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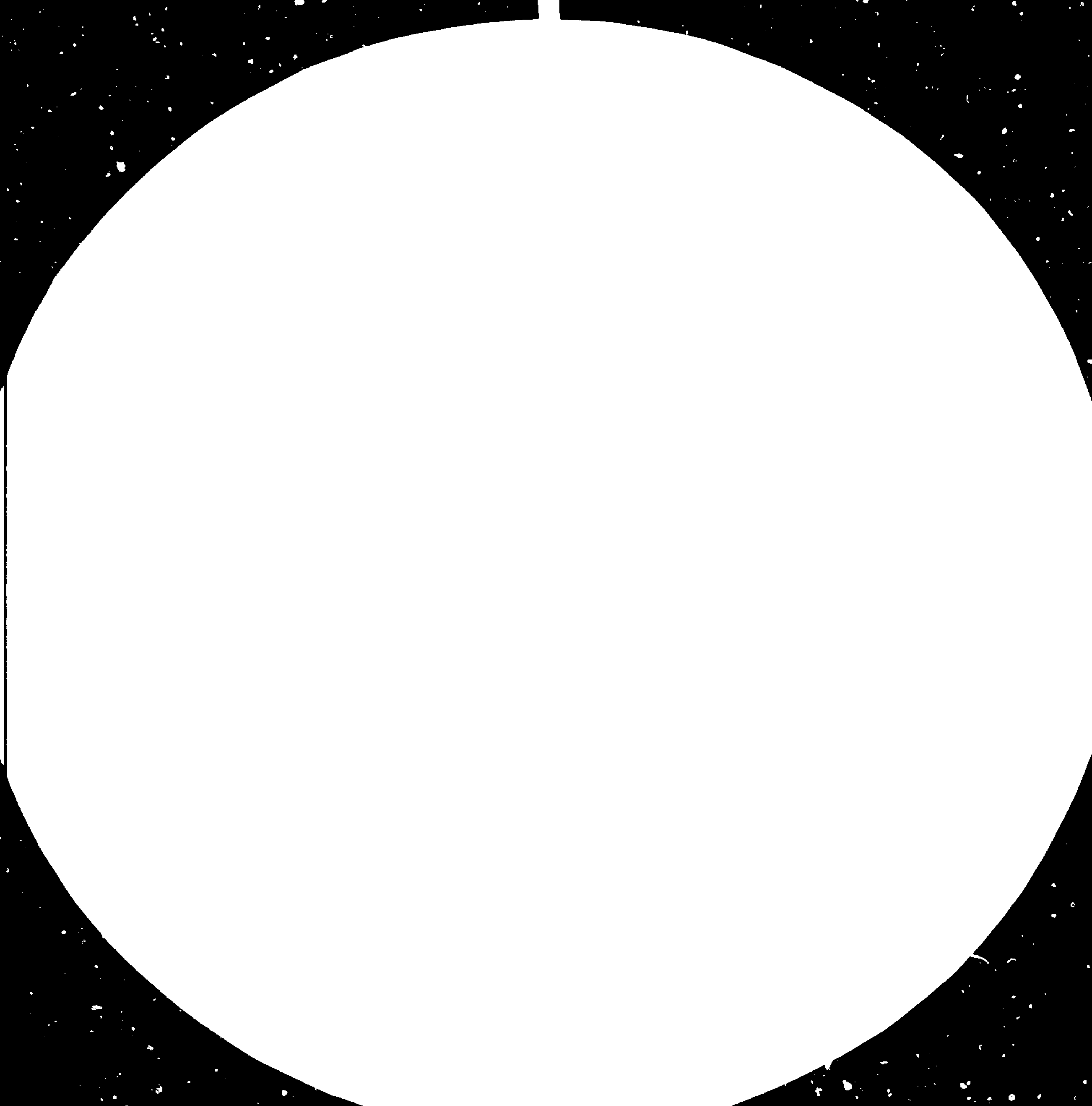

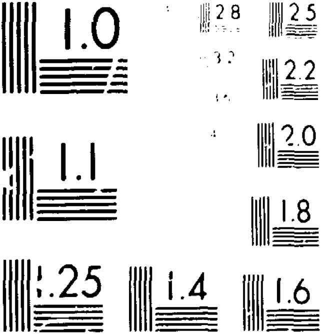
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UNITED NATIONS INDUSTRIAL
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TECHNICAL CONSULTATIONS ON CORROSION IN FERTILIZER PLANTS

VS/INT/78/183

Mission report: Corrosion control work in Bangladesh, China, Egypt, Saudi Arabia and Tunisia

Based on the work of Pekka K. Ruuskanen, expert in corrosion in fertilizer plants

V.81-20446

Explanatory notes

References to "tons" (t) indicate metric tons.

