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JORDAN

Technical report: Corrosion/Erosion of Equipment*

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

Based on the work of A. F. Dimon, Expert in corrosion/erosion of equipment

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ABSTRACT

Corrosion and errosion is extremely troublesome. Many hours have been spent in down time because of equipment failures, and in making repairs. By using proper materials and construction techniques most of the problems would be eliminated. Good corrosion resistance has been found in high Cr Steels with low carbon.

Corrosion monitoring instruments that will record corrosion rates are necessary so potential points of weakness in the process streams can be identified. Corrosionmeter, Nondestructive testing, and Magnaflux are some of the methods used.

Process tankage are scheduled to receive cathodic protection. An impressed current system will be installed for each tank. There will be a total of eight(8) separate systems.

The Fresh Water Pipeline System shall receive corrosion protection from another kind of Cathodic Protection Design, sacrifical magnesium anodes. These anodes will be placed at each pipe joint. Each pipe joint will be bonded. The sections of line that will receive cathodic protection will be isolated with insulated flanges. There is some weathering

and deteriation from the hot sun and sand storms. Recoating of all the steel on a routine basis is advisable.

INTRODUCTION

The work described has been requested by the Government of Jordan for the Arab Potash Company, Ltd. This work was done by Alfred F. Dimon, the UNIDO expert who was assigned to the project. The Job Description is included in the Annex I.

Time spent at the plant was March 4, 1990 to March 22, 1990, a total of 17 days. During this time all production facilities were examined; corrosion problems discussed; interdepartment interfacing reviewed; and general operation of the plant from raw material to finished product examined.

The interfacing of responsibility between Operations and Maintenance was examined. Under staffing of the Corrosion and Material Engineering Department was discussed. A Quality Assurance function would keep management informed regarding the progress of repairs without interfering with the work of Middle Management. The Technical Department could very easily become involved with Quality Assurance. Interfacing with Material Engineering would assure record of all job completions. Easy retrival of all information could be by using computers.

I. DISCUSSION

A. Investigating Corrosion Failures

Examining pieces of equipment that had failed because of corrosion/erosion had an extremely high priority. This emphasized the need for this study and the reasons why failures have occured. During plant shut down for major repairs, obtaining evidence of corrosion and erosion causes keep personnel busy.

Internal corrosion in the hot process streams is the most severe. Carbon steel is the predominate material of construction. The hot carnallite slurry, because the interior of the pipe wall is rought, accumulates on the pipe wall at random locations. Local differential corrosion cells form causing severe pitting with eventual penetration. Catastrophic reduction in wall thickness has dictated the use of lined pipe and high corrosion resistant steels; vis., Hastalloy, Inconal, and Monel. The high nickel steels have not, however, given the length of service as expected. The use of exotic materials does not solve all problems. Carbon steels with different percentages of alloying ingredients have more flexibility and are more economical.

Carbon Steel

The carbon steel group is by far the most common material of construction. The corrosion rate or the susceptibity to corrode is governed by the heterogeneity of the alloy. Impurities in the alloy in the form of cathodic inclusions cause dissolution of the steel. This condition is aggrevated during fabrication of steel shapes. For an example, when pipe is manufactured, this is more true for seamless pipe, stresses are induced as the mandral penetrates the steel. The pipe is then quenched and annelled. The anodic and cathodic areas are present will cause pitting type corrosion.

The temperature that the steel is exposed to is another important variable. Cold slurry is not very aggressive and pitting and evidence of corrosion is minimal. However, the hot process lines are vulnerable. The hot slurry is very aggressive. Oxygen that is intrained in the process system tends to remain. There is no way to deairate in a closed system and the corrosion process continues (1). For open streams, oxygen is removed above 80°C and corrosion rates decrease (1). The oxygen concentration of the process streams is the main reason for corrosion. Keeping the oxygen concentration at a minimum will solve a major maintenance problem. The installation of corrosion coupons and probes will allow monitoring of areas where corrosion is worst. Locate the monitoring devices at areas where pitting and loss of wall thickness have been detected.

B. Changes In Temperature

Differential temperature heat gradients are responsible for thermogalvanic couples. This condition initiates local corrosion cells, the hottest being anodic to its cooler

(1) Tomashov, N.D., Therory of Corrosion And Protection Of Metals. The Macmillan Company, 1966, p 315-316.

counterpart. This condition is common in boilers/pipelines and in heat exchangers (1).

