

FABRICATION OF VACUUM-FORMED SOCKETS FOR LIMB PROSTHESES

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It seems to be self-evident that the fit and alignment of an artificial leg are the most important technical factors that enter into the success of individual cases. These two factors are interdependent to a certain extent.

The evaluation of the relationship between the patient and the prosthesis, on both a clinical, individual basis and on a research basis, has been a most difficult problem. Through the years a number of attempts have been made to develop transparent sockets to make these evaluations more reliable.

The Navy Prosthetics Research Laboratory used sockets made of Plexiglas in their studies of above-knee fittings in the 'Fifties and the J. E. Hanger Company of Atlanta in their pioneering work with the total-contact above-knee sockets in the early 'Sixties used Plexiglas, but fabrication of sockets with this material required an extraordinary amount of time because it was not possible to form a socket from a single piece of the material.

The Army Medical Biomechanical Research Laboratory proposed a method of casting a clear socket using an acrylic (2), but the technique required relatively expensive materials and such extreme care for satisfactory results to be obtained that it was not adopted by others.

New York University later developed a simpler technique for casting transparent sockets with polyester resins (1), but the process is sufficiently tedious and time-consuming that it has not been adopted for routine clinical use.

In 1970 with fiscal support from SRS², a research group at Rancho Los Amigos Hospital developed a practical, efficient method of making transparent sockets by vacuum-forming polycarbonate sheet over a male model. The original technique was reported in the March 1972 issue of *Orthotics and Prosthetics*. Subsequent experience with polycarbonate indicates that its best use in prosthetics is probably as a check socket, because of the problem of attaching it to an endoskeletal type of prosthesis for long periods of use.

This advantage alone justifies use of vacuum-formed sockets, but the method is also applicable to other plastic materials. Furthermore, vacuum-formed sockets are useful for teaching.

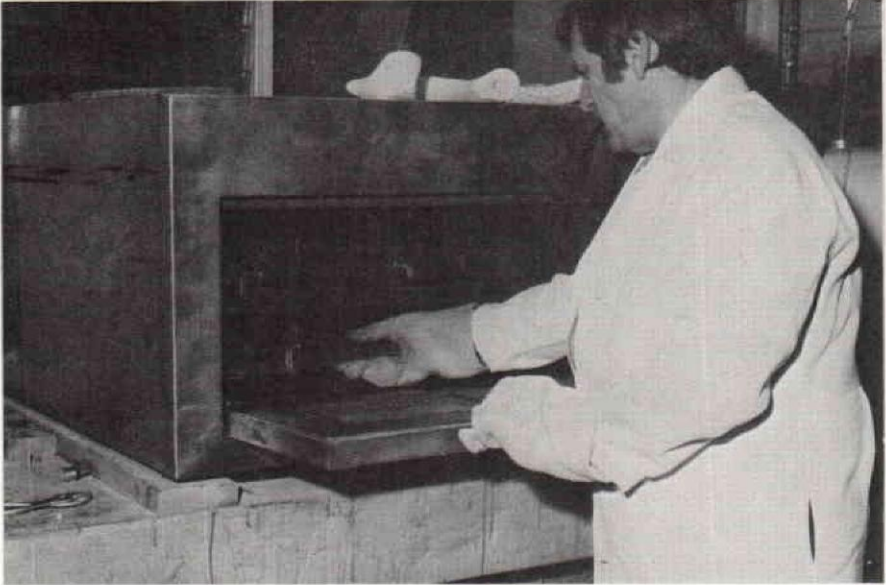
This manual covers the fabrication and use of check sockets made of transparent polycarbonate³ sheet, and suggests methods of fastening the socket to the rest of the prosthesis when temporary use is desired.

