



Designation: B 254 – 92 (Reapproved 1998)

Endorsed by American  
Electroplaters' Society  
Endorsed by National Association  
of Metal Finishers

## Standard Practice for Preparation of and Electroplating on Stainless Steel<sup>1</sup>

This standard is issued under the fixed designation B 254; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last approval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

### 1. Scope

1.1 Various metals are electrodeposited on stainless steel for color matching, lubrication during cold heading, spring-coiling and wire-drawing operations, reduction of scaling at high temperatures, improvement of wettability (as in fountain pens), improvement of heat and electrical conductance, prevention of galling, jewelry decoration, and prevention of superficial rusting.

1.2 This practice is presented as an aid to electroplaters and finishing engineers, confronted with problems inherent in the electrodeposition of metals on stainless steel. It is not a standardized procedure but a guide to the production of smooth adherent electrodeposits on stainless steel.

1.3 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems<sup>2</sup>

### 3. Nature of Stainless Steel

3.1 Because previous metal treatment may have a more pronounced effect on the final finish when stainless steel is being electroplated, the metal finisher should become acquainted with the fabrication procedure, grade, and mill finish of the stainless steel with which he is working before outlining his electrodeposition procedure (see Appendix X1).

3.2 Stainless steel surfaces are normally resistant to a wide variety of corrosive elements. This property is the result of a thin transparent film of oxides present on the surface. Because this film rapidly reforms after it has been stripped off or

penetrated, it protects stainless steel against corrosion. An adherent electrodeposit cannot be obtained over the oxide film normally present on stainless steel. However, once this film is removed by surface activation and kept from reforming while the surface is covered with an electrodeposit, any of the commonly electroplated metals may be electrodeposited successfully on stainless steel.

3.3 Where the finished product is to be subjected to severe exposure, the deposit produced by the proposed electroplating sequence should be tested under similar exposure conditions before adoption, to determine whether the natural corrosion resistance of the stainless steel has been impaired by the presence of the electrodeposit.

### 4. Nature of Cleaning

4.1 The preparation of stainless steel for electroplating involves three basic steps in the following order:

4.1.1 Removal of scale. If scale removal is necessary, one of the methods outlined in Appendix X2 may be used (Note 1). See also Practice A 380.

4.1.2 Removal of oil, grease, or other foreign material by cleaning, and

4.1.3 Activation immediately before electroplating.

4.2 *Precleaning*—Removal of fabricating lubricants and finishing compounds from the stainless steel may have to be undertaken immediately following the fabrication or finishing operation (Note 2).

4.3 *Electrocleaning*—Anodic cleaning is generally preferred (Note 3).

4.4 *Metal Lubricants*—Metal lubricants such as copper, lead, or cadmium, applied to stainless steel wire for cold heading, wire drawing, or spring forming are removed by immersion in a solution of 200 mL of concentrated, 67 mass %, nitric acid (density 1.40 g/mL) diluted to 1 L at 50 to 60°C. See Practice A 380.

NOTE 1—Oil, grease or other fabricating lubricants should be removed by cleaning before heat treating.

NOTE 2—Spray cleaning with a nozzle pressure of 200 to 400 kPa (30 to 60 psi) in a power washer, using an alkaline or emulsion-type cleaner, is the generally preferred method, especially for the removal of heavy drawing, buffing, or polishing compounds. Soak cleaning or vapor degreasing may also be used. Extreme examples of such compounds are

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee B-8 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.02 on Substrate Preparation.

Current edition approved Jan. 15, 1992. Published May 1992. Originally published as B 254–51 T. Last previous edition B 254–79 (1985).

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.03.

drawing or stamping lubricants containing unsaturated oils, which if left on the surface, form by air-oxidation tenacious films that are very difficult to remove.

NOTE 3—When brightness is important, alkalinity, current density, and temperature should be kept as low as the part will permit. This is an essential requirement when cleaning work on racks bearing auxiliary lead anodes or when high chromium alloys (such as UNS Types S44200 and S44600) are being cleaned.

