EQUIPMENT MANAGEMENT: SPIRAL OF PROGRESS

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Equipment used in chemical industry is the most advance from engineering point of view at the moment of its initial application. Nevertheless it sooner or later fails during the operation in a manner that was difficult to predict. The solutions found to eliminate operational problems serve as a basis for further improvement of the design and material of the equipment.

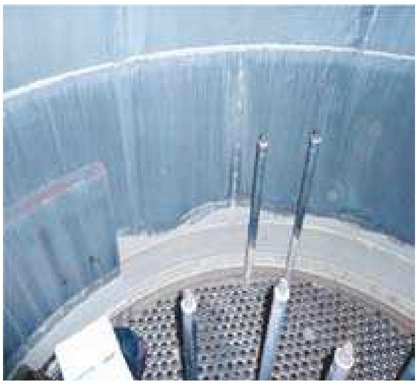
The process of creation starts from an idea. At the next stage research and development of the idea lead to experimental studies. Then design and engineering documents are prepared. Later, the piece of equipment is formed in metal and it is delivered to the site. In the process of operation the data from corrosion inspections and equipment failures are collected. After the reason for the malfunction is found methods and solutions are developed to repair the damage during an overhaul or annual turnaround.

Accumulated experience is used in ideas how to improve the equipment and then those ideas are implemented in new equipment for the same industrial application. The cycle repeats on the next level of excellency.

NIIK (R&D Institute of Urea) has been a part of the constant improvement in urea industry for the past 60 year. In the article we investigate every aspect of the spiral of progress and show cases when deviations at any stage result in undesirable consequences for the operation and suggest solutions how to avoid failures with right equipment management advised by experienced personnel from a specialized organization.

1 Idea

As the first example we'll use liquid dividers in a top chamber of a stripper. It's well known that long-term effective operation of the stripper (which is a falling film heat exchanger) depends on the melt distribution on the tube sheet that affects uniform film formation in heat exchanging tubes. At a certain point of the time a stripper with a half-ring liquid was the most commonly used type. However numerous inspection results showed that melt distribution level was uneven. Two waves rushing from the side holes collided opposite to melt inlet nozzle.



a) wave coming out of the hole

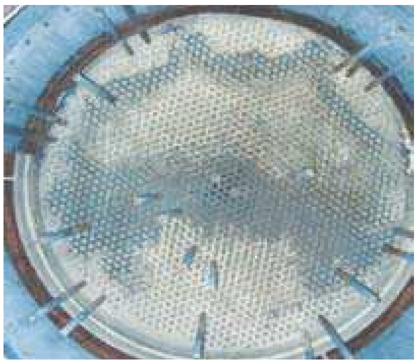
b) collision zone of two waves
Picture 1.1 – Uneven melt level in the stripper

This observation during the inspection led to development of the ring-type liquid divider – a very low cost modernisation – that resulted in drastic efficiency improvement. Picture 1.2 a) shows uniform distribution of the melt in the stripper equipped with ring liquid divider.

Deposits formation on the tube sheet is one more marker that helps to reveal if the melt level is uniform. Picture 1.2 shows deposits location on the tube sheets from different strippers.

a) Ring liquid divider of NIIK design – deposits are located on the same distance from the wall

b) SBN ring liquid divider – evident dislocation of the deposits from the center of the tube sheet, deposits formation area varies greatly



c) Tube sheet from a striper with a half-ring liquid divider
Picture 1.2 – Deposits distribution on tube sheets from different strippers

