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CORROSION PROBLEMS AND REMEDIAL MEASURES IN FERTILIZER PLANT

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RESUME

Saudi Arabian Fertilizer Company (SAFCO) et National Chemical Fertilizer Company (IBN AL-BAYTAR) ont des unités d'ammoniac, urée et engrais complexes modernes avec une énorme capacité. L'unité d'ammoniac Ibn Al Baytar de 1500 t/j, conçue par Kellogg, fonctionne depuis août 1987 et constamment au-dessus de 105 % de capacité. Snamprogetti a conçu l'unité d'urée avec une capacité de 1500 t/j qui marche depuis 1991, la capacité ayant constamment atteint 115 % par des modifications nécessaires

La communication est centrée sur quelques problèmes de corrosion constatés dans les unités Ibn Al Baytar d'ammoniac, d'urée et d'engrais NPK. Les études de cas de corrosion pour les problèmes suivants sont présentés avec le détail des mesures de correction mises en oeuvre.

1. *Problème typique de corrosion dans la pompe de sortie de H_2SO_4 et les lignes de recyclage des unités NPK.*
2. *Problème de corrosion spécifique sur les plateaux du laveur MEA de l'unité d'ammoniac.*
3. *Attaque de corrosion des soudures de buse due à une déficience du revêtement de l'absorbeur MP de l'unité d'urée.*

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The advent of large single stream plants in Petroleum, Petrochemical and Fertilizer Industries has placed enormous responsibilities on the Maintenance and Inspection functions. With increasing plant costs, profitable operation can be achieved only by operating the plants continuously and by avoiding un-scheduled down time due to equipment failures. Modem advancing trends in Science and Technology result in new processes, materials and machinery, for huge capacity automated operations, which in turn pose new problems.

CORROSION IN FERTILIZER INDUSTRIES

In the Fertilizer Industries, where corrosive fluids are handled at high temperature and pressure, the best proven materials for the service conditions are always insisted upon, as downtime due to material failures would over-ride additional initial costs of better materials. Materials, however, can not be chosen to last forever, and some corrosion degradation or deterioration is always expected in due course of years. For certain new processes, unproven materials may be used due to the newness of the process. Corrosion, therefore, is always present in a process plant and its rate must be monitored regularly to avoid failures and to plan for periodic replacement.

Starting from an ordinary carbon steel to complicated high alloy steels, variety of special alloys are being used in our plants, depending upon service conditions. Even though all possible care is exercised on material selection from the design stage, premature failures due to « corrosion » do occur and remedial measures are being constantly implemented to control or to avoid the recurrences.

In the present paper, two of the typical corrosion case studies which were encountered in our Fertilizer plants are discussed.

CASE STUDY I

NOZZLE LEAK IN MEDIUM PRESSURE ABSORBER IN UREA PLANT

Background

Ibn Al Baytar Urea Plant is of Snamprogetti design and has had successful operating history. Initial period of operation had many equipment problems, which were attended one after the other, by suitable repairs or modifications.

Medium Pressure Absorber (MPA) (Figure 1)

Process

MPA is a vertical tower, where:

- Carbonate solution with a mixture of gases consisting of NH_3, CO_2, H_2O enters the bottom of the column
- Gases consisting of NH_3, CO_2 and water vapour from the bottom of the column
- Cold liquid ammonia and ammonia solution are introduced in the bubble cap trays as reflux
- CO_2 and H_2O condense as ammonium carbonate and fall back to the bottom of the column and leave out.
- Rectified rich ammonia vapour with traces of CO_2 and inerts leave the top of the column

Material

1. Nozzle material is carbon steel 3" SHC.160 A-106 Gr. B., 10 mm thick (Figure 2)
2. Nozzle lining material is SS 316L, 3 mm thick
3. Shell material A-106 Gr. B., 23 mm thick
4. Shell lining SS 316L, 3 mm thick

Incident

- On March 9, 1993 mini shutdown was made due to boiler problem. During start-up of the plant, severe leak developed from solution outlet nozzle.
- The ammonia leak was found to be at the weld neck flange / nozzle, jetting to a length of 350-400 mm.
- Plant was shut down again, the pipe joining the nozzle was dropped. The nozzle was offered for inspection.

Inspection

1. From flange side, nozzle was visually checked. Liner was found punctured at six places near the weld.
2. From shell side, the nozzle was visually checked at the location where it joins the vessel. The carbon steel nozzle was found exposed and corroded at three locations. It became very clear that the weld joining shell liner to nozzle liner has failed and caused the whole problem.
3. Ferrite content reading were taken on this weld. It was found 3-4% which is beyond limit (.2% max).
4. The condition of the C.S nozzle was assessed after grinding both sides of the SS316 liner. The C.S nozzle was found severely corroded (4-7 mm) deep grooves covering 45 mm of nozzle length from shell side. Corrosion grooves continued along nozzle and nozzle liner until it reached the flange weld where it failed.