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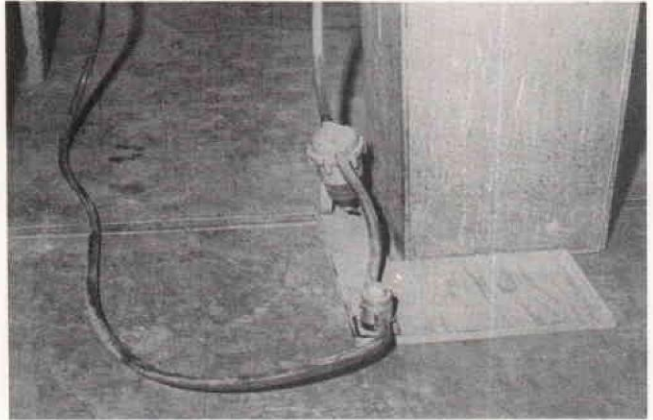
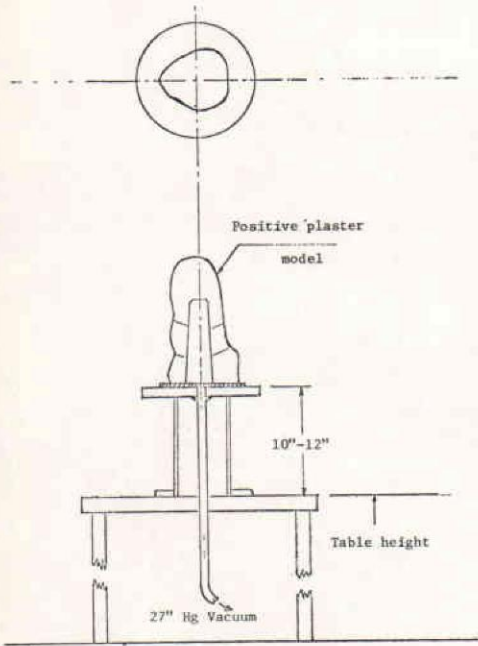
³ Supplied by General Electric as Lexan. Other suppliers use other trade names.

FABRICATION OF TRANSPARENT SOCKETS



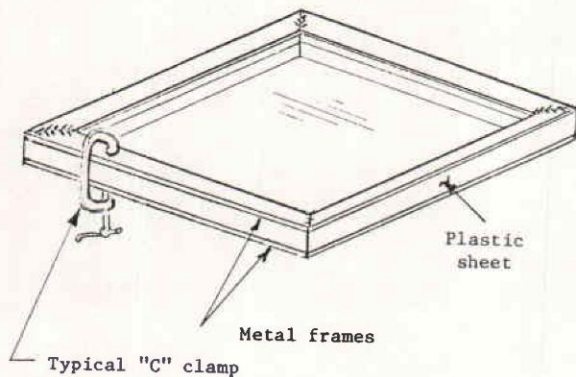
Unfortunately, polycarbonate absorbs water from the atmosphere, and to avoid the formation of bubbles and other imperfections during molding it is necessary to remove the moisture prior to vacuum-forming the plastic sheet. The time required to remove the heat varies with thickness of the plastic sheet and the humidity. During the course of the experiments it was found that material $\frac{3}{8}$ " thick could be rendered free of moisture when subjected to a temperature of 275° F. for 36 hours. A second-hand pizza oven proved to be quite satisfactory for this purpose.

The only special pieces of equipment needed not found in most prosthetics and orthotics facilities are a workstand and frames to hold the sheet plastic and tapered mandrels for use in making the male model. Each of the items can be fabricated easily and very inexpensively in a prosthetics facility.

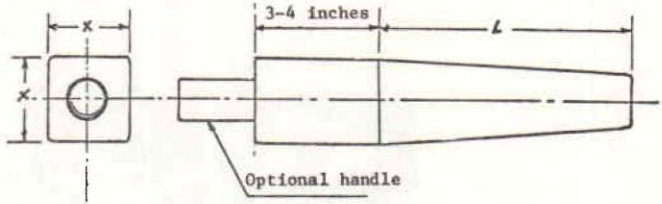


The simple workstand made of wood and pipe provides a base for the positive cast and a point of entry for the airflow into the vacuum system.

A foot-operated valve in the vacuum line makes control of the vacuum easier for the operator, and a water trap should be installed between the air entry and the foot-operated valve to prevent an accumulation of moisture in the vacuum tank.



