MARCH 1969


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*Editor*
Audrey J. Calomino

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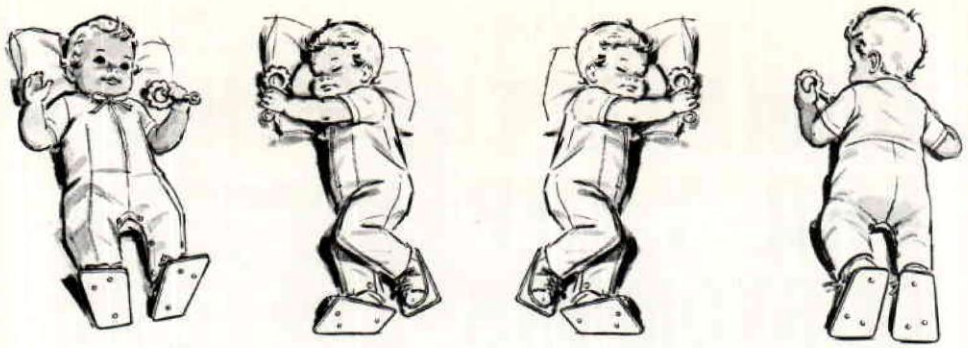

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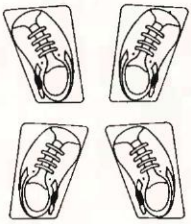

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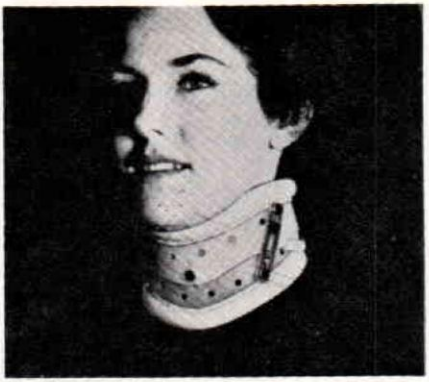

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# International Actions and Programme in Prosthetics

## Panel Discussion

*Tuesday, 2 July 1430 hrs.*

William A. Tosberg

Since the World Rehabilitation Fund, Inc. was founded in 1955, its primary function has been to bring rehabilitation personnel from other countries to the United States for advanced training. Well over 1,000 long- and short-term fellowships have been given to physicians, physical therapists, social workers, prosthetists and orthotists, but with primary emphasis on fellowships for physicians.

Nine prosthetic-orthotic trainees from six countries have been brought to the United States for long- or short-term training. Trainees from Ceylon and Hong Kong were provided with fellowships for a four-month course in India; two trainees from Peru, one from Guyana, one from Colombia, and one from Chile have received fellowships for the four-month course currently being given (May to August, 1968) at the Association For the Aid of Crippled Children in Sao Paulo, Brazil, under the sponsorship of UNICEF and the Pan American Health Organization with the support of the World Rehabilitation Fund, Inc.

Some years ago the World Rehabilitation Fund, Inc. agreed to serve as central agency for a collaborative effort among U.S. government and voluntary agencies for the collection and distribution

of used but serviceable prosthetic and orthotic devices to countries where such supplies were not available. Since the inception of the program over 125,000 such devices have been sent to 27 different nations.

The World Rehabilitation Fund, Inc. also has a policy whereby it will pay the tuition fee only for any persons from outside the United States, in any of the rehabilitation disciplines, who wish to take one of the short courses at the Prosthetic and Orthotic School, Postgraduate Medical School, New York University.

Under this program, fellowships have been given to 165 physicians, 58 physical and occupational therapists, and 22 prosthetists and orthotists, from 56 countries.

The most significant undertaking of the World Rehabilitation Fund, Inc. in prosthetics and orthotics has been the sponsorship, either independently but more frequently in conjunction with other agencies, both governmental and nongovernmental, of a series of short courses and consultations by Mr. Juan Monros. The cooperating and co-sponsoring agencies have included the United Nations, the Pan American Health Organization, UNICEF, the World Veterans Federation, the International Society for Rehabilitation of the Disabled, the American Leprosy Missions Inc., the U.S. Social and Rehabilitation Service, the U.S. Agency for International Development, and a number of national, government and voluntary agencies.

This program began in 1961 when Juan Monros, a Spanish national, completed four years of training in prosthetics and orthotics at the Institute of Rehabilitation Medicine, New York University Medical Center, New York City: The Institute for the Crippled and Disabled, New York City; and the Veterans Administration Prosthetic Center, New York City.

Under this program, a total of 168 trainees have participated in eleven such courses. Five of the courses were held in Brazil, two in 1962 and one each in 1965, 1966 and 1968; one in Peru in 1961; two in India, in 1963 and 1967; one in Ethiopia in 1964; one in Haiti in 1960; and one in Vietnam in 1965.

To the best of our knowledge, outside of the group trained in Vietnam, all but four of the persons who received the training are employed in prosthetics and orthotics, and we anticipate that two of the four will be employed in the near future. In Vietnam, a number of trainees have been drafted, but some have subsequently been reassigned to prosthetics and orthotics.

The World Rehabilitation Fund, Inc. provides the following publications for trainees enrolled in these courses:

"Diagonal Type Socket for Hip Disarticulation Amputations"

"A Hemipelvectomy Prosthesis"

"A Flexible Casting Brim Technique for Above-Knee Total Contact Socket"

"Patellar Tendon Bearing Below-Knee Prosthesis"

"Stump Edema"

"Immediate Post-surgical Prosthetics"
"Hygiene of the Stump"
"Step into Action"
"Wheelchair Prescriptions"
"Orthopedic Appliances Atlas —Vols. 1 and 2"
"Upper Extremity Orthotics"
"Rehabilitation Monograph No. 21—Self-Help Devices"

Each trainee also receives continuing subscriptions to "Orthotics and Prosthetics" and "Prosthetics International", and former Spanish-speaking trainees receive subcription to "Revista".

The World Rehabilitation Fund, Inc. and the agencies with which it has cooperated, as well as Mr. Monros, have never contended that these short courses, plus subsequent consultations, can provide the trainees with the level of technical ability and professional sophistication found among graduates of longer term training programs in well-established prosthetic centers. That has not been the intention. The purpose is to provide a practical method of bringing modern artificial limbs and braces to as large a number of disabled persons as possible, in the shortest possible time, at the lowest cost possible, in parts of the world where prosthetic and orthotic services were not formerly available.

Dr. Howard A. Rusk, President of the World Rehabilitation Fund, Inc. has said, "We have been extremely gratified by the success of these short courses, as have been institutions and agencies which have employed the graduates. It is our plan to continue these, and hopefully expand them to other parts of the world, particularly Asia and Africa, where basic prosthetic and orthotic services are so badly needed."

Mr. Juan Monros has also provided consultation services for various prosthetic and orthotic programs, in addition to the above-named courses, in Bolivia, Burma, Ceylon, Chile, Colombia, Dominican Republic, Ecuador, Ethiopia, Greece, India, Jordan, Lebanon, Nicaragua, Pakistan, Peru, Taiwan, Thailand, Tunisia, UAR (Egypt) and Vietnam, and has visited some of these countries as many as eight to ten times.

# Clinical Education and Requirements—A Prosthetist's Views

by

William A. Tosberg, C.P.O.

## THE PROSTHETIST'S ROLE IN THE CLINIC

We have discussed the many responsibilities of the prosthetist as well as the qualities he needs to meet them. One of those responsibilities relates to his position as a member of the clinic team. Here he is in contact not only with the patient but also with physicians and members of other paramedical disciplines.

In order to make a meaningful contribution to such a clinic, it is essential that his education and experience be diversified so that he is qualified to discuss all aspects of amputee rehabilitation. Courses in public speaking and public discussion help to prepare the prosthetist for this role. In a clinical climate it is not enough for the prosthetist to be fully familiar with all prosthetic principles. It is equally important that he be able to discuss these principles in terms easily understood by all other members of the team. It is essential that he be specific in his language. He must not only know but also be able to explain the properties of all materials used in his field. The advantages as well as the shortcomings of different designs and constructions have to be enumerated. His mind must be flexible in order that he may understand and evaluate the physician's recommendations.

At this point it should be mentioned that the prosthetist should

not only have full knowledge of all anatomical terms used in the field of prosthetics, but he must also be familiar with the physiology and kinesiology of the various joints since the physical therapist and also the occupational therapist will discuss the training of the amputee with him.

It is self-evident that, in a clinical situation, the prosthetist is looked upon as a professional only if he acts and behaves as such. His manner of speech, the way he dresses and his cooperation with other members of the team determine his acceptance within the group.

It is almost mandatory that in addition to a well-rounded training in the science of prosthetics, the prosthetist's education should include the foundations of different areas of medicine. He must acquire a general knowledge of the skeleton. Any amputation by necessity will lead to the removal of some bony tissue. What are the names of the different bones? What is their cellular structure? How does the skeleton support the body? What is the effect of an amputation on the affected extremity and on the body as a whole?

Equally important is the study of muscle action, and the interplay between the muscles and the skeleton. The purpose of a prosthetic device is the reestablishment of function. Since the function of an extremity depends upon muscular activity, the prosthetist must know the origins, insertions, and functions of the muscle groups which activate the extremity. This knowledge helps him in the design of joints for artificial limbs, but even more important it helps him determine the design requirements of the best socket for a given amputation.

## INFLUENCE OF SURGERY

Since the construction of a socket is greatly influenced by the amputation surgery, the clinically trained prosthetist must be familiar with the various surgical techniques. Guillotine amputation, myoplasty, myodesis, primary and secondary closure, cineplasty, disarticulation, and many other surgical terms are constantly used during prosthetic clinics.

The type and location of the scar and the suture materials may all affect the healing of the stump. The prosthetist must be familiar not only with surgical techniques and surgical terms, but he should also be prepared to discuss the level of amputation with the surgeon and the influence of this level on the function of the prosthetic replacement. Advantages and disadvantages of different levels of amputation from the prosthetic point of view have frequently influenced surgical judgment.

Quite often pain will lead to the rejection of an artificial limb. What is pain and what causes pain? The prosthetist has also to learn about such factors as neuromata and phantom sensation. Both of these phenomena have led to the rejection of a prosthetic device. Only infrequently can an adjustment of the socket influence either one, nevertheless discussion

with the physician may provide a clue to alleviation of the difficulty.

## ENGINEERING AND BIOMECHANICS

Engineering principles must be fully understood because the alignment of an artificial leg is dependent upon the laws of physics and biomechanics. Pressures within the socket depend on the area over which forces can be distributed. Pressure-sensitive and pressure-tolerant areas require different treatment. Stability within the stance phase as well as the swing phase of ambulation is governed by weight and force lines.

Acceleration and deceleration of the lower leg in an above-knee amputation are controlled by the laws of the compound pendulum. Mechanical and hydraulic friction mechanisms available to control the swing of the shank and foot must not only be fully known and understood, but the prosthetist must also be able to discuss the characteristics of these devices with the group in order to arrive at a prescription from which the amputee will derive the greatest benefit.

With the advent of external power, especially in applications to upper-extremity prostheses, a new era of prosthetics is emerging. What are the indications for pneumatic versus electronic systems and how do these systems influence the various functions of the prosthetic mechanism? What is the hardware tolerance of any given amputee?

It is well known that the emotional reaction to an amputation varies considerably from patient to patient. Therefore, the prosthetist has to be able to recognize that a prosthesis will only fulfill the functional and emotional requirements to a limited degree depending upon the degree of acceptance by the patient.

The foregoing discussion indicates only part of the qualifications that the clinical prosthetist must possess if he is to function in his role as a member of the amputee treatment team.

How can this diversified knowledge be acquired? One would think that a good technical background is most important because the prosthetist's responsibilities on the team are primarily of a mechanical nature. Extensive experience as a technician in a well organized facility would best prepare him for this responsibility. In addition to this mechanical training, academic training is needed in many fields that are only tangentially related. Courses which would prepare him for public discussion and psychological understanding, for example, are taught in a liberal arts college. Anatomy, physiology and kinesiology are taught in medical schools. Materials, design engineering and biomechanics are taught in engineering colleges.

In order to prepare a clinical prosthetist it would therefore seem to be essential that a training program which cuts across these fields

is needed. Fortunately, universities in the United States and also in some European countries have recognized this need.

## PROFESSIONAL EDUCATION

There are several schools in America that prepare students for an Associate of Arts degree in this field. One university offers a full four-year college curriculum which culminates in a Bachelor of Science degree in prosthetics and orthotics. The first two years are devoted to the study of subjects which are primarily related to the liberal arts.

However, many courses are directed towards the prosthetist's special field of interest. The student is exposed to amputee patients and he is also made familiar with the materials utilized in the construction of prosthetic devices. He learns their properties as well methods of fabrication; he learns to use the tools and machines required in the construction of prosthetic devices. Various pieces of specialized machinery are available for his use and under the guidance of qualified teaching personnel he is required to construct prostheses which have been prescribed under actual clinical conditions. Clinical affiliation not only with rehabilitation centers but also with commercial prosthetic facilities is part of his training.

Only through such intensive and extensive educational processes is it going to be possible to develop personnel able to function under the rigid requirements of a well-organized amputee clinic.

# The Facility Case Record Study

## A Preliminary Report

by

Barbara R. Friz, M.S.* and Frank W. Clippinger, Jr., M.D.†

In the spring of 1965 the Conference of Prosthetists of the American Orthotic and Prosthetic Association, in the interest of upgrading professional standards of prosthetics practice, decided to encourage prosthetists to institute a system for keeping complete and accurate records on amputee patients. Subsequently, a standard record form was developed on which pertinent information related to the case history, physical findings and prosthetic prescriptions could be recorded.

Recognizing that information recorded in this manner could yield vast amounts of valuable data, the Conference of Prosthetists further decided to incorporate in their records duplicate tear-off sheets which could be assembled for purposes of collecting such data. The Committee on Prosthetic-Orthotic Education‡ (CPOE), National Research Council, furnished the participating facilities with the forms and ac-

* Executive Secretary, Committee on Prosthetic-Orthotic Education, Division of Medical Sciences, National Research Council, National Academy of Sciences, Washington, D. C.

† Associate Professor, Division of Orthopedic Surgery, Duke University Medical Center, Durham, North Carolina; Chairman, Subcommittee on Prosthetics Clinical Studies, Committee on Prosthetic-Orthotic Education.

‡ The Committee on Prosthetic-Orthotic Education is supported by the Social and Rehabilitation Service, Dept. of Health, Education and Welfare, and by the Prosthetic and Sensory Aids Services of the Veterans Administration.

cepted responsibility for collecting, processing and analyzing the data. Instructions were distributed to guide participants in completion of the forms.

The purpose of this preliminary report is to present data reported by the participating facilities. Discussion of results and conclusions will be included in a final detailed report.

## METHODS

Forty-four facilities participated in the project and, for over a period of two years, submitted copies of case record forms to the CPOE office. The cut-off date for entering new case records was June 30, 1967.

Each of the facility record forms was edited in the CPOE office. An attempt was made to clarify any questionable entries and obtain complete information on all data by sending follow-up forms to the prosthetics facility owners. Because the data items on the forms were not pre-coded, it was necessary to set up a coding system and to translate and record each item on the form according to this system. The data were then transferred to IBM data processing magnetic tape.

In February 1968 an ad hoc working group met with the CPOE staff and with a consultant for data processing from the National Research Council to formulate pertinent questions which could be answered by the computer technique.

The prosthetists participating in the study represented thirty states, and for purposes of this study, the states are grouped according to geographical areas as shown in *Figure 1*. The highest percentage of participation by prosthetists was in the East Central region, and the lowest percentage in the Western region. (*Figure 2.*)

## SUBJECTS

Information was collected on a total of 8,323 patients, 7,954 of whom were fitted with one prosthesis; 364 with two; four with three; and one with four. This group presented a total of 8,698 amputations, of which 4,034 were "new" amputations and 4,664 were "old." (*Figure 3.*) (The term "new" in this discussion indicates a first fitting and is applied to both the amputee and the amputation. "Old" indicates a replacement prosthesis.)

| New England | East Central | South | Mid-West | West |
|---|---|---|---|---|
| Mass. | N. Y. | Ga. | Ohio | Mont. |
| Conn. | N. J. | S. C. | Ind. | Idaho |
| R. I. | Pa. | Tenn. | Ill. | Ore. |
| | Md. | Okla. | Mich. | Calif. |
| | N. C. | La. | Mo. | Wyo. |
| | W. Va. | Fla. | Neb. | Utah |
| | Va. | Texas | Minn. | |

**FIGURE 1—Breakdown by states into geographical areas.**

| New England | East-Central | South | Mid-West | West |
|---|---|---|---|---|
| 1,630* | 2,745 | 1,410 | 2,509 | 404 |
| (18.7%) | (31.6%) | (16.2%) | (28.8%) | (4.6%) |

* Represents number of forms submitted.

**FIGURE 2—Participation of facilities by geographical area.**

| | |
|---|---|
| Amputees with one fitted extremity | 7,954 |
| Amputees with two fitted extremities | 364 |
| Amputees with three fitted extremities | 4 |
| Amputees with four fitted extremities | 1 |
| TOTAL | 8,323 |

| | |
|---|---|
| Number of new amputations | 4,034 (46.4%) |
| Number of old amputations | 4,664 (53.6%) |
| TOTAL | 8,698 |

**FIGURE 3—Number of amputees and amputations in study.**

All statistics reported in this study refer to amputees who were fitted with prostheses. *Non-fitted amputees are not included.*

## FINDINGS

### *Comparison with Amputee Census*

In a study of 12,000 new amputees, commonly known as the "Amputee Census" and reported by Glattly* in 1964, the characteristics of the amputee population, including sex and age of the amputee, and cause, side, and level of the amputation were investigated. A well-defined pattern of these characteristics was established.

In this facility case record study, the pattern approximates that of the former study, thus giving us confidence that our sample includes a typical cross-section of the fitted amputee population.

In comparing statistics of the present study with those of the Amputee Census, we include only the 4,034 "new" patients. *Figures 4, 5, 6, 7* and *8* show that corresponding tabulations in the two studies approximate each other very closely.

In the present study, distribution by age agains shows the highest incidence of amputations occurring in the seventh decade. (*Figure 4.*) Newly fitted amputees over age 50 account for 61.1 percent of the total. Because many geriatric amputees are not prosthetically fitted, the incidence of amputation in the older age groups would presumably be even higher if statistics on non-fitted amputees were available.

