Harness for Shoulder Disarticulation Amputees*

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"What can you do for a shoulder disarticulation case? How do you harness to make the arm work right? What if the poor guy can't seem to get the hang of locking and unlocking the elbow?

Whenever limbfitters get together, that's the first question asked—or the loudest. Not many answers are heard. And no wonder, when the amputee has so little excursion to harness, and the socket itself has to limit that motion to provide stability!

How to operate the elbow lock? The *Manual of Upper Extremities Prosthetics* (1952) mentions nudge control and lanyard control. How can a man pick anything up two-handed if he has to use one hand to operate an elbow lock? *Human Limbs and Their Substitutes* (1954) mentions chin nudge control only. But our patients don't seem to like it much. Where do we go from here?

Not much help can be found in print. To the best of the present writers' knowledge, no other publication gives us any guidance whatever. In fact, before Thomas and Haddan's *Amputation Prosthesis* 1945), the SD (shoulder disarticulation) arm seems to have been dismissed as a mere sleeve-filler. Thomas and Haddan pointed out the real though limited functional value many SD amputees got from their prostheses. The harness they described consisted of a leather shoulder cap and a single, webbing chest strap.

Compare this recommendation with the shoulder amputation arm described by A. A. Marks in the 1898 edition of *A Treatise on Artificial Limbs,* page 232: "The arm is provided with a pad that rests on top of the shoulder, which is held in place by means of straps passing around the body." (The illustrations make clear that the "pad" in question is what we would call a fitted shoulder socket.) The arm "is capable of rotating immediately above the elbow joint. The elbow is capable of flexion and extension, which is controlled by a flexion strap, one end of which is fastened to the interior of the forearm, and the other passes around and under the opposite shoulder. A movement of the shoulders will contract this strap and bring the forearm to a horizontal position, where it is locked by a mechanical device which is concealed in the forearm. The release button to this lock is placed on the underside of the forearm, and easily accessible. Artificial arms for shoulder amputations are made with strict regard to minimum weight, and in order to attain this result the hand is usually attached permanently to the forearm, and the extension strap is dispensed with." Satisfied wearers included "a lady of fashion, frequently seen in society," who said that she had "passed many evenings at balls and receptions without arousing the slightest suspicion that her left arm was artificial."

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New Developments

The Army Prosthetics Research Laboratory can now report four new harnessing systems for SDs, all of which have worked successfully at the laboratory and in the field. Each of them does away with the annoying manual or chin-operated elbow lock. Complete descriptions will be found later in this article.

We have also worked out a "block and tackle" cable system that cuts the excursion required in half. Based on one of the principles used in the inertia or velocity lock, this two-to-one excursion step-up can be used on any of the systems described here, as well as on the old dual control with manual lock.

Also presented here is a harnessing method for women SDs which conquers the chest strap problem. Appearance is greatly improved, and the girl can wear all the low necklines she wants without any sacrifice of arm stability.

Before giving you the details of these developments, let us review what we're trying to do, and what body motions we have to work with.

What Must A Harness Have?

A. COMFORT. Put this first because a prosthesis will usually not be worn unless it's comfortable. An arm may be a wonderful piece of mechanism —a real triumph of the limbmaker's art—but if it's hanging in the back of the closet, its functional value is exactly zero. Remembering this, we can, when necessary, sacrifice a bit of function for the sake of the wearer's comfort.

B. FUNCTION. We have to be careful to arrange the system to work with the terminal device prescribed. For example, in a dual control system with a voluntary opening hook, after full elbow flexion an additional 2 1/4 inches of excursion is needed to open the terminal device. This is inherent in the system—it's not because you make a mistake somewhere. So, if our amputee wants a voluntary opening hook and wants to be able to open it at his mouth, we must arrange to give him extra excursion. We might do this by the excursion step-up mentioned above. Or we might go to triple control, described later.

Another answer is to change the terminal device instead of the harnessing. If a VC (voluntary closing) TD is used, then the excursion that was used up in flexing the forearm is regained for TD operation at the cost of a slight increase in force to trip the locked cam and thus relax the control cable.

C. SUSPENSION. In most cases, the arm suspension is just another function of the working parts of the harness. We must hold the shoulder socket snugly against the stump to prevent the prosthesis from sliding off.

What Body Motions Can We Harness?

