March 21, 1967 L. PORTEN 3,309,714

PNEUMATIC CUSHION SOCKET WITH A POROUS FILLER

Filed Jan. 27, 1964 2 Sheets-Sheet 1

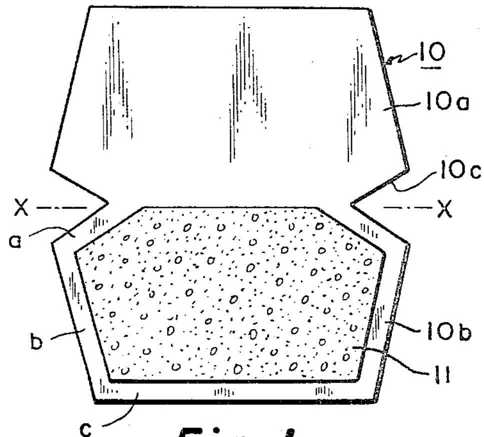

Fig. 1

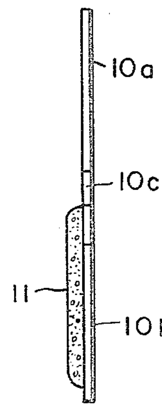

Fig. 2

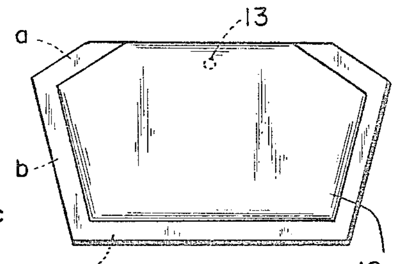

Fig. 3

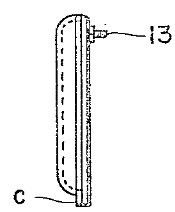

Fig. 4

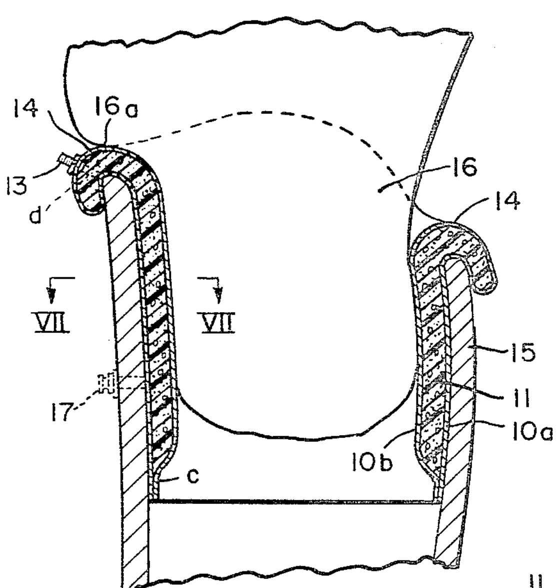

Fig. 6

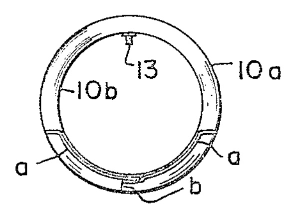

Fig. 5

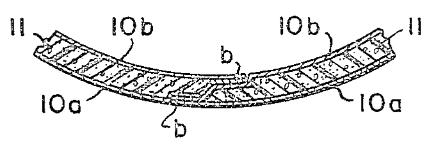

Fig. 5A

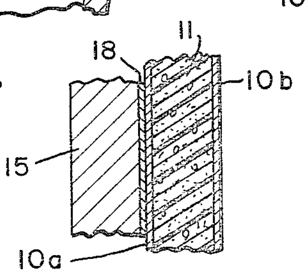

Fig. 7

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PNEUMATIC CUSHION SOCKET WITH A POROUS FILLER

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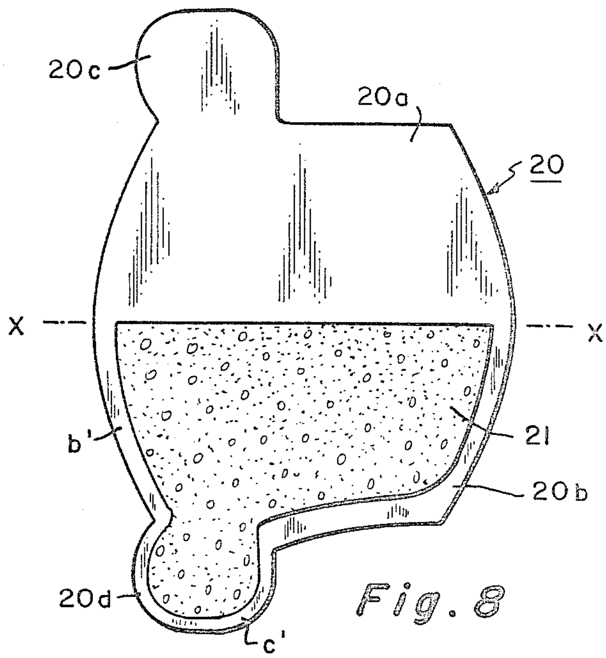

Fig. 8

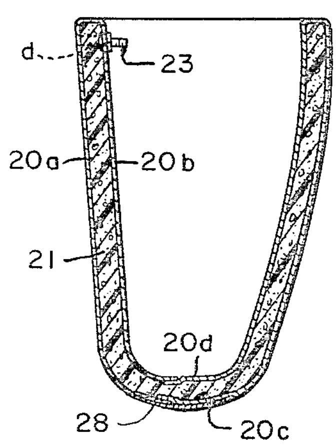

Fig. 9

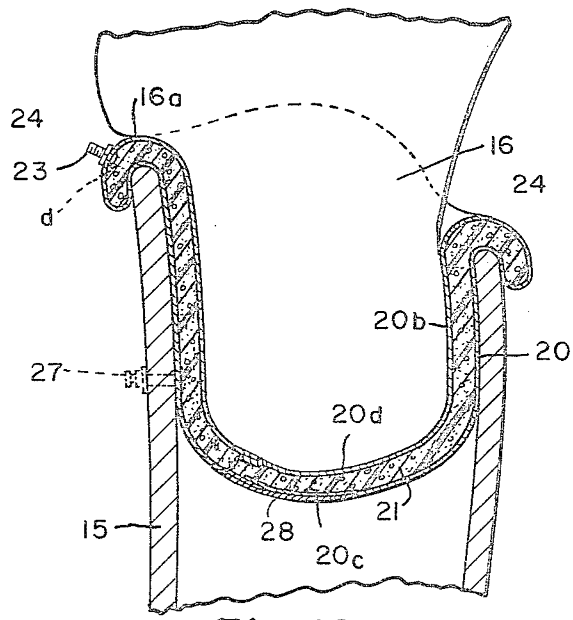

Fig. 10

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PNEUMATIC CUSHION SOCKET WITH A POROUS FILLER

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Filed Jan. 27, 1964, Ser. No. 340,324
7 Claims. (Cl. 3—20)

This invention relates to a socket device for mounting artificial limbs in the nature of legs on amputated stumps and particularly, to a prosthesis socket which will insure full patient comfort and which can be readily adjusted by the patient or amputee as the need may arise.

Although there have been a number of sockets designed for fitting an artificial prosthesis to an amputee's stump, none of them have been fully satisfactory. As a result, it has been customary to use a plaster of Paris negative and positive in order to obtain an accurate fitting. However, even the best fitting prosthesis tends to become uncomfortable due to stump conditions, such as changes or shrinkage of the stump, change in the weather, etc. Increasing age has an influence as well as tenderness of the stump and the scar. In diabetic cases, too much pressure in a given area may cause dangerous skin ulcerations and infections. Direct contact between the bony and tender parts of the stump and the hard wall of the artificial leg must also be avoided.

