



White Paper

SOLVING PROBLEMS IN MEDICAL EQUIPMENT DESIGN WITH ELECTROFORMS



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Medical product designers are often challenged to make precision mechanical or structural parts out of metal for prototypes or small production lots. Electroforms made of thin layers of metal formed on a dissolving mandrel have long provided designers with unusual shapes. In recent years, electroforms have solved a variety of problems for medical equipment designers seeking strong, thin-walled, precision metal parts. Electroforms have provided flexible joints, hermetic seals, electromagnetic shields, and other special functions. With knowledgeable technical support, medical equipment designers can use them to meet unusual requirements and short deadlines without high tooling costs. Equally important, medical engineers can use electroforms to achieve shapes, properties and functions that are available no other practical way. Often, one-piece electroforms replace stampings, machined parts, complex assemblies, or brazements and weldments.



Medical designers have used Servometer® electroforms to meet unusual requirements and short deadlines without high tooling costs. Equally important, medical engineers can use electroforming to produce parts that can be made no other practical way.

Part-for-part, short-run electroforms naturally cost more than stampings mass-produced in amortized dies. Each aluminum mandrel produces a single part. As a rule of thumb, the cost per part is about the same as for stampings in a 100-piece lot. In high volume production, stamping spreads tooling and setup costs over thousands of identical parts, so unit part costs will be lower. However, for prototype quantities or low-volume production with running changes, electroforms can be made and modified at a fraction of the cost of stampings.

Electroforming also produces shapes and tolerances too difficult or too expensive to machine. Medical device designers have used electroforms to provide cost-effective production solutions to very different design problems:

- A long, thin nozzle for a blood analyzer needs a precise orifice profile practically impossible to machine.
- A thin-walled cover for operating room instrumentation must shield electronic circuitry from electromagnetic interference (EMI), yet the short production run cannot justify costly stamping tools.
- To aim a tiny camera accurately, a thin-walled retainer for a diagnostic imaging probe requires tolerances too tight to machine affordably. The precision part must also protect electronics from EMI and moisture, and must itself withstand repeated sterilization with harsh chemicals.

Thin, Strong, Flexible

How do electroforms pay off for medical equipment manufacturers? The benefits are in size and weight savings, simplified assembly, and geometries and functions not economically available in metal parts fabricated other ways.

Like most advanced products, medical devices are getting smaller, so designers are looking for strong, low-mass parts to fit tight spots. The proprietary electroforming nickel used in preceding examples is ideal for miniature medical parts. It has 125,000 psi minimum tensile strength, 110,000 psi minimum yield strength, and 270 Vickers hardness. The combination of strength and ductility makes nickel uniquely suitable for flexible bellows as well as rigid electroformed components. Density is just 0.321 lb/cu in. Electroformed parts preserve all the desirable mechanical properties of the metal in almost any shape. They emerge with a shiny finish that is easy to clean and tolerate common sterilizing and autoclaving chemicals.

Medical equipment design engineers commonly need unusual shapes made to tight tolerances. Electroforming mandrels made of aluminum are CNC-machined; electro-coated with nickel, copper, or gold, then chemically dissolved away to leave a thin, strong shell. Internal dimensions of electroforms can be verified before the parts are made, and electroforming reproduces dimensions far more accurately than stamping. Unlike annealed stampings, fully hardened electroforms need no heat-treating that can distort finished shapes. In addition, unlike metal cutting and bending, electroforming makes precise parts without the induced machining stresses that can warp thin components.

Hollow electroformed parts can have walls just 0.0003 in. thick, one-tenth the thickness limit of common stampings.

Thin-walled electroforms capture fine details and make parts of many sizes. Electrical bellows contacts with walls only 0.0005 in. thick have been electroformed for circuit boards. Flexible nickel bellows just 0.020 in. diameter have been electroformed for laboratory instruments. Shapes less than 0.2 in. across have been produced for minimally invasive surgical instruments. Electroforming has even made ultra-lightweight reflectors several feet in diameter for non-medical applications. Maximum wall thickness for electroforms is about 0.025 in. Servometer® has varied the wall thickness at different locations of the same part to maximize rigidity and flexibility selectively.

Flexible Shapes

Flexible electrodeposited nickel bellows are widely used as sensing elements in air regulators, switches, gauges, actuators, and pressure compensators. The electroforming process makes bellows' walls just one-quarter the thickness possible with mechanical hydroforming. The sharp radii of the bellows segments can also be made just three times the wall thickness, far smaller than radii produced by mechanical forming.

Thin walls and ductile nickel give electroformed bellows just one-fifth to



Servometer® electroformed a rigid, low-mass blood analyzer probe (center) with a 0.023 in. orifice at about a third the cost of precision machining and manual finishing. The probe has walls just 0.008 in. thick.

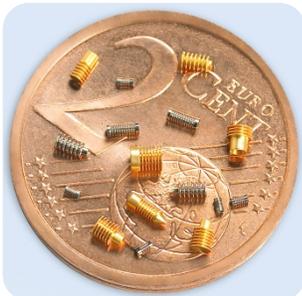
one-tenth the spring rate of hydroformed brass bellows of the same size. The force required to extend and compress their convolutions is very low and stays consistent from part to part. In addition, the dynamic properties of nickel can give electroformed bellows an essentially infinite life of 1016 cycles.

