Maximising heat exchanger cleaning

Powerful chemical cleaning programmes reduce downtime and increase the efficiency of heat exchangers

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Oil refineries and petrochemical plants operate with quite a large number of heat exchangers. Fouling is an omnipresent problem, causing significant losses in energy recovery or generating an increase in pressure drop. Periodical cleaning is mandatory even if distillation equipment is well designed. If fouling is observed, it can initiate a series of downstream problems. In many cases, heat exchangers are taken out of service because of severe pressure drop increase, not reduced heat transfer.

Heat recovery is essential in process units which are operated with reactors. Typical process units with feed/effluent exchangers installed are hydrotreaters, hydrocrackers, catalytic reformers, paraffin dehydrogenation plants, paraxylene plants, and methanol synthesis plants. Feedstock is heated to a high temperature to be vaporised and reacted with a gas, which in most cases is hydrogen. The desired reaction products and unreacted gases are de-superheated and condensed for separation. Some process units still operate

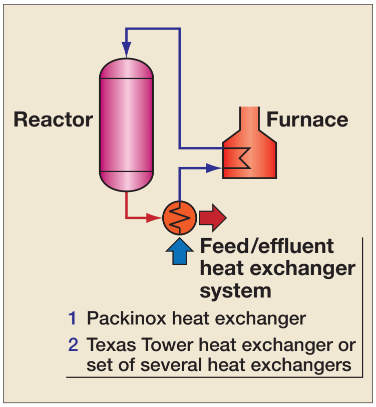

Figure 1 Feed/effluent heat exchanger network

with heat exchanger networks of at least six to 12 exchangers installed horizontally. More common are Packinox plate heat exchangers or Texas Tower tubular heat exchangers, which are installed vertically (see **Figure 1**).

Heat exchanger performance can be restored by traditional mechanical cleaning methods, tailor-made chemical cleaning programmes, or a combination of both. Mechanical cleaning of complex heat exchanger networks using high pressure cleaning technologies can take several days. Classical alkaline cleaning procedures are sometimes still used in oil refineries and petrochemical plants to remove the organic portion of deposits such as oil and grease, followed by acid cleaning to dissolve scale and soften deposits. But the results with such classical cleaning programmes are often only moderate, and further mechanical cleaning is required with additional costs.

The combination of alkaline and acid cleaning is not the method of choice when viscous, tenacious materials such as heavy fuels or additives from upstream processes need removing. High-performing aqueous cleaning programmes from the Kurita CD series can significantly reduce downtime with excellent results. Metal surfaces heavily fouled with oils, grease, tars, waxes, fatty oils or other substances are cleaned without the need for costly organic solvents such as light cycle oil (LCO), diesel or white spirit. Water is sufficient for the preparation of the chemical cleaning solution, which is circulated with suitable equipment. Heat exchanger networks are cleaned in a few hours, with deposits and sticky layers dissolved into the aqueous cleaning solution.

Chemical cleaning programmes such as Kurita CD-9931 offer a number of advantages when it comes to cleaning complex heat exchanger networks (see **Figure 2**):

- Significantly reduced downtime for cleaning
- Less labour intensive work compared to mechanical cleaning
- Cleaning solution reaches inaccessible areas
- Metal surfaces are not mechanically damaged
- Cleaning can be done in situ.

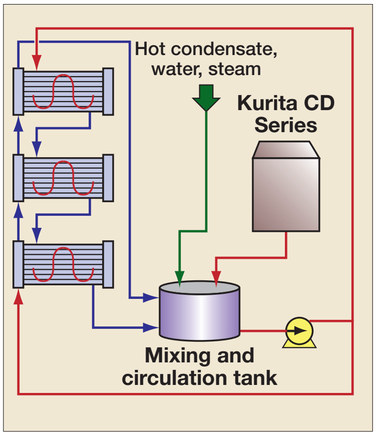

Figure 2 Chemical cleaning of heat exchanger network

Texas Tower and Packinox heat exchangers

Texas Tower tubular feed/effluent heat exchangers are installed in an upright position, with two exchangers usually connected in series to provide good heat recovery. Generally, such heat exchangers do not show significant pressure drop increase, which is why they are often not cleaned during every shutdown. But when performance drops, serious consequences may occur.

Packinox is the brand name of Alfa Laval with the largest type of welded plate heat exchanger design currently available anywhere in the world. Just one combined feed/effluent plate heat exchanger after the reactor is usually sufficient to cool down the hot gases. All heat transfer takes place inside the large welded bundle block inside a pressure vessel, so no process fluids circulate in the shell itself. Such heat exchangers have a very compact structure, and can operate as high as 550°C. Common materials for construction are stainless steel (SS316 or SS321), titanium or highly corrosion resistant austenitic steel in a carbon steel shell (see **Figure 3**).

Feed/effluent exchangers are frequently cleaned during planned shutdowns when the pressure drop or hot approach temperature (HAT) reach a certain level. The thermodynamics of heat recovery can be determined by superimposing curves showing the heat demand of the reactor feed and the heat release of the reactor effluent. Texas Tower and Packinox feed/effluent heat exchangers require more cleaning effort than classical heat exchangers as the large welded heat transfer bundle cannot be perfectly cleaned mechanically. Tailor-made chemical cleaning programmes from the Kurita CD series are used when very efficient cleaning results are required.