In my work in this field, I have found that although wool stump socks will ordinarily give some cushioning effect between the stump and the socket of an artificial leg or limb that very often the parts of a body stump, such as a leg stump, are so tender and sore that even liners will not help to relieve the soreness. There has been a need for a relatively soft socket which will provide a substantially equal holding force on the stump, without causing irritation of particular portions or areas, which will give a full feeling of comfort and naturalness, and which can be adjusted by the wearer for accommodating it to changes in the condition of the stump. Finally, the socket should be effective for retaining the artificial limb in a secure connected or joined relation with respect to the natural stump of the wearer.

There have heretofore been both air and liquid inflatable as well as so-called suction sockets, but they have not given a feeling of comfort and aliveness, and have tended to concentrate or increase pressure on localized areas where movement, for example, is being effected. That is, a socket which involves a dual wall construction employing a fluid agency as the essential positioning and intervening medium creates a somewhat unreal, bumpy and uncomfortable feeling to the wearer. Further, there is a tendency for the socket to shift and move too much so that the stump loses contact and security.

It has been an object of my invention to develop a prosthesis socket that will meet problems heretofore presented by prior constructions;

Another object has been to devise a new and improved form of prosthesis socket which will provide the advantageous features of an adjustable socket without its disadvantageous features;

Another object has been to devise an improved mounting socket for connecting or positioning an artificial limb on the stump of the wearer which will be suitable for both above knee and below knee amputations;

A further object of my invention is to develop a new method of making a prosthesis socket, such as a stump socket which will result in a relatively inexpensive and highly satisfactory product;

A still further object of my invention has been to devise a prosthesis socket construction that will enable the wearer to have a maximum of comfort and security and, at the same time, which will be simple and practical in utilization and have a long period of useful life;

These and other objects of my invention will appear to those skilled in the art in view of the illustrated embodiments, the description thereof and the claims.

In the drawings,

FIGURE 1 is a side view in elevation showing a layout pattern of a piece of material that is cut-out in readiness for forming a socket; a porous resilient filler or liner member is shown applied thereto;

FIGURE 2 is an end view in elevation on the same scale as and of the layout of FIGURE 1;

FIGURE 3 is a side view in elevation on the same scale as and showing the material of FIGURES 1 and 2 lapped or folded over to provide a flat preliminary shape in readiness for sealing abutting side and bottom selvage edges to provide the desired wall construction; this figure also shows a valve stud mounted in position on an inner side of the folded material adjacent its upper edge;

FIGURE 4 is an end view in elevation on the same scale as and of the same preliminary shape shown in FIGURE 3;

FIGURE 5 is a top end view on the scale of FIGURES 3 and 4 and showing the folded material of such figures with its side edges brought together to define a somewhat cylindrical or rounded shape, in readiness for sealing the edges together;

FIGURE 5A is an enlarged fragmental horizontal section on the scale of FIGURE 6, illustrating details of how longitudinal edges of the socket device are secured or joined to form a cylindrical or rounded, sleeve-like body shape of FIGURE 5;

FIGURE 6 is an enlarged side view in elevation and partial section on the scale of FIGURE 5A illustrating the positioning or mounting of a completed socket device of my invention between a stump of the wearer and an artificial limb; in this view, the upper portion of the socket has been turned or folded outwardly and downwardly over the upper edge of an artificial limb to define a top shoulder and in such a manner as to turn the valve stem outwardly. This view further shows the socket after its longitudinal or vertical side edges have been sealed together to form a unitary rounded construction; this view shows the resilient space-filling and positioning action of the socket device as constructed and before air is introduced into it;

FIGURE 7 is a greatly enlarged fragmental section taken along the line VII—VII of FIGURE 6 to illustrate the use of an adhesive layer between a wall surface of the socket device and an abutting wall surface of the prosthesis;