Analysis

As can be understood from the incident, corrosion attack of lined C.S. nozzle was attributed to wrong electrode selection which had excess ferrite content. Practically, this means poor corrosion resistance and less service life of weld in ammonium carbonate service. After weld failure, ammonium carbonate attacked the C.S and propagated along liner / nozzle span until it reached the weld. The corrosion then diverted its path along the HAZ and leaked outside.

Temporary Repair

1. Corroded nozzle was overlay welded where deep grooves were noticed at its end using Inconel 182 electrodes. Final layers were made with Thermanit 25/22/H filler wire.

2. Sleeve pipe (2" schedule 10 SS 316L) was inserted and welded at both ends to vessel liner & flangeliner using Thermanit 25/22/H (urea grade). (Figure 3)

3. DP check and leak test was made after repair and found O.K.

Permanent Repair

During April, 1993 Turn Around, permanent repair was done. Repair was nothing but replacing the existing C.S. nozzle with new SS 316L nozzle. Following is the procedure for replacement:

- **Removing the existing nozzle :**

1. Internal pipe side welds were removed by grinding.
2. The liner of the vessel was ground around the nozzle for width of 5 mm.

   Nozzle was gas cut and removed from inside of the vessel by gas cutting around pipe OD.

- **Installing the New SS 316 Nozzle** (Figure 4)

3. Beveled surface of compensating pad plate and shell was ground finished
4. External welding of new nozzle to carbon steel shell was done using AWS E-309-MO electrode.
5. Internal welding of new nozzle to shell liner was done using Thermanite 25/22/MO electrode.
6. DPT & leak test were made on the new joint and found O.K.

Inference

1. As can be understood from the article, corrosion attack of lined C.S. nozzle was attributed to wrong electrode selection which had excess ferrite content. Practically, this means poor corrosion resistance and less service life in ammonium carbonate service.

2. It is preferable to go for full SS316L nozzle rather than accepting liner protection for carbon steel nozzles in lined vessel, especially in highly corrosive service conditions.

Conclusion

Any leak in the process industry needs to be given due importance to avoid failures and catastrophy. The exact reason for such leak has to be thoroughly reviewed to plan for the right corrective measure to avoid recurrence.

CASE STUDY: II

FREQUENT H_2SO_4 LEAKS IN NPK PLANT

Complex Fertilizer plants of Ibn Al Baytar, is one of the largest in the world. High capacity production of NPK grades (1650 MTPD), DAP (900 MTPD) and clear Liquid Fertilizer grade (10-34-0) are being achieved to compete the world market. Sulphuric acid is one of the raw materials used to control mole ratio to prevent ammonia loss, in addition to precisely controlling the composition range of NPK grades. The plant has a huge tank for storing concentrated H_2SO_4 with loading and unloading pump facilities. (Figure 5)

Carbon Steel in Sulphuric Acid Service

Carbon steel is being successfully used in many plants for concentrated Sulphuric Acid services. Generally, in our plant concentrated H_2SO_4 did not pose any problem in Utility and NPK plants. But in acid mixing zone in Utility DM Plant, frequent leaks were encountered due to dilute acid back up, which resulted in internal corrosion of carbon steel piping.

Even though carbon steel pipes rendered good service life in H_2SO_4 handling in NPK plant, discharge and recycle lines of H_2SO_4 unloading / transfer pumps experienced frequent leaks on account of high velocity flow.

Incident

During the first year, after plant commissioning, there was no problem in any area of sulfuric acid. In 1992, there was noticed a minute leak on the drain pipe weld of the casing. Upon changing over to the other pump, the same type of weld leak happened and the same casing damage was observed. Later leaks started showing on the weld locations, elbows, reducer.

Pump Features

Pump casing is made of cast 20-25-4, 5+ Cu equivalent to ASTM CN7M material.
Material trade name (Alloy 20), Carpenter 20
Pump capacity 18 MT/hr.
No. of stand-by pumps is one

Inspection

Upon inspection, following were our observations:

A) **Pump**: Minute leak on the drain pipe weld of the casing.

The particular pump was opened for internal inspection. Following were observed:

1. Pump casing was having general thickness reduction of 7 mm from original thickness of 14 mm.
2. Deep grooves of 5-7 mm were noticed on the casing itself.
3. Impeller was having severe erosion marks at periphery.

B) **Piping**:

Discharge line leak at elbows, weld locations, reducer.

a. Reducer on pump down stream leaked due to thickness reduction

b. Thickness reduction of 1-1.5 mm was noticed on all pump D/S piping namely :

* Main sulphuric acid line feeding the plant
* Minimum flow line
* Unloading pump discharge line to tank

C) **Tank:**

The outlet nozzle of H_2SO_4 Storage tank got thinned down from original thickness of 8.5 mm to 4.5 mm due to erosion/ corrosion.

Analysis

As plant draw rate of sulfuric acid is normally much less than pump capacity (5 ton/hr against pump capacity of 18 ton/hr), discharge valve was throttled. So the following phenomenon took place:

1. Erosion corrosion on casing inside due to acid recirculation and high liquid velocity.
2. As 13 ton/hr was recycled back to sulphuric acid tank, liquid velocity inside the discharge line and the minimum flow line become more than the tolerable limit (3ft/sec). This caused erosion-corrosion and consequent leakage especially at elbows where fluid changes direction.

