Shortening of two bimetallic urea strippers in situ: extension of the operational life and reliability by refurbishment.

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Two bimetallic urea strippers which had been in service for more than 20 years were reaching the end of their operational life due to corrosion at the bottom tubesheet that affected the tubesheet, the tube protrusion and the tube-to-tubesheet weld joints

This paper details a unique restore operation that extended the units' life and reliability by several years and consisted in removing and restoring the tube protrusions and tube-to-tubesheet joints at the bottom tubesheet by shortening the stripper length of 40mm

1. Introduction

Indian Farmers Fertiliser Cooperative Limited, Aonla Unit is a fertilizer complex situated in the state of Uttar Pradesh in India and is engaged in manufacturing urea. The complex consists of two streams of 1740 MTPD capacity ammonia plant and four streams of urea plant (namely 11 & 21 Units coupled with ammonia-I plant and 31 & 41 Units coupled with ammonia-II plant) of 1515 MTPD capacity each.

Ammonia production process is of M/s Halder Topsoe, Denmark and urea production process is of M/s Snamprogetti (now Saipem), Italy. The line-1 comprises of ammonia-I and urea-I plants (*i.e.* 11 & 21 Units) along with offsite facilities and utilities which was commissioned in 1987 and line-2 comprises of ammonia-II and urea-II plants (*i.e.* 31 & 41 Units) which was commissioned in 1996.

Captive power plant of the complex consists of 2 gas turbines each having capacity of 18 MW capacity. In urea-II plant (31 & 41 Units), two bimetallic strippers supplied by M/s FBM, Hudson, Italy are in use since commissioning and have bimetallic tubes. Tubes are made of 2 mm 2RE-69 (UNS S31050) with inside lining of Zirconium (0.7 mm thick). Both tube sheets have 10 mm thick weld overlay of 25.22.2 CrNiMo. Total tube thickness is 2.7 mm.

Passivation air at pressure of 160 kg cm-2 at the rate of 45-50 Nm3 hr-1 is continuously fed in the bottom of the stripper to passivate 25.22.2CrNiMo material at the bottom and protect it against corrosion at high operating temperature.

AXO WELDING is an Italian company specialized in servicing, repairing, and modifying static urea equipment.

Since its foundation in 2004 it served urea plants in the Middle East, North and South America, Europe, China, South East Asia, India, and Bangladesh. It is a qualified contractor of world-class companies such as PETRONAS, YARA, SABIC and many others.

AXO WELDING offers a deep knowledge of the materials employed, of the manufacturing and welding techniques, and of the specific problems of the high-pressure section of urea plants.

Figure 1: Urea Stripper 31-E-01

2. Construction Details

Stripper units 31-E-1 and 41-E-1 have the following, identical, main features:

Make: FBM HUDSON

Year made: 1995

Operating Temperature: 205 °C

Operating pressure, tube side (Carbamate + Urea solution): 146 kg cm^2

Operating pressure, shell side (steam): 23 kg cm^2

Total No of tubes: 1.677

Tube material: 25.22.2CrNiMo + Zirconium bimetallic construction

Tube thickness: 2.0mm 25.22.2CrNiMo + 0.7mm Zn

Tube OD: 25.4 mm

Tube ID: 20.0 mm

Tube pitch: 33 mm Triangular

Tube length: 6000 mm

Tubesheet thickness: 245 mm

Tubesheet Weld overlay: 10 mm 25.22.2CrNiMo

Protrusion of tube from bottom tubesheet: 5 mm

Tube-to-tubesheet joint design: full-fillet strength weld with no

Ferrule material: 25Cr22Ni2Mo

Distributor pipe material: 25Cr22Ni2Mo

As in all strippers manufactured in those years, the protrusion of the tubes from the tubesheets was 5mm because the technology of the time did not consent to weld tubes of such a pitch and diameter with a longer protrusion.

Due to the small protrusion, the heat of the weld would cause a harmful disbonding between the internal zirconium layer and the external 25.22.2CrNiMo layer of the tubes. For this reason it was required to remove the zirconium layer on a length of 15mm from the edge of the tube, an operation which would avoid the disbonding but would leave the final part of the tube exposed to the fluid corrosion.

