A BETTER WAY TO MAKE OPTICAL REFLECTORS

By **EUGENE N. CASTELLANO**

As a process, electroforming will provide faithful reproduction of the reflector surface, *repeatability in production, metal reflectors that are more durable, easier to handle and corrosion resistant, plastic reflectors too, if desired, close tolerances and the ability to handle complex and intricate shapes. You can even incorporate mounting brackets and flanges in the design and they will become an integral part of the reflector.*

Space aged technology applied to an old process has propagated a new fabrication method of producing optical reflectors with great precision in production quantities.

The technology is the electroforming process where there has been a better understanding of electrochemistry and the role of additives in the process. Electroforming is being applied to produce reflectors for applications in electronics—microwave systems—, electro-optical equipment, aerial photography, laser technology, and to produce industrial reflectors and mirrors.

In its simplest terms, electroforming is an electrochemical process of metal fabrication. The technique uses an electrolyte, an anode to supply the metal, control of electrical current, and special techniques to control the deposit of metal on the mandrel (matrix) of the reflector. When the reflector is fabricated, the mandrel is either removed and reused, or it is destroyed in the process of removing it from the finished reflector.

The mandrel has the same relationship to the reflector that a mold has to a casting. Mandrels can be machined, constructed, or molded from many different materials depending upon requirements of the finished product which will be discussed later.

There are basically two methods of making reflectors with the electro-forming process. First (method A), a metal reflector can be made directly from a machined mandrel. Second (method B), a mandrel is electroformed from the original master, and then finished metal (electroformed) or plastic reflectors are made from the mandrel.

Method "A" of producing reflectors directly from the original mandrel by electroforming is shown in figure 1. When it is immersed in the plating tank, the mandrel becomes the cathode in the process. Metal is deposited on the mandrel—which has been specially treated to facilitate its eventual removal from the finished reflector. Also, special coatings of masking are applied where no metal deposits are desired, or a thief, shield, or conforming anode is used to electroform certain shapes.

When you only consider that a part is immersed in a tank full of an electrolyte and metal is deposited on the part, it might seem that the subject was electroplating not electroforming. There are similarities and basic differences between the two processes. Electroforming techniques permit much thicker coatings of metal to be deposited, but, the fundamental difference between the two processes is that electroplating of a component is usually for the purpose of altering the properties of the exposed surface for wear, reflectance, corrosion resistance or simply appearance, while electroforming is used to actually produce the component—that is, after the metal is deposited, the mandrel is removed and the "plating" becomes the structural form of the component. Of course, the same ability to control wear, corrosion resistance, electrical properties, and other

PRODUCING ELECTROFORMED REFLECTORS

METHOD A

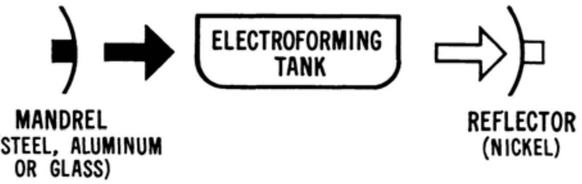

Figure 1. A permanent machined mandrel is placed in the electroforming tank which contains an electrolyte, metal anodes (copper, nickel etc.) that are suspended in the electrolyte, and a source of electric power that can be controlled adequately. The mandrel becomes the cathode and metal deposits on it form the reflector's structural and reflective surface. When formed, the mandrel is removed from the finished reflector and is reused.