FIGURE 8 is a side view in elevation showing a layout pattern of a piece of material that is cut-out in developing a modified form of socket whose lower end is closed; a porous resilient filler or liner member is shown applied thereto;

FIGURE 9 is an enlarged vertical sectional view on the scale of FIGURE 8, showing the pattern material after it has been folded over, its selvage edges have been sealed together, and its vertical side edges have been brought together to define a rounded shape; the tab-like portions of the material used in forming the closed bottom end have been slit to better enable them to be shaped into a relatively smooth-faced rounded closure;

And, FIGURE 10 is a vertical view in elevation and partial section on the scale of FIGURE 9, showing a completed closed end socket device and as utilized in its mounted relation between a stump and an artificial limb or prosthesis; this view shows the resilient space-filling and positioning action of the socket device as constructed and before air is introduced to it.

In carrying out my invention, I discovered that a practical, fully comfortable, natural-feeling, and adjustable as well as inexpensive socket device could be devised which would meet the adverse factors heretofore presented from the standpoint of fluid or air chamber devices. I utilize a tough, wear-resistant, tractable or pliant covering material that will have a high resistance to moisture and perspiration as well as aging, that will be resistant to distension, and that will be capable of ready and effective sealing to provide a leakproof chamber. One of the best materials in this connection is a resin treated fabric product sold under the trademark, Naugahyde; this a vinyl coated fabric material available in sheet rolls; it has a relatively smooth highly polished surface on its outer resin side, does not harden or crack, is resistant to scuffing, can be flexed, and does not tend to wrinkle in service; it is a product of the United States Rubber Company. Its back surface or unfinished side exposes the closely knitted cotton fabric that is impregnated by the resin. Although other resin moisture-proof cover material, such as a vinyl chloride polymer resin sheeting in the nature of Koroseal, a trademarked resin product of the B. F. Goodrich Company may also be used, I find that the Naugahyde material is tough and strong and has a little more stretch for use with bony stumps.

The covering material is provided with an adherent layer, filler or liner of plastic foam sheeting material made from expanded resin beads, such as a polystyrene resin, that is highly resilient, and that is employed to fully fill the spacing between the inner and outer walls of the socket device. The filler material is secured fully along one side of its length and only to the inside of the inner wall of the socket to loosely abut the inside of the outer wall thereof. I discovered that the foam material, in addition to being highly resilient, should define a multiplicity of minute air spaces therein that approach microscopic, air-receiving interstices, so that air may be introduced under pressure between the sealed-off inner and outer walls of the socket to fill such interstices and expand the foam material substantially uniformly along its full length and thus, provide a multitude of somewhat cellular, air-expanded, resilient, connecting links that are air suspended between each other and whose resistance to deformation is increased proportionately to the amount of air introduced therein. In this manner, I provide a full resiliency of the socket while, at the same time, provide it with a holding strength that enables the stump to be effectively secured to the artificial limb. Since the air is, in effect, carried in a multitude of small cells or chambers and the air of each chamber has a somewhat segregated, opposed relation with the air in adjacent cells, the application of a localized compressing force on the socket, as during the movement of the artificial limb, such as encountered in the walking of the patient, will prevent a localized concentration of pressure on such area, such as will cause annoyance to the wearer. In addition, the socket gives a live feeling to the wearer that is amazing to further contribute to his or her comfort in using the artificial limb.

The socket acts as a highly effective pressure and shock absorber. The thickness of its filler material may be varied depending upon the nature of the stump, whether it is fleshy or primarily of a bony nature, and upon the amount of space that is to be provided between the stump and the inner wall of the prosthesis. I have found that it can be successfully utilized in thicknesses varying between ⅛ and ¾ of an inch with an optimum of ⅜ of an inch. It will be noted that the filler material should fill the spacing and provide support between the inner and outer walls of the socket device when it is in its mounted position between the stump and the prosthesis, before air is applied thereto.

