Application Of External Power In Upper Extremity Orthotics*

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In dealing with the patient who has severe paralysis of the upper extremity, the orthotist often is confronted with the problem of lack of available muscle power for the control of a device. It is frequently necessary to resort to an external source of power to operate desired motions. In selecting an external source of power one must consider the efficiency of the source used, its ease of application, availability and cost of replacement.

After investigation, it was found that the source that most satisfactorily provides these essentials is carbon dioxide.[1] Carbon dioxide is a low molecular weight gas which liquefies at 750 pounds, 72° F. It is non-toxic, non-combustible, costs approximately 10 cents per pound in liquid form, and is readily available almost anywhere in the United States.

Before attempting a fitting utilizing carbon dioxide for external power, the orthotist should have a good understanding of the components necessary in order to convert this power into motion. The external power system consists of the following parts: the cylinder for storing gas; the pressure regulator for reducing the tank pressure to a useable range from 0 to 90 pounds; connecting tubing; valve; pneumatic actuator, which may be an artificial muscle, piston and cylinder, or bellows.

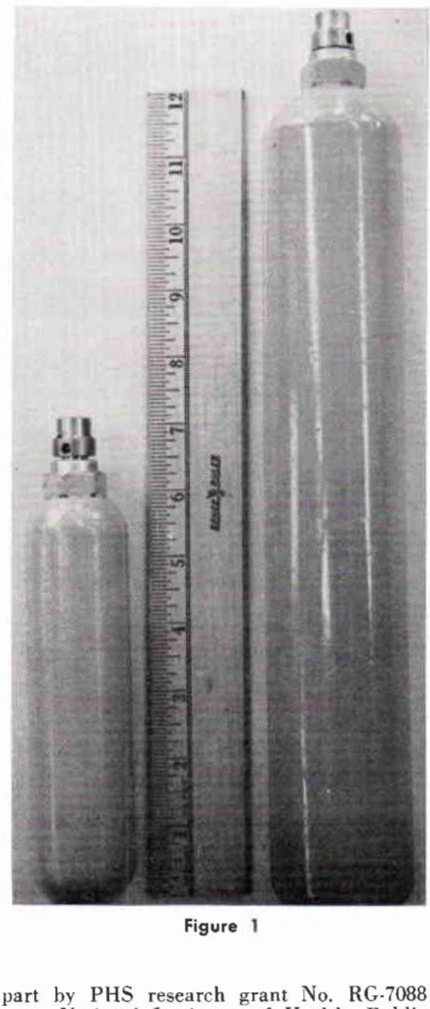

Figure 1

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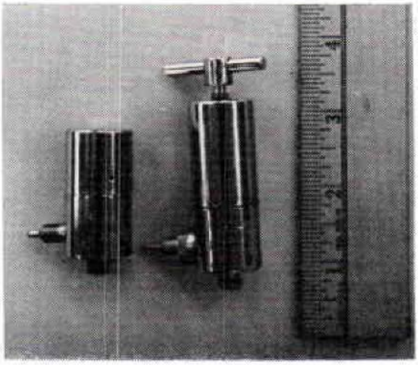

Figure 2

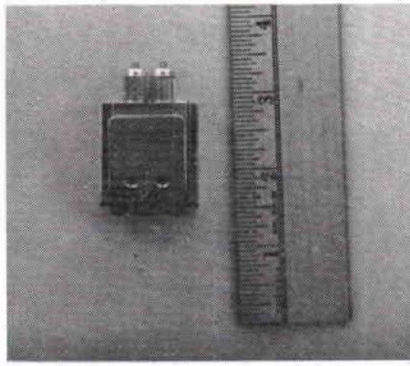

Figure 3

Experience has shown that two cylinder sizes will handle most cases. The small cylinder is satisfactory for use on ambulatory patients where weight is a problem and the large cylinder is satisfactory for wheel chair patients where the weight need not be a consideration (Fig. 1).

There are currently two pressure regulators in use. One is adjustable, and provides pressure in the range of 0 to 90 pounds, which may be raised or lowered by means of the adjusting screw on top of the regulator. The non-adjustable type is pre-set at 50 pounds and provides no feature of adjustment. The only advantage of the non-adjustable regulator is that it is smaller (Fig. 2).