3. Operational Problems and Maintenance History of 31 Unit Stripper

Bimetallic HP stripper at 31 Unit has been in continuous operation since 1996. Periodical inspections during annual turnarounds were carried out. Corrosion in liner welds and general uniform thinning of bottom tube ends were noticed. Liner welds defects were repaired from time to time and were in good condition. All operating parameters of stripper were found normal during period from 1996 to 2012.

In year 2012 the first leak was experienced. As a result, plant steam got contaminated with NH3 and CO2 which caused sudden increase in conductivity of LP steam at E-5 outlet and hence the plant was stopped to attend the repair.

During inspection, severe corrosion in bottom portion of tube to tube sheet weld joints were observed (Figure 2). Weld deposits had developed porosities. During soap solution test, on pressurizing the shell side with air at 3.5 kg cm-2, air leak from 13 nos. tube to tube sheet weld joints was observed.

IFFCO tried to carry out the repair of the tubes by welding but the tube ends – which were already thinned-down – would not stand it, and the repair attempt only caused more leaks from the tubes internal surface. Finally all of the 13 tubes were plugged. When welding the plugs, the affected tube-to-tubesheet welds were covered by weld overlay (Figure 3).

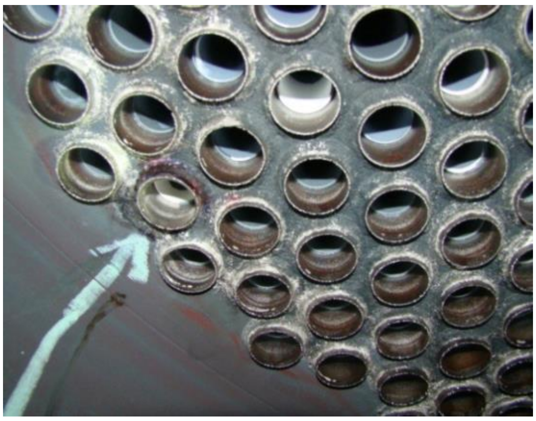

Figure 2: Condition of the bottom TTS welds in 2012

4. Operational Problems and Maintenance History of 41 Unit Stripper

IFFCO

5. Aim of the job

Both strippers had been operated quite carefully, but even in well managed plants it is not unusual for bimetallic strippers to be replaced twenty years after their first commissioning.

Overall, the main problems which lead to the replacement of this type of equipment are normally concentrated at the bottom tubesheet because that is the area where the operating conditions are the most demanding for the materials involved.

The scope of our job was to extend the life of the units by repairing the bottom tubesheet and tube-to-tubesheet welds, but also to introduce some improvement. In particular, in the twenty years since the strippers were manufactured, developments in the welding technology made it possible to weld the tubes with a longer protrusion, thus eliminating the need to remove the protective zirconium layer from the tube end.

6. Preparation and qualification.

Our choice for welding the new tube-to-tubesheet joints fell on a POLYSOUDE P6 welding generator equipped with TP-60 automatic, orbital GTAW welding head. First of all we must work on the welding procedure and, since we planned to execute the whole activity during a normal shutdown without removing the units from their location on the plant, we had to qualify the process for welding overhead – a position that is not used in the workshop manufacturing of new strippers.

To this scope, we prepared a mock-up of the tubesheet in accordance to the requirements of SAIPEM specification CR-UR-528 Rev. 00. The mock-up piece had the following characteristics:

Base:

Material: ASTM A105

Width: 460mm

Length: 720mm

Thickness: 100mm

Weld overlay:

Welding process: SAW

Welding filler material: 25.22.2CrNiMo

PWHT after first pass: 610 °C ± 10 °C - Holding time 2:30 Hrs

Total thickness: 10mm

Bore:

Hole diameter: 26.9mm -0mm / +0.25mm

Hole pitch: triangular, 33mm

Tubes:

External layer:

O.d.: 26,5mm

Thickness: 2mm

Material: ASTM A213 UNS S31050

Internal layer:

O.d. 22,5mm

Thickness: 0,7mm

Material: ASTM B523 UNS R60702

Note: The external diameter of the mock-up tubes and the bore diameter of the mock up piece was actually bigger than that of the stripper because in the meantime the manufacturing specification for stripper bimetallic tubes had been changed. This arrangement was accepted as representative of the welds that we would make on site because the resulting tube o.d.- to - tube o.d. distance was smaller than that of the tubes on site.

