

Mechanical Tube Plug Technology for High Pressure Heat Exchangers in Ammonia and Urea Plants

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The Pop-A-Plug® system is a mechanical tube plug to seal leaking or degraded high-pressure heat exchanger tubes. The design objective was to produce a fast and simple way to install mechanical tube plug with better-installed stability than a welded plug.

This paper provides an update on the technical developments and successes of the Pop-A-Plug in Ammonia and Urea Plants.

Introduction

SKW STICKSTOFFWERKE PIESTERITZ GMBH (SKW) is the largest producer of ammonia and urea in Germany, domiciled at one of the best locations throughout Europe, in a largely agricultural region of Germany. The company operates two Kellogg ammonia plants, each with an output of 1,650 MTPD (1819 STPD) (first name plate: 1,350 MTPD) (1488 STPD), three Stamicarbon CO₂ stripping plants (all with a capacity of over 4,000 MTPD) (4410 STPD), one Uhde nitric acid plant and other plants for the production of special products.

Ammonia Plants of SKW are designed by M. W. Kellogg, USA and engineered by Toyo Engineering Cooperation. The plants were commissioned in 1973 and 1975. It is a conventional steam reforming process. The Capacity was enhanced to 1,650 MTPD (1819 STPD) in 1989.

This Kellogg Ammonia Plant operates a secondary reformer 103-D followed by 2 primary waste heat boilers 101-CA/CB in parallel, followed by one secondary waste heat boiler 102-C.

Problem Description

Leaking tubes and some other tubes with cracks identified by Eddy Current Testing (ECT) required sealing off by plugging. Pitting corrosion due to caustic reaction resulted in tube leakage.

The only known process for sealing the leaking tubes was the installation of tube plugs with a thread. These plugs were welded into the tubes with preheating and post heat treatment. This repair process is lengthy and could take up to a total of 3 days to

complete. Also subject welded plugs suffer from circumferential cracks after the units have gone back into service and are exposed to the temperature cycles of the waste heat boiler. (See Figure 1)

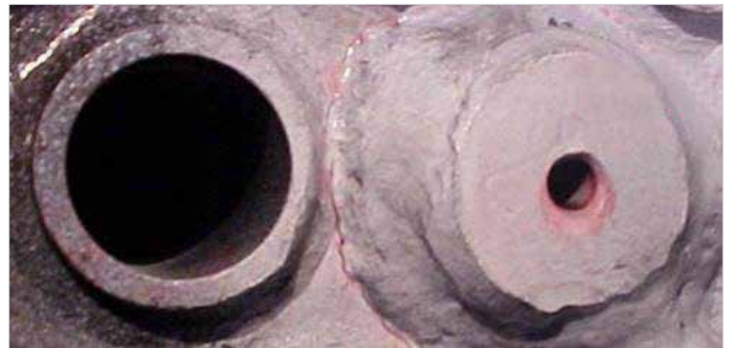


Figure 1. Example of welded plugs

Applications Details Unit 102-C

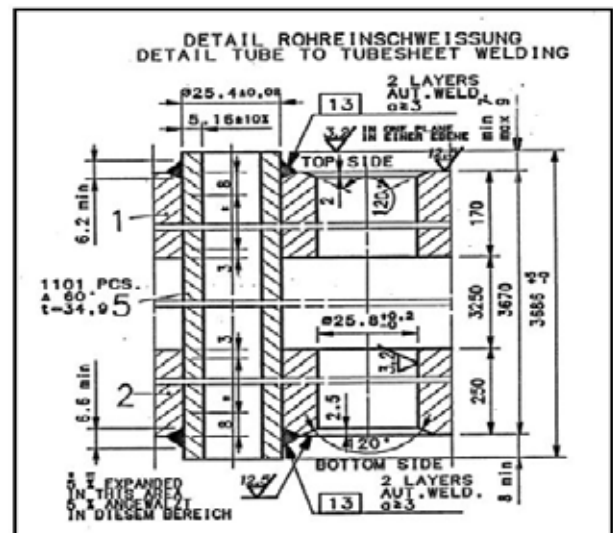


Figure 2. Tube to Tubesheet Welding drawing

The heat exchanger 102-C is a fixed tube vertical heat exchanger with 1,101 tubes 25.4 mm (1.00 in) OD x 5.16 mm (.203 in) wall (material of tubes and tube sheet: Pressure hydrogen resistant steel 10 CrMo910 (ASTM A 182 F22). See Figure 2 for tube to tubesheet configuration. Process conditions are as follows.