## 5. Cleaning Solutions

5.1 The types of solution control, electrodes, heating coils, and rinse tanks normally used for cleaning carbon steel are satisfactory for stainless steel. Equipment previously used for the cleaning or processing of carbon steel should not be used. See Practice A 380.

## 6. Racking

6.1 The general principles of good racking as used in chromium electroplating processes apply. However, the high electrical resistance of stainless steel requires rack construction methods that minimize potential contact problems and increase the number of contact points.

NOTE 4—Because of the high electrical resistance of stainless steel, especially in fine-coiled wire articles such as watch bands, chains, jewelry, etc., it is necessary to provide a larger number of contacts. As an example, a watch band 110 mm long made of 1.0-mm diameter wire has been found to require at least three contacts.

## 7. Activation

7.1 After the cleaning operation and before the electroplating operation, the parts must be completely activated, that is, the thin transparent film of oxides must be removed from the surface to be electroplated (Note 5). This film will reform if the parts are allowed to dry or are exposed to oxygen-containing solutions. For this reason, the shortest interval practicable should elapse between the time the parts are removed from the activating solution and covered by the electrodeposit, unless a simultaneous activation-electroplating procedure is used.

NOTE 5—The etching practice may be more severe for nondecorative applications than for decorative applications.

7.2 The following activating procedures have been used. The procedure selected will depend upon the nature of the part and preceding or subsequent processes (see 7.7). In the following solution formulas, the concentrations are expressed on a volume basis as follows:

Liquids: as volume per litre of solution

Solids: as mass per litre of solution

7.3 The commercial grade acids and salts used in the formulas include:

Sulfuric acid: 93 mass %; density 1.83 g/mL

Hydrochloric acid: 31 mass %; density 1.16 g/mL

Nickel chloride:  $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$

Copper sulfate:  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$

NOTE 6—**Precaution:** Sulfuric acid should be slowly added to the approximate amount of water required with rapid mixing, and then after cooling, diluted to exact volume.

### 7.4 Cathodic Treatments:

7.4.1	Sulfuric acid	50 to 500 mL/L
	Water	to 1 L
	Temperature	room
	Time	1 to 5 min
	Current density	0.54 A/dm <sup>2</sup>
	Anodes	pure lead
7.4.2 <sup>A</sup>	Hydrochloric acid	50 to 500 mL/L
	Water	to 1 L
	Temperature	room
	Time	1 to 5 min
	Current density	2.15 A/dm <sup>2</sup>
	Anodes	electrolytic nickel strip or nickel bar

<sup>A</sup> See Patent No. 2,133,996.

7.4.3 After immersion in a solution containing 100 to 300 mL/L of hydrochloric acid diluted to 1 L at room temperature for 30 to 60 s, treat cathodically in:

Sulfuric acid	50 to 500 mL/L
Water	to 1 L
Temperature	room
Current	0.54 to 2.7 A/dm <sup>2</sup>
Anodes	pure lead

### 7.5 Immersion Treatments:

7.5.1 Immerse in a solution of sulfuric acid containing 200 to 500 mL of acid diluted to 1 L at 65 to 80°C (with the higher temperature for the lower concentration) for at least 1 min after gassing starts. If gassing does not start within 1 min after the parts have been immersed, touch them with a carbon-steel bar or rod. This activation treatment will produce a dark, adherent smut that is removed in the electroplating bath. A cathodic current of at least 0.54 A/dm<sup>2</sup> may be used to accelerate activation. Lead anodes are suitable for this solution.

7.5.2 Immerse in the following solution:

Hydrochloric acid	1 mL
Sulfuric acid	10 mL
Water	to 1 L
Temperature	room
Time	26 s

NOTE 7—This practice has been used with success for chromium electroplating on stainless steel automobile parts in a conveyerized process. It is not recommended before copper or nickel electroplating.

