The NYU Transparent Socket Fabrication Procedure[1]

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Richard Hanak

It has been recognized for a long time that a transparent socket that could be made to fit the stump would be a useful tool in studying the relationship between the amputation stump and the socket of a prosthesis. Early attempts by a number of investigators to devise sockets of acrylics such as Plexiglas and Lucite were abandoned because of the difficulty encountered in controlling the contours and because of the inordinate amount of time required for fabrication of a single socket.

In 1966, the New York University Prosthetics and Orthotics group undertook a comprehensive study to develop a practical method of fabricating a transparent socket using newer materials and fabrication techniques.

The criteria for the selection of the transparent material to be utilized for the socket were that it be water-clear with good transparency, have adequate strength and fracture resistance, and be non-toxic. The method of fabrication was to be reasonably simple and was not to require an excessive amount of actual working time or sophisticated equipment; the materials and equipment were to be readily available.

Two basic approaches were explored: vacuum forming and casting.[4] Transparent polycarbonate sheet material was used in the attempts to make a socket using the vacuum forming method. Below-knee sockets were made by this method, but it was necessary to form the socket in two parts and to bond them together, a procedure which was time-consuming and which required extreme care if accuracy was to be obtained.

Both epoxy and polyester resins were tried for casting transparent sockets. Satisfactory results could be obtained with epoxy resins, but excellent results were obtained consistently with polyester casting resins when RTV silicone rubber was used on the outer surface of a male plaster slush mold and the casting surfaces were covered with polyvinyl chloride film. This article describes the procedures, in a step-by-step fashion, for fabrication of a transparent socket using polyester casting resins.

[1] This study was conducted under the general supervision of Sidney Fishman, Ph.D., Project Director, Prosthetics and Orthotics, New York University Post-Graduate Medical School, New York, N. Y. 10016; under Grant RD-2372-M from the Social and Rehabilitation Service, Department of Health, Education, and Welfare.

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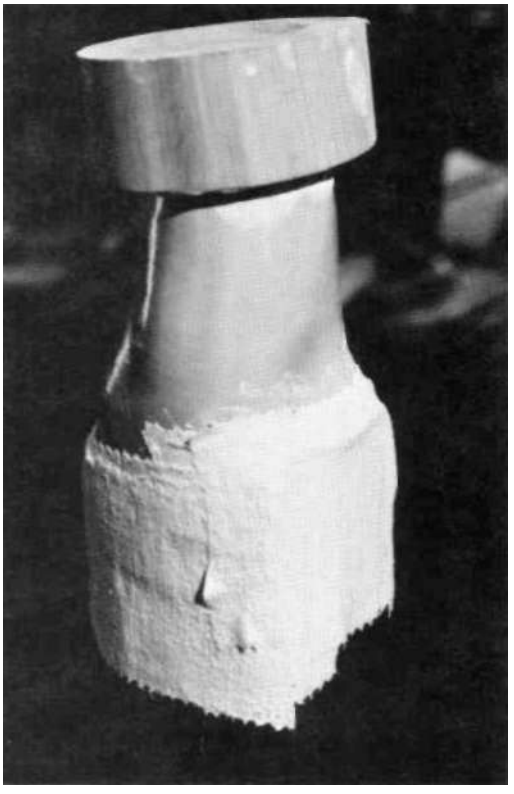
[4] R. Lipskin and T. Grille, "The Development of the NYU Transparent Socket Fabrication Technique," November 1968.

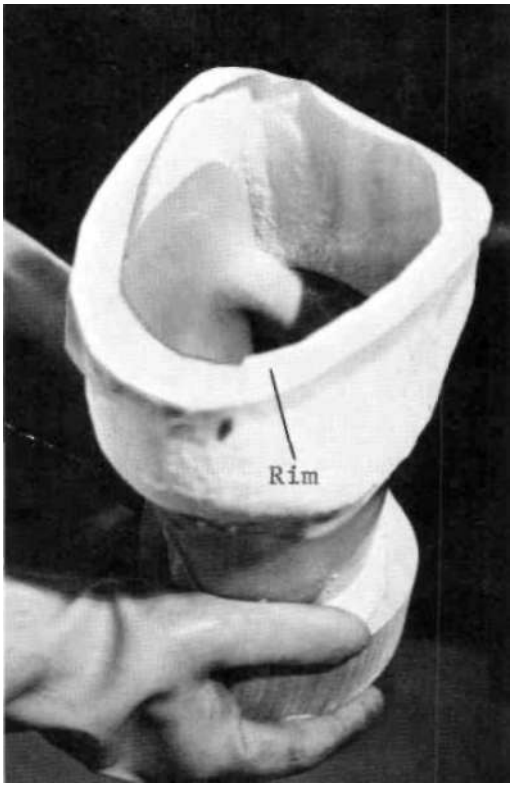
SILICONE MALE MOLD

A conventional hard socket is supported on a wood attachment block during the fabrication of the silicone rubber male mold.



1. Using approximately five layers of plaster bandage, the proximal trim line of the conventional socket is built up to the level that existed prior to trimming (about 1 in. above the proximal end of the socket with the interior surface made reasonably flat). After the plaster bandage has hardened, any rough interior areas are sanded smooth, and any plaster that interferes with the interior contour is removed.

2. To facilitate separation of the silicone shell from the hard socket, the interior surface of the hard socket is sprayed with Dow Corning Silastic RTV Mold Release.



3. In order to retain the liquid silicone rubber in the hard socket, masking tape is used to form a V2-in.-wide rim around the proximal edge of the plaster-bandage buildup.

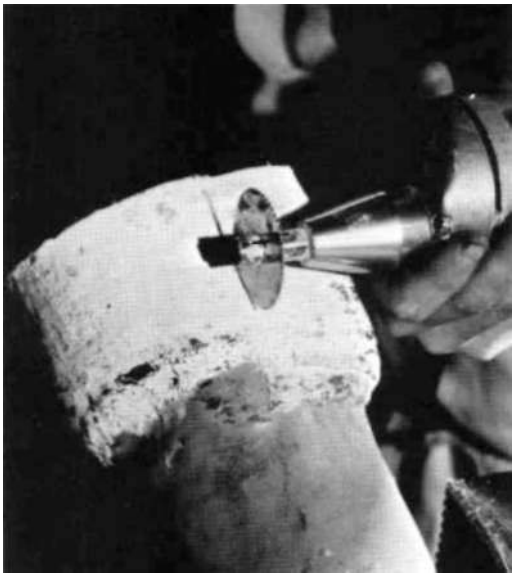
4. Dow Corning Silastic D RTV Silicone Rubber is mixed with 5% by weight of Silastic D RTV thinner. One-half to one lb of silicone is used for BK sockets and 1-1/2 to 2 lb are used for AK sockets, depending upon socket size.

5. Stannous octoate catalyst is added in a ratio of 100 drops or 2.2 gm to 1 lb of silicone rubber. This provides a 10-min working and a 1-hr curing time, which is the optimum for this procedure. The working time can be changed by varying the amount of catalyst. (Although this catalyst recommendation differs from the product-use instructions, its use is suggested because it has been found to be more convenient.) If stannous octoate is not available, a proportion of one part of standard catalyst to five parts of silicone rubber is used.