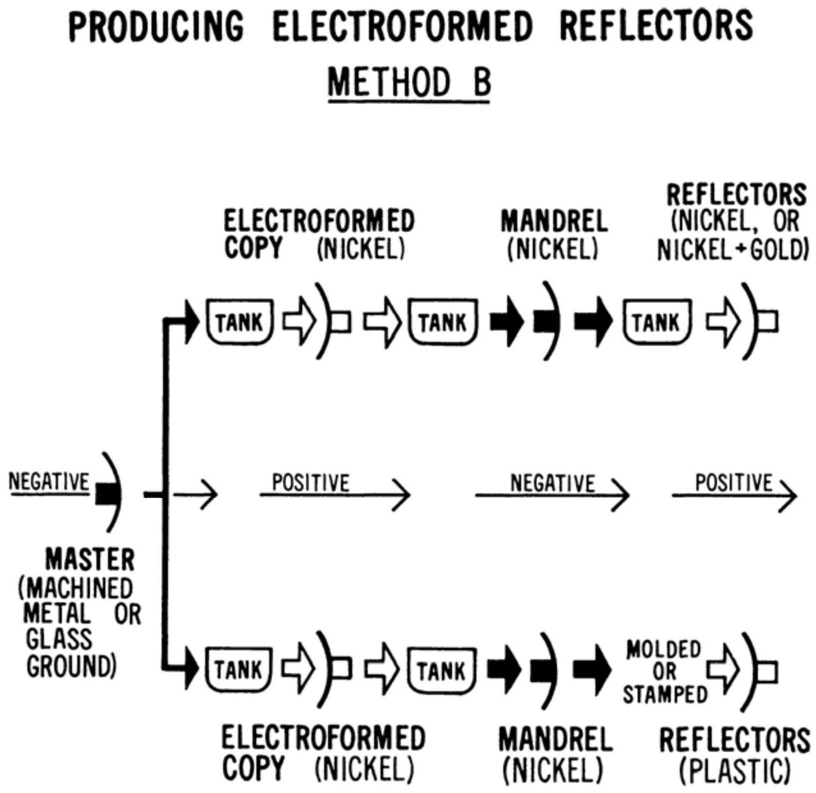

Figure 2. Each tank is an electroforming tank using a supply of metal anodes, electrolytes, additives and electric current to form the successive electroformed products including finished metal reflectors, or electroformed mandrels for plastic reflector production.

physical characteristics is easily achieved by selection of material and process controls.

In producing reflectors with method "B", a permanent machined master is normally made for the first step. Then, the master is prepared and put into the tank where electroforming of a mandrel begins. The electroformed mandrel can be held to dimensional tolerances of ±0.0001 inches. It is so precise, that the tiniest scratch on the master will be on the electroformed mandrel—which will be an opposite copy of the original. If the master is positive, the electroformed mandrel will be negative and vice versa. The electroformed mandrel is used to electroform completed reflectors shown in figure 2, Method "B". Obviously, several mandrels can be made from the same master, stretching out the useful life of the master.

Step-And-Repeat Method

Where high quantities of precise reflectors are desired, an extension of Method B called the Step-And-Repeat Method is used.

In this method, a model of the reflector in negative form is machined out of hardened 58 Rc 440 stainless steel, although 302 and 304 stainless can be used if the desired quantities of reflectors is moderate. The machined component is called a master and it is used to electroform several positive copies of the master out of nickel. Then, several negative mandrels are electroformed from the positive copies. The mandrels in turn are used to electroform as many as 10 or 20 copies of the finished reflector. Figure 3 illustrates the Step-And-Repeat Method. In this manner' the method uses the electroforming process, not only to make finished reflectors, but to produce positive copies of the master and third generation negative mandrels for the actual production.

Let's use actual numbers to illustrate the application of this process. Suppose you start with a master machined from 440 stainless steel which has been hardened to 58 Rc. The desired volume of production is over 300 electroformed nickel reflectors. If four positive electroforms are made from the master and four negative mandrels are electroformed from each of those, you will have 16 mandrels precisely duplicating the original master down to the smallest surface variations.

Each of the 16 mandrels is capable of producing up to 20 finished reflectors, or a total of 320 reflectors. Normally you might only get 10 finished products from each mandrel before it would need to be repolished. However, if each of the 16 mandrels is hard-coated with chrome plating and then polished, it is possible to obtain 20 electroformed reflectors from each mandrel before repolishing is required. Of course, if desired, the finished reflectors could be produced in plastic from the 16 mandrels, thereby greatly expanding the number of finished products obtainable from each mandrel.