### 7.6 Simultaneous Activation-Electroplating Treatments:

7.6.1	Nickel chloride <sup>A</sup>	240 g
	Hydrochloric acid	85 mL
	Iron	should not exceed 7.5 g/ L
	Water	to 1 L
	Temperature	room
	Electrodes	nickel

<sup>A</sup> See U. S. Patent No. 2,285,548-9.

7.6.1.1	Anodic Treatment:	
	Current density	2.2 A/dm <sup>2</sup>
	Time	2 min

7.6.1.2	Followed by Cathodic Treatment:	
	Current density	2.2 A/dm <sup>2</sup>
	Time	6 min

7.6.2	Nickel chloride <sup>A</sup>	240 g
	Hydrochloric acid	126 mL
	Water	to 1 L
	Electrodes	nickel
	Temperature <sup>B</sup>	room
	Current density (cathodic)	5.4 to 21.5 A/dm <sup>2</sup>
	Time	2 to 4 min

<sup>A</sup> See U. S. Patent No. 2,437,409.

<sup>B</sup> Bath may require cooling or reduction in hydrochloric acid content if temperature exceeds 30°C.

7.6.3	Nickel chloride	30 to 300 g/L
	Hydrochloric acid	15 to 160 mL/L
	Water	to 1 L

	Electrodes	nickel
	Temperature	room
	Current density	0.55 to 10.75 A/dm <sup>2</sup>
	Time	½ to 5 min
7.6.4	Hydrochloric acid	undiluted commercial grade (7.2)
	Copper sulfate	0.4 g/L
	Electrodes	nickel
	Temperature	room
	Current density	4.5 to 6.6 A/dm <sup>2</sup>
	Time	1 to 5 min

NOTE 8—Nickel anode materials containing greater than 0.01 % sulfur are not recommended for use in acid nickel strike baths operated at pH 0.5, or lower, to avoid oxidation of sulfides by hydrochloric acid (see section 7.6.1, section 7.6.2, section 7.6.3, section 7.6.4, and 7.7).

7.7 A combination of more than one type of treatment may be necessary to ensure a high degree of adhesion. For example, the following has been used in the automotive industry for nickel plating on UNS Type S30200 stainless steel:

	Sulfuric acid	650 mL
	Water	to 1 L
	Potential (cathodic)	10 V
	Electrodes	lead
	Temperature	room
	Time	2 min

*Followed by:*

	Nickel chloride	240 g
	Hydrochloric acid	120 mL
	Water	to 1 L
	Electrodes	nickel
	Temperature	room
	Time	2 min
	Current density (cathodic)	16.2 A/dm <sup>2</sup>

This is followed by transfer without rinsing to a Watts (or higher chloride) nickel bath with a pH of 1.5 to 2.0.

## 8. Rinsing

8.1 The parts should be transferred to the cold-water rinse and to the plating solution as rapidly as practicable after the activating procedure; otherwise the surface will passivate itself and the electrodeposit will not be adherent.

8.1.1 The rinse water should be kept slightly acid (approximately pH of 2.5 to 3.5). The acid carryover from the activation operation will maintain this pH in many instances.

8.1.2 In conveyORIZED operations where trace contamination of plating solutions with chloride and sulfate from activating solutions will produce an unsatisfactory electrodeposit, spray-rinse operations subsequent to the activation treatment will remove these contaminants.

8.1.3 If the simultaneous activation-plating procedure is employed and nickel plating follows, the intermediate rinse need only be superficial and the length of transfer time is not so important.

## 9. Electroplating

9.1 An adherent electrodeposit of commonly electroplated metals (cadmium, copper, brass, chromium, gold, nickel, or silver) may be electrodeposited directly on stainless steel provided the surface of the stainless steel is active.

NOTE 9—Nickel may be electrodeposited at normal current densities directly on properly activated stainless steel from standard nickel-electroplating solutions if the pH of the solution is between 2 and 4. A pH of 2 is preferred.

NOTE 10—When a chromium-electroplating solution containing 400 g/L of chromic acid is used for decorative chromium electroplating, better coverage and a wider bright range is obtained by operating at a current density of 16.2 A/dm<sup>2</sup> and 49°C.