The SD amputee may have lost our classic control motion, humeral flexion, but he still has the use of some of the most powerful muscles in the body. Plenty of force is provided by:

A. OPPOSITE SHOULDER SHRUG—forward rotation of the arm on the non-amputated side (as used in above-elbow lock control) (*high* force available)

B. SCAPULAR ABDUCTION—forward motion of the amputated stump, causing the distance between the shoulder blades to increase. (*high* force available)

C. SHOULDER ELEVATION—lifting of the amputated stump, causing the shoulder girdle to rise. (*low* force available)

Since we have plenty of force available, but little excursion, we must use ways of getting the most out of the excursion we do have. This was discussed above, under "Function." The inertia or velocity lock used with a pectoral cineplasty transmission

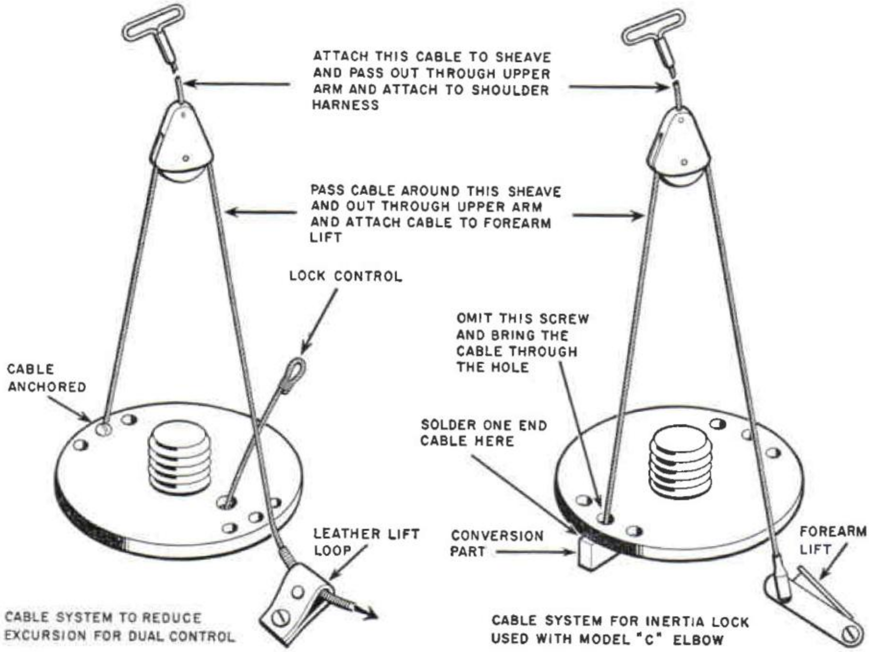


Fig. 1

reduces the excursion needed; now we have used the same idea in simpler form as an excursion step-up for other SD harnesses.

The new cable system is based on a two-to-one pulley, or sheave, and is explained in Figures 1 and 2.

What Prosthetic Controls Must We Supply?

A. Terminal Device Operation —Most commercially available TDs require an average of 2 1/4 inches excursion and 3-9 bs. force for operation. This is a high force requirement for our harness.

B. Forearm Flexion—Normally, 2-3″ excursion and 9-12 lbs. force are required to achieve 135 degrees flexion—another high force requirement.

C. Elbow Lock Operation — Elbow control requirements range from 0.5 to 0.9 inches of excursion, and 2-9 lbs. force. The minimum required force is low.

Three combinations of these controls are now in existence:

1. Triple Control—requires separate body motions for each prosthetic control, one each for forearm flexion, terminal device operation, and elbow lock. Three controls, three body motions.

2. Dual Control—combines two prosthetic controls harnessed to one body motion. At present, TD operation and forearm flexion are the two combined. As far as this writer knows, no one has tried a dual control system that combines other controls except as follows:

3. Inertia Lock—In this system, forearm flexion and elbow lock operation are harnessed to one body motion. Its best application may be found in pectoral cineplasty SD amputees. To operate at its maximum, two high force and high excursion motions must be available. (See Figures 2 and 3).