According to some authorities the corrosion resistance of carbon steel can be regulated by alloying (1). Steel with 13% chromium is resistant to super-heated steam. When the carbon content is more that 1% the weldability is jeopordized. Proper annealling to remove the CrC is necessary. The heat exchangers that heat the brine use steam as a heat source. The tubes corrode in a short time and need replacement. A high chromium steel would furnish the necessary corrosion resistance instead of using the expensive Hastealloy. As a percausion the high chromium steels can not exceed (17% to 18%) and the carbon content can not exceed 0.4% to 0.5%.

C. Welding

Proper welding electrodes are critical and compatability with the base metal is necessary so penetration of the weld from corrosion or mechancial failure will not occur. Penetration of the welds in the water lines is common. Impigment of the liquid on adjacent equipment and on employees who are working in the area is troublesome and implies poor housekeeping methods. A sample of the weld that failed should be taken for an analysis. These tests can be made at the plant. As the plant expands, the need for a meturgical laboratory should become more urgent.

D. Atmospheric Corrosion

Deteriation of external metallic surfaces is minimal.

There is very little contamination from the plant. All spillage is cleaned up in a reasonable length of time. However at the bag house and loading warehouse there is a source of dust which collects on the structural steel surfaces throughout the plant. Rain and condensation mixing with the potash dust form a corrosive condition. In addition, high winds and sand furnish an erosive condition. All metallic surfaces should be coated. The entire plant needs recoating. As a beginning, the piping that is bare should be coated.

Since the pipe is in an area where employees are working or work pass, cleaning the pipe should be done by power wire brushing. All loose rust scale and dirt should be removed. Tightly adhering rust can remain. A brush type sand blast would be too hard to use because many of the pipe runs are on scaffolding. Consequently confinement of the sand is almost impossible.

After the pipe is cleaned, prime with zinc-rich paint and top coat with Epicon*R hi-build coating. Both coatings are manufactured by Cook's Paint And Varnish Company, Kansas City, MO. 64141, or use what was used during the original construction. This coating has held up but needs replacing now. In addition to the piping, the structural steel and tanks need to be coated.

E. Corrosion Control Of Process Tankages

Decomposation Tanks

The Decomposation Tanks are a intergal part of the process stream. Carnellite cake is dumped in the tanks and mixed with the effluent from the Carnallite thickner and with fresh water. There are six tanks in series that hold the Carnellite while decomposition to sylvinite takes place. The liquid is corrosive and all of tanks receive corrosion protection.

Cathodic Protection Design

Cathodic Protection will be used to protect the bottom and tank interior. Low resistivity slurry will provide good current distribution throughout the tank's interior. High silicon-iron anodes will be distributed thoughout the tanks as illustrated on the Drawing No. 1.

Anodes will be attached to the tank with the anode stud insulated as is shown on Drawing No. 1. Teflon sleeves will be placed over each anode stud. A No. 8 copper wire cable insulated with high density polyethylene insulation will be connected to the anodes and run to a junction box. A 200 volt D.C. at 50 amp D.C., oil cooled rectifier with silicon diode rectification will be used to energize the anodes. The rectifier will be located in switch room No. 2. An interrupter shall be built into the unit so interruption of the rectifier can be realized. This is important for testing and adjusting the Cathodic Protection system.

All electrical connections will be placed in one-inch diameter galvanized steel conduit covered with polyethylene coating. The sixteen No. 8 AWG cables will be run in conduit to the anode junction boxes. The electrical connection to the rectifier shall be by a No. 6 AWG seven strand copper wire insulated with the same material. Even though the cable is suitable for direct burial, the cable will be placed in conduit to prevent mechanical damage.

The Decomposation Tank complex is electrically continous. This means that current from one Cathodic Protection system will affect tanks that are not directly connected. The C.P. system is designed for a required current density per square foot of tank surface. Current losses can not be tolerated. Consequently all six (6) tanks will need to be put under Cathodic Protection. All six tanks will use the same design.

Crystallizer Wash Tank

The Crystallizer Wash Tank is used to hold water when the crystallizers require cleaning. There is no coating on the interior surfaces and corrosion protection is recommended. The steel surfaces can be cathodically protected with silicon-iron Type G anodes. Anodes weigh 5 pounds each and placed on No. 8 AWG seven strained copper cable in groups of three (3) placed on seven (7)-foot centers shall be used. The Cathodic Protection Design requires four (4) strings placed on 90° centers. The anode strings will be suspended from the tank roof on supports for inspection and easy removal when repairs are required. Each anode lead wire will be run in PE coated GS conduit. A rectifier rated at 25V DC and 20A DC, oil cooled, furnished with an interrupter and silicon diode rectification will energize the anode. The unit will be located in Control Room No. 1.