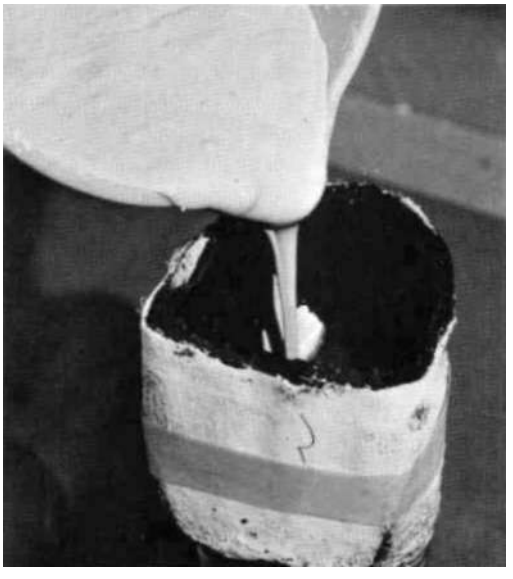
6. The mixture is poured into the hard socket, then the socket is rotated by hand so that the entire inner surface is covered. After this has been accomplished, the socket is rotated only in one direction to insure an even distribution of the mixture to a uniform thickness of approximately % in. The rotation (in one direction) is continued until the mixture is set (10-15 min); the mixture is then allowed to cure at room temperature for 45 min.

A uniform wall thickness of approximately 1/8 in. is important in order to provide adequate shock absorption during break-out and to avoid the formation of an undersized socket.

7. The silicone-rubber shell is pulled away from the medial wall, and a slit is made down the medial side of the socket. The slit will simplify the removal of the completed male mold by permitting the



hard socket to be spread open. The slit is started *V2* in. below the proximal brim and ended 2 in. short of the distal edge. (A wooden tongue blade and a clamp can be used to keep the silicone shell away from the medial wall while cutting the socket.)

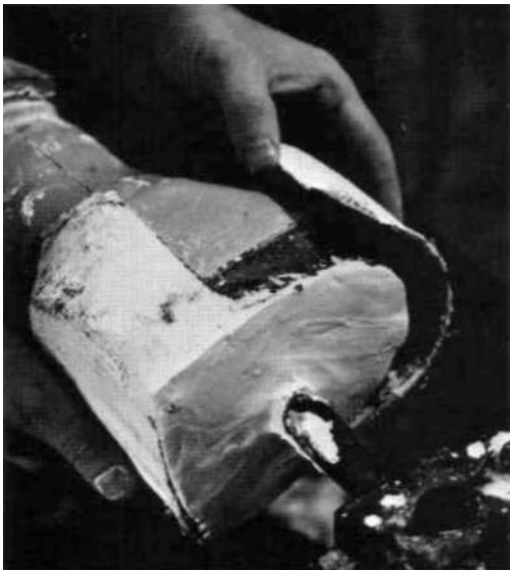


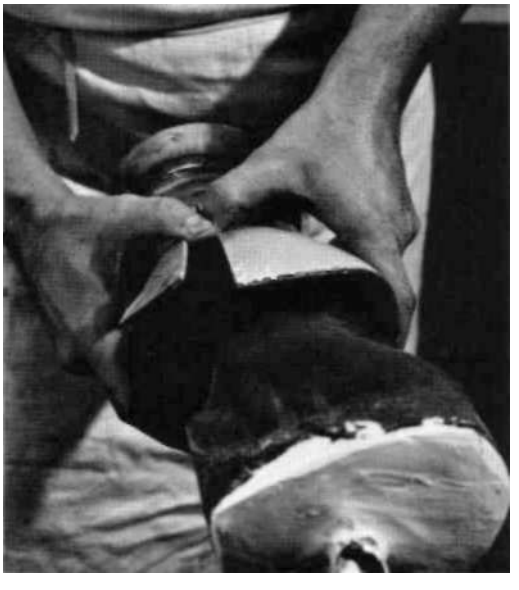
8. The male mold will be fabricated with a hollow core in order to simplify breaking it out of the transparent socket.

With the silicone shell in the hard socket, a plaster slush mold is poured to a 3/4-in. thickness, except at the distal end, where the thickness should be approximately 1-1/2 in. The plaster is allowed to set.

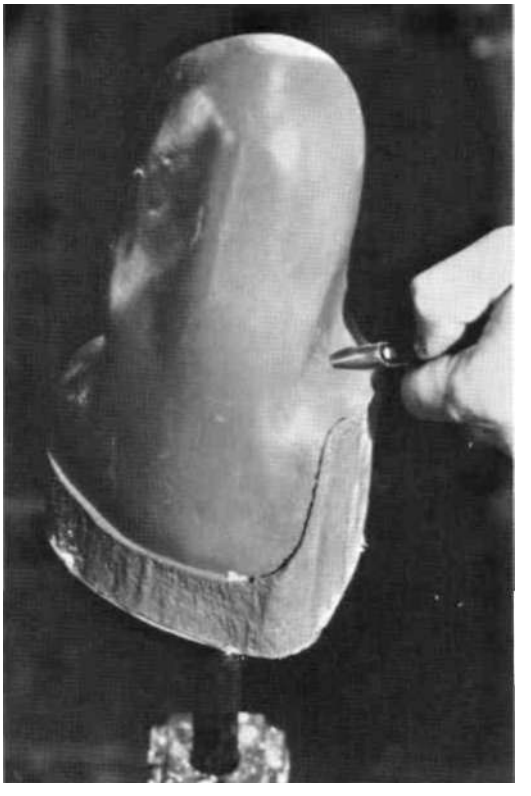
9. A pipe drilled with a few vacuum holes is inserted as a mandrel into the slush mold, and secured at its distal end with additional plaster. The middle section of the mold is filled with paper, and plaster is added at the proximal end of

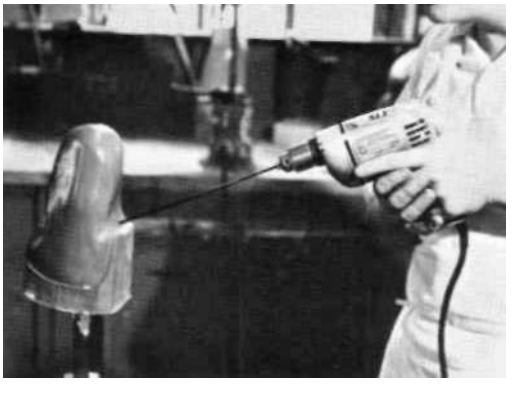
the mold to secure the mandrel. The plaster is allowed to set.