Figure 3: Mock up piece

When the mock up piece was ready, we organized a test welding session at AXO WELDING workshop at the presence of SAIPEM and Third Party inspectors, during which we welded No. 92 tubes on 8 rows. When welding was complete, a group of No. 19 tubes was selected for metallographic/corrosion/macro testing and No. 4 groups of No. 7 tubes each were identified for flaw assessment/mechanical testing according to SAIPEM specification CR-UR-528. The position of the selected tubes is shown in the following sketch:

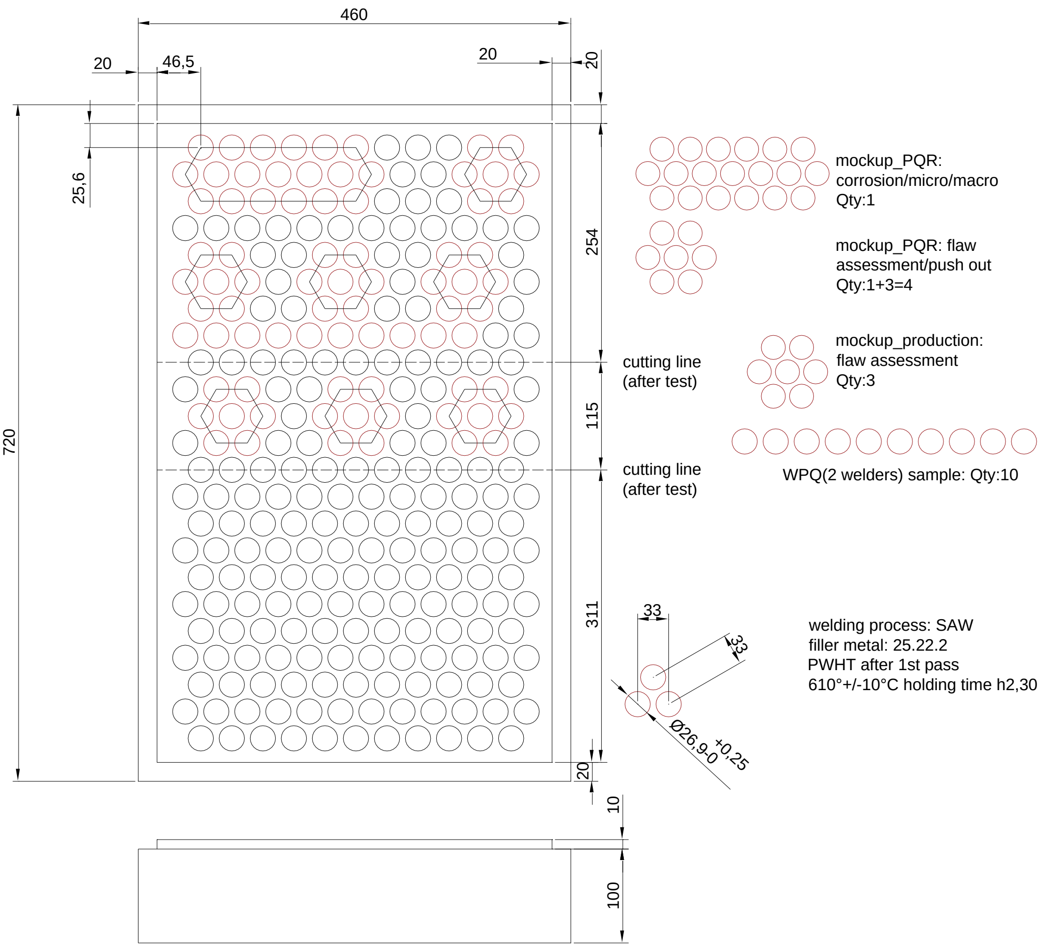

Figure 4: Mock up piece testing scope

The mock-up tube-to-tubesheet welds were subjected to the following scope of testing:

a. Testing scope per ASME Code section IX:

   1. VT + PT
   2. Macrographic examination per QW193.1

b. Testing scope per SAIPEM Cr-Ur-528 Rev. 0 (Cr-Ur-510 Rev. 4):
   1. Metallographic examination
   2. Ferrite content
   3. Corrosion test: huey test on No. 10 huey cycles with measurement of weight loss
   4. Corrosion test: assessment of the maximum depth of attack
   5. Flaw assessment test
   6. Mechanical test: push out

Testing was performed at a SAIPEM accredited laboratory.

Of the remaining tubes some had been welded before the testing session in order to set up the welding parameters and train the welders; and the rest was kept un-welded, to be used on site for the mandatory production tests.

Finally, we used the welded tubes which were not deemed part of the testing program as a sample to set up the tube protrusion reaming process.

7. Shortening method.

Qualifying the welding procedure was the necessary precondition for the job to be performed. While that was ongoing we planned the shortening method, which was articulated into the following activities:

a. Remove all plugs from the plugged tubes.
b. Machine the tube protrusions flat with the tube-to-tubesheet surface.
c. Machine further into the tube-to-tubesheet weld overlay to completely remove the penetration of the TTS welds into it and free the tubes from any bond to the tubesheet.
   This is an operation to be performed very carefully, in order to remove only the minimum quantity of weld overlay necessary to free the tubes and no more.

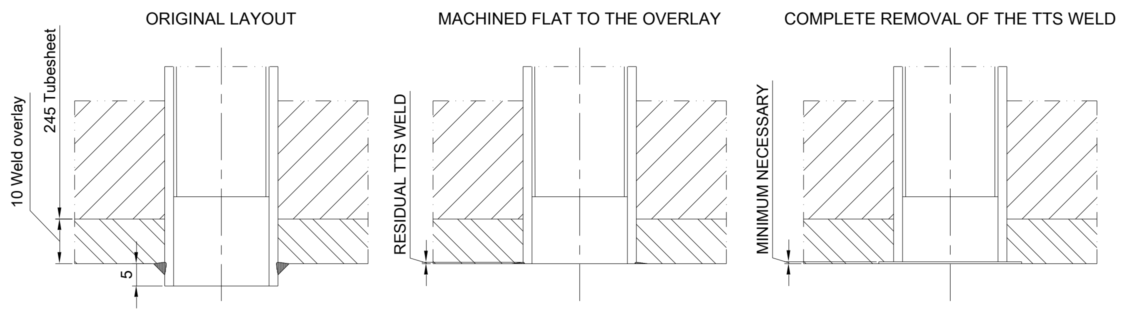

Figure 5: Sequence of machining of tube ends

d. Validate by PT examination that all of the TTS welds have been eliminated.
e. Do a buffing of the tubesheet to clean out the layer of corrosion from the surface.
f. Clean the gap between the tubes and the tubesheet.

   Expansion of the tubes is forbidden by the manufacturing specifications of bimetallic strippers. Between the tube and the tubesheet hole there must actually be a tiny gap, so that any leak in the TTS joint will cause ammonia to seep into the steam and be detected promptly. That gap was a central element of our shortening procedure, and it was of essence that it should be clean from any dirt accumulated during the years in operation and from any corrosion product left by the past leaks. To this purpose we recommended that the shell side be pressurized by MP steam so that steam and high-temperature condensate would flow through.

g. Lift up the bottom tubesheet and channel.

To achieve this we designed two flanges to be welded on the shell, joined by No. 16 x M30 threaded bars. Between them a 40mm wide cut would be made into the shell. Bypass of the expansion joint would be obtained by No. 8 stiffening bars welded between the top lifting flange and the supporting structure.