NOTE 11—A bright nickel electroplate under chromium, preceded by one of the simultaneous activation-electroplating treatments, may often be used to advantage for better color matching and elimination of chromium buffing.

9.2 Where practical, the parts should have the current applied during entry into the electroplating solution.

## 10. Stripping

10.1 Nitric acid is the preferred stripping solution.

10.2 Decorative chromium electrodeposits have been stripped in a solution of 500 mL of concentrated, 31 mass % hydrochloric acid (density 1.16 g/mL) diluted to 1 L at 45 to 50°C for 1 min.

NOTE 12—Overstripping will result in etching.

NOTE 13—Decorative chromium electrodeposits may also be stripped anodically in any alkaline solution.

10.3 Cadmium is stripped successfully without current by immersion in a solution of 120 g/L of ammonium nitrate.

## 11. Post Electroplating Operations

11.1 Post electroplating operations such as stress relieving, buffing or coloring, and forming or drawing may be applied to stainless steel in the same manner as to any other basis metal, as long as the natural differences in the characteristic of the stainless steel are taken into consideration. The stainless steel supplier should be consulted for guidance in regard to these characteristics.

## 12. Test Methods

12.1 The methods of testing for thickness, hardness, and adhesion of electrodeposits applied with the usual basis metals may be employed for similar tests on stainless steel.

NOTE 14—An exception to this is the determination of the thickness of chromium on stainless steel by the hydrochloric acid drop method. Because gassing continues after the chromium coating has been penetrated, the accuracy of this method may be questionable for this application.

## APPENDIXES

### (Nonmandatory Information)

#### X1. STAINLESS STEEL GRADES

X1.1 There are many standard grades and many more special grades of stainless steel. Each grade has a specific use, and each may present an individual finishing problem. The common grades are classified as:

X1.1.1 *Martensitic*, or hardenable magnetic chromium grades. UNS Types S40300, S40500, S40600, S41000, S41400, S41600, S42000, S43100, S44002, S44003, and S44004 are the more common alloys of this grade.

X1.1.2 *Ferritic*, or nonhardenable magnetic chromium grades. UNS Types S43000, S43020, and S44600 are alloys of this type.

X1.1.3 *Austenitic*, or nonhardenable, nonmagnetic chromium-nickel alloys. UNS Types S20100, S20200, S30100,

S30200, S30300, S30400, S30500, S30800, S30900, S31000, S31600, S31700, S32100, and S34700 are the more common alloys of this type.

X1.1.4 *Precipitation-hardening* or hardenable chromium nickel-alloys. UNS Types S17400, S17700, S15700, and S35000, are some examples of this type (Note X1.1).

NOTE X1.1—The precipitation-hardening types of stainless steel should be electroplatable by one or more of the procedures in this practice, but difficulties may be encountered with types containing relatively high levels of manganese, molybdenum, and silicon. In the fully aged condition, these grades of stainless steel may be susceptible to hydrogen embrittlement due to electroplating (see X3.3).

#### X2. MILL FINISHES

X2.1 Stainless steels can be obtained with a variety of finishes.

X2.1.1 *Bar and Wire Stock*—The common finishes applied to bar and wire stock are:

X2.1.1.1 Hot-rolled (scale present),

X2.1.1.2 Hot-rolled and pickled (scale removed),

X2.1.1.3 Rough-turned (round bars only),

X2.1.1.4 Cold-drawn,

X2.1.1.5 Centerless-ground (round stock only), and

X2.1.1.6 Polished (rounded stock only).

