2015 WJTA-IMCA Conference and Expo
November 2-4 • New Orleans, Louisiana

Paper

Mechanical Tube Cleaning: The Emerging Trend in Maintaining Heat Exchanger Efficiency

Christopher K. Van Name
Conco Services Corporation
Verona, Pennsylvania, U.S.A.

Jason R. Wilburn
Conco Services Corporation
Verona, Pennsylvania, U.S.A.

ABSTRACT

Industry today places a high importance on safeguarding the health and wellbeing of both its employees and the environment. Managers in chemical plants and refineries have been tasked to find better, safer ways to clean their heat exchangers while minimizing the impact of wastewater. An emerging trend in maintaining the cleanliness of heat exchangers has been the use of mechanical tube cleaners. These mechanical systems utilize a variety of shooting, brushing and drilling methods combined with low-pressure water (under 700 PSI) to safely and quickly remove even the most tenacious deposits, restoring heat transfer efficiency. As an alternative to current practices, these mechanical tube cleaning systems offer a much smaller footprint than traditional high-pressure water methods, and allow the equipment to be placed much closer to the heat exchanger further reducing congestion during the overhaul. By utilizing lower water pressure, these mechanical tube cleaning systems are much safer to use and generate far less wastewater than high-pressure water methods. The mechanical cleaning technology has proven to be safe, effective and environmentally sound. This paper will address five case studies where positive results were achieved with this emerging technology.

Organized and Sponsored by WJTA®-IMCA®

SECTION 1 – INTRODUCTION

No matter what the type of heat exchangers nor which industries they are being employed in, eventually all of these units will foul. As fouling builds up on the interior walls of a heat exchanger's tubes, it forms an insulating barrier that interferes with heat transfer. While the type of deposits, their tenacity to adhere to the tube walls and their insulating value depend on the fluids or gases flowing within the tubes, the end result of their presence is the same, a loss in productivity. As the heat transfer rate drops, so does the heat exchanger's efficiency. This loss of efficiency will not only negatively impact the unit's production capacity, but will also drive up the cost of the final product. To reduce this impact and help keep production flowing at peak efficiency, heat exchanger performance must be monitored and when fouling is identified, the deposits removed. While high-pressure water cleaning (hydroblasting) has historically been the method of choice for fouling mitigation, in industrial markets the use of mechanical tube cleaners with low-pressure water has been gaining popularity. Early identification of fouling characteristics and a fundamental knowledge of cleaning system capabilities are essential in determining the most effective cleaning technology to employ.

Safety

Now more then ever, safety on the jobsite has become the number one priority of plant management. With this focus on safety, conventional approaches to heat exchanger cleaning have been revised, and new and innovative cleaning methods have been developed. Recent strides in cleaning technologies using mechanical tube cleaners and low-pressure water provide for very safe cleaning applications with unprecedented results. Low-pressure water means less pressure and a smaller safety zone. Figure 1. Low-Pressure Water Footprint, shows a typical safety zone for a low-pressure water application, while Figure 2. High-Pressure Water Footprint, shows the larger safety zone required for high-pressure water cleaning of the same heat exchangers. High-pressure water applications often use from 10,000 to 40,000 or more PSI to remove tube deposits while low-pressure water mechanical methods use under 700 PSI to provide a thorough cleaning. In addition, low-pressure water mechanical cleaning requires significantly smaller crew sizes than high-pressure water methods. As an added benefit, low-pressure water mechanical cleaning is done in place; it is no longer necessary to dismantle the heat exchanger and move it to a separate work zone for cleaning. This reduces the risk of accident, injury and component damage.

Environmental Impact

When considering the various options available for cleaning heat exchangers, the environmental impact of the various cleaning methods must weigh into the selection process. The amount of secondary waste (wastewater) generated by each cleaning method and the ease and cost of disposal of this waste is often a concern. One great environmental advantage of the low-pressure water mechanical cleaning methods is water conservation. Less water use means less water to clean up or to reclaim in the post-cleaning phase.

Speed

"Time is money," and for plants in the processing industries that saying holds true. When a unit is down for maintenance, that unit is not making money. Giving consideration to the environmental impact of how a heat exchanger is cleaned is important. However, the reality is that for many managers, budget constraints will drive the decision-making process on how to clean. Because new and innovative low-pressure water mechanical cleaning applications require far less unit downtime than the high-pressure water approach, it is the cleaning method that is most economically advantageous for industry. The time required for low-pressure water mechanical cleaning can be 70% less than high-pressure water methods. This can mean a unit down time of hours cleaning with mechanical cleaners versus days with hydroblasters.