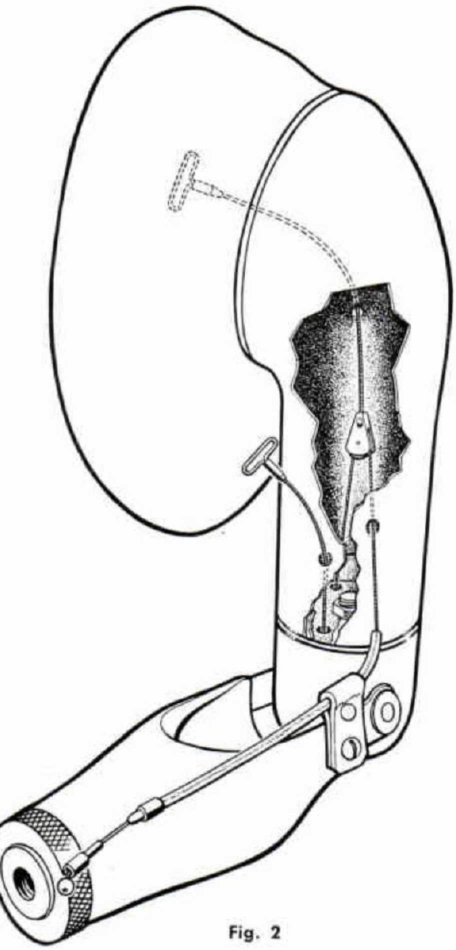


Fig. 2

Harnessing Women SDs

Before proceeding with diagrams and description of the present systems of SD harnessing, let's consider an important modification applicable to all of them. All present systems require a chest strap, and are shown as such in the concluding section.

Since the chest strap is unacceptable to most women, some kind of alternative is usually worked out—something that resembles a neck loop has been seen, and so has an arrangement where an extra waist strap anchors the chest strap and pulls it away from the breasts.

Now a method has been worked out that eliminates the chest strap by combining it with the one piece of harness a non-amputee woman normally wears—namely, the brassiere. As shown in Figure 4, a bra of sturdy material (not chiffon or lace!) is used, and a one-inch width of harness material is sewed around the lower margin (known to bra designers as the "diaphragm band"). For easy adjustment, a buckle is placed at Point "C". A clip type disconnect at Point "D" is necessary for ease in laundering. The elastic suspensor strap is sewed at Point "A" and fastened at Point "B" with a snap type fastener.

If this causes rotation of the brassiere for flat-chested individuals, or if greater stability is desired, the system shown in Figure 5 may be used. Here the bra is used only for suspension and the opposite shoulder loop for function.

Types of Shoulder Disarticulation Harness

The order in which the harness types are given below is as follows: Dual control with Shoulder Elevation Elbow Lock comes first because, in the writer's observations, it is the one most used with the least trouble. Dual Control with Opposite Shoulder Lock comes next, because it is the one shown on most present armamentarium display boards. Triple Control is third, appropriately. Dual Control with Nudge of Manual Lock is not described because, in the writer's opinion, the latter is definitely the least desirable system of all. Inertia Lock is last because it is limited in use to those with a pectoral cineplasty.

For an over-all comparison of the five harness systems, from the viewpoints of terminal device, controls, body control motions, advantages, and disadvantages, see the reference chart at the end of this discussion.

I. Scapular Abduction Dual Control With Shoulder Elevation Elbow Lock

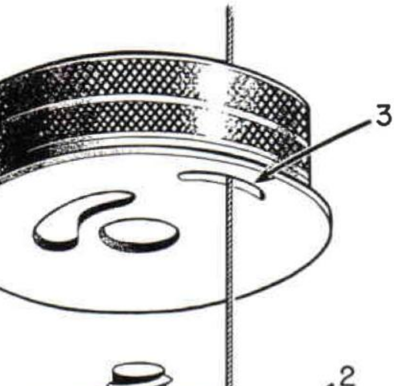


Fig. 3 (at left)

1. Disassemble the elbow and remove the lock lever. Drill a 1/16" hole near the end of the lever. Insert a 3/64" diameter cable and solder the end to hold it securely.

2. Drill a 1/16" hole through the elbow plate directly over the hole you just drilled in the locklever.

3. Cut an arc at least 1 1/4" long directly over the hole you have just drilled in the elbow plate. (Drill a series of 1/8" holes and finish with a file.) Reassemble the elbow. Drill a hole[1] in the front of the socket to allow straight pull of the cable to the forearm lift lever. Drill a hole[2] in the back of the socket to allow straight pull of the cable attached to the control attachment strap. Run the new cable from the lock lever, over the pulley assembly to the forearm lift lever. (Note that a swivel is used with the lift lever.) The new cable should be long enough to allow full forearm flexion. Small fair leads protect the cable as it passes through the holes in the socket. The front fair lead is held in place by a leather keeped, while the back fair lead is held by a retainer and base plate which affords a reaction point. System then appears as in Figs 1 and 2 with exception of dual cable control.

A. *Controls*

1) Dual control with scapular abduction for forearm lift and terminal device operation.

2) Elevation of shoulder on amputated side for elbow lock control.

B. *Discussion* (Fig. 6)

This system is very similar to the one described above. It differs only in operation of the elbow lock. The harness is again reduced to meet the comfort requirement of the amputee.

The elbow lock control is fastened to a waist strap positioned below the rib cage to provide an anchor to oppose shoulder elevation. Shoulder elevation provides an ample amount of both excursion and force for satisfactory elbow locking operation.