The distribution of right-sided and left-sided amputation is almost equal in both studies, and lower extremity amputations still

* Glattly, H. W., "A Statistical Study of 12,000 New Amputees," Southern Med. J., 57:1373–1378, November 1964

account for about 85 percent of all fitted amputations. (*Figure 5.*) The number of male amputees continues to outnumber the number of female amputees by about three to one. (*Figure 6.*)

The relative incidence of trauma as a cause of amputation decreased by four percent; the incidence by cause as shown in the other three tabulations increased, but by a relatively small amount. (*Figure 7.*) In *Figure 8* a higher incidence of below-knee amputations and a lower incidence of above-knee amputations is reflected in the more recent study. Those sites of amputation not shown in *Figure 8* each total less than 2.0 percent of all new amputations. Among new patients there were a total of 3,254 above-knee and below-knee amputations. Of these, 50.9 percent were above-knee.

## Replacement Prosthesis

Amputees returned to the facility for a replacement prosthesis for several reasons, but "worn out" is listed in over 60 percent of the cases. "Outgrown" is next in frequency, appearing in approximately 12.5 percent of cases. Whereas 41 percent of new prostheses were above-knee (*Figure 9*), only 30 percent of replacement prostheses were above-knee. In the below-knee amputee, the situation is reversed, and the percentage of replacement prosthesis is greater (52 percent) than that of the new prostheses (39.6 percent).

The average age of all replaced

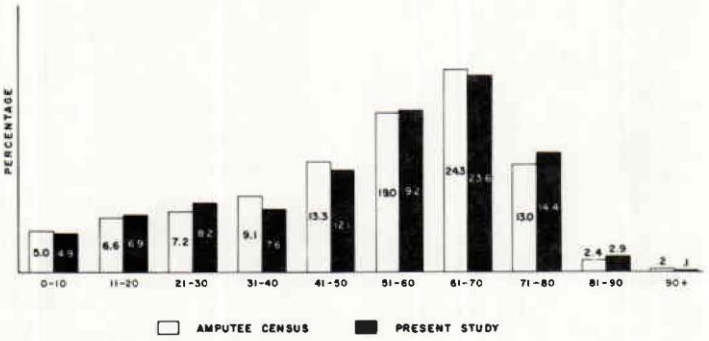


**FIGURE 4—Distribution by age.**

| | Amputee Census | Present Study |
|---|---|---|
| Left side | 49.2% | 51.2% |
| Right side | 50.8% | 48.8% |
| Upper Extremity | 14.9% | 14.4% |
| Lower Extremity | 85.1% | 85.6% |

**FIGURE 5—Distribution by side and extremity. Comparison of "Amputee Census" and present study.**

prostheses was 6.1 years. The above-elbow prostheses averaged 9.2 years; the below-elbow prostheses, 6.5 years; the above-knee prostheses, 6.2 years; and the below-knee prostheses, 5.8 years.

## Source of Patient

The tabulation in *Figure 10* reflects the prevalence of amputee clinic referrals. There is still a small group (4.7 percent) of new amputees who are receiving prosthetic fittings without a physician's referral.

## Source of Payment

Of the 8,631 prostheses for which source of payment was reported, 25.8 percent were paid for exclusively by the amputee, his family, or both. (*Figure 11.*)

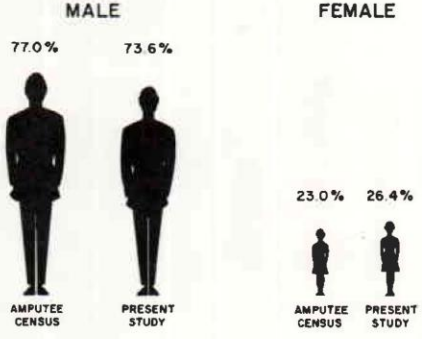


**FIGURE 6—Distribution by sex.**

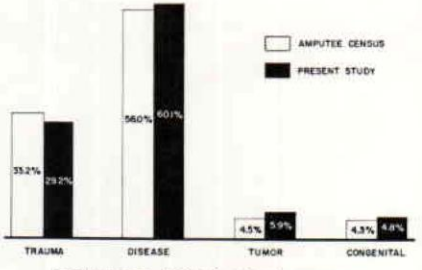


**FIGURE 7—Distribution by cause.**

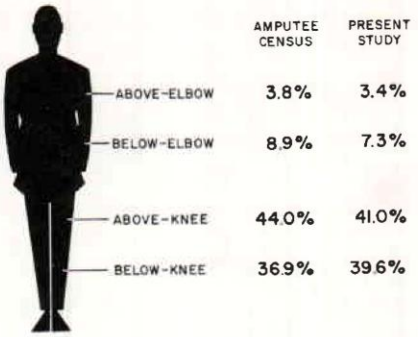


**FIGURE 8—Distribution by site of amputation.**

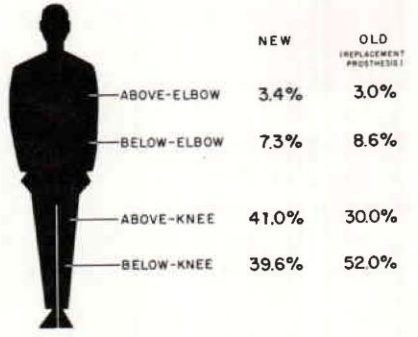


**FIGURE 9—Distribution by site of new and old amputations.**

Either insurance or compensation alone accounted for payment of 9.9 percent, and essentially all the remaining prostheses were paid for by different governmental agencies. Approximately 400 were paid for from more than one source; the Veterans Administration is the only source of payment not appearing in combination with any other source. The Medicare Act had been in effect during the second year of data collection only.

## Components. Lower Extremity.

Prosthetics practice in terms of types of components used by pros-

thetists varied moderately according to geographical location. The frequency of use of various components is shown in *Figures 12–21*.

In this study the quadrilateral socket is the overwhelming choice of prosthetists in fabrication of above-knee prostheses, although plug sockets are still used in 5.8 percent. (*Figure 12.*) Wood is used 56.9 percent of the time in fabrication of above-knee sockets; plastic, 38.6 percent; and leather 4.2 percent. Leather is used with greatest frequency in New England (17 percent). Wood is the shank material used in 95.2 percent of above-knee prostheses.

Hydraulic knee components show an 8.4 percent preference (*Figure 13*), with the Western area showing the highest percentage of usage (17.3 percent) and the Midwest area the lowest (4.6 percent).

The pelvic belt remains the suspension of choice for above-knee prostheses. Suction socket alone or combined with some other type of suspension is used

| | New Patients | Old Patients |
|---|---|---|
| Amputee Clinic | 2,467 (61.4%) | 2,485 (54.6%) |
| Physician | 1,362 (33.9%) | 899 (19.7%) |
| Not Referred | 188 (4.7%) | 1,169 (25.7%) |

**FIGURE 10—Souce of patients.**

| Source | Prostheses | Percentage |
|---|---|---|
| Amputee and/or family | 2,228 | 25.8 |
| Bureau of Vocational Rehabilitation | 1,944 | 22.5 |
| Veterans Administration | 1,238 | 14.3 |
| Welfare | 928 | 10.8 |
| Insurance and compensation | 854 | 9.9 |
| Social Security | 400 | 4.6 |
| Children's Bureau | 550 | 6.4 |
| Other | 83 | 1.0 |
| Combined sources | 406 | 4.7 |
| TOTAL | 8,631 | |

**FIGURE 11—Source of payment.**

| | Prostheses | Percentage |
|---|---|---|
| Quadrilateral | 2,563 | 85.3 |
| Plug | 173 | 5.8 |
| End Bearing | 21 | .7 |
| Hard and/or Open End | 154 | 5.1 |
| Other | 93 | 3.1 |
| TOTAL | 3,004 | |

**FIGURE 12—Sockets, above-knee prostheses.**

| | Prostheses | Percentage |
|---|---|---|
| Single Axis | 2,470 | 85.7 |
| Hydraulic | 243 | 8.4 |
| Other | 169 | 5.9 |
| TOTAL | 2,882 | |

**FIGURE 13—Knee components, above-knee prostheses.**

| | Prostheses | Percentage |
|---|---|---|
| Pelvic Belt | 1,684 | 56.3 |
| Suction | 544 | 18.2 |
| Silesian Band | 377 | 12.6 |
| Suction Plus | 311 | 10.4 |
| Other | 76 | 2.5 |
| TOTAL | 2,992 | |

**FIGURE 14—Suspension, above-knee prostheses.**

| Age | Prostheses | SACH | Other | Percent SACH |
|---|---|---|---|---|
| 5 or less | 19 | 14 | 5 | 73.7 |
| 6–11 | 36 | 28 | 8 | 77.8 |
| 12–17 | 93 | 78 | 15 | 83.9 |
| 18–20 | 55 | 45 | 10 | 81.8 |
| 21–50 | 983 | 615 | 368 | 62.6 |
| 51–64 | 847 | 432 | 415 | 51.0 |
| 65+ | 896 | 392 | 504 | 43.8 |
| TOTAL | 2,929 | 1,604 | 1,325 | 54.8 |

**FIGURE 15—Foot components, above-knee prostheses.**

in 28.6 percent (*Figure 14*) of the total above-knee prostheses, and 17 percent in above-knee prostheses prescribed for amputees over age 50.

The SACH foot is used with greater frequency than any other foot component, although in the older age groups the frequency of use declines markedly for both above-knee prostheses (*Figure 15*) and below-knee prostheses (*Figure 16*). In children the SACH foot is used almost exclusively for those with below-knee prostheses, but slightly less frequently for those wearing above-knee prostheses.

The patellar- tendon-bearing socket in this study out-numbers all other kinds of sockets for below-knee amputees. (*Figure 17.*) Suspension by knee cuff alone is most widely used by teenagers, with a lower frequency of use in young children and in the 65-and-above age groups. (*Figure 18.*) Wood is used in 90 percent of the below-knee shanks.

| Age | Prostheses | SACH | Other | Percent SACH |
|---|---|---|---|---|
| 5 or less | 70 | 68 | 2 | 97.1 |
| 6–11 | 113 | 108 | 5 | 95.6 |
| 12–17 | 149 | 138 | 11 | 92.6 |
| 18–20 | 83 | 80 | 3 | 96.4 |
| 21–50 | 1,546 | 1,218 | 328 | 78.8 |
| 51–64 | 1,010 | 696 | 314 | 68.9 |
| 65+ | 969 | 568 | 401 | 58.6 |
| TOTAL | 3,940 | 2,876 | 1,064 | 73.0 |

**FIGURE 16—Foot components, below-knee prostheses.**

| | Prostheses | Percentage |
|---|---|---|
| PTB | 2,245 | 56.4 |
| Hard & Open End | 668 | 16.8 |
| Hard | 610 | 15.3 |
| Hard & Soft Insert | 121 | 3.0 |
| Other | 333 | 8.4 |
| TOTAL | 3,977 | |

**FIGURE 17—Sockets, below-knee prostheses.**

| Age | PTB Prostheses | Percent Knee Cuff | Percent Cuff with Waist Belt |
|---|---|---|---|
| 5 or less | 45 | 35.6 | 20.0 |
| 6–11 | 74 | 58.1 | 23.0 |
| 12–17 | 109 | 76.1 | 11.9 |
| 18–20 | 65 | 76.9 | 9.2 |
| 21–50 | 903 | 62.2 | 14.4 |
| 51–64 | 530 | 64.2 | 11.7 |
| 65+ | 446 | 58.5 | 15.0 |
| TOTAL | 2,172 | | |

**FIGURE 18—Suspension, PTB socket prostheses.**

| Age | Double Wall | Single Wall | Other | Total |
|---|---|---|---|---|
| 5 or less | 7 | 1 | 1 | 9 |
| 6–11 | 12 | | 1 | 13 |
| 12–17 | 12 | 1 | | 13 |
| 18–20 | 16 | 3 | | 19 |
| 21–50 | 138 | 10 | 3 | 151 |
| 51–64 | 35 | 3 | | 38 |
| 65+ | 7 | 3 | | 10 |
| TOTAL | 227 | 21 | 5 | 253 |

**FIGURE 19—Sockets, above-elbow prostheses.**

| Age | Pre-Flexed | Double Wall | Single Wall | Other | Total |
|---|---|---|---|---|---|
| 5 or less | 20 | 44 | 2 | 2 | 68 |
| 6–11 | 11 | 39 | 2 | 2 | 54 |
| 12–17 | 11 | 37 | 4 | 3 | 55 |
| 18–20 | 2 | 26 | 3 | 2 | 33 |
| 21–50 | 21 | 238 | 26 | 5 | 290 |
| 51–64 | 4 | 84 | 14 | 1 | 103 |
| 65+ | 3 | 23 | 6 | — | 32 |
| TOTAL | 72 | 491 | 57 | 15 | 635 |

**FIGURE 20—Sockets, below-elbow prostheses.**

| | Hand Type | Hook Type |
|---|---|---|
| Passive | 113 (29.5%) | — — |
| Voluntary Opening | 144 (37.6%) | 859 (89.2%) |
| Voluntary Closing | 124 (32.4%) | 95 (9.9%) |
| Other | 2 (0.5%) | 9 (0.9%) |
| TOTALS | 383 | 963 |

| | |
|---|---|
| Total voluntary opening and closing hands | 268 |
| Voluntary opening hands | (53.7%) |
| Voluntary closing hands | (46.3%) |

**FIGURE 21—Terminal devices, hand and hook types.**

### *Components. Upper Extremity.*

In this study double wall sockets are used in 89.7 percent of all above-elbow prostheses (*Figure 19*), and 77.3 percent of below-elbow prostheses (*Figure 20*). No distinction is made between the Muënster and other types of preflexed sockets in below-elbow prostheses. These numbered 72, or 11.3 percent of the total 635 below-elbow prostheses.

Sixty-nine percent of the elbow units in the above-elbow prostheses are internal locks. In addition, 9 percent have spring flexion assists. In below-elbow, the elbow hinges are flexible in 64.2 percent of prostheses. The triceps pad is the most frequently used type of arm cuff (56 percent), and cuff materials are usually plastic (61.1 percent). The ring figure 8 harness is the most frequently used type of harness, 45.7 percent in the above-elbow prostheses and 53.8 percent in the below-elbow prostheses.

The passive or cosmetic hand was prescribed 113 times (29.5 percent of the total number of hand types) (*Figure 21*). Of the 268 mechanically controlled hands, the voluntary opening hand was prescribed 7.4 percent more often than the voluntary closing hand. In the

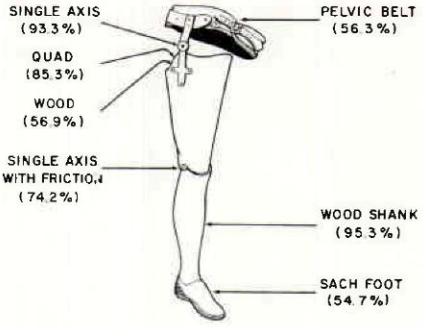


**FIGURE 22—Above-knee prosthesis.**

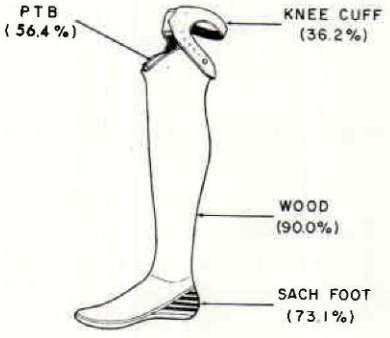


**FIGURE 23—Below-knee prosthesis.**

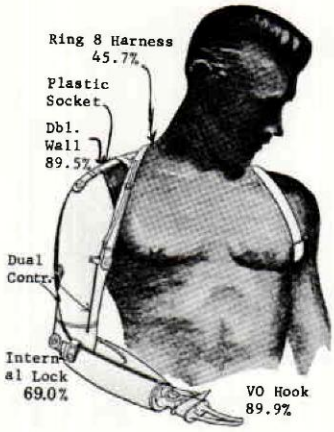


**FIGURE 24—Above-elbow prosthesis.**

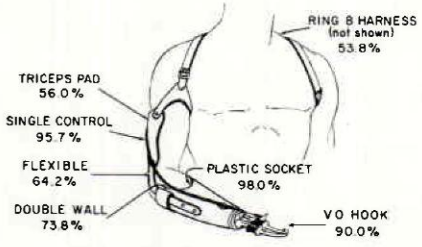


**FIGURE 25—Below-elbow prosthesis.**

**Four types of prostheses showing most frequently used components.**

hook type terminal device the voluntary opeining hand was used approximately 90 percent of the time. The most frequently used components for four types of prostheses are shown in *Figures 22 to 25*.

This paper illustrates the types of tabulations and correlations that can be developed from the facility record data now stored on magnetic tape. Much more information remains to be retrieved. We invite your suggestions and recommendations in selection of those tabulations that you would like to see developed.

# Ulnar Nerve Palsy Splint

by

Patricia Wilkerson, O.T.R. and Robert Keagy, M.D.

The splint illustrated is used to prevent hyperextension of the fourth and fifth metacarpophalangeal joints. It consists of a one-inch wide contoured cuff made of Orthoplast. It is fitted to the hand so that full flexion of the MP joints is allowed and the palmar arch is maintained.

The cuff is secured by velcro

FIGURE 1

which originates from the palmar portion, crosses the web space below the MP joint of the index finger, and attaches onto the dorsal portion of the cuff. Originating from the dorsum of the cuff are two posts which extend over the MP joints and terminate in semi-rings at the mid-point of the proximal phalanges of the fourth and fifth digits. The posts and semi-rings are immovable and act as a stop to the phalanges thus preventing extension of the MP joints beyond zero degrees. During flexion of the MP joints, the posts remain in position extending free.

The Orthoplast material allows adequate rigidity to maintain the form and position of the splint and yet permits sufficient flexibility so the splint does not interfere with hand mobility.