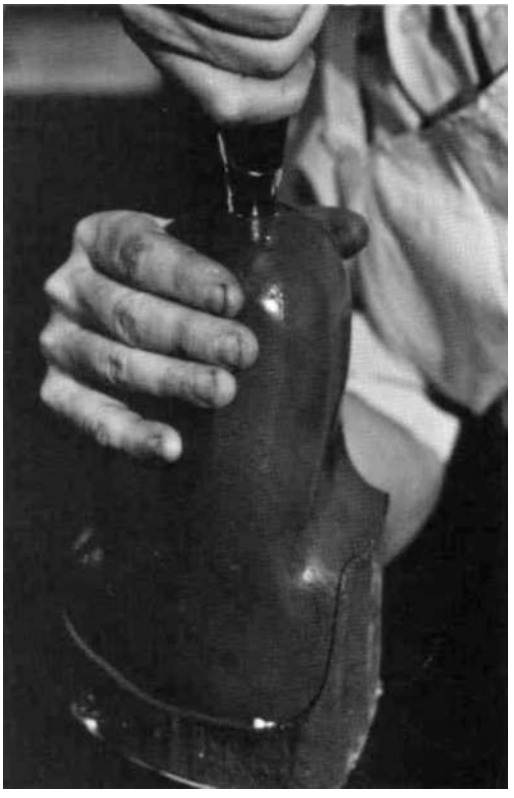


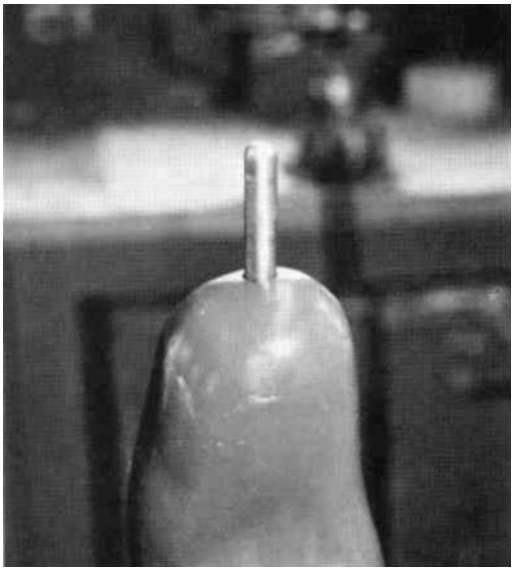
10. To separate the completed male mold from the hard socket, the plaster-bandage buildup is removed, the socket is opened along the slit, and the socket is slipped off.





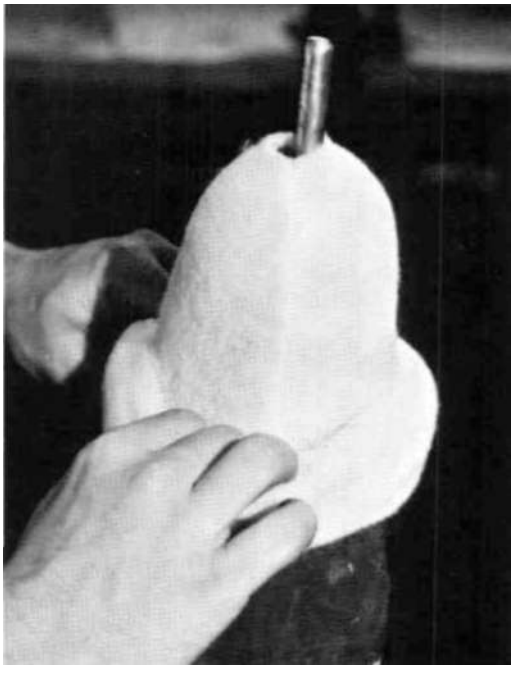
11. To permit the application of vacuum to the undercut areas, 1/8-in. holes are punched through the silicone shell and Vs-in. holes are drilled through the underlying plaster. The holes must be cut through to the void space in the male mold.

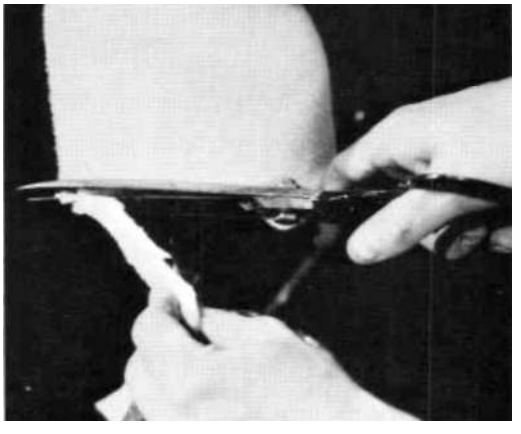




FEMALE MOLD

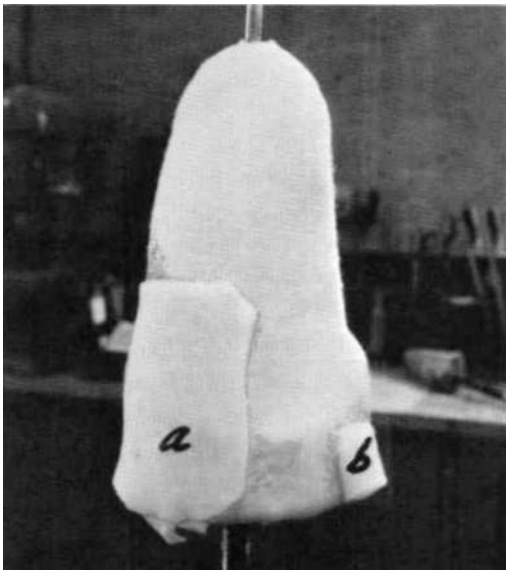
12. An alignment pin is used to insure correct alignment of the distal ends of the male and female molds during casting of the transparent socket. A hole 1/2 in. in diameter is punched in the silicone shell, and one 1/2 in. in diameter and 3/4 in. deep is drilled into the distal aspect of the male mold. An alignment pin, cut 1/2 in. in diameter by 3 in. long of nonferrous metal rod. is inserted into the distal hole.





13. In order to provide a 1/4-in. wall thickness for the transparent socket, a 1/4-in. Dacron felt sleeve, a 1/8-in. Dacron felt sleeve, and a cotton stockinette sleeve are prepared, all to fit over the male mold. Compression eventually will reduce the thickness of the sleeves to the desired

1/4 in. Holes 1/2 in. in diameter are cut in the ends of the sleeves to permit clearance of the alignment pin. The two felt sleeves are pulled over the male mold and trimmed even with the proximal edge of the mold.

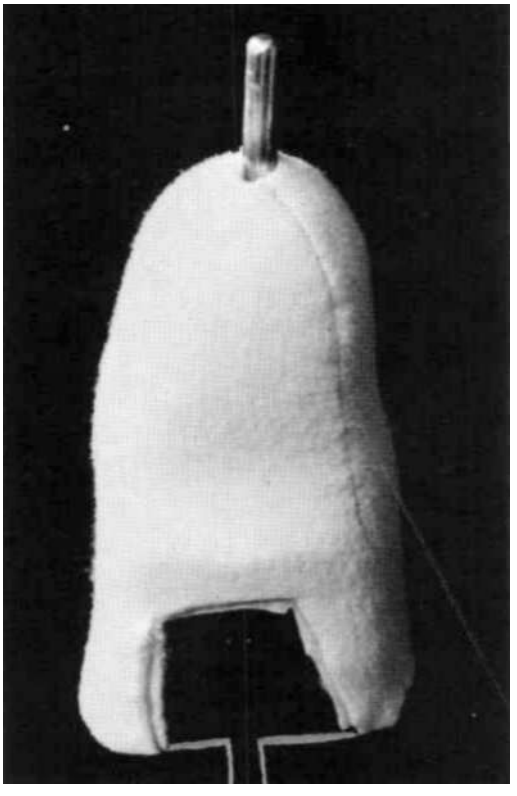


AK Sockets Only

To reinforce the proximal-lateral wall, a 5-in. x 7-in. strip of 1/8-in. felt is attached to the outer sleeve with Barge cement (*a*).

