A New German Method of Aligning Above-Knee Prostheses

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German mechanics have always had a well-deserved reputation for painstaking, precision work. This is the result of apprentice training in special schools, where the prospective worker must meet established standards of competence, before he is accepted for employment by the industry into which he wishes to enter.

In the field of prosthetics, this reputation for precision workmanship tolds true. The Bundsinnungsverband fűr das Orthopadie-, Chirurgie-, Mechaniker-, und Bandagisten-Handwerk is an organization similar in scope to our OALMA, which supervises the training schools, in something of the same relationship our national organization has to the Certification program.

German work in prosthetics first caught the attention of Americans when the Commission on Amputations and Prostheses, sent to Europe in 1946 by the National Research Council, found that German prosthetists had developed a means of securing an above-knee prosthesis to the body by use of suction. The suction socket program in the United States, following the

Fig. 1. Amputee in Balancing Apparatus.

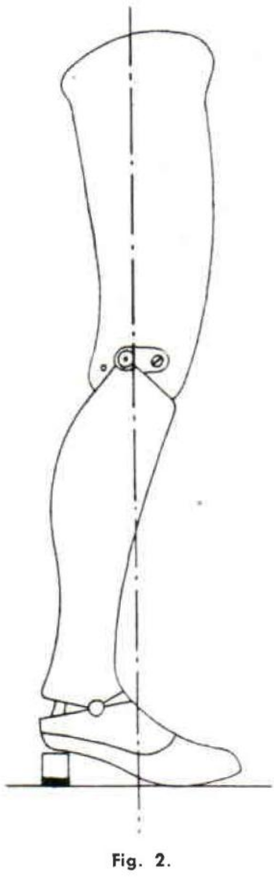

Fig. 2.

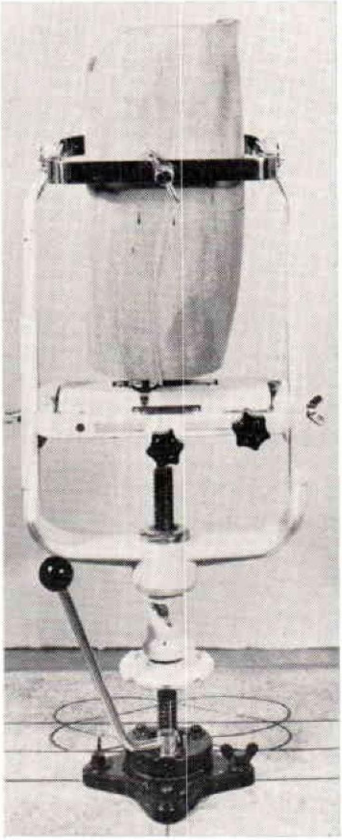

Fig. 3. Balancing Apparatus showing Controls.

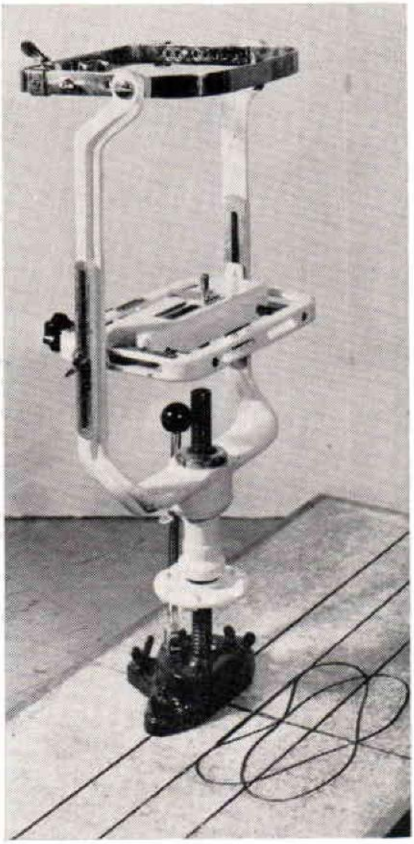

Fig. 4. Base-board Markings of Balancing Apparatus.

report of the Commission, sparked and popularized the prosthetics research program of the past decade, which has done so much for those of us in prosthetics.

Colonel Leonard E. Peterson's report on the Commission's European trip commented on German experiments with mechanical alignment of above-knee prostheses. He mentioned one German firm which had a "fitting or aligning machine", another a "fitting machine which can be adjusted for height, and then adjusted for abduction." Still another German firm had a "walking machine, used to adjust, align, and locate the components of above-knee prostheses."

