

# SILASTIC ARTIFICIAL HEARTS CONSTRUCTED ON WAX MOLDS

STEPHEN R. TOPAZ, B.S.M.E.

*Department of Artificial Internal Organs*

ARTIFICIAL heart ventricles are currently made of Silastic,\* a silicone rubber, in the following manner. At the factory, sheets of Silastic are calendered around dacron fabric. These sheets are then layered around a mold in the form of a heart ventricle; the seams are reinforced by Silastic. The Silastic on the cast is vulcanized in an autoclave at a temperature of 270 F. for five minutes; next it is cured by heating in an air oven at a temperature of 350 F. for four hours. The result is an odorless, whitish plastic that is remarkably inert.

After the complex Silastic parts are constructed by layering, the mold must be removed. Therefore mold material should not only have a good surface finish, but it should be able to be broken out, melted out, or dissolved out.

Glass is an excellent material for a mold, however, delivery from the factory cannot always be prompt. The chief disadvantage of plaster molds is that they do not have a good surface finish. Wax is a good material from which complicated forms can be cast easily (*Fig. 1*), and a smooth surface finish can be obtained. The drawback with some waxes, particularly those containing flame retarders, is that in affecting the vulcanizing agent they affect the curing of the Silastic.

After appropriate experimentation it was found that vulcanization of the Silastic in an autoclave with steam could be performed at temperatures of approximately 270 F. even with wax molds that have a melting point of approximately 150 F., because vulcanization is instantaneous and the Silastic is on the outside of the mold.

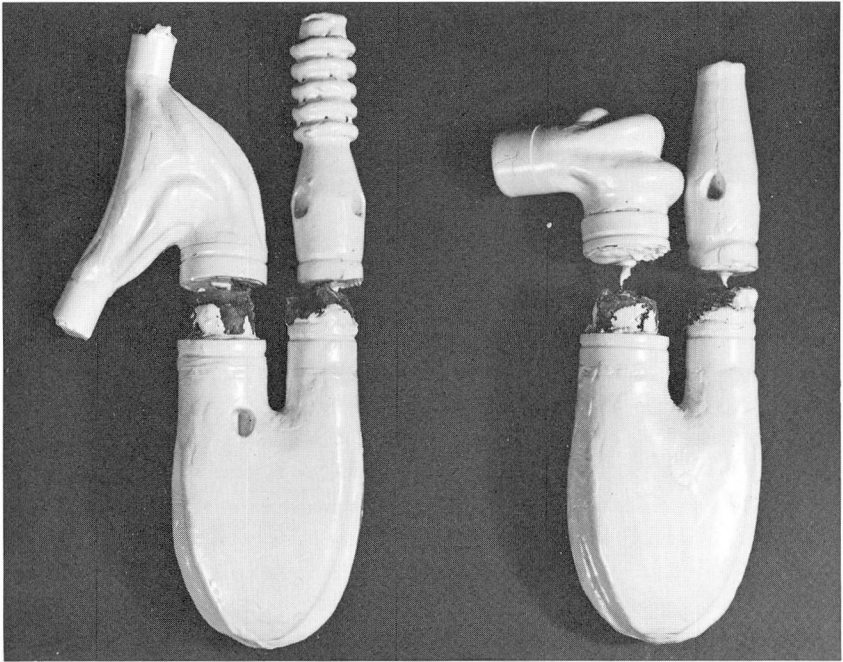
The next problem was to produce a proper surface on the wax mold so that a glossy smooth surface of the "ventricular" wall would result without interference from the vulcanizing agent. Stalked lumps of wax were coated with several types of materials (*Fig. 2*). The Silastic was layered on the test pieces of wax, and the units were autoclaved; during vulcanizing the wax melted and was drawn off. Curing proceeded as mentioned. The Silastic parts were then inspected in regard to finish, vulcanization and cure, and removal of wax and coat (*Table 1*).