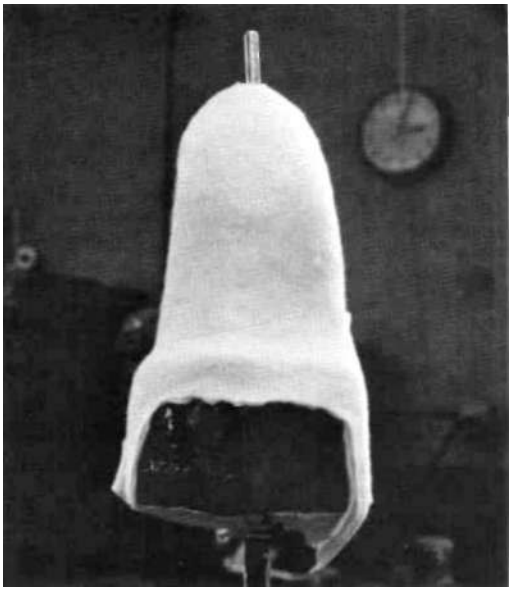
Because of limited space between the male and female molds for AK sockets, a means for pouring the polyester resin into the completed female mold must be provided by creating a lip, or inlet, at its proximal anterior brim (*b*). A triangular piece of 1/4-in. felt is rolled to form a funnel and fastened with Barge cement to the anterior brim of the outer sleeve so that the top of the funnel is even with the top surface of the mold. (The funnel is not needed in the below-knee socket fabrication, because in that case there is adequate space between the male and female molds.)

14. To facilitate alignment of the male and female molds, and to insure a uniform wall thickness of the transparent socket, the felt is cut away in the region above the posterior socket trim line as illustrated. The female mold will be contoured so that a proximal surface of this mold will contact the corresponding surface of the male mold.



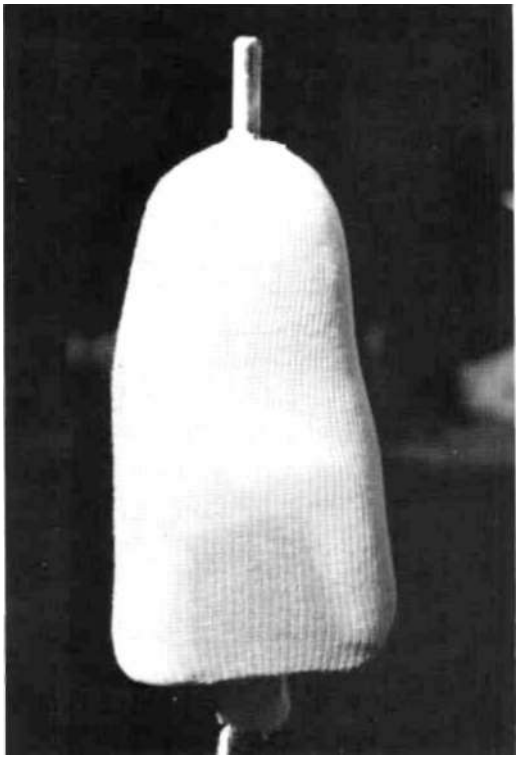
BK Sockets Only

The felt layers are cut out in the region above the popliteal trim line. The cutout should not cross the popliteal trim line.

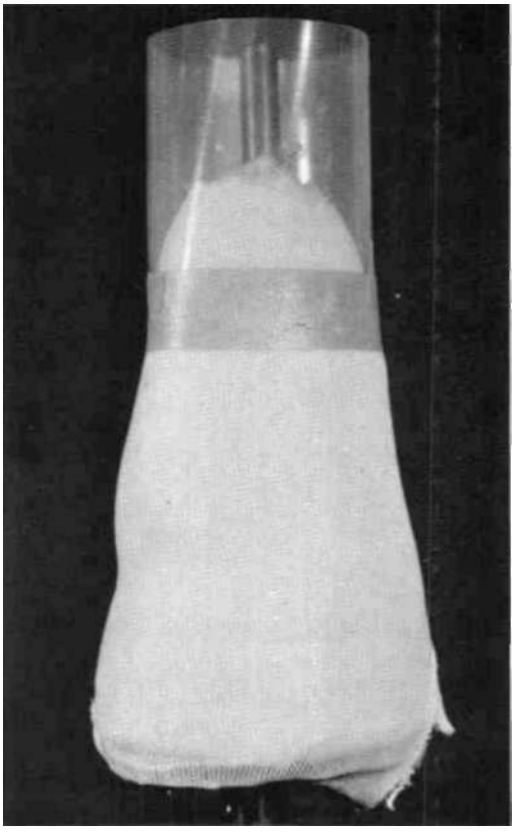


AK Sockets Only

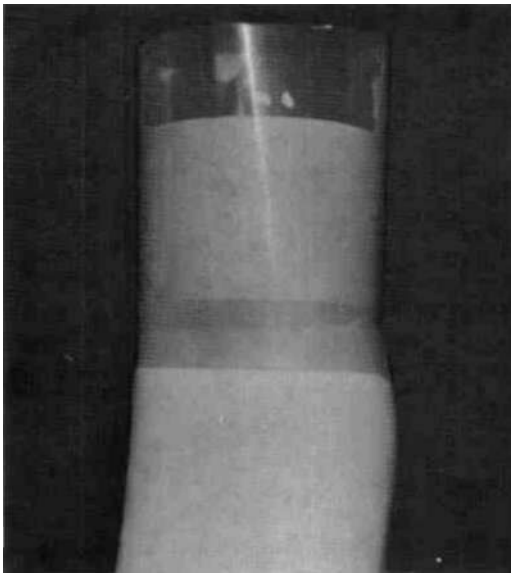
The Dacron layers are trimmed in the flat areas above the posterior and medial brims, leaving approximately 1 in. of uncut material above the socket trim lines.