X2.1.2 *Sheet and Strip Stock*—The common finishes applied to sheet and strip stock are:

Finish	Sheet	
		Description
No. 1	Hot-rolled, annealed and pickled (white-pickled finish)	
No. 2B	Bright full cold-rolled finish	
No. 2D	Dull full cold-rolled finish	
No. 4	Standard polish (bright finish with fine polishing lines)	
No. 6	Standard polish tampico finish (soft luster, satin finish)	
No. 7	High luster polish (glossy, bright, buffed finish)	

  

Finish	Strip	
		Description
No. 2	Full finish, right cold rolled	
No. 1	Full finish, dull cold rolled	

#### X3. CONDITION FOR ELECTRODEPOSITION

X3.1 All of the common grades of stainless steel with normal heat treatments, in the full range of hardness, and in the forms mentioned above, with any surface finish free of scale, and when properly activated may be covered with electrodeposits of commonly electrodeposited metals.

X3.2 The smoothness of stainless steel surface to be electroplated should be comparable with the requirement of the

finished product. Grinding checks, glazing, and heat-treating stains on the stainless steel should be avoided.

X3.3 The high-carbon grades (UNS Types 42000, 44002, 44003, and 44004) may be subject to hydrogen embrittlement during electroplating operations. This may be overcome by heating the electroplated articles at 150 to 260°C for 1 to 3 h after electroplating.

#### X4. EFFECT OF FABRICATION

X4.1 Stainless steel alloys are susceptible to improper fabricating procedures in forming or heat-treating, therefore, an investigation of difficulties encountered in producing an adherent deposit on stainless steel should start with the procedures

used for fabrication. Technical assistance for such investigations is furnished by the suppliers of stainless steel. Their assistance may often be helpful in planning for electroplating on stainless steel.

## X5. METHODS OF SCALE REMOVAL

X5.1 Scale on stainless steel such as that resulting from treatment during or subsequent to fabrication or forging must be completely removed to obtain satisfactory adhesion of the electrodeposit. The scale formed on stainless steels is generally tenacious and may be somewhat more difficult to remove than scale on carbon steel. Mechanical methods, such as sandblasting and tumbling, and chemical methods, such as pickling in acid solutions or in molten salts include:

### X5.1.1 *Blasting*:

X5.1.1.1 This treatment serves to break up the hard scale and render it more responsive to pickling operations. The scale that usually develops on the martensitic and ferritic grades because of high annealing temperatures and long annealing cycles can be broken up only by sandblasting. Blasting is not usually employed on products made of sheet, strip, or tubing. Even if all scale has apparently been removed by blasting, it is necessary to pickle the parts before electroplating.

X5.1.1.2 Air-driven or rotary-impelled iron-free sand, stainless steel shot or aluminum oxide grit may be used. Ordinary steel shot, turkish emery, natural corundum, and other iron-containing abrasives are undesirable because they are likely to embed rust-producing iron in the surfaces being processed. Fragments, deburred particles, or other fines must be kept out of the blasting medium. The operation must be controlled very carefully, and the force of the blasting stream must be kept diffused to prevent unevenness of the surface.

X5.1.2 *Shot Peening or Wheel Abrading*—This cold-working process may also be used for scale removal.

X5.1.3 *Tumbling*—This far gentler method of scale removal is generally used on parts that have been stamped, machined, or drawn to a practically completed shape.

X5.1.4 *Wet Tumbling*—A final finish approaching that of a color-buffed finish may be obtained by the proper selection of abrasive, speed of rotation, and time. The tumbling media should be completely removed if the parts are to be stored in a humid atmosphere 24 h or more before activation. A solution consisting of 200 to 400 mL of concentrated 63 mass %, nitric acid (density 1.40 g/mL) diluted to 1 L operated at 50 to 60°C, followed by a cold water rinse, will effectively remove the tumbling media.

X5.1.5 *Wire Brushing and Grinding*—These procedures may be used for scale removal under certain conditions. Only stainless steel wire brushes should be used for wire brushing scale from stainless steel. Particles of steel from a carbon steel brush will embed themselves in the stainless steel and show rust in a very short time. Pickling after wire brushing is not very effective in removing embedded particles. Stainless steel wire brushes are commercially available. Commercial grinding compounds free from iron are probably more economical to use than stainless steel wire brushes.

X5.1.6 *Pickling*—This procedure usually follows preliminary scale removal by other means.