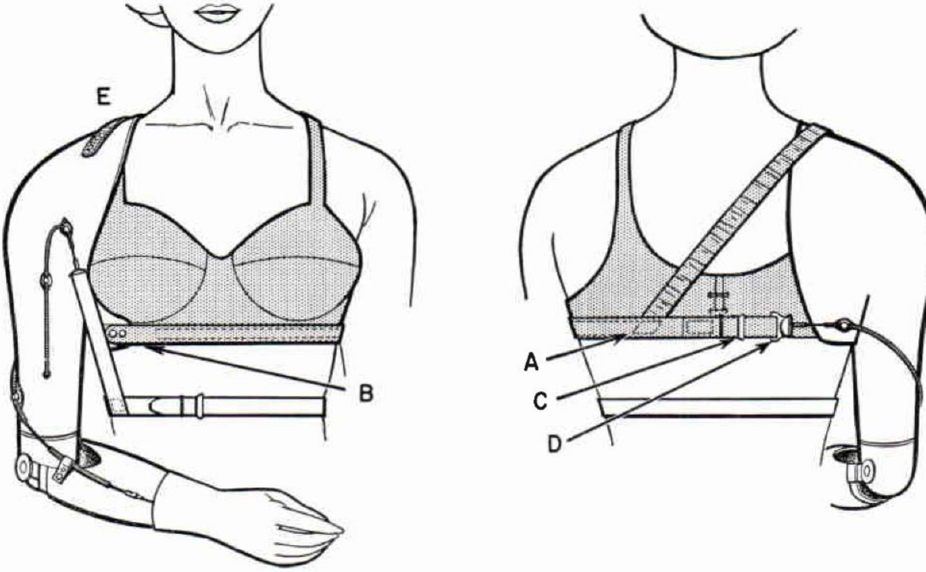
Another way for anchoring the elbow lock control is by attachment to an item of clothing, eliminating the waist strap. For a male amputee, the control may be anchored to a button on the waistband of his trousers near the opening of the fly. This position permits the control to pass out of the shirt between buttons, thus requiring no special opening (see Fig. 9). For female amputees the strap may be attached to a girdle if elimination of the waist strap is desired.

This system offers an advantage over oposite shoulder shrug elbow locking by the removal of involuntary unlocking of the forearm. Training is somewhat simplified and success may be determined at time of fitting.

II. Scapular Abduction Dual Control With Opposite Shoulder Lock

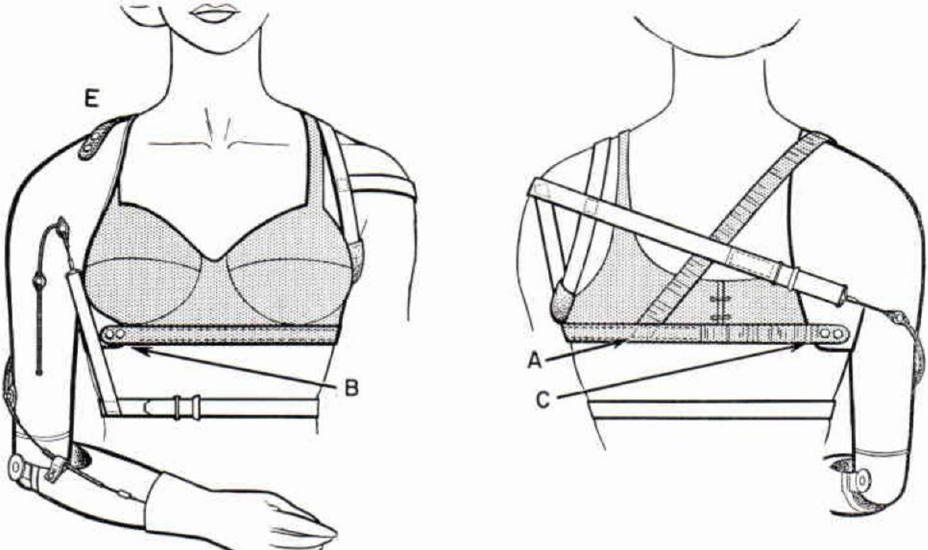
A. *Controls*

1) Dual control with scapular abduction for forearm lift and terminal device operation.



