Repair critical-service exchangers with innovative methods

In this case history, unconventional maintenance techniques stopped chronic leaking for an olefin's heat-exchanger circuit

R. RAJKUMAR, Reliance Industries Ltd., Surat, India

A common problem for heat exchangers is tube to tube-sheet leaks. For large petrochemical facilities, such leaks occurring and re-occurring are critical concerns and are a high priority for process and maintenance engineers. At times, conventional remedial actions can result in reduced processing throughput and unscheduled downtime. Both adversely impact plant profitability. In this case, we will investigate an innovative method to repair a critical-service propylene heat exchanger cost-effectively.

THE PROBLEM

Propylene gas loss was noticed from the cracking plant circuit. This loss was traced to heat exchangers within the circuit. Two sets of condensers, known as propylene-tower condensers (E-555) and propylene refrigerant condensers (E699), are part of the propylene circuit. The propylene tower outlet handles gas at 85°C and is routed through E555 exchangers (8 exchangers). The propylene gas is cooled by cooling water and sent to the propylene reflux drum.

The propylene compressor outlet is set 100°C; the gas is sent through E699 exchangers (10 exchangers) where it is also cooled by cooling water and sent to a surge drum. Tables 1 and 2 summarize operating data for both heat exchanger circuits. E555s were designed per ASME Sec VIII, Div 1, 1989, Add 91 B & TEMA 1988-R-AEM. E 699 heat exchangers have a design code ASME Sec VIII (Div 1) 1989, Add 91B, and TEMA 1988 AEM type R.

FIG. 1 Inspection of the propylene exchanger shows deposits on the tube sheet after service.

Process investigation. The exchangers were opened and thoroughly inspected. The observations from the inspections include:

- Minor deposits were found at tube's internal surface, tube sheet and channel.
- Cleaned surfaces revealed very minor corrosion effect on channel ID. No significant corrosion damage could be seen on tube's ID.

TABLE 1. Exchanger details for propylene tower E 555 Series

Parameter	Shell side	Tube side
Construction material	Carbon steel	Carbon steel
Design temperature, °C	75	65
Operating temperature, °C	44.5	34
Design pressure, kg/cm^2	22	15
Operating pressure, kg/cm^2	17.8	5
Service	Propylene	Cooling water
No. of tubes	3,390	
Dry weight, metric ton	45	

TABLE 2. Exchanger details for propylene tower E 699 series

Parameter	Shell side	Tube side
Construction material	Carbon steel	Carbon steel
Design temperature, °C	100	65
Operating temperature, °C	81.5	34
Design pressure, kg/cm^2	19	13
Operating pressure, kg/cm^2	16.9	5
Service	Propylene	Cooling water
No. of tubes	3,390	
Dry weight, metric tons	45	

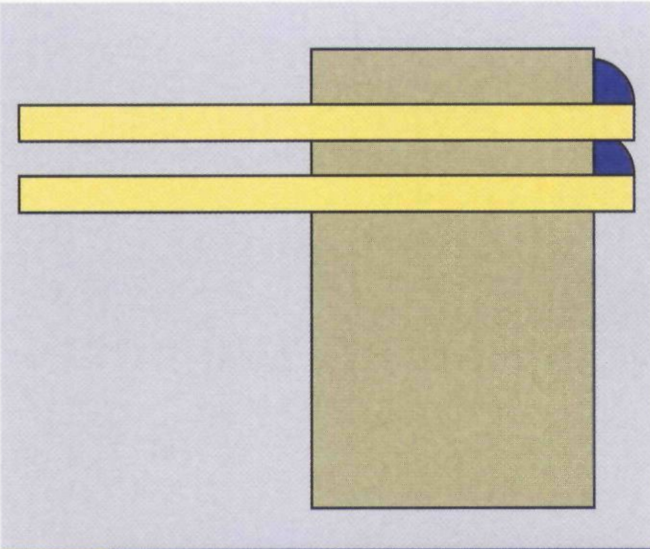

FIG. 2 Location of the deposits on tube sheet.

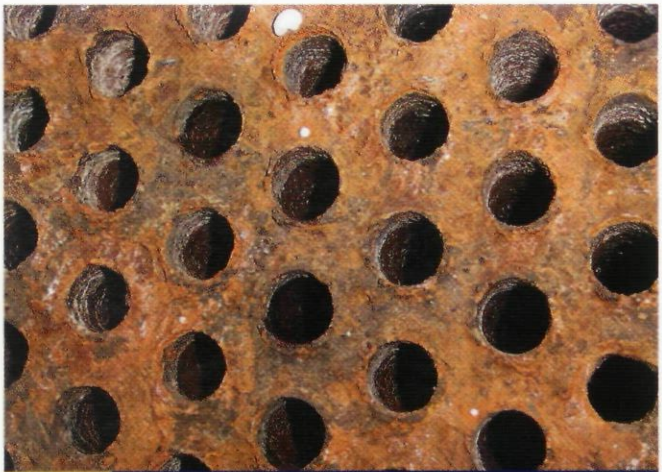

FIG. 3 View of the TTSJ before the repair.

