# Fabrication and Application of Transparent Polycarbonate Sockets[1]

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The potential usefulness of transparent sockets in both research and clinical practice has been recognized for many years. The Navy Prosthetics Research Laboratory used sockets made of Plexiglas in their studies of above-knee fitting during the fifties, and the J. E. Hanger Co. of Atlanta found Plexiglas sockets very useful in their pioneering work with the total-contact above-knee sockets in the early sixties, but fabrication of sockets with this material requires an extraordinary amount of time because it has not been 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 has not been adopted widely.

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

A method of vacuum-forming polycarbonate[3] sheet material has been developed that should make the use of transparent sockets practical in routine clinical practice.

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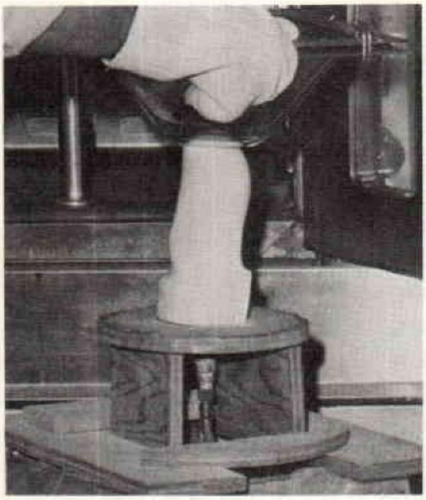
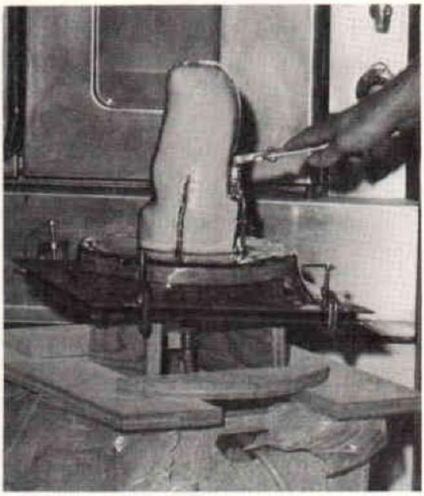
[1] This investigation was supported, in part, by Grant No. 23-P-55290/9 from the Social and Rehabilitation Service, Department of Health, Education, and Welfare, Washington, D.C. 20201. This article is adapted from a progress report made to SRS in November 1971.

[2] 7601 East Imperial Highway, Downey, California.