Since 1946, our Research Program in the United States has been working on mechanical means of aligning above-knee prostheses, and our schools in Los Angeles and New York have taught the "adjustable leg" method, a marked improvement over older methods of aligning "by the book". During this period, the Germans have advanced their aligning methods, also. One firm, The Otto Bock Orthopaedische Industrie, of Duderstadt, has developed a three-unit apparatus which balances the amputee over a fixed point, to determine the maximal degree of effort-free alignment.

Balancing over a fixed point gives equal value to *both medial-lateral and antero-posterior alignment.* Otto Bock prosthetists say the use of a prosthetic foot, as in the "adjustable leg" method of aligning, tends to nullify any effort to determine the optimum antero-posterior alignment. Their method permits the center of gravity to fall, as it should in relaxed standing position, well ahead of the ankle joint.

The relation of antero-posterior alignment to effortless balance is cited in the conclusions of Kottke and Kubicek* that "under normal conditions of relaxed standing the hip is fully extended and the center of gravity of the body mass above the level of the hip is posterior to the center of the hip joint. This provides a torque, forcing the hip into complete extension, and preventing collapse of the hip. The center of gravity of the head, trunk, and arms during normal standing falls posterior to the hips and anterior to the knee, causing locking of both joints without muscular contracture."

With the Otto Bock balancing apparatus the prosthetist can determine the point at which the amputee's superincumbent weight (head, trunk, and arms) is supported in the socket, so that it may be properly aligned above the support point on the floor. If anterior tilt of the pelvis is such as to produce flexion contracture of the hip on the amputated side, which physical therapy has not succeeded in correcting, the balancing apparatus can compensate for this flexion contracture to a considerable degree by an anterior tilt of the socket.

There are three separate units in the German aligning equipment. Each one has its special function. The three units are:

1. Balancing apparatus (portable)
2. Transfer jig (portable)
3. Precision belt-sander (motorized)

Balancing Apparatus

The heart of the aligning equipment is the balancing apparatus shown in Figs. 1 to 9. When the socket is in the frame, and the amputee stands in it, the effect is that of standing on a pylon, with the distal end firmly fixed to the floor but movable in all directions. By careful application of the center-of-gravity principle mentioned previously, the amputee can be given a relaxed standing position without muscular effort, such as the normal person attains when the center of gravity falls as it should.

The unit is set on a free-working ball-and-socket fixture attached to a floor board measuring about 2 feet by 4, permitting a full stride forward and back. As shown in Fig. 3, the inner frame on which the socket rests can be raised or lowered to any desired position, depending on the length of the socket being tested. At the side of this socket support are two adjusting knobs, one for moving the lower end of the socket forward or back, the other moving it from side to side. Calibrated scales give a reading of each position, permitting the prosthetist to reset the mechanism, repeat the balancing process, and see if a new position shows the same reading.

The entire outer frame is held on a threaded center post, so that any desired elevation may be set. Adjustments in height are readily made at any stage of the balancing process, and a set-screw holds the setting until a change in elevation is desired.

The locking lever in the base plate allows the unit to be locked in any position.

Fig. 4 shows the markings on the base board. Lines are drawn thru the ball-and-socket center point at right angles, representing the medial-lateral center line, and the antero-posterior line. The latter line is approximately three

*Relationship of the Tilt of the Pelvis to Stable Posture—Frederic J. Kottke, M.D., Director of Rehabilitation, University of Minnesota Hospitals, and William G. Kubicek, Ph.D.

inches from a parallel line representing the sagittal plane, and at an equal distance on the opposite side is the line used to locate the heel of the foot in the dynamic phase of the process. Foot patterns show the heel against the sagittal plane line, which is where the foot should be in the static phase. The two foot markings show how the apparatus is used for both right and left fittings.

Before making use of the balancing apparatus, the socket is of course fitted in the usual manner. The balancing apparatus makes it possible thereafter to check the fitting at every phase of the procedure.

When the socket has ben fitted, and a tentative elevation established, the socket is placed in the frame of the balancing apparatus, and clamped firmly into place. A steel plate attached to the bottom of the socket makes contact with a stud on the inner frame on which the socket rests. This stud is visible in Fig. 4.

The apparatus is set at the predetermined elevation, and the amputee steps into the socket, the apparatus being unlocked to permit this to be done easily. The amputee's foot is placed in the pattern on the base board, and he will have his shoe on during this procedure.