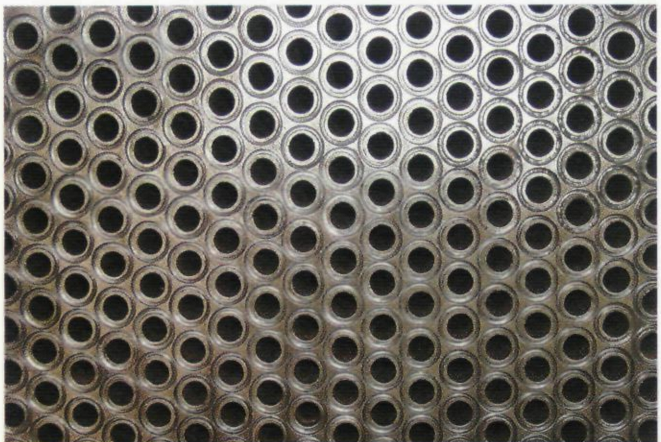

FIG. 4 View of the TTSJ after the repair.

FIG. 5 In situ machining of the exchanger TTSJs.

- In some tubes, circumferential grooving was observed between tube-to-tube sheet joints (TTSJs) strength welding and tube edges. Fine pin holes were found at many places.
- The tube sheet was found sound for service.

A leak test was done on the shell side at 16 kg/cm^2; no leaks from the tubes were detected. However, some tubes were leaking from the TTSJ. The leaking TTSJs were repaired locally by gas tungsten arc welding (GTAW) process.

Repair results. However, within 12 months of the repair, the exchanger developed leaks again from the TTSJ. The exchanger was reopened; the following observations were made:

- Blackish/brownish colored deposits (4 to 5 mm thick) observed at both (east and west side) tube sheets.
- When cleaning the exchanger, tube sheet had a brownish, fine scale layer with corrosion effects on tube sheet and TTSJ fillet weld/tube sheet ligaments. Tube edges were severely corroded, causing detachment/leakage path in a few of the TTSJs.
- Tube ID surface found had slight deposits.
- Leak test was done at a shell-side operating pressure (17.0 KSC). Leakage was observed from 269 TTSJ (out of 3,730 × 2 = 7,460 joints).
- Nugget-type deposit was found at dish-end internal surface, at a few locations. With cleaning, a brownish scale with under-deposit corrosion effects was observed (Figs. 1 and 2).

Channel surface had a blackish/brownish layer of slight deposits. However, the outlet pass chamber of the channel was completely encrusted with a brownish scale/rust-type layer. The outlet nozzle also had brownish rust type scale/deposits. Due to the failure within 12 months, it was decided to completely repair all the TTSJs. The tubes in these exchangers were protruding out of the tube sheet, indicating under-deposit corrosion.

To avoid low-velocity, under-deposit corrosion, cooling water flow for this exchanger was increased. However, the cooling water flowrate was observed as 0.7m/s as against the required minimum flowrate of 1m/s. To increase the cooling water flowrate to 1m/s, the cooling water network had to be modified; unfortunately, this action was not viable.

Design deficiency. The tube sheet was not designed and constructed with internal grooves to allow strength expansion during manufacturing. The original design applied light expansion and strength welding. However, this construction method did not support the processing service for this exchanger application. **Result:** TTSJ leaks occurred due to under-deposit corrosion. Strength expansion and seal welding were needed to mitigate this type of corrosion in the propylene circuit.

Second repair. Considering the processing conditions and the current design of the exchangers, these procedures were adopted to repair the tubes:

- The existing damaged tube edges and TTSJ fillet weld were completely removed/flushed-off by using cutting/facing tool.
- Further grooving around 2–3mm deep was made in tube sheet, adjacent to tubes OD to facilitate fillet welding of TTSJs. Proper tool/fixture arrangements were made to avoid further damage of tube edges/ligaments.
- All TTSJs were welded under strict quality adherence checks (Figs. 3 and 4).

Second repair results. With the second repair, the TTSJ failed again within 12 months. Because the TTSJs were welded two times earlier, a third time welding would lack sufficient strength.