Metal frames are required so that a firm grip can be provided around the periphery of the plastic sheet during the drawing process. Two ordinary "C" clamps have been found to be satisfactory in holding the assembly together. Steel or aluminum material $\frac{1}{8}$ " thick provides adequate stiffness.

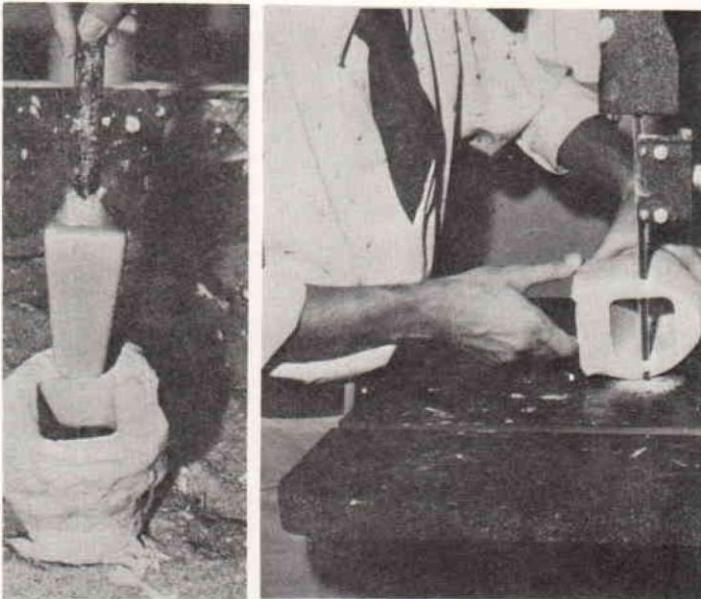


TAPERED MANDREL

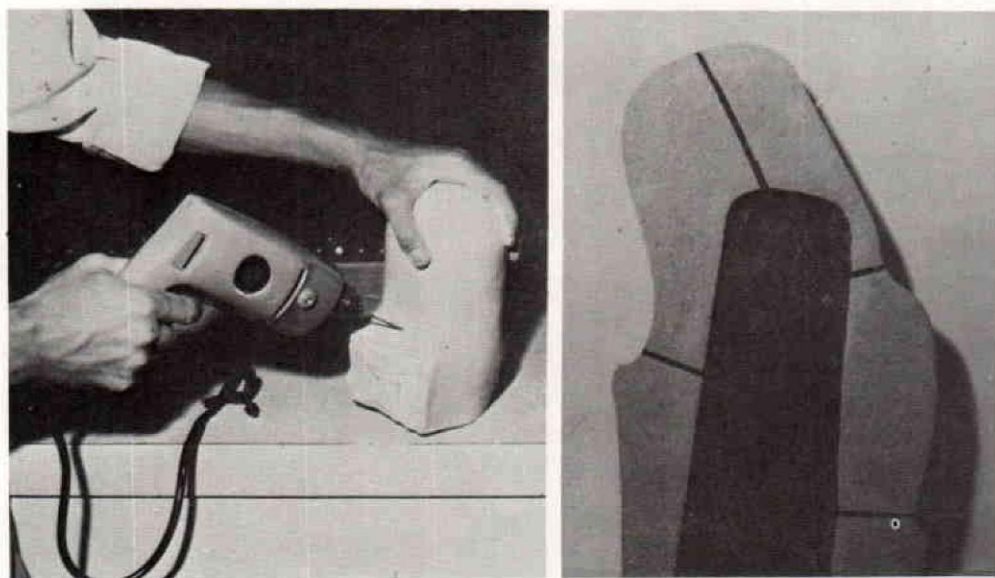
Make from wood--cover with two layers of plastic laminate

Vary cross-section dimensions (x) and length (l) to provide a range of sizes.