The prosthetist then locks the apparatus in a position where the amputee is comfortable, and explains the workings of the apparatus. He illustrates the extremes of abduction-adduction, and flexion-extension, then brings the apparatus into a neutral position. The locking lever is now released, and the balancing procedure has begun.

Fig. 5 shows the socket in place, ready for the amputee to step into.

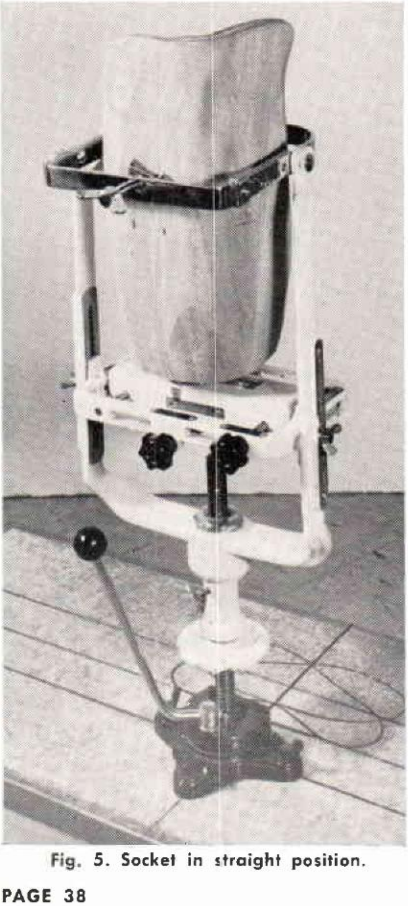

Fig. 5. Socket in straight position.

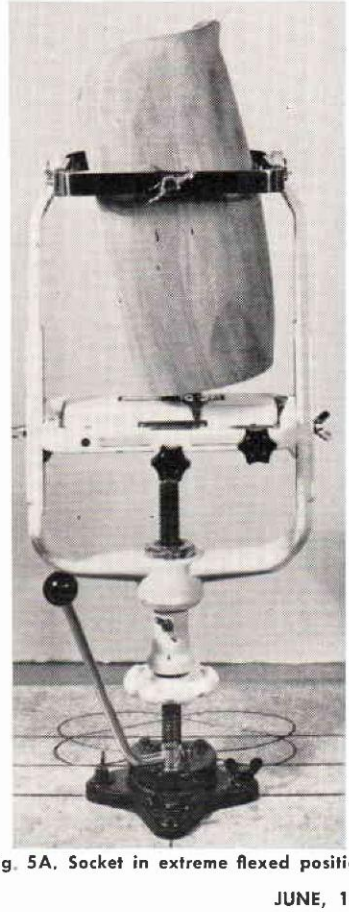

Fig. 5A. Socket in extreme flexed position.

Fig. 5A shows the socket in an extreme flexed position.

At first, the positioning of the socket is tested in the static phase. (Fig. 6) All adjustments in the medial-lateral direction are tried, and then in the antero-posterior direction. The procedure is a repeating one, that is, the amputee is asked to tell which adjustment seems most comfortable, and requires the least muscular effort in a relaxed position, a reading of the two scales is made, then all adjustments are changed, and the prosthetist tests all positions again.

After a second trial, the readings are noted again, and if they do not correspond closely to the readings on the first trial, the various positionings between the two readings are tried out. It may be necessary to go thru this repeated testing a number of times for best results, but the changes in posiion are very easily made, so the process is not necessarily a long one.

When both amputee and prosthetist feel that the optimum alignment has been reached in the static phase, the amputee is asked to take a normal step, forward, then back, and the dynamic phase of the balancing procedure follows. (Fig. 7) The amputee may be provided with a pair of canes, or the balancing apparatus may be placed between parallel bars, to aid him in determining the most comfortable position. Greater pressure on one of the canes or parallel bars indicates the correction to be made.

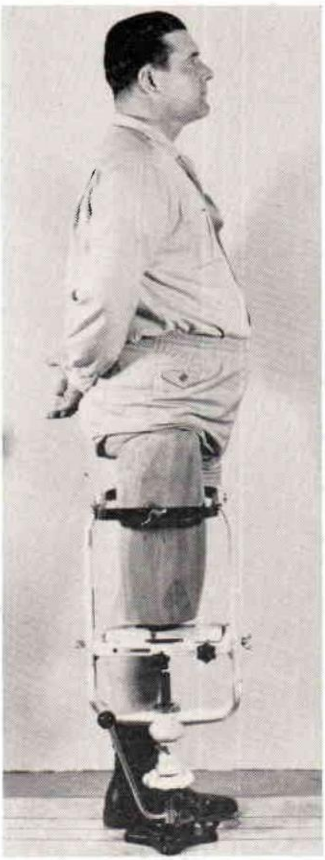

Fig. 6. Amputee in Normal Relaxed Standing Position.