# Electrical Response and Electromyograms of Upper-Extremity Muscles in Quadriplegics

by

Gerhard M. Doerr, M.D.[1] and Charles Long II, M.D.[2]

## INTRODUCTION

This study is intended to determine the feasibility of electrical stimulation of forearm muscles in quadriplegics and their use as power to drive hand-forearm orthoses. Specifically, an attempt was made to answer the following questions:

1. What is the nature and distribution of paralysis in those muscles of interest from the orthotic point of view?

2. Can denervated (lower motor neuron) muscles be comfortably, safely and usefully electrically stimulated?

3. Can innervated but paralyzed (upper motor neuron) muscles be comfortably, safely and usefully stimulated?

The idea of using an electrically stimulated weak or paralyzed muscle to power or drive splints or braces has been applied in the past. Liberson (1) and Gracanin (2) stimulated the peroneal nerve in hemiplegics to aid in dorsiflexion

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of the foot. In this laboratory, Long (3) devised the electrophysiologic splint for use on the forearm muscles of quadriplegics. Experimental work in this area is in progress; Steinberger (4) attempts to maintain denervated muscle in functional condition by continuing intermittent stimulation with intramuscular electrodes. Surface stimulation is used routinely in several European paraplegic centers (5); continuous electrical stimulation is applied to entire muscle groups to maintain activity and muscle volume until recovery occurs or until it becomes clear that the lesion is irreversible and complete. Crochetiere (6) and others at Case Institute of Technology have investigated the feasibility of controlled electrical stimulation of paralyzed muscle. Vodovnik (7) has published data on the efficiency and pain response to different currents. It has been our early clinical impression that applications of electrical stimulation in upper extremity orthotics are not effective in providing useful prehension, even within a splint. The electrophysiologic splint earlier described in this laboratory has never been successful clinically, as reported by Long and Masciarelli. We felt it necessary to review the basic electroneurophysiology of the forearm muscles to determine retrospectively the factors which might be responsible generally for the apparent failures, and to determine whether the electrical stimulation method could be improved.

## MATERIAL AND METHOD

Eight patients with traumatic quadriplegia were chosen at random. Their injuries were as recent as three months at the time of initial testing, and as old as six years. In three patients, it was possible to repeat testing several months after initial testing. All patients had a clinically complete, permanent cord transection at the levels given in their histories. All patients had almost symmetrical involvement of both arms; therefore, all testing was done on one arm only. None of the patients had reconstructive forearm-hand surgery. All patients had good range of motion in the arms tested, except one (E. B.) who had moderate spasms and tightness, with slightly restricted passive range of motion.

No attempt was made to correlate findings with anatomic details of injury, X-rays, or method of treatment, such as laminectomy.

The following tests were done on each patient:

1. Manual muscle test: Only muscles testing fair or less were used for further electrical testing.

2. Electromyography: To demonstrate presence or absence of evidence of denervation.

3. Strength-duration and strength-frequency curves: To demonstrate presence or absence of denervation, the degree of denervation, if present, and to compare the findings with EMG evidence.

A TECA constant current chronaxie meter was used. No

effort at elaborate skin preparation was made, such as sandpapering or cleaning the skin with ether. The muscles tested were selected on the basis of their usefulness for hand-forearm orthoses. The muscles most frequently tested were biceps, extensor carpi radialis, extensor digitorum, flexor digitorum profundus or superficialis.

No attempt was made objectively to determine whether an electrically stimulated, paralyzed muscle is efficient enough to be of practical value; however, the clinical observations and impressions gained during the testing, regarding strength, consistency of response, and fatigue are reported.

The diagram (Table 1) shows the possible combinations of strength-frequency curves and EMG findings. Absence of denervation evidence on EMG with fairly normal strength-duration/strength-frequency curves indicate an upper motor neuron lesion. Denervation on EMG, with denervation type strength-duration/strength-frequency curves proves the lesion to be low motor neuron. EMG evidence of denervation combined with fairly normal strength-duration/strength-frequency curves indicates a mixed upper motor neuron/lower motor neuron lesion.

Chronaxies were considered normal at any value falling under 1 millisecond.

Following is the list of patients tested:

(Motor level indicates lowest spared segment.)

1. T. L.:
   Car accident 11–24–65, age 19
   Fracture-dislocation C5–6
   Motor Level: C6, biceps good plus extensor carpi radialis fair, otherwise zero
   Tested: Eleven months following injury.
2. T. M.:
   Diving accident 7–11–66, age 24
   Dislocation C4-5
   Motor Level: C4, biceps trace, otherwise zero
   Tested: Four months and ten months following injury.
3. D. B.:
   Car accident 9–4–66, age 20
   Fracture-dislocation C4-5

| | | ELICITED RESPONSE | |
|---|---|---|---|
| | | NORMAL | DENERVATED |
| EMG | NO DENERVATION | U M N | – |
| | DENERVATION | MIXED | L M N |

TABLE 1

| | TOTAL | U M N | MIXED | L M N |
|---|---|---|---|---|
| T.L. | 4 | 1 | | 3 |
| J.M. | 2 | | 1 | 1 |
| D.B. | 3 | | 2 | 1 |
| H.S. | 3 | | 2 | 1 |
| E.B. | 2 | 1 | 1 | |
| W.H. | 3 | | 2 | 1 |
| D.P. | 5 | | | 5 |
| P.C. | 3 | 2 | | 1 |
| TOTAL | 25 | 4 | 8 | 13 |

**TABLE 2**

Motor Level: C4, all zero including biceps
Tested: Three months and eight months following injury.

4. H. S.:
   Diving accident 6–10–63, age 15
   Fracture-dislocation C4-5
   Motor Level: C4, all zero including biceps
   Tested: Three years and five years following injury.
5. E. B.:
   Fell hitting forehead against table edge 9–2–66, age 48
   No bone injury demonstrated
   Cord injury C4 level
   Motor Level: C4-5, biceps poor minus, otherwise zero
6. W. H.:
   Diving accident 6–6–61, age 15
   Fracture-dislocation C5-6
   Motor Level: C5, biceps good minus, otherwise zero
   Tested: Six years following injury.
7. D. P.:
   Assaulted 12–10–67, age 44
   Fracture-dislocation C6–7
   Motor Level: C7-8, biceps normal, triceps trace extensor carpi radialis good, flexor carpi ulnaris trace otherwise zero
   Tested: Three months following injury.
8. P. C.:
   Car accident 5–22–65, age 22
   Fracture-dislocation C5-6
   Motor Level: C6, biceps normal, extensor carpi radialis fair minus, otherwise zero
   Tested: Three years following injury.

## FINDINGS

Table 2 shows the statistical distribution of the upper motor

neuron, mixed, and lower motor neuron lesions. In the total of 25 muscles tested 4 were upper motor neuron lesions, 8 were mixed lesions, and 13 were lower motor neuron lesions.

The chronaxie values are shown in Table 3. They fall in line with the appearance of the curves and the classification of the muscles, with two exceptions: 1) one high chronaxie in a mixed muscle and 2) too low chronaxie values in lower motor neurons muscles.

The strength-duration and strength-frequency curves are clear cut and consistent on repeated testing, immediately and at a later date. There are only a few areas really suggestive of a "kink" in the strength-duration curves; these are disregarded since these muscles are not reinnervating and the "kinks" are probably artefacts.

The motor points more or less coincided with those given in motor point charts, but this was not entirely consistent. Motor points were usually quite critical and a matter of a few millimeters. Spill-over to other muscles was often

| | TOTAL | U M N | MIXED | L M N |
|---|---|---|---|---|
| T.L. | 4 | 0.4 | | 40.0<br>50.0<br>50.0 |
| J.M. | 2<br>2 | | 0.14<br>1.8 | 10.5<br>? |
| D.B. | 3 | | 0.23<br>0.17 | ? |
| | 3 | | 0.23<br>? | 1.75 |
| H.S. | 3 | | 0.55<br>? | 0.28 |
| | 3 | | 0.25<br>0.3 | ? |
| E.B. | 2 | 0.06 | 0.32 | |
| W.H. | 3 | | 0.4<br>0.3 | ? |
| D.P. | 5 | | | 8.0<br>10.2<br>10.0<br>?<br>? |
| P.C. | 3 | 0.5<br>0.25 | | 0.76 |

**TABLE 3**

| | BICEPS | | | TRICEPS | | | E C R | | | E D C | | | FLEX. DIG. | | | F C U | | | 1st D I | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | U | M | L | U | M | L | U | M | L | U | M | L | U | M | L | U | M | L | U | M | L |
| T.L. | | | | | | + | + | | | | | + | | | + | | | | | | |
| J.M. | | | + | | | | | | | | + | | | | | | | | | | |
| | | | + | | | | | | | | + | | | | | | | | | | |
| D.B. | | | + | | | | | | | | + | | | | + | | | | | | |
| | | | + | | | | | | | | + | | | | + | | | | | | |
| H.S. | | | + | | | | | | | | + | | | | + | | | | | | |
| E.B. | | | + | | | | | | | | + | | | | + | | | | | | |
| | | + | | | | | | | | + | | | | | | | | | | | |
| W.H. | | + | | | | + | | | | | + | | | | | | | | | | |
| D.P. | | | | | | + | | | | | | + | | | + | | | + | | | + |
| P.C. | | | | | | | | | + | + | | | + | | | | | | | | |
| | | 2 | 3 | | | 3 | 1 | | 1 | 2 | 4 | 2 | 1 | | 4 | | | 1 | | | 1 |

**TABLE 4**

pronounced. This may have been aggravated by the use of a large pad for the reference electrode. Spread along nerve trunks peripherally was present, especially in testing the biceps. It was consistently difficult to obtain good strength-duration curves in the triceps and extensor carpi radialis muscles.

Most patients had no sensation and therefore no discomfort, but those with even slight sensory return complained of pain or at least discomfort, especially with increasing current. For instance, D. P. was unable to tolerate strength-frequency curve testing in the finger flexors and first dorsal interosseus. In this case there was minimal muscle reaction in the comfortable range of current, but considerable discomfort with currents capable of eliciting satisfactory contraction. Skin reddening occurred regularly in the vicinity of the motor point, especially after long testing due to difficulty with the motor point.

Table 4 shows the distribution of the lesions in the different muscles. Those muscles most useful for clinical use in orthoses, using electrical stimulation, such as biceps, finger flexors and finger extensors, were heavily mixed, or lower motor neuron lesions. It was observed that near normal chronaxia values and good strength-duration curves did not necessarily mean that the muscles were clinically useful for electrical stimulation. Many such mixed muscles showed poor muscle bulk, strength, endurance or excursion. Fatique occurred, particularly in muscles with poor response on prolonged testing.

## CONCLUSION

Lower motor neuron muscles cannot be electrically stimulated to orthotically useful function in this series of patients. Upper motor neuron muscles react easily to electrical stimulation, but are relatively rare in traumatic quadriplegia. Some mixed muscles show

fairly good strength-duration curves, sometimes almost approaching upper motor neuron muscles in their reaction. Most others are closer to a lower motor neuron muscle in their reaction. Some show relatively high chronaxie values in spite of good shape of the curve, suggesting high current requirements, possibly leading to pain and/or burns, if functional contraction levels are to be reached.

These findings strongly suggest that electrical stimulation will not form a suitable source of driving power for the paralyzed muscles of quadriplegics in general. Isolated instances of specific, stimulatable muscles may occur, but practical use of electrical stimulation in multi-joint systems seems impossible. Work on the serial stimulation of denervating muscle, beginning immediately after injury, should be pursued to see if this apparently impossible situation can be changed by stimulation therapy.

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# Telephone Services for the Handicapped

by
RICHARD A. SULLIVAN, M.D.[1] FRED H. FRIEDEN, M.D.[2] JOY CORDERY, M.A.O.T., O.T.R.[3]

As a result of a two-year study carried out by the Institute of Rehabilitation Medicine of the New York University Medical Center, a relatively under-emphasized aspect of the total rehabilitation need of the disabled patient was developed. This was an evaluation and training program to assist patients in acquiring the most efficient telephone equipment or combination of equipment which best meets their physical needs.

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## BACKGROUND OF THE STUDY

In 1965, representatives of the American Telephone and Telegraph Company and the Institute of Rehabilitation Medicine discussed the problem of providing adequate and efficient telephone service for customers who had upper-extremity disabilities. These discussions led to the sponsorship by the American Telephone and Telegraph Company of a two-year cooperative investigation into the telephone service and equipment needs of the motion handicapped.

## PURPOSE OF THE STUDY

The purpose of the study was to investigate the use of standard telephone equipment in meeting the needs of the disabled for telephone service. All of the pres-


**FIGURE 1—THE ABOVE-ELBOW AMPUTEE: A) Although the APRL hand may be used by this amputee to hold a regular telephone receiver, the weight of this hand, together with the abducted position of the arm and the necessary slight turn of the head, makes this an uncomfortable position to hold for a lengthy period of time.**

ently available equipment was tested to determine:

1. Which readily available items of equipment could be used by persons with a specific disability without the need for modifications.

2. Which equipment required only simple modifications to become usable.

3. How many disability categories would require the development of entirely new equipment to achieve independent use of the telephone.

4. Would such new equipment, if indicated, be feasible to develop on a standard basis, when compared to the number of disabled and disability categories which required such specialization of equipment, or should these requirements be met on a special basis.

It was hoped that specific equipment and specific disabilities could be matched, thus allowing easier accommodation of patients by the telephone companies. The types of disabilities were classified into broad categories, and the special needs for telephone service of the individuals so handicapped were outlined.

The results are to be published in two information manuals; the first, for the Bell Telephone Sys-

tem, to assist the Bell System representative in evaluating and equipping the handicapped customer; and the second, a Rehabilitation Monograph published by the Institute of Rehabilitation Medicine, to provide information for rehabilitation center personnel to assist them in evaluating the needs of the disabled for telephone service and making them aware of the types of equipment and modifications that are available to the individual patient.

## METHOD AND SCOPE OF THE STUDY

Three hundred and five patients representing the full range of diagnostic categories which result in upper-extremity disabilities were extensively evaluated and studied. They were first tested using the regular available telephone equipment following the normal pattern of use. The patients were tested at the hospital, at home and at their places of employment.

Each patient was evaluated in detail for his residual functional motion, his performance using the different types of equipment, and his vocational and social need for independent use of the telephone. In addition, the individual techniques which the patients had developed to give them independent use of the telephone were evalu-

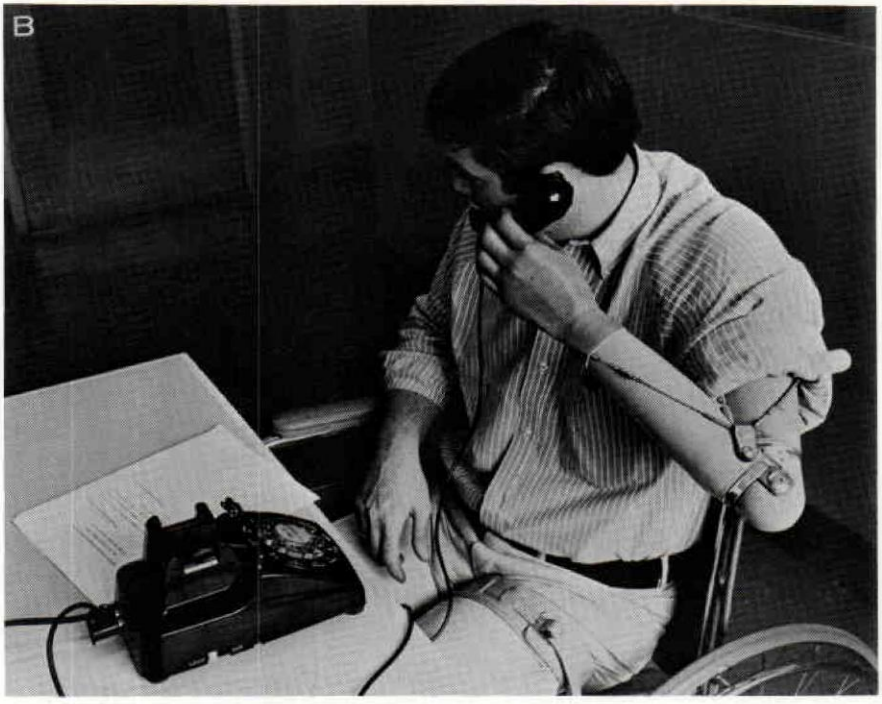


**FIGURE 1—B) The Wear-it-or-Hold-it Handset is lighter in weight than the standard receiver. But its use is also precluded by the abducted position of the arm and the excessive rotation of the head necessary for placing the ear and mouth to the set.**

ated and, if feasible, were used as an evaluation technique and instruction method for similarly disabled patients.

Each item of equipment was evaluated for its physical requirements for normal operation. This information was correlated with the data received from the evaluation of the functional motion and the ability to perform of the patients with a variety of upper-extremity weaknesses and deformities. From this data, some criteria was established whereby items of equipment could be matched to the disability of the individual patient.

## RESULTS OF THE STUDY

Upon completion of the study, the following general conclusions could be reached:

1. It is technically possible to provide a usable telephone installation for almost any person with upper-extremity disability by combining appropriate telephone equipment with the patient's self-help devices (prosthetic hooks, activities-of-daily-living splints, tenodesis splints, etc.). The available Bell equipment was found to have the potential, unmodified or with only slight modifications, for meeting the needs of all but a very few.

