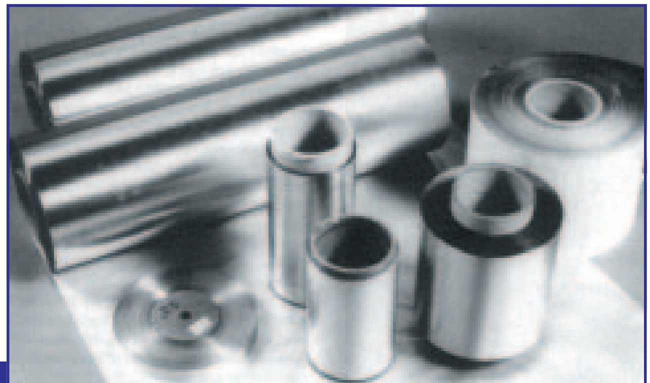
P&SF asked two long-time AESF members who have backgrounds in electroforming to share their experiences concerning the most interesting or unusual electroformed part that they had been involved with designing. What follows are comments from Dr. George DiBari, director of nickel plating products for Inco, and Jack W. Dini, a surface finishing consultant, former researcher with Sandia and Lawrence Livermore National Laboratories, and a past president of AESF.

Unusual Electroforming Accomplishments

Two experts in the field share some experiences about this unique surface finishing application.

From Dr. George DiBari

Electroformed Nickel Foil



Nickel foil is manufactured for a variety of applications. (Photo courtesy of Inco Selective Surfaces.)

Perhaps the most interesting contribution that I was involved with, along with contributions from electroplating colleagues on both sides of the Atlantic ocean, was the development of electroformed nickel foil.

It began with efforts to produce nickel foil for printed circuit boards for high-temperature service. The experiments conducted in our laboratory at Sterling Forest, NY, included study of the electrodeposition of nickel non-adherently on aluminum strip, and separation of the nickel foil from the aluminum using a machine designed for the purpose.

This approach was not completely successful, because aluminum ions would eventually accumulate in the electroplating solution and interfere with processing. The traditional approach—electrodepositing metal on rotating drums—was successful, and electroformed nickel foil was produced on a semi-continuous basis in the pilot area of our laboratory. The anticipated market for electroformed nickel foil in printed circuitry never materialized, so the project on this side of the Atlantic was terminated.

Later, associates in our laboratory in Birmingham, England, reactivated the project and perfected methods for electroforming foil. This involved finding clever ways to prevent nickel from depositing and sticking to the outer edges of the rotating drum, making it possible to produce foil in large coils on a continuous basis. Nickel foil, 99.99 percent pure, is now being produced by continuous electroforming from concentrated nickel sulfamate solutions at current densities of 45 A/dm^2. Because of the high anode current density, a specially designed conforming anode basket is used so that concentrated anolyte can be withdrawn from the bottom of the basket and discharged into the bulk of the solution. An activated spherical nickel anode material containing sulfur keeps the anode potential low enough to prevent oxidation of sulfamate anions, which plays havoc with controlling internal stress, appearance and purity of the nickel. Foil as thin as 6 µm and as thick as 200 µm is readily electroformed. (Tissue paper is about 6 µm thick.)

The foil is used as fire-resistant blankets in North Sea oil rigs, and as a substitute for asbestos in graphite gaskets for high-temperature applications. Electroformed nickel foil is laminated into doors to make them fire-resistant in the construction industry.

The most successful application is in foil 13 µm thick, coated with a thin black oxide film that has high absorbtivity and low emissivity, making it suitable for solar energy applications. The foil is being used in 25 countries around the world to utilize energy directly from the sun.

DiBari's Electroforming Contributions

Dr. George DiBari's contributions to the electroforming industry include company-sponsored seminars in various parts of the world, developing and disseminating technical literature (such as *Nickel Electroforming*), and working with ASTM Committee B8 to develop electroforming standards. One result was ASTM Standard B832, a guide to electroforming with nickel and copper.