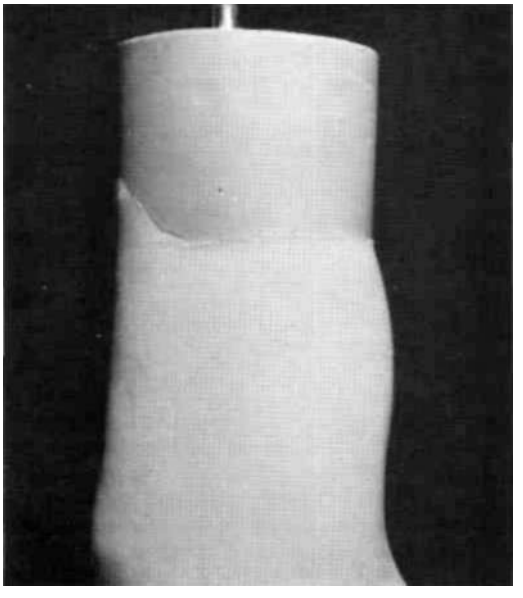


15. The stockinette sleeve is now pulled over the felt on the male mold and tied to the mandrel.

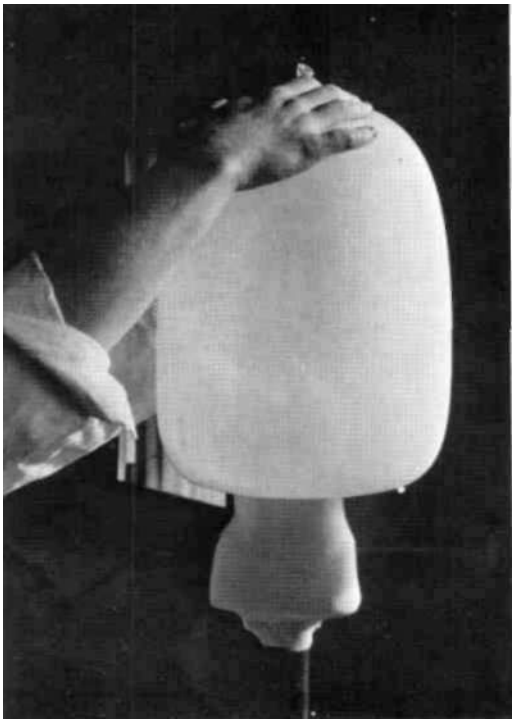


16. To provide for the transparent socket pedestal, a piece of 1/32-in.-thick plastic sheet is wrapped around the distal end of the male mold, over the sleeve, beginning at the point where the male mold starts to slope in and extending to the distal end of the alignment pin. The vertical seam and horizontal juncture line are sealed with tape.

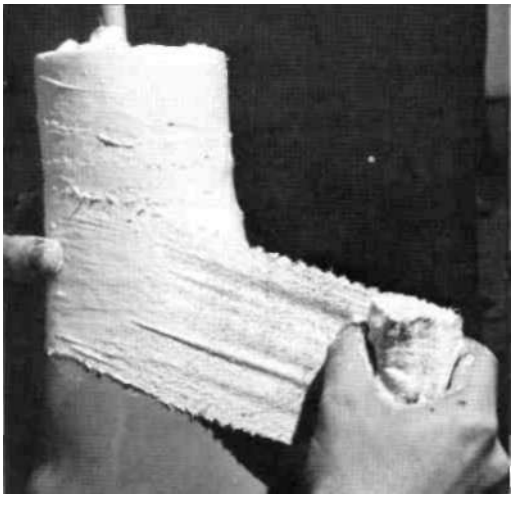




17. Plaster is poured into the cylindrical cavity formed by the plastic sheet, leaving 1/2 in. of the alignment pin exposed above the plaster level. The plaster is allowed to set, and the plastic sheet is removed.

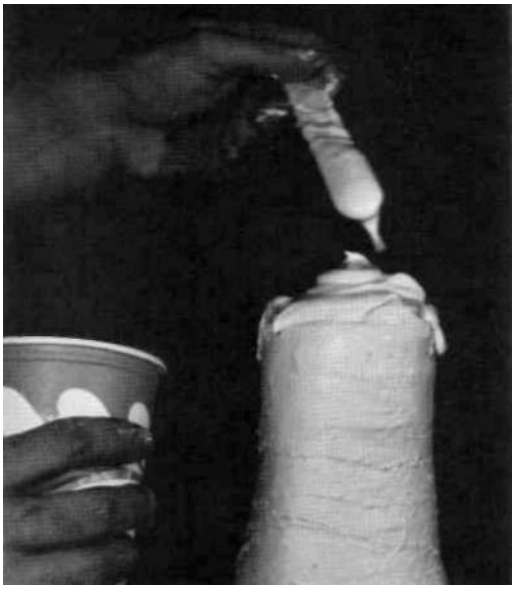


18. An inflated balloon is inverted over the lay-up and pushed downward as the air is slowly released. The distal end of the balloon is tied off around the alignment pin, and the proximal end around the mandrel. The balloon is then covered with a coat of silicone spray.

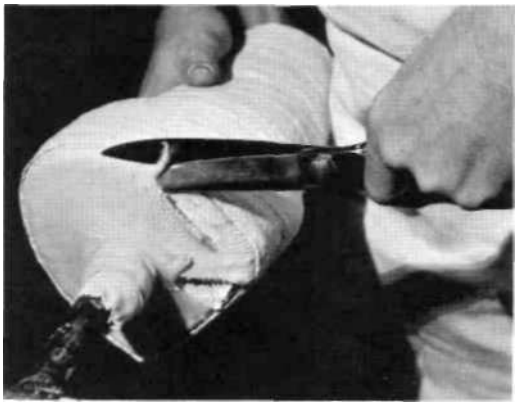


19. To fabricate the female mold, 4-in. plaster bandage is wrapped around the

balloon-covered male mold, starting at the distal end and overlapping each previous wrap by approximately 3 in. until a 4- to 6-layer thickness is achieved. Care is taken to avoid using excessive tension while applying the plaster bandage so as to prevent compression of the felt and reduction of the wall thickness of the transparent socket. In addition, the undercuts *{e.g.,* the patellar region in BK sockets) are minimized or reduced by bridging the bandage in that area.

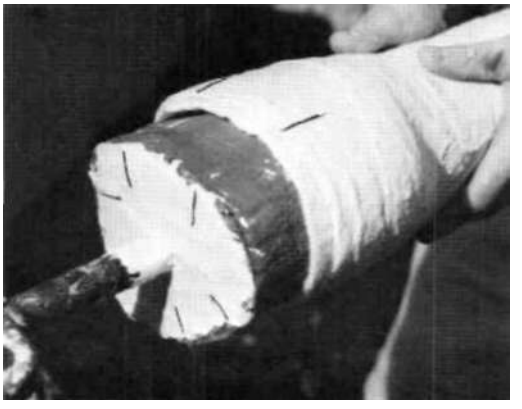


To provide a good receptacle for the exposed length of the alignment pin, it is covered with additional plaster, and the plaster is allowed to set.



20. The balloon and stockinette are trimmed off to expose the proximal end of the mold.

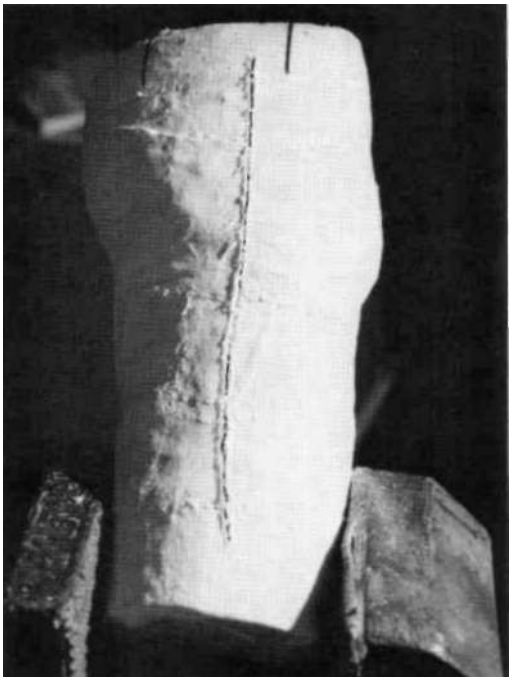
21. Using a combination square or a strip of metal bent to 90 deg as a guide, orientation lines are drawn on the proximal ends of the molds to provide references for their realignment. Two lines on each of the four sides are sufficient.