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

## THE PROCEDURE

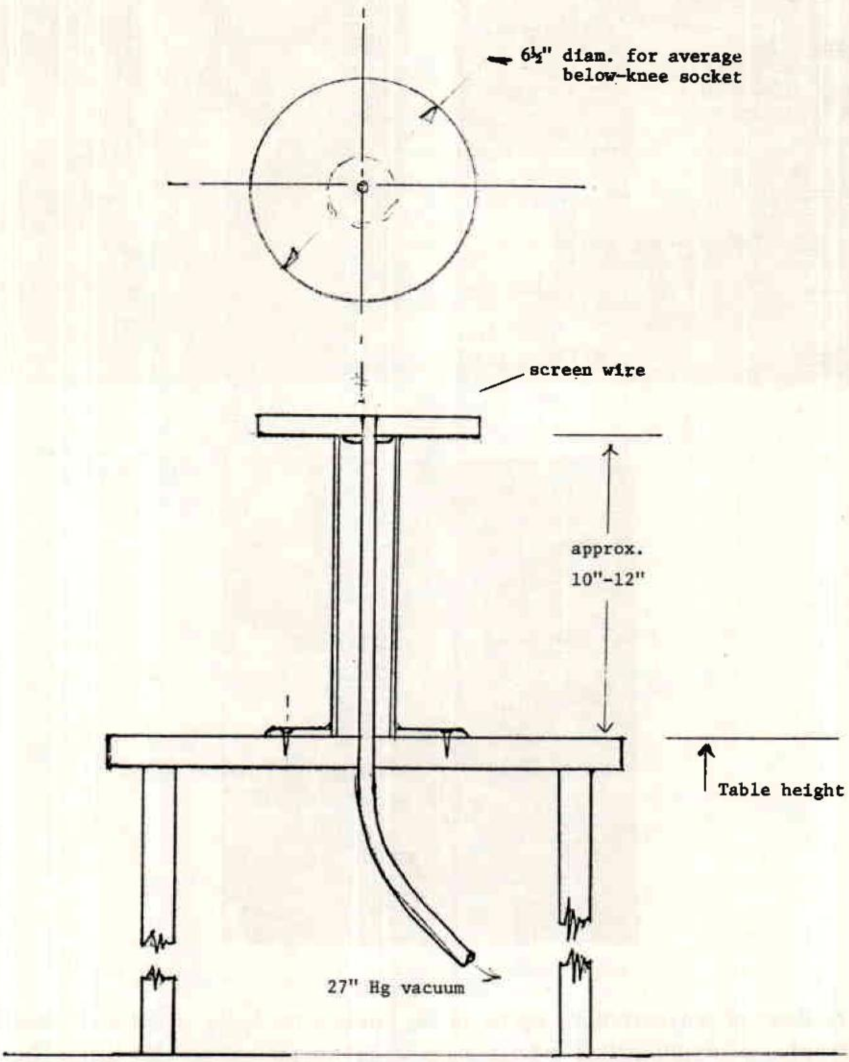




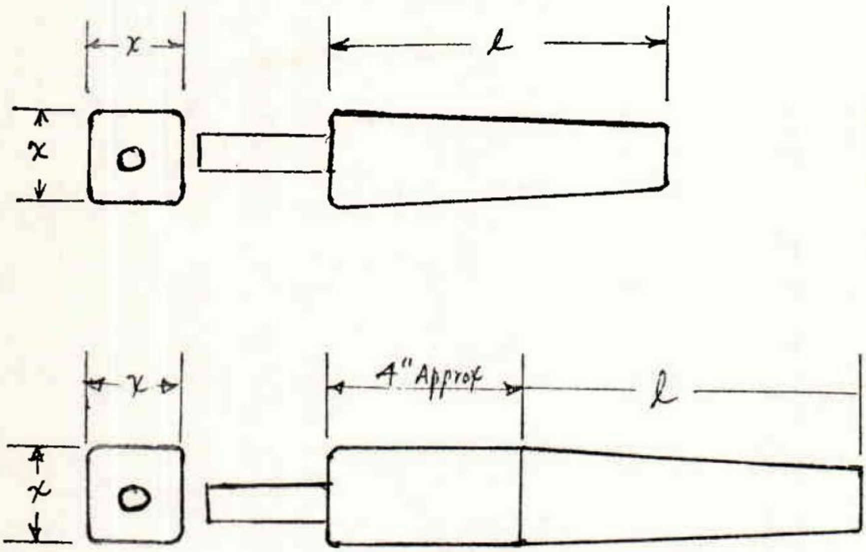
A sheet of polycarbonate up to ⅜-in. thick, after being dried and heated properly, is simply pulled over a male model of the stump and drawn into place with a vacuum supply. No special tooling is required, and no extra care is required to obtain satisfactory results. The socket can be worked with ordinary tools, can be bonded readily, and is sufficiently strong for use in most prosthetics applications. Some of the properties of polycarbonate sheet are given in Appendix A.

A step-by-step procedure for fabrication of a below-knee socket is set forth in the following sections.

## EQUIPMENT REQUIRED




No special equipment is required other than a workstand that will support the male model so that vacuum can be applied during the forming process.