The study disclosed that stand-

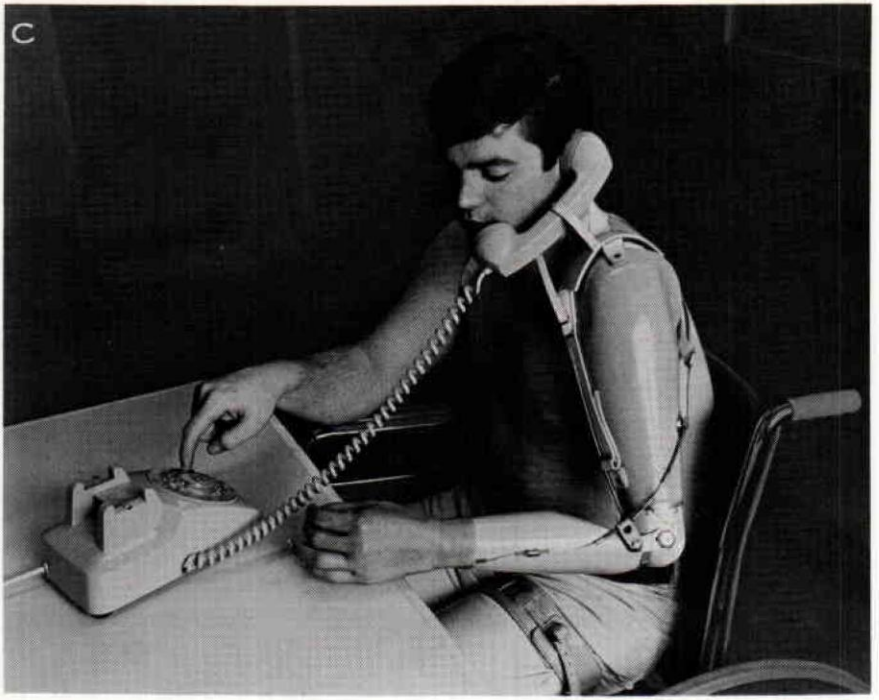


**FIGURE 1—C) A shoulder rest attached to a regular receiver provides appropriate assistance to the user of an APRL hand. The shoulder rest will not displace when it can lodge against the proximal edge of the socket.**

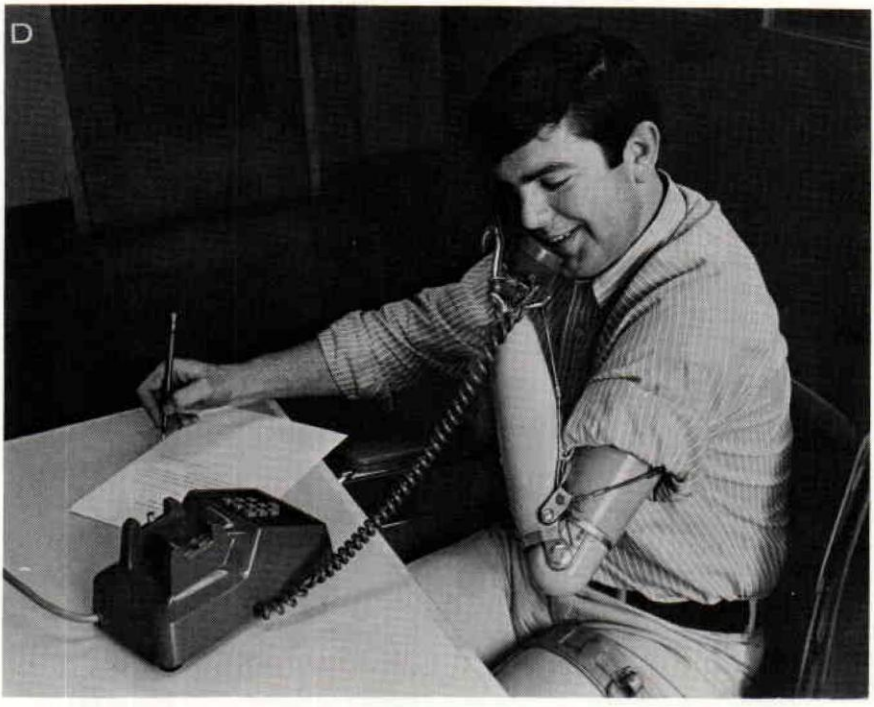


**FIGURE 1—D) Holding a standard receiver in a prosthetic hook to the ear on the same side necessitates an abducted position of the arm. Holding the handset in the distal curve of the hook and placing it at the opposite ear allows a more comfortable position for a prolonged conversation. The handset must be placed into the hook by the other hand.**

ard equipment could be used in four distinct ways:

—in the normal manner, without the need for special devices or instrument positioning.

—in an unconventional way, by the repositioning of the apparatus. For example: The quadriplegic who finds rotary dialing less difficult to use by turning the telephone set around.

—with minor equipment modifications. For example: A lever placed over a pinch-operated turnbutton switch thus allowing operation of the switch by lever pressure rather than the more sophisticated and often physically lost pinch mechanism.

—using the equipment for a purpose other than which it was originally designed and used. For example: Using a line button as an "off-on" switch allows call connections and disconnections merely by pushing the button. This allows the patient to leave the relatively heavy receiver permanently off the cradle.

2. Though the ability to use a telephone independently depended to a large extent on the choice of equipment appropriate to the patient's physical function, the technique employed to operate the equipment was found to be of equal importance.

3. The study gathered impor-

tant information about the equipment per se, such as the amount of pressure needed to operate the individual levers and buttons, the shapes and sizes of these levers and buttons, and the weight and shape of the telephone equipment which needs to be lifted and grasped by the patient. Such information should be helpful when future equipment is designed for use either by normal or disabled persons.

4. Many patients required devices to hold the receiver to the ear. Two types of holding arms were found to be of value during the study. This type of equipment is not ordinarily furnished by the telephone companies but


**FIGURE 2—SPEAKERPHONE TELEPHONE: A) G. H. is a spinal cord quadriplegic. The high level of his injury left him with the ability to move his arms only by shoulder elevation. With the aid of balanced forearm orthoses and ADL long opponens orthoses with attachments, he is able to use the control stick of his motorized wheelchair (1), to type, to operate a tape recorder (2), an electric page turner (3), and to use a Speakerphone telephone. A Speakerphone consists of a transmitter unit and a loudspeaker unit (the dial is provided by its associated regular telephone). The phone is switched "on" and "off" by pressing buttons on the transmitter. The workplace is arranged for maximum efficiency and accessibility from a wheelchair.**

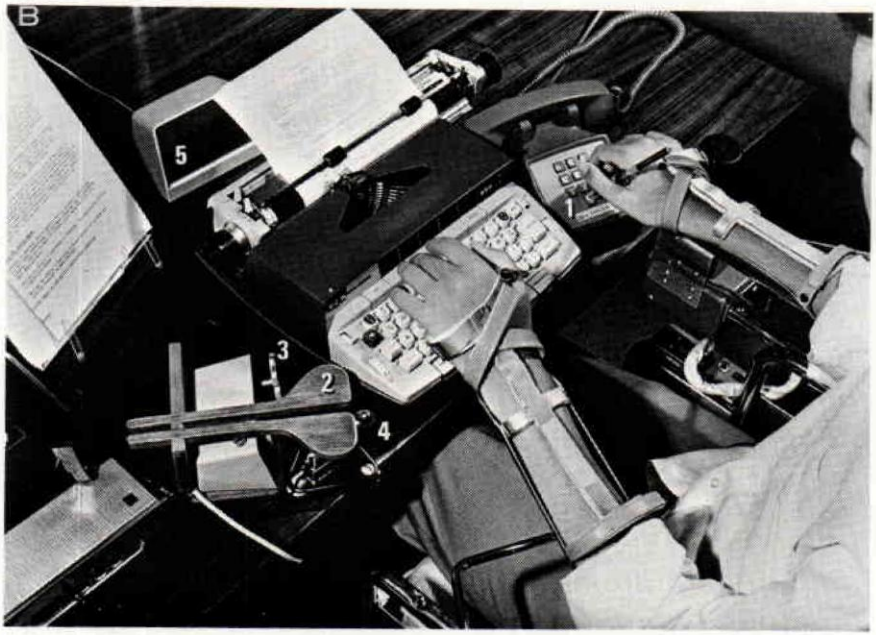


**FIGURE 2—B) G. H. can exert a downward force of 1½ lbs. by the pencil secured to his right hand and 1 lb. by the pencil in his left, so the push button Touch-Tone dial (1) was located under his right hand. Although the Speakerphone "on-off" buttons on the transmitter can be depressed by a pencil after they have been fitted with enlarged tops, a paddle-lever device (2) into which the transmitter fits is more appropriate for G. H. The device reduces the operating force required and, by providing a wide surface to contact, allows G. H. to approach and operate the telephone most easily. The volume-control knob has been replaced by a wheel (3) to allow its adjustment by pencil. The microswitch for the tape recorder (4) may be seen in front of the Speakerphone transmitter. The loudspeaker (5) of the Speakerphone incorporates no controls and could be placed out of the immediate work area.**

is available through commercial sources.

5. While it was possible to classify the types of disabilities into broad diagnostic categories, there was little correlation between these diagnostic categories and the types of equipment which the patients found to be the most useful and serviceable. The variations in physical function, even among patients with the same diagnosis, clearly showed that each patient must be evaluated individually as to his needs for telephone equipment.

## DISCUSSION

In general, it can be said that all persons who are able to communicate orally should be able to initiate and terminate a telephone call when properly evaluated for the types of equipment that best compensates for their physical deficit. All patients who can grasp or hold a receiver have the potential to use a rotary dial, with the exception of those who have a visual perceptual problem or those who cannot sufficiently control their involuntary tremors and athetoid movements.

The great majority of patients will be able to dial without assistance as pushbutton (Touch-Tone®) service becomes more universally available.

Successful use of a rotary dial requires muscle strength in the arm (or neck and trunk), equipment which offers a minimum of resistance, the employment of an appropriate technique which best corresponds with the patient's disability, and the training in the development of this skill. Fewer severely disabled are able to use a rotary dial as opposed to the more easily managed Touch-Tone system. Where no form of dial is usable because of the severe loss of function, an arrangement often may be made whereby the telephone operator can be reached through one simple motion and the calls then made verbally with the assistance of the operator.

A basic problem which the study hoped to overcome through the publication of the manuals was that when a disabled person or those concerned with his rehabilitation called the local telephone company for assistance, there was no guide or information available to the companies to help them assist these people with their individual problems. Frequently, the only recourse was to call in the engineers of the Bell System to devise a special installation for the one disabled person. This was a time consuming and inefficient process, and one that resulted in extra expense both for the patient and to the Bell System. This study has shown that there is far less need for elaborate special installations than had been assumed. Simple modifications of standard equipment and a better understanding by the telephone company representative of the disability of the patient should suffice in most instances.

It was found that standard Bell System equipment was available to answer many of the problems about which rehabilitation workers have long been aware. For example, holding arms to hold the receiver to a patient's ear have been commercially available for some years, but the methods used to connect and disconnect calls have been crude. Often heavy metal bars or "kiddy-proof" guards were used to keep down line buttons. This study showed that the line transfer switch on a two-line telephone or the line buttons on a six-button telephone can be used for this purpose and solve this problem.

A receiver which weighed only 8½ ounces was found to be more suitable for some patients. It was used in many instances where the regular 11½ ounce receiver proved to be too heavy.

Some of the newer items of equipment, such as the lightweight headset and the Card Dialer were found to provide the answer to cases that could not previously be helped.

Because the full range of Bell System equipment was evaluated, information is now available to enable the disabled person to choose telephone equipment suitable to his needs. As mentioned above, this information is to be distributed throughout the Bell

System in the form of a manual. It is designed to assist the Bell representative to fully evaluate and provide for the needs of the disabled customer. For use in local rehabilitation centers, a monograph will be published by the Institute of Rehabilitation Medicine in September of 1968 and this will outline an evaluation technique and full equipment survey which should prove invaluable to the occupational therapist and vocational counselor.

The Bell System telephone equipment used in the study is similar in function to the telephone equipment employed by the many independent telephone companies. Thus the findings of the study are broadly applicable throughout the United States and not just in the territories served by Bell System operating telephone companies. And there are well established routines whereby copies of Bell System printed material—such as the information manual on service for the handicapped—can be purchased by independent telephone companies.

## SUMMARY

A two-year cooperative study was conducted at the Institute of Rehabilitation Medicine of New York University Medical Center under the sponsorship of the American Telephone and Telegraph Company to evaluate the telephone equipment available and its ability to be successfully used by the handicapped. It was found that it is technically possible to provide telephone service to all disabled persons with neuromuscular involvement or absence of all or part of the upper extremities. The study resulted in the publication of two manuals which provide information that allows the needs of the disabled person for telephone service to be evaluated and met, both in the community and in the rehabilitation centers of the country. It also resulted in the perfection of an evaluation technique for rehabilitation centers under the direction of the Occupational Therapy department to functionally evaluate the needs of the patient and prescribe the most efficient telephone equipment for his use.

# Direct Forming of Below-Knee Patellar-Tendon-Bearing Sockets with a Thermoplastic Material

by

The Staff[1]

## INTRODUCTION

Research and development groups especially in Toronto, Miami, and New York have recently been using thermoplastic material which when softened can be applied on the body to form orthotic or prosthetic sockets. Sockets for both fracture braces and artificial limbs have been made with these materials.

Noted has been the particularly successful employment of tubes and sheets made from a material called POLYSAR* X-414 synthetic rubber, a resin available from the Polymer Corporation of Sarnia, Ontario, Canada. Johnson & Johnson of New Brunswick, New Jersey, has made this thermoplastic available in sheet form. Recently, Delford Industries of Middletown, New York has been extruding tubes made from Polysar X-414; such tubes are now available from the U. S. Manufacturing Company of Glendale, California.

[1] This article was submitted by Mr. Anthony Staros, Director of the VA Prosthetics Center, New York, N. Y., on behalf of his staff who performed the research and development work underlying the procedure described.

* Registered Trade Mark of the Polymer Corporation Limited.

Presented in this article is a description of the use of tubes made from this particular synthetic balata (rubber) in direct forming of sockets on below-knee amputation stumps. An evaluation of this procedure and of the material is now being conducted by the Committee on Prosthetics Research and Development, National Academy of Sciences—National Research Council. In addition, five clinic teams in the United States are fitting patients following the described procedure. New York University's Prosthetic Research Study is evaluating the use of the thermoplastic tubes in forming below-elbow sockets directly on amputation stumps. It is expected that these evaluations will proceed expeditiously and that sometime during 1969 results can be made available to clinicians and practitioners throughout the world.

Mr. Henry Gardner of the VA Prosthetic Center presented a demonstration of direct forming at the 1968 National Assembly of the American Orthotic and Prosthetic Association and it was felt desirable to support that presentation with the material presented here. Eventually, after the evaluations described above are completed, step-by-step manuals will become available. Hopefully, university and college educational programs will consider presenting this or a similar technique in their curricula.

In the meantime we should like prosthetists and orthotists to give some consideration to the information contained in this article. We believe that this procedure or one like it with the same material can expedite the provision of prostheses for patients who now sometimes have to wait an excessively long time for a limb. The prosthesis as described seems to offer improvements over present types of temporary prostheses; we also believe that there are possibilities for using this type of device in "semi-permanent" and definitive prostheses. Most important, however, is the fact that amputee rehabilitation may be realized at a much faster rate.

## SIGNIFICANCE OF THE METHOD

Our experience suggests that use of tubes made from Polysar X-414 synthetic rubber in the direct forming of below-knee sockets will expedite prosthetic care of patients. The presently described method of direct forming can be used at least for temporary below-knee sockets in conjunction with a metal skeletal (pylon) structure. Moreover, it seems possible to use the same plastic in forming sockets for definitive prostheses, provided a reasonably simple cosmetic treatment can be applied to the skeletal structure.

With cases for whom so-called temporary prostheses may be used, it is often desirable to render a cosmetic treatment to the limb either while a permanent or definitive prosthesis is being formed or for the period when prescription of a definitive limb is questionable. The method of fin-

ishing described here might be used for such situations.

Some researchers are interested in the possibility of using the socket-forming method described here, or a modified method with the same material, to form sockets at some point in the immediate postsurgical prosthetic fitting routine. We are certain that attempts will be made to use this particular synthetic rubber or a material like it at the time of the first rigid dressing change. Indeed several research groups are interested in the possibility of using this material in tubular form for the first rigid dressing. Careful and very deliberate technique development is certainly required before such applications become routine.

The possibility therefore exists of developing a thermoplastic rigid dressing which could gradually be modified to a below-knee weightbearing socket for early ambulation. Then it can be subsequently altered as needed for the definitive socket. The same "pylon" structure can be used throughout, from time of surgery up to and including employment of the definitive prosthesis. Because of the ability to alter the contours of a thermoplastic socket through post forming, and also because the "pylon" structure contains alignment adjustability, practitioners may eventually have available a reasonably adjustable prosthesis as amputee stump changes take place and as amputee capability improves. The prosthetist can thus alter the biomechanics of the prosthesis as needed through changes both in fit and alignment. And later during the use of the definitive prosthesis, the ability to adjust both fit and alignment would be beneficial in allowing simple corrections to overcome some of the socket comfort problems normally seen in clinics.

Thus, forming sockets directly on amputation stumps is a potentially valuable procedure offering possibilities for improved socket fit, easier socket modification, and substantial reduction in fabrication time. The techniques may also be more readily mastered than those used for fabrication in the conventional manner, as when an intermediate plaster-of-Paris replica must be formed.

The direct-forming process depends on the use of a material which: (a) is plastic at temperatures moderately above ambient but requires reasonably high temperatures to soften subsequently; (b) is easily worked under conditions found in most limb shops; (c) has a "poor memory", i.e., once set, it should not change its shape; (d) exhibits minimum "creep" or deformation under load even at temperatures slightly above body temperature; (e) is non-toxic; (f) has a reasonable strength-to-weight ratio; and (g) is reasonably flexible in its "hardened" state.

## THE MATERIAL, POLYSAR X-414

POLYSAR X-414, a synthetic similar to natural rubber, pos-

sesses most of the necessary properties listed above. At temperatures between 160 degF and 180 degF it becomes plastic. It doesn't give up its heat readily and thus can be applied to the amputation stump within a minute or two after softening. It remains reasonably plastic after its surface temperature drops twenty to thirty degrees. When plastic, it exhibits extraordinary cohesive properties.

Laboratory tests indicate that after it cools and becomes nonplastic, it maintains its shape even under stress and subsequent heating to temperatures 120 degF. Other tests have shown that conventional fastenings, rivets, and screws are adequately retained so that it is possible to use all conventional components and accessories with sockets made using this particular synthetic rubber.

Clinical findings indicate that the sockets will remain durable provided excessive heat exposures are avoided. Leaving the limb in the sun, in the trunk of a car on a hot day, or leaning against a house radiator can cause distortions. Amputees should be cautioned about such situations.

Excessive exposure to perspiration may also cause erosion of the material after about a year. Normally, stump socks will act as adequate barriers.

The synthetic rubber is quite flexible, not presenting the rigid, unyielding socket chamber typical of most plastic laminates. Indeed, this characteristic of the thermoplastic used in this procedure may be one of its major advantages.

## THE DIRECT-FORMING METHOD

Using tubes made from this resin, forming of a socket directly on the stump is reasonably simple. One step with this material is equivalent to the whole process of fabricating a conventional socket, thus making it unnecessary to: (a) make a plaster-of-Paris wrap cast; (b) pour a positive cast; (c) modify the positive cast; and (d) laminate. These steps with modified stump replicas are certainly error prone, based on hand-formed contours. It seems desirable to eliminate these and the lamination process in forming artificial limbs.