The scheme in Figure 6 shows graphically the preparation that we made. Lifting is obtained by tightening the nuts of the threaded bars. The point of reaction for the strain is shifted to the supporting structure through the stiffening bars without stressing the expansion joint.

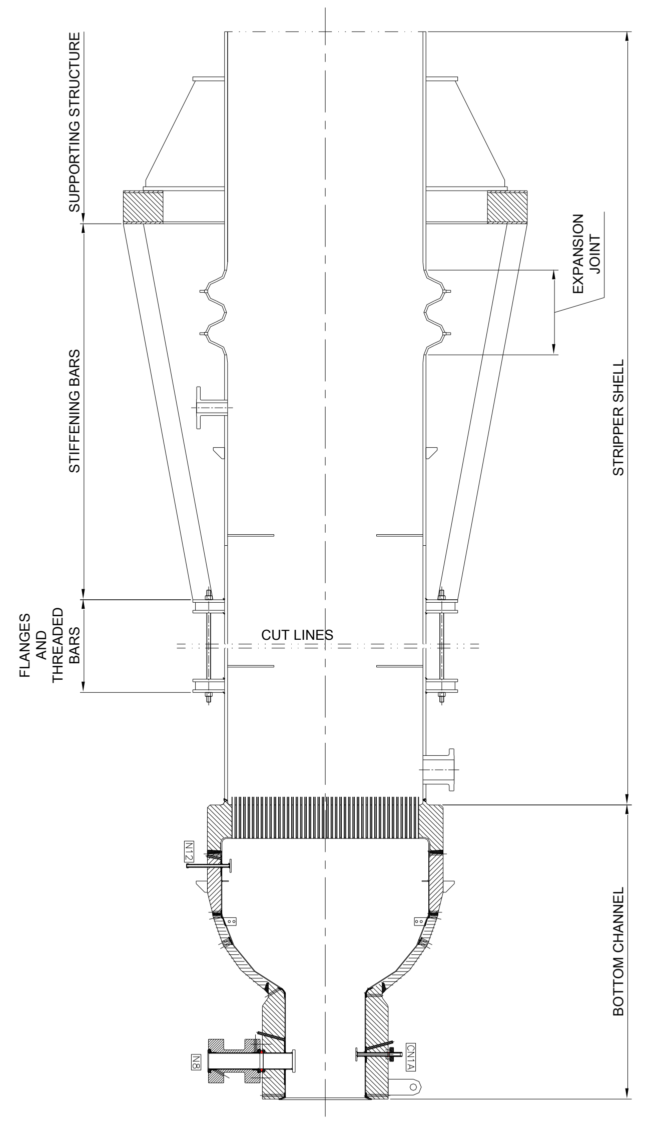

Figure 6: Preparation for shortening

h. Bevel, weld and NDE the shell.

i. Machine the tubes to protrusion of 18mm

After the bottom channel is lifted the tubes extend by about 30mm beyond the tubesheet surface and must be machined to the required protrusion of 18mm before welding the TTS joints. In this process the area of the tube from which the zirconium was removed when the stripper was manufactured is completely eliminated, along with the corroded tube end. What is left is a solid bimetallic tube protrusion.

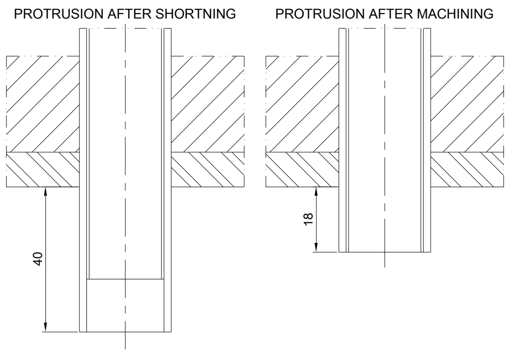

Figure 7: final machining of tube ends

j. Weld the new Tube-to-Tubesheet joints

   At the beginning, mid-way and end of welding activities it is required that a sample of No. 7 tubes on the mock-up piece be welded. The mock-up joints shall then be subject to flaw assessment on site at the presence of a third party inspector.

k. Put new plugs into the formerly plugged tubes

l. Perform the final testing program inclusive of:
   1. Hydrostatic test of shell side
   2. Hydrostatic test of tube side
   3. 100% PT examination of new TTS joints
   4. Air-and-soap leak test of new TTS joints
   5. Ammonia leak test of new TTS joints

8. Problems encountered in shortening unit 31

In June 2016 IFFCO planned the shutdown of 31 line, and we had our first chance to apply our method to an actual site job.