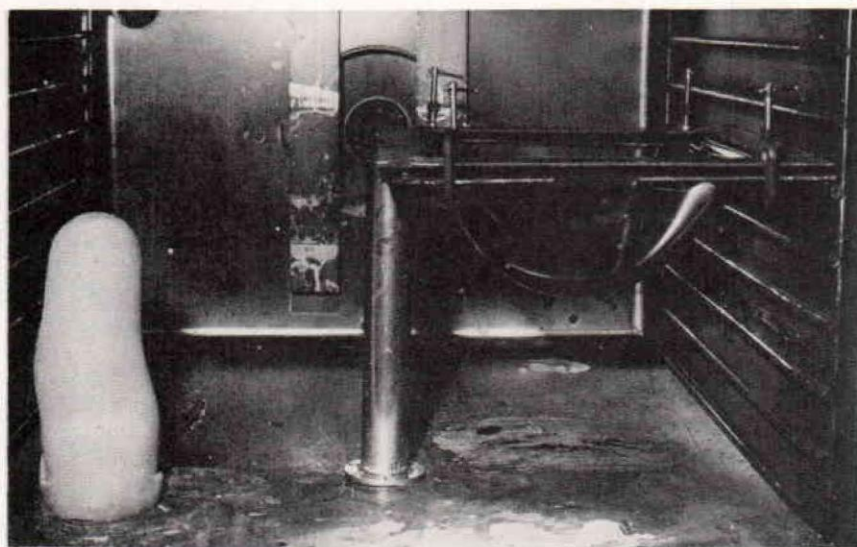
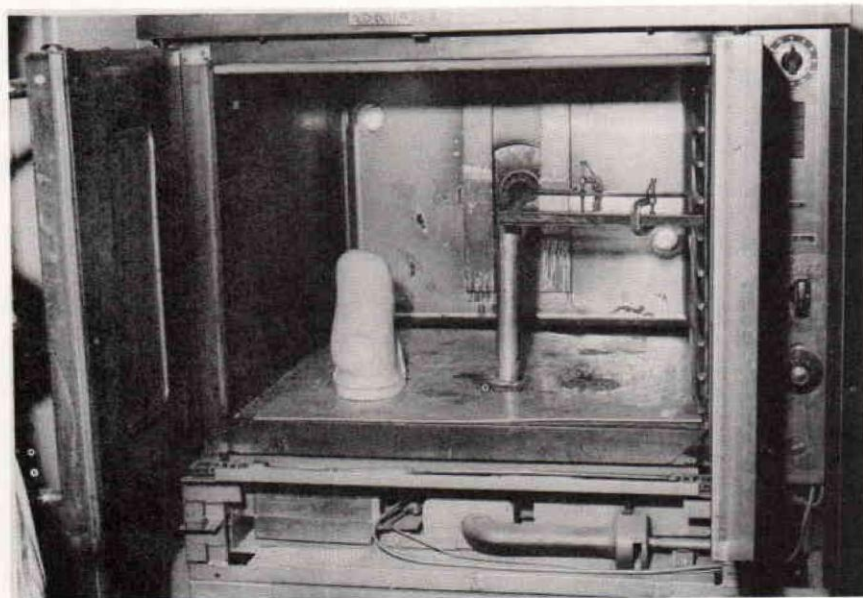
Tapered mandrels are used to provide a lengthwise cavity in the positive cast to insure that the air flows in such a manner that the plastic sheet will not bridge across undercuts on the surface of the cast. They may be made of most any rigid material. Wood covered with two layers of polyester-dacron laminate was used in the course of the development project.



The plaster-of-Paris wrapped cast is taken in the regular way and a positive model is poured using a well-greased tapered mandrel to form a lengthwise cavity. A flat surface is provided on the proximal end so that it will stand firmly on the work pedestal.



After the positive model has been modified according to the regular practice of the prosthetist, 1/16" diameter holes are drilled from the outer surface, especially in the undercut areas, to the inner cavity to prevent "bridging."