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

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

BCIC	Bangladesh Chemical Industries Corporation
ICI	Imperial Chemical Industries
MPa	Mega pascal
MS	Milli Siemens
SABIC	Saudi Arabian Basic Industries Company
SAFCO	Saudi Arabian Fertilizer Company
SCC	Stress corrosion cracking
SIAPE	Société Industrielle Acide Phosphore
TSP	Triple superphosphate

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ABSTRACT

As a follow up to the "Technical Consultation on Corrosion in Fertilizer Plants", held at Sandviken, Sweden, in August 1979, an expert in corrosion control was sent on a mission of one month under the project Technical Consultations on Corrosion in Fertilizer Plants" (US/INT/78/183).

The objective of the mission was to assess the practical impact of the Consultation Meeting. To that end the expert went to Bangladesh, China, Egypt, Saudi Arabia and Tunisia, in order to meet with participants of the Sandviken Consultation on Corrosion at the fertilizer plants where they came from.

The expert found that in most countries the papers handed out at the Consultation Meeting have been translated and distributed to the engineers of the plants and that the information gained at Sandviken has been put to use to solve corrosion problems in the respective factories. It was also reported that the know-how has been very helpful in negotiations with engineering companies.

The expert further inquired about any new corrosion problems experienced in the plants he visited, gave <u>ad-hoc</u> advice on some of them and ascertained whether and how UNIDO or Sandvik AB could assist in solving others. New corrosion problems arose principally in connection with equipment materials in urea and ammonia synthesis as well as in water-cooling heat-exchangers.

In addition to specific recommendations made for each plant, the general ones include the following: the management of fertilizer plants should be aware of the economical importance of corrosion control when planning such an activity; in each plant one experienced engineer should be enabled to specialize in corrosion control and all required training should be offered to him; UNIDO should continue to convene technical consultation meetings every two years; and the co-operation between producers of construction material, manufacturers of equipment and fertilizer producers should be intensified.

CONTENTS

INTRODUCTION

In accordance with the resolution of the Industrial Development Board of the United Nations Industrial Development Organization (UNIDO), which stressed the need for training of national personnel for industrial development, UNIDO, together with the Arab Federation of Chemical Fertilizer Producers (AFCFP), held a seminar at Baghdad, Iraq, in March 1978, on "Key Factors of Raising Productivity in Fertilizer Plants".

As a result of this seminar UNIDO was requested to organize a technical consultation on corrosion in the fertilizer industries in order to facilitate an exchange of experience among fertilizer manufacturing companies from developing and developed countries and to promote in broad terms the transfer of knowledge in this field from suppliers of corrosion-resisting materials to their potential users.

Subsequently UNIDO approved the project "Technical Consultations on Corrosion in Fertilizer Plants" (US/INT/78/183) and proposed to Sandvik AB to organize the meeting which then took place at Sandviken, Sweden, in August 1979.

The technical programme was planned by Sandvik AB in close co-operation with UNIDO. C. Keleti, Senior Industrial Development Officer, Chemical Industries Branch, was officer in charge on behalf of UNIDO, and W. Kamel, represented the Non-governmental Organization section of UNIDO.

When the technical consultation project was conceived by UNIDO, a mission was included in the project activities. For this purpose an expert was appointed for one month to follow up on the corrosion situation in fertilizer plants in five selected countries from which participants took part in the Technical Consultation Meeting. The countries chosen were Bangladesh, China, Egypt, Saudi Arabia and Tunisia.

The objective of the mission was to assess the impact and degree of implementation of the know-how gained on corrosion at the Consultation Meeting, to inquire and record possible new corrosion problems and to work out recommendations to UNIDO and Sandvik AB for further assistance to the above-mentioned countries.

RECOMMENDATIONS

1. Since the economical loss caused by corrosion in a fertilizer plant often totals several million dollars a year, the management of fertilizer plants, when planning corrosion control, should assess the importance of such work against that background.