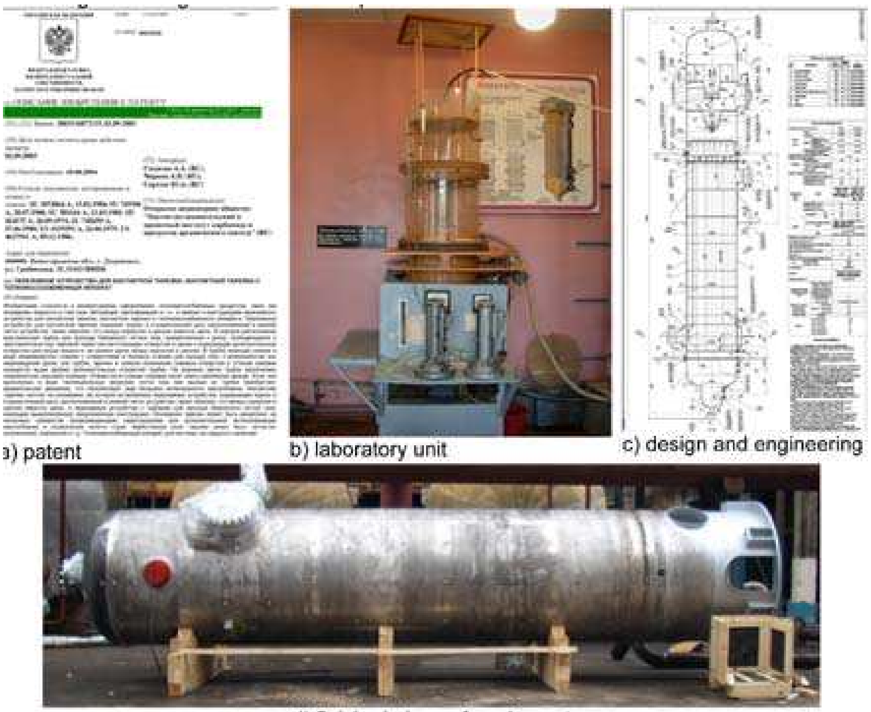
During the corrosion inspection we collect visual and statistic information that can be used to evaluate equipment condition and assess operational conditions (in this case – from hydrodynamic point of view) resulting in process optimization and improvement of equipment design.

2 Research & development

The idea undergoes a process of experimental trials to prove its usefulness. Experimental (laboratory scale) and pilot (industrial scale) units are built to test the idea. This can be done either inside the company that develops and idea or by utilizing facilities of a partner company (Picture 3.1 b).

3 Design

After the idea passes initial experiments and tests design documents are developed according to existing standards and requirements.



a) patent b) laboratory unit c) design and engineering

d) finished piece of equipment

Picture 3.1 – From idea to the final result

4 Manufacturing supervision

Even the finest idea and design can be ruined by improper implementation. Manufacturing supervision is extremely important to avoid serious consequences during the operation. Below several examples are given when poor quality of the equipment was the result of the lack of supervision during the fabrication.

4.1 Stripper pos. E-201, Austrian manufacturer

The inspection was carried out after the first year of operation. On the inner surface of heat exchanger tubes made of Sandvik 2RE69 serious pitting corrosion was noticed in the area of welding. The tubes condition is shown in Picture 4.1.

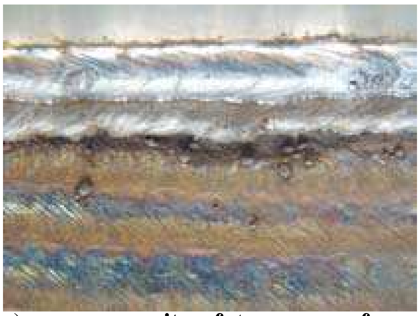
Picture 4.1 – Pitting corrosion on inner surface of heat exchanging tubes
The pitting was the result of the wrong welding parameters used at fabrication stage.

4.2 Middle part of the scrubber pos. E-203, Italian manufacturer

The inspection was carried before the installation of the vessel. After the inspection it was forbidden to install the equipment and use it in operation. The defects are shown in Picture 4.2.

a) a pinhole on liner weld, the result of an arc impact after the electrode was removed