3. Another reason for wall thinning, which does not do with liquid velocity, is the high temperature measured (55 Deg C) on discharge piping during summer. At high temp., preferential corrosion is favored at top of pipe.

Recommendation

Short Term

A Pump

1. Thickness reduction on pump casing was repaired by overlay welding using thermanite 25/22/2 electrode or Inconell 182. After welding, machining to required size was done.

2. Impeller was replaced by spare one.

B Piping

1. Minimum flow line size was increased from 1½" to 3".

2. The recycle line size was enlarged to bring down the acid velocity as low as possible. However, this idea did not succeed.

3. The reducer material was changed from C.S to Uranus B6, which is a better material than C.S at high velocity.

C Tank

Tank nozzle, drain pipe were welded with external carbon steel sleeves (10 mm thick) in two halves.

Recommendation

Long Term

- Existing pumps of 18 MT/hr were replaced by three pumps with lower capacity of 6.3 MT/hr to suit the normal demand of the plant. The spare pumps can be used in case of high sulphuric acid demand.

- Minimum flow line was modified to be leading to pump suction instead of going to tank to avoid overload on unloading line. (Figure 6)

- Discharge line thickness was increased from 3" Sch 40 to 3" Sch 80.

- Welding was carried out by TIG welding process for high quality welds.

- It was recommended to provide insulation on all piping to protect the pipe from high temperature exposure during summer.

Safety

As weld failures were experienced many times, it was a personnel safety precaution to cover all welds by PVC shields to confine leaks or sprays in case it happen. Also, all flange connections were provided with such protection.

Welding Sulphuric Acid Line

Certain steps have to be followed before / during welding of sulphuric acid line:

- Thoroughly purge acid line with nitrogen before welding to remove any acid traces which could create weld defects.

- Locally clean with wire brush.

- In non-electrical isolated sulphuric acid tank, it should be made sure that the tank is free from free hydrogen. Free hydrogen could cause explosion due to welding spark. This can be made by purging the tank with nitrogen.

Conclusion

1. High capacity pump selection was the main reason for pump and related piping problems.

2. Although C.S. is a proven material for sulfuric acid service, it should be used within its allowable limits (See graph).

The responsibility on Inspection and Maintenance to identify any corrosion problem, even in the initial stage is vital to carry out necessary improvements on material & design. Sharing the experiences of others through published articles or through this type of seminars will help to achieve trouble free operating conditions.