The connecting tubing that has been found to be most satisfactory is .162 O.D. .055 I.D. polyvinyl chloride, 150 pound burst.

The valves most commonly used are the lever valve (Fig. 3), the slide valve (Fig. 4), and the microswitch activated solenoid valve (Fig. 5). All valves have three positions: a position of fill, a position of hold, and a position of exhaust. It was found necessary to provide a position of hold because the amount of force available for control in the paralyzed patient is quite limited. With the position of hold, a patient can fill the pneumatic actuator, close the hand on a pencil for example, and then relax and maintain this force until the valve is actuated to the exhaust position. This enables the patient to maintain prehension with no expenditure of energy.

The lever valve requires about four ounces of activating force and is designed for use where the control source is a push, such as in plantar flexion or dorsiflexion of the foot (Figs. 6, 7), abduction of the thigh, or nudge control using the chin. This valve is used most commonly with wheel chair patients.

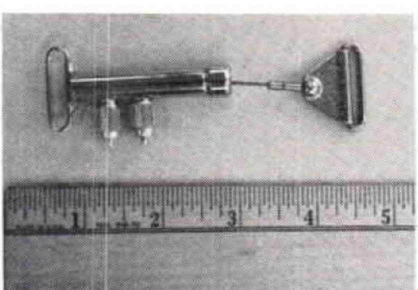

Figure 4

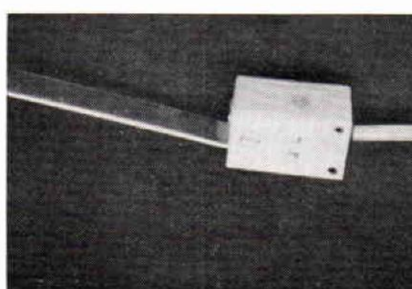

Figure 5

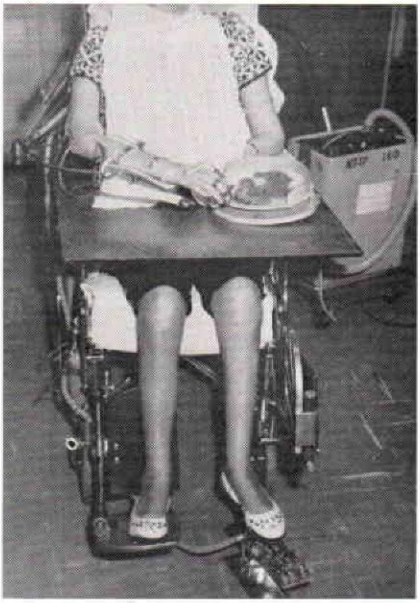

Figure 6

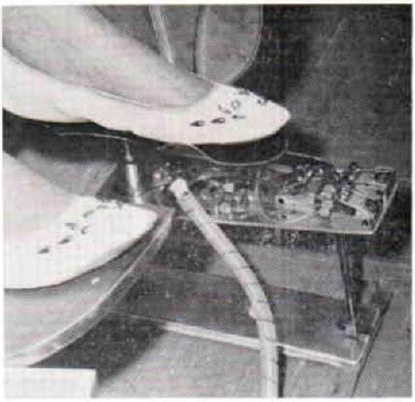

Figure 7

The slide valve requires about eight ounces of activating force and is designed to be inserted directly into the harness (Fig. 8). This valve is primarily for use with the ambulatory patient in conjunction with a shoulder harness.

The solenoid valve has an activating force of about four grams and is designed for application where force and excursion are extremely limited. For example, it can be mounted to utilize trace finger flexion to activate an artificial muscle driven flexor hinge splint (Fig. 9). By wiring the solenoids in parallel it is possible to control two artificial muscles with one activator whereby one artificial muscle will fill as the other one exhausts, thus providing an agonist antagonist action. This can be quite helpful when applying pneumatic actuators to mobile arm supports, such as ball bearing feeders.