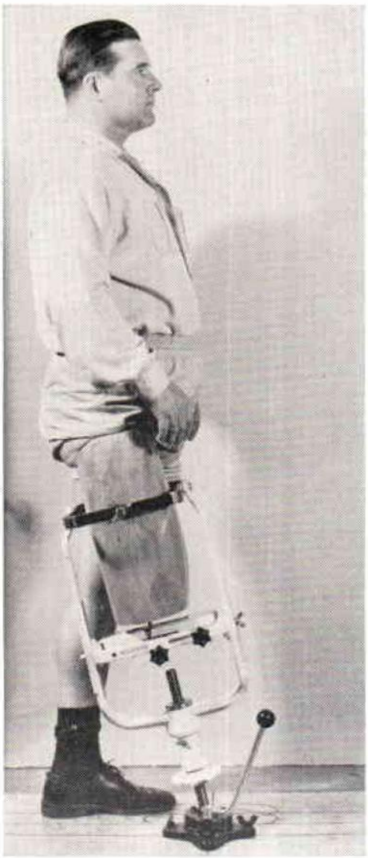

Fig. 7. Dynamic Phase at Beginning of Stride.

In the dynamic phase of the procedure, it is important for the amputee's foot to be placed so that the heel is centered along the line drawn on the base board for that purpose. Any tendency on the part of the amputee to deviate in one direction or the other indicates need of adjustment of the abduction-adduction knob, of course.

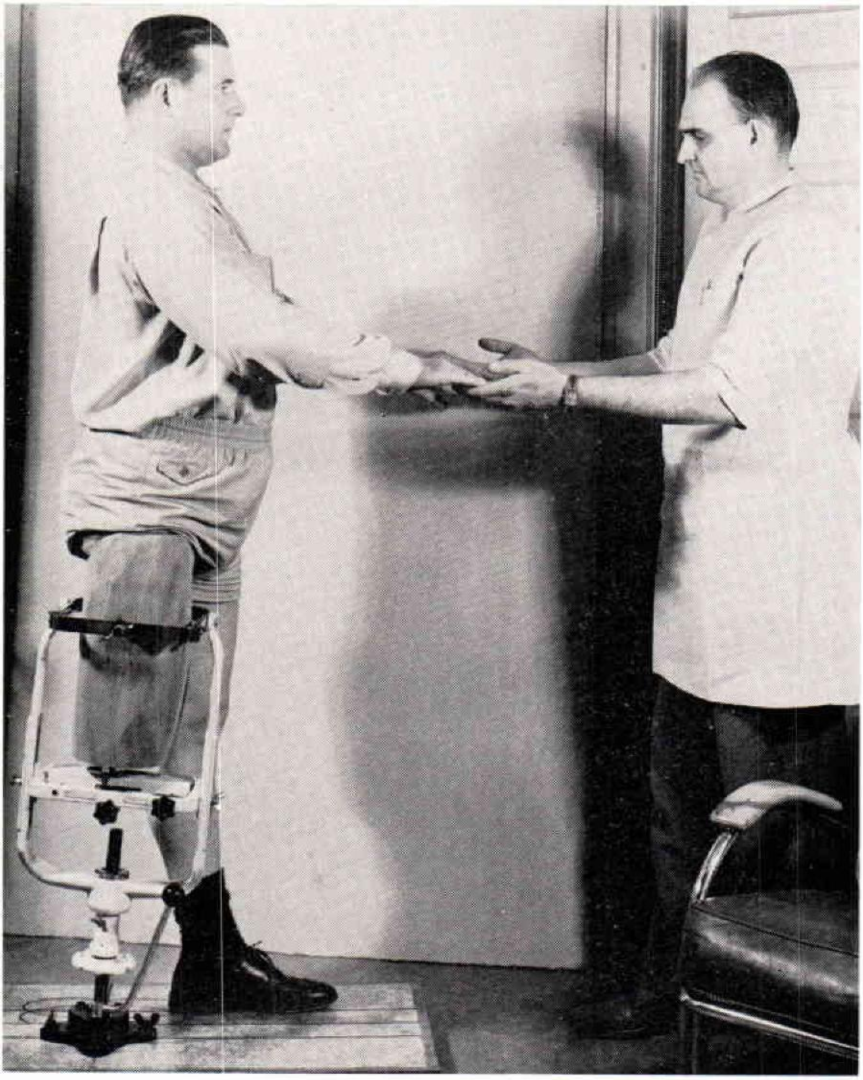

Fig. 8. Finger-Tip Test.