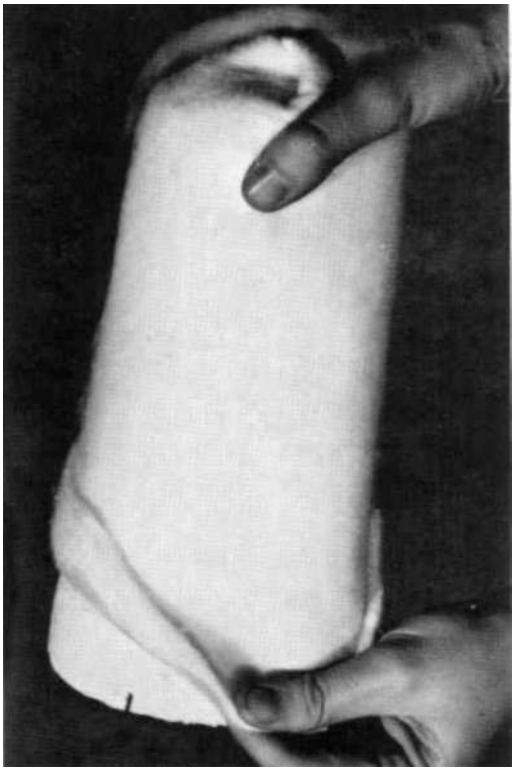


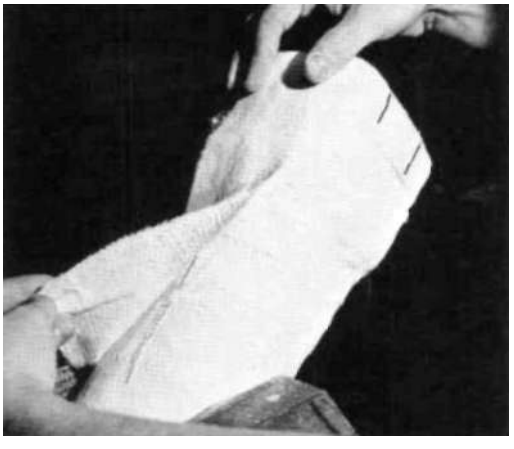
22. The molds are separated, and the felt and stockinette lay-up is removed from the inside of the female mold.

23. The plaster pedestal is broken out of the female mold, and the balloon and the alignment pin are removed without breaking the pin's receptacle.

24. At this point, a slit is made in the female mold to simplify its removal from the transparent socket after casting. Starting 1 in. below the proximal rim on the







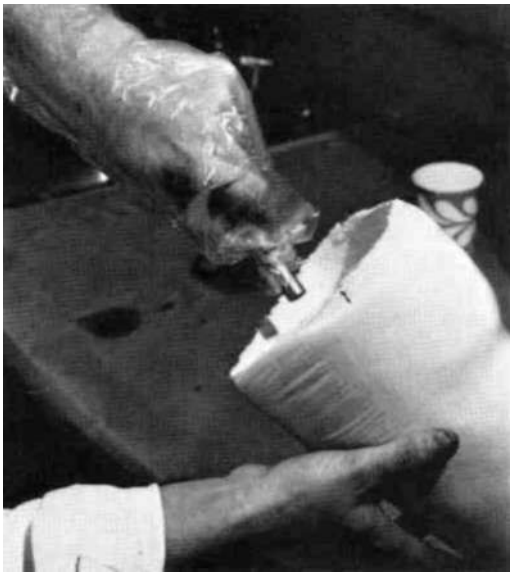
medial side, a cut is made vertically along three-quarters of the socket length. The cut is covered with two vertical layers of plaster bandage on the exterior surface. The interior surface is smoothed where necessary.

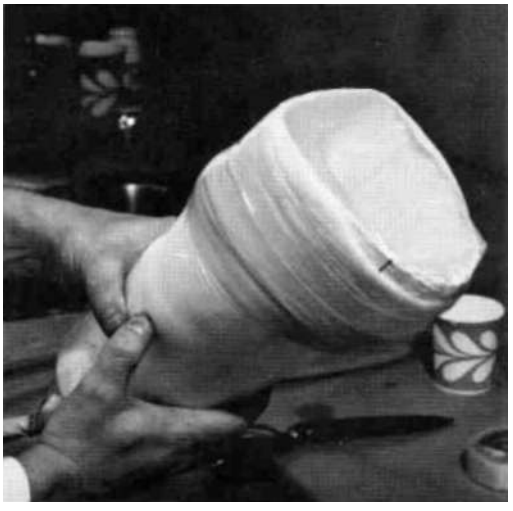
25. To complete the mold, 1/16-in.-dia vacuum holes are drilled in the undercut area of the female mold to insure the correct surface contour on the transparent socket.

ALIGNMENT OF THE MOLDS AND CASTING

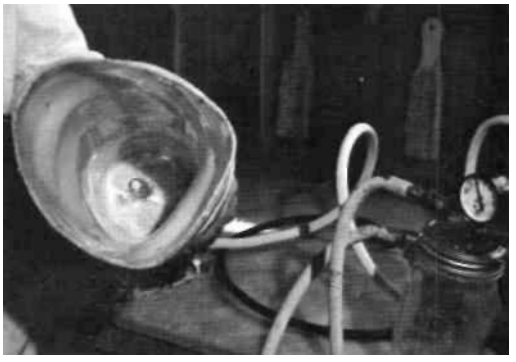
26. The outer surface of the female mold is covered with a 1/4-in. felt sleeve. A PVA bag is pulled over this sleeve, and both covers are trimmed even with the proximal edge. A vacuum tube is attached to the distal end of the PVA bag and secured with plastic tape.

27. A heavy coating of Vaseline petroleum jelly is applied to the inside surface of the female mold.



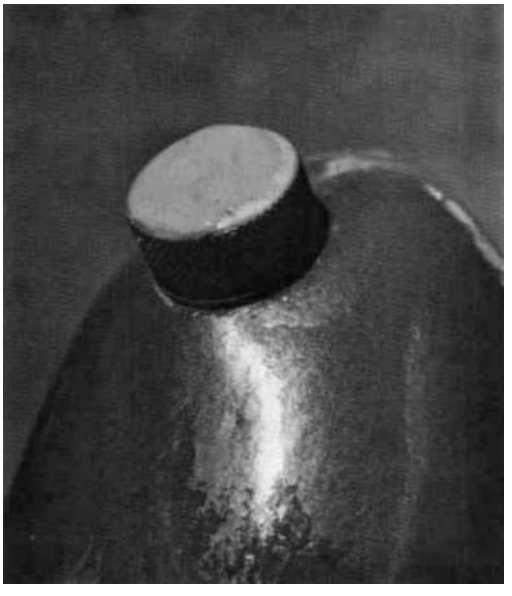


28. The end of a second PVA bag is fastened to the alignment pin with a rubber band and then both are inserted (glossy side in) into the alignment pin receptacle in the female mold. The interior PVA bag is lapped over the exterior PVA bag and sealed with pressure-sensitive tape. At least 4-in. overlaps must be provided because this PVA bag will later be fastened to the male mold mandrel.



