A New Method for In-Situ Plating of Components with Electroless Nickel

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Electroless nickel coatings is a well-known method of protecting surfaces against corrosion and wear. They have been used for over 40 years in many applications in the oil and gas, chemical, heavy machinery and aerospace industries. This paper describes a new patented, in-situ process of applying electroless nickel coatings to components that, because of their size or location, could not be plated in the past.[1] The process sequence will be described in detail, including experience gained from coating a 1,800 gallon vessel and a discussion of the economical viability of the process.

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Electroless Nickel

Electroless nickel coatings are obtained by chemical reduction from an aqueous plating solution without an external current. High phosphorus electroless nickel coatings, containing up to 13 percent by weight of phosphorus, have a unique amorphous structure. The coating has a high hardness of 500 to 550 HV_{100}, is non-magnetic, and has a melting point of 890°C (1630°F).

Due to its amorphous structure, the coating does not contain any grain boundaries, which are preferred sites for corrosion to begin. Hence, electroless nickel is a well-known finish for components to be protected from wear and corrosion in aggressive environments like those in the oil and gas, chemical or mining industry.

The corrosion resistance of electroless nickel coatings has been the subject of numerous papers and investigations. As an example, Table 1 compares the corrosion resistance of 50 to 75 µm (1 to 2 mil) thick, high phosphorus, electroless nickel coatings to that of bare steel in various oil and gas and chemical environments.[2 3 4 5] In these environments, electroless nickel coatings typically provide many years of reliable service under severe conditions.

Table 1
Corrosion Resistance of Electroless Nickel and Mild Steel in Various Environments (Corrosion Rates in µm/y)

Chemical	Electroless Nickel	Mild Steel
5% Phenol @ 95 °C	11	310
9% Brine with CO_2 and H_2S @ 150 °C	38	560
Seawater @ 40°C	1.5	125
Sulfuryl Chloride @ 40 °C	2	200
50% Caustic Soda @ 93 °C	9	533
75% Phosphoric Acid @ 40 °C	19	1270

Unlike conventional electroplating processes, the electroless nickel reaction does not require an electric current. It is driven only by chemicals in the bath and by temperature. Thus, the deposit thickness is not influenced by local current density or shielding effects and is completely uniform even on the most complex shaped components.

The advantages of electroless nickel coatings can be summarized as:

- Superior adhesion
- Freedom from pores and grain boundaries
- Outstanding corrosion resistance
- High wear resistance
- Easy release
- Prevents product contamination

However, these properties are only obtained if all of the components' surfaces are totally immersed in the plating solution and are free from oil, oxides and other contaminants. This requirement limits the application of electroless nickel coatings primarily to new components, which can easily be transported to a traditional plating facility and which are small enough to fit into its cleaning, activation and plating tanks.

To extend the beneficial properties of electroless nickel to components that cannot be transported to a traditional plating facility or are too large or heavy to be processed in a normal facility, a new in-situ plating process was developed. The philosophy of the new method was to bring the coating process to the site of the component to be plated, rather than vice versa. While in-situ plating has occasionally been practiced in the past, it has never been as practical, reliable or economically viable as today.

The In-Situ Process

The in-situ plating process was originally developed to protect equipment in aggressive environments on oil and gas production platforms in the North Sea, where space restrictions and the difficulty of removing corroded components required a new coating technology.

However, the process is also suitable for other components, including reactor vessels or tanks, cooling jackets, heat exchangers, piping or any equipment that cannot be processed in a traditional plating line. The process itself is simple and straightforward. The five or six different cleaning solutions needed in standard electroless nickel plating lines are not required. Nor are cleaning or plating tanks. Instead only a few steps are needed with the process because the component itself, along with a small amount of ancillary equipment, is used as the cleaning and plating tank. What makes the in-situ process unique is that a single solution is used for various process steps. It is not necessary to makeup and then discard new solutions for each process step.

Time and solution savings can be significant with the refurbishment of components that have already been in service. With the in-situ plating process it is possible to coat components without dismantling them or shipping them to a plating facility.

Table 2 compares the process steps necessary for traditional electroless plating with that for the in-situ technology for a used component from a process plant.

After the component is shutdown, it is mechanically cleaned by shot or sand blasting to remove all scales, debris and excessive oxide from the surface, which allows acid activation to be more effective. When necessary, this step can be supplemented by steam or chemical cleaning to remove organic films or other contaminants.