For some critical sealing applications, seamless, non-porous bellows are tested leak-tight to 1×10^{-9} cc of helium per second. Servometer® engineers have also integrated flexible bellows into rigid parts, eliminating welds and other potential leak points. Flexible sections in rigid parts can accommodate component misalignment and eliminate welding, soldering and other costly assembly steps.

The rigorous development and testing associated with medical devices often requires frequent, rapid design iterations during prototyping. To speed development and reduce cost, prototype electroforms can be supplied within weeks rather than the months required to tool new stampings. Based on rough drawings, CAD/CAM files, or stereo lithography shapes, electroforms often give medical designers parts impossible or impractical to machine.

Fine Details

When designers of a blood analyzer required a nozzle to aim a precise fluid stream, they designed a 5 in. long probe with a 0.023 in. orifice. The nozzle needed to neck-down with a carefully defined internal shape to dispense pressurized reagent at the correct angle. Initial attempts to machine the probe from steel tubing proved fruitless. The orifice was nearly impossible to manufacture with the correct tip configuration, and the walls were so thin that they deformed under machining pressure. Spinning and mandrel drawing were ruled out because the geometry made it impossible to withdraw the mandrel after forming. Investment casting and plunge-EDM operations followed by manual de-burring would have been prohibitively expensive. Likewise, molded plastic parts would have required costly injection molds that could not be amortized with low-volume parts. Moreover, the finished moldings would not have provided the required strength and rigidity.



Servometer® engineers have integrated flexible bellows into rigid parts, eliminating welds, and other potential leak points.

Electroforming produced a rigid, low-mass probe in small lots at about a third the cost of precision machining and manual finishing. The probe has walls just 0.008 in. thick, and an ID of exactly the correct profile for proper nozzle function. Electroforming nickel will not oxidize in air and is unaffected by alkaline liquids. To guarantee the purity of the reagent flow, the electroform is isolated from the fluid by an internal polymer coating applied in a secondary operation.

Multiple Layers

When another design team needed an instrument cover to protect electronics from operating room interference, they had to incorporate electromagnetic shielding within an existing space. The already-finalized design of the instrument would not allow a greatly increased wall thickness for the 2 by 2 by 2 in. cover. With the instrument produced in only limited quantities, an investment in stamping dies for a conductive metal cover was considered excessive.

An electroform provided a shielded answer within the existing footprint at about one-tenth the cost of a stamping. Servometer® routinely electrodeposits a layer of copper between inner and outer layers of nickel for additional leak protection. The same conductive copper layer provides an extremely effective EMI shield. The instrument makers got their EMI shielding in walls less than 0.01 in. thick.

Assembly Advantages

A leading manufacturer of diagnostic imaging equipment sought to reduce the size of its solid state camera probe, but faced a complex manufacturing challenge. The miniaturized camera retainer at the tip of the probe had to be made to precise tolerances to keep the device properly aimed and focused.



Electroforms are available in a variety of shapes, sizes, thicknesses and materials.

Less than 0.2 in. diameter, the Electrodeposited micro-miniature nickel bellows down to 0.020 in. diameter are used as sensing elements in air regulators, switches, gauges, actuators, and pressure compensators. Servometer® engineers have also integrated flexible bellows into rigid parts, eliminating welds, and other potential leak points. Servometer® manufactured a half-inch long retainer that required walls just 0.003 in. thick with tolerances of +/-0.0005 in. The housing had to withstand temperatures from 75 to 250°F and protect the camera during ethylene oxide sterilization.

Stamping the new retainer was out of the question due to the deep draw and required accuracy of the part. Machining the camera jacket was likewise beyond the capability of most machine shops because the process itself would deform the walls. Project engineers also concluded manual machining, if possible, would be exorbitantly expensive. Electroforming provided a strong, precision camera housing and one-tenth to one-twentieth the cost of precision manual machining. The nickel electroform met the harsh environmental requirements of the application. The accuracy of the camera retainer has also eliminated clumsy alignment steps and reduced assembly time and cost.

For all their advantages, Electroforms demand special design and manufacturing facilities with special expertise. A close working relationship and early involvement are essential between the device design team and Servometer's design engineers. Servometer's design engineers will offer engineering support to maximize the payoffs of Electroforms. Medical designers will benefit by working with Servometer® because of our history of customer collaboration for new product development, CAD/CAM capabilities, CNC machines, and electroforming facilities to produce quality parts with short turnaround time. With Servometer's process and application insight, the shapes and potential of Electroforms are only limited by the designer's imagination.

About Servometer

Since 1957, [Servometer](#) has pioneered the manufacture of electrodeposited miniature metal bellows, bellows assemblies, contact springs, flexible shaft couplings and structurally rigid electroforms. Servometer miniature bellows are used in a variety of critical applications where high reliability and long-term use are required. Servometer has supported customers with quality products and technical service for over 50 years. Their unique, patented electrodeposition process has led Servometer to become the leading supplier of miniature metal bellows manufactured by this method.

In 2007, Servometer acquired BellowsTech, Inc. of Ormond Beach, Florida, creating [BellowsTech, LLC](#), a premier manufacturer of metal edge welded bellows and assemblies, encompassing a wide array of alloys and dimensional configurations. The flexibility of material and size of metal welded bellows, as well as application expertise, have led BellowsTech into a diversity of industries including aerospace, medical, test, semiconductor, solar, and oil and gas.