

●
● ● **Electroless nickel plating:**
● ● **A general description of electroless**
● ● **nickel plating and its effect on Bal Seal®**
● ● **spring-energized seal performance in**
● ● **reciprocating and rotary service**

● ● **Technical Report**
● ● **TR-16 (Rev. E; 7-27-15)**
● ● **(100-63-4)**

19650 Pauling
Foothill Ranch, CA
USA 92610-2610
t +1 949 460 2100
f +1 949 460 2300
www.balseal.com

Jollemanhof 16, 5th floor
1019 GW Amsterdam
The Netherlands
t +31 20 638 6523
f +31 20 625 6018
www.balseal.nl

Suite 901, Chinachem
Century Tower
178 Gloucester Road,
Wanchai, Hong Kong
t +852 28681860
f +852 22956753
www.balseal.com.hk



Contents

1.0	Summary	3	4.11	Requirements after Plating	8
2.0	Purpose of Plating	3	4.11.1	Stress Relieving	8
3.0	When to Use Electroless Nickel Plating	3	4.11.2	Surface Finish after Plating	8
3.1	For Corrosion Resistance	3	5.0	Properties of Boron Electroless Nickel Plating	8
3.2	For Wear Resistance in Hard-to-Reach Areas	4	5.1	Variation in Hardness	8
3.3	Electroless Nickel vs. Chrome Plating vs. Boron Electroless Nickel Coating: the Advantages and Disadvantages of Each Method	4	5.1.1	As Plated	8
3.4	Recommended Plating Thickness	4	5.1.2	Heat Treated	8
4.0	Properties of Electroless Nickel Plating	5	5.2	Corrosion Resistance and Surface Structure	8
4.1	Variation in Hardness	5	5.2.1	As Plated	8
4.1.1	As Plated	5	5.2.2	Upon Heat Treatment	8
4.1.2	Heat Treated for One Hour at 750 °F (400 °C)	5	5.3	Friction Properties	9
4.2	Corrosion Resistance and Surface Structure	5	5.4	Uniformity of Plating Thickness and Deposition Rate	9
4.2.1	As Plated	5	5.5	Adhesion of Plating and Material Being Plated	9
4.2.2	Upon Heat Treatment	5	5.6	Dimensions of Parts before and after Plating	5
4.3	Friction Properties	5	5.7	Surface Finish and Plating	9
4.4	Uniformity of Plating Thickness and Deposition Rate	5	5.8	Boron Electroless Nickel Plating Specifications	9
4.5	Adhesion of Plating and Material Being Plated	6	5.9	Surface Cleaning and Activation Prior to Plating	9
4.6	Dimension of Parts before and after Plating	6	5.10	Quality Control of Boron Nickel Electroless Plating Process	10
4.7	Surface Finish before and after Plating	6	5.10.1	Effects of Contamination	10
4.7.1	Plating Thickness from 0.0001 to 0.0006 in. (from 0.0025 to 0.0152 mm)	6	5.10.2	Control of Plating Bath Condition	10
4.7.2	Plating Thickness >0.0006 in. (>0.0152 mm)	6	5.11	Requirements after Plating	10
4.8	Electroless Nickel Plating Specifications	6	5.11.1	Stress Relieving	10
4.9	Surface Cleaning and Activation Prior to Plating	7	5.11.2	Surface Finish after Plating	10
4.10	Quality Control of Electroless Nickel Plating Process	7	6.0	Sources of Supply	10
4.10.1	Effects of Contamination	7	7.0	References	11
4.10.2	Control of Plating Bath Conditions	7			

The information, descriptions, recommendations and opinions set forth herein are offered solely for your consideration, inquiry, and verification and are not, in part or in whole, to be construed as constituting a warranty, expressed or implied, nor shall they form or be a part of the basis of any bargain with Bal Seal Engineering, Inc.. If any sample or model was shown to or provided by Buyer/User, such sample or model was used merely to illustrate the general description and type of goods. Such use is not to be construed as a warranty that the goods will conform to the sample or model. Furthermore, THE IMPLIED WARRANTY OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE AND ALL OTHER WARRANTIES, IMPLIED OR EXPRESSED, ARE EXCLUDED AND SHALL NOT APPLY. This document provides product options for further investigation by Buyers/Users having technical expertise. The Buyer/User, through its own analysis and testing, is solely responsible for making the final selection of the products and for assuming that all performance, safety and warning requirements for the application are met. It is recommended that Buyers/Users run evaluation testing under actual service conditions to determine whether proposed Bal Seal Engineering products are suitable for the intended purpose. Nothing contained herein or in any of our literature shall be considered a license or recommendation for any use that may infringe patent rights. (LE-17)

PATENTS: The items described in this report include products that are the subject of the following issued United States patents: 5,979,904; 5,992,856; 6,050,572; 5,984,316; 6,161,838 and others, as well as foreign patents or products where patents are pending. (LE-88G)

©Copyright 2016 Bal Seal Engineering, Inc. U.S.A.