The prosthetist can help the amputee during the dynamic phase of the balancing procedure by standing in front of him, with hands extended, palms up. The amputee places his finger tips on the prosthetist's hands; as he takes his steps, it will be apparent to the prosthetist, by the pressure on one hand or the other, whether the socket should be abducted or adducted, and this is also helpful in determining the most comfortable position of flexion-extension. Fig. 8 illustrates this being done.

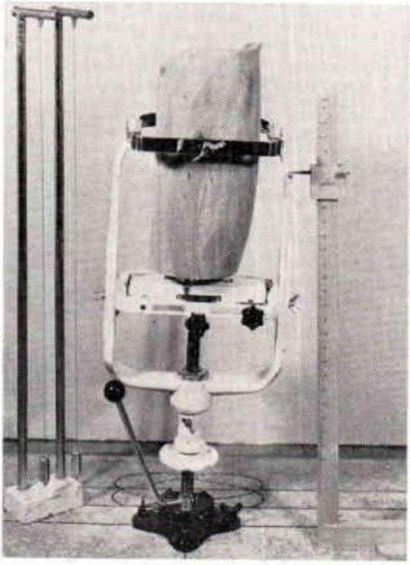

Fig. 9. Plumb Lines and Elevation Marker.

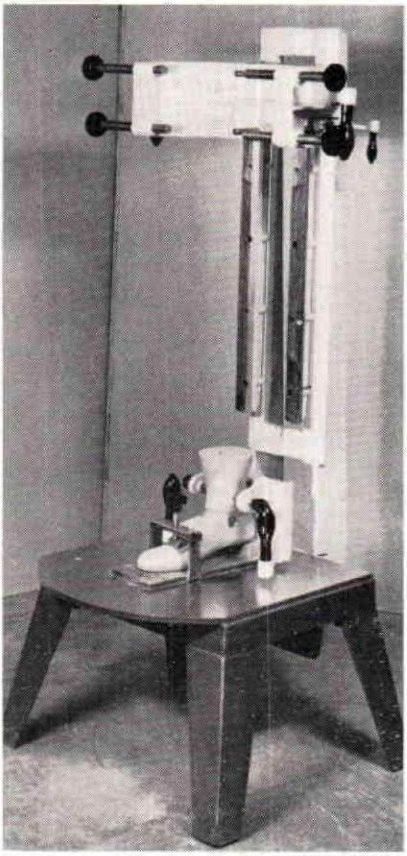

Fig. 10. Transfer Jig with Foot in Place. Socket Bracket on Sliding Posts.

As in all phases of providing an amputee with a prosthesis, complete co-operation between amputee and prosthetist is essential.

Scale readings in both the static phase and the dynamic phase of the procedure must be reconciled, of course, and this makes it necessary to shift from static phase to dynamic phase, and back again. Once again, it should be emphasized that the entire balancing procedure, static phase, dynamic phase, elevation adjustments, and changes for flexion or extension of the socket, abduction or adduction, are readily made in one continuous trial, with the amputee standing in the socket thruout. The apparatus may be locked at any time, to give the amputee a moment of rest, if he becomes tired.

The locking device has one other important service to render. During the static phase, when a comfortable alignment has been found, the prosthetist may lock the apparatus in place for a few moments, and then, without warning to the amputee, release the lock, noting with care in which direction the amputee tends to fall. This will readily show whether a still better point of balance can be found.

For new amputees that are older and/or unsteady when standing, the procedure may have to be somewhat more restricted. In such cases, the balancing may be done in the static phase, with only rudimentary steps being taken, if any.

By alternately locking the unit in place, and releasing it, and by the finger-test described above (Fig. 8), it is possible to give this new amputee a very satisfactory degree of balance, so that he may maintain a relaxed standing position without muscular effort.

Marking the Socket for Transfer

When the best possible alignment has been agreed upon, the amputee steps out of the apparatus, and the prosthetist proceeds with the marking of the socket, for transfer to the transfer jig. The apparatus is locked for this marking process.