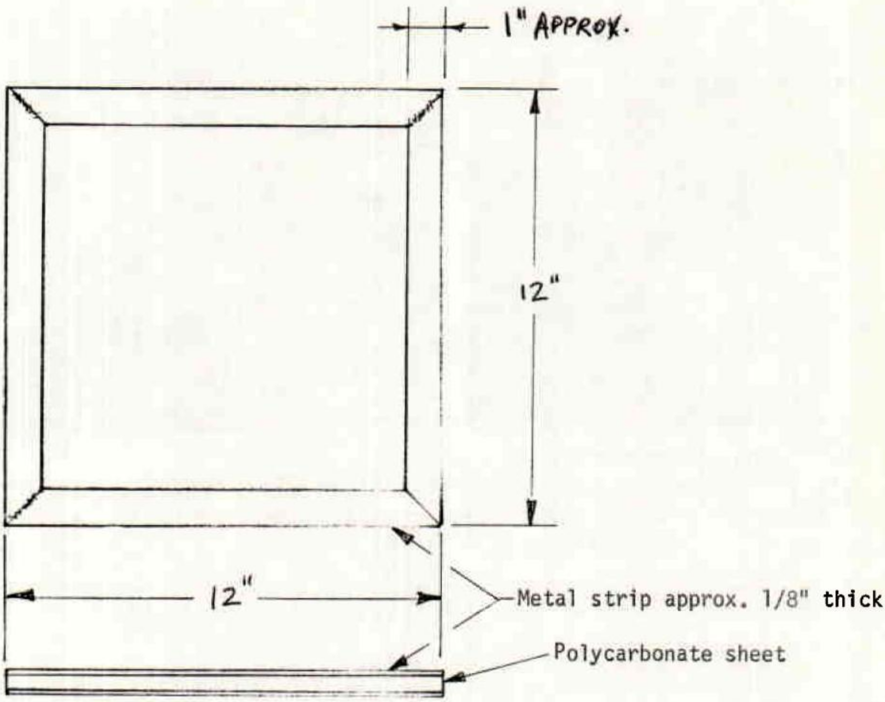



TAPERED MANDREL

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

Vary cross-section dimensions ($x$) and length ($\ell$) to provide a range of sizes

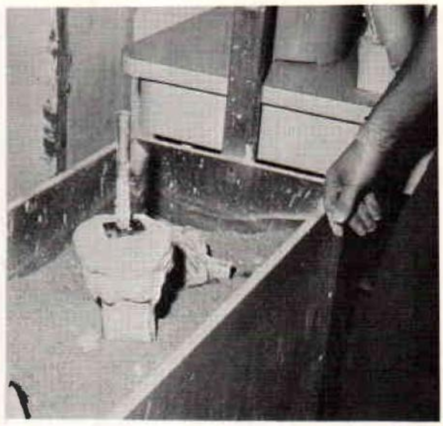
In order for the vacuum to exert sufficient force over the surface of the male model, a removable mandrel is used when the male model is cast, and small holes are drilled between the outer surface and the cavity formed by the mandrel. Mandrels used in the development project were tapered segments with a square cross section and were made from wooden 2 x 2's. They were covered with two layers of plastic laminate to facilitate removal and to provide for increased life.



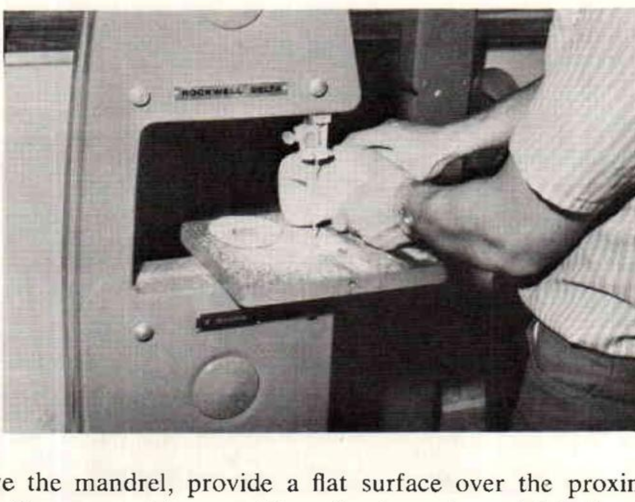

To permit proper handling of the polycarbonate sheet when heated, it is necessary to hold it in simple metal frames. Strip metal about ⅛-in. thick and inexpensive "C" clamps were used in the development program.

## STEP-BY-STEP PROCEDURE

### PREPARATION OF MODEL

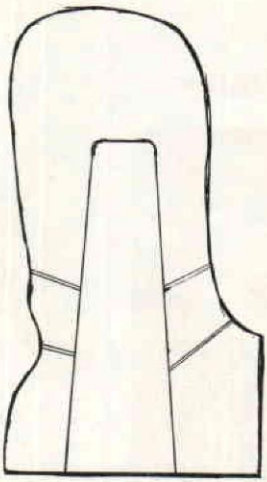


Take a cast of the stump in the usual manner. Pour a male model, using a mandrel to provide the cavity necessary for passage of air during the molding process, and modify as desired. Vaseline or some other parting agent such as "Slipicone" is used on the mandrel. Ordinary plaster-of-Paris may be used, but it is better to use a plaster type that can be heated to 500°F without fracturing.[4]



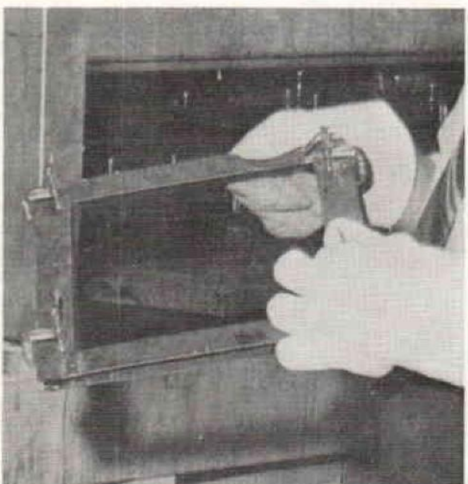
Remove the mandrel, provide a flat surface over the proximal end by sawing or filing to provide a good base for the male model during the molding phase.