1.0 Summary

This report outlines the process of electroless nickel plating, including its advantages, disadvantages, limitations, and requirements in achieving a good quality plated surface. Electroless nickel plating is used in applications where corrosion resistance is desired and with plating intricate surfaces or small or deep bores. A uniform thickness with medium to high hardness can be achieved. The process is limited to certain types of metals and requires a strict, high level of quality control. Electroless nickel plating can greatly enhance Bal Seal® spring-energized seal performance by lowering friction and increasing the hardness of the dynamic mating surface to reduce seal abrasion and extend seal life.

2.0 Purpose of Plating

The purpose of electroless nickel plating is to improve corrosion resistance, increase the surface hardness of the material, provide a uniform and dense coating, and in most cases, maintain the same surface finish the material had prior to plating.

Electroless nickel plating consists of the deposition of a nickel-phosphorous alloy onto the metal surface by a chemical bath, not by electrodes or external electrical charges. This method permits the plating of hard-to-reach surfaces, such as small or deep bores and intricate shapes. Coating thicknesses for engineering uses vary from 0.0003 to 0.0008 in. (from 0.0076 to 0.0203 mm) with hardness from approximately 48 to 52 Rockwell C. When the plating is heat treated at approximately 750 °F (400 °C) for one hour, the obtainable hardness varies from 58 to 64 Rockwell C.

Boron electroless nickel plating is another process that may be used. It produces higher hardness when required. The process allows for increasing the hardness from 60 to 62 HRC and from 70 to 72 HRC when heat treated.

Electroless nickel plating provides a higher hardness, significantly improving Bal Seal® spring-energized seal performance. A harder surface greatly reduces the coefficient of friction and the adhesive force, resulting in lower wear and longer Bal Seal® spring-energized seal life.

3.0 When to use Electroless Nickel Plating

Electroless nickel plating can be used in the as-deposited condition or may be hardened, depending on the intended service conditions.

3.1 For Corrosion Resistance

Because of its excellent corrosion resistance, nickel plating is used as deposited when the plated part is intended for a corrosive environment, such as brine, acids, etc. The plated part should not be hardened after coating, because hardening significantly reduces its corrosion resistance.

3.2 For Wear Resistance in Hard-to-Reach Areas

Electroless nickel plating is used when it is difficult or impossible to produce a uniform chrome plate using electrodes, such as in small or deep bores. The coating is hardened when increased wear resistance is desired for rotary or reciprocating service.

3.3 Electroless Nickel vs. Hard Chrome Plating vs. Boron Electroless Nickel Coating: the Advantages and Disadvantages of Each Method

Method	Advantages	Disadvantages
Electroless nickel plating	<ul style="list-style-type: none"> • High corrosion resistance in as-deposited condition • Maintains better uniform thickness and surface finish • Can plate small diameters, deep bores, and intricate shapes 	<ul style="list-style-type: none"> • Requires high standards of quality control of surface preparation and plating solution • Softer than chrome plating • Some metal limitations
Hard chrome plating	<ul style="list-style-type: none"> • Harder than electroless nickel plating • Relatively easy to plate • Cost is similar to electroless nickel plating, depending on parts 	<ul style="list-style-type: none"> • Coarse surface finish after plating • Small bores and intricate shapes are difficult to plate
Boron electroless nickel plating	<ul style="list-style-type: none"> • Can be placed on titanium; hardness is superior when compared with others • Higher operating temperatures • Requires no secondary machining • Combines extreme hardness, corrosion resistance, ductility, and low coefficient of friction 	<ul style="list-style-type: none"> • Cost-effective against hard chrome but is higher in cost when compared with electroless nickel • Can be plated on aluminum; undercoating is required

3.4 Recommended Plating Thickness

Generally, the most desirable plating thickness is from 0.0005 to 0.0008 in. (from 0.0127 to 0.0203 mm). Thicker plating could leave a wavy or rough surface that might require refinishing.