MEDIUM PRESSURE ABSORBER ASSEMBLY DRAWING

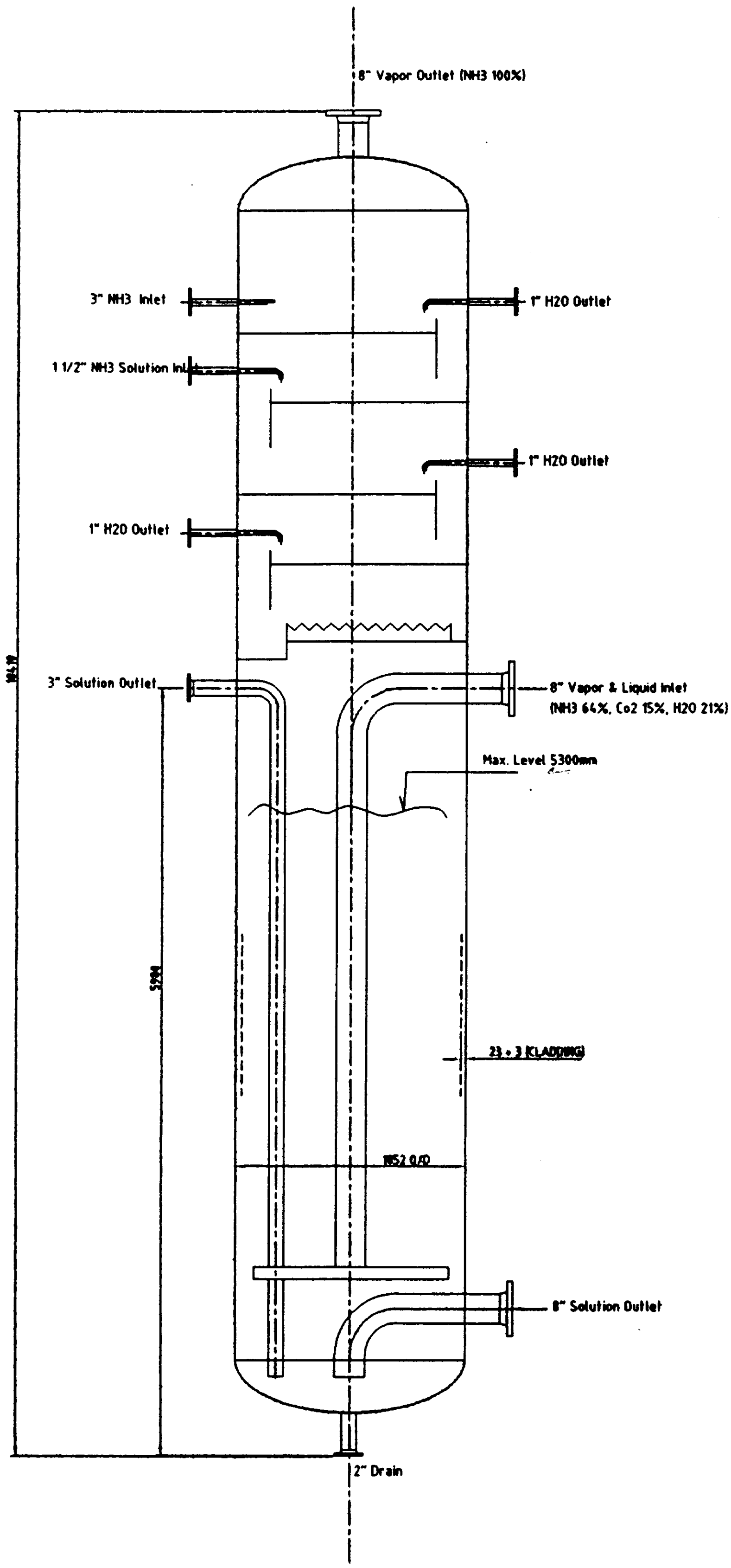
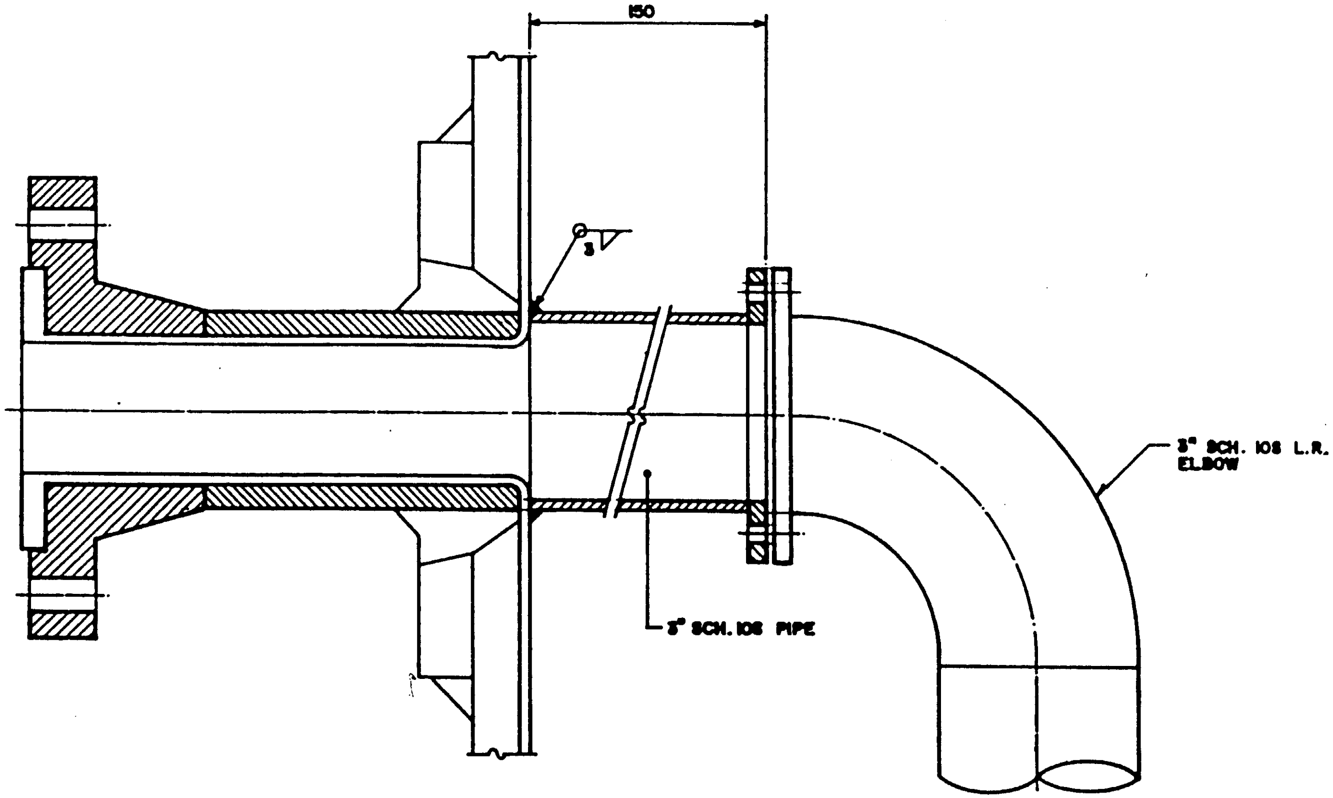