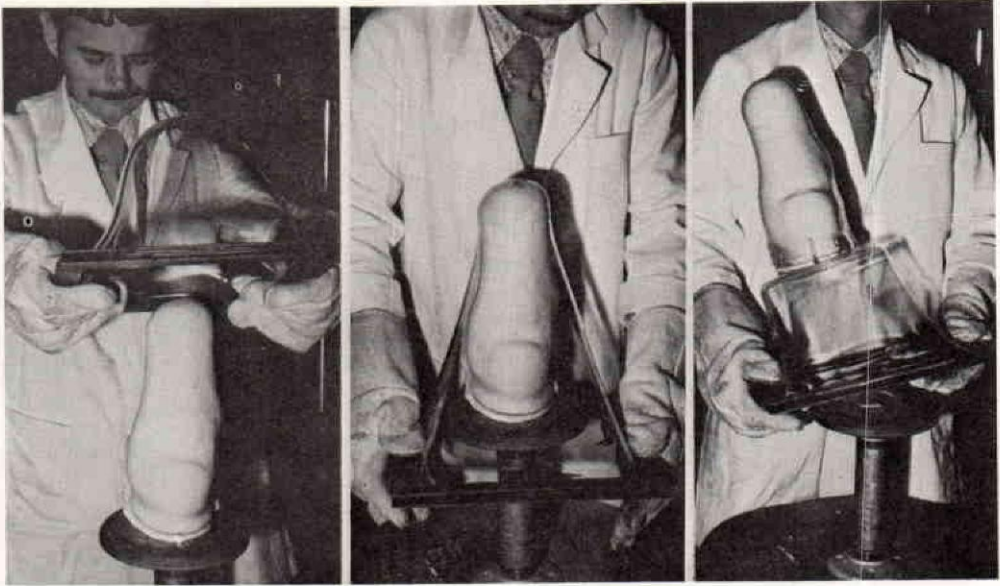


The polycarbonate sheet ($12 \times 12 \times \frac{3}{8}$ " for the average below-knee amputee) that has been placed in the metal frame and dried adequately is removed from the drying oven and placed in a circulating oven at 400° F. until the sheet sags under its own weight to a distance about $\frac{2}{3}$ the length of the positive cast. Because the rate of heat loss of polycarbonate is quite high, it is a good idea to heat the positive cast at the same time, but, of course, caution should be exercised because a wet cast will explode if subjected to high heat too rapidly.



The positive cast is placed on the screen wire on the pedestal of the workstand, and Slipicone⁴ is applied as a parting agent.

⁴Dow Corning Corporation, Midland, MI.

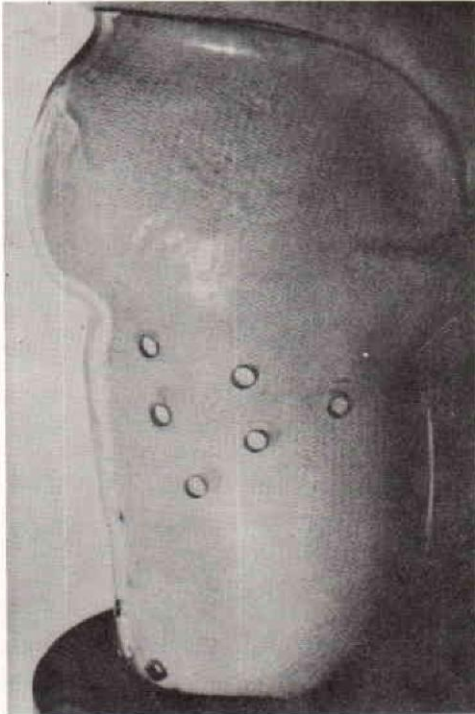
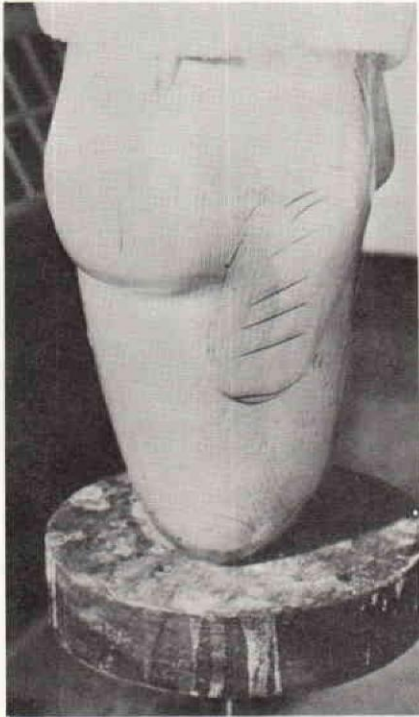


The plastic, in its frame, is removed from the oven, rotated 180° about the horizontal axis, drawn down over the positive model, and the vacuum is applied. The result is a perfect, clear reverse reproduction that conforms to every contour on the surface of the positive model.