The second step is to prepare the component for plating by closing any openings and masking all areas that must not be coated (like sensors, view-glasses, rupture disk membranes). Piping connections between the component and an ancillary solution reservoir must be provided. The reservoir must be equipped with circulation, filtration and heating capacity.

Then the component is filled with deionized water, which is circulated and heated to about 80EC (180EF). After the temperature

Table 2
Comparison of the Process Sequence of Traditional Electroless Nickel Plating and of the In-situ Coating Process for a Used Component, Such as a Heat Exchanger or a Reactor in a Chemical Plant

	Electroless Nickel Plating Sequence		In-Situ Coating Sequence
1.	Mechanical cleaning	1.	Mechanical / chemical cleaning
2.	Remove part from installation	2.	Prepare part for plating
3.	Ship to plater	3.	Subsequent pickling, activating and coating in one solution
4.	Prepare part for plating	4.	Remove solution
			Rinse, remove rinse water
5.	Clean part	5.	Put back on line
	Rinse		
6.	Acid pickling	6.	Put back on service
	Rinse		
7.	EN plating		
	Rinse		
8.	Ship to installation site		
9.	Reassemble		
10.	Put back to service		

of the water and the component have reached the desired temperature, a small amount of acid is added to lower the solution pH and to pickle the steel. Because of the higher temperature, only a very small amount of acid is required to clean and activate the steel.

After only a few minutes, the steel surfaces are very clean, free of any oxide films, and metallurgically very active. These conditions result in the superior adhesion and freedom from porosity of the in-situ coating on steel surfaces.

In the third step, the acid is neutralized to prepare the solution for plating. Then, part of the neutralized water is removed from an external reservoir tank while the component to be plated remains completely filled with the solution. The removed solution is replaced by electroless nickel makeup concentrate, which is circulated through the component. Because of the active and clean surface produced by the process, plating begins immediately, ensuring the perfect bond between the steel and the coating. A typical coating produced by in-situ plating and its bond to its substrate is shown in Figure 1.

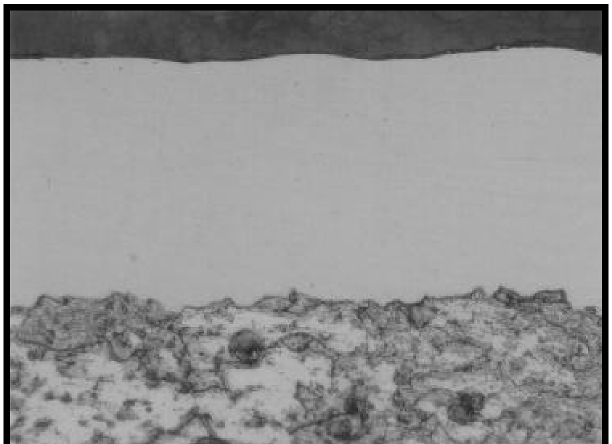

Figure 1
Cross Section of the In-situ Coating on a Mild Steel Substrate Showing its Superior Adhesion and Freedom from Porosity (1000x Magnification)

Plating is allowed to continue until the desired coating thickness is obtained. Typically, the plating solution's temperature, pH and chemical composition are monitored and adjusted with an automatic controller. Even for severe corrosion resistance applications, the process is usually completed after six to eight hours of plating. Finally, the solution is removed. The component is rinsed and dried and put back into normal service. Comparing this sequence with the number of steps in conventional electroless nickel plating, shows that the in-situ process takes less time and requires a much smaller volume of chemicals.

The advantages of the in-situ electroless nickel coating process are the following:

- Reduced plating solution volumes
- Shorter processing time
- Superior coating quality
- Selective coating of internal surfaces is possible
- Coating thickness is variable depending on service conditions
- Coating of components is carried out on-site without disassembly and shipment
- Produces no hazardous waste

Not only has the in-situ plating process and its results been proven in laboratory and pilot-plant tests, but also in a commercial scale application. The vessel shown in Figure 2 was plated with electroless nickel by the in-situ method. The vessel is 180 cm (6 feet) in diameter and 440 cm (8 feet) high, made from mild steel, and has a capacity of 6800 L (1800 gallons). The

Figure 2
1800 Gallon Mild Steel Vessel to Be Plated with Electroless Nickel

vessel was equipped with an 8-inch flange on the spherical bottom through which the electroless nickel solution was introduced from an external reservoir after passing through a heat exchanger. The solution was allowed to return to the reservoir tank by gravity flow. Figure 3 shows a schematic view of the set-up.