Mother Liquor Tank

The Mother Liquor Tank is larger than the Decomposation Tanks. Hot brine, which is corrosive, is stored in the tank. High silicon-iron anodes will be attached to the tank wall. There shall be 32 anodes placed in rows of eight (8) on 90° centers. The installation will be energized by a 50A DC and 100V DC rectifier.

F. Fresh Water Pipelines

There are two (2) potable water pipelines providing water to the residential community called the Township and to the Potash Plant. The line furnishing water to the Township will be discussed first.

Water is obtained from wells that are pumped to a pumping station where it is treated and pumped to a containing reservior at the Township. This section of the fresh water piping system is carbon steel, 10 inches in diameter, and approximently five (5) miles long. The soil resistivity is corrosive ranging from less than 1000 ohm-centimeters to 2300 ohm-centimeters. At 2 and 3 meters depth, which is approximently 6 and 9 feet respectively, the soil resistivity measured 15,000 to 20.000 ohm-centimeters. At the time of this writing, there have been six (6) leaks, the first being six (6) years ago, the water line is ten (10) years old. The repair method is by clamps. Some pitting on the exterior surfaces was detected. None of the victolic couplings were bonded and no insulating flanges installed at the time of construction.

The pipeline runs through cultivated areas which are irrigated and fertalized, the leaks were in those areas.

The line has a superficial shop coating with no bonds across the couplings. Without an electrically continous pipe, Cathodic Protection can not be applied. This is true for either impressed current or sacrificial anodes.

It is recommended that the section of pipeline between the road to the Potash Plant and the Pumping Station be isolated. This is the section that is in the agricultural area and is exposed to the lowest soil resistivity where there have been the most leaks. The length of line is approximently 2.5 miles. Install an insulated flange on the west side of the road at the Township reservior and Pump Station. The flange should be placed in a concrete lined manhole so the flange and pipe will remain dry. Bond every pipeline joint with a No. 6 AWG stranded copper wire with high density polyethylene insulation. Cadweld each bond with a No. 15 charge and throughly coat with Bitumastic 55 Coal Far Epoxy. Attach a 17-lb. prepackaged galvomag anode furnished with a 10 ft. long No. 12 solid copper wire. Cadweld wire to the pipeline see Drawing No. 2. Thoroughly saturate the bentonite backfill which is around the anode with water. A total of 660 anodes will be required. The isolated section of line will partially protected furnishing, a swing of 250 to 300 mv. A 850 mv potential to $CuSO_4$ may not be reached because of the bare condition of the pipe but a 300 mv shift in potential will arrest corrosion.

Another water line extending from the Safi Pumping Station to the Arab Potash Plant requires corrosion control. The pipeline is approximately 24 inches in diameter and 6589 meters in length. The pipe was installed bare with no bonds across the spigot and socket joints. No form of corrosion control was applied to the line at the time of construction.

The as-built drawings for the Safi Fresh Water Pipeline indicate that from the Safi Pump Station to marker 3000 and from marker 3500 to 4050 a total of 3550 meters the pipe line is sleeved. Since the pipe has spigot and socket joints which probably are not bonded the pipe will not be electrically continuous. This condition can not be tolerated because Cathodic Protection can not be applied when the line is like this. It is recommended that the sleeved section of pipe be isolated from the pipe that will receive Cathodic Protection. Weld the sleeve to the pipe and install an insulated flange at both ends of the line. The short section of line that is sleeved should be isolated also. The sleeved areas represent over half of the line. What remains(3039 meters) have couplings that can be bonded and sacrificial anodes attached.

The construction drawing does not indicate what kind of sleeve--metallic or nonmetallic, what size, how the water line is installed, etc. This information is necessary in order to design a Cathodic Protection system.

It is recommened that before any cathodic protection be applied to the line construction be done as mentioned above. By making the entire line electrically continuous and insulating at both ends the natural potential of the line can be measured and the need for corrosion control determined. Ductial iron, another form of Cast Iron, has a tolerance for corrosive conditions. By eliminating the hot spots, no Cathodic Protection will be necessary.

On-the-other-hand, if a form of corrosion control is necessary, it is recommended that a hot spot type cathodic protection system be installed. A hot spot design will only swing the soil causing a potential difference large enough to prevent corrosion current from leaving the line. No interference will be experienced by this kind of design.