When removing the first plugs some ammonia / carbamate solution trapped into the tubes was released. The rest of this activity was performed by wearing full face masks with ammonia filters.

The machining of the TTS joints took longer than expected because, being the very first experience of the sort, we proceeded very carefully and repeated the sequence reaming / PT validation / reaming several times before all joints were completely removed.

Figure 8: reaming of tube ends

Figure 9: preparation of tubesheet

After completion of this part and running of steam from the shell side through the tube-tubesheet interstices, we cut the shell without any particular difficulty.

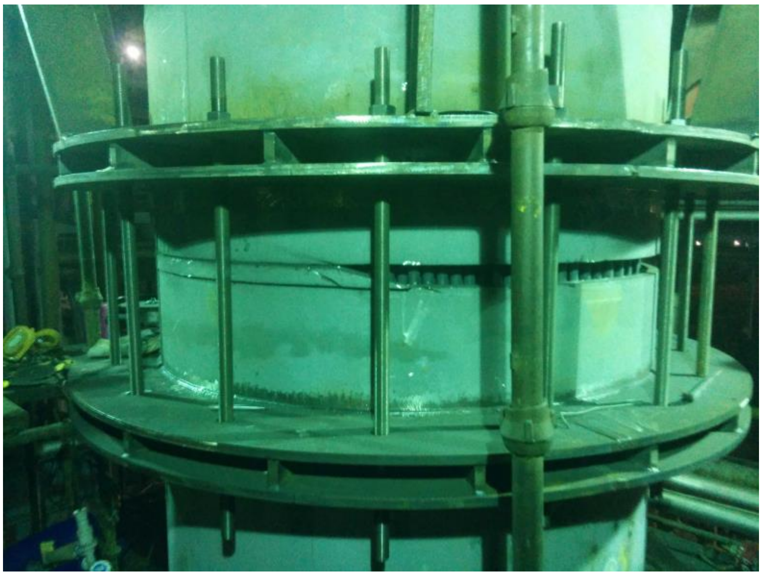

Figure 10: cutting the shell

The first real problem emerged when we lifted the bottom. The first tightening of the threaded bars started on the nightshift of July 15th and proceeded during the following dayshift, and the result that it produced was:

- The shell gap was reduced by 6mm only, then the tightening force increased to the point of making it impossible to proceed any further.
- No. 112 tubes, irregularly distributed across the surface of the bottom tubesheet, were jammed into their tubesheet holes due to some dirt or corrosion deposits and would not slide downwards.
- The other tubes slid downwards until they protruded by 3-4mm, but the amount of protrusion was not uniform throughout the surface. It was shorter in the areas where the number of jammed tubes was higher and longer in the areas which were freer to slide.

In the next four days, until June 19th, we tried several approaches to disengage the jammed tubes, including:

- Heating the bottom tubesheet to melt down the trapped carbamate solution;
- An attempt to clean the tube-tubesheet interstices by a solution of 5% nitric acid;
- Some further reaming concentrated on the tube material (not affecting the TTS area);
- Some releasing and tightening of the bars, but none of them was successful;

Finally we decided to machine the jammed tubes on the top tubesheet to allow them to slide upwards rather than forwards.

This procedure was successful although it had the downside that the affected tubes must be plugged. No. 29 of them belonged to the group of tubes that had already been plugged, so after this modification the total number of plugged tubes increased by: (112 – 29) = 83 which, added to the 57 existing ones, brought the total to No. 140 (No. 141 because one tube was reamed by mistake).

According to SAIPEM, the process licensor, the maximum number of tubes which can be plugged without an impact on the stripper effectiveness is 10%. In this stripper 10% of the total number corresponded to 167 tubes, hence the plugging of 141 tubes was still within the acceptable limit.