SECTION 2 – HYDROBLASTING VERSUS MECHANICAL TUBE CLEANING

For many industries, hydroblasting with up to 40,000 or more PSI of water pressure has always been the preferred method for cleaning heat exchangers. However, there are significant trade-offs associated with this approach. When compared to the footprint required for low-pressure water mechanical cleaning methods, the hydroblasting footprint is sizable. Hydroblasting requires multiple water trucks and cleaning apparatus/pumps on site, and a large number of technicians must be present to not only operate the equipment but also to ensure that the large safety zone is maintained. In addition, the duration of cleaning is lengthy compared to mechanical tube cleaning because water alone is not the best cleaning agent. Furthermore, the environmental impact of using thousands of gallons of water to clean one heat exchanger is a scenario drawing greater scrutiny than ever. In drought-stricken parts of the world where industry and agriculture are bound by strict water usage laws that can come with stiff penalties, the water usage requirements of high pressure water cleaning have made this approach unviable.

Newer cleaning systems utilizing mechanical tube cleaners operate at far lower water pressures than hydroblasting. A typical water pressure for a low-pressure application is under 700 PSI compared to the average range of 10,000 to 40,000 PSI used in hydroblasting. Also, the cleaning components of these mechanical systems are smaller, more specialized and require fewer technicians than high-pressure water methods. Fewer technicians means less unit congestion, lowering the safety risk for the labor force and the equipment being cleaned. Additionally, the environmental impact of mechanical cleaning with low-pressure water is far less than with high-pressure water methods. Mechanical cleaning uses on average 90% less water than hydroblasting. That dramatic reduction in water consumption equates to 90% less contaminated wastewater to be contained and treated, saving money. It also means less exposure to contaminated wastewater for personnel and nearby aquifers. Figure 3. HPW vs. LPW Charts, compares the crew size, safety footprint, wastewater generated and water pressure requirements for hydroblasting versus mechanical tube cleaning of 21 heat exchangers.

In Figure 3. HPW vs. LPW Charts, cleaning the 21 heat exchangers using hydroblasters at 20,000 PSI generated 48,000 gallons of wastewater while the mechanical tube cleaning method at 500 PSI generated only 5,000 gallons of wastewater, see Figure 4. HPW vs. LPW Wastewater. This large disparity in water usage despite the superior cleaning results of the low-pressure method is in part explained by the differing mechanics of the two methods. The Hydroblast method pumps water 70% of the time the system is operating, dramatically driving up water consumption and creating vast quantities of wastewater. The mechanical tube cleaner shooting method pumps water for only the three seconds it takes for the mechanical cleaner to be propelled through the tube. The flow is then stopped, conserving water.

There are three basic types of low-pressure water mechanical tube cleaning systems on the market today: tube shooting, brushing and drilling. Depending on the type of deposit and the extent of the fouling, these systems are often used in combination to provide superior cleaning to hydroblasting, see Figure 5. HPW vs. LPW Cleaning Results. Low-pressure water mechanical tube cleaning is effective at removing the most tenacious deposits including:

- particulate and biological fouling
- calcium-carbonate
- asphalt
- baked-on hard deposits
- acrylic
- high-density polyethylene
- iron oxide and others

Tubes cleaned with these low-pressure water systems are ready for Eddy Current or other non-destructive testing and require no additional cleaning or preparation. Once brought back online, these units will show an immediate recovery of production capacity and heat transfer. Through low-pressure mechanical cleaning, these results are achieved safely, quickly and efficiently.

Tube shooting methods, such as with Conco's TruFit™ system, utilize a mechanical tube cleaner (pig) propelled through a tube using low-pressure water at under 700 PSI, see Figure 6. Tube Shooting. Mechanical tube cleaners are available in a variety of sizes, materials and configurations, see Figure 7. Mechanical Tube Cleaners. The best mechanical tube cleaners to use are ones custom engineered to match the interior diameter of the tubes to be cleaned, the tube materials and the types of deposits. Typical configurations include mechanical tube cleaners with spring tension metal blades and stainless steel wire brushes. Special application mechanical tube cleaners are also available such as the Cal-Buster™, see Figure 7d. Calcium Cutter, equipped with "glass-cutter wheels" to score and break apart Calcium-Carbonate deposits or U-Tube Cleaners, see Figure 7b. U-Tube Cleaner, designed to navigate and thoroughly clean the bends of U-Tube units. While low-pressure water is used to propel the mechanical tube cleaner down the length of the tube, it also serves to flush out the deposits as they are loosened.