Figure 3
Schematic View of the Set-up for In-situ Plating of the 1800 Gallon Vessel

First, the vessel was mechanically cleaned by grit blasting. Then, the vessel was plated with the method described above. After eight hours of plating time and a total process time of 11 hours (including pretreatment and pickling), the average deposit thickness was 80 to 90 µm. Even at the location of highest solution flow rate (the bottom inlet flange) a thickness of 60 µm was plated. The coating was free of any porosity, covered all weld seams and flanges evenly, and proved excellent adhesion even under severe punching tests. Figure 4 shows the bottom of the vessel after plating was complete.

Another advantage of the in-situ plating process is that it produces no hazardous waste. After plating of the component is complete, the plating solution is typically only about 25 to 50 percent old. It still has a long useful life remaining. Accordingly, the plating solution is stored in drums or totes and returned to a plating shop where it is used to plate parts. The solution used to coat the 1800 gallon vessel was subsequently used to plate thousands of additional parts.

Figure 4
The 1800 Gallon Vessel after the In-situ Coating Was Complete

Economical Aspects

Large tanks and reactors have occasionally been plated with electroless nickel in the past. However, these jobs always required that each cleaning, activating and plating solution be pumped into and then out of the vessel consecutively with one or more rinsing cycles between each process step. Because of the time needed to accomplish these actions, the large volume of chemicals needed, and the resulting large volume of waste produced, this technique has found little use.

One of the major maintenance contractors for offshore oil platforms in the North Sea did an economic evaluation that shows how the cost of the in-situ electroless nickel plating process compares to other corrosion protection technologies in the oil and gas industry. The evaluation was done for the pipeline connecting the oil well riser with the inlet flange of the first separator vessel on the platform. This pipeline was suffering from severe corrosion and erosion caused by the brine and sand contained in the oil, and its high temperature and flow rate. The pipeline consisted of a 16 meter (52 feet) long pipe with various valves, flanges and connections. At the time of the study, it was being protected by the continuous injection of corrosion inhibitors at its inlet.

For the cost comparison, following alternative scenarios were evaluated:

Alternative 1, New mild steel pipeline with continued inhibitor injection
Alternative 2, In-situ electroless nickel coating of a new mild steel pipeline
Alternative 3, New pipeline in solid duplex stainless steel
Alternative 4, In-situ electroless nickel coating of the existing mild steel pipeline

The result of the cost comparison study is shown in Table 3.

Table 3
Cost Comparison of the Different Alternatives to Solve the Corrosion Problem With a 16-meter Long Pipeline on an Offshore Platform in the North Sea

	Alternative 1 Mild steel with corrosion inhibitor	Alternative 2 In-situ EN on new mild steel	Alternative 3 New duplex stainless steel	Alternative 4 In-situ EN on existing mild steel
Material	$17,900	$17,900	$26,500	
Prefabrication	$36,500	$36,500	$51,300	
Installation	$35,200	$35,200	$36,000	
Corrosion Inhibitor	$82,800			
Cleaning				$3,500
EN Coating		$30,000		$48,800
Total	$172,400	$119,600	$113,800	$52,300
Relative to Alternative 1	100%	69%	66%	30%

The conclusion of the cost comparison study was that continuation of service with mild steel piping was the most expensive because of the corrosion inhibitor cost. The cost for a new pipeline, either in stainless steel or electroless nickel coated mild steel, was about the same if the cost of the duplex stainless steel was assumed to be only 1½ times that of mild steel. This assumption is very optimistic concerning the cost fluctuations in the stainless steel market and the frequent lack of availability of certain grades.

Despite the higher cost for cleaning and in-situ electroless nickel coating the existing equipment, this alternative was by far the most cost efficient. It saved over $100,000 over the platform operator's present method. This example demonstrates the economic viability of the in-situ coating process.

Summary

The new in-situ plating technology is a unique method for applying high phosphorus electroless nickel coatings on components that, because of their size or location, could not be plated in the past. The in-situ process also results in shorter processing times and requires smaller volumes of cleaners and chemicals than other methods and produces no hazardous waste. The coating from this method provides exceptional resistance to corrosion, abrasion and wear, scaling, fouling or product contamination. It is economically viable and ideal for protecting vessels, jackets, exchangers, piping and other process equipment in the oil and gas, chemical, food and other industries.

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