Regardless of the material used, obtaining a perfect replica of the below-knee stump is extremely painstaking. Even if it were simple, such a replica would not represent the best biomechanical shape for sound weight-bearing and control. When casting the stump, consideration must be given not only to the distortions caused by pressures upon the passive stump mass but also to the special requirements of weight-bearing and control during ambulation.

When using conventional hand-casting procedures, the stump is subjected to pressures of unknown magnitude and distribution yielding a contour which may provide the proper forces for prosthesis control and support of body weight in the socket. However, when the stump is subjected to equal pressure as in the method described here, deformations will

take place as a function of the resistive characteristics of the underlying tissues. The bony tissues of the stump will tend to protrude more as the soft tissues are compressed. (The pressure on the fleshy tissues will tend to reduce any edema present; the socket contour so determined will then maintain some control of edema.)

By employing uniform pressure application, maximum advantage can be taken of the more stable (less resilient) areas of the stump by a concentration of the higher portion of the required support and control forces in these areas, on surfaces such as the ligamentous structures of the patella and the condylar flares of the tibia. Then, during ambulation, the horizontal control forces acting about the stump will be combined vectorially with the vertical support forces. The resultant forces act roughly normal (at 90 deg) to the broad sloping condylar surfaces of the stump, a desirable condition which minimizes the shear forces.

Experimentation with various pressure-casting methods has been carried on for several years. In 1958, Mr. Paul Leimkuehler of Cleveland, Ohio used a vacuum system for casting below-knee stumps. His system was based upon the "dilatancy" principle. In 1960, Mr. Colin McLaurin then at Northwestern University experimented with a hydraulic method of pressure casting. In 1963, Mr. T. Meyer of Detroit, Michigan also used a hydraulic method of casting. All of these methods required the use of a canister or rigid pressure chamber and a casting stand. The complexity of the techniques discouraged further development. With the availability of materials such as Polysar X-414, a renewed effort was made to develop an adequate pressure-casting method. This led to the design and application of a pneumatic pressure system.*

The pneumatic pressure-forming apparatus presented here is designed to control the external pressures used to form the plastic socket over the below-knee amputation stump. Although wide-scale clinical results of pressure molding are not yet available, limited experience suggests that the pneumatic pressure method is a great improvement over current socket forming and casting methods since (1) pressures are better controlled, (2) variations in hand and finger pressure of the prosthetist are eliminated, (3) replicas or sockets need very little modification, (4) the system can be used with the patient seated or even supine, as on a postsurgical recovery table, and (5) the results are reproducible.

In this procedure, a synthetic rubber tube is heated to a temperature of 180 degF and pulled over the protected stump (Fig. 1). The pneumatic pressure sleeve, when placed over the plastic socket material and inflated under

* Actually a (partial) vacuum system yielding the same pressure differential could be used as well.

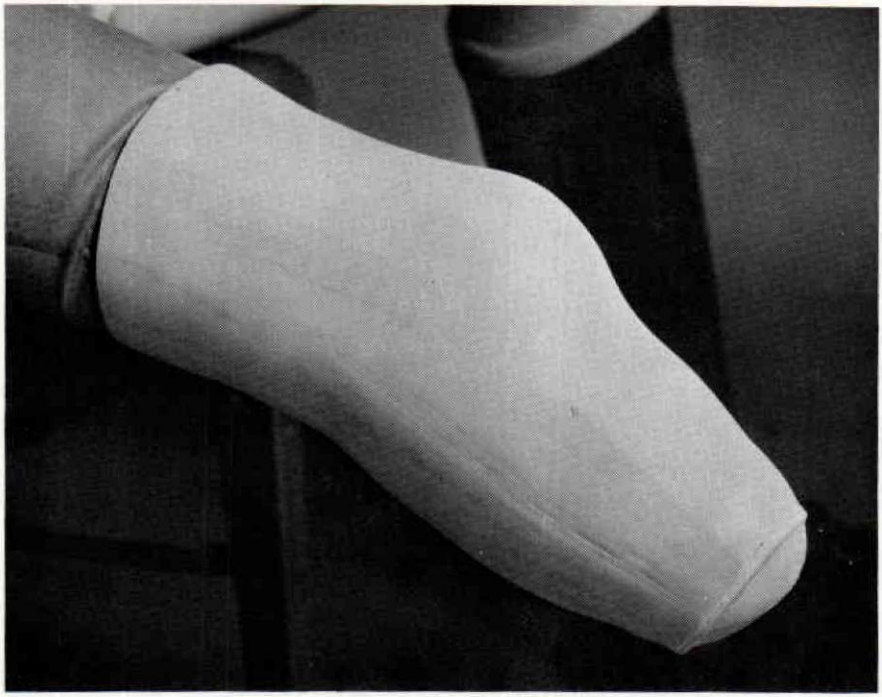

**FIGURE 1—Softened Plastic Socket Material on Stump Before Pressure Application.**

a controlled pressure, applies the compression needed to form the plastic material intimately about the stump contours.

## FORMING EQUIPMENT

The pneumatic pressure sleeve is a double-walled cone of small taper which is large enough to fit over the largest knees and stumps. The inner and outer walls are connected at the top forming an air-tight closed-end conical sleeve 18 in. long (Fig. 2). Air is introduced into the pressure sleeve chamber by means of a bicycle pump. An air gauge with valve is inserted in the line for observation and control of the pressure magnitude. When air is introduced into the sleeve, the diameter of the outer wall enlarges only slightly with expansion further restricted by a 5-ply wool stump sock placed over the pressure sleeve. The inner wall however moves inward freely thereby tending to close the conical opening and applying pressure on the synthetic rubber tube on the stump.

## PREPARATION OF THE PATIENT FOR SOCKET FORMING

A careful evaluation of the stump must be conducted prior to forming the socket. All stump characteristics, especially conditions which require special considerations for socket comfort,

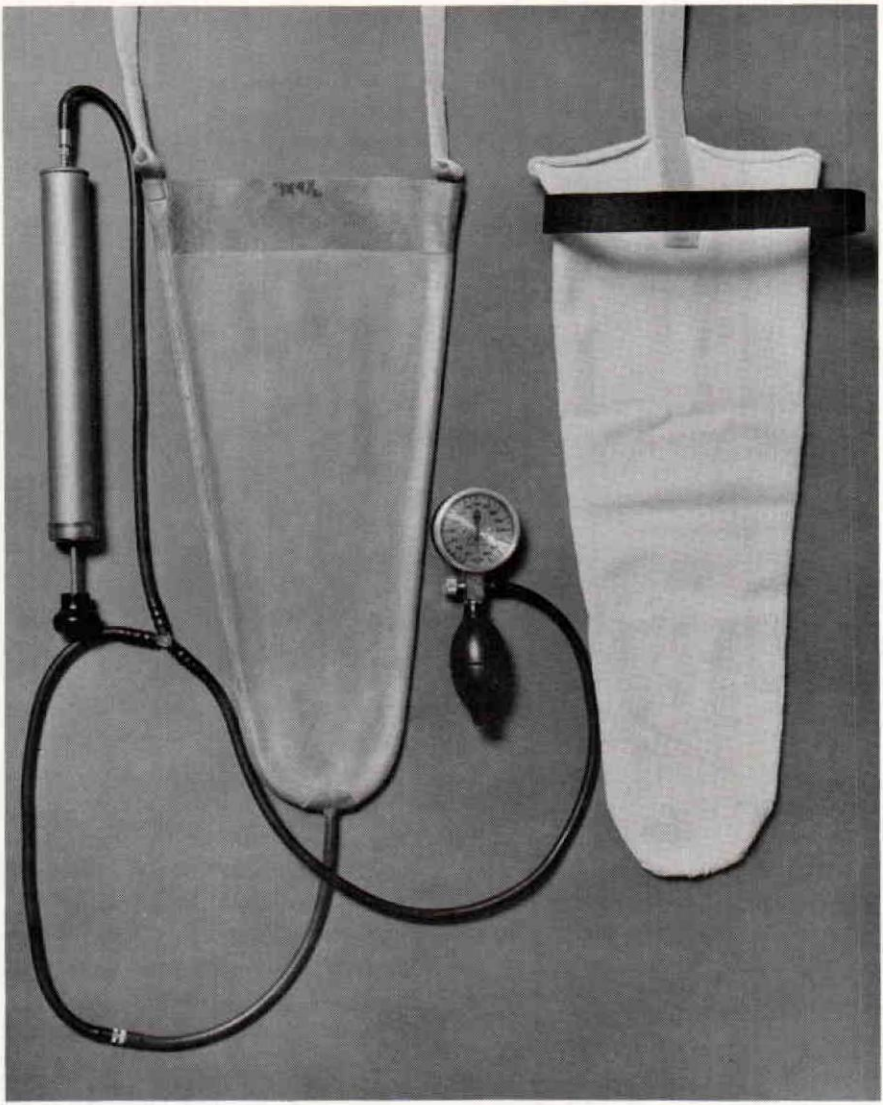

FIGURE 2--Pneumatic Pressure Forming Apparatus. On the right, the rubber inner sleeve over which the synthetic rubber tube is placed. On the left, the pressure sleeve with pump and gauge.

must be noted. Other usual prosthetic data such as the measurements required for the fabrication of the prosthesis are also essential.

With the patient seated, a lightweight cast sock is applied snugly (Fig. 3). To maintain tension, the top of the sock is clamped to elastic straps equipped with Velcro loops for attachment to a mating section of Velcro hooks fixed to the back of the patient's

chair. The clamps are attached medially and laterally at the top of the sock.

The stump end is capped with a ½-inch thick soft-felt pad to form an extension (Fig. 4). The edges of the pad are skived; it is also split radially for easy contouring over the stump end. A series of pads ranging in diameter from 3 to 4½ inches in ½-inch increments will accommodate the various stump-end sizes. Regardless of the size, an uncut center of at least one and one-half inches diameter is left.

The pad should not be perfectly circular. A slight anterior projection should extend beyond the circular contour to cover the anterior distal tibia. The anterior border of the cap is then positioned to provide a distal continuation of the tibial crest line and form a relief for the end of the tibia.

A strip of felt cut to form a tibial crest relief is positioned from the superior border of the tibial tubercle extending distally *over the capped end of the stump* (*Fig. 5*). The portion of the tibial relief pad over the tubercle is made approximately 1¼ inches wide and tapered down to a ⅝-inch width for the entire length of the tibial crest relief. All edges are carefully skived. The felt pads are attached to the cast sock with medical adhesive. A second lightweight cast sock is pulled snugly over the tibial relief and extension

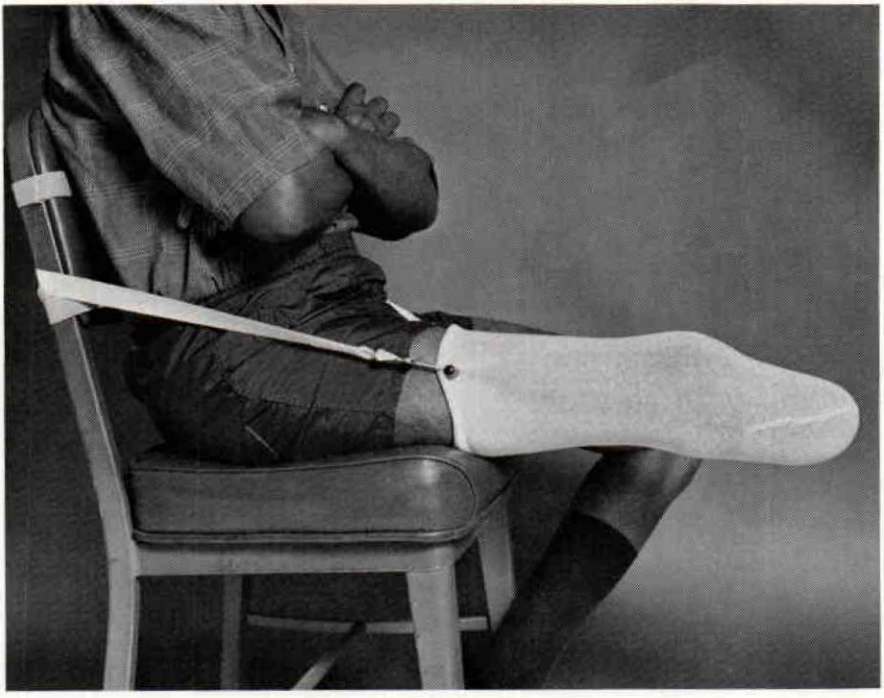

**FIGURE 3—Application of Lightweight Cast Sock.**

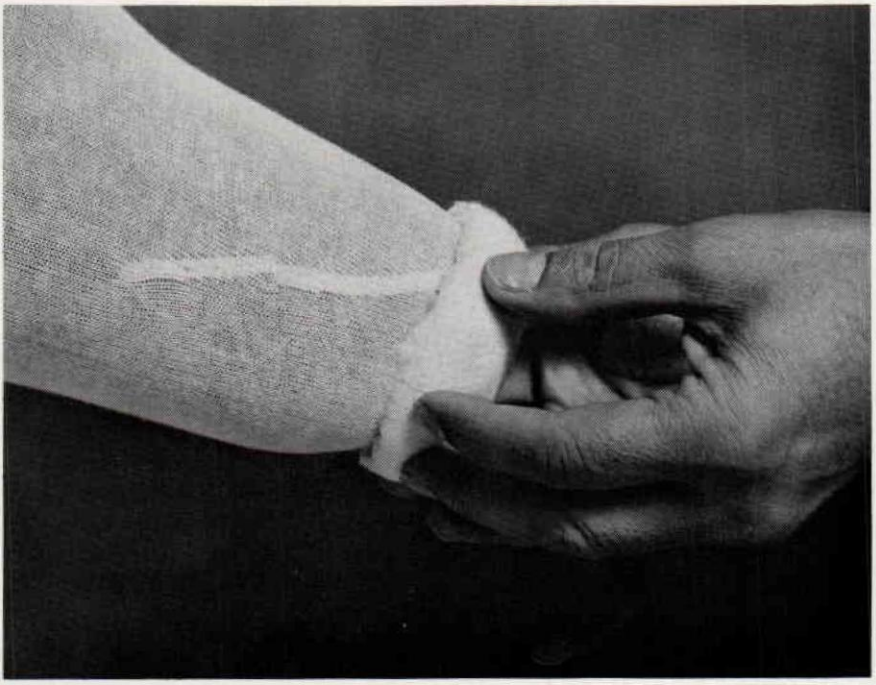

FIGURE 4—Application of the distal pad. Medical adhesive spray is used to form the bond of pad to cast sock.

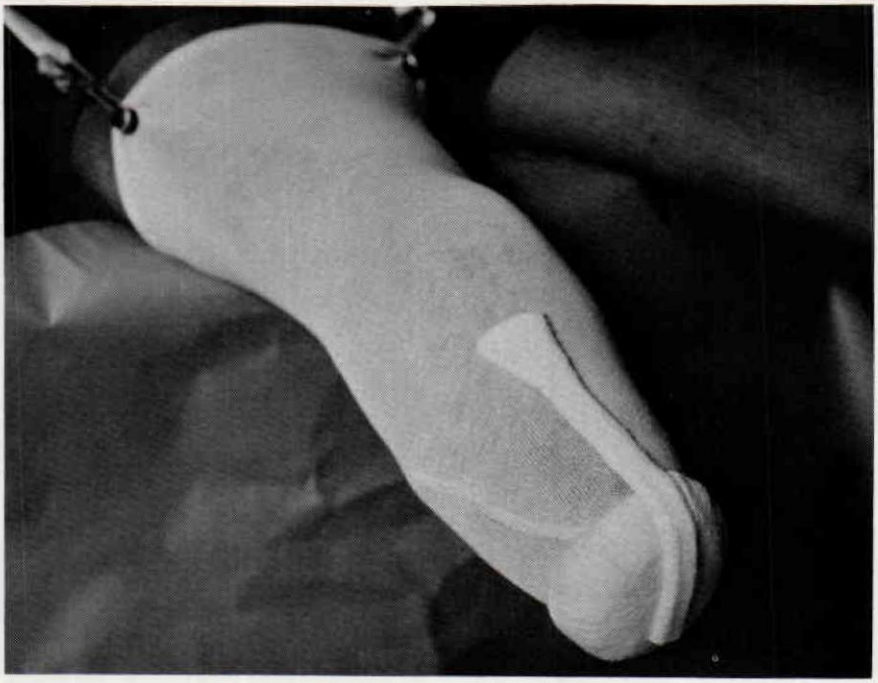

FIGURE 5—Placement of the Relief for the Tibial Tubercle and Tibial Crest.

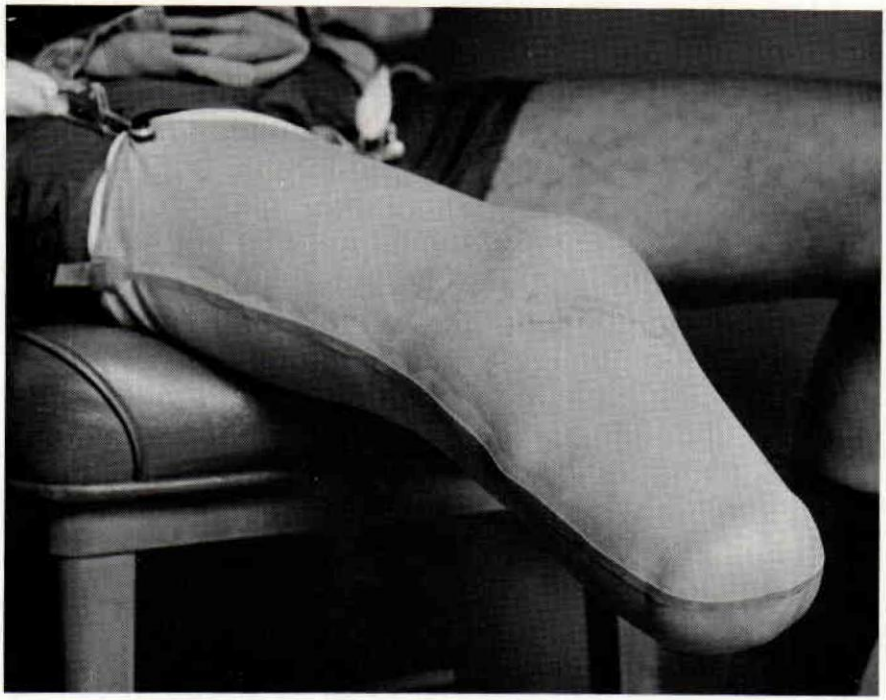

**FIGURE 6—Stump with Rubber Sleeve Applied.**

and fastened in the same manner as the first sock.