4.0 Properties of Electroless Nickel Plating

Electroless nickel plating has several properties that change when the plating is heat treated. It is important to select the proper plating condition to suit the application.

4.1 Variation in Hardness

4.1.1 As Plated

From 48 HRC to 52 HRC

4.1.2 Heat Treated for One Hour at 750 °F (400 °C)

From 58 HRC to 64 HRC

4.2 Corrosion Resistance and Surface Structure

4.2.1 As Plated

The surface structure is smooth, amorphous (non-crystalline), dense, non-porous, and continuous with excellent corrosion resistance.

4.2.2 Upon Heat Treatment

The surface becomes a crystalline structure with higher porosity and micro cracks caused by contraction of the plated surface. The corrosion resistance decreases significantly.

4.3 Friction Properties

The coating consists of a nickel phosphorous alloy containing from 3 to 13% phosphorous, some trace impurities, and the balance nickel. Good frictional properties are produced by the phosphorous content, providing natural lubricity, minimizing heat buildup, and reducing scoring and galling. The coefficient of friction of electroless nickel-plated steel is about 0.13 when lubricated and 0.40 when not lubricated, which is slightly higher than the friction of electrodeposited chromium. The friction properties are not affected by heat treatment.

4.4 Uniformity of Plating Thickness and Deposition Rate

Uniform thicknesses can be obtained on most surfaces, including small and intricate areas. Deposition is controlled by the surface charge of the part to be plated. Because the surface charge is completely uniform across the entire surface area of the part, deposition is the same at all points.

4.5 Adhesion of Plating and Material Being Plated

Adhesion of electroless nickel plating to the base metal depends on the ability of the metal to react with the plating solution to form a strong bond.

Hardening types of stainless steels and alloy steels can be electroless nickel-plated with excellent bonding. These materials can be heat treated at 750 °F (400 °C) after plating for additional hardness but with low corrosion resistance.

Aluminum can be electroless nickel plated with excellent bonding. Series 300 stainless steel can also be electroless nickel-plated, but requires additional processing. Heat treating of aluminum or series 300 stainless steel results in low tensile strength.

Carbon steels inhibit adhesion of the plating, especially if materials are hardened. The presence of carbon in the steel prevents good adhesion. Aluminum is used as plated with no heat treatment after plating.

4.6 Dimension of Parts before and after Plating

Dimensioning of parts should account for plating buildup. Generally, parts machined 0.0005 in. (0.0127 mm) undersize and then plated from 0.0005 to 0.0008 in. (from 0.0127 to 0.0203 mm) can be finished to size with minimal polishing, lapping, or honing.

4.7 Surface Finish before and after Plating

(Please see section 4.7.2 and 4.11.2)

4.7.1 Plating Thickness from 0.0001 to 0.0006 in. (from 0.0025 to 0.0152 mm)

Minimal changes occur on the surface during plating. Therefore, when the plating thickness is from 0.0001 to 0.0006 in. (from 0.0025 to 0.0152 mm), the surface finish prior to plating should be approximately the same as after plating.

4.7.2 Plating Thickness >0.0006 in. (>0.0152 mm)

Shot peening or grit blasting may be required to roughen the non-plated surface and provide good adhesion to the base metal during plating. It may be necessary to machine the plated surface after plating by polishing, honing, or lapping to achieve the desired surface finish.

4.8 Electroless Nickel Plating Specifications

This report conforms to Aerospace Material Specification SAE-AMS-2404 for electroless nickel plating.

4.9 Surface Cleaning and Activation Prior to Plating

The surface must be thoroughly cleaned to obtain good adhesion of electroless nickel plating to the metal surface. Failure to eliminate all types of surface contamination results in lower adhesive bond strength and causes flaking or blistering of the coating during post-plating heat treatments as the contaminants are baked out. Once the surface is cleaned, it must be activated by pre-plating treatments designed to make the metal surface more reactive to the plating solution. Some passive metals, such as stainless steels, may require additional processing steps after activation to provide good adhesion. A nickel strike, performed in a highly acidic electroless nickel bath, provides a foothold for the plating.

4.10 Quality Control of Electroless Nickel Plating Process

In addition to the surface cleaning and activation processes described above, several strict quality control requirements are necessary during electroless nickel plating. The electroless nickel plating process is more sensitive to variations than electrodeposited chrome plating in which fewer parameters must be as strictly controlled. It is essential to select a plating vendor with a high level of quality control to ensure positive results when using the electroless nickel process.

