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Standard Guide for Electroforming with Nickel and Copper[1]

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1. Scope

1.1 This guide covers electroforming practice and describes the processing of mandrels, the design of electroformed articles, and the use of copper and nickel electroplating solutions for electroforming.

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

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B183 Practice for Preparation of Low-Carbon Steel for Electroplating

B242 Guide for Preparation of High-Carbon Steel for Electroplating

B252 Guide for Preparation of Zinc Alloy Die Castings for Electroplating and Conversion Coatings

B253 Guide for Preparation of Aluminum Alloys for Electroplating

B254 Practice for Preparation of and Electroplating on Stainless Steel

B281 Practice for Preparation of Copper and Copper-Base Alloys for Electroplating and Conversion Coatings

B311 Test Method for Density of Powder Metallurgy (PM) Materials Containing Less Than Two Percent Porosity

B343 Practice for Preparation of Nickel for Electroplating with Nickel

B374 Terminology Relating to Electroplating

B489 Practice for Bend Test for Ductility of Electrodeposited and Autocatalytically Deposited Metal Coatings on Metals

B490 Practice for Micrometer Bend Test for Ductility of Electrodeposits

B558 Practice for Preparation of Nickel Alloys for Electroplating

B571 Practice for Qualitative Adhesion Testing of Metallic Coatings

B578 Test Method for Microindentation Hardness of Electroplated Coatings

B636 Test Method for Measurement of Internal Stress of Plated Metallic Coatings with the Spiral Contractometer

B659 Guide for Measuring Thickness of Metallic and Inorganic Coatings

B849 Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement

E8 Test Methods for Tension Testing of Metallic Materials [Metric] E0008_E0008M

E384 Test Method for Microindentation Hardness of Materials

3. Summary of Electroforming Practice

3.1 Electroforming is defined (see Terminology B374) as the production or reproduction of articles by electrodeposition upon a mandrel or mold that is subsequently separated from the deposit.

3.2 The basic fabrication steps are as follows: a suitable mandrel is fabricated and prepared for electroplating; the mandrel is placed in an appropriate electroplating solution and metal is deposited upon the mandrel by electrolysis; when the required thickness of metal has been applied, the metal-covered mandrel is removed from the solution; and the mandrel is separated from the electrodeposited metal. The electroform is a separate, free-standing entity composed entirely of electrodeposited metal. Electroforming is concerned with the fabrication of articles of various kinds.

4. Significance and Use

4.1 The specialized use of the electroplating process for electroforming results in the manufacture of tools and products

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

that are unique and often impossible to make economically by traditional methods of fabrication. Current applications of nickel electroforming include: textile printing screens; components of rocket thrust chambers, nozzles, and motor cases; molds and dies for making automotive arm-rests and instrument panels; stampers for making phonograph records, videodiscs, and audio compact discs; mesh products for making porous battery electrodes, filters, and razor screens; and optical parts, bellows, and radar wave guides (**1-3**).[3]

4.2 Copper is extensively used for electroforming thin foil for the printed circuit industry. Copper foil is formed continuously by electrodeposition onto rotating drums. Copper is often used as a backing material for electroformed nickel shells and in other applications where its high thermal and electrical conductivities are required. Other metals including gold are electroformed on a smaller scale.

4.3 Electroforming is used whenever the difficulty and cost of producing the object by mechanical means is unusually high; unusual mechanical and physical properties are required in the finished piece; extremely close dimensional tolerances must be held on internal dimensions and on surfaces of irregular contour; very fine reproduction of detail and complex combinations of surface finish are required; and the part cannot be made by other available methods.

5. Processing of Mandrels for Electroforming

5.1 *General Considerations:*

5.1.1 Mandrels may be classified as conductors or nonconductors of electricity, and each of these may be permanent, semipermanent, or expendable (Table 1).

TABLE 1 Types of Mandrel Materials

Types	Typical Materials
Conductors	
Expendable	Low-melting point alloys; for example, bismuth-free 92 % tin and 8 % zinc
	Aluminum alloys
	Zinc alloys
Permanent	Nickel
	Austenitic Stainless
	Invar, Kovar
	Copper and brass
	Nickel-plated steel
	Nickel/chromium-plated aluminum
Nonconductors	
Expendable	Wax
	Glass
Permanent (or Semi-Permanent)	Rigid and collapsible plastic; for example, epoxy resins and polyvinyl chloride
	Wood

5.1.2 Whether or not a mandrel is a conductor will determine the procedures required to prepare it for electroforming. Conductive mandrels are usually pure metals or alloys of metals and are prepared by standard procedures but may require an additional thin parting film to facilitate separation of the electroform from the mandrel (unless the mandrel is removed by melting or chemical dissolution).

5.1.3 Whether or not a permanent or expendable mandrel should be used is largely dependent on the particular article that is to be electroformed. If no reentrant shapes or angles are involved, it is possible to use permanent, rigid mandrels that can be separated from the finished electroform mechanically and reused. If reentrant angles and shapes are involved, it is necessary to use mandrel materials that can be removed by melting or by chemical dissolution, or materials that are collapsible, such as polyvinyl chloride and other plastics. In some cases, multiple piece mandrels are used that can be removed even with reentrant features.

5.1.4 Many solid materials can be used to fabricate mandrels for electroforming, but the following generalizations may help in selecting a suitable material: permanent mandrels are preferred for accuracy and for large production runs; expendable mandrels must be used whenever the part is so designed that a permanent mandrel cannot be withdrawn; and it is important that the mandrel retain its dimensional stability in warm plating baths. Wax and most plastics expand when exposed to electroplating solutions operated at elevated temperatures. In such cases, it may be necessary to use acid copper, nickel sulfamate, and other electroplating solutions that function at room temperature.

5.2 *Mandrel Design:*

5.2.1 The electroforming operation can often be simplified by design changes that do not impair the functioning of the piece. Some of the design considerations are summarized in 5.2.2, 5.2.3, 5.2.4, 5.2.5, and 5.2.6. Examples of mandrel shapes that may present problems during electroforming are illustrated in Fig. 1.

5.2.2 Exterior (convex) angles should be provided with as generous a radius as possible to avoid excessive build up and treeing of the deposit during electroforming. Interior (concave) angles on the mandrel should be provided with a fillet radius of at least 0.05 cm per 5 cm (0.02 in. per 2 in.) of length of a side of the angle.

5.2.3 Whenever possible, permanent mandrels should be tapered at least 0.08 mm per m (0.001 in. per ft) to facilitate removal from the mandrel. (Where this is not permissible, the mandrel may be made of a material with a high or low coefficient of thermal expansion so that separation can be effected by heating or cooling).

5.2.4 A fine surface finish on the mandrel, achieved by lapping or by electropolishing, will generally facilitate separation of mandrel and electroform. A finish of 0.05 μm (2 μin.) rms is frequently specified.

5.2.5 Flat bottom grooves, sharp angle indentations, blind holes, fins, v-shaped projections, v-bottom grooves, deep scoops, slots, concave recesses, and rings and ribs can cause problems with metal distribution during electroforming unless inside and outside angles and corners are rounded.

5.2.6 An engineering drawing of the mandrel, the electroformed article, and auxiliary equipment or fixture for separating the electroform from the mandrel should be prepared. The

[3] The boldface numbers in parentheses refer to the list of references at the end of this standard.