II. CONCLUSION

Corrosion control is essential for efficient operation of the Potash Plant. Intelligent use of corrosion moderatoring devices will assist in locating areas of potential failures. Using corrosometer probs permanently installed in the process streams will provide valuable information on corrosion rates.

The corrosometer measures resistance of the probe element which is made out of the same material as that being measured. Resistance is measured in Ohms then converted to mils per year to give the corrosion rate.

Metallurgical considerations are very important. Using economical materials and having them resistant to the process stream is necessary. For cold process streams, carbon steel has a corrosion tolerance. The hot process streams require a high chromium (13% or over) and a low carbon (less than 1%). The tubes and tube sheets require the same material.

Corrosion control of the process tanks will be by Cathodic Protection. An impressed current design for each Decomposation Tank, Mother Liquor Tank, and the Crystallizer Wash Tank will be used.

The Fresh Water Pipeline will be cathodically protected by sacrificial anodes. The anodes will be attached to the pipeline where leaks have occurred. This form of cathodic protection will furnish local protection to areas where it is needed.

Atmospheric corrosion is noticeable at areas where there is a high dust concentration. Coating of the structural steel will eliminate all atmospheric effects.

III.RECOMMENDATIONS

The following recommendations are suggessted to assure that proper corrosion control is applied.

1. Use zinc-rich primer and top coat with Epicon-R hi-build for atmospheric corrosion control.

2. Use high chromium steels low in carbon for the hot process lines.

3. Use impressed current Cathodic Protection system for the process tankage.

4. Use sacrificai anodes to cathodically protect the fresh water pipelines. Isolate sections with insulated flanges, bond joints, and coat all thermowelds.

5. Organize a Corrosion and Materials Engineering Laboratory. Suggested equipment needed is:
   (a) Brincll Hardness Tester
   (b) Grinding Machine
   (c) Polishing Machine
   (d) Metallurgical Microsope
   (e) Plastic Mounting Machine
   (f) Corrosometer with Corrosion Probes
   (g) M.C.M. Corrosion Meter
   (h) Potentialstate
   (i) Glassware

IV. APPENDIX

Job Description

Specifications

Drawings

Impressed Current

Cathodic Protection Design Fig. 1

Sacrificial Anode Design Fig. 2

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

JOB DESCRIPTION

DP/JOR/87/009/11-72/J18201

Post title	Maintence Consultant in corrosion/ erosion of equipment
Duration	Two weeks
Date required	As soon as possible
Duty Station	Amman, Jordon
Purpose of the project	The project is aiming at laying the foundation for an upgrading of maintenance and operational routines in different enterprises. The main emphasis is to identify bottlenecks and shortfall, to participate in improving installations work routines and conditions in co-operation with counterparts and officials.
Duties	The consultant will be assigned to the Arab Potash Co. Ltd. (APC) in order to make an assessment of the factory situatuon and shortcomings in maintenance, management and operational routines in particular, as well as to engage in corrective activities in close co-operation with local specialists.

Specifically the expert duties will be as follows:

- Provide overall information on the status of corrosion/erosion prevention in the world and the possible ways of tackling this problem.

- Assess the existing corrosion and erosion problems on the plant to classify them into two parts from the point of view of what may be done immediately without entailing additional funds, equipment and international personnel and what should be done subsequently.

- To put the priorities on the activities to be done immediately and to prepare the plan on implementaion of those activities including adequate guidelines, literatures and manuals. The results of this assessment are to conclude a sepa.ate chapter in the expert's report.

- Assess the exiting corrosion/ erosion prevention and maintenance system in the plant and to provide technical advice to its improvement.

- Provide with necessary recommendations on training of relevant personnel.

- At the end of his assignment to the project the consultant should submit a report on his assessment of the latest development in the corrosion/erosion prevention in the world as well as the assessment of the existing problems in this field in the Arab Potash Co. Ltd. The report should also contain the technical recommendations for overcoming corrosion/erosion problems in the company, the plan of their implementation, the necessary scope and program for personnel training to deal with the above mentioned problems; final report with observations, findings, and recommendations on above mentioned activities, to be discussed and agreed upon with appropriate national counterparts.

Qualifications

University degree in mechanical or instrumental engineering (or equivalent) with extensive experience on corrosion/erosion protection.

Language	English. knowledge of Arabic an advantage.
Background information	Please see the attached.

