TECHNICAL BRIEF

Heat Exchanger Deposit Removal using Pressurized Liquid Nitrogen (LN_2)

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Abstract

Pressurized liquid nitrogen (LN2) can be used as a highly effective means for completely and rapidly removing the most tenacious deposits encountered in petroleum refinery process equipment. As a result, significant improvements can be seen in process flow rates and control and in process energy and pollution management. In addition, the use of a non-water based cleaning method ensures that there will not be any reactions with the deposit and that there will be minimal waste streams or pollution to the surrounding area.

In this paper, a detailed description is given of the NitroLance™ Ultra High Pressure liquid nitrogen cleaning system which uses a controlled stream of liquid nitrogen at pressures up to 55,000 psig and temperatures down to -250 ºF to penetrate and breakup just about any deposit. Using varying nozzle configurations, the system can be customized to clean heat exchangers and process equipment encountered in sulfur recovery units and associated heat exchangers such as waste heat boilers, sulfur condensers, and catalytic reactors.

A case history is presented from Frontier El Dorado Refining on the effectiveness of the LN2 cleaning system on their waste heat boilers.

SRU Function and Performance

In refinery operations, the emission limits are very restrictive and often utilize the improved Claus SRU recovery system. The efficiency of the Claus sulfur recovery unit can deteriorate with time if the boilers, converters, and condensers have deposit buildup. While heat exchangers play a critical role in realizing SRU efficiency, they are only effective if the equipment is maintained and kept clean of fouling deposits.

Overview of Typical Cleaning Methods

Cleaning of refinery heat exchanger tubes is often done with high pressure water (hydroblast), hydrodrilling, acid cleaning or mechanical scrapers and brushes. These methods require disposal of deposits and polluted water/chemicals that are often in the thousands of gallons which may require EPA mandated cleanup and proper disposal1.

Now with this new method of liquid nitrogen cleaning, no secondary waste stream is produced. The fouling deposits removed by the NitroLance™ cleaning process can be easily vacuumed up or blown out of the tubes. This lack of effluent production by NitroLance™ represents a significant cost savings to refineries over traditional water-based methods.

Introduction to LN2 Cleaning Technology

NitroLance™, developed by Conco Systems of Verona, Pennsylvania uses pressurized liquid nitrogen to clean various types of refinery heat exchangers and other industrial surfaces. It can be used to clean tube internals with small rotating carriers with insertable jets, or with larger specialized manifolds to clean external heat exchanger surfaces including delicate finned tube heat exchangers.

The typical NitroLance™ process flow is shown in Figure 1. The commercial high purity liquid nitrogen comes from the supplier at -321°F2. The NitroLance™ system pressurizes it to between 5,000 PSI and 55,000 PSI. Then, utilizing a temperature controller, the flow is directed while expanding almost 700 times on and into the surface to be cleaned. The controlled flow and temperature is regulated between -160°F and -250°F. The complete system is mounted on a mobile platform that is moved to close proximity of the heat exchangers being cleaned. The NitroLance™ hose and nozzle can extend up to 300 feet from the mobile platform while delivering LN2 to the heat exchanger being cleaned.