2. It is further recommended to the management of fertilizer plants to let an engineer who is well-acquainted with the production equipment, concentrate only on corrosion problems thus improving quickly his experience and knowledge. The management should afford him an opportunity to visit other fertilizer plants, construction material producers and corrosion conferences to discuss problems with operating, maintenance and research personnel. The expertise of a corrosion specialist can also gainfully be employed in planning work and for the training of the personnel.

3. UNIDO should continue to convene technical consultation meetings every two years with representatives of fertilizer plants, construction material producers and equipment manufacturers. In addition to the material problems of equipment, other questions connected with corrosion control work, like the use of inhibitors, cathodic protection etc. could be treated extensively.

4. The co-operation between producers of construction material, manufacturers of equipment and fertilizer producers should be intensified in order to obtain better-quality corrosion-proof equipment. Co-operation with UNIDO should be enhanced to achieve better dissemination of information.

VISITS TO FERTILIZER PLANTS IN BANGLADESH, CHINA, EGYPT, SAUDI ARABIA AND TUNISIA

A. Dacca, Bangladesh

Meetings and participants

The only meeting at Dacca was arranged on Thursday, 20 November 1980, in the office of Chittagong Urea Fertilizer Project of the Bangladesh Chemical Industries Corporation (BCIC) and the participant was F.H. Chowdhury.

Use of the know-how

After the Sandviken meeting Mr. Chowdhury had changed his post and so far has not had a possibility to employ the know-how gained at Sandviken. However, he will have many possibilities of applying his knowledge in the future in connection with his planning work.

Unresolved corrosion problems

Mr. Chowdhury could not yet mention any corrosion problems for which he would need help from UNIDO or Sandvik AB.

Future assistance by UNIDO

In Mr. Chowdhury's opinion organizing the co-operation with manufacturers of corrosion-proof mateirals is important.

Recommendations

An assistant, who could concentrate on corrosion problems in the fertilizer industry would be very useful in planning and construction work and for the training of personnel in BCIC.

B. Ghorasal, Bangladesh

Meetings, participants and plants

Meetings were arranged for Tuesday 18, Wednesday 19, and Friday 21 November 1980 with the following participants: M.S. Rahman, B.K. Mozumbar, Z. Islam and M.D. Sayeed. The following plants were discussed: ammonia 660 t/d with natural gas raw material, Imperial Chemical Industries (ICI) steam reforming, Geamerco-Vetrocoke carbon-dioxide removing, Toyo engineering, urea 1,100 t/d.

Use of the know-how

The know-how gained in Sandviken had not been used.

Unresolved corrosion problems

The following problems were mentioned:

(a) Corrosion in heat-exchangers and cooling-water systems;

(b) Corrosion in the waste-heat boiler and methanator as well as economizer tube sheet;

(c) Corrosion of Geamerco-Vetrocoke solution reboiler;

(d) Hydrogen attack in the synthesis gas;

(e) Corrosion in carbon dioxide superheater tubes and intercooler tubes of carbon dioxide compressor.

Future assistance by UNIDO

The persons present at the meetings felt that it was important that UNIDO continued its efforts to increase the know-how of corrosion control work among the fertilizer producers.

Recommendations

1. The chlorination of the cooling water in order to prevent bacteorological contamination causing precipitates is one of the factors responsible for the corrosion in stainless-steel heat-exchangers as well as carbon-steel equipment. One way to control this is to exchange material at some critical points, especially that of heat exchanger tubes. For example, tube material C 0.02, Cr 19.5, Ni 25, Mo 4.5, Cu 1.5 lasts long in cooling water with a high Cl_2-content. In several places it is possible and economical to change the carbon steel or concrete pipes to PE-plastic pipes, which are often cheaper and last longer. PE-plastic pipes are at present in common use in industrial and domestic fresh water and waste water pipelines. It could be expedient to send exact descriptions of plant conditions to some manufacturers of materials and ask their recommendations.

2. The management of BCIC in the Ghorasal plant knew that ICI has some know-how for controlling corrosion in the case of synthesis gas economizers and is considering to buy the license for the same.

3. In the case of Geamerco-Vetrocoke solution reboiler tubes, a corrosion-resistant material of type C 0.02, Cr 25, Ni 22, Mo 2.1, N 0.12 is a good solution. It could be profitable to ask the recommendations of material producers.

4. It is possible to prevent hydrogen attack in synthesis gas by changing to resistant material like type C 0.03, Cr 21, Ni 34, Ti, Al in PWR finish.