Marking is done with a plumb line on three sides of the socket, posterior, medial and lateral, directly above the lines marked on the base-board through the ball-and-socket center point. The front and back struts of the balancing apparatus are offset to facilitate this marking, as shown in Figs. 1 and 4.

Fig. 9 shows the accessories used in the marking. The frame holding two plumb lines should be placed so that the plumb lines are directly in line with the base-board markings thru the center point. The edge of the base block of the frame is in this line, but in Fig. 9, to make the illustration more clear, this base block was set at an angle, showing the plumb lines clearly. With the plumb lines to guide him, the prosthetist places a mark at top and bottom of the socket on three sides.

The two plumb lines make it possible for the prosthetist to be very accurate, which of course is essential in this part of the procedure. When the socket is removed from the apparatus, the marks are joined by penciled lines, which are then used in setting the socket in the transfer jig.

The other accessory is a vertical elevation-marking device, with which the prosthetist marks an arbitrary elevation point, e.g., 27 inches, which then becomes the guide for establishing the elevation in the transfer jig.

With carefully marked vertical lines on three sides of the socket, and an arbitrary elevation mark, the socket is now ready for assembly, via the transfer jig, with the other components of the prosthesis.

Transfer Jig

The transfer jig is essentially two vertical grooved posts, along which removable brackets, or frames, holding the socket and the knee-shin assembly, may be raised or lowered. Hand grips permit these brackets to be readily removed from the posts on which they slide. Fig. 10 shows the transfer jig, with the frame for the socket in position, and the foot already set in the base-plate bracket. Fig. 11 shows the three prosthetic components with their respective brackets. The prosthetist is in the process of removing the socket bracket from the jig.

The foot-ankle assembly is first put in place. On the base plate are markings which correspond to the medial-lateral and antero-posterior lines through the balance point on the balancing apparatus. The toe-out of the foot is set at the usual five-seven degrees and the foot is then set ahead or behind the center line (Fig. 2), depending on the type of the foot being used. A foot with a soft ankle action (SACH foot, for example) will be placed back of center, while a foot with little ankle action will be placed ahead of this center line. Adjustable clamps in back, and on both sides, secure the foot-ankle in the desired position.

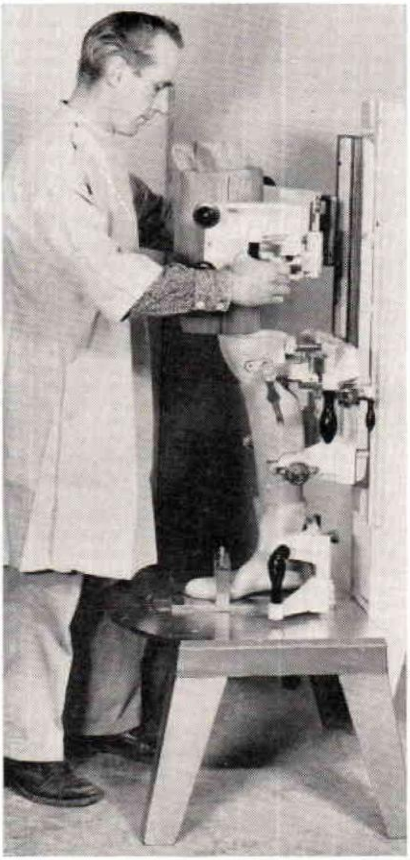

Fig. 11. Prosthetist Removing Socket Bracket from Transfer Jig.

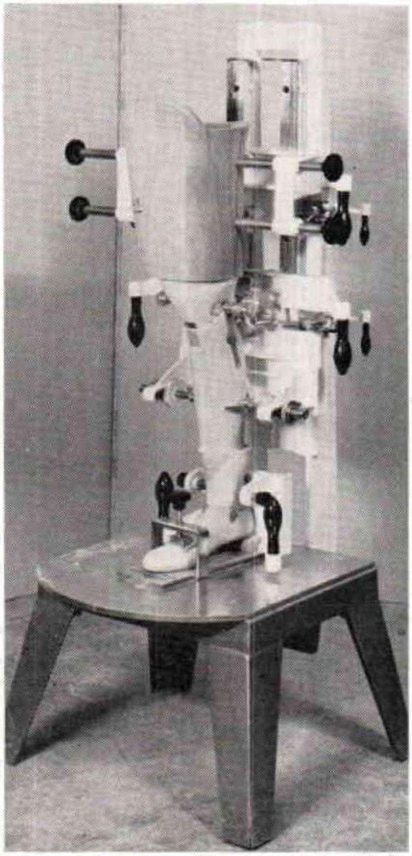

Fig. 12. Three Components in Transfer Jig, Ready for Cutting Down.