Referring to FIGURES 1 and 2 of the drawings, I have illustrated a piece of covering material **10**, such as Naugahyde, patterned or cut-out to provide an inner side wall portion **10*b*** and an outer side wall portion **10*a***. The cover material **10** may have a thickness of about $\frac{1}{64}$ to $\frac{1}{16}$ of an inch. Notching **10*c*** between the two portions represents fold line X—X to provide the preliminary shape of FIGURES 3 and 4. The underside or the exposed fabric side of the material **10** is on the inside and the finished or smooth resin outer surface is on the outside of the preliminary shape of FIGURES 3 and 4. In FIGURES 1 and 2, a unitary resin foam liner or layer member **11** has been cemeted, heat-bonded or otherwise suitably secured to and along the inner surface of the portion **10*b*** that is to constitute the inner side wall of the socket device.

As shown in FIGURES 3 and 4, when the portion **10*a*** is folded-over the inner side wall portion **10*b***, selvage edging *a*, *b*, and *c* is provided along the bottom and the side edges of the flat shape portion **10*b*** that is in close abutment with edges of the portion **10*a***. The edging of the two portions **10*a*** and **10*b*** may be sealed, either with a suitable cement or by a hot iron up to the edges of the liner **11**. The outer side surface of the liner **11** is left free with respect to the inner surface of the outer side wall portion **10*a*** and is only secured to the inner side wall portion **10*b***. A suitable valve stem **13** of conventional construction may be mounted, as shown in FIGURES 3 and 4, to extend from adjacent the back or top edge of the inner side wall portion **10*b*** so as to provide for the inflation and deflation of the cellular interstices of the porous lining **11**. Any suitable conventional valve, such as a tire valve, or a commercially available push-in closing and pull-out opening valve (see **17**) may be used and may be provided with a nipple or screw connection for connecting it to a small hand pump. The hand pump may be carried by the wearer of the prosthesis in a pocket, in a handbag or in the hollow portion of a prosthesis, such as **15**. The prosthesis **15** may be made of any suitable material, such as aluminum, or resin impregnated fiber glass or fabric material, etc.

When the socket device, as constructed in accordance with FIGURES 1 to 7, is to be utilized, as with a prosthesis or artificial leg **15**, the device is placed between the stump **16** and the leg **15**, adjacent the hollow upper end of the leg, and the upper portion of the device is turned-over, as indicated in FIGURE 6, to provide a cushion seat in the nature of a rounded supporting nose, rim or bead **14**. Thus, if a conventional tire type of valve stem such as **13** is used, it will extend outwardly. If desired, a commercial stem valve **17**, such as the push and pull type shown by the dotted lines of FIGURE 6, may be mounted to extend through the wall of the prosthesis **15** from the outer side wall portion **10*a*** of the socket device. The type of valve stem **17** shown is pulled outwardly to open its fluid passageway when air is being introduced into or exhausted from the socket chamber, and is pushed in to close off the passageway.

In FIGURE 7, I have indicated that a thin adhesive layer member **18** may be secured to and about the outer side of the outer side wall **10*a*** along its length to mount the socket device along cooperating side surface and edge portions of the hollow back or upper end of the prosthesis **15**. This adhesive may be similar to the adhesive used for medical adhesive tape so as to prevent slipping of the socket once it has been properly resiliently positioned and before it has been inflated. The layer **18** may be a fabric having its non-adhesive side secured, as by cementing to the outer side of the outer wall portion **10*a***, in order that its adhesive side may face and be placed in a removably-adherent relation with the inner side of the wall of the hollow end portion of the prosthesis **15**.