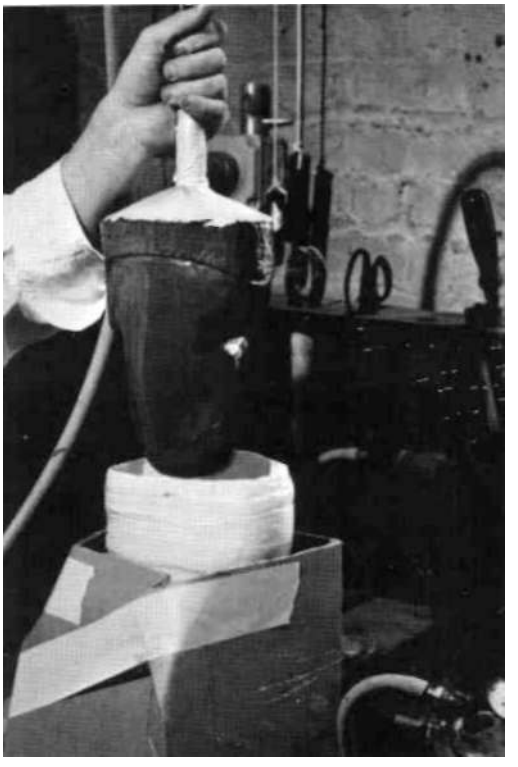
29. Vacuum is applied and the wrinkles are smoothed out on the interior PVA bag. This lining provides the smooth exterior surface of the transparent socket.

30. A PVA sheet (glossy side out) is pulled over the male mold and fastened to the mandrel with plastic tape. The sheet is reinforced around the alignment pin with plastic tape, and a 1/2-in. hole is cut through the tape and the PVA bag for the alignment pin. Vacuum is applied and the wrinkles in the PVA sheet are smoothed out.

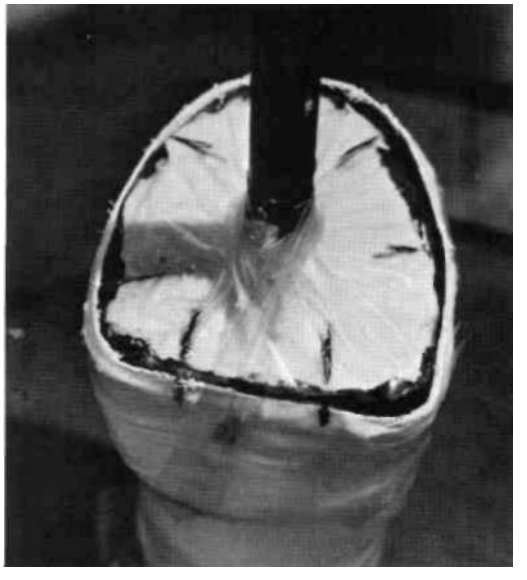


AK Sockets Only

The valve body may be placed before or after casting. If placement is done before casting, the valve body is filled with beeswax and glued with Barge cement to the PVA sheet on the male mold in the appropriate location. The valve body must be so located that it will not subsequently contact the wall of the female mold during the casting procedure.



31. The female mold is placed in a bench vise or other supporting device, with the proximal end up and proximal edges horizontal. The male mold is oriented in the female mold by means of the alignment pin and placed all the way down on the pin.

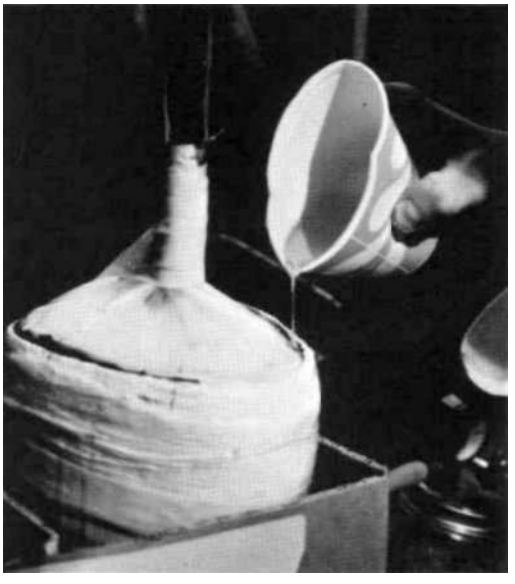


BK Sockets Only

The posterior surfaces of the molds are butted in the region superior to the popliteal trim lines, and the orientation marks are aligned. The molds are taped together securely to maintain the alignment.

AK Sockets Only

The surfaces superior to the posterior and medial brims are butted and the orientation marks aligned. The molds are secured with tape.

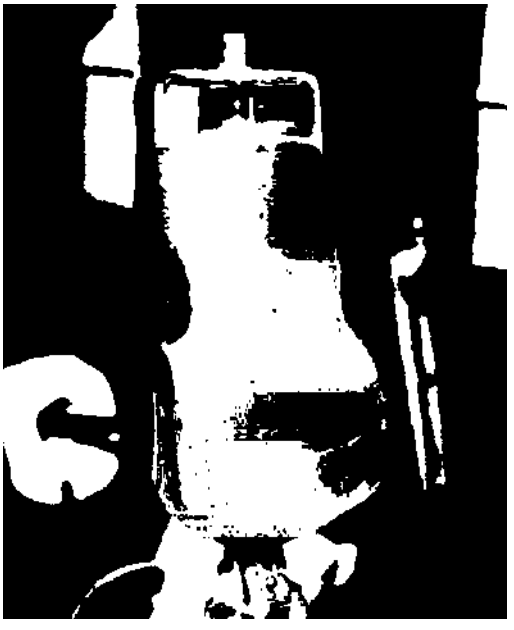


32. One to 1-1/2 qt of polyester casting resin for below-knee or 2 to 3 qt for above-knee sockets (depending on the size) are combined with the catalyst, with constant stirring. The manufacturer's instructions are followed regarding the amount of catalyst required to obtain a "slow setting time." Ideally, the resin should have a 1/2-hr gel time, which is adequate time for pouring. The resin is poured slowly and continuously while the female mold is simultaneously tapped to prevent any air bubbles being entrapped in the casting.

33. After the resin has set to a soft gel (about 30 min), the tape around the PVA bags is removed, and the outer PVA bag and Dacron sleeve are removed. The male mold PVA bag is punctured around the pipe, and the female mold PVA bag is pulled secure and tied to the mandrel.