The socket is then placed in position. The bracket holding the socket has two vertically aligned pinpointed clamps on either side, which are now set along the vertical lines previously drawn on the sides of the socket. These clamps, and therefore the lines established in the balancing procedure, are now directly above the center line on the base plate.

Two similarly pin-pointed clamps are set along the vertical line marked on the posterior of the socket. These clamps, in turn, are directly above the antero-posterior line on the base plate.

With the socket and foot-ankle set in the transfer jig in proper alignment, the bracket holding the socket can be raised to permit the placing of the knee-shin component in the center bracket of the transfer jig. This component is aligned medial-laterally to provide the best cosmetic appearance, as the over-all alignment of the prosthesis has been established by the positioning of the socket and the foot-ankle components. The antero-posterior position of the knee axis is determined by the type of prosthetic knee used,—conventional or friction stabilized. (Fig. 12)

By means of the arbitrarily marked elevation on the socket, it is a simple matter to determine at what levels the three component parts must be sawed, and each section is removed in turn, the bracket in each case fitting into a flat-bed wood form which provides accuracy in cutting at the band-saw. A precise horizontal cut is made at the bottom of the socket, the top of the foot-ankle section, and top and bottom of the knee-shin component. (Fig. 13)

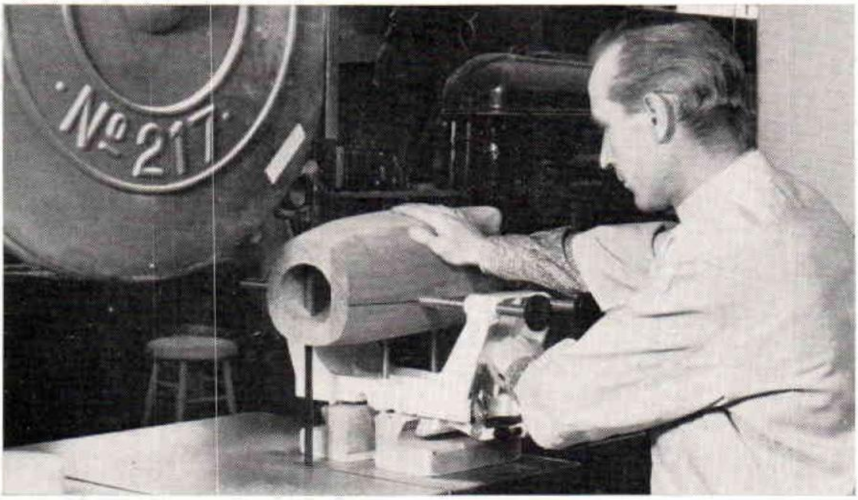

Fig. 13. At Band Saw, with socket held in line with bracket and special wooden frame.

Precision Belt-Sander

As each component is sawed at the proper level, it is taken to the belt-sander for surfacing, in preparation for bonding. The German precision belt-sander is shown in Fig. 14. On this unit, the transfer jig brackets slide

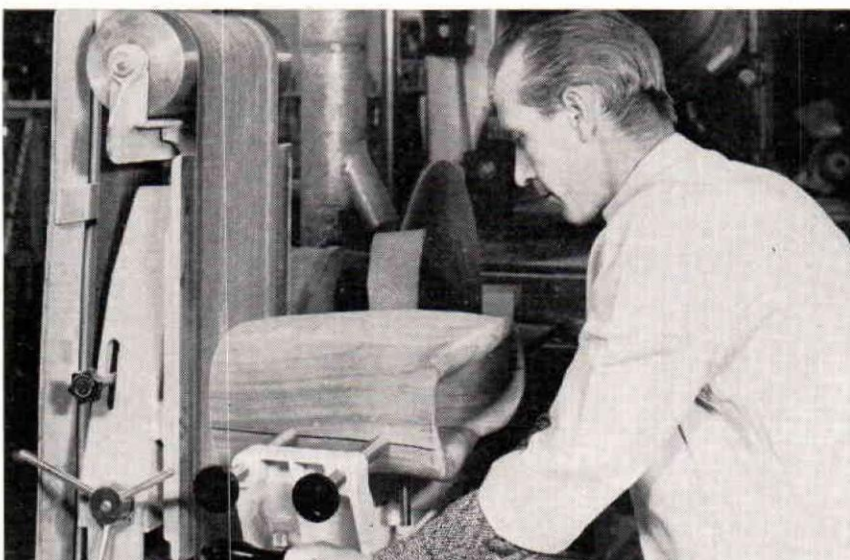

Fig. 14. At Sanding Unit.