Tube side:

Pressure	35.5 BarG (515 PsiG)
Temperature (Low)	340°C (644°F)
Temperature (High)	450°C (842°F)
Fluid	Process Gas

Shell side:

Pressure	118.0 BarG (1621 PsiG)
Temperature	330°C (626°F)
Fluid	Steam Boiler Feed Water

Applications Details Unit 123-C1/C2

The heat exchanger 123-C1/C2 is a heat exchanger with tubes 19.05 mm (.75 in) x 3.10 mm (.122 in) (material of tubes and tube sheet: 10 CrMo910 (ASTM A 182 F22). See Figure 3 for tube to tubesheet configuration.

Tube side:

Pressure	320.0 BarG (4641 PsiG)
Temperature	345°C (653°F)
Fluid	Process Gas

Shell side:

Pressure	115.0 BarG (1667 PsiG)
Temperature	330°C (626°F)
Fluid	Boiler Feed Water

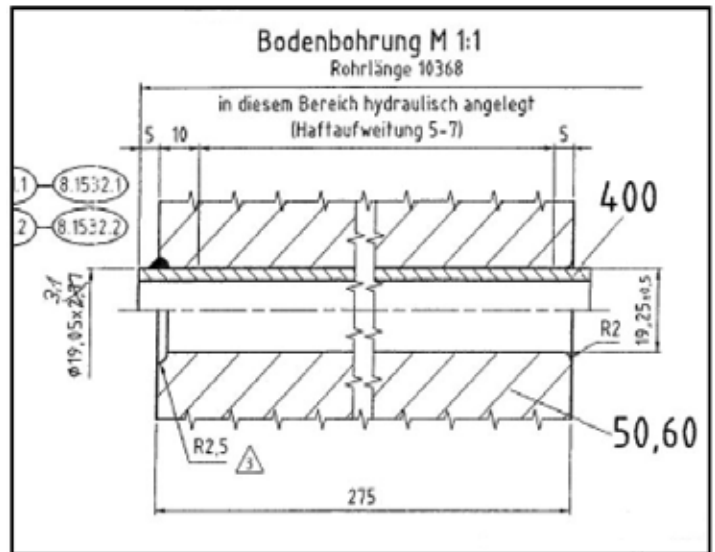


Figure 3. Heat exchanger drawing 123-C1/C2

Pop-A-Plug Features



Figure 4. EST Group Pop-A-Plug P2

The Pop-A-Plug system eliminates the need for welding tube plugs. The system is long proven in fossil fuel and nuclear power generation stations. The Pop-A-Plug heat exchanger tube plugging system is the only plug that features internally serrated rings designed to maintain a leak-tight seal under extreme thermal and pressure cycling.

The Pop-A-Plug is installed using a controlled force, which protects against damage to tube sheet ligaments and the adjacent tube sheet joints. Thus the life of the heat exchanger is extended and costs are reduced when you need to re-tube. Pop-A-Plug system takes only minutes to install.

The system is available in a wide array of materials such as *F11*, *F22*, *Zirconium*, *Alloy Steel*, *Standard Stainless Steel*, *904L*, *SX*[®], *Saramet*[®], among others and can be matched to the tube or tube sheet it is installed in. Matching the material eliminates differences in thermal expansion rates and ensures a perfect seal is maintained during temperature cycles experienced by the heat exchanger.

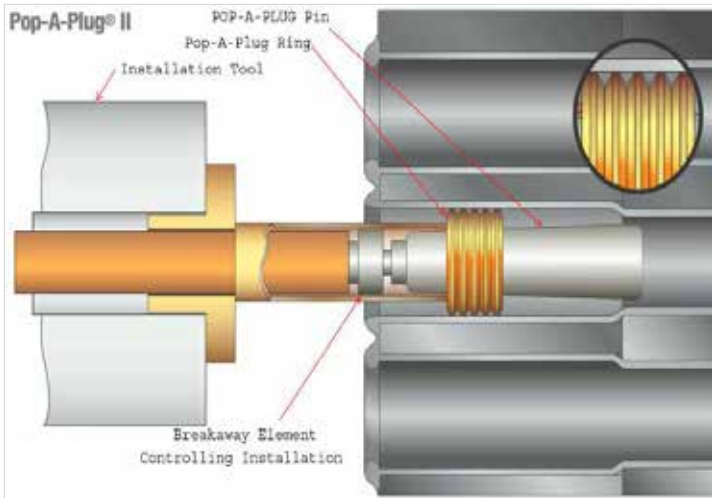


Figure 5. Pop-A-Plug installation inside tube

Solution

SKW approached EST to find a solution to plug these heat exchanger tubes without welding and within a shorter timeframe with improved reliability.