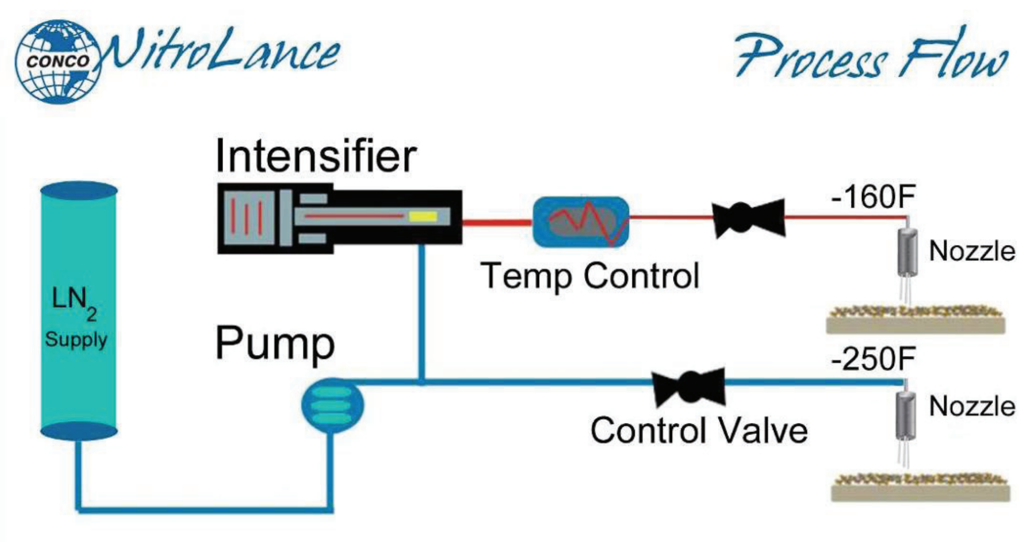


Figure 1.NitroLance™ Process Flow

LN2 Cleaning Mechanisms

The NitroLance™ cleaning system delivers pressurized liquid nitrogen to the cleaning surface and rapidly removes deposits through three mechanisms of action: mechanical pressure, super cooling and thermal/volumetric expansion as shown in Figure 3.

1. **Mechanical Pressure** - The pressure exerted at the nozzle tip of the system is regulated from 5,000 PSI to 55,000 PSI based on the equipment being cleaned and fouling characteristics present.
2. **Super Cooling** - The super cool liquid nitrogen (-160°F to -250°F at the nozzle) facilitates embrittlement fracturing of semi-porous fouling deposits.
3. **Thermal/Volumetric Expansion** - As the high density vapor penetrates the cracks and crevices of the fouling deposit, it rapidly converts to a gas expanding nearly 700 times. This rapid expansion, combined with the delivered pressure and cold temperature, causes the fouling deposit to break apart and release its bond with the parent metal.

Figure 2. NitroLance™ mobile platform with LN_2 tanks, generator, pumps and temperature controller.

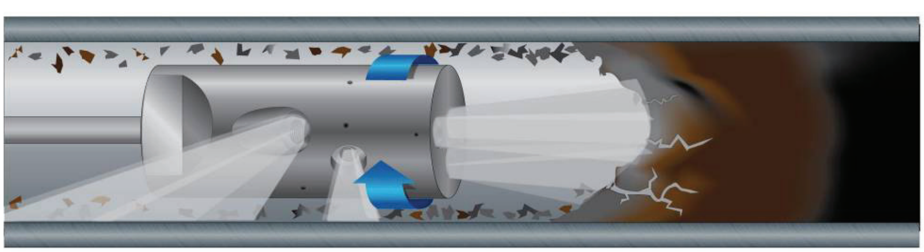


Figure 3. The LN2 removes the deposit by thermal/volumetric expansion, cold temperature, and pressure.

LN2 Effects on Base Metal

An evaluation of the effects of LN2 on base metal was performed by Air Liquide Corporation to examine possible changes to the metal's grain boundaries and structure, as well as the potential for shrinkage or modifications of mechanical properties that might result from the cold temperatures. Micro-structural observation and micro-hardness measurements were performed on steel (ATTM A516 60) before and after LN2 cleaning. As shown in Figure 4 and Figure 5, LN2 cleaning of basic carbon steel induced no micro-structural grain modifications or changes in the surface micro-hardness of the base metal.