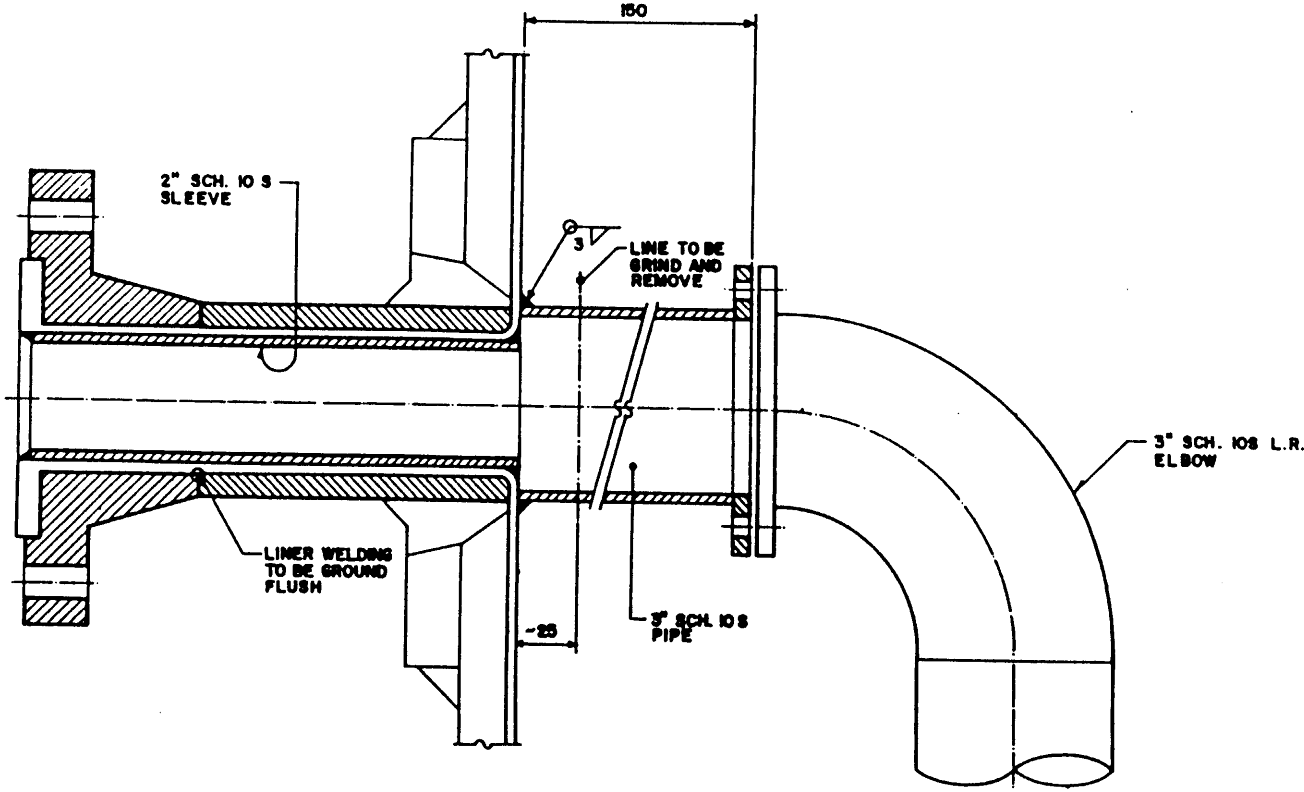
Fig.1

FIG. 2



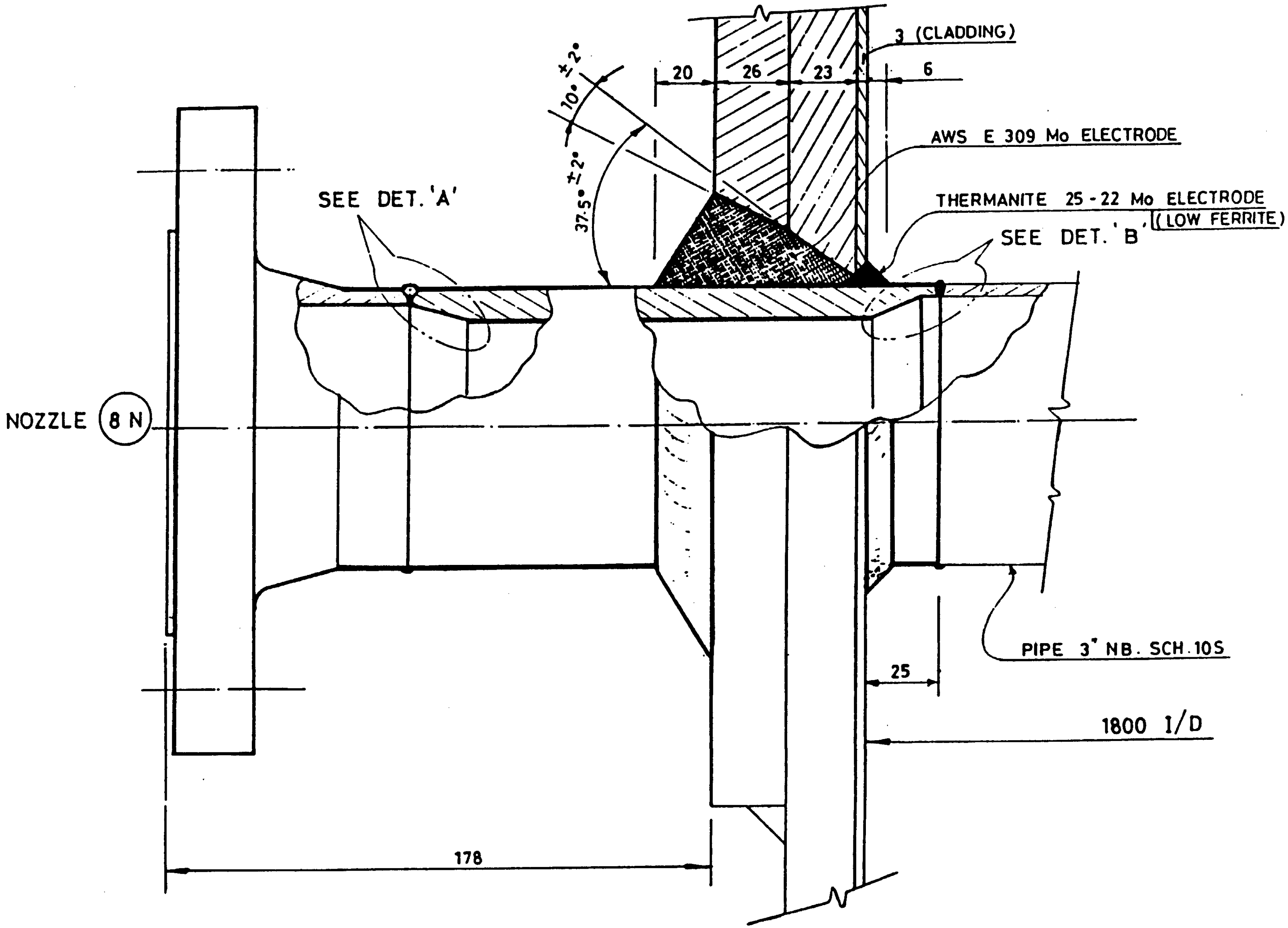
OLD NOZZLE ARRANGEMENT