A rubber sleeve is then pulled over the stump (Fig. 6). The top edges of the rubber sleeve are attached to the waist belt to hold the rubber and stockinette under a constant tension. The end of the rubber sleeve must be pulled up into firm contact with the stump end. At this point, the stump is covered by two lightweight cast socks and the rubber sleeve, a total thickness equivalent to that of the five-ply wool stump sock the patient is expected to wear with the socket.

The anterior-to-posterior knee measurement is recorded at the level of the patellar tendon using the VAPC knee calipers (Fig. 7). The medial-to-lateral dimensions of the epicondyles of the femur are measured in the same manner. These dimensions are useful in determining the accuracy of the socket. The maximum depth of the patellar ledge is determined by the measurement made at this time.

## SOCKET FORMING

A suitable section of ¼-inch wall synthetic rubber tubing is selected. Its length should be approximately 1½ times the distance measured *from the top of the knee to the end of the extension cap* (*Fig. 8*). The diameter of the tube selected should be

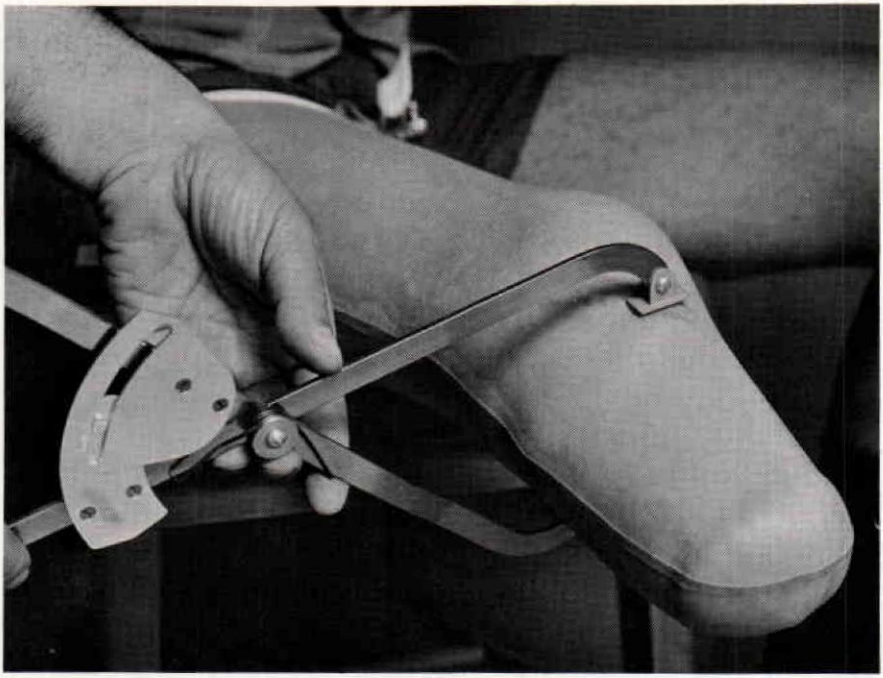

**FIGURE 7—Measuring Stump Dimensions with the VAPC Calipers.**

one-third of the mid-stump circumference.

The tube end is capped prior to direct forming (Fig. 9). The end of the tube is made plastic with a heat gun and shaped into a round cylinder. When cooled, the end of the tube is sanded even on a disc sander. The sanded surface of the tube end is then cleaned with trichloroethylene to promote bonding. Also the surface of a flat piece of ¼ inch synthetic rubber is cleaned so that it may be bonded to the tube end. The flat section is heated in an oven or with a heat gun to approximately 180 degF. The tube end and the flat section are placed together which produces a bond. A ⅛-inch hole is drilled in the center of the tube cap to permit air escape during direct forming. The cap is trimmed to match the outer contours of the tube. The inside surfaces of the tube are carefully cleaned to remove all plastic dust created by cutting and drilling. *When heated, the dust will cohere to the inner walls causing undesirable irregularities in the surface.*

The capped tube thoroughly free of dust is softened by immersing it completely in water heated to a temperature of 180 degF. or just under the boiling point for 4 to 6 minutes. *The inner walls of the heated tube must be prevented from touching since they will cohere instantly.* This may be prevented by standing the tube on the end in the water container.

After heating, the tube is removed from the container. The exterior surface of the rubber sleeve on the stump and the interior surface of the thermoplastic sleeve are lubricated with I.M.S. silicone spray.

Part of the tube is preshaped into a cone prior to placing it over the stump. With the hands together (palms out), the upper half of the tube is stretched into a cone to facilitate slipping it over the knee (Fig. 10). With a light grip on the tube sides (with the palms of both hands), the tube is pushed onto the stump and carried up over the knee (Fig. 11).

The upper socket borders are trimmed with a pair of bandage shears leaving the posterior borders approximately ½ inch higher than required, for later rolling out of the material to form a relief for the ham strings. The anterior socket border is cut above the superior pole of the patella leaving the medial and lateral walls 1 in. higher (Fig. 12). It is desirable to wait a few minutes, permitting the temperature of the tube to drop slightly, before pulling the pressure sleeve over the plastic tube.

The pressure sleeve has two straps attached to its proximal border. The straps are made from the "loop" part of the Velcro, and when passed around behind the patient's chair, are mated with a "hook" strap of Velcro, affixed to the back of the chair. To main-

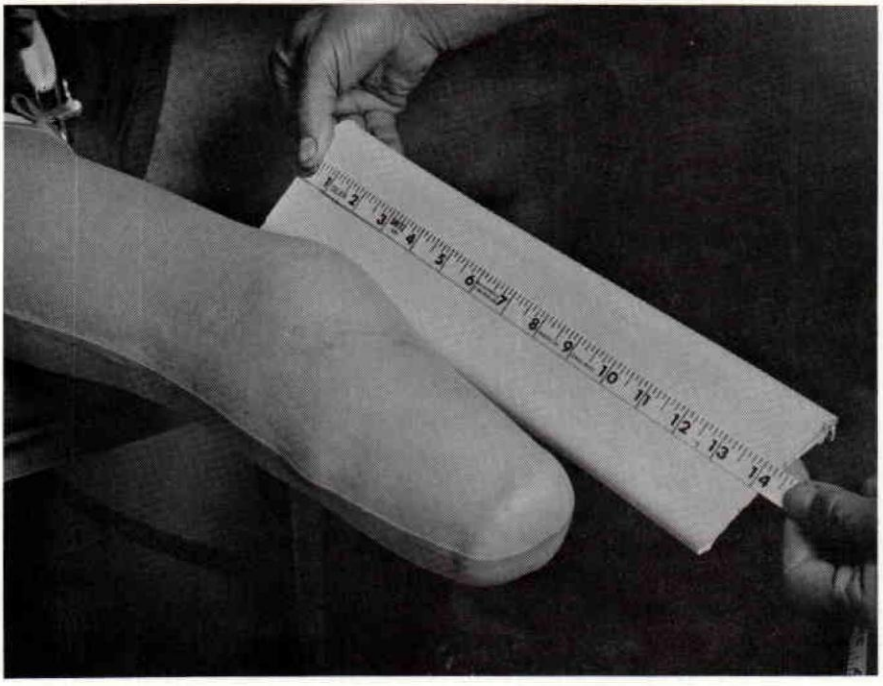

FIGURE 8—Selecting the Proper Length of Tubing.

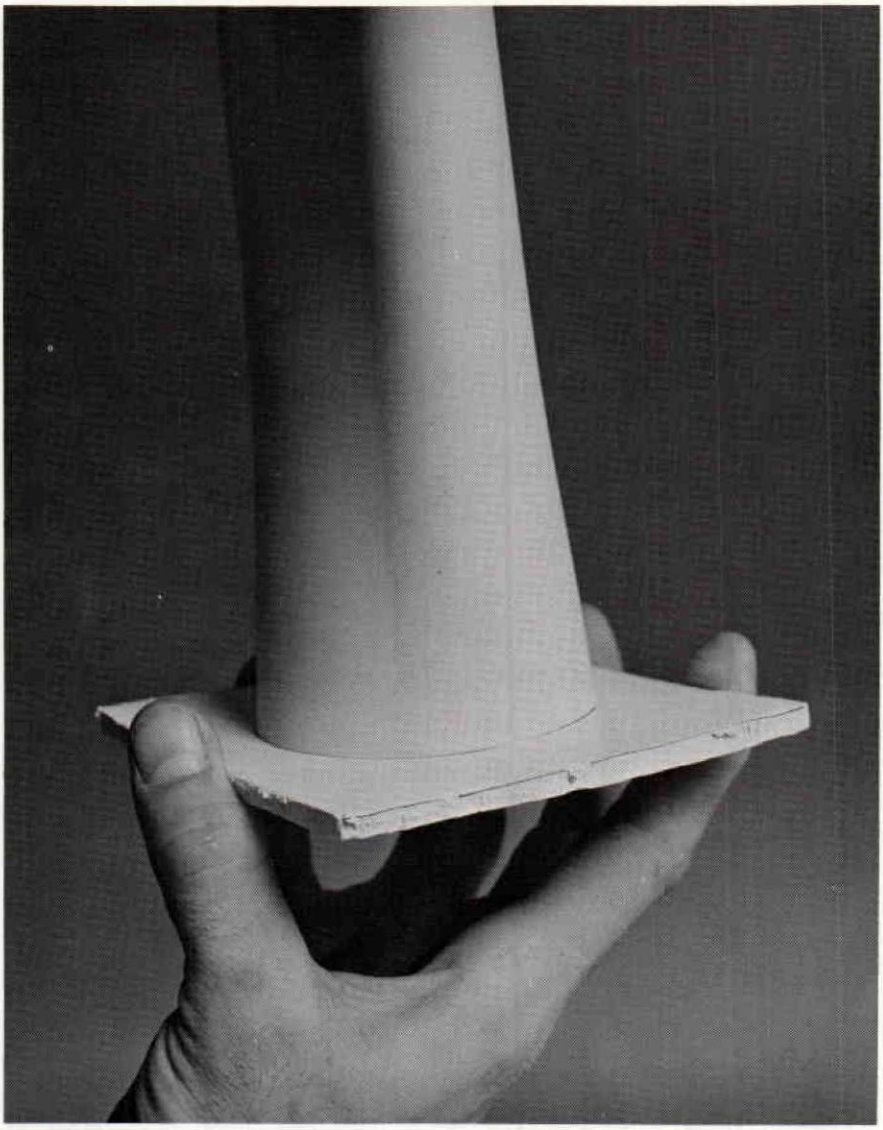

**FIGURE 9—Tube end capped prior to direct forming.**

tain tension on the strap, the patient must be seated as far back as possible on the chair.

The conical pressure sleeve is pulled up over the stump and knee to touch the end of the capped tube. The pressure sleeve straps are placed around the chair back and fixed to the mating Velcro. The pressure sleeve cover (a 5-ply wool stump sock) is pulled snugly over the pressure sleeve and fixed by straps to the Velcro on the back of the chair. A loop of Velcro material is wrapped around the top of the stump sock

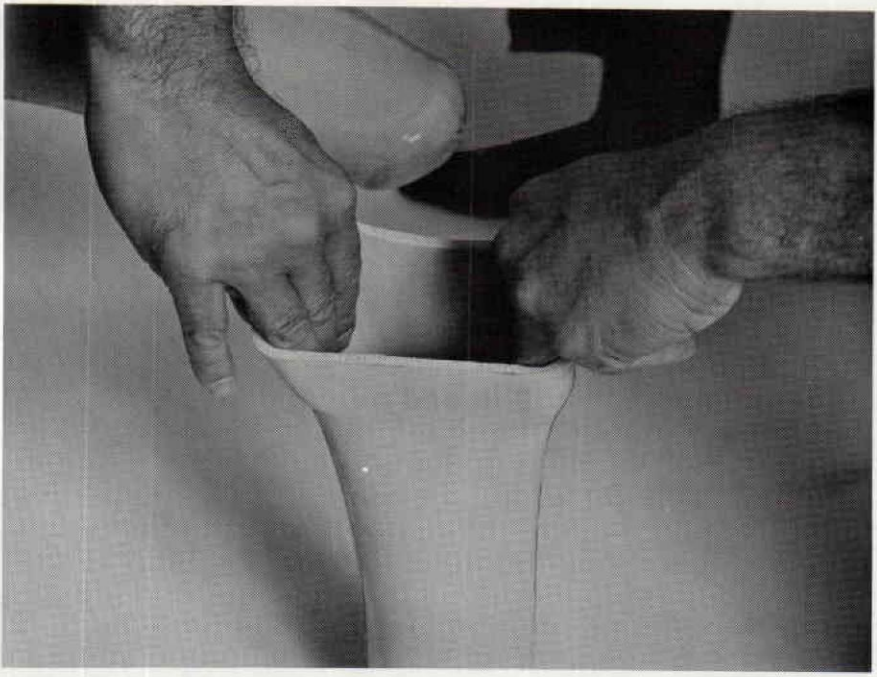

**FIGURE 10—Stretching One End of the Tube into a Conical Shape.**

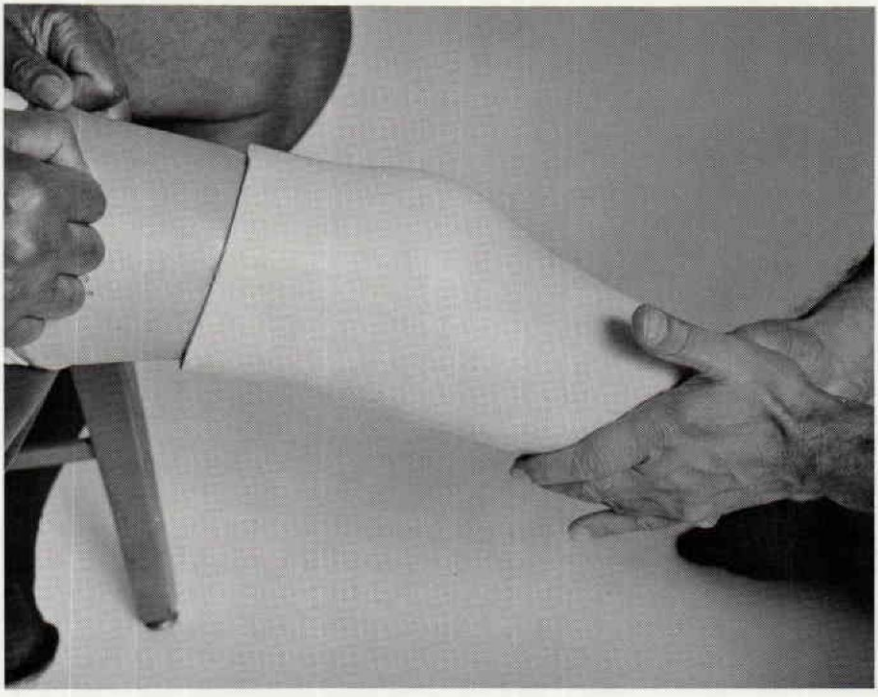

FIGURE 11—Application of the Tube to the Lubricated Sleeve on the Stump.

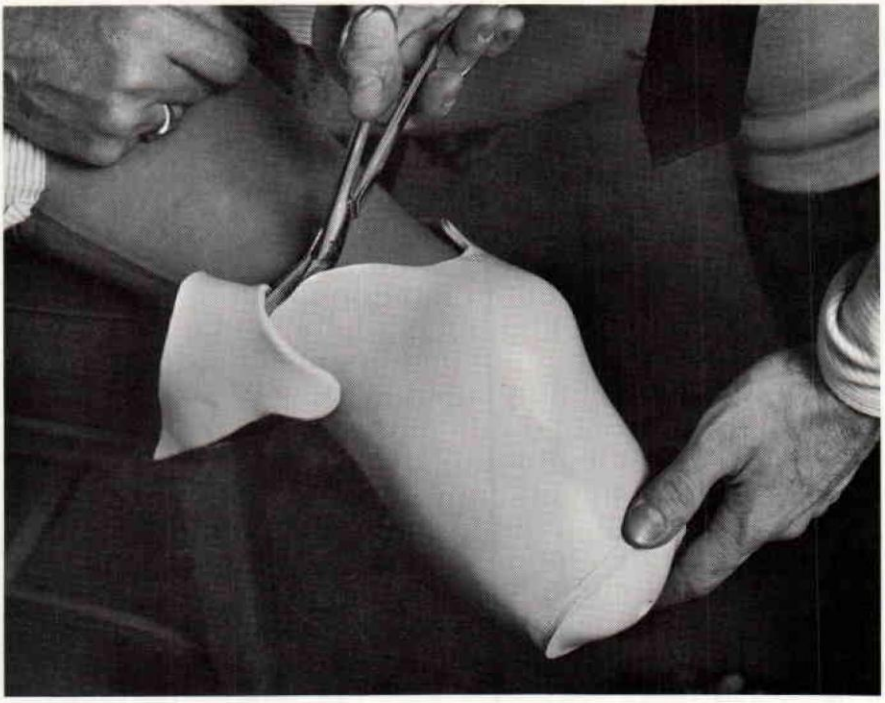

**FIGURE 12—Trimming the Upper Socket Borders Before Pressure Molding.**

to hold the sock snugly against the thigh. The pressure sleeve is then inflated (Fig. 13). Pressure of 1½ psi or 80 mm Hg is maintained for approximately 15 minutes before removal of the sleeve and the socket.

An adjustable pylon is prepared with a wood socket attachment block 1½ inches thick and 3 in. in diameter. The wood block is tapered to form a slightly smaller diameter around the bottom. Then the wood block is fastened permanently to the pylon with bolts and cement.

Before the socket is mounted upon an adjustable pylon with a foot for dynamic alignment and walking trails (Fig. 14), a 6-inch long section of 3 in. diameter plastic tubing is heated and bonded around the lower socket following the same procedure used in bonding the tube end. Before bonding, the end of the thermoplastic tube is stretched to provide a generous clearance about the lower socket. Inadvertent touching of the tube to the socket will result in a weld preventing the proper placement of the tube on the socket. This placement is critical to achieve the planned initial socket flexion between socket and pylon.