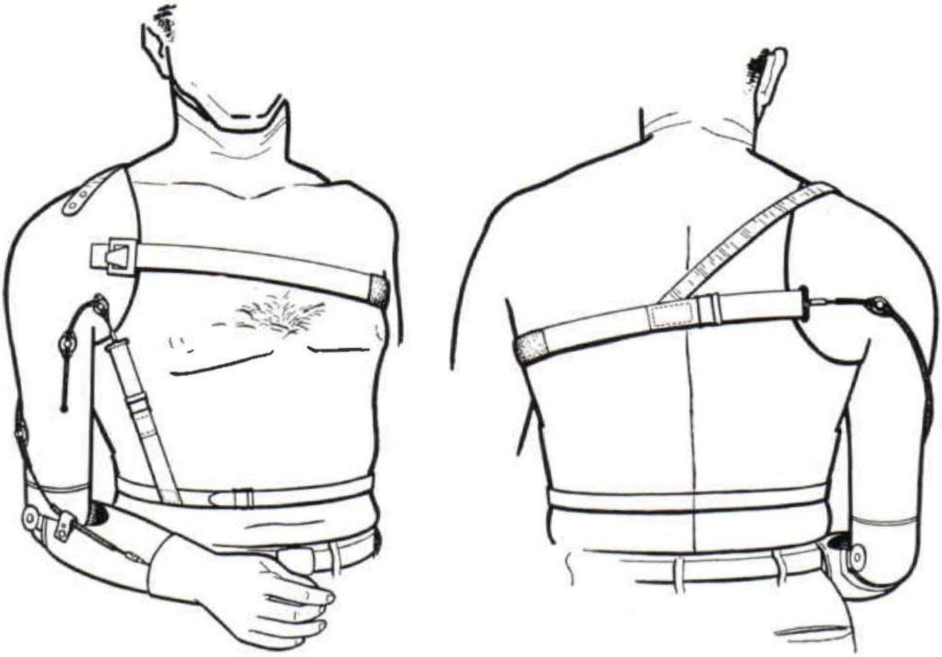
SCAPULAR ABDUCTION DUAL CONTROL
WITH SHOULDER ELEVATION ELBOW LOCK

Fig. 4



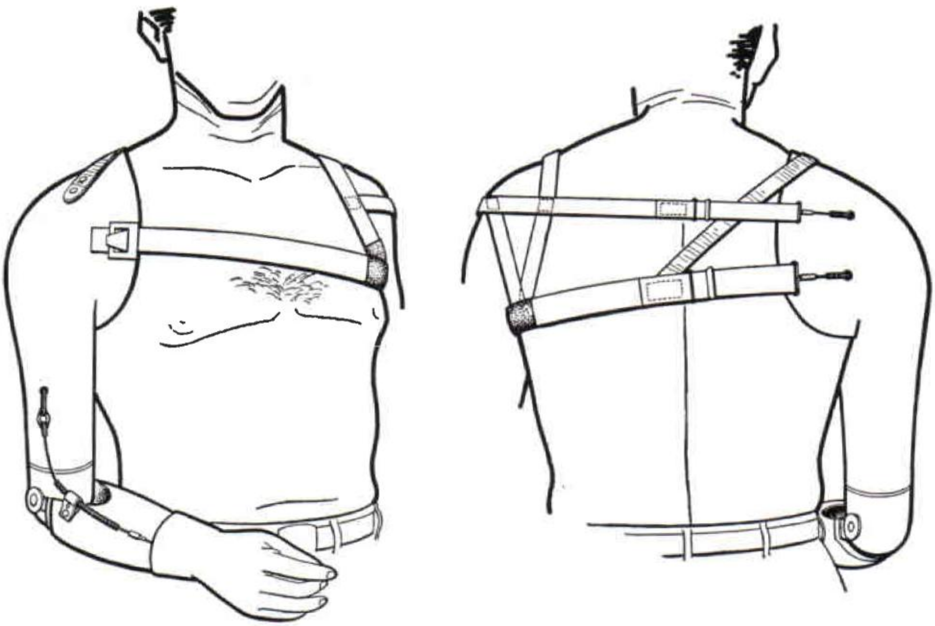
OPPOSITE SHOULDER DUAL CONTROL
WITH SHOULDER ELEVATION ELBOW LOCK

Fig. 5



SCAPULAR ABDUCTION DUAL CONTROL
WITH SHOULDER ELEVATION ELBOW LOCK

Fig. 6



SCAPULAR ABDUCTION DUAL CONTROL
WITH OPPOSITE SHOULDER LOCK

Fig. 7

B. *Discussion* (Fig. 7)

This system reduces the amount of harnessing required to operate the three basic controls for the shoulder disarticulation prostheses. It employs the conventional dual control system for forearm lift and terminal device operation. When the elbow is unlocked, scapular abduction flexes the forearm. When the elbow is locked scapular abduction operates the terminal device.