In FIGURES 8 to 10, inclusive, I have illustrated a modified socket device in which covering material **20** is formed by cutting it into a flat pattern illustrated in FIGURE 8. This pattern includes a front or outer wall portion $20a$ and an opposed, back or inner wall portion $20b$ which are to be folded over each other along line X—X in a manner corresponding to the method disclosed in FIGURE 3. Before the folding-over is accomplished, however, a piece of filler material or a filler member **21** is secured, as by cementing, to the fabric side of the portion $20b$ to leave selvage edging b' and c' thereabout, and in such a manner that the filler material **21** is secured fully along its inner surface thereto. When the covering material **20** is folded-over substantially along its center line X—X of FIGURE 8, or along the top edge of the filler material **21**, it will be noted that the selvage edging b' and c' of the portion $20b$ is to then be secured to corresponding outer edges of the portion $20a$ to provide a sealed, substantially flat shape or form which is then used in making the rounded shape of FIGURE 9. The shape of FIGURE 9 is formed by bringing vertical edges of the dual wall material together and cementing or heat-sealing them. A valve stem **23** may be secured adjacent the upper or inner end of the portion $20b$ of the pattern shown in FIGURE 8 and before such pattern is folded over and then formed into the rounded shape of FIGURE 9.

It will be noted that forward or bottom tab portions $20c$ and $20d$ which respectively extend from the wall portions $20a$ and $20b$, are slit or cut, so that the bottom of the shape of FIGURE 9 may have a relatively smooth fitting relation, particularly from the standpoint of the portion $20d$ which lies along the inside of the shape and is thus adapted to abut the end of the human stump **16**. Such bottom edges may be sealed-off, as by cementing or by the application of a hot iron. I preferably apply a small rounded, bottom closure piece or patch **28** to the outer bottom end portion $20c$ of the shape of FIGURE 9 so as to provide a substantially uninterrupted exposed forward end portion. The bottom patch piece **28** may also be cemented or sealed in position.

The same as accomplished in connection with the socket device of FIGURE 6, the socket device of FIGURE 10 is mounted in position on the prosthesis **15** in an outwardly and downwardly overlapping relation with the edge of the back portion of the wall of the prosthesis, so that the valve stem **23** projects outwardly and the inner side wall portion $20b$ defines a resilient protective positioning bead **24** for a portion $16a$ of the stump **16** which rests thereon. Also, as in the case of the embodiment of FIGURE 6, the valve **23** may be eliminated and a valve **27** (corresponding to **17**) substituted which, as shown in dotted lines, is mounted to extend through the wall of the prosthesis **15** and to extend from a fitted relation with respect to the outer side wall portion $20a$. The socket device of FIGURE 10, if desired, may be provided with an adhesive layer corresponding to **18** of the embodiment of FIGURE 7.

It will be noted that the filler layer **21** of the socket device of FIGURE 10 is free along its outer side with respect to the outer side wall portion $20a$, but is in abutment therewith; it provides a resilient positioning medium for the stump **16** which maintains it in a spaced relation with the wall of the prosthesis or artificial leg **15** when the device is mounted in position and even before fluid or air is introduced into the interstices of the layer **21**. It will also be apparent that the layer **21** serves in the same manner as the layer **11** of the embodiment of FIGURE 6, in the sense that when the interstices of its multi-cellular structure are filled with a suitable amount of air, its holding or positioning action is increased and its resiliency proportionally lessened, and in the sense that any localized pressure exerted on the socket, for example by the stump **16**, will not cause a corresponding localization or lumping of resisting or positioning force on the stump, thereby not only contributing to the comfort of the user, but also eliminating chafing and making sore spots on various portions of the stump. The lining **11** or **21** may be of any suitable commercially available foamed or expanded resin material in sheet form, such as polyurethane resin.