4.10.1 Effects of Contamination

Various pre-plating steps remove contamination from the metal surface. However, contamination can also occur in the plating process during plating if there are contaminants in the plating bath. Various metal contaminants can be co-deposited with the nickel, resulting in lower adhesion of the plating and increased internal stress in the plating; this will cause cracking and brittleness.

4.10.2 Control of Plating Bath Conditions

The electroless nickel plating process requires accurate control of the plating bath temperature, the nickel content, the pH level, and the filtration. One particular disadvantage of electroless nickel plating is that the batch can decompose in the presence of fine particles. Continuous filtration is required to prevent decomposition. Excellent results can be achieved with proper quality control of the pre-plating steps, the nickel bath, and post-plating treatments.

4.11 Requirements after Plating

Several steps are required to finish a part after plating.

4.11.1 Stress Relieving

Stress relieving is necessary after electroless nickel plating. This consists of heat treating the part at 375 °F (190 °C) for at least three hours, per military specification SAE-AMS-2404.

Stress relieving improves adhesion and reduces peeling, cracking, and hydrogen embrittlement of the plating. Hydrogen is released during the chemical plating process and must be discharged from the plating to prevent loss of ductility.

4.11.2 Surface Finish after Plating

The surface finish of a part after plating is generally the same as the finish before plating. Further honing, lapping, or polishing is required to improve the finish after plating. When the plating is hardened by heat treating, a slight film of oxidation or stress cracking may occur on the surface, requiring a final polishing to obtain the desired finish. Surface finishes to 1 RMS (0.9 Ra) can be obtained on electroless nickel plating parts.

5.0 Properties of Boron Electroless Nickel Plating

It is important to select the proper technique to suit the application.

5.1 Variation in Hardness

5.1.1 As Plated

from 60 HRC to 62 HRC

5.1.2 Heat Treated

for eight hours at 590 ° to 725 °F (310 ° to 385 °C) for 90 minutes.

5.2 Corrosion Resistance and Surface Structure

5.2.1 As Plated

Boron nickel has a knoop hardness of 800–850 HK converted to 60–62 HRC on the Rockwell C scale.

5.2.2 Upon Heat Treatment

Boron nickel coating has a hardness approaching 1250 HK converted to 70–72 HRC on the Rockwell C scale.

5.3 Friction Properties

Boron nickel has a low coefficient of friction. A part sliding across a boron surface rides on top of the coating nodules. The area of contact is less than one half of that of a non-coating part.

5.4 Uniformity of Plating Thickness and Deposition Rate

A uniform coating is deposited on all areas of the part being coated. The normal deposition rate is 0.0005–0.0035 in. (0.0127–0.0889 mm) per hour.

5.5 Adhesion of Plating and Material Being Plated

Boron nickel has excellent adhesion properties and can be used on titanium and aluminum.

5.6 Dimensions of Parts before and after Plating

Dimensioning of parts should account for plating buildup. The side coating thickness can vary between 0.0002 and 0.0040 in. (0.0051 and 0.0102 mm). A typical callout would be 0.0008–0.0010 in. (0.0203–0.0254 mm), or 0.0012–0.0015 in. (0.0305–0.0381 mm).

5.7 Surface Finish after Plating

The surface finish is uniform after plating and requires no secondary machining.

5.8 Boron Electroless Nickel Plating Specifications

The report conforms to ASTM B607-91 for boron nickel plating.

5.9 Surface Cleaning and Activation Prior to Plating

To obtain good adhesion of boron nickel plating to the metal surface, it is essential that the surface be thoroughly cleaned. Failure to eliminate all types of surface contamination will result in lower adhesive bond strength and will cause flaking or blistering of the coating during post-plating heat treatments as the contaminants are baked out. Once the surface is cleaned, it must be activated by pre-plating treatments. These treatments are designed to make the metal surface more reactive to the plating solution. Some passive metals, such as stainless steels, may require additional processing steps after activation to provide good adhesion.

5.10 Quality Control of Boron Nickel Electroless Plating Process

5.10.1 Effects of Contamination

Various pre-plating steps remove contamination of the metal surface. However, contamination can also occur during plating if there are contaminants in the plating bath. Various metal contaminants can be co-deposited with the nickel. This results in reduced adhesion of the plating and increased internal stress in the plating, which causes cracking and brittleness.