To operate the elbow lock the opposite shoulder shrug is harnessed by attaching the elbow control to the posterior wall of the shoulder cap using resular cable and housing (see Fig. 8). If the alternator spring in the elbow is not strong enough to return the control cable to the relaxed position, an additional spring may be added on the inside of the upper arm section. This will often make it easier for the amputee to separate opposite shoulder shrug from scapular abduction, thus preventing involuntary locking and unlocking of the elbow.

The involuntary locking and unlocking, inherent in this system, is the most serious disadvantage. However, if care is taken to separate the two operating body motions by keeping the chest strap at least mid-scapula and the opposite shoulder loop as high as possible these motions can be separated with proper training. Also, if the lock control loop is adjusted to require somewhat of an extreme shoulder shrug the separation of control will be made easier. Experience has shown that it is difficult to determine the success of the system as applied to an individual case at the time of fitting.

III. TRIPLE CONTROL SHOLDER DISARTICULATION HARNESS

A. *Controls*

1) Opposite shoulder shrug to operate terminal device.

2) Scapular abduction to operate forearm flexion.

3) Elevation of shoulder on amputated side for elbow control.

B. *Discussion* (Fig. 9)

Prosthetic Devices Study, Research Division, College of Engineering, New York University, Field Technical Report No. 1, reports this method being used successfully in the field.

The controls for the three basic functions are harnessed separately employing the triple control system. (Figure 9). The separation of terminal device operation from forearm flexion offers improved control of prehension since no excursion or force that affects the terminal device operation is introduced during forearm flexing. This advantage may be used very successfully with cases in which a voluntary opening terminal device is indicated or with a voluntary closing device to eliminate involuntary opening as found in dual control.

Again this system, as in the scapular abduction dual control with shoulder elevation elbow locking, overcomes the difficulty of separation of the body motions operating the controls. The result is, of course, simplified training and the determination of success at time of fitting.

The following description and illustrations are quoted from the previously mentioned NYU report:

a) *Chest Strap for Forearm Lift*

The control cable enters the shoulder cap at a posterior-inferior aspect to connect with a pulley on the inside of the upper socket. Another cable attached to the turntable (see Fig. 2) passes through the pulley sheave and exists on the lower end of the upper socket passing in front of the elbow center. This cable terminates on a metal forearm lift.

b) *Axilla Loop for Terminal Device Operation*

The control strap from an axilla loop crosses the seventh cervical vertebrae (or just below it) connecting to a cable which enters the shoulder cap on its posterior-superior aspect.

This cable passes through the upper socket and exits at its lower end above the elbow and is guided to the terminal device by a retainer plate on the forearm.

c) *Shoulder Elevation for Elbow Lock Control*

The control cable runs from the top of the elbow turntable inside the upper socket and leaves the shoulder cap on the anterior side. This cable is guided by cable housing and a retainer plate toward the nipple line and attaches to a control strap which fastens to the fly button or (girdle.)

The system, as presented, employs the two-to-one pulley system for reducing elbow lift cable excursions as described earlier in this report. Note that this, as in the foregoing system may be used with external cable routing if it is indicated.

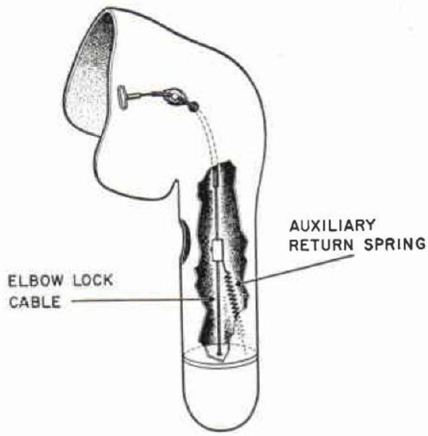


Fig. 8

IV. Inertia Elbow Lock With Pectoral Cineplasty Terminal Device Control

A. *Controls*

1) Scapula abduction for forearm lifting and elbow locking.

2) Pectoral cineplasty terminal device operation.

B. *Discussion*

The inertia lock, as shown in Figure 10, employs the same body motion to lift the forearm and operate the elbow lock. The initial cable excursion lifts the locking bar from the locked position thus allowing the continuing force and excursion to lift the forearm. Upon quick relaxation of the lift control the locking bar engages with the forearm eliminating a separate control for this function.

The terminal device is connected to the pectoral tunnel using the Bowden cable load housing. Care should be exercised to prevent internal rotation of the arm socket. The line of pull should be on approximately the same level as the shoulder joint. Excess friction shoud be avoided, especially about the elbow pivot joint.