The pneumatic actuators most commonly used are the artificial muscle and the piston and cylinder. There are two artificial muscles, weave 100-1 and weave 100-2. It can be seen from the force-tension curves (Figs. 10, 11) that the muscle weave 100-2 has approximately the same excursion but

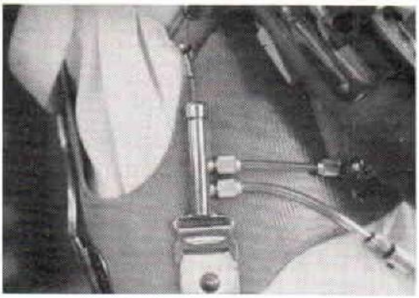

Figure 8

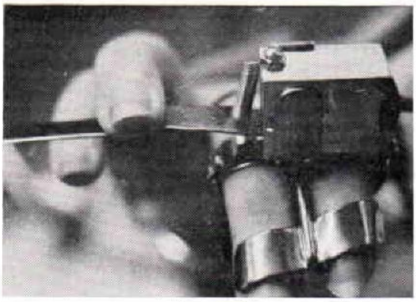

Figure 9

twice the force of weave 100-1. Weave 100-1 has a life of about 1,000,000 cycles, as compared to weave 100-2 with approximately 15,000 cycles.

One advantage of the artificial muscle over a piston and cylinder is that an artificial muscle has no static friction. When gas is ejected at low pressures into a piston and cylinder, there is a tendency for the sealing medium to adhere to the cylinder wall, causing the pressure to build up and then the piston to move. This causes an uneven, jumpy action. This situation does not occur in the artificial muscle or bellows actuator. Another advantage of the artificial muscle is that alignment is not critical. With a piston and cylinder one must be very careful to obtain accurate alignment or the system will not function properly. A third advantage of the artificial muscle is its weight. It is extremely light as compared with a piston and cylinder.

The disadvantage of the artificial muscle is that it is inadequate when one attempts to apply considerable force through great excursion, such as is needed in the mobile arm support for the wheel chair patient, because it will only contract about 30 per cent of its length. In these cases it is necessary to use a piston and cylinder.

We have found it to be more practical in most cases to use the double acting piston which we can control with one valve, as described above in relation to the solenoid valve. This supplies us with a bi-directional power and has a tendency to minimize the static friction inherent in the piston and cylinder.

It is quite often necessary to operate a number of artificial muscles from one power cylinder. This can be achieved by the use of a manifold connection of all the connecting tubes.

This article is the first of a two-part series. The second part will cover fitting techniques, etc.

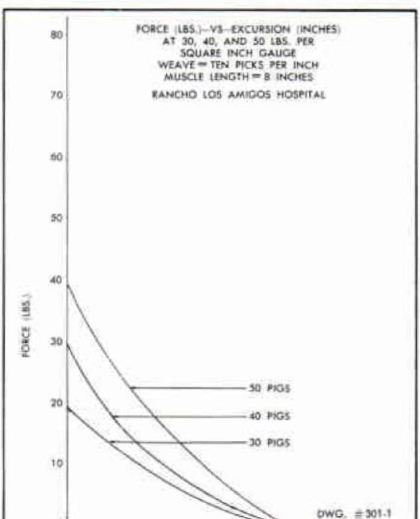

Figure 10

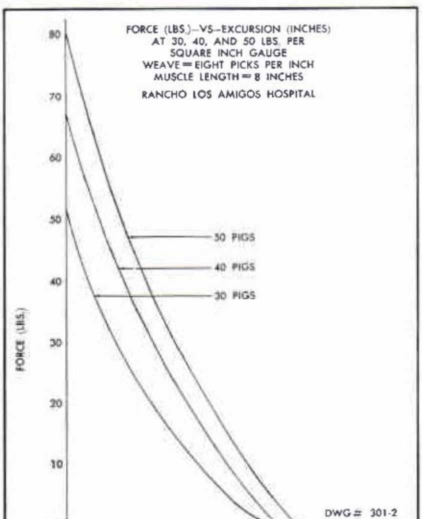

Figure 11

REFERENCE

[1] Snelson, R. and Conry, J.: Recent advancements in functional arm bracing correlated with orthopedic surgery for the severely paralyzed upper extremity. Orthopedic & Prosthetic Appliance J., 12: 41-49, March 1958.