[4] Easy Out Plaster, 1516 Coolidge St., San Diego.

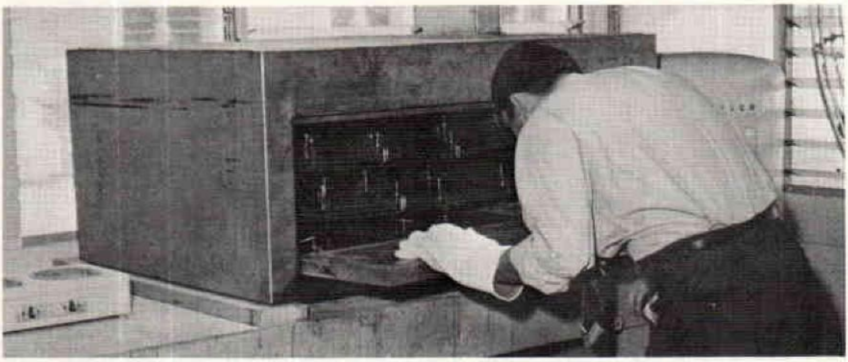


Drill air passages in the undercut areas from the outside surface to the cavity formed by the mandrel. A steel wire approximately 1/16-in. in diameter makes a good drill.

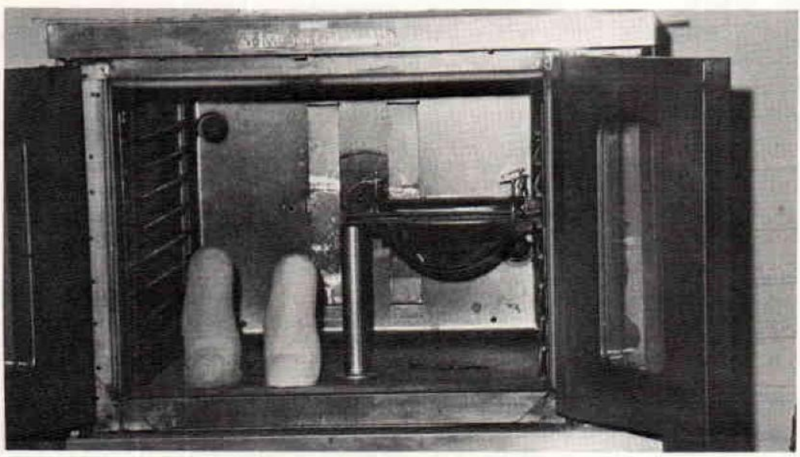
## PREPARATION OF THE POLYCARBONATE SHEET



Place a 12 in. x 12 in. sheet of polycarbonate in the metal frames. Material ⅜-in. thick is satisfactory for most adults. Material ¼-in. thick should be used for children and lightweight adults.

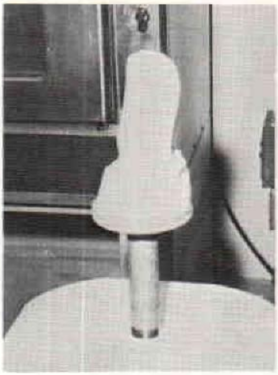


Heat the ⅜-in. material for 36 hours at 275-300 deg. F. to drive out the moisture absorbed by the polycarbonate. If the water is not removed the resulting socket will contain bubbles. It must be maintained at a temperature well below the melting point. A pizza oven was used quite satisfactorily in the development program.