While the inertia lock has been very successfully used for short above-elbow and shoulder disarticulation cineplasty cases, at present it is *not* recommended for the conventional shoulder harness prostheses. Separation of body motions control has been the major shortcoming in non-cineplasty cases.

V. Nudge and Lanyard Control

This system is described in detail in Section 7.7—7.9 of "The Manual of Upper Extremity Prosthetics." Since this method should be employed only as the last possible choice it will not be discussed in detail but will be covered in the summary.

VI. Summary

A general discussion of the shoulder disarticulation control requirements and the accompanying necessary body motions is offered for reference. Experience has shown that the dual control system, when employed with a voluntary opening terminal device, usually exceeds the excursion available thus limiting full opening at mouth. Careful consideration of excursion required with respect to the terminal device indicated and excursion available, should be used to select the harness method offering the greatest potential.

Basically, three body motions are used in the systems previously discussed, and with proper attention to locating reaction points and control straps the motions may be harnessed to obtain the desired results. These motions are defined for the purpose of discussion.

When the operating excursion exceeds the amount available, a system using a two-to-one pulley is explained and illustrated, both for conventional and the inertia ebow locks. Also described is brassiere suspension for women SDs.

Previously, "The Manual of Upper Extremity Prosthetics" has recommended the nudge or lanyard control exclusively. In addition to this manually operated elbow lock, four other combinations of control are offered to operate the prosthesis without aid of the normal hand. These combinations vary the application of the body motions to the prosthesis control using four separate possibilities. From an analysis of the described system the Shoulder Disarticulation Reference Chart is offered the prescription team. (Fig. 11).

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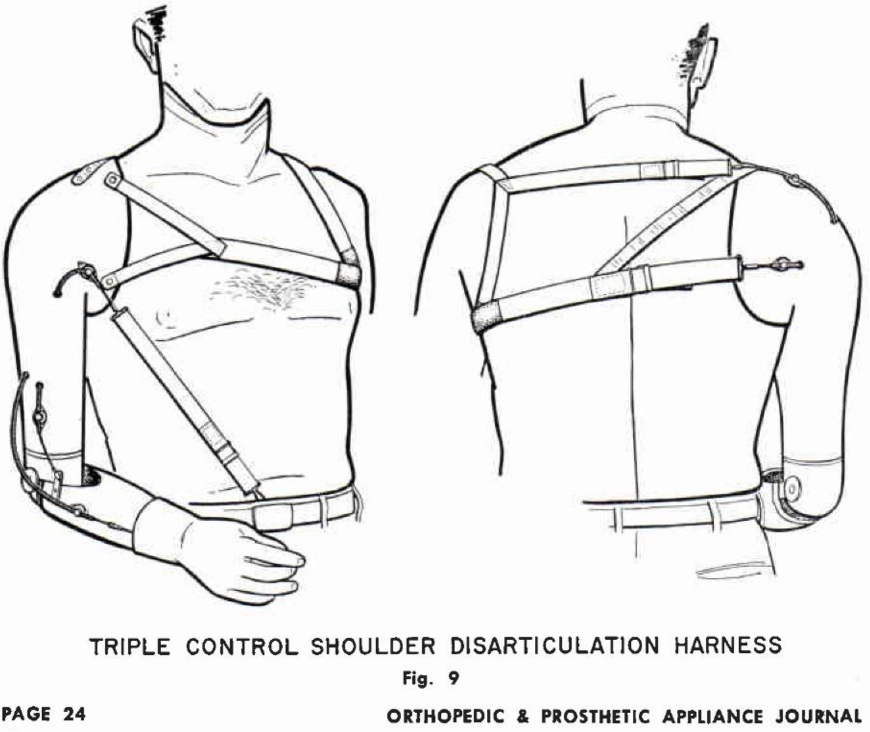
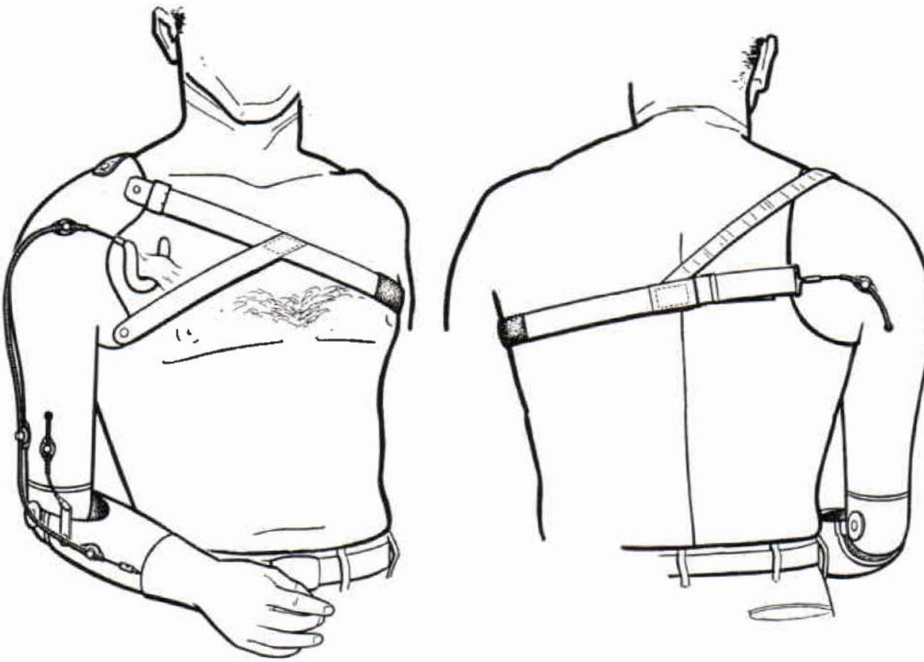