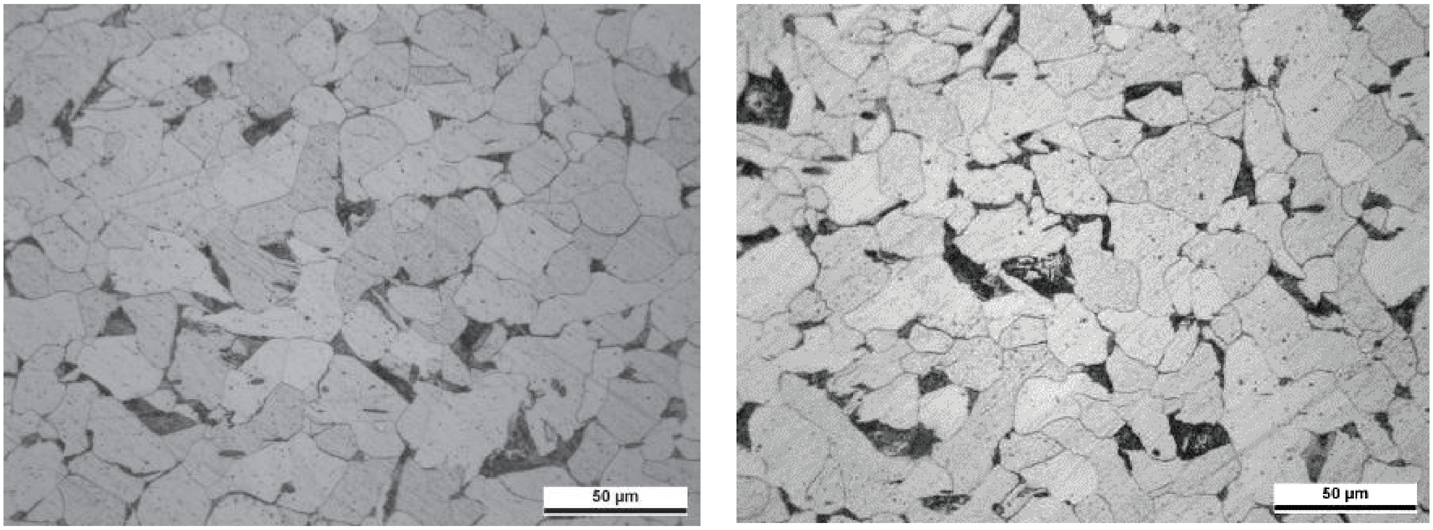


Figure 4. 3µm diamond polished ASTM A 516 60 before (left) and after (right) cleaning with liquid nitrogen.

Sample	***Vickers Scale***	***M1***	***M2***	***M3***	***Average (Hard.Units)***
ASTM A 516 60/ASME SA 516 60 before NitroLance	HV0.3/15	161	147	146	151
ASTM A 516 60/ASME SA 516 60 after NitroLance	HV0.3/15	146	158	152	152

Figure 5.Micro Hardness Measurement

Shrinkage or modifications of the mechanical properties of the base metal is avoided due to the cleaning process being performed at a relatively fast rate of speed (greater than 10 ft/min). Combined with this fast speed and brief contact with the LN2, the base metal only dropped in temperature between 9°F and 18°F on average. This small temperature drop induced no notable metal shrinkage and had no notable influence on mechanical properties of the base metal.

Case History of NitroLance™ at Frontier El Dorado Refining Company

A LN2 cleaning performed at Frontier El Dorado Refining Company in El Dorado, Kansas provided insight into the speed achievable utilizing liquid nitrogen in place of high pressure water. In the case of Frontier El Dorado, it was a waste heat boiler that had significant deposits of iron pyrite. The deposits on the tube ID ranged from 0.20 in. thick to 0.32 in. thick. Similar deposits were on the tube sheet. These deposits decreased both the heat transfer and reduced the overall unit efficiency.

Previous cleanings of this boiler were done by hydroblast technique and resulted in thousands of gallons of effluent that needed treatment by the plant's wastewater treatment system. The time to clean utilizing hydro-blasting often reached 12 shifts. As an outage approached in 2008, the LN2 system was evaluated by Frontier's engineers and was then scheduled for cleaning on the 308 gas side steel tubes and tubesheet of this unit.

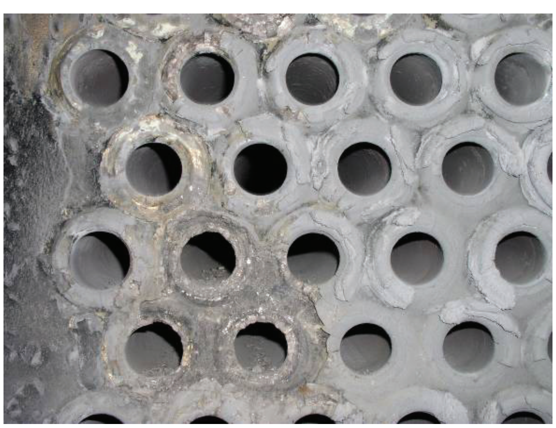
Cleaning Process and Visual Results

At the start of the outage, Conco technicians configured the NitroLance™ to a pressure of 50,000 psi and a nozzle temperature of -250ºF. Figure 6 shows the technicians in protective gear (including jump suits, full face masks, rubber boots, and cryogenic insulated gloves) with the NitroLance™ lance and nozzle while removing the deposits.