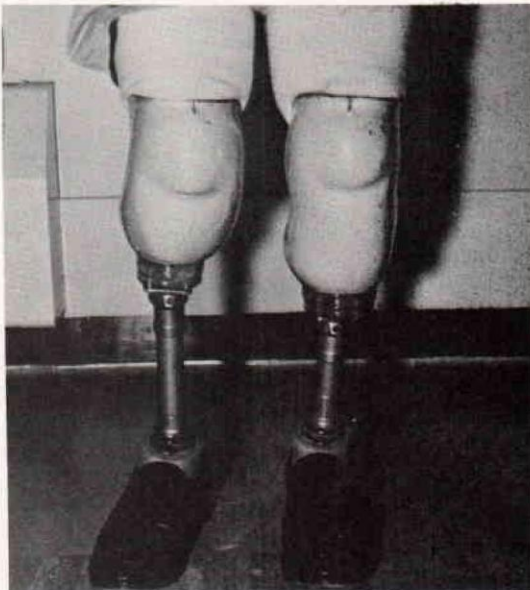
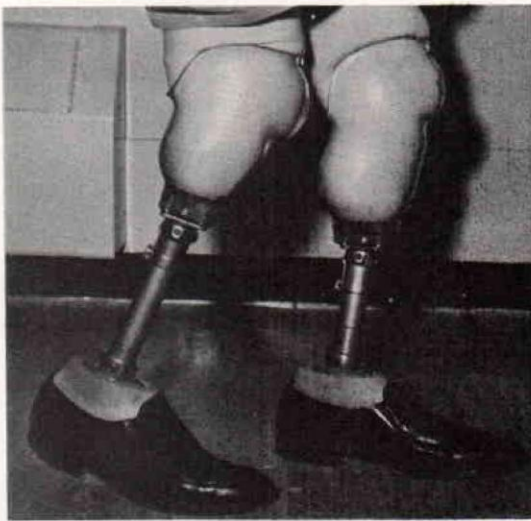
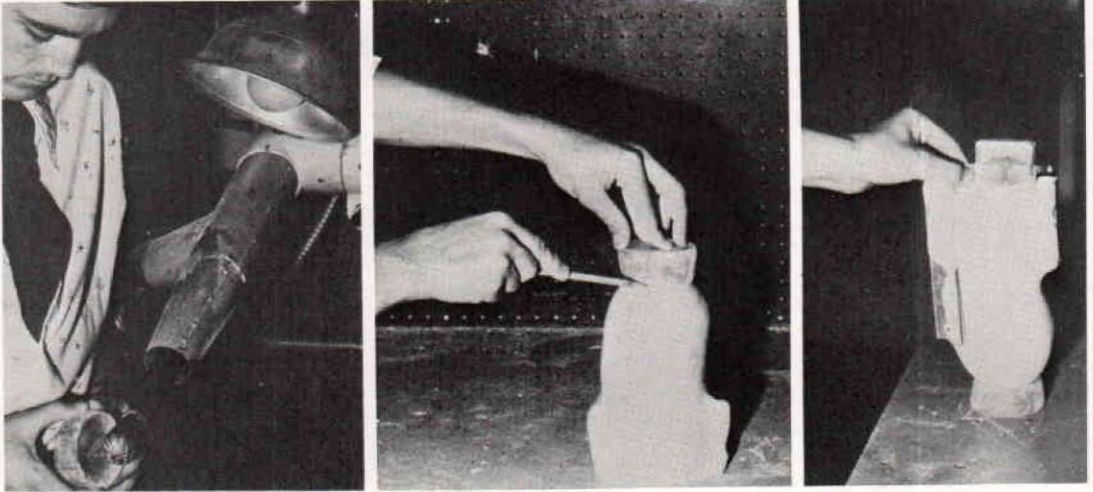
Cooling is quite rapid but can be accelerated by using air from a compressed air system.