As a point of interest, this is the manner in which electroforming is used by manufacturers who stamp out Fresnel and lenticulated lenses. The 16 or so electroformed mandrels are used to press out plastic lenses by the hundreds. By using the Step-And-Repeat Method, the stampers can vastly increase the

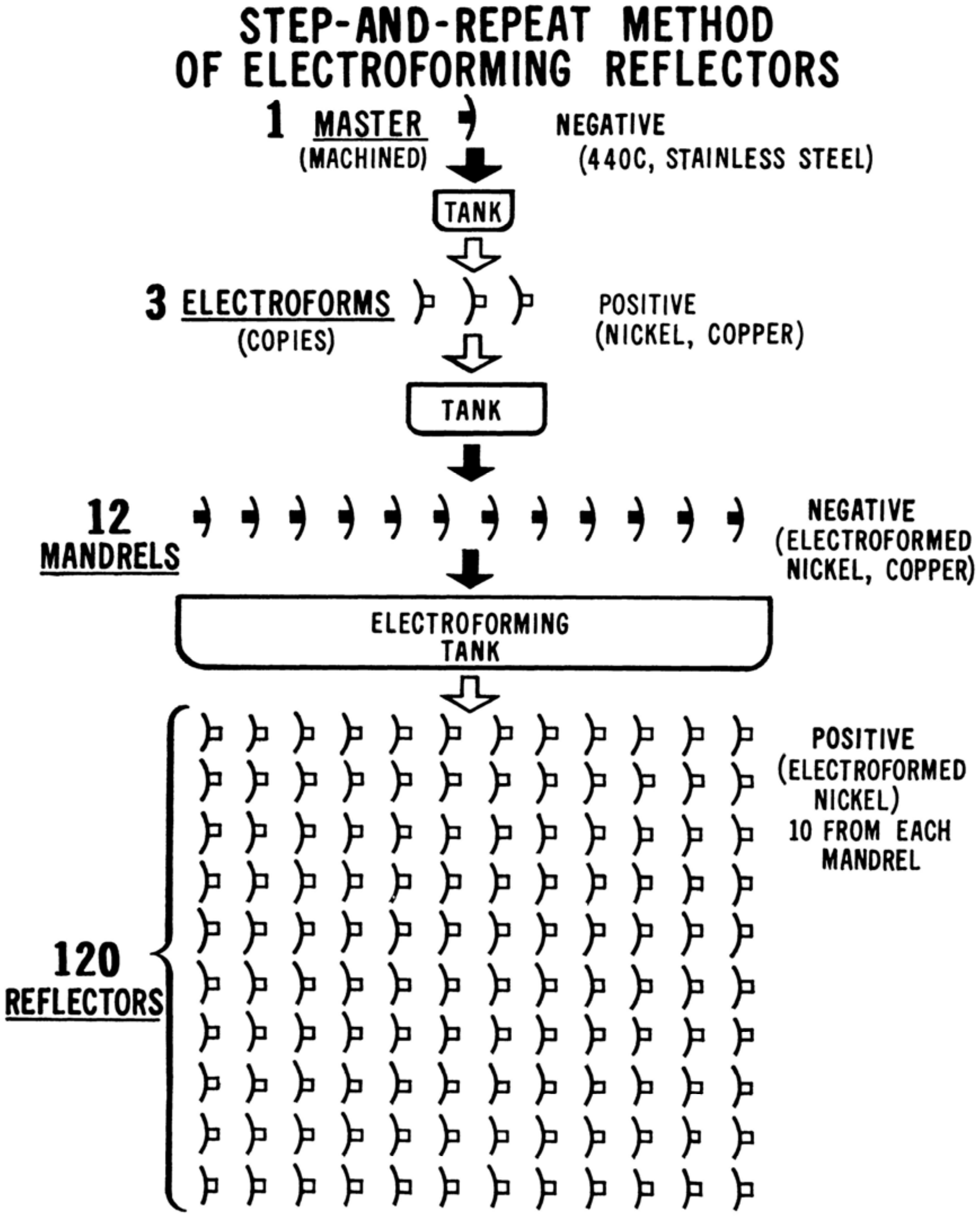

Figure 3. The number of electroformed copies of the master and electroformed mandrels from those copies is an option *of the designer. Double the number of metal reflectors can be obtained from these 12 mandrels by hard coating them with chrome plating and polishing. Also, the designer could choose to make more positive copies (electroforms in step 2) and subsequently more mandrels from each copy easily doubling the output in that manner.*