The plastic tube extending distally from the socket is fitted over the wood pylon attachment block. The tube is taped tightly to the wood block and permitted to cool. Any excess tubing extend-

ing below the wood can be trimmed while the plastic is still soft (Fig. 15). After it hardens, the tube is fastened permanently to the wood block with four wood screws set through the plastic into the wood at 90 deg. angles to one another.

## SOCKET MODIFICATIONS

A heat gun is used to modify the socket. To focus the output of the heat gun, a metal cone is made to fit over the end of the gun (Fig. 16).

The hand should be placed inside the socket against the surface to be modified. Heat is directed to the *immediate area from close range* until the heat is sensed by the fingers through the socket wall. *Large areas should not be heated nor should heat be directed against the socket for a prolonged period of time.*

Excessive temperature will cause the plastic to boil and discolor. When molding for a pressure point, one finger should press from inside the socket, and the surrounding areas should be supported on the outside of the socket with the fingers of the other hand. After the molded area has cooled sufficiently to retain its shape, the socket should be chilled with cold water or refrigerated for a short period of time to re-set the plastic. *Caution must be exercised to avoid heating the entire*

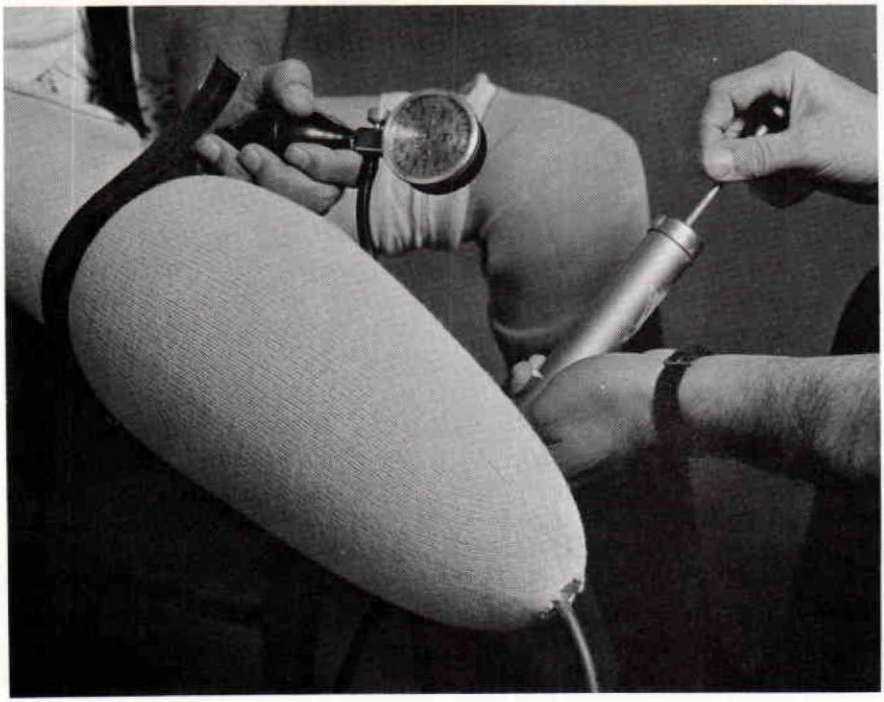

**FIGURE 13—Application of Pressure to Pressure Sleeve Which Has Been Covered with a 5-Ply Wool Stump Sock.**

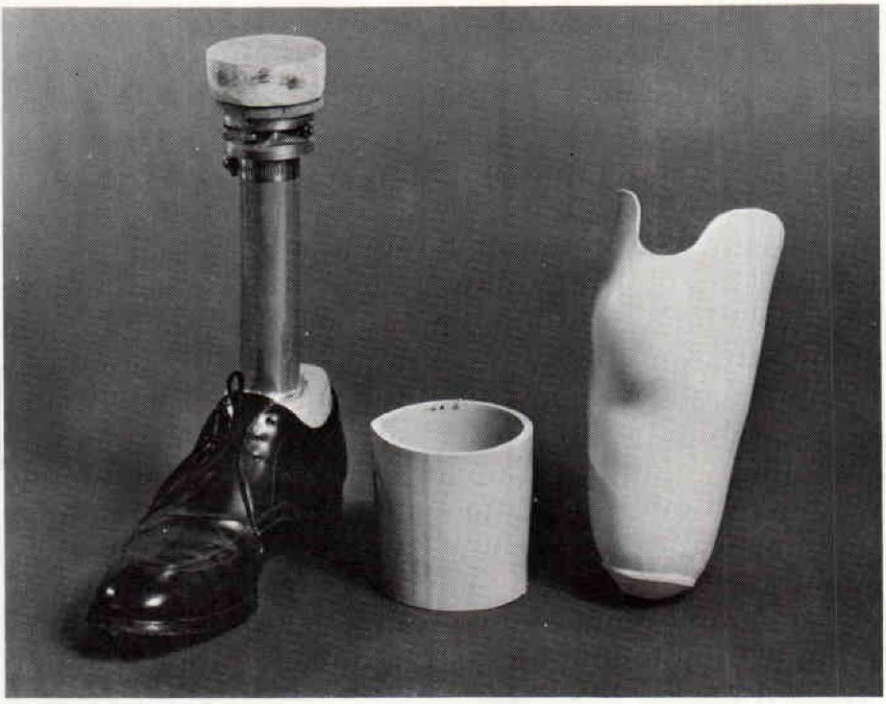

FIGURE 14—Socket and Pylon with Connecting Plastic Tube.

*socket by holding the heat gun near the intended spot to be molded. The heat should be concentrated on the one spot until the pressure applied with the fingers on the hand inside the socket causes the material to yield.*

A similar procedure should be followed if a more pronounced patellar-tendon ledge is required. The previously obtained A-P measurement will determine the depth of the patellar ledge. For patients who have previously worn prostheses, the A-P measurements obtained by caliper are used to determine the depth of the ledge. For patients who have had recent amputations, the patellar-tendon ledge is not molded to the maximum depth in one adjustment. Instead 3 or more adjustments at intervals of one month should be made until the recorded A-P dimension is reached.

The posterior socket border is heated and rolled out to form a smooth radius for comfortable knee flexion (Fig. 17). The posterior socket level is maintained approximately ½ inch above the patellar tendon level.

Several kinds of PTB suspension can be provided with this socket. The socket can be trimmed at the regular PTB level and a separate cuff used above the knee. Or a suprapatella and strap suspension combined with supracondylar suspension can be provided as follows: the patient's stump is covered with *a* cast sock and *a* snug fitting

rubber sleeve. The medial and lateral socket walls above the level of the upper border of the patella are softened by holding the socket bottom up in hot water to this depth. The socket is placed on the patient; then the patient is seated in a chair with his knee flexed at approximately 45 deg. and his stump pushed firmly into the socket. The plastic is molded firmly against the thigh over the condyles (Fig. 18).

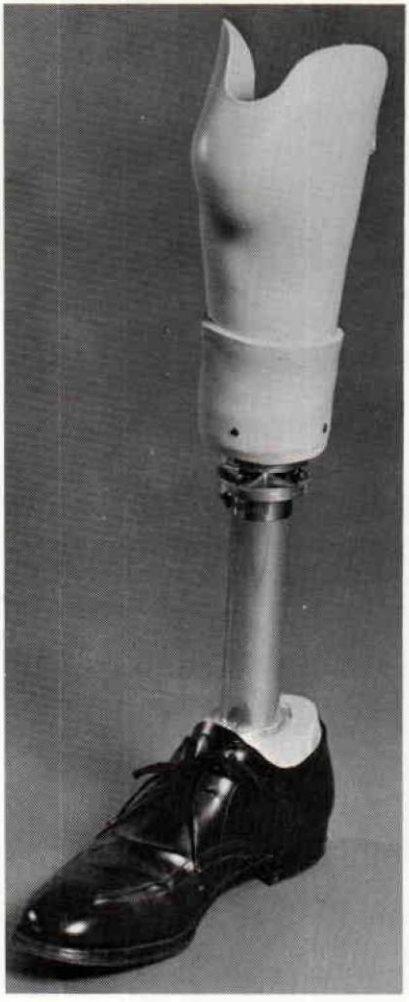

**FIGURE 15—Socket Joined to Pylon by Bonded Plastic Tube.**

If during the molding process a line of demarcation develops between the soft and hard areas, that edge should be warmed with a heat gun.

To accommodate the suprapatellar strap, two rectangular slots with their long axes parallel to the socket's long axis are placed in the socket on each side of the quadriceps tendon and at right angles to the intended path of the strap. To increase the effectiveness of the suprapatellar strap, the elastic strap is positioned so that its inferior border passes across the upper edge of the patella (Fig. 19). The slots should be angled slightly forward at the bottom to permit the strap to rest flatly against the anterior of the thigh.

After the patient has been fitted and the prosthesis aligned, the bottom of the socket chamber should be foamed to obtain a total-contact fitting. Three ⅛ in. holes are drilled through the socket wall where the extension was blended into the stump contour. A P. V. A. cap is formed over the stump sock-covered stump end. A foam mixture is prepared and poured into the socket (Fig. 20). The patient's stump is inserted into the socket and then the patient stands in the socket until the foam has set. The foam mixture may vary, depending upon the type of stump and condition of the distal tissues. Usually, a combination of foam and R.T.V. rubber is used. To avoid difficulty in

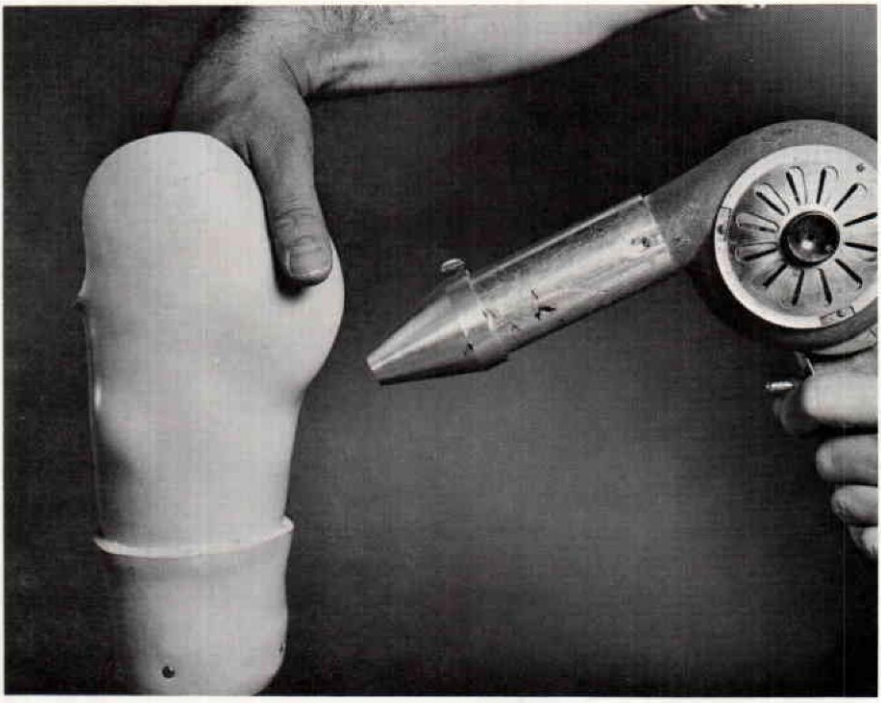

**FIGURE 16—Heat Gun with Modified Cone for Control of Heating Area.**

quickly inserting the P.V.A.-covered stump into the socket, the patient should wear a light weight sock and the P.V.A. should be powdered.

## SHAPING AND FINISHING

A semi-rigid foam leg shape can be made from pre-fabricated sections of a B.F. Goodrich Co. foam product called Koroseal "Spongex."

Beginning at the level of the patella, a paper pattern is cut to fit around the socket at this level. The pattern is traced upon the first foam section (Fig. 21). The foam is carefully sanded to form a hollow for the socket. It is necessary to obtain a tight "gap-free" fitting of the foam to the socket. Best results are obtained from a *slight stretch fit*. For this, the foam is heated in an oven at 180 deg. and then placed over the socket.

To cover the remaining part of the pylon, a foam block is cut long enough to match the distance between the bottom of the foam surrounding the socket and the top of the foot *plus* ¼ *in.* A hole is made through the length of the foam large enough to receive the pylon tube. Since the foam is semi-rigid, the cut out areas for the alignment coupling and ankle plug of the pylon are made slightly undersize to form a *snug fit about the pylon* (*Fig. 22*).

A ½-inch hole is bored trans-

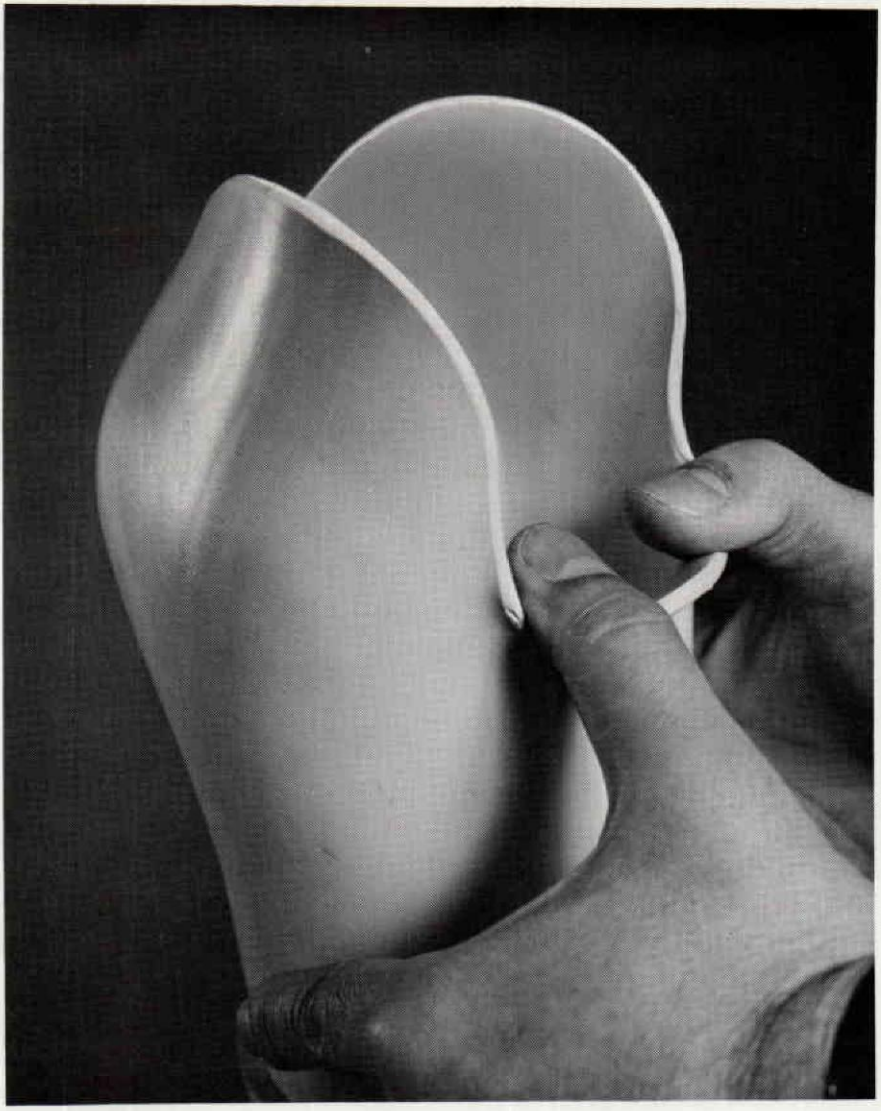

FIGURE 17—Rolling out the softened posterior socket wall.

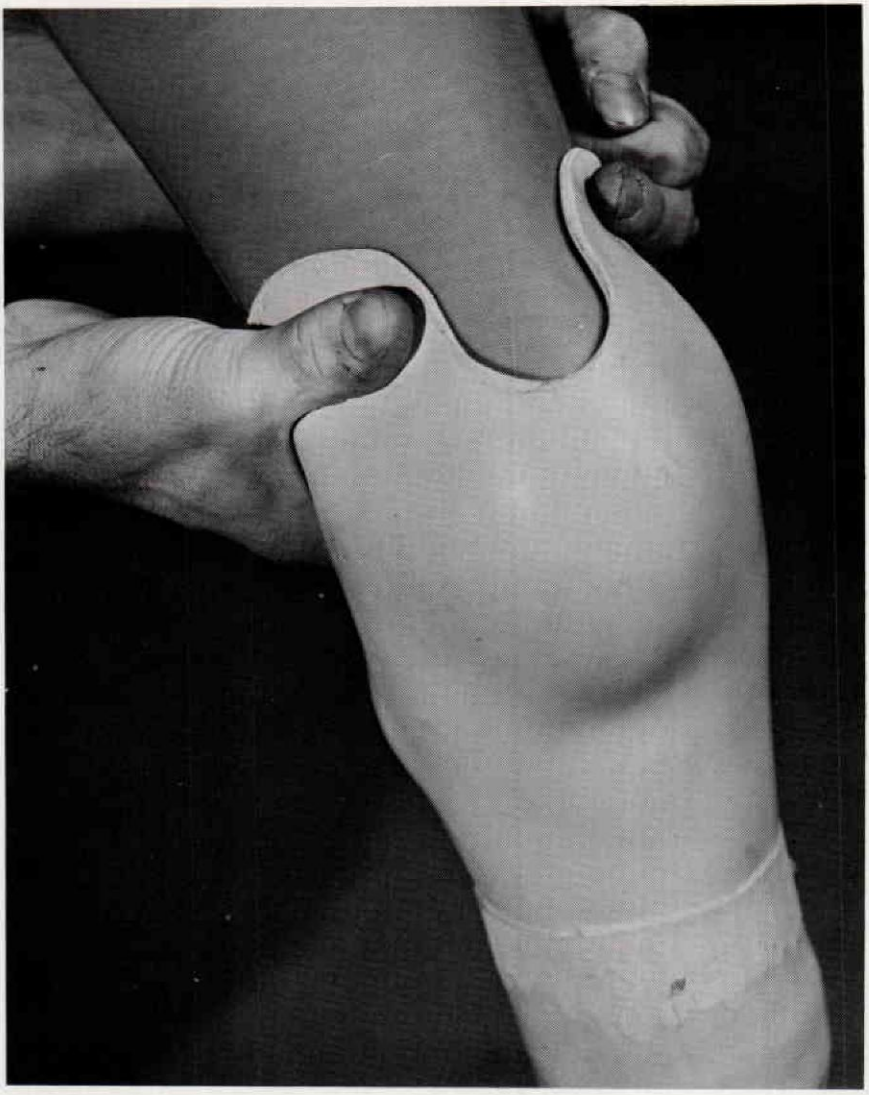

FIGURE 18—Molding the Supracondylar Contours of the Upper Socket.

