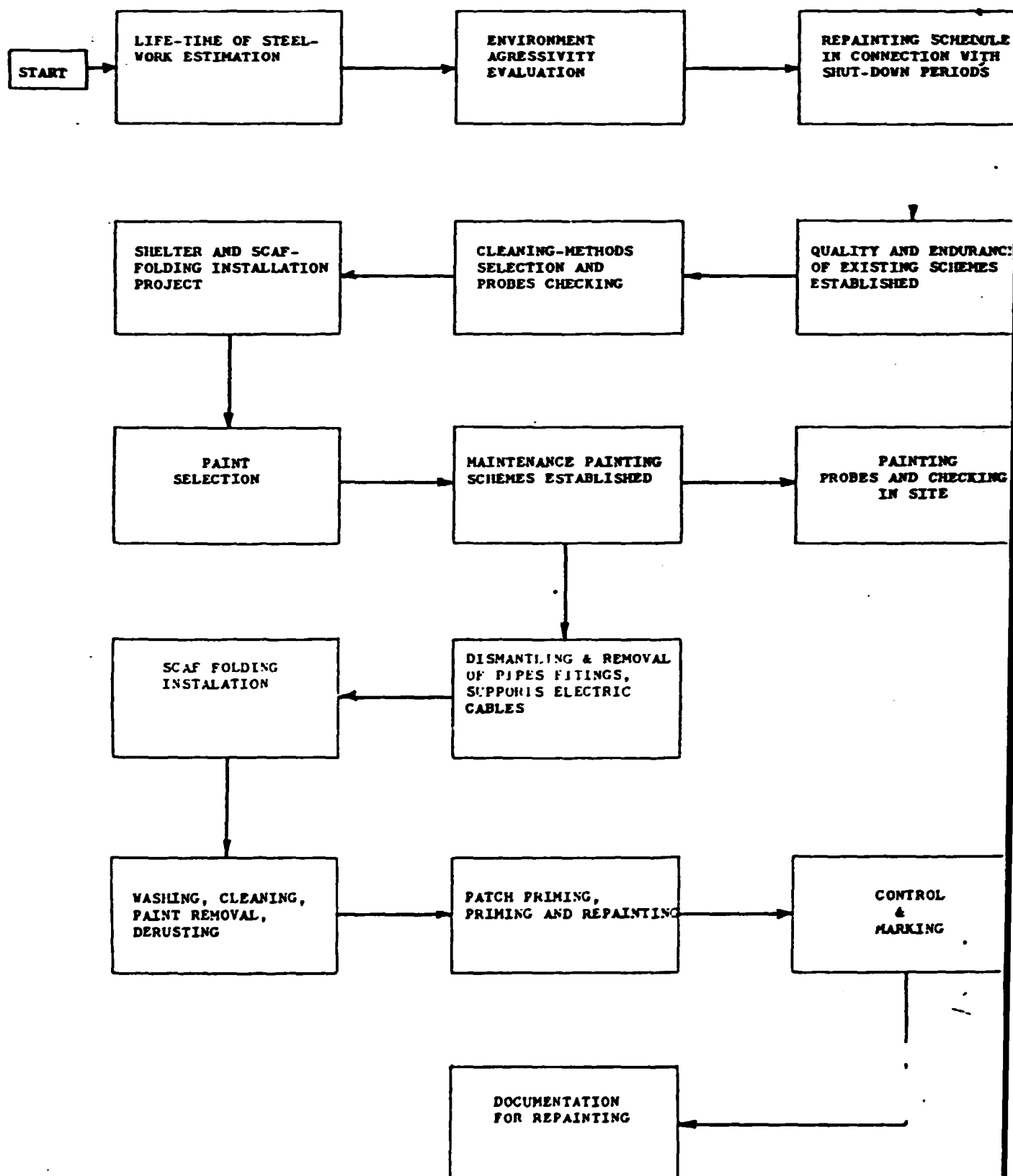
RE PAINTING OLD STRUCTURES - FLOW SHEET

TABLE - 3

Guide values for drying time and temperature resistance.

Binder type	Shop primer		Primer coat drying time.		Top coat drying time.			Type of drying.	Temperature resistance range °C.
	Coating thickness μm	Hours	Hours	At a coating thickness of μm	Hours	At a coating thickness of μm .	At a coating thickness of μm .		
Epoxy Resin ester	25	8 16	40	- 80	8 16	40	- 80	Air drying	120 to 150
Chlorinated rubber	Hot appli- cable.	8	35	80	8	35	80	Air drying.	60 to 80
Chlorinated rubber modified.	-do-	16	35	80	16	35	80	-do-	
Cyclorubber	-do-	8	40	-	8	40	-	-do-	80 to 120
Cyclorubber modified.	-do-	16	40	-	16	40	-	-do-	
Polyvinyl butyral	25							-do-	100 to 120
Epoxy resin	25	16	50	80	16	50	80	Chemically cured.	120 to 150
Polyurethane									
Tar pitch epoxy resin.	Hot appli- cable.	16	120	-	16	120	-	-do-	
Tar pitch polyurethane resin.									
Silicone resin:	-do-	8	30	-	8	25	-	-do-	300 to 400
Ethyl silicate	20	16	80	-	-	-	-	-do-	300 to 400

TABLE - 4

STEEL SURFACE / TREATMENT ADVISED FOR PAINTING.

Type of coating (primer)	Film thickness.	Exposure conditions	Grade of cleanliness advised.	Profile (µm) advised.
Oil based	40-50 µm	mild	Sa 2	100 max.
alkyd modified	50-40 µm	normal	Sa 2 1/2	75 max
Chlorinated rubber	20-40 µm	severe	Sa 2 1/2	20-40
Epoxy/iron oxide	20-50 µm	Corrosive	Sa 3	20-50
Epoxy zinc rich	20-30 µm	severe	Sa 3	20-30
Epoxy coal tar	100-200 µm	severe, corrosive	Sa 2 1/2	75 max
Wash primers	10-25 µm	severe	Sa 3	30 max.

Remarks :- Blast - cleaning is most effective on steel that has not been allowed to rust. Where steel has been allowed to rust badly, longer times for blast-cleaning may be required. Sometimes high quality standards cannot be economically achieved. It is therefore advisable to blast-clean steel as soon as is practicable after rolling or delivery on site.