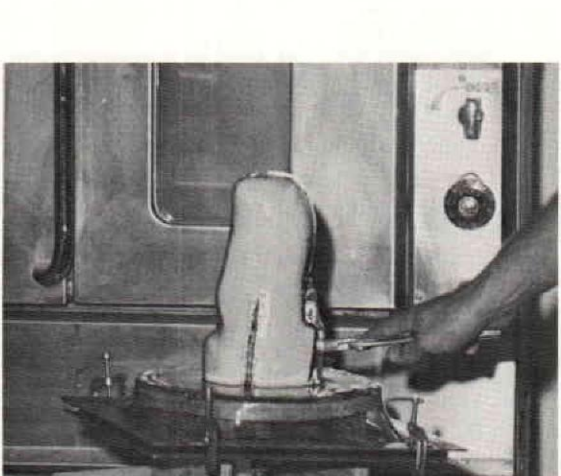


Elevate the temperature to 400 deg. F. until the sheet sags under its own weight to a depth equal to about ⅔ the length of the male model. This requires about 10-15 minutes. It is desirable to use another preheated oven. The male model is placed in the 400 deg. F. oven at the same time or slightly before the polycarbonate sheet. A heated model allows the prosthetist more time in forming the socket.

## FORMING THE SOCKET



Place the heated male model on the stand. Drape the material still in the frame over the male model, push downward until the polycarbonate contacts the plywood base supporting the male model, and apply 27″ Hg vacuum. (Even better results seem to be obtained when the frame and material are turned 180° about the horizontal axis, eliminating the invagination process. It is felt that there is less tendency for formation of built-in stresses when this procedure is used.)

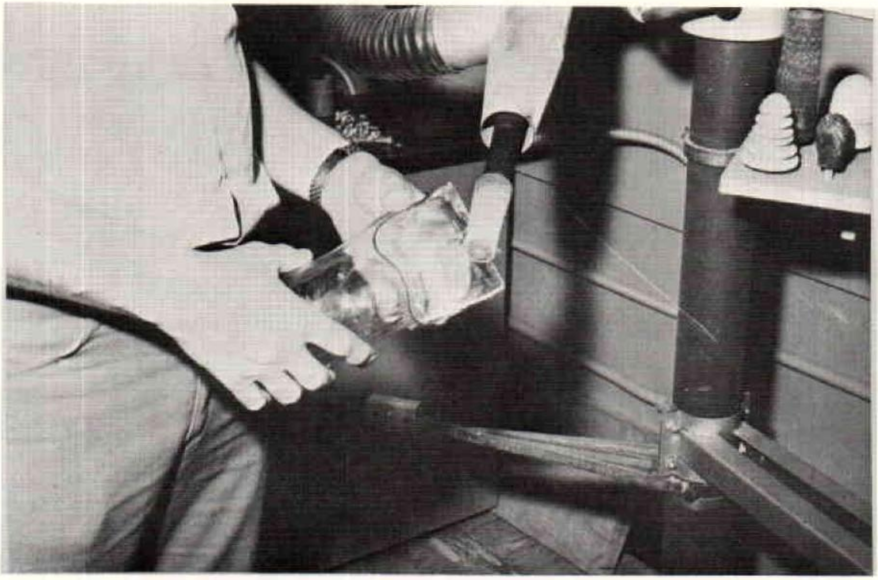


If webs form at the base, use pliers to pinch the sides together so that the inner surface is smooth.

## FINISHING THE SOCKET

When the socket has cooled to the point where it can be handled easily, remove it and the cast from stand (this is only a matter of minutes). Remove the plaster, usually by knocking on the outside of the socket with a rubber hammer. The larger the mandrel used, the easier this step is.

Use a cast cutter to remove most of the material proximal to the trim line of the socket.

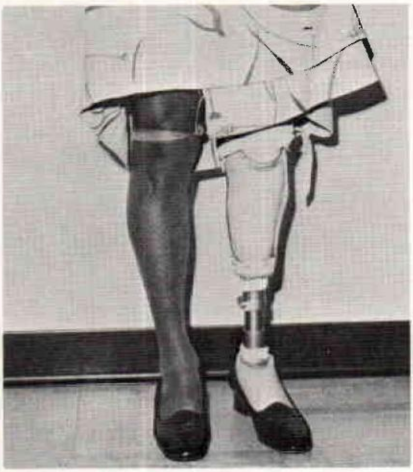


Trim proximal border using band saw and buffer.

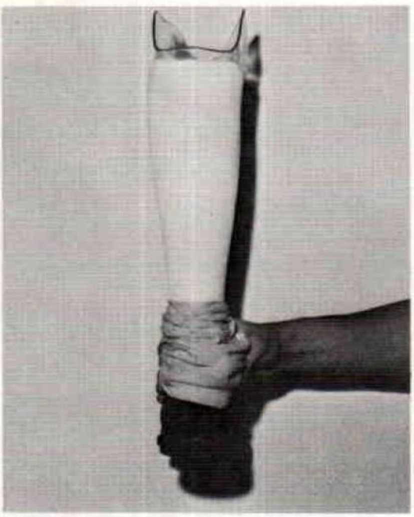
Socket is bonded to a Lexan disc approximately one inch thick—four inches in diameter. Using a burr on the router, a cavity is made to accept the end of the socket. A three-part cement [5] is mixed and poured into the cavity of the mounting block. The socket is held in slight flexion and adduction until the cement sets. The mounting block is then drilled and tapped and the pylon is screwed to it.