Figure 6. Technician cleaning tube internals (left) and tubesheet (right) with NitroLance™

Twenty foot long LN2 lances with special nozzle carriers were used to clean each waste heat boiler tube. Also, different feed rates of the rotation nozzles were evaluated by checking the internal tube's cleanliness with a borescope. Once the optimum cleaning rate was determined, the process of cleaning the unit's 308 tubes was started. Results: the LN2 cleaning process was completed in only one shift or 12 hours. Deposits were easily vacuumed up and disposed of properly.

The visual results are dramatic and are shown in a comparison of before cleaning (Figures 7) and after cleaning (Figure 8). The results indicate a thorough cleaning in each tube with no tube damage.



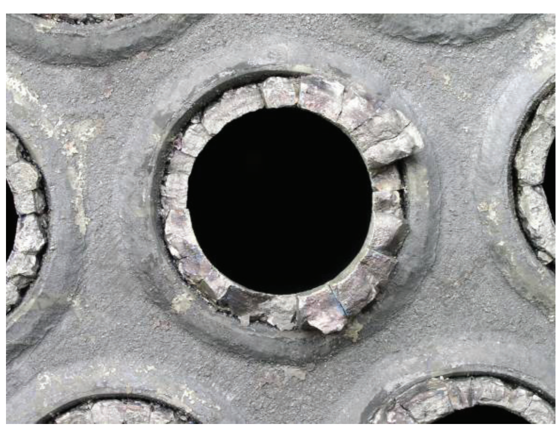


Figure 7. Tubesheet and tube internal with 0.32" iron pyrite deposit before LN2 cleaning

Figure 8. Tube internals after cleaning with NitroLance

Performance Results

After the waste heat boiler was brought back in service, immediate results showed that the process gas side temperature was reduced from 800ºF to 650ºF, or the original operating temperature specification. Thus, the heat transfer performance of this unit was brought back to design conditions and the overall plant efficiency was improved.

A calculation on the total iron pyrite deposits removed from this heat exchanger was approximately 19.7 cu ft.; weighing 6,202 lbs, or 3.1 tons. The deposits were easily vacuumed up and properly disposed. The time to clean, as previously mentioned, was only 1.5 shifts compared to 12 shifts with the previously used hydroblast cleaning technique. This includes the added benefit that no external heaters were necessary to dry out any moisture left by the hydroblast cleaning.

Other LN2 applications

The cleaning of this waste heat boiler was so effective that Conco Systems is now being utilized to clean the Frontier El Dorado's sulfur condensers. Other plant equipment will be considered including catalytic reactors and any other fouled heat exchangers.

Overall, nitrogen cleaning with NitroLance™ provides a new and innovative technique for rapidly removing various deposits in refineries and industrial facilities without damaging the parent tube metals.

Summary: Benefits of LN2 Cleaning in Refineries

Proper maintenance of plant equipment plays a critical role in boosting plant efficiency, and can improve plant efficiency and output. Historically, heat exchanger cleaning has been performed utilizing high pressure water, or chemical cleaning, both of which produce a significant volume of effluent that require tedious handling and disposal at considerable cost, plus leaving a wet unit that must be thoroughly dried out prior to return to service. The recent introduction of this new technology utilizing pressurized liquid nitrogen not only speeds up the cleaning process, but does it without producing secondary waste streams, thus saving refinery plants both time and money. Liquid nitrogen also appears to be an optimal choice for many other process applications within refineries and industrial facilities where its speed of deposit removal and zero-waste stream benefit is advantageous.

References:

1. Environmental Protection Agency (EPA), Code of Federal Regulations, 40CFR, Part 419, II 11.0, Petroleum Refinery, 2010 Effluent Guidelines
2. Air Liquide Corporation, Gas Encyclopedia (www.encyclopedia.airliquide.com/encyclopedia.asp)

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