When dealing with thick, hard, baked on deposits, brushing or drilling may become necessary. For tube brushing applications only, a flexible shaft system like the Excaliber™ can be used. This system uses a brush mounted to the tip of a flexible shaft rotating at up to 2,500 RPM and a low-pressure water to remove deposits. As the flexible shaft rotates, the unit pumps water at 30 to 125 PSI through the shaft casing to the brush, pushing out deposits as they are loosened, see Figure 8. Tube Brushing. Because of their flexible shafts, these type of systems are ideal for cleaning heat exchangers in tight locations, and with an output water flow of only 3 to 7 GPM, generate far less wastewater then hydroblasting operations.

For those situations where the tube is completely blocked or the deposit is too tenacious for a flexible shaft system to handle, then a rigid shaft system or HydroDrill™ is recommended. This system uses a drill bit mounted to the tip of a rigid shaft. As the shaft rotates, the unit pumps water at 250 PSI through the shaft and orifices in the drill bit, pushing out deposits as they are loosened, see Figure 9. Tube Drilling. The HydroDrill has a very low output water flow at only 2 to 3 GPM, keeping wastewater to an absolute minimum. The HydroDrill is designed for maximum cleaning effectiveness. Drill bits are sized to be 0.005" below the minimum tube I.D. They feature long shanks to ensure that the axis of the bit and the axis of the tube are in complete alignment. In addition, the bits are designed with carbide tips on the leading edge only and rounded corners to ensure no sharp edges directly impact the tube wall. The drill also rides on a thin layer of water for lubricating bearing surfaces between the bit and tube.

SECTION 3 – FIVE HEAT EXCHANGERS AND THE LOW-PRESSURE WATER TECHNOLOGIES USED TO CLEAN THEM

Crude Bundle Shooting

A Midwest refinery historically used hydroblasting to clean U-tube style crude bundles. However, the plant's management found that this high-pressure water method was not getting the job done to their satisfaction. Since hydroblasting equipment is unable to pass through the U-bend of the exchanger tubes, the heat transfer surface areas in the bends were not being cleaned. They believed the deposits left in the bends were interfering with the heat transfer, preventing the heat exchangers from performing at maximum efficiency. To mitigate this problem and see if there would be a measurable difference in heat transfer efficiency recovery by cleaning all the way through the U-bends, management decided to try the mechanical cleaning shooting method using U-Tube cleaners custom sized to the Tube I.D.s, see Figure 7b. U-Tube Cleaner, and low-pressure water to remove the deposits. After shooting all the tubes in two sequential cleanings, spaced five months apart, the heat exchangers showed a 20% increase of the Heat Transfer Coefficient upon initial start-up. Management was pleased with the results. The refinery is now utilizing this low-pressure water mechanical cleaning method on their other U-tube exchangers and experiencing similar results.

Polyethylene Unit Maintenance

A major Gulf Coast chemical manufacturer routinely requires cleaning of the U-tube heat exchangers in its polyethylene unit to remove the build-up of product in the tubes. The cleaning is required not only to recover the heat transfer efficiency, but also to restore production rates. The plants management knew from experience that the rigid lances used by hydroblasters were incapable of navigating through and completely removing the deposits in the bend of the tubes. They also knew that any deposits left in the tubes would negatively impact both the unit's heat transfer efficiency and production rates. Leaving deposits in the tubes was unacceptable. To remove the build-up of product throughout the tubes, management turned to mechanical tube cleaners and low-pressure water to get the job done. The tubes were first loaded with specialized mechanical cleaners, see Figure 7b. U-Tube Cleaner, custom sized to the tube I.D.s and designed to navigate through the bend of the tubes. The cleaners were then shot through the tubes using a hand held water gun shooting a stream of low-pressure water. The water not only served to propel each cleaner down the length of its tube, but also pushed out the product build-up as it was loosened, leaving the tube thoroughly cleaned. This mechanical method not only allowed the entire tube lengths to be cleaned, but by positively displace the fouling material, management found this cleaning process to be faster than hydroblasting. They now recognize mechanical tube cleaning with low-pressure water as the most effective cleaning method for these exchangers. The plant has since developed a written standard procedure based on using specialized U-tube mechanical cleaners for these exchangers.