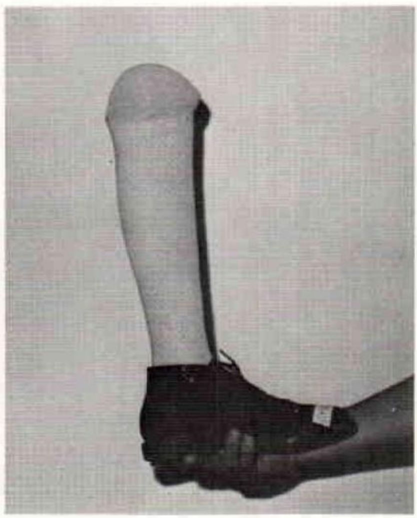
[5] Cement PS-18 available from Industrial Polychemical Service, 17116 South Broadway, Gardena, California.

## APPLICATIONS



Dynamic alignment is carried out.





A cosmetic cover and hose are applied.

## REFERENCES


1. Grille, Thomas, Ronald Lipskin, and Richard Hanak, *The NYU transparent socket fabrication procedure,* Artif. Limbs, 13:2:13-30, Autumn 1969.
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.

# APPENDIX A

## PROPERTIES

Parts properly fabricated from the LEXAN 9500 series will exhibit these properties:

| | Property | Average Value | A.S.T.M. Test |
|---|---|---|---|
| Physical Properties | Specific gravity | 1.20 | D 792 |
| | Odor | None | — |
| | Taste | None | — |
| | Refractive index at 25 C | 1.586 | — |
| | Rockwell hardness | M70 R118 | D 785 |
| | Abrasion resistance, Taber abraser with CS-17 wheel | 10 mg/1000 cycles | D 1044 |
| | Impact strength, notched Izod, ⅛-inch specimen | 14 ft-lb/in. of notch | D 256 |
| | Impact strength, unnotched Izod, ⅛-inch specimen | > 60 ft-lb/in | D 256 |
| | Tensile-impact, S-type specimen | 225 ft-lb/in.$^2$ | D 1822 |
| | Tensile-yield strength | 9,000 psi | D 638 |
| | Tensile-ultimate strength | 9,500 psi | D 638 |
| | Tensile modulus | 345,000 psi | D 638 |
| | Elongation | 90% | D 638 |
| | Compressive strength | 12,500 psi | D 695 |
| | Compressive modulus | 345,000 psi | D 695 |
| | Flexural strength | 13,500 psi | D 790 |
| | Flexural modulus | 340,000 psi | D 695 |
| | Shear-yield strength | 6,000 psi | D 732 |
| | Shear-ultimate strength | 10,000 psi | D 732 |
| | Poisson's ratio | 0.37 | — |
| | Modulus of rigidity | 116,000 psi | — |
| | Deformation under load, 4000 psi 77 F | 0.2% | D 621 |
| | 158 F | 0.3% | |
| | Fatigue endurance limit (Krause method), 1800 cycles/min., 73 F, 50% RH | 1,000 psi | |
| | Light transmission (⅛-inch thick disk) | 85% | — |
| | Water absorption, 24 hour immersion | 0.15% | D 570 |
| | equilibrium 73 F | 0.35% | |
| | equilibrium 212 F | 0.56% | |

| | | | |
|---|---|---|---|
| Thermal Properties | Heat deflection temperature | 264 psi: 275 F; 66 psi: 285 F | D 648 |
| | Thermoforming shrinkage | .007-.009 in./in. | D 955 |
| | Thermal conductivity | $4.6 \times 10^{-4}$ cal/sec/cm$^2$/°C/cm<br>0.02255 BTU/sec/ft$^2$/°F/in | — |
| | Coefficient of linear-thermal expansion | $3.75 \times 10^{-5}$ in/in/°F | |
| | —30 C to 30 C | $6.7 \times 10^{-5}$ in/in/°C | D 696 |
| | Flammability | Self-extinguishing | D 635 |
| | Brittle temperature | Below —135 C | D 746 |
| | Specific heat | 0.30 | |