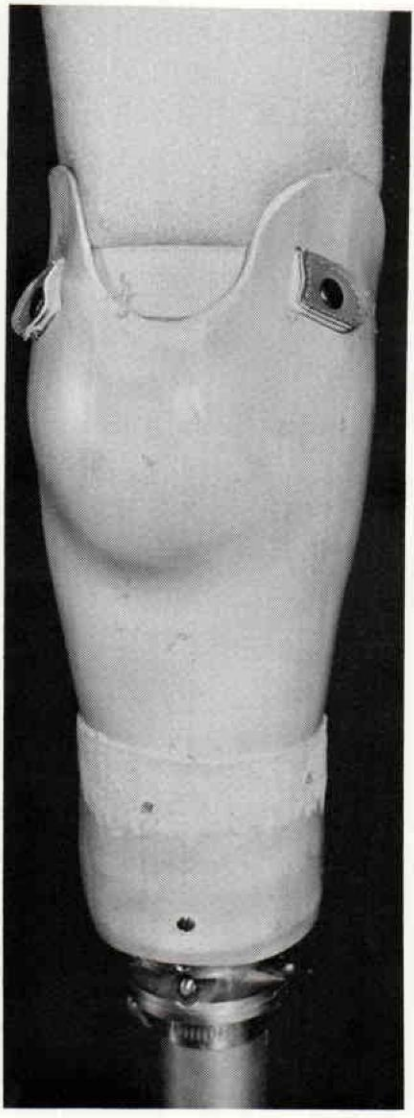

FIGURE 19—The Suprapatellar Strap Rests Firmly Against the Quadriceps Tendon.

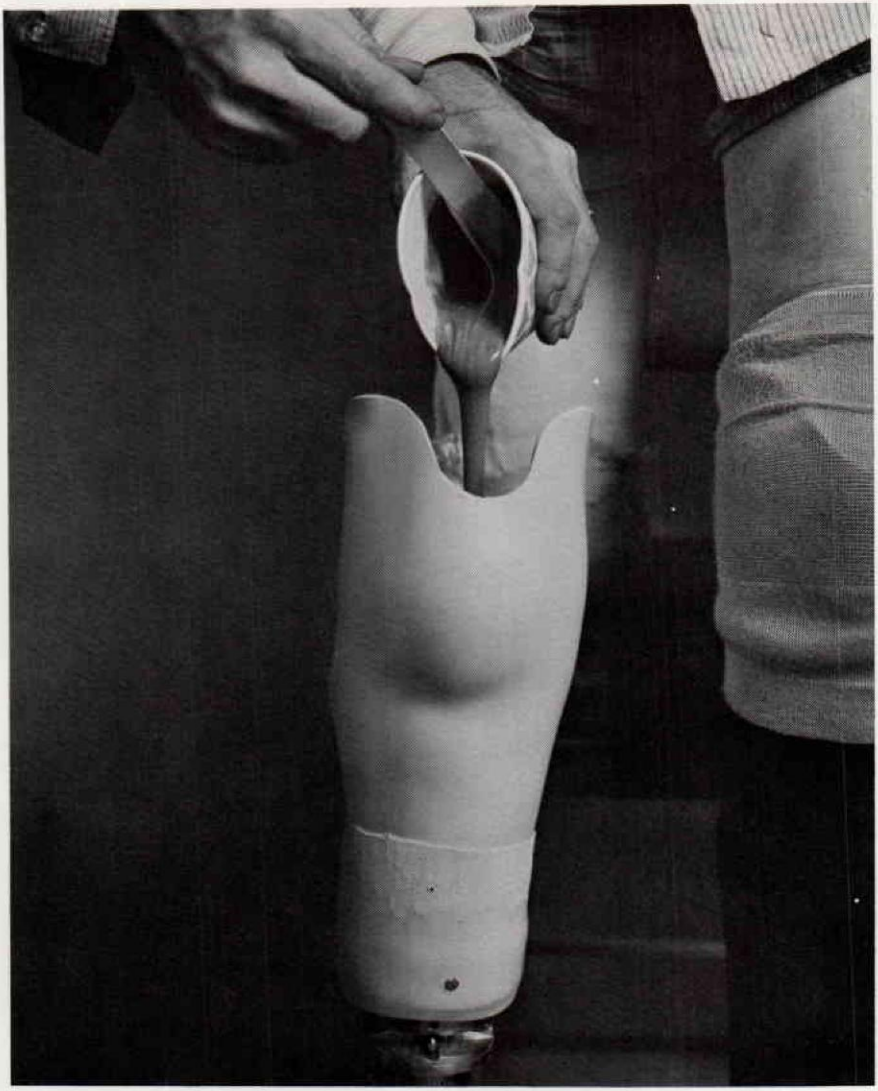

FIGURE 20—Pouring Foam Mixture to Form Total Contact Socket Bottom.

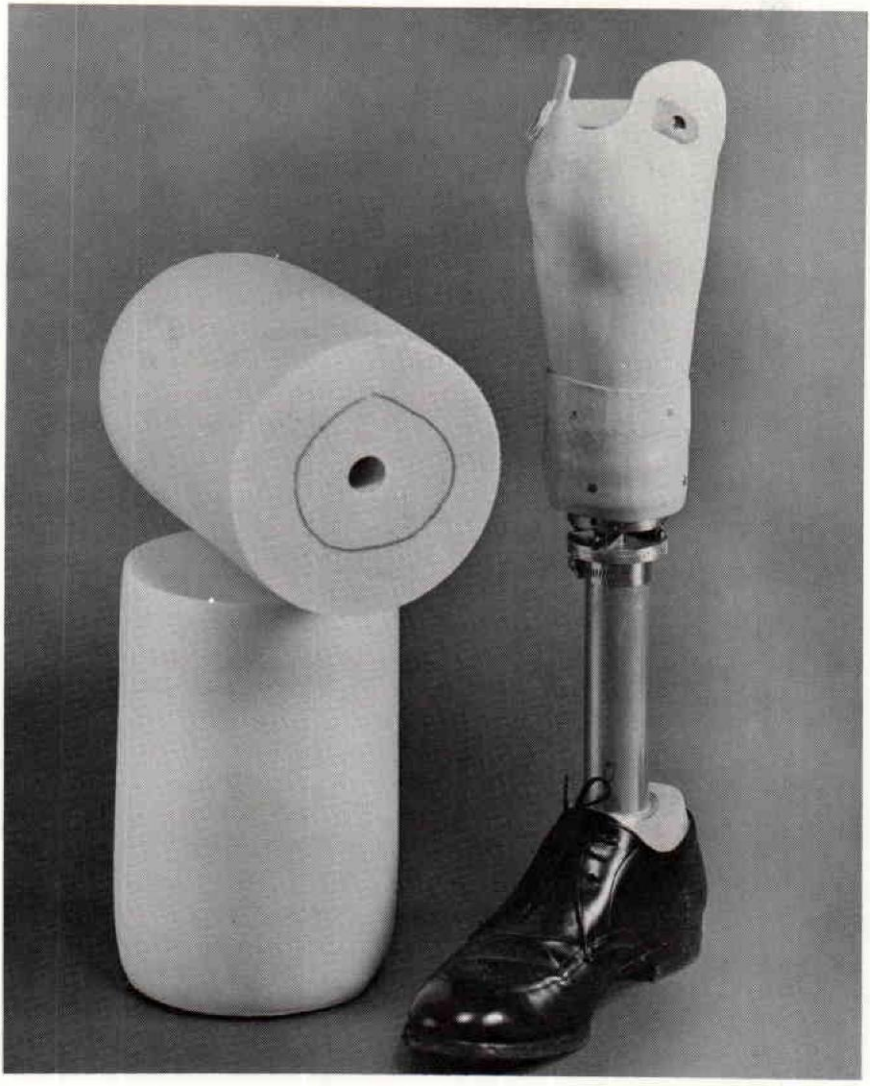

FIGURE 21—Foam Blocks Prepared for Fitting Over the Pylon and Socket.

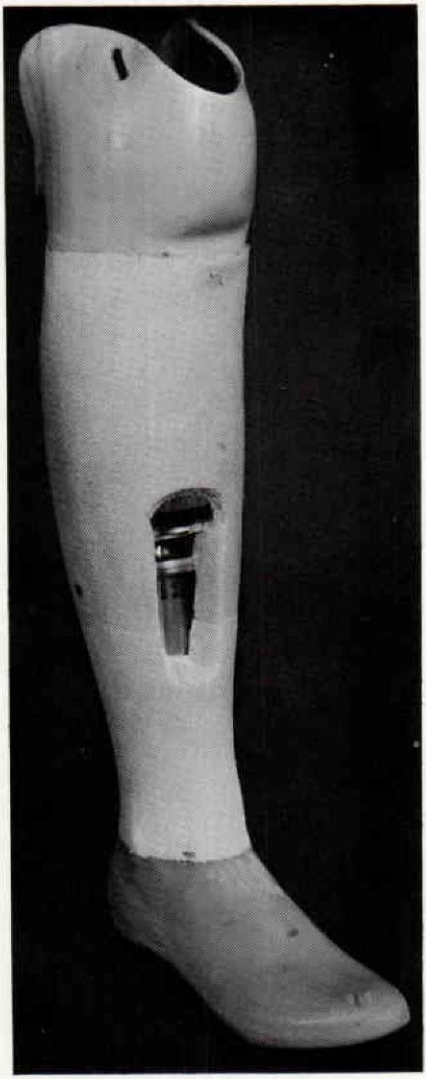

FIGURE 22—Cutaway of Shaped Foam Cover Showing Close Fitting to Pylon and Socket.

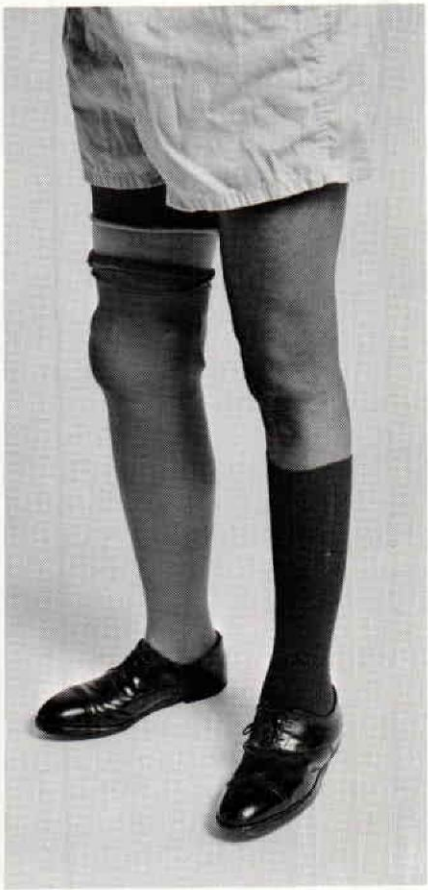

FIGURE 23—Finished Prosthesis with Stocking over Foam.

versely through the foam block to permit entry of a screw driver to fasten the tube clamp. The bottom foam block is not glued to the top foam block. Compression of the extralength foam block between the socket base and the foot will prevent any movement of the foam and permit easy removal for alignment adjustments.

Shaping is done by a band saw or knife and final sanding with a drum or cone sander. A flexible polyurethane coating over the foam or a stocking cover is recommended for cosmesis (Fig. 23).

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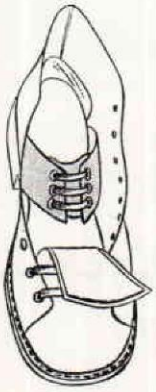

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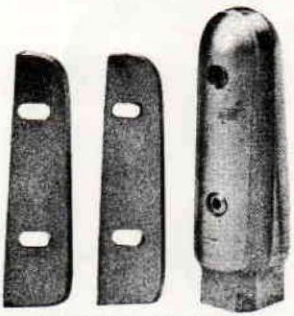

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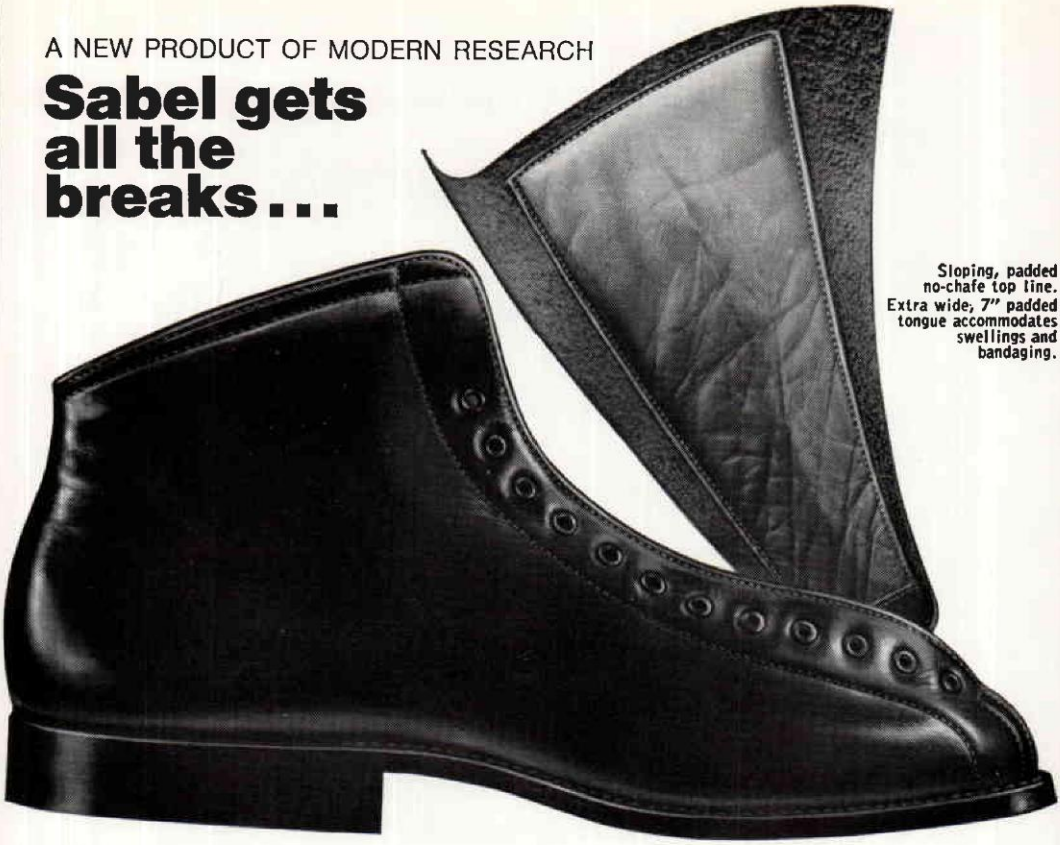

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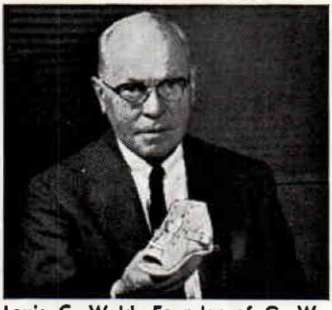

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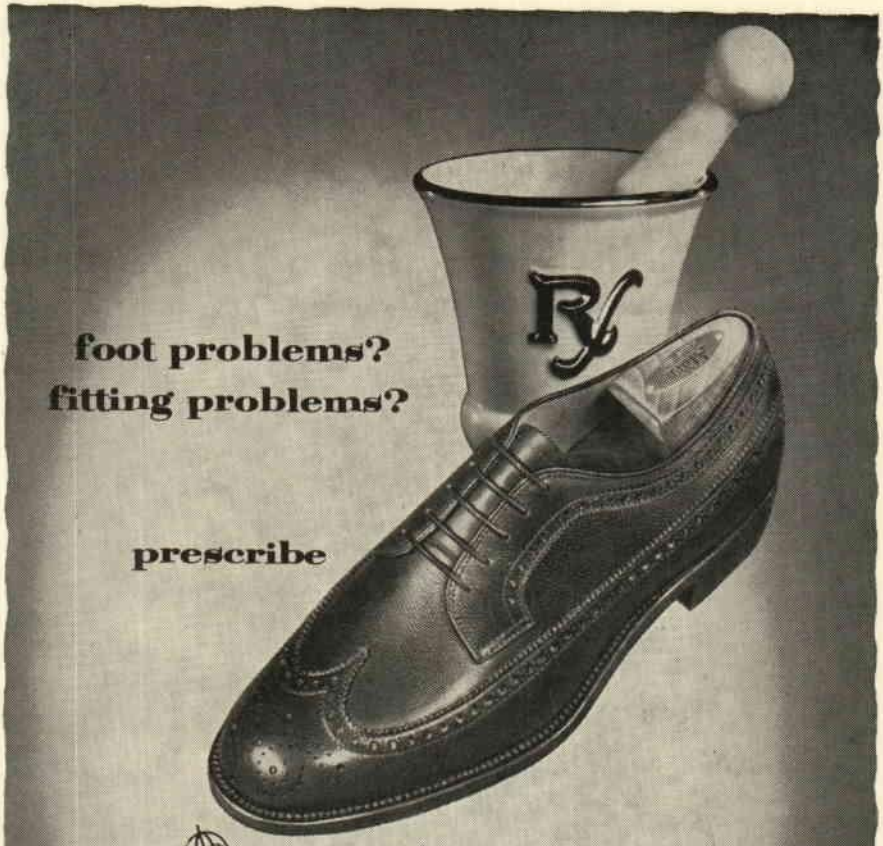


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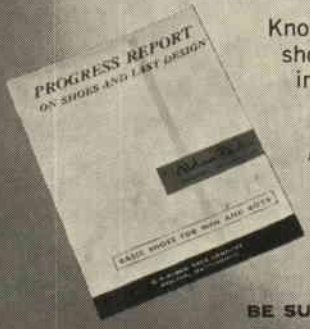


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