Hydrocracker Fin-Fan Tube I.D. Cleaning

For years, a West Coast refinery had been hydroblasting the tube interiors of a set of eight fin-fan coolers in its Hydrocracker Unit with 20,000 PSI of water. The hydroblast work typically took several weeks to complete and was not always done to test ready standards. Often, the cleaning results from hydroblasting were not sufficient to obtain good test data. In addition, environmental regulations required that the plant capture and treat the vast amounts of wastewater generated by this high-pressure water cleaning method. Furthermore, set-up and tear-down of the wastewater capture system was a major factor in the duration of the hydroblasting operation, increasing the time it took to bring these units back online. In searching for a better, faster way to clean these tube I.D.s, plant management found a technology that combined low-pressure water mechanical tube cleaning with a unique manifold bridging system, see Figure 10. Tube Bridge. This bridge allowed the tube cleaners to safely traverse the gap in the manifolds at the ends of the tubesheets, making low-pressure water mechanical tube cleaning viable for cleaning fin-fan units. Management decided to give this new technology a try. Requiring a much smaller safety area/footprint and generating far less wastewater than hydroblasting operations, the low-pressure water mechanical tube cleaning system, tube bridge and wastewater capture device were quickly set up on the first fin-fan unit. The tube bridge was then loaded with standard metal tube cleaners, see Figure 7a. Metal Tube Cleaner, custom sized to the tube I.D.s. The cleaners were then shot with low-pressure water through the tubes, exiting the tube bridge on the far side of the unit. Utilizing this method, cleaning the set of eight fin-fan coolers took only ten 12-hour shifts. This far less than the time required by hydroblasting, allowing the units to get back online much sooner. It also produced 90% less wastewater that had to be captured and treated. Post-project reports from the plant also indicated that the tube cleanliness was better using mechanical tube cleaners with low-pressure water than any other cleaning method. The tubes were test-ready clean, allowing the plant to obtain much better test results.

Tantalum Tube Brushing

A chemical manufacturer with a heat exchanger containing 151, 6 ft. long Tantalum tubes experienced a process upset, the result of which was a hard baked on “varnish” in the tubes. While Tantalum has great corrosion resistance, the wall thickness of these ¾” tubes is only 0.020”. With such thin walls, plant management felt that hydroblasting and even “shooting” cleaners was not an option. Working with its contractor, the management determined that the best way to restore the heat exchanger to acceptable operating cleanliness, while at the same time safeguarding the integrity of the thin tube walls, was through a combination of mechanical brushing and low-pressure water flow to remove the deposits. To mitigate the “varnish” problem, the cleaning crew used a pneumatic rotary tube cleaner equipped with a flexible shaft and brush, custom sized to the tube I.D.s. While the spinning brush was fed down the length of each tube by the cleaning crew, water was pumped through the shaft casing to the brush, pushing out deposits as they were loosened. Cleaning was completed in a single 12-hour shift, with no tube damage. As an added benefit, with an output water pressure under 125 PSI and only 3 to 7 GPM of flow, the crew required a very small safety area/footprint, minimizing disruption to other plant operations.

Calcium Hydroxide Drilling

A chemical manufacturer has a heat exchanger where Calcium Hydroxide deposit build-up will completely plug the tubes. As this build-up occurs it greatly reducing the flow rate and of the unit. Past attempts to mitigate the problem and restore the heat exchanger to maximum efficiency included hydroblasting, as well as chemical cleaning with Inhibited Hydrochloric acid. However, no matter how long the cleaning crews hydroblasted or chemically cleaned, they could not get all the tubes 100% clean. During a recent outage the plant's management had the heat exchanger acidized for five days. Upon completion of the acidizing, the post-cleaning flow rate was measured and found to be at only 1,500 GPM. This rate was far below the OEM specs. One month later, management decided to try mechanical tube cleaning and low-pressure water to mitigate the problem. To thoroughly clean all the tubes and restore the heat exchanger to maximum performance, the cleaning crew mounted a HydroDrill to the front of the tubesheet. The drill bits selected were custom engineered to be 0.005" below the minimum tube I.D.s. As the crew guided the rotating drill bit down the length of each tube, water was pumped through the hollow rigid shaft to orifices in the drill bit, pushing out deposits as they were loosened. The cleaning duration was 48 hours and all the tubes were opened fully. When the exchanger was returned to service, the flow rate had increased to >3,100 GPM, more than double the flow after acidizing. HydroDrilling has not only proven to be the only cleaning tactic able to open every tube, but was also the quickest of all the cleaning techniques employed.