Applications and communications regarding this Job Description should be sent to:

Project Personnel Recruitment Section, Industrial Operations Division

UNIDO, VIENNA INTERNATIONAL CENTRE,P.O. Box 300, Vienna Austria

SPECIFICATIONS

Anodes - The anodes used for the impressed current design shall hi-silcon iron TYPE K, 55 pound with a bolt for attachment furnished. A teflon sleeve for insulation the stud included. These anodes are hi-silcon iron TYPE G, 5 pound attached to a No. 8 AWG stranded copper wire cable. Assemble three (3) anodes per cable on seven (7) foot centers. Cable shall be 75 feet long. There shall be four (4) anode assemblies.

Rectifier - The rectifier shall be single phase, oil cooled, have silican diode rectification, bridge connected, have a 110/220 V AC input, be furnished with a DC ammeter and voltmeter showing maximum rated output at full scale at

2% accuracv. The rectifier cabinet shall be constructed of 11-gauge steel with factory applied grey backed enamel finish. Rectifier shall be equiped with an interrupter gibing an off and on cycle of 10-off and 5-on, four (4) times a minute. Safety devices shall include magnetic circuit breaker and an efficiency filter. The rectifier ratings are as follows:

1. 50 Amp at 200 Volts
2. 20 Amp at 25 Volts
3. 50 Amp at 100 Volts

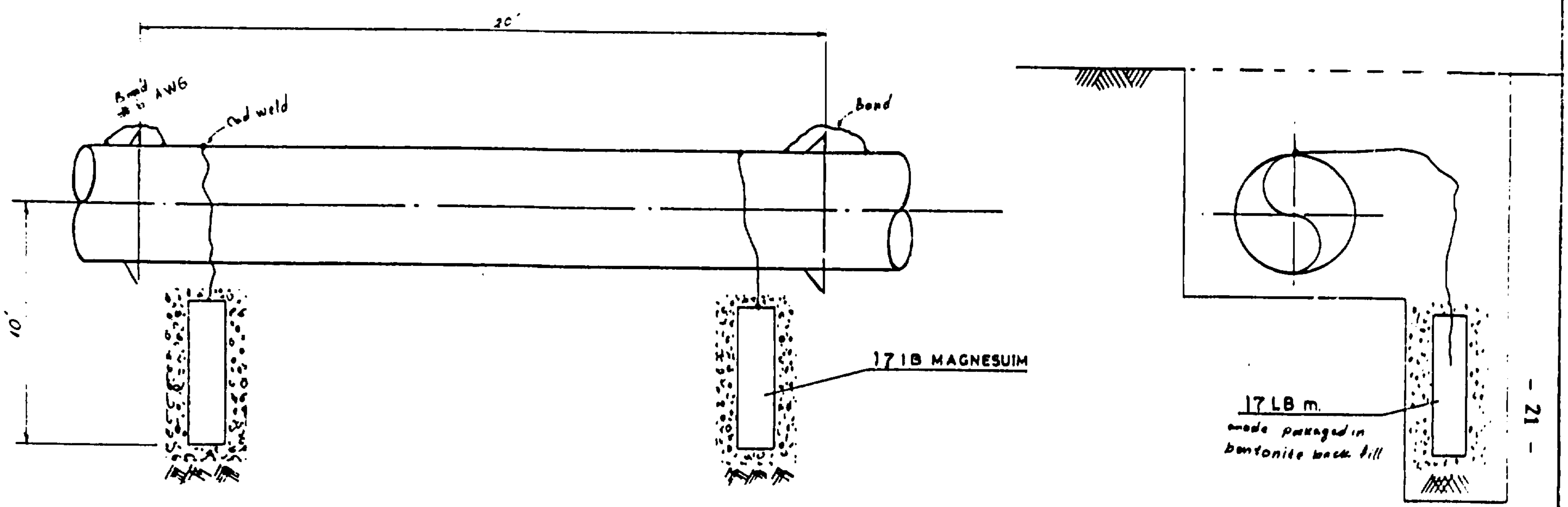
Anode Junction Box

Anode wires shall teriminate at a junction box. Connections for each anode and a shunt so the anode current can be measured. Each unit will be furnished with an ammeter. The Anode Junction Box shall be made from 11-gauge steel with a grey backed-enamel finish. The anode junction boxes shall hold the following numbers of anodes:

1. Decomposition Tank - 16 anodes
2. Crystallizer Tank - 4 anode strings
3. Mother Liquor Tank - 32 anodes

Wire Cable - Wire cable shall be No. 8 and No. 6 AWG stranded copper wire insulated with high density polyethylene insulation.