34. After the resin has set to a firm gel (about 1 hr after pouring), the plaster strips are peeled off the slit in the female mold. The female mold is then removed

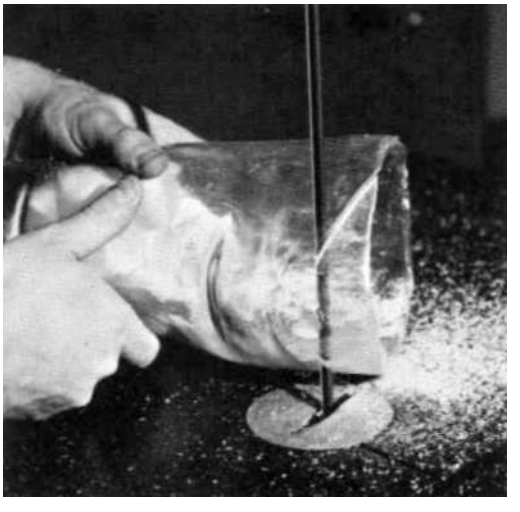
by spreading the slit open, with care being taken not to tear the PVA bag on the transparent socket. The resin is allowed to cure for an additional hour at room temperature.



35. The vacuum equipment is removed. The transparent socket (on the male mold) is heated in the oven at 165 deg F for 4 hours. The oven is turned off, and the socket is left until the oven cools to 125 deg F. This heat-treating helps to eliminate any internal stresses that may have developed during the curing phase.

FINISHING THE SOCKET

36. The PVA bags are cut along the proximal edge of the male mold. To protect the transparent socket surfaces from scarring, the PVA bags are left in place. The plaster slush mold is carefully chiseled away, and the mandrel and silicone shell are removed.



37. The socket is cut down to the proximal trim lines, using a band saw and electric sander. The rough edges are smoothed by hand-rubbing with fine-grade sandpaper. The transparency can be restored to these edges by applying a surface coating of resin to the area, covering with a PVA sheet, and allowing to cure.

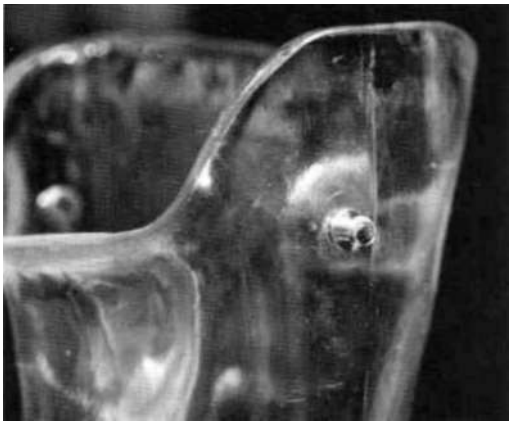
38. Any flashing on the interior surface around the alignment pin is removed, and the bottom of the hole is sealed with tape. The hole is filled with resin and allowed to cure.

AK Sockets Only

If the valve body was placed before the casting, a hole saw of the same size as the valve body diameter is now used to bore through to the valve body. To improve the boring angle, the distal corner of the socket pedestal is sawed and ground down.

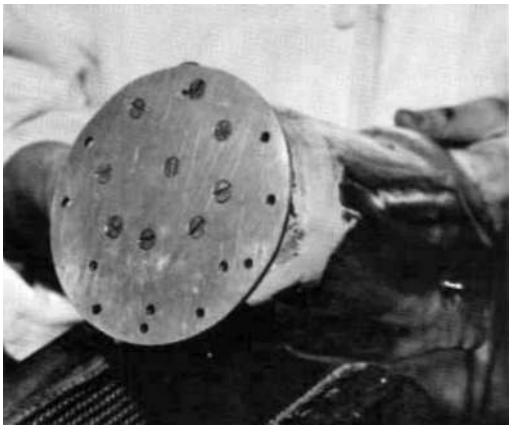
If the valve body has not yet been placed, the anteromedial corner of the socket pedestal is sawed and ground off to provide a flat surface. Then, using a hole saw of the same size as the valve body diameter, a hole is bored through the socket wall. The valve body is carefully secured in place with either polyester resin or epoxy cement so that the inner surface of the valve body is flush with the inner surface of the socket.

39. Before the socket is attached to an adjustable leg, the pedestal base is sanded flat and to the proper alignment angulation, using a disk sander.



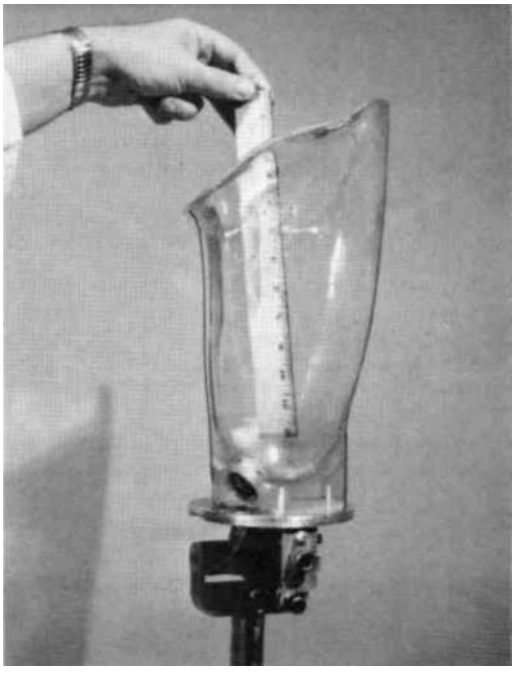
BK Sockets Only

Suspension-strap retainers are attached to the below-knee socket with #8-32 flat-head machine screws. The holes may be countersunk by using an inside countersink tool.

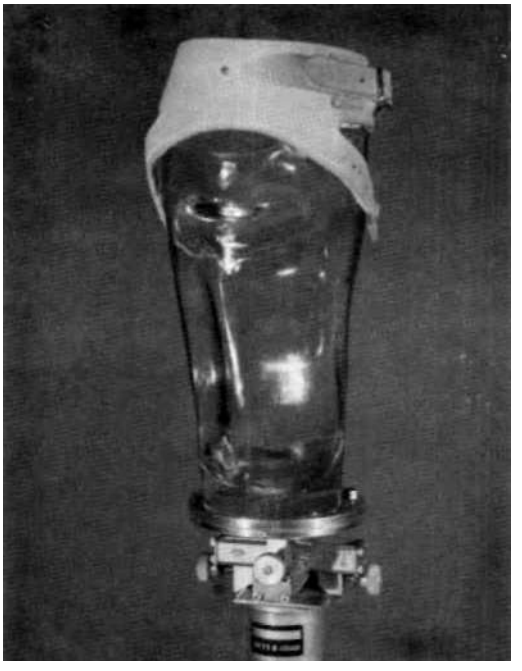


40. The socket attachment plate is fastened to the transparent socket by drilling and tapping eight holes in the pedestal base and securing with flat-head machine screws.

41. The PVA bags are removed, and the completed transparent socket is polished with silicone spray and a soft cloth. (This spray is also a good lubricant to facilitate donning the socket.)



Completed above-knee socket mounted on an adjustable leg.



Completed below-knee socket.