FIG. 3



<u>MODIFIED NOZZLE ARRANGEMENT</u>

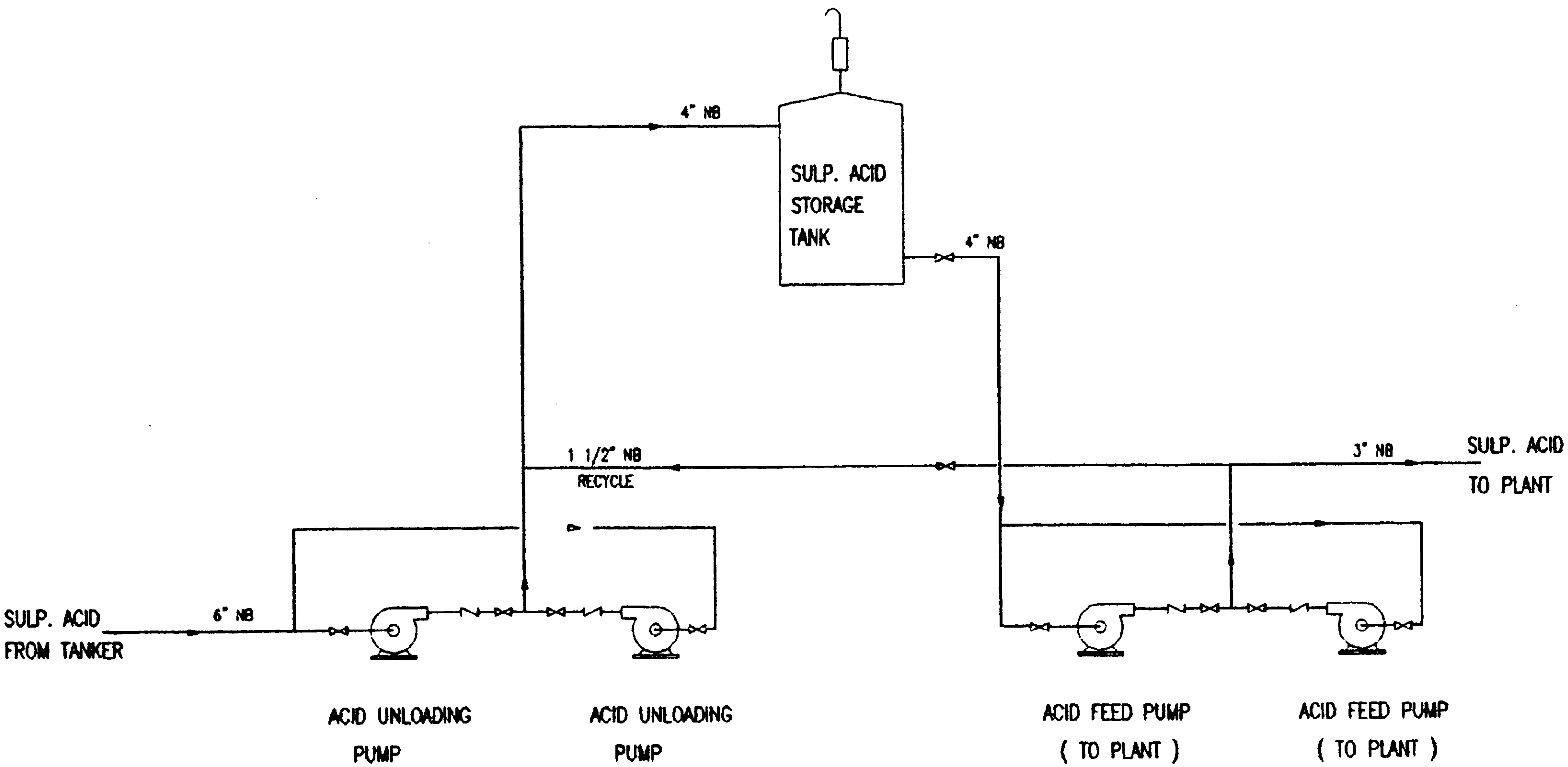
FIG. 4