SECTION 4 – CONCLUSION

Each year, fouled heat exchangers cost the processing industries billions in lost production, capacity and revenue. While traditional high-pressure water methods can be used to mitigate tube fouling, the large crew sizes, huge footprints, high volume of waste water and lengthy time required by hydroblasting operations to thoroughly clean a heat exchanger are causing many plant managers to rethink how they are cleaning their tubes. To improve the performance of fouled heat exchangers, operators must first understand the nature of the fouling, and then commit to better stewardship of their heat exchangers. Fortunately, there has never been a better time for heat exchanger maintenance. Innovation of new and improvements of existing cleaning technologies are resulting in better outcomes with less waste, which is good for business and the environment. Low-pressure water mechanical cleaning methods featuring minimal crew sizes, small footprints, low volumes of waste water and short cleaning times offer a next generation tool kit of highly effective and responsive cleaning for any plant that operates heat exchangers.

ACKNOWLEGEMENTS

The authors acknowledge Conco Services Corporation for their willingness to share their technology and experience with industry.

REFERENCES

Saxon, George E., Jr. and Putman, Richard E., "The Practical Application and Innovation of Cleaning Technology for Heat Exchangers," Edited by Paul Watkinson, University of British Columbia, Canada; Hans Müller-Steinhagen, German Aerospace Centre (DLR) and University of Stuttgart; and M. Reza Malayeri, German Aerospace Centre (DLR), Heat Exchanger Fouling and Cleaning: Fundamentals and Applications, ECI Symposium Series, Santa Fe, New Mexico, USA, May 18-22, 2003, Volume RP1.

Wilburn, J., "Low Pressure Mechanical Tube Cleaning… The Safe, Fast and Efficient Alternative to Hydroblasting," a BIC Alliance Webcast, Baton Rouge, Louisiana, USA, April 14, 2015.

Meyer, T., "Emerging Trends in Heat Exchanger Cleaning Improves Safety and Reduces Wastewater," Environmental, Health and Safety Seminar, Galveston, Texas, USA, June 1-4, 2015.

Saxon, George E., Jr, "Innovation and Efficiency: Low-Pressure Water Mechanical Cleaning of the Heat Exchanger Cases, Cases in Heat Exchanger Cleaning," Heat Exchanger Fouling and Cleaning XI, Enfield, Ireland, June 7-12, 2015.