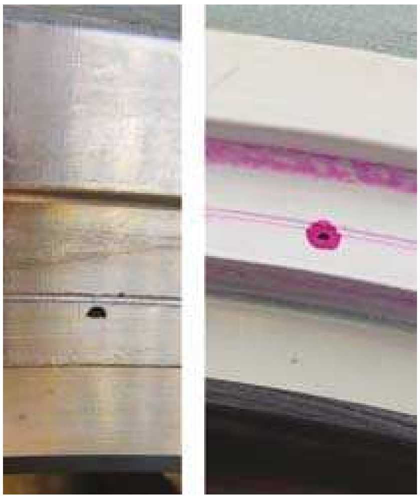
b) membrane weld joint lack of fusion during welding and cut up weld joint



c) numerous spits – future areas of corrosion

d) lack of shielding gas during welding – gray color of the joint

e) cracks nozzle welding joint

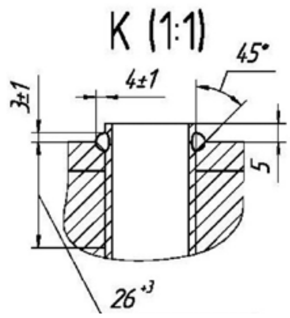


f) gasket surface cavities before and after dye penetrant test

4.3 Precondensator E-303A, Ukrainian manufacturer

The inspection was carried out during the installation of the new precondensator.
Tubes material steel 316Ti did not match with the specified in engineering documents steel 316L UG. Tube to tube sheet welding joints did not correspond to design specifications. Some of the welds were performed using SMAW instead of TIG welding. Numerous cases of cavities and flux contamination were revealed. Two tubes were plugged during manufacturing. Tube sheet is shown in Picture 4.3.

a) actual welding joints



b) design

Picture 4.3 – Precondensator pos. E-303A tube sheet

The shown cases are just a few examples why more and more plant operators are relying on NIIK (R&D Institute of urea) expertise during the supervision of manufacturing process. Proper supervision is a reliable solution to assure problem-free operation.

5 Corrosion inspection

What happens if the equipment condition is monitored by under qualified personnel or if the operation process does not comply with the requirements? Below are few examples to illustrate such cases.

5.1 Carbamate condenser T-506

The vessel was a part of a relocated urea unit. The permission for operation of the vessel was issued by an organization that was authorized to grant permits, but lacked the most important aspect – expertise in urea plants inspections. After nine months of operation a leakage was observed in the shell of the vessel near the lower tube sheet. NIIK (R&D Institute of Urea) insisted that the operation of the plant must be stopped and the place of leakage thoroughly examined, but instead the plant management decided to weld a leaking area in the shell and continue plant operation. A week after there was another leakage in the shell and this time the plant was stopped to discover a major corrosion damage in the tube sheet. Repairs took more than 5 weeks.

a) welded shell penetration damage

b) another shell penetration damage

c) tube sheet damage revealed after shell and tubes were dismantled

d) tube sheet damage

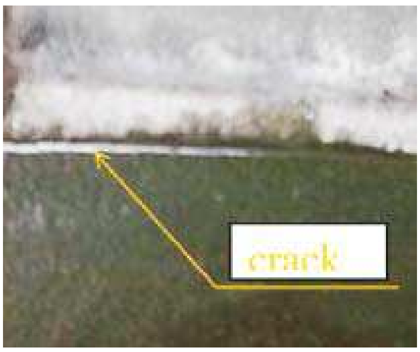
e) cracks in a tube from the tube sheet area

f) metallography examination of the tube

Picture 5.1 – Tube sheet damage in carbamate condenser T-506

5.2 Reactor R-901

NIIK (R&D Institute of Urea) specialists recommended to perform a major overhaul of the reactor with partial replacement of the liner in July 2011. In 2012 the plant was still in operation, no repairs were done on the reactor.
On June 08, 2012 there was ammonia detected by leakage control system of reactor pos. R-901 liner, the reactor has been used since 1982. The plant called for NIIK specialists to evaluate leakage consequences.
After the plant was shut down and reactor was opened internal inspection of liner welding joints showed a penetrating damage in a form of a crack in the welding joint between the second and the third liner belts (if counted from the top down).
In order to evaluate how far the damage got under the liner, a part of the liner was cut off in the damaged area with dimensions 400x200 mm.
After the part of the liner was removed numerous defects were revealed:
1) multiple layer shell of the reactor and the ring weld joint of the shell were damaged severely, corrosion depth was 25 mm (30% of the shell thickness);
2) the corrosion spread further under the liner.
Followed overhaul to evaluate the damaged shell area, shell repairs and liner replacement took 26 days of 24 hours' work. 26 days the plant has been shut down.