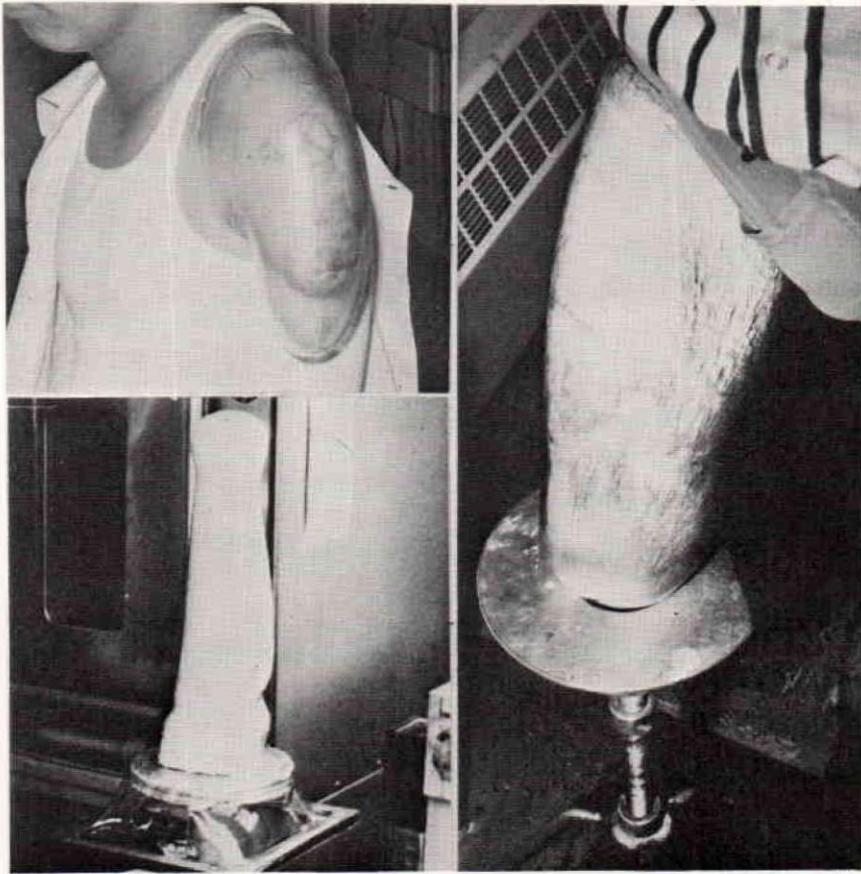
After the excess material and the frame have been cut away, the plaster, because of the cavity formed by the mandrel, is removed easily by hammer blows on the outside of the newly formed socket. The socket can now be trimmed and made ready for use.



If it is to be used as a check socket $\frac{1}{4}$ "- $\frac{3}{8}$ " holes are drilled at points that are considered to be troublesome and observations can be made to determine what further modifications to the positive model seem indicated.



If the socket is to be used temporarily, whether for clinical, teaching, or research purposes, it may be mounted on a pylon-type prosthesis by cementing the distal end to a disc of polycarbonate which in turn can be bolted to the proximal part of the pylon. Care must be taken, though, to provide a gradual change in cross-section at the junction in order to avoid fractures at this point. For extremely active and heavy patients, the retaining straps supplied with most pylons may be used to provide additional security, but their use, of course, reduces the areas of the stump that can be observed.



The example shown has been a socket for a below-knee amputee, but the technique is equally applicable to other levels of amputation.

LITERATURE CITED

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2. Margetis, Peter M., Walter L. Shepard, Robert E. Plumb, and Fred Leonard, *A fluid resin technique for the fabrication of check sockets*, *Orth. and Pros.*, 22:4:8-27, December 1968.
3. Mooney, Vert, and Roy Snelson, *Fabrication and application of transparent polycarbonate sockets*, *Orth. and Pros.*, 26:1:1-13, March 1972.