FIG.2

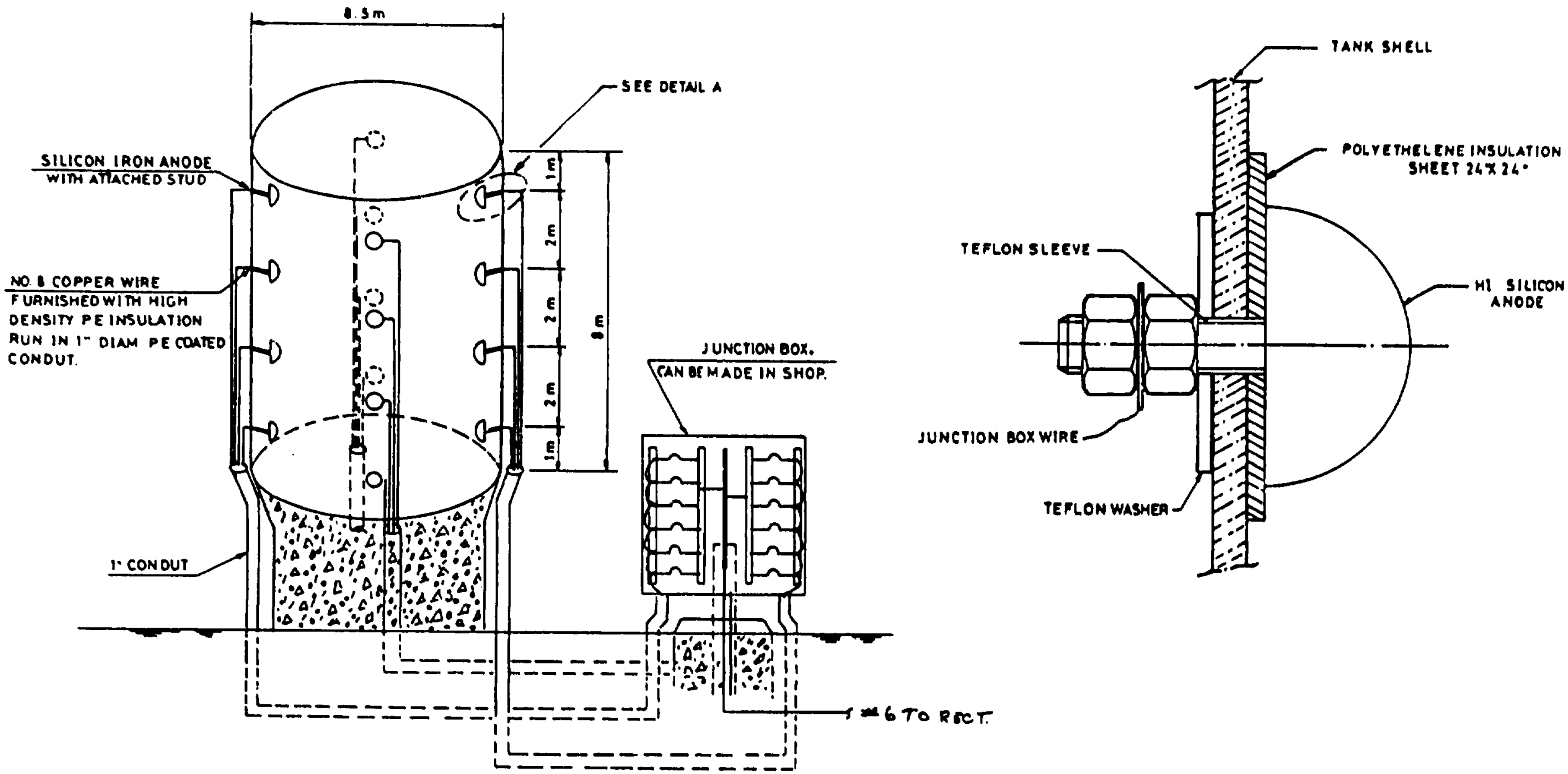


Note :

1. Coat all Cad-weld with Bitumastic 55.
2. Place anodes in water and throughly saturated back fill with water.

SACRIFICIAL ANODE
INSTALLATION DETAIL.

FIG. 1



CATHODIC PROTECTION SYSTEM FOR DECOMPOSITION TANK