When the tubes were free to slide the bar tightening operation was completed rapidly and without any further incidents. In order to assure that the lifting of the bottom part would be perfectly even, we installed No. 4 dial gauges at 0° 90° 180° and 270°.


Figure 11: jammed tube (center)


Figure 12: bottom lifted completely

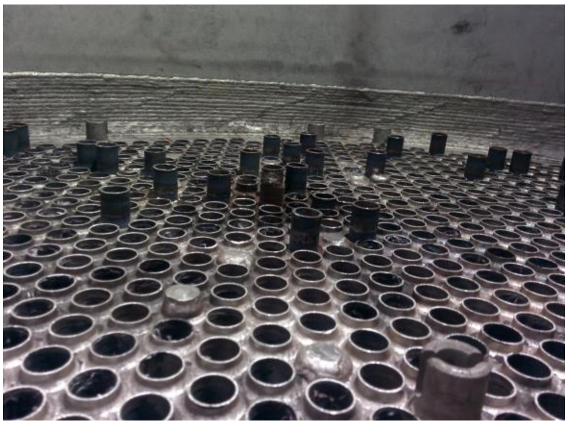
Figure 13: tubes protruding upside

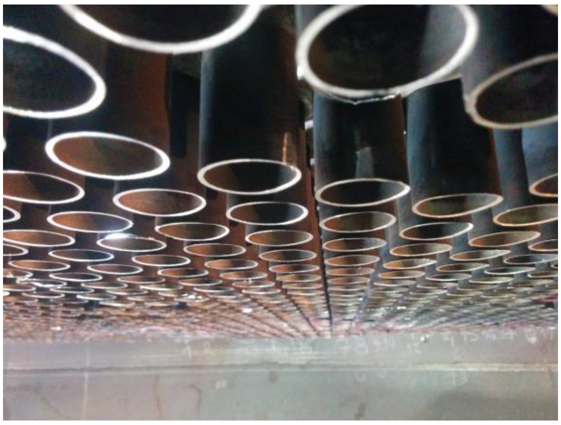
Figure 14: tubes protruding downside

The machining of the tubes to 18mm of protrusion was a straightforward activity were we faced not incidents.

Welding, though, in some instances was made difficult by pockets of solidified carbamate solution trapped in the interstice between some of the tubes and the tubesheet. The carbamate solution, when heated by the welding arc, would sublimate into gaseous phase, expanding rapidly and blowing out through the molten pool, creating a defect in the ongoing joint and sometimes also in the nearby ones and forcing the weld to stop. Most of the time this defect was corrected simply by remaking the root pass over the existing root pass, while in five cases we were forced to ream the first root pass before remaking it.

In spite of all the difficulties encountered the welding activity took roughly the estimated time.

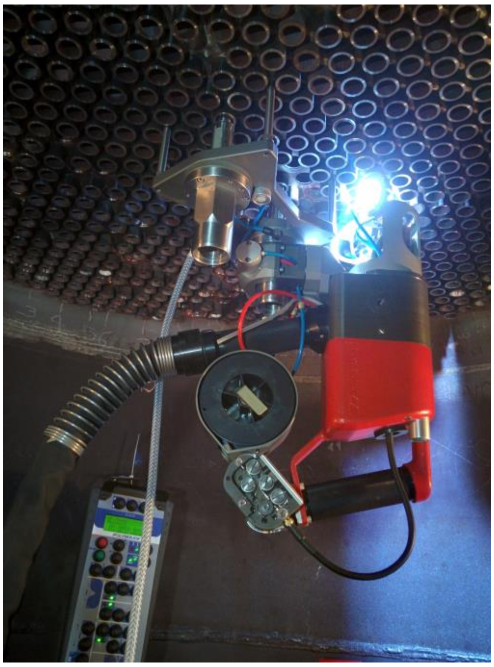

Figure 15: welding the new TTS joints

Figure 16: welding the new TTS joints

Before the shortening job No. 57 tubes had been plugged to stop leaks.