The first step was for EST Group to investigate the use of ASTM A 182 F22 Class 3 for manufacturing Pop-A-Plugs.

For size selection it was decided for heat exchanger 102-C to have the plugs installed inside the tube. A controlled surface and tolerance was achieved by means of machining (reaming and brushing) the tube inside diameter to a diameter of 16.0 mm (.63 in).

For size selection it was decided for heat exchanger 123-C1/C2 to have the plugs installed inside the tube sheet (tube section to be removed). A controlled surface and tolerance was achieved by means of machining (reaming and brushing) the tube sheet inside diameter to a diameter of 20.0 mm (.787 in).

EST Group engineered, manufactured and qualified the appropriate Pop-A-Plug made from ASTM A182 F22 Class 3 for each heat exchanger. The information below highlights the plugs manufactured for SKW's units.

Heat Exchanger 102-C

EST Group Part #P2-630-CR-SP-0611

Max 413.6 BarG/537.8°C (6000 PSIG/1000oF)

Heat Exchanger 123-C1/C2

EST Group Part #P2-790-CR-SP-0611

Max 344.8 BarG/537.8°C (5000 PSIG)/1000°F

Qualification Testing

SKW provided 10CrMo9 10 bar stock material for EST Group to manufacture test coupons in order to install the plugs as per the installation instructions and procedures supplied with the plugs.



Figure 6. Test Coupon (10CrMo9.10) with P2-630-CR-SP-0611



Figure 7. Test Coupon (10CrMo9.10) with P2-790-CR-SP-0611

Thermal Heat Cycles

Test Coupons (10CrMo9.10) with P2-630-CR-SP-0611 (ASTM A182 F-22 Class 3) installed have been exposed to thermal heat cycles (temperature selected was process gas entry temperature) by SKW as below:

- Increase from 22°C (72°F) to 400°C (752°F): 4 hours
- Holding Time at 400°C (752°F): 2 hours
- Cool down from 400°C (752°F) to 22°C (72°F): *Overnight*

Test Coupon (10CrMo9.10) with P2-790-CR-SP-0611 (ASTM A182 F-22 Class 3) installed have been exposed to thermal heat cycles (Temperature selected by SKW) by SKW as below:

- Increase from 22°C (72°F) to 350°C (662°F): 4 hours
- Holding time at 350°C (662°F) : 2 hours
- Cool down from 350°C to 22°C: *Overnight*

Test	Test Coupon - Number	Test Criteria	Result
1	P2-630-CR-SP-0611	Bubble Leak Test with Air 0.5 BarG (7.25 PsiG)	Passed
2	P2-790-CR-SP-0611	Bubble Leak Test with Air 0.5 BarG (7.25 PsiG)	Passed
3	P2-630-CR-SP-0611	Withstand Pressure Test with Air 1.1 x Tube Side Pressure = 126.5 BarG (1835 PsiG)	Passed
4	P2-790-CR-SP-0611	Withstand Pressure Test with Air 1.1 x Tube Side Pressure = 352.0 BarG (5104 PsiG)	Passed
5	P2-630-CR-SP-0611	1 ½ to 1 Safety Ratio Pressure Test with Water 1.5 x Max Pressure Pop-A-Plug = 1.5 x 413.6 = 620.4 BarG (8996 PsiG)	Passed
6	P2-790-CR-SP-0611	1 ½ to 1 Safety Ratio Pressure Test with Water 1.5 x Max Pressure Pop-A-Plug = 1.5 x 344.8 = 517.2 BarG (7499 PsiG)	Passed

Hardness measurement

Following the successful completion of the pressure tests, the coupons of both plug sizes were sectioned and etched to review sealing characteristics and perform a hardness test.