5. The corrosion of the CO_2 superheater tube looks in the test sample like a stress corrosion crack; however, to be sure, it had to be analysed in a metallographical laboratory. UNIDO sent the sample together with a description of equipment and process to the laboratories of Sandvik AB. The test results and suggestions for a solution of the problem are given in annex I.

C. Sichuan, China

Meetings, participants and plants

Meetings were arranged daily between Monday 24 and Friday 28 November 1980 and the participants were: Y. Zhong from Chengdu Chemical Engineering and Design Institute, C.G. Fann and W.H. Ho from Sichuan Corrosion Control Information Centre, Y.C. Deng and S. Ruan from Sichuan Chemical Plants, I.R. Wang from Foreign Affairs Bureau of the Ministry of Chemical Industry and M.Z. Wen from Luchow Chemical Plants. The following plants were discussed: Sichuan old plants (own know-how, ammonia 600 t/d, saltpeter 550 t/d, urea 360 t/d, ammoniumbicarbonate 350 t/d), Sichuan new plants (Toyo engineering, natural gas as raw material, ammonia 1,000 t/d, urea 900 t/d), Luchow old plants (ammonia 300 t/d, ICI process/Humphrey and Glasgow Engineering, urea 500 t/d, Stamicarbon, in operation since October 1966), and Luchow new plants (ammonia 1,000 t/d, Kellogg Engineering, urea 1,500 t/d, Stamicarbon Engineering, in operation since March 1977).

Use of the know-how

After Mr. Zhong's return from Sandviken, all papers of the meeting were translated into Chinese, a book was printed in 3,000 copies and distributed to more than 400 fertilizer and chemical enterprises in China. All this happened during autumn 1979.

Unresolved corrosion problems

Mr. Yilie Zhong, Mr. Shi-Ruan and Mr. Ming-Zhen Wen had each prepared a paper about corrosion problems in the fertilizer industry of the Sichuan area. Because they have already detected the reasons and found a way of controlling corrosion in many cases, the following contains only important unresolved problems:

(a) Rupture of tubes of the primary steam reformer using natural gas as feedstock;

(b) Corrosion of waste heat boiler after the secondary steam reformer;

(c) Hydrogen embrittlement in ammonia synthesis apparatus under high pressure and temperature;

(d) Corrosion in Benfield carbon dioxide removal equipment;

(e) Corrosion in urea synthesis equipment under high pressure and temperature in contact with carbamate, carbon dioxide and urea solutions;

(f) Corrosion in nitric acid plant;

(g) Corrosion in cooling water systems

- (i) Universal corrosion of carbon steel pipes and devices;
- (ii) Stress corrosion cracking of stainless steel heat-exchanger tubes;
- (iii) Corrosion of water pump impellers.

Future assistance by UNIDO

It is important that UNIDO continues to organize the exchange of corrosion control know-how between fertilizer producers and equipment material manufacturers by convening seminars and expert meetings. In addition to the material problems of equipments, other questions connected with corrosion control, like the use of inhibitors, cathodic protection etc. could be treated more extensively.

Recommendations

1. Due to their good creep properties, centrifugally-cast high-alloy tubes are commonly used as catalyst tubes in primary reforming furnaces. In addition to the most common tube material HK 40 (C 0.4, Cr 25, Ni 20), HP 35 (C 0.4, Cr 25, Ni 35) has also been used in recent years. Especially for reformer outlet system "pigtail" tubes, alloy 800, corresponding to Sandvik Sanicro 31 H, with the basic composition C 0.07, Cr 21, Ni 31 and additions of Al and Ti, is the dominating material. For very serious creeping cases Sandvik Sanicro 32 should be considered. The creep strength has been improved significantly by adding 3% tungsten to the afore-mentioned composition. Another effect of the tungsten addition is an improved resistance to carburization.

2. Deposits of silica and potash are often causing corrosion on tubes of the waste-heat boiler directly after the secondary reformer. Silica derives probably from the secondary reformer catalyst and potash from the primary reformer catalyst. Their reaction products, in the temperature range between 300°-400°C, are causing corrosion attacks on carbon steel and on low-alloy steel at temperatures towards the lower limit of that temperature range. At higher temperatures it leads to pitting corrosion. A higher Ni content would in this environment increase the corrosion resistance. Materials of type Alloy 600, equivalent to Sandvik Sanicro 70 (Ni 72%) have proven to have sufficient resistance. Since even with that high Ni level intergranular stress corrosion cracking can occur in highly pure water or steam at the extreme temperatures and pressures prevailing in the waste heat boiler, the best solution is to use composite tubes consisting of Sanicro 70 or corresponding material on the gas and alkaline melting side, and carbon steel (e.g. Sandvik 4L7) on the steam side.