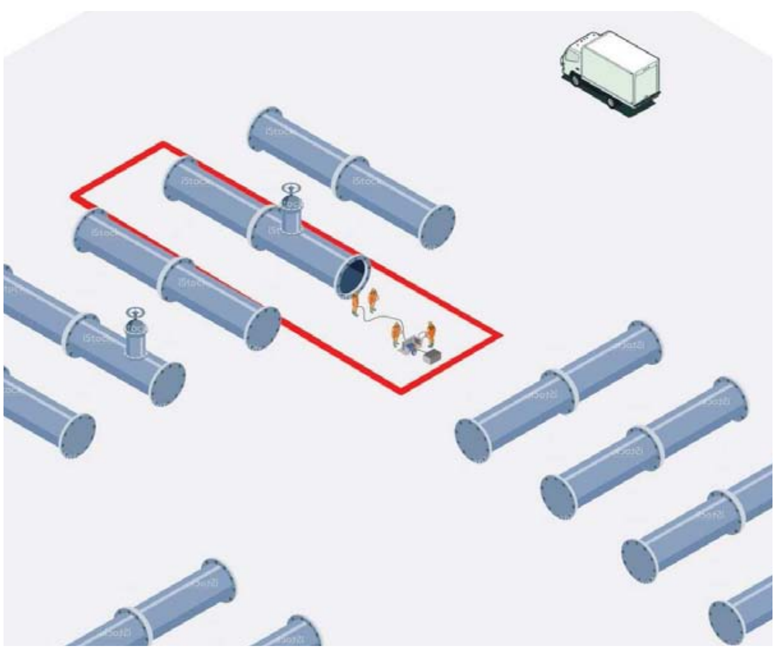

Figure 1. Low-Pressure Water Footprint

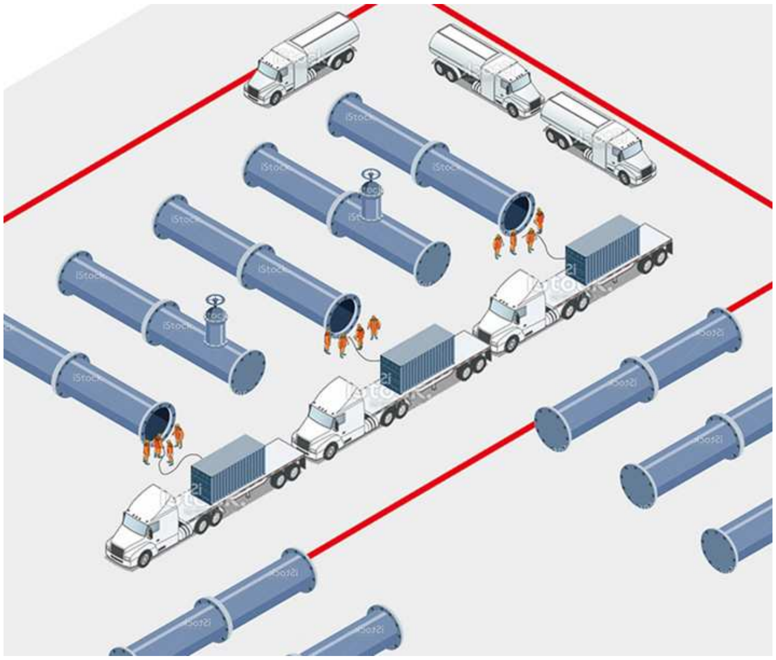

Figure 2. High-Pressure Water Footprint

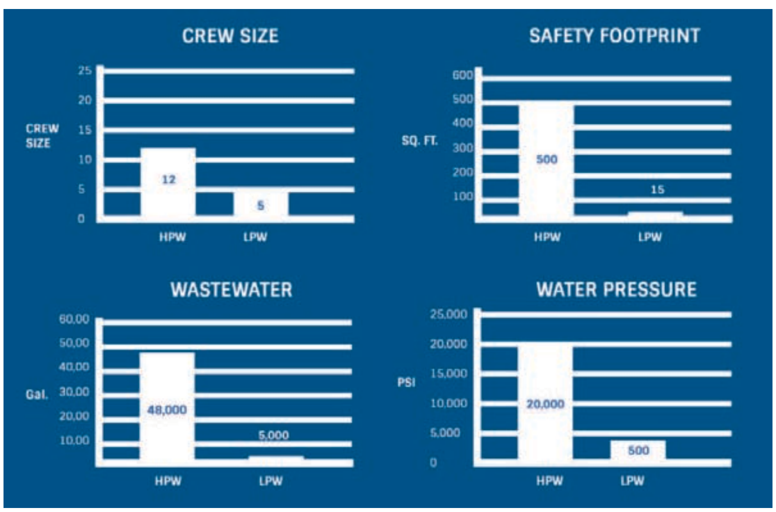

Figure 3. HPW vs. LPW Charts

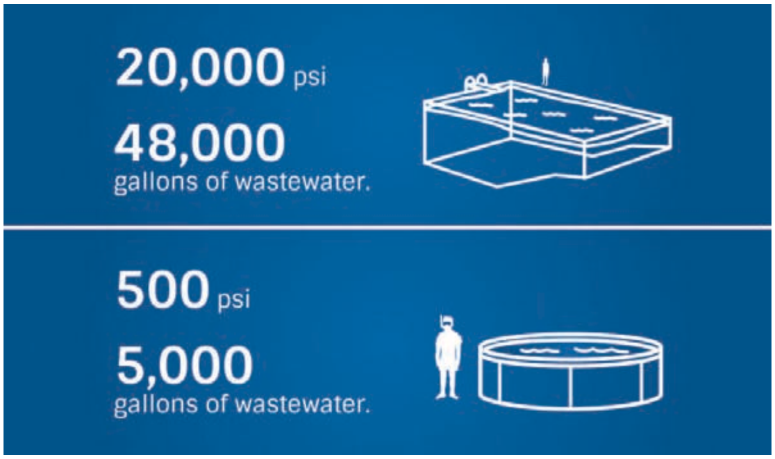

Figure 4. HPW vs. LPW Wastewater

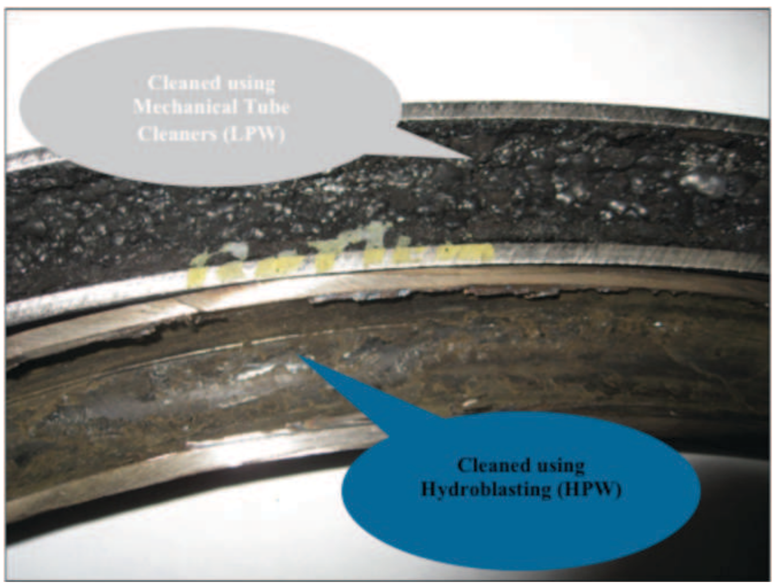

Figure 5. HPW vs. LPW Cleaning Results