It will be apparent from the above description that the improved socket device of my invention may be made in either the form of a hollow open-end cylindrical shape or in the form of a cylindrical shape having a closed forward end portion, depending upon the particular requirements of the installation. The construction of both forms is similar, in that the cover piece **10** of the pliable air-tight covering material is cut into a pattern shape, such as illustrated in FIGURE 1 which, in effect, has two complementary halves $10a$ and $10b$ that are connected along a transverse center line represented by X—X. Before the halves are folded, a piece **11** of the resilient light-weight porous resin filler material is cut out to a shape that is complementary with one half $10b$ of the covering piece, but has a smaller size pattern in order to leave edge spacing a, b and c along the half of the cover piece for sealing the two edges together. Before the two halves of the covering material are folded-over and sealed together to provide a dual wall construction, a valve stem **13** or **17** may be mounted to project outwardly from the smooth or resin side of the pattern piece **10** at a suitable location thereon, both from the standpoint of the finished shape and from the standpoint of providing a fluid flow passageway to the free or unsecured side of the filler piece **11**.

As shown particularly in FIGURE 3, the pattern piece **10** with the filler material **11** cemented or secured along the inner or fabric side of one of its halves is then folded about its transverse center line X—X upon itself with the inner or fabric sides of its halves $10a$ and $10b$ in an opposed relationship and with the longitudinal and forward edges a, b and c in an abutting relation. These edges may then be sealed together by a suitable cement or by a heat application where the resin material is of a thermoplastic nature. The sealing provides a dual-wall one-piece construction having an inner chamber, wherein the halves of the cover piece **10** are in a spaced relation that is defined by the thickness of the filler material **11**, and wherein the filler piece **11** has a free abutting relation with the inside of the other half $10a$ of the cover piece.

In the next step, the dual wall sealed-off construction is then picked up and its longitudinal edges are brought into abutment and sealed, as by cementing or a heat application to defined a sleeve-like cylindrical shape, see the joint of FIGURE 5A. This cylindrical shape thus has a back edge or end that is defined by the transverse center line X—X of the fold of the cover material **10** and, as shown in FIGURE 6, the back end of the cylindrical shape may then be folded outwardly and downwardly to provide a cushioned supporting edge or bead for the stump and, at the same time, to provide a forwardly open spacing, groove or slot to receive the end of the enclosing wall of the open hollow inner end portion of the prosthesis **15**.

In the modified construction shown particularly in FIGURES 8 to 10, inclusive, the halves $20a$ and $20b$ of the material of the cover piece **20** are provided with projecting tab portions $20c$ and $20d$ which are used in forming a closed front or forward end of the socket. As will be noted, the filler piece **21** has a projecting tab portion $20d$ which fills the spacing between the tab portions of the two halves of the covering material to provide a continuation of the fluid or air chamber between the halves. When the dual wall construction formed from the pattern of FIGURE 8 is then shaped into a cylindrical form by bringing its longitudinal edges together and sealing them, the tab portion of the dual wall construction may be provided with diagonal slits to facilitate forming the closed end. Also, a separate rounded patch piece **28** of the cover material may be provided and secured in position over the outer forward end of the closed end of the socket to give it a finished appearance and a reinforced construction. If desired, and as before indicated, a piece of adhesive fabric, such as **18** of FIGURE 7, may be secured about the outer wall 20*a*, as described in connection with the embodiments of FIGURES 5 and 6.

In both embodiments of my socket, the side and bottom edges are brought together in such a manner that the resultant finished socket device or shape has resilient filler material along the full extent of the shape to give it a fully resilient chamber-defining relation along its full extent. That is, for example, the side edges when sealed, in effect, overlap the chambered and filler material supporting portions of the dual wall construction rather than meeting merely in a flat abutting relationship which would provide no filler chamber or resilent backing between the walls at the particular area or location involved. By using the filler material along the full extent of the socket as formed, its interstices, cells or air space that approach microscopic size, as defined by thin connecting resin cellular body portions of the material, may be expanded by the introduction of a fluid, such as air, to force the inner and outer walls of the pliable cover material outwardly and increase the holding action proportionally to the fluid pressure thus built up within the porous filler and its multiplicity of minute cells or interstices. A uniform action is attained and lumping force concentration in a particular area of the socket is avoided. In both embodiments, where a valve stem **13** or **23** is used that is secured to the inner wall portion **10***b* or **20***b*, a hole or passageway *d* is provided leading from the inner secured end of the stem to the free abutting side of the filler layer **11** or **21**, in order that air may be directly introduced to the unsecured side.