DiBari has hopes that the current series of electroforming course/symposia being co-sponsored by AESF and the Nickel Development Institute (NiDI), will continue to generate interest in this versatile manufacturing technique, which creates remarkable and valuable products for industry and consumers.

From Jack Dini

Electroforming Large Thin-walled Parts

This is one of the most difficult electroforms with which I was involved. Rudy Johnson and I (during our time together at Sandia) were charged with nickel electroforming large, thin-walled structures. The parts were 30 cm long with a taper from 15 cm on one end to 23 cm on the other. Thickness ranged from 150 to 250 µm (6 to 10 mils). The mandrel material was highly polished aluminum.

The difficulty was in separating the part from the mandrel, because the nickel electroplate was so thin. The electroform would tend to buckle, regardless of what was done to prevent it: Heating, cooling, heating parts before immersion in the plating solution, use of retaining rings, welding torches, etc. Success was finally realized by coating the mandrels with a tungsten disulfide lubricant, and then heating the mandrels to 80 °C prior to immersing in the plating solution. This was followed by soaking the plated assembly in liquid nitrogen for 15 to 20 min prior to using tape that had been fastened to the electroform before the mandrel was filled with the nitrogen. Results of this work were published in the September 1970 issue of *Metal Finishing.*

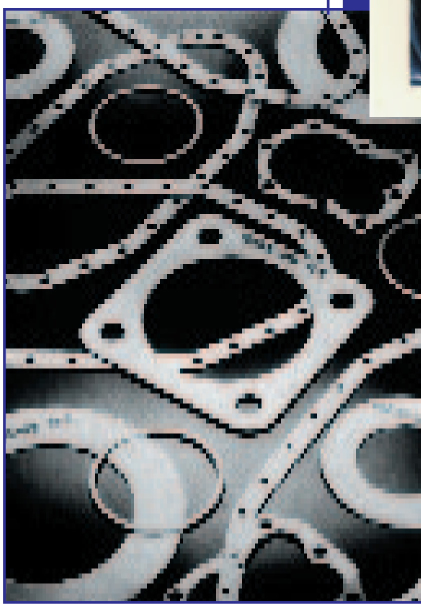
This application of electroformed copper was the result of a team headed by Jack Dini at Lawrence Livermore National Laboratory. The part was featured on the cover of the March 1982 issue of P&SF (above).

Electroforming Copper Targets For a Neutron Source Facility

This experience comes under the heading of “helping to save Dini’s reputation.”

In January 1980, I moved from Sandia to Lawrence Livermore National Laboratory (LLNL). One of the first challenges we faced was that of fabricating cooling channels for our neutron source test facility (at that time the world’s most intense 14-MeV neutron source).

Prior to my arrival at LLNL, others had tried diffusion bonding, using etched channels as one part of the fabrication and a copper sheet as the other. This provided only occasional success.



Nickel foil is used as reinforcement in gaskets to replace asbestos. (Photo courtesy of Inco Selective Services.)

I said, “We can fabricate the channels by using electroforming.” This would involve filling the etched channels with wax; making the wax conductive; plating with about 20 mils of copper to close over the channels; and removing the wax to leave the clear, closed-over channels.

This time, just as many other times in my career, I was fortunate to be involved with a group of very talented individuals who could take an idea and make it a reality. Wendell Kelley was our plating supervisor at the time, and along with Richard Carlos and Ernie Lopez, they successfully demonstrated that targets could be electroformed quite successfully. Carlos became the key man on this project, which resulted in fabricating at least 100 targets over the life of the test facility. This work was published in the March 1982 issue of *P&SF.* P&SF

About the Authors

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Jack Dini, 1537 De Soto Way, Livermore, CA 94550, is a retired supervisor of fabrication processes, Materials Fabrication Division, Lawrence Livermore National Laboratory. He is a past president of AESF and a recipient of the Society’s Scientific Achievement Award (1985). He has published numerous technical papers and is the author of a book on electrodeposition.