NEW NOZZLE ARRANGEMENT

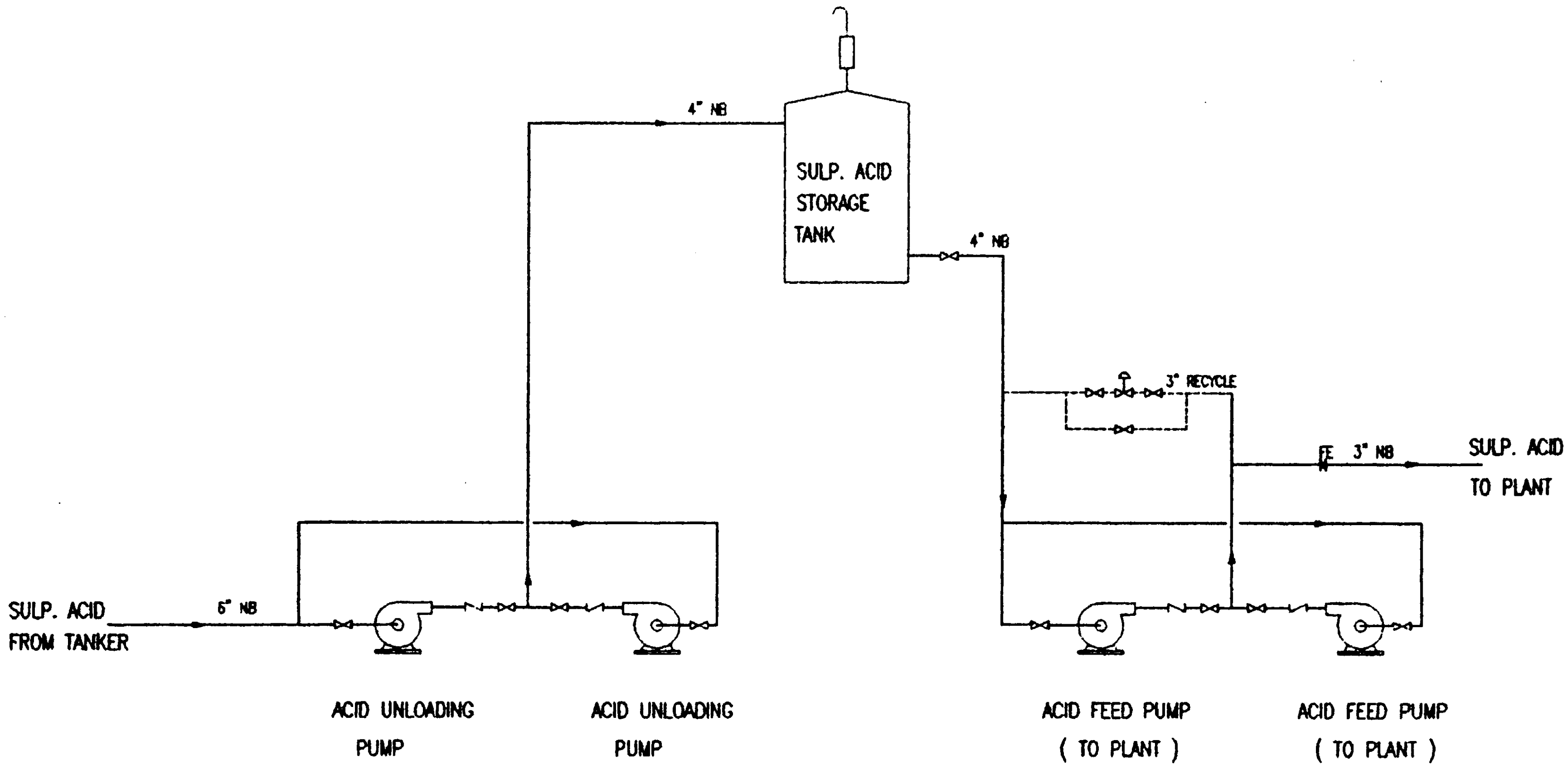
SULPHURIC ACID UNLOADING / FEED SYSTEM (OLD ARRANGEMENT)