a) crack in the ring weld joint between 2nd and 3d liner belt

b) Corrosion damage of the shell with the depth reaching 25 mm

Picture 5.2 – Damage in the liner and in the shell under it

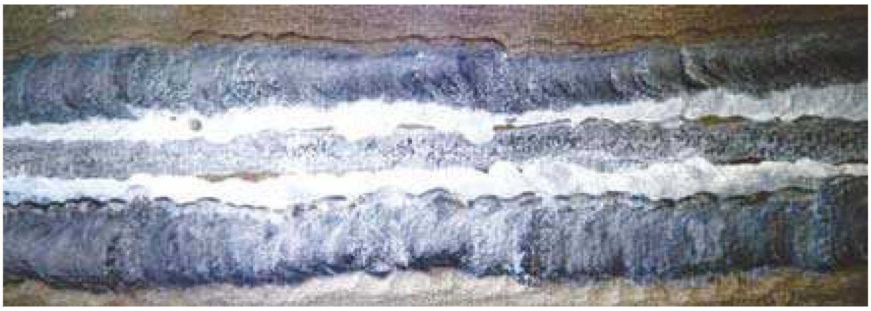
6 Repair

Whilst for a major overhaul contractor specialists are invited, regular maintenance is performed by a staff that might be not aware of special requirements to carrying out repairs in urea plants.

6.1 Reactor R-901

The inspection in 2011 showed that reactor pos. R-901 can be used as an illustration on how not to do the maintenance of reactor liner.
Liner welds had numerous sings of repair welds performed at different times using different methods. Most of the repair welds were done over the heat affected zone left from the fabricator of the reactor. Most probably the staff tried to fight thickening of the material in the heat affected zone (HAZ). Partially some of the welds were replaced by new ones, but this had been done carelessly and did not correspond to special methods of welding for such applications:
- improper welding consumables were used (the welding joints were almost completely destroyed by corrosion);
- amperage was too high during the welding (corrosion thinning up to 2 mm in heat affected zone at some repair weld, welding joints with numerous cavities and in poor condition);
- welding joint geometry was uneven (large beads, gas flame deviation during welding, lack of fusion in the weld joint levels);
- welding overlay by SMAW the beads thickness is 5-6 mm that is almost the same as the liner thickness.

The list of defects can be much longer, but we'll stop here. Picture 6.1 show most of the cases of weld defects in liner welds.



a) thinning in HAZ in repair welding joints with depth up to 1 mm – high amperage during the welding, black weld bead with cavities – insufficient protection of the welding groove

b) welding joint geometry deviations – welding at low amperage

c) overlay welding joints completely destroyed by corrosion caused additional thinning of the liner with depth of 2 mm. Wrong welding consumables were used.

d) repair overlay of the base welding joint. Done manually by arc welding with a coated electrode – spits on base metal, bad weld joint geometry and large beads

Picture 6.1 – «Repair» weld beads on reactor liner

During the emergency shutdown in 2012 inspection there was a shell damage found with the depth of 45 mm (54% of shell thickness) caused by liner penetration damage. After almost a month's work to repair the shell and liner the plant management was still not sure whether or not to replace the liner.

We should probably thank the management of the plants that at the multimillion costs demonstrate again and again how careful we should be with the equipment management at every stage: procurement and manufacture, operation, maintenance and repairs.

We should learn from others' mistakes, consider them and create new equipment based on the accumulated experience – this is the right approach to equipment management.
There is no end in the perfection cycle of equipment improvement. Cooperation between operators and qualified research and development engineering organizations help to achieve maximum profit and assure safety of operation of urea plants.