3. Hydrogen attack in synthesis gas can be prevented only by changing to durable material like type C 0.03, Cr 21, Ni 34 plus additions of Al and Ti. This material has a very high resistance to high-temperature hydrogen attack. It is recommended to use PWR finish like Sanicro 30 or equivalent.

4. In carbon dioxide removal systems severe corrosion can occur owing to contact with hot aqueous solutions of carbon dioxide in the presence of amines, potassium carbonate or other absorbents. The corrosion attack is accelerated by increased process stream velocities. Poor heat-transfer that causes hot spots in reboilers and heat exchangers also accelerates the attacks. Especially

in the regenerator reboiler, where the temperature is the highest of the whole carbon dioxide removal system and the corrosion conditions are the worst, materials with a higher content of alloying elements than in AISI 304 or AISI 316 are required. Material C 0.02, Cr 25, Ni 22, Mo 2.1, N 0.12 has solved several severe reboiler corrosion problems in MEA, Benfield and Vetrocoke gas cleaning systems.

5. Ammonium carbamate which develops in the reactions taking place in the reactor and stripper of the urea synthesis equipment is a very aggressive corrosion agent on stainless steel. Important is the oxygen content; if it were kept on the right level and the specifications for the manufacture or repair of the equipment were carefully observed (e.g. Stamicarbons specifications), no corrosion problem would exist even when using normal AISI 304 or 316 steel. However, as it is not possible to control reaction conditions and the quality of the cooling water to the extent that they are absolutely safe, the use of steel of type C 0.02, Cr 25, Ni 22, Mo 2.1, N 0.12 (like Sandvik 2RE69 or equivalent) has to be recommended for the reactors, strippers and carbamate condensers in a urea synthesis system.

6. To ensure reliability in service and to minimize the maintenance problems in nitric acid systems, it is advisable to use AISI 304L "Nitric Acid Grade", Sandvik 2R12 or equivalent material. However, for processes requiring relatively high pressure (up to 0.9 MPa), conditions which exist in heat exchanger tubes and shells, it is recommended to use high-purity austenitic stainless steels of type Cr 25, Ni 20, and Cr 25, Ni 22, Mo 2, like Sandvik 2RE10 and 2RE69 or equivalent.

7. To prevent corrosion in cooling water systems the following is recommended:

(a) If for technical or economical reasons it is not possible to purify the water so as to prevent corrosion of carbon steel, different materials should be used, for example PE-plastic pipelines for diameters up to 1,600 mm, and glass-reinforced plastic material for tubes of a larger diameter. In many countries PE-tubes are widely used for industrial and domestic fresh and waste water pipelines;

(b) If the water contains chlorine gas or chloride ions causing stress corrosion cracking in the heat exchanger tubes, Sandvik 2RK65 or an equivalent material (C 0.02, Cr 19.5, Ni 25, Mo 4.5, Cu 1.5) should be employed;

(c) Sometimes the corrosion of water pump impellers cannot be avoided even by using resistant alloys. The more economical solution could be the utilization of rubber-lined or plastic pumps.

D. Beijing, China

A meeting was arranged on Monday, 1 December 1980, in the Ministry of Chemical Industry in which participated the Ministry's specialists working on corrosion problems. Various corrosion problems experienced in their own work were discussed but no new problems were added to the ones mentioned in the preceding section. The Chinese translation of the papers of the Sandviken meeting had been distributed to them.

E. Alexandria, Egypt

Meetings, participants and plants

Meetings were arranged on Saturday 6 and Sunday 7 December 1980. The participants were R. Farghaly, M. Gaber, M. Hamza and W. Kelada. The following plants were discussed: ammonia 1,000 t/d, Uhde engineering, raw material natural gas; urea 1,550 t/d, Stamicarbon engineering (single stream, vaporization prilling), operations started in 1979. The calculated production losses due to corrosion were in 1979 about $3 million.

Use of the know-how

Papers from the Sandviken meeting were distributed to the engineers of the plants.