along fitted grooves, so that the sanding process can be kept to a rigidly held horizontal level. The vertical sanding belt is backed up by a metal plate, to permit the prosthetist to press the surface to be smoothed against this plate.

This combination of rigidly held component, with accurately aligned sanding surface, preserves the alignment of the sawed surfaces, and at the same time provides an absolutely level surface, an end result that is extremely difficult to accomplish by ordinary means.

Final Assembly

When the four cut surfaces of the three components have been smoothed in the sander, they are again assembled in the transfer jig. If the prosthesis is to be tried out "in the rough" as is usually the case, then the parts of the prosthesis are spot-glued, and gravity plus a slight pressure maintained for perhaps two minutes, gives a well-bonded result and the prosthesis is ready for trial. The aligning procedure is not a complicated one, and once the prosthetist has been thru the various stages, the process becomes quite automatic.

Conclusion

For more than a decade now, prosthetists have sought mechanical means of aligning above-knee prostheses, in the interest of greater accuracy. Various methods have been used, with marked success, as compared to the older method of aligning by eye, or "by the book". Otto Bock Orthopädische Industrie, of Duderstadt, Germany, has been through much the same experimental process, and has recently brought to the United States aligning equipment which makes use of a new principle of alignment.

Otto Bock prosthetists cite several advantages of the balancing-over-a-fixed point method, in addition to the more accurate aligning accomplished in the antero-posterior phase:

1. The balancing apparatus permits checking the fit of the socket at every part of the stride.
2. Adjustments-in-place are possible, resulting in faster, more accurate aligning.
3. The fear of falling, or collapse of the knee, especially important to the new amputee, is removed.
4. The transfer jig provides a fast, accurate method of cutting to length, and final assembly.
5. The precision belt-sander provides accuracy in sanding components to be bonded, without the distortion that develops with ordinary sanding equipment.

Mechanical alignment of above-knee prostheses is here to stay, apparently. Undoubtedly, there will be improvements in the processes now being used to accomplish the accuracy of alignment so greatly desired. The Otto Bock method described has advantages over others which have been introduced in the past decade, and several American prosthetic facilities are using this equipment with excellent results.

A. P. Gruman is a native of Minneapolis, and received a B.A. degree from Carleton College, with a major in economics. Following overseas service in World War I, he was employed by the Winkley Artificial Limb Co. in September, 1919. His training in prosthetics and business management was under Lowell E. Jepson, founder of the Winkley Co. He has served the O.A.L.M.A. in various capacities, and was president in 1948-49. Currently he is president of the Winkley Company, and his son, Robert C. Gruman, is executive vice president.

THREE NAMED TO OVR ADVISORY COUNCIL

The Secretary of Health, Education and Welfare, has announced three appointments to the National Advisory Council on Vocational Rehabilitation.

The Council reviews applications for Federal funds from sponsors of research and demonstration projects in rehabilitation. It recommends approval of those which show promise of making valuable contribution to rehabilitation of disabled persons. Miss Mary E. Switzer, Director of the Office of Vocational Rehabilitation, is Chairman of the Council.

The three new members are: Miss Louise Baker of Lincoln, Nebraska; Weston Howland of Milton, Massachusetts; and Dr. Frank H. Krusen of Rochester, Minnesota.

Chester C. Haddan, Past President of OALMA, is one of the other nine members of the Advisory Council.

Miss Baker is a former director of Public Relations for the National Society for Crippled Children and Adults. She is the author of several novels, one of which is based on her experiences as an amputee.

Mr. Howland is an Industrial Consultant in Boston who has long been active in rehabilitation and other health fields.

Dr. Krusen is Professor of Physical Medicine and Rehabilitation at the Mayo Foundation. He is Chairman of the Committee on Rehabilitation, American Medical Association, and Consultant on Restorative Medicine to the Chronic Disease Program of the U. S. Public Health Service. He served on the Baruch Committee on Physical Medicine immediately following World War II.