5.10.2 Control of Plating Bath Condition

The pH bath for boron nickel is 12.5. After a mild bath at 195 °F (90.5 °C) for 15–20 seconds with no current applied, hydrogen concentration increases by 5 ppm on plated titanium panels. A chemical reaction known as autocatalytic reduction causes the coating to form on the part.

5.11 Requirements after Plating

Several steps are required in order to finish a part after plating.

5.11.1 Stress Relieving

Contact the plater/processor for temperature and time at temperature.

5.11.2 Surface Finish after Plating

Boron nickel usually does not require secondary machining or grinding due to its uniform deposition. Boron nickel has the proper dimension and finish immediately after plating.

6.0 Sources of Supply

The following companies provide services such as shot peening or electroless nickel plating in accordance with SAE-AMS-2404. These companies are listed for reference only. The customer must verify the quality and workmanship of the vendor.

Shot Peening/Grit Blasting Vendors

Embee Inc.
2158 S. Hathaway St., Santa Ana, CA 92705
(714) 546-9842 or (323) 585-5973

Hytex Finishes Co.
8127 S. 216th St., Kent, WA 98032
(253) 872-7160

Imagineering Enterprises, Inc.
1302 W. Sample St., South Bend, IN 46619
(574) 287-2941

Metal Improvement Co.
472 Barell Ave., Carlstadt, NJ 07072
(201) 935-1800

Metal Improvement Co.
1940 NW 70th Ave., Miami, FL 33126
(305) 592-5960

Metal Improvement Co.
9410 East Hardy, Houston, TX 77093
(713) 691-0257

Metal Improvement Co.
678 Winthrop Ave., Addison, IL 60101
(630) 543-4951

Metal Improvement Co.
3239 E. 46th St., Vernon, CA 90058
(323) 585-2168

Electroless Nickel Plating Vendors Per SAE-AMS-2404

Electro-Coatings of Iowa, Inc.
911 Shaver Rd., NE, Cedar Rapids, IA 52402
(319) 363-9602

General Magnaplate Corporation
1331 West Edgar Rd., Linden, NJ 07036
(800) 441-6173

Imagineering Finishing Technologies
1302 W. Sample St., South Bend, IN 46619
(574) 287-2941

Multichrome/Microplate Company, Inc.
1013 West Hillcrest Blvd., Inglewood, CA 90301
(310) 216-1086

Nickel Technologies, Inc.
240 Valley Pike Rd., Bristol, TN 37625-3926
(800) 874-8531 or (423) 878-6894

Poly-Plating, Inc.
2096 Westover Rd., Chicopee, MA 01022
(413) 593-5477

Techmetals, Inc.
345 Springfield St., Dayton, OH 45403
(937) 253-5311

7.0 References

The following references were consulted in preparing this report. For further information on the use of electroless nickel or other platings in contact with Bal Seal® spring-energized seals under specific conditions of speed and pressure, consult our technical sales department.

1. Military Handbook 132 (Ord) Dept. of the Army Technical Bulletin TB-700-8010-1, Protective Finishes
2. Stabuff Technology Transfer Report, Electroless Nickel, *State of the Science*
3. ELNIC, Inc. Report: The Engineering Properties of Electroless Nickel Coatings
4. ELNIC, Inc. Guide to the Corrosion Resistance of ELNIC Electroless Nickel
5. Standard Specification for Electroless Deposited Coatings of Nickel Phosphorous Alloys for Engineering Purposes, ELNIC Inc.
6. Aerospace Material Specification, SAE-AMS-2404, (SAE Warrendale, PA)
7. Garret Pneumatic Systems Division Approved Processing Sources Report No. T40152-01
8. Parker Hannifin Corp., Approved Process Suppliers List, Report No. 580-107
9. Hamilton Sundstrand Approved Suppliers List, Report No. 80
10. Payer, J. H. et al., "NBS-Battelle Cost of Corrosion Study (\$70 Billion!), Part 1 – Introduction," *Materials Performance*
11. Bennet, L. H. et al., "Economic Effects of Metallic Corrosion in the United States," *NACE Annual Conference*, March 12-16, 1979, Atlanta, GA
12. Metzger, W. H., "Characteristics of Deposits," *Symposium on Electroless Nickel Plating*, American Society for Testing Materials, STP 265