Unresolved corrosion problems

(a) Corrosion in heat exchangers of urea systems (water/ammonia-urea solution);

(b) Corrosion in intercoolers of carbon dioxide compressor (carbon dioxide/treated water, pH 6.5-7, total hardness 125-150 ppm, NH_3 1-20 ppm);

(c) Corrosion of underground raw water pipeline (⌀ 48", length 1,700 m, carbon steel, coated outside with epoxy resins);

(d) Pinpoint corrosion in oil coolers (carbon steel);

(e) Corrosion in the steam generator for ammonia synthesis process (U-bent heat exchanger, shell H II, tubes X10CrNiTi 18/9). Steam temperature 149°C, pressure 9.7 bar. Gas inside the tubes CO_2 17.99%, CO 8.39%, H_2 61.21%, CH_4 0.26%, N_2 29.00%, Ar 0.29%, temperature 228°C, pressure 29.4 bar. Boiler feed water purified in ion exchangers, Si 0.006, conductivity 0.2 MS (maximum) Corrosion appears in tube bends progressing from outside to inside.)

Future assistance by UNIDO

The participants requested UNIDO to provide a corrosion adviser to Abu Qir plants for a period of not less than three months, to finance training courses in developed countries, and to arrange a seminar on corrosion for fertilizer plants in co-operation with the Egyptian Corrosion Society.

Recommendations

1. If the reason for corrosion in the heat exchangers of the urea systems and the intercoolers of the carbon dioxide compressor is the chloride or chlorine content of cooling water and provided that it is not economical to improve the quality of water, the material of the heat exchanger tubes has to be changed. Sandvik 2RE69 or equivalent (C 0.02, Cr 25, Ni 22, Mo 2.1, N 0.12) would be suitable because of its resistance to all aggressive agents in urea processes and to chloride.

2. Corrosion of underground raw water pipeline can be avoided by using cathodic protection, a measure which the management of the Abu Qir plants has already planned. It is also possible to replace the pipes by 1,000 mm ∅ PE-plastic pipes (for 10 bar), which would correspond to a steelpipe of 1,200 mm ∅ (48").

3. The reason for pinpoint corrosion of oil coolers is probably the chloride content of the cooling water. In that case the material of the tubes has to be changed, e.g. to Sandvik 2RK65 or equivalent (C 0.02, Cr 19.5, Ni 25, Mo 4.5, Cu 1.5).

4. To solve the corrosion problem experienced with the U-bent tube of the steam generator a sample has been sent to the laboratories of Sandvik AB for metallographical investigations. The results and recommendations for material are given in annex II.

F. Riyadh, Saudi Arabia

Meetings, participants and plants

The only meeting at Riyadh was arranged on Wednesday 10 December 1980 and the participant was A. Al-Rashid. The following plants were discussed: Ammonia 1,000 t/d, Kellogg engineering; urea 1,600 t/d, Stamicarbon engineering.

Use of the know-how

A. Mohsen, one of the participants of the Sandviken consultation meeting has distributed the papers to the other engineers of the Saudi Arabian Basic Industries Company (SABIC). The know-how has been used in negotiations with engineers of Kellogg and Stamicarbon.

Unresolved corrosion problems

Since the afore-mentioned plants are not in operation, no corrosion problems have occurred.

Future assistance by UNIDO

Mr. Al-Rashid is convinced that dissemination of corrosion know-how and co-operation on such issues as losses caused by corrosion is important and thinks that UNIDO should continue in its efforts.

Recommendations

It is suggested that the management of the company designate one engineer who would concentrate only on corrosion problems in the fertilizer industry. That kind of expert could be very useful in planning and construction work as well as in the training of SABIC's personnel.

G. Damman, Saudi Arabia

The representative of the Saudi Arabian Fertilizer Company (SAFCO) at the Sandviken consultation meeting, Mr. Al-Mekenzy was abroad during the expert's mission. The corrosion engineer of SAFCO was also not available for a meeting, but upon his request the expert sent him a short questionnaire. He agreed to reply directly to UNIDO.

H. Sfax, Tunisia

Meetings, participants and plants

One meeting was arranged on Saturday 13 December 1980 with M. Ben-Charrada. The following plants were discussed: sulphuric acid (98%), 750 t/d + 300 t/d; phosphoric acid (28%), 400 t P_2O_5/d; TSP (47% P_2O_5) 1,000 t/d (granulated).

Use of the know-how

After the Sandviken meeting Mr. Ben-Charrada had distributed the papers tc the other engineers of the company (SIAPE).

Unresolved corrosion problems

(a) Corrosion of sulphuric acid cooler on water side;
(b) Corrosion on gas side of waste-heat boiler;
(c) Corrosion in filters (stainless steel).