Wax alone and wax coated with butal, graphite, or polyurethane interfered with vulcanization of the Silastic. A coating of a releasing agent, usually a soap dissolved in water to form a paste, helped to produce a good product, but it did not overcome the drawbacks common to some coating agents. Polyvinyl alcohol with a releasing agent gave the best results, but the more easily obtainable shellac and

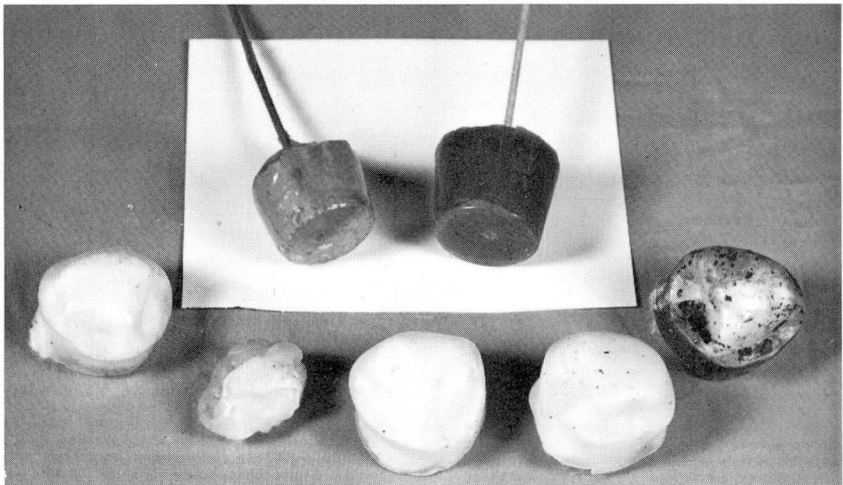
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*\*Dow Corning, Midland, Michigan.*



**Fig. 1.** Wax molds of artificial hearts ready to be layered with Silastic; note the right and the left ventricles each with its atrium and arterial connections. The valve seats will unite the parts, as they each fit between an atrium and a ventricle, and between a ventricle and the pulmonary artery or the aorta.



**Fig. 2.** Stalked lumps of wax (Gulf Petrowax A) finished or coated, autoclaved, and cured as described in the text. Two molds are shown on white paper; the black one has been coated with graphite. Around the paper are the Silastic cups removed from the molds and inverted to show the surface finish. The second from the left was not cured.

**Table 1.** — *Evaluation of Silastic artificial hearts made from wax molds; the order of coating is from the outside to the inside*

Wax mold	Finish	Vulcanization and cure	Removal of wax and coat
Type of finish			
Flame	Fair	Poor	Poor
Flame and releasing agent (RA)*	Fair	Fair	Poor
Ether	Fair	Poor	Good
Ether and RA*	Good	Poor	Good
Hot air	Good	Inferior	Poor
Hot air and RA*	Good	Poor	Poor
Acetone	Good	Good	Good
Acetone and RA*	Good	Good	Fair
Hand rubbed	Good	Good	Good
Hand rubbed and RA*	Good	Good	Good
Coating			
Plexiglas	Good	Good	Good
Plexiglas and RA*.	Good	Good	Excellent
Butal	Good	Poor	Good
Butal and RA*	Good	Good	Excellent
Graphite	Poor	Inferior	Inferior
Graphite and RA*	Poor	Inferior	Inferior
Polyurethane	Excellent	Poor	Excellent
Polyurethane and Estane lacquer 5'40X1†	Excellent	Good	Excellent
Polyvinyl alcohol (Evanol 52-22)‡	Excellent	Good	Good
Polyvinyl alcohol and RA*	Excellent	Excellent	Extra good
Polyvinyl alcohol and polyurethane	Excellent	Excellent	Extra good
Polyvinyl alcohol and polyurethane and RA*	Excellent	Excellent	Extra good
Polyurethane and polyvinyl alcohol	Poor	Poor	Poor
DeSantes varnish	Extra good	Extra good	Good
DeSantes varnish and RA*	Good	Good	Good
Waggenman flat shellac	Extra good	Extra good	Fair
Waggenman flat shellac and RA*	Extra good	Extra good	Fair

\*Releasing agent, Ivory Soap in water.

†B. F. Goodrich Co.

‡E. I. DuPont de Nemours & Co.

varnish also gave acceptable results, and preserved well the details of the contours of the cast.

### Summary

Silastic layered on wax molds to make artificial hearts can be vulcanized in an autoclave, by using either polyvinyl alcohol with soap as a releasing agent, or varnish, to counteract the interference of the wax with vulcanization.