X5.1.6.1 The scale formed on stainless steel during forging, heat treating, welding, and other high-temperature processing will vary greatly with the grade and heat-treating environment.

If it is heavy, blasting or shot peening before pickling will prove economical and time-saving because it will remove much of the brittle scale and crack the underlying layers, thus affording a more uniform removal in the pickling baths.

X5.1.6.2 The martensitic and ferritic grades are the more difficult to pickle. Full annealing of these alloys causes a very tight scale to develop that usually requires blasting to break. Sandblasting should always be followed by pickling to remove mill scale or particles of iron embedded in the surface.

X5.1.6.3 The high-carbon grades (UNS Types S42000, S44002, S44003, and S44004) should never be acid pickled in the fully hardened condition. Stress relieving at 150 to 370°C for 1 to 2 h after hardening and before pickling is essential to avoid pickling cracks. These grades require careful watching during the pickling operation to prevent severe etching. Polishing with iron-free abrasive grit or sandblasting are preferred methods of scale removal to avoid etching.

X5.1.6.4 One recommended procedure for pickling consists of two steps: scale softening and partial removal in sulfuric or hydrochloric acid, followed by final scale removal in a nitric-hydrofluoric acid solution. In the following solution formulas, the concentrations are expressed on a volume basis employing the following commercial grade acids:

Sulfuric acid: 93 mass %; density 1.83 g/mL

Hydrochloric acid: 31 mass %; density 1.16 g/mL

Nitric acid: 63 mass % HNO<sub>3</sub>; density 1.38 g/mL

Hydrofluoric acid: 52 mass %; density 1.20 g/mL

See Note 6.

(1) The first step employs an 80 to 110-mL solution of sulfuric acid diluted to 1 L at 65 to 70°C for 10 to 45 min or a 100 to 150 mL solution of hydrochloric acid diluted to 1 L at 50 to 60°C for 30 to 90 min. A suitable inhibitor should be used, and the parts should be rinsed thoroughly before they are advanced to the second step. (2) The second step consists of immersion in a solution containing 60 to 100 mL of nitric acid and 15 mL of hydrofluoric acid diluted to 1 L at room temperature for 10 to 30 min, or until the smut has been removed. The time, for smut removal, required for the austenitic grades (except the free-machining 18Cr-8Ni grade, UNS Type 30300) may be shortened by the use of a solution containing 100 mL of nitric acid and 15 mL of hydrofluoric acid diluted to 1 L at 60 to 70°C until the smut has been removed. This latter method should not be used on the martensitic or ferritic grades nor on UNS Type S30300 austenitic stainless steel.

X5.1.7 *Molten Salt Treatment*—Several molten salt treatments are suitable for scale removal.

X5.1.7.1 The molten sodium hydride bath—acid treatment<sup>3</sup> for scale removal is widely used commercially. In this process, the reduction of the scale is accomplished by immersion of the work in a molten sodium hydroxide bath containing 1½ to 2 mass % of sodium hydride. The scale is reduced in a period of time varying from a few seconds to about 15 min after the work

<sup>3</sup> U. S. Patent 2,377,876.

has reached the operating temperature of 400°C. The work is then removed, quenched in water, given a brief dip in a sulfuric acid solution and then brightened in a solution containing 60 to 80 mL of nitric acid diluted to 1 L or a solution containing 100 mL of nitric acid and 20 mL of hydrofluoric acid diluted to 1 L. Although this process has been used primarily in large scale continuous units, intermittent use for smaller batch-type operations is practicable.

X5.1.7.2 Another molten-salt bath used successfully for scale treatment is the proprietary bath<sup>4</sup> containing sodium hydroxide and oxidizing salts.

X5.1.7.3 Electrolytic molten baths may also be employed.

X5.1.7.4 Molten salt methods are especially suited for pickling stainless steel because the molten caustic does not attack the metal in any way.

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<sup>4</sup> U. S. Patent Reissue 22887 (Original U. S. Patent 2,395,694).

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