Future assistance by UNIDO

The company considers it important that UNIDO arranges conferences on corrosion problems in specific areas of the fertilizer industry, for example in the production of sulphuric acid. It was also emphasized that the papers for the conference should be sent to the participants well in advance, so that the participants have enough time to prepare questions relating to their own problems.

Recommendations

1. For the prevention of corrosion of sulphuric acid coolers (product coolers) the heat exchanger tubes should be made of, for example, Sanicro 28/2RK65. Anodic protection is required if seawater or other chloride-containing cooling water is used.

2. Corrosion on the gas side of the waste-heat boiler can be prevented by ensuring that the temperature of the gas is always above the condensation point.

3. Regarding the corrosion problem in the filters, not enough information could be obtained to make recommendations. It is therefore suggested to send detailed information about the conditions and the material of the filter, possibly together with a test sample of corroded metal, to some of the producers of stainless steel (e.g. to the laboratory of Sandvik AB) and to ask for a recommendation.

Annex I

TEST RESULTS - TUBE OF CO_2 SUPERHEATER IN UREA PLANT OF BCIC, GHORASAL

Background

A sample of the 3 mm thick wall was taken from tubes that have been working under the following conditions

Tube side: CO_2 t_{in} = 105-110°C

t_{out} = 40-45°C

Shell side: Cooling water (composition, pH etc. unknown)

Estimating the inlet temperature of the water to be about 30°C, the maximum temperature of the wall will be around 70°C.

Investigation

The chemical composition of the sample was determined to be (percentages)

C	Cr	Ni	Mo
0.06	18.6	9.3	0.09

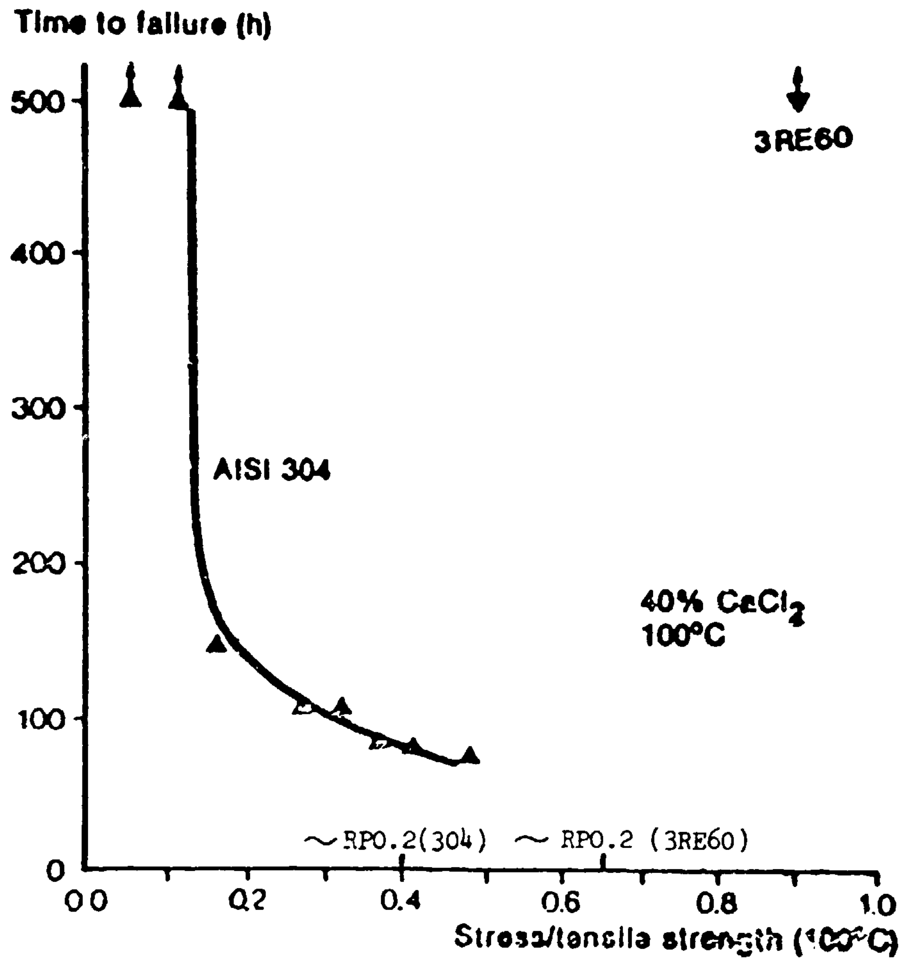
which corresponds to austenitic stainless steel, type 304.