Fig. 5



SULPHURIC ACID UNLOADING / FEED SYSTEM (NEW ARRANGEMENT)

Fig. 6



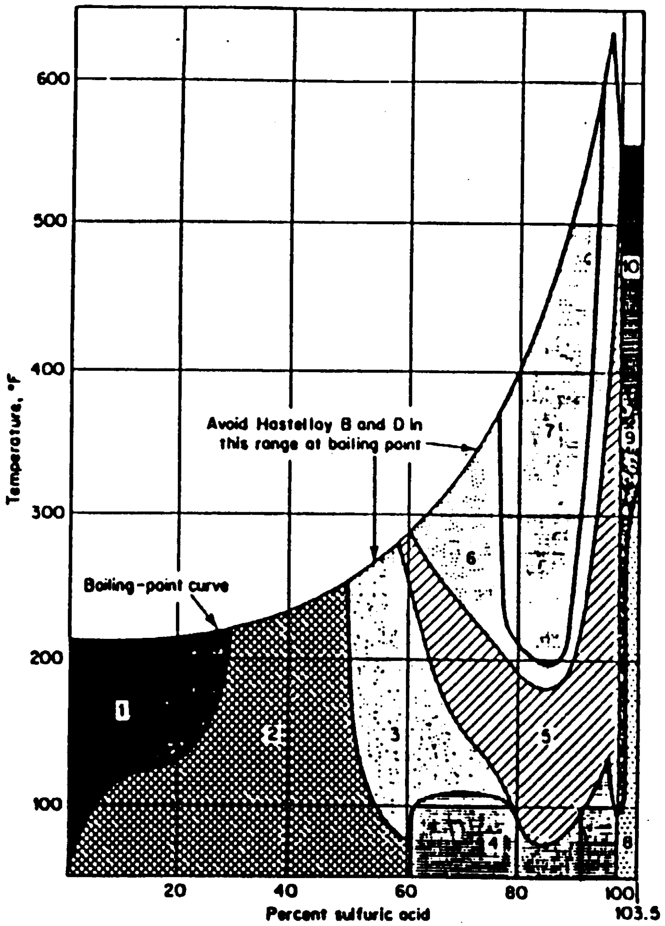


Figure 7-12 Corrosion resistance of materials to sulfuric acid—corrosion rate less than 20 mpy. *(Courtesy G. A. Nelson, Shell Development Co.)*

Code for sulfuric acid chart shown in Fig. 7-12

Materials in shaded zones having reported corrosion rate less than 20 mpy

Zone 1

10% aluminum bronze (air free)
Illium G
Glass
Hastelloy B and D
Durimet 20
Worthite
Lead
Copper (air free)
Monel (air free)
Haveg 43
Rubber (up to 170°F)
Impervious graphite
Tantalum
Gold
Platinum
Silver
Zirconium
Nionel
Tungsten
Molybdenum
Type 316 stainless (up to 10% aerated)

Zone 2

Glass
Silicon iron
Hastelloy B and D
Durimet 20 (up to 150°F)
Worthite (up to 150°F)
Lead
Copper (air free)
Monel (air free)
Haveg 43
Rubber (up to 170°F)
10% aluminum bronze (air free)
Ni-Resist (up to 20% at 75°F)
Impervious graphite
Tantalum
Gold
Platinum
Silver
Zirconium
Nionel
Tungsten
Molybdenum
Type 316 stainless (up to 25% at 75°F) aerated

Zone 3

Glass
Silicon iron
Hastelloy B and D
Durimet 20 (up to 150°F)
Worthite (up to 150°F)
Lead
Monel (air free)
Impervious graphite
Tantalum
Gold
Platinum
Zirconium
Molybdenum

Zone 4

Steel
Glass
Silicon iron
Hastelloy B and D
Lead (up to 96% H_2SO_4)
Durimet 20
Worthite
Ni-Resist
Type 316 stainless (above 80%)
Impervious graphite (up to 96% H_2SO_4)
Tantalum
Gold
Platinum
Zirconium

Zone 5

Glass
Silicon iron
Hastelloy B and D
Durimet 20 (up to 150°F)
Worthite (up to 150°F)
Lead (up to 175°F and 96% H_2SO_4)
Impervious graphite (up to 175°F and 96% H_2SO_4)
Tantalum
Gold
Platinum

Zone 6

Glass
Silicon Iron
Hastelloy B and D (20-50 mpy)
Tantalum
Gold
Platinum

Zone 7

Glass
Silicon Iron
Tantalum
Gold
Platinum

Zone 8

Glass
Steel
18 Cr-8 Ni
Durimet 20
Worthite
Hastelloy C
Gold
Platinum

Zone 9

Glass
18 Cr-8 Ni
Durimet 20
Worthite
Gold
Platinum

Zone 10

Glass
Gold
Platinum