Figure 8. P2-630-CR-SP-0611 sectioned

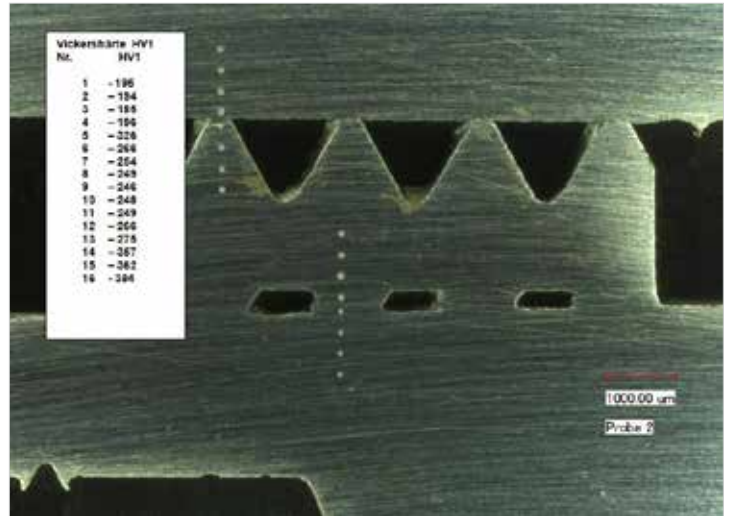


Figure 9. P2-630-CR-SP-0611 detail of sealing ring

Vickers hardness HV1
Nr. HV1
1 - 195
2 - 194
3 - 185
4 - 196
5 - 326
6 - 266
7 - 254
8 - 249
9 - 246
10 - 248
11 - 249
12 - 266
13 - 275
14 - 357
15 - 362
16 - 384

Figure 9 table detail

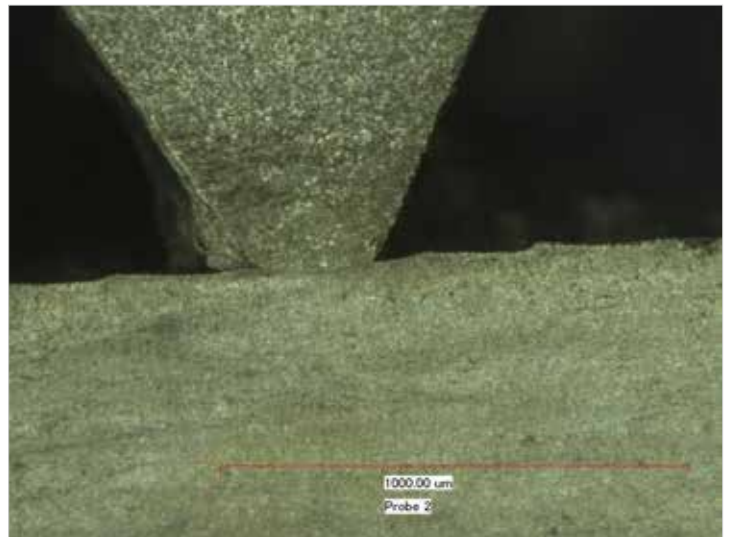


Figure 10. P2-630-CR-SP-0611 detail serration

Conclusion

The Pop-A-Plug successfully passed all qualification tests. And based upon the successful testing, SKW has approved the use of Pop-A-Plugs in ASTM A 182 F22 Class 3 material in the Ammonia plant heat exchangers.

As a direct result significant reductions in repair time will be accomplished. Pop-A-Plugs can be installed in a matter of hours compared to 3 days with welded tube plugs.

EST Group will always review every application for Pop-A-Plugs in detail prior to order and installation to ensure proper application. EST Group has experienced and certified Pop-A-Plug installation companies available.

Developments

Based on results, the next phase of this program has started. This is to develop a suitable Pop-A-Plug to plug tubes in High Pressure Heat exchangers of a Urea Plant by using Safurex® material and meeting the specific design criteria applicable.

Pop-A-Plug is a registered trademark of EST Group, Hatfield, PA, USA.

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Reference

de Rijk, A.G.C.M. (Ron) (2012). Mechanical Tube Plug Technology for High Pressure Heat Exchangers in Ammonia and Urea Plants. In John David Pierce (Chair), *57th AIChE Safety in Ammonia Plants and Related Facilities Symposium*. Chicago, Illinois; pp 295-300.