After the shortening job the condition was:

- No. 112 jammed tubes
- No. 2 tubes which had problems with the tube-to-tubesheet weld
- No. 2 tubes which were reamed / plugged by mistake
- No. 29 tubes where formerly existing plugs have been restored

Total: 145 tubes to be plugged (on a maximum acceptable of 167)

IFFCO designed different types of plugs for top and bottom tubesheet and for tubes having no protrusion from the tubesheet surface (the tubes that were jammed into the bottom tubesheet) and tubes that protruded from the tubesheet surface (some of the tubes previously plugged, which did slide down but were not reliable)

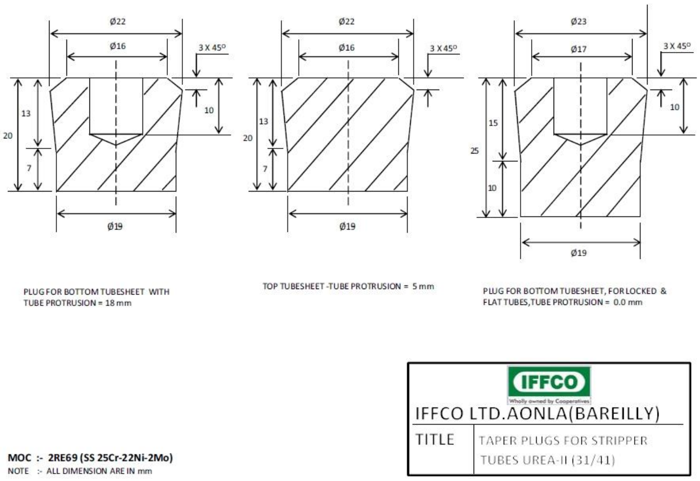

Figure 15. Details of taper plugs used during shortening

Figure 18: Design of plugs

9. Testing after shortening

Air-and-soap leak test at 0.35 Kg/cm^2 fund No. 2 leaking TTS welds: one at the bottom tubesheet and one at the top. Re-testing after repair was positive.

Tube-side hydrostatic test at 147 Kg/cm^2 was carried out to comply with the requirements of the construction code. During this test 8 to 10 drops of water were observed through the inspection flange on condensate-outlet nozzle. The following PT examination evidenced some indications that were promptly repaired.

During shell-side hydrostatic test at 26 Kg/cm^2 some seepage of water was noticed, coming from the contact area between the zirconium and the stainless steel layers of No. 8 tubes. The 8 tubes were plugged on both ends.

Ammonia leak testing at 1.0 Barg pressure (0.7 Barg nitrogen + 0.3 Barg Anhydrous ammonia) showed no leaks.

10. Re-commissioning

After modification and shortening, stripper unit 31 was running at full plant load and attained peak load of 115%. All the running parameters were found normal and within the desired range. Average conductivity of LP steam at E-5 (carbamate condenser) remained less than 10 μmho cm^{-1} during this period and – as of today – the operational life of the unit has been extended by more than four years.

11. Conclusions

The shortening of stripper 31 lasted 48 days overall and presented some very difficult challenges because it was the first of its kind to be performed and because of the number of leaks that the unit was affected from before the shortening job.

One year later we were able to complete the same job on stripper 41 in 35 days. Still a long time for a shutdown but getting more reasonable. The difference between the two jobs were in the experience that we accumulated on the first one and the fact that on the second stripper IFFCO decided to go for a shortening before the condition of the tubesheet and the tubes got as bad as that of unit 31 (only 85 tubes needed plugging on unit 41).

Bimetallic strippers installed of this age are facing or may face similar problem in near future. It can be considered a cost effective short term solution as cost of stripper shortening is around 10~12% of stripper replacement cost. Attention should be given on not to run stripper with increased conductivity of LP steam at E-5 and take up shortening job at first instance of tube to tube sheet weld joint failure. By taking complete new TTS welding with shortening of stripper job at early stage, we can avoid the various difficulties faced during shortening of IFFCO Aonla stripper and job duration can be reduced significantly to perform the job within 25~30 days shutdown period.