TRIPLE CONTROL SHOULDER DISARTICULATION HARNESS

Fig. 9



INERTIA ELBOW LOCK WITH PECTORAL CINEPLASTY TERMINAL DEVICE CONTROL

Fig. 10

SHOULDER DISARTICULATION REFERENCE CHART

CABLE SYSTEM AND HARNESS ARRANGEMENT	RECOMMENDED TERMINAL DEVICE	REQUIRED HARNESS CONTROLS	BODY MOTIONS REQUIRED	ADVANTAGES	DISADVANTAGES
SCAPULAR ABDUCTION DUAL CONTROL WITH SHOULDER ELEVATION ELBOW LOCK	VOLUNTARY CLOSING	• CHEST STRAP • WAIST STRAP OR CLOTHING ATTACHMENT	• SCAPULAR ABDUCTION • SHOULDER ELEVATION	• NO EXCESSIVE HARNESS • GOOD SEPARATION OF CONTROLS • SUCCESS CAN BE DETERMINED AT TIME OF FITTING • NO TRAINING PROBLEM	• CLOTHING ATTACHMENT OR WAISTBAND REQUIRED
SCAPULAR ABDUCTION DUAL CONTROL WITH OPPOSITE SHOULDER LOCK	VOLUNTARY CLOSING	• CHEST STRAP • OPPOSITE SHOULDER LOOP	• SCAPULAR ABDUCTION • OPPOSITE SHOULDER SHRUG	• HARNESS ONLY ABOUT THE SHOULDER GIRDLE	• POOR SEPARATION OF CONTROLS (e.g. INVOLUNTARY LOCKING AND UNLOCKING OF THE ELBOW) • TRAINING PROBLEM • UNABLE DETERMINE SUCCESS AT TIME OF FITTING
TRIPLE CONTROL SHOULDER DISARTICULATION HARNESS	VOLUNTARY CLOSING VOLUNTARY OPENING	• CHEST STRAP • WAIST STRAP OR CLOTHING ATTACHMENT • OPPOSITE SHOULDER LOOP	• SCAPULAR ABDUCTION • OPPOSITE SHOULDER SHRUG • SHOULDER ELEVATION	• SELECTION OF EITHER TYPE TERMINAL DEVICE • MAXIMUM AMOUNT EXCURSION AVAILABLE TERMINAL DEVICE REGARDLESS POSITION OF FOREARM	• MAXIMUM HARNESS REQUIRED • PATIENT MUST HAVE ALL 3 GOOD BODY MOTIONS
INERTIA LOCK WITH PECTORAL CINEPLASTY TERMINAL DEVICE CONTROL	VOLUNTARY CLOSING	• CHEST STRAP • CINEPLASTY TRANSMISSION	• SCAPULAR ABDUCTION • PECTORAL CINEPLASTY	• MINIMUM HARNESS • GOOD PREHENSION CONTROL	• RECOMMEND FOR CINEPLASTY ONLY • TRAINING REQUIRED FOR INERTIA LOCK CONTROL
NUDGE OR LANYARD LOCK CONTROL WITH DUAL CONTROL CABLE SYSTEM	VOLUNTARY CLOSING	• CHEST STRAP • NUDGE OR LANYARD CONTROL	• SCAPULAR ABDUCTION • CHIN NUDGE OR MANUAL LOCK OPERATION	• NO TRAINING PROBLEM • GOOD FOR BILATERAL S/D CASES	• MANUAL OPERATION • COSMETICALLY OBJECTIONABLE

Fig. 11