SPECIFIC PHYSICAL PROPERTIES OF ELECTROFORMED METALS

	Units	Silver	Copper	Nickel
Density	lb./cu. in.	.379	.32	.322
Specific Gravity, 20°/4°			8.9	**8.908**
Melting Point	°F °C	1761 961	1980 1080	**2650** **1455**
Specific Heat (32-212°F) (0-100°C)	B.t.u./lb./°F Cal./g./°C	.0559 .0559	.092 .092	.11 .11
Linear Coef. of Expansion (32-212°F) (0-100°C)	 10-^{6}in./in./°F 10'^{6}cm./cm./°C	 10.4 18.8	 9.2 16.5	 7.5 13.5
Thermal Conductivity (32-212°F) (0-100°C)	 B.t.u./sq.ft./hr./°F./in. Cal/sq.cm./sec./°C./cm.	 2960 1.0	 2700 .93	 470 .16
Specific Resistivity (20°C.)	microhm-cm.	1.59	1.7	7.0
Temp. Coef. of Sp. Resistivity (0-100°C)	 (per °C)	 .0041	 .004	 .006
Modulus of Elasticity in Tension	10^6 lb./sq.in.	.10	16	28
Crystal Structure		F.C.C.	F.C.C.	F.C.C.
Lattice Constant (A$_0$)	A.U. = 10*^{8}cm.	4.086	3.608	3.517

reflector, the selection of the material from which the mandrel or the master will be made will have cost and quality influences.

Mandrels can be made from stainless steel, glass, copper, carbon steel, brass, aluminum or epoxy. As far as stainless steel is concerned 302, 303, or 304 stainless is adequate if only a few reflectors are going to be made from the mandrel before it is repolished. However, for mass production 440C stainless steel hardened to 58 Rc would probably be the choice for the original mandrel. This would enable 30 or 40 nickel electroformed reflectors to be produced before the mandrel would require polishing.

As mentioned, glass and aluminum can be used to make the mandrel. But, glass mandrels crack very frequently when they are used in any sort of volume production. Glass, however, is cheaper and easier to grind. Aluminum mandrels can be machined easily, but they will not produce many reflectors and produce different colors than nickel. There is no real advantage in machining the original mandrel out of soft steel since aluminum is easier to machine, but soft steel is used sometimes.

It can be readily seen that the method and materials used to produce mandrels for large production quantities of reflectors is dependent upon the reflector's shape, production requirements, and tolerances.

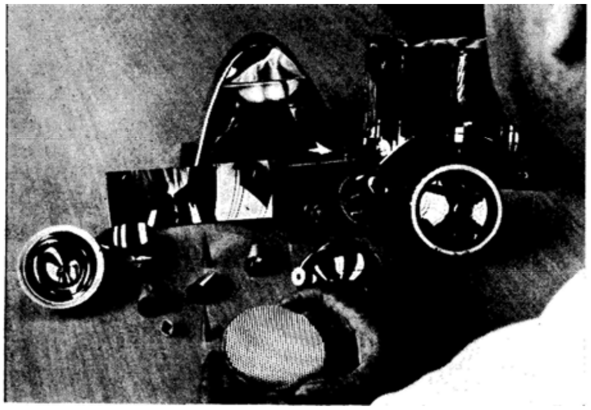

Figure 4. The number, size and shape of electroformed reflectors being produced by the electroforming process is growing daily, according to the Electroforming Division of Heli-Coil Corporation. The company points to the fact that the process can reproduce virtually any urface with greater fidelity, repeatedly and more economically than any other known metal forming process. Electroforming is now competing directly with glass through production of plastic reflectors.

Meet the Author

Eugene N. Castellano is General Manager of the Electroforming Division, Heli-Coil Corporation, a title he has held since he joined the company in 1965. Prior to that time, he spent 11 years in top management positions as Technical Director and Plant Manager of Bart Electroforming Company, Newark, N.J., and as Division Manager of the Electrochemical Division of Seymour Manufacturing Company, Seymour, Conn. A graduate of Seton Hall University, he holds two patents in the electrochemical field—one for the electrodeposition of smooth fine grain copper deposits, and one for organic additives for the deposition of leveled nickel deposits. He is a member of the American Electroplater's Society, a member of the USASI Standards Committee B.46 on the classification and designation of surface finish qualities and is Chairman of Subcommittee 11 for revision of Section 6 on roughness comparison specimens.

HeliCoil
Electroforming Division

For further information on solutions to specific electroforming problems, contact:

Eugene N. Castellano, General Manager
Electroforming Division/Heli-Coil Corporation
Augusta Drive
Danbury, Connecticut 06810
Tel. (203) 744-4300