By metallographical examination, the sample showed extensive crackings of the kind illustrated in figure I. The appearance of these cracks is typical for stress-corrosion cracking (SCC).

SCC is normally formed in standard austenitic stainless steels under tensile stresses, when exposed to chloride-containing water at temperatures above about 60°C. The stresses can be formed, for instance, as residual stresses at welds, during fabrication or during service from vibrations or high internal pressure. On steels of type 304, which are very susceptible to SCC, a stress level as low as 15% of the tensile strength may be sufficient to provoke cracks under certain conditions (see figure II).

Figure I. SCC cracks formed on cooling-water side of 304 tube

Figure II. Diagram showing time to SCC-failure as a function of relative stress (A comparison of steel of type 304 and Sandvik 3RE60)



The yield strength (0.2% offset) of 304 is about 40% of its tensile strength, whereas for 3RE60 the yield is about 65% of the tensile strength.

In that case, the cracks have started from the water side, which means that chlorides must have been present in the water. The stresses probably derive from vibrations during service, in combination with the relatively high internal pressure.

Recommendations

In order to solve the cracking problems, it is recommended to change to a ferritic-austenitic steel (e.g. Sandvik 3RE60), which is extremely resistant to SCC. A comparison with 304 is made in figure II, which is valid for a concentrated chloride solution. The excellent behaviour in laboratory conditions has also been experienced in practice in a great number of different applications.

3RE60 has more than double the strength of ordinary 304, which means that a 50% reduction in wall thickness is possible.

Annex II

TEST RESULTS - TUBES OF AISI 321 STEAM GENERATOR IN NH_3 PLANT OF ABU-QIR FERTILIZER AND CHEMICAL INDUSTRY COMPANY, ALEXANDRIA

Background

The sample (25 mm ∅ x 1.55 mm) was taken from a tube in the position of a supporting baffle (row 8/tube 11), and the service conditions were as follows:

Tube side:	Synthesis gas,	t = 228°C
		pressure 29.4 bar
		CO_2, CO, H_2, CH_4, N_2
Shell side:	Steam	t = 149°C
		pressure 9.7 bar

Investigation

The chemical composition of the sample was determined to be as follows (percentages):

C	Cr	Ni	Mo	Ti	N
0.048	17.1	10.3	0.37	0.52	0.010

This corresponds to steel of type AISI 321.

Pitting attacks could be observed on the shell side of the tube in the baffle position. The micrograph of such an attack is shown in figure III. No other failure was noticed on the specimen, but on a hand-written piece of paper attached to the letter, some notes regarding corrosion from outside of the bends in the U-bent tubes were put down.

Pitting corrosion on standard austenitic steel of type 304/321 normally occurs in chloride-containing water solutions, and the risk of this type of corrosion is increased in the presence of crevices. Such solutions may also provoke SCC in ordinary austenitic steels.

The cause of the pitting attacks is most probably the presence of small amounts of chloride in the water, which may have enriched in the crevices between tube and baffle plate. A remedy against these attacks is to select a molybdenum-containing stainless steel.

Figure III. Pit formed on shell side of tube at baffle position

Although no bent specimen was received for investigation, it is most likely that SCC is the kind of corrosion that has occurred on the bent part of the tubes. The tensile stresses necessary to induce SCC, probably are residual stresses from the bending operation. This type of corrosion can be inhibited by selecting a ferritic-austenitic steel, which under normal conditions is unsusceptible to SCC. In figure IV, the time to cracking versus relative stress level is given for austenitic 304 and ferritic-austenitic Sandvik 3RE60 (type 321 can be considered equal to 304 in this respect). As can be seen, extremely high stress levels are necessary to provoke SCC on 3RE60 in the actual conditions, whereas stresses in the order of 15% of the tensile strength may suffice to make 304/321 crack.

Recommendations

3RE60 contains 2.7% molybdenum which makes it much more resistant to pitting than 321; its ferritic-austenitic microstructure also makes it withstand the risk of SCC. It will thus form the optimal choice in this application. Another factor of importance is the more than twice as high yield strength of 3RE60 compared to 321, which allows a considerable reduction of wall thickness of the tubes. In this case, tubes of dimension 25 x 1.25 mm are recommended.

Figure IV. Diagram showing time to SCC-failure of 304 and Sandvik 3RE60 as a function of relative stress