A quadriplegic or similarly disabled individual who has paralysis of the hand and wrist, but whose wrist extensors have fair plus or better strength, can be successfully fitted with a wrist-driven flexor hinge splint, an R.I.C. plastic tenodesis splint, the Engen reciprocal wrist extension-finger flexion orthosis, or similar device (1, 2, 3). A successful fitting is achieved when the patient has some return of useful function. For the patient whose wrist extensors are too weak to use the above type splints, other means must be used to achieve useful hand function. Body motions such as shoulder elevation or scapular abduction can be harnessed as a power source for the hand splint. However, the patient who has weak wrist extensors and who does not have other body motions which can be harnessed is left with no means to power his hand splint except by using power from some external source. In recent years many such externally powered devices have been fitted to patients using electricity and compressed gas as a power source (1, 4, 5, 6, 7, 8).

The electric power unit for a hand splint (described below) is an outgrowth of the NU Power Unit for the upper-extremity amputee (9). This prosthetic power unit is basically a d.c. permanent magnet motor driving a highly efficient (90 percent) ball-bearing nut and screw to convert rotary motion to linear motion. It is capable of exerting 25 lb. force in either direction (pushing or pulling). This, in fact, could be increased to 31 lb. using a smaller pitch ball-bearing screw just recently available (10).

Figure 1 shows Model I of the prosthetic power unit adapted for powering the hand splint of a C-5, C-6 quadriplegic. The power unit, plus batteries, is contained in an aluminum box 10 x 2 x 1% in. in size. The box is mounted to the wheelchair frame in any convenient location such as shown in Figures 2a and 2b. The unit is connected to the hand splint using a prosthetic control cable and cable housing.
with a Teflon liner (Fig. 3). A highly efficient ball-bearing screw and nut were replaced with a less efficient drive screw with a standard #6-32 screw thread and Teflon nut to provide self locking. The control switch (Fig. 3) operated by the opposite arm consists of a double pole, double throw, momentary contact, center off switch with an extension on the operating lever to provide a larger “target” for the patient. Energy is supplied by nickel-cadmium button cells with a capacity of 500 mah. The unit is adjusted to provide the patient with a prehension force of 4 lb. by decreasing the battery voltage. During patient
training this was found to be adequate for activities of daily living, yet it was deemed low enough to prevent skin damage to anesthetic fingers in the event of prolonged contact with an object. A quadriplegic has been using the powered splint for 24 months with no major problems (Fig. 4).

![Figure 4](image)

FIGURE 4.—The quadriplegic fitted with the unit shown in Figure 5.

Since the prosthetic power unit is capable of more force than is required to operate the hand splint, it was decided to use a less powerful, more simplified unit, but retain the same basic configuration for the drive mechanism. The resultant unit is shown in Figure 5. The d.c. permanent magnet motor is coupled directly to the #6-32 drive screw, the thrust force developed during operation of the unit being borne entirely by the thrust washers of the motor. The Teflon nut (under the cover plate in Fig. 5) is attached directly to the control cable. When the patient grasps an object the control cable is loaded not only in tension, but also in torsion. This torsional load tends to twist and untwist the cable strands during grasping and releasing; however, this cyclic load is low enough to prevent a torsional mode of failure. Solid (music) wire can also be used to provide the system with the ability to push as well as pull. This allows for the use of a weaker finger extension spring on the splint with the advantage of less cable force being required to overcome this spring force and more force being utilized directly for prehension. The patients do notice the additional stiffness in the control cable but feel that it is not objectionable. The battery pack is composed of seven nickel-cadmium cells encased in shrinkable tubing and placed inside of the power unit case as shown in Figure 5.

Units have been fitted to six quadriplegics with success. It has given the patients prehension which it is felt could not have been accom-
plished by means other than external power. In each case on/off switching has been the control mode. In addition to the hand control mentioned above, shoulder elevation and head motion have been used (Fig. 6 and 7). All but one splint are of the Rancho type as shown in Figure 3. The remaining splint is an Engen finger prehension orthosis with a friction wrist joint (Fig. 8).

Figure 5.—Simplified drive mechanism.

Figure 6.—Control switch operated by shoulder elevation.

Figure 7.—Control switch operated by head motion. This switch assembly can also be positioned for shoulder elevation control on either left or right. This gives a choice of several control sites which can be evaluated to find the optimum location.
CONCLUSION

Although our experience has been limited to the fitting of six patients, the units described in this article have been very reliable. None of the units has experienced malfunction, except when the patient has neglected to recharge the battery. All of the control methods have been on/off switching; however, two patients will be studied as possible candidates for myoelectric control systems.

REFERENCES