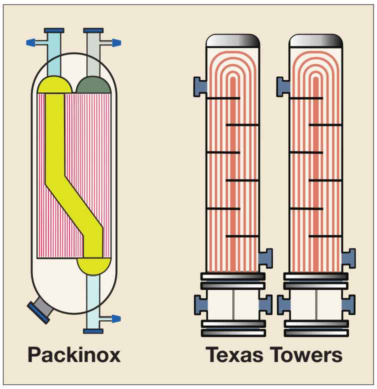

Figure 3 Packinox feed/effluent heat exchanger and Texas Towers

When the HAT goes up, the Packinox plates or Texas Tower tubes are dirty and need to be cleaned. If the reason for cleaning is a high differential pressure and the Packinox or Texas Tower tubes are coked up (carbon deposits), a chemical programme will not be very effective. By using a controlled combustion procedure, coke deposits can be removed from the plates or tubes. But more often, the fouling material consists of sticky hydrocarbon deposits such as polynuclear aromatics (PNA), ammonium salts and, in many cases, iron oxides. Here, a powerful chemical cleaning programme is the method of choice.

Case study 1

In a European refinery, the Packinox plate heat exchanger of a catalytic reforming unit was chemically cleaned for a technical check and maintenance work (see **Figure 4**). In general, the manufacturer Alfa Laval recommends two possible cleaning methods: 'fill and drain' or 'circulation'. A number of technical requirements and instructions have to be complied with for safe cleaning. Steps must therefore be taken to ensure that shell and combined feed side pressures are always higher than the effluent side pressure.

Under the supervision of Leader Technology, which specialises in chemical cleaning, blind flanges were installed.

These were equipped with fittings for liquid level tubes, fill and drain nozzles, and nitrogen injection. Via flexible hoses, the fittings on the blind flanges were connected to the mixing and circulation tank to provide a circulation loop system. Following manufacturer guidelines, the shell and combined feed side was always filled first, before the effluent side was treated. At a later time, the effluent side was drained first, before the shell and combined feed side was treated.

Stress corrosion cracking (SCC) of the high quality alloys might be possible when they come into contact with oxygen (air), water and sulphur species such as H_2S or metal sulphides. Based on the NACE Standard RP0170-97 to provide protection of austenitic stainless steels and other austenitic alloys from polythionic acid stress corrosion cracking, a 1.5 wt% soda ash solution was prepared with condensate at a temperature range of 40-45°C. Following all instructions and guidelines, the Packinox plate heat exchanger was filled in the correct order and the aqueous solution circulated via a mobile mixing and circulation tank as a 'pre-flushing step' to neutralise the acidic components. After one hour, this solution was drained to the sewer system and a fresh 1.5 wt% soda ash solution was prepared with condensate. After ensuring adequate circulation, Leader Technology applied the cleaning agent Kurita CD-9931 to the soda ash solution for circulation and removal of the viscous, tenacious fouling materials. The target pH range of the chemical cleaning solution is 8-9.5 and a pH of about 9 was

Figure 4 Packinox plate heat exchanger

maintained by adding soda ash. Every hour, a sample was taken to check the appearance, pH, conductivity, chloride and iron concentration.

After around 10 hours, the dirty cleaning solution was drained and the Packinox rinsed with clean water plus the addition of 1.5 wt% soda ash for about 60 minutes. In this part of the cleaning procedure, the soda ash solution was used as a passivation step to provide a protection layer on the metal surface. After 5 bar steam was added for about one hour to remove remaining volatile gases, nitrogen was blown from the top to the bottom for about 10 hours as a drying step to avoid any catalyst poisoning with water after restart of the process unit. After cleaning, a hot approach temperature of 37°C to the customer´s satisfaction was achieved at full capacity.

Case study 2

The Packinox plate heat exchanger of a catalytic reforming unit was chemically cleaned by Leader Technology, following all operating instructions and guidelines for safe and complete cleaning. The aim of the cleaning was again the preparation of a clean heat exchanger for a technical inspection with maximised energy recovery and increased heat transfer efficiency to reduce energy consumption and emissions. Following all guidelines and instructions, the Packinox shell and combined feed side and the effluent side were filled and drained in the correct order.

During the circulation step with the Kurita CD-9931 cleaning solution, Leader Technology stopped the pump for about 30 minutes. The valves of the combined feed side and effluent side were opened to perform nitrogen bubbling in order to obtain a mechanical cleaning effect. Then the two valves were closed again and the circulation pump restarted for some hours. After drying, the Packinox heat exchanger was handed over to the customer for inspection in a very clean condition. All requirements were fulfilled with results to the customer´s satisfaction.

The rinsing operation after drainage of the cleaning solution was performed with 1.5 wt% soda ash, diluted in demineralised water. Final drying was once again done with nitrogen, which was blown from the top to the bottom for 10 hours.

Conclusion

Heat recovery in heat exchanger networks is essential during shutdowns. Hydroblasting technologies might take three to five days for cleaning, and traditional alkaline/acid cleaning methods often show only moderate results. Tailor-made modern cleaning concepts are the method of choice when inaccessible areas must be cleaned.

Texas Tower and Packinox heat exchangers require more cleaning effort, with chemical cleaning programmes showing significant benefits. Downtime is reduced with less labour intensive work, and cleaning can be done in situ without damaging the metal surfaces. Up to 70% cost reduction is possible when expensive solvents are not needed and water can be used to circulate the cleaning solution.

Further reading

1 Speight J G, *The Chemistry and Technology of Petroleum*, Fourth Edition, 2006, CRC Press, ISBN 0-8493-9067-2.

2 Jafari M, Iranshahi D, Rahimpour M R, Progress in catalytic naphtha reforming process: a review, *Applied Energy*, 2013.

3 Aitani A, Catalytic naphtha reforming, *Encyclopedia of Chemical Processing*, 2006.

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