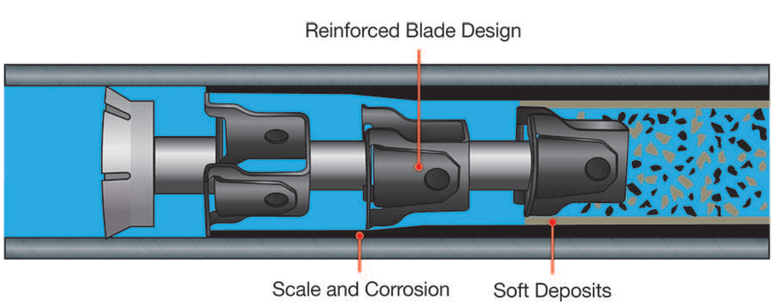

Figure 6. Tube Shooting

7a. Metal Cleaner **7b.** U-Tube Cleaner

7c. Heavy-Duty Cleaner **7d.** Calcium Cutter

7e. Stainless Steel Brush

Figure 7. Mechanical Tube Cleaners

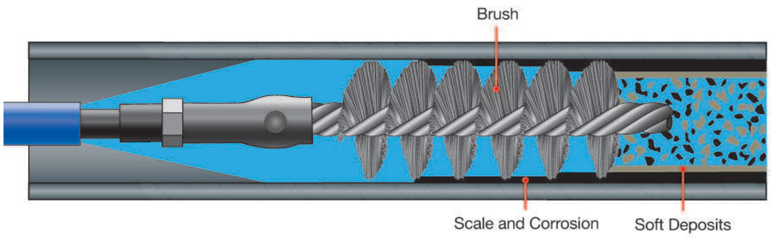

Figure 8. Tube Brushing

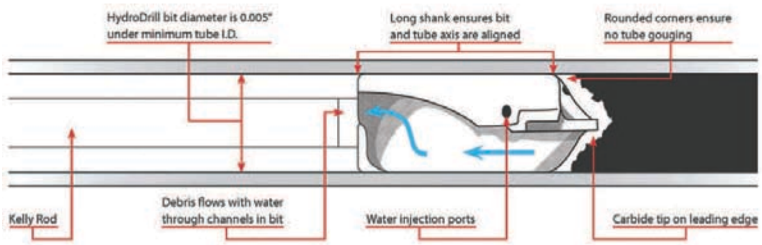

Figure 9. Tube Drilling


Figure 10. Tube Bridge

All figures courtesy of Conco Services Corporation.