Third repair. The exchanger's top tier was removed. The unit was sent for tube-sheet, gasket face and bolt face machining on a floor mounted horizontal boring machine. New repairs included:

- Thickness of the tube sheet was reduced up to 5mm, which is well within the limits as prescribed by ASME
- Tube to tube-sheet welding was uniformly removed by machining
- J grooves were machined
- Full expansion of all tubes was completed
- Tube sheet was coated with glass flakes.

Repair of bottom-row exchangers. For the bottom-row exchangers of the stacked arrangement, the top exchangers had to be removed. This was not a viable option, since two exchangers could not be taken out of service at any time. Hence in situ machining was done to repair the bottom exchangers

In situ machining of tube sheet. Normally, in situ machining is done only on the gasket-seating area of a tube sheet. In this case, it was necessary to machine the entire surface of the tube sheet with high accuracy. A special purpose machine was used for tube-sheet face machining. Required surface finish and flatness as per standard was achieved with this method (Figs. 5 and 6).

FIG. 6 View of the finished in situ machined to the tube sheet surface.

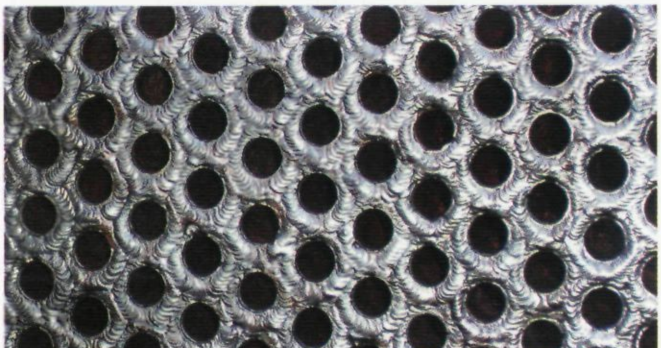

FIG. 7 View of the root weld and finish welds of the tube sheet.

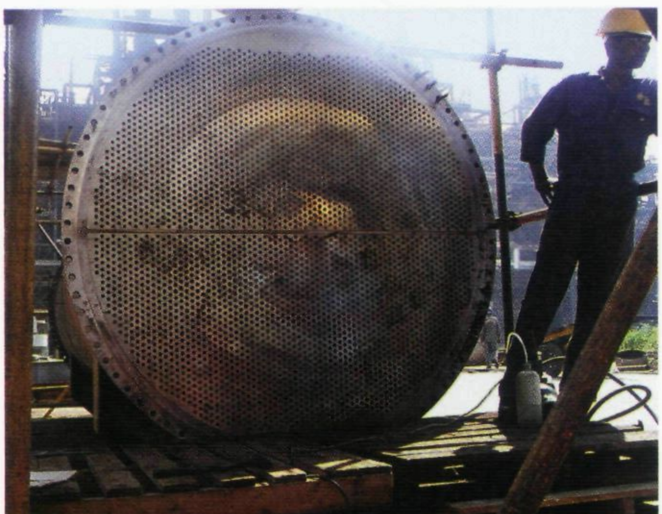

FIG. 8 Finished surface of tube sheet after applying the copper and glass flake epoxy coatings

The tubes were reamed to make ID of all the tube ends uniform. Using a multi-point milling cutter, J grooves were prepared.

Welding of TTSJ. Tube to tube sheet welding was done by argon welding technique. All the necessary nondestructive testing (NDT) checks were done during the process (Fig. 7).

Rolling of tube ends. A light expansion was done to expand the tubes in the tube sheet to remove the distortion caused to the tube during welding.

Pneumatic testing. The pneumatic testing was done subsequently at three pressures, first at 2.0 bars, then at 7.0 bars and last at 17.0 bars.

Coating on tube sheet. First, copper-flake blasting was applied. Later, a glass-flake epoxy coating was applied with a minimum thickness of 600 μ (Fig. 8).

Outlook. After 12 months, the first repaired exchanger was inspected onstream. The condition of tube sheets was excellent; no pitting or TTSJ failure was detected. The quest of maintenance excellence enabled this integrated petrochemical manufacturer to apply innovative maintenance methods. Often, unconventional methods, if studied, can produce significant and relevant solutions to many perennial problems. **HP**

R Rajkumar, is Senior Vice President in Central Engineering Services of Reliance Industries Limited, Hazira Manufacturing Division, India. He has 35 years of experience in fertilizers, synthetic polymers and petrochemical industries. His area of expertise is maintenance and turnarounds in the petrochemical field. Mr. Rajkumar is strong believer of using innovative ideas for solving chronic problems. He is the leader of Engineering Team in Hazira, which has successfully implemented many innovative ideas to improve plant and equipment reliability, productivity and availability. The de-bottlenecking and turnaround strategies have been redefined in Hazira under his dynamic leadership.