An important feature of a socket produced in accordance with my invention rests in the fact that it provides the wearer with a "live" feeling that is necessary for comfort and practical usability. I have determined that a sheet of thermoplastic resin material having a resin surface applied on both sides facilitates the sealing-off of the chamber, as accomplished by a controlled electrical heating iron or press. Since various resin materials have different melting or bonding temperatures, I employ a press or iron whose electrical heating element is connected through a variable resistance to the source of current. I then gradually bring the temperature up by decreasing the resistance, and apply the iron to a scrap piece of the resin material, until the material begins to melt. Thereafter, I retain the variable resistance at such a setting for the sealing operation. This avoids the danger of burning the resin. I have found that a fully satisfactory secured, airtight seal may be obtained in this manner and that ordinary cements are not suitable in this connection, using a resin material such as Naugahyde. The sealing operation may be visually controlled and, after it is completed, I check for air-tightness of the joint. The hot iron may be re-applied to any localized leakage area. Although a sheet of material which has a fabric exposed on one side can be satisfactorily bonded in this manner, I find that the heat application has to be maintained a few seconds longer to assure a full penetration of the melted resin into the joint.

While I have shown exemplary embodiments of my invention, it will be apparent to those skilled in the art that the principles thereof can be embodied in other structures, and that various changes may be made without departing from its spirit and scope.

What I claim is:

1. An improved prosthesis socket for receiving a stump and mounting it within a back open end portion of an artificial limb, a sleeve-like body having a back open end portion adapted to receive the stump, said body comprising a pliable air-tight cover of fabric material that has a

smooth outer surface, said cover having spaced-apart inner and outer side walls along said body and connecting end closure walls that seal-off said inner and outer side walls to provide a closed-off inner chamber within and along the side walls of said body, a lightweight porous and resilient filler material defining a plurality of minute air spaces therewithin and positioned to extend fully along the chamber between said inner and outer side walls to fill the spacing, said filler material being secured along one side face to only one of said side walls and having a freely abutting relation along its opposed side face with the other of said side walls, said inner side wall being adapted to receive and fully conform to the configurations of the stump and said outer side wall being adapted to fit within the open end portion of the artificial limb, and valve means secured to project from one of said side walls and having a passageway connected to the free abutting side face of said filler material for introducing air fully along said face to the air spaces thereof and for expanding the air spaces to provide a desired uniform resilient holding strength to said body for effectively securing the artificial limb to the stump.

2. An improved prosthesis socket as defined in claim 1 wherein said filler material is in the form of a unitary member.

3. An improved prosthesis socket as defined in claim 1 wherein the side walls of said body are turned outwardly and downwardly at the back open end portion thereof to define a cushion seat adapted to fit over the back open end portion of the artificial limb and upon which a transversely-projecting portion of the stump may rest.

4. An improved socket as defined in claim 1 wherein said cover has an outer surface of impregnated resin material have a thickness within a range of about $\frac{1}{64}$ to $\frac{1}{16}$ of an inch, and said filler material has a thickness within a range of about $\frac{1}{8}$ to $\frac{3}{4}$ of an inch.

5. An improved prosthesis socket as defined in claim 1 wherein said cover is of one-piece of material whose ends extend forwardly to a front end closure wall and are sealed together in a smooth relationship thereat.

6. An improved prosthesis socket as defined in claim 1 wherein said body is adapted to resiliently position the stump within the open back end portion of the artificial limb before air is introduced into the chamber, and said cover is a closely woven fabric whose inner face defines the inner chamber and whose outer face has a smooth resin surface for receiving the stump.

7. An improved prosthesis socket as defined in claim 1 wherein the one side face of said filler material is secured to and along said inner side wall and the opposite side face thereof has a free abutting relation with and along said outer side wall.

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