The I.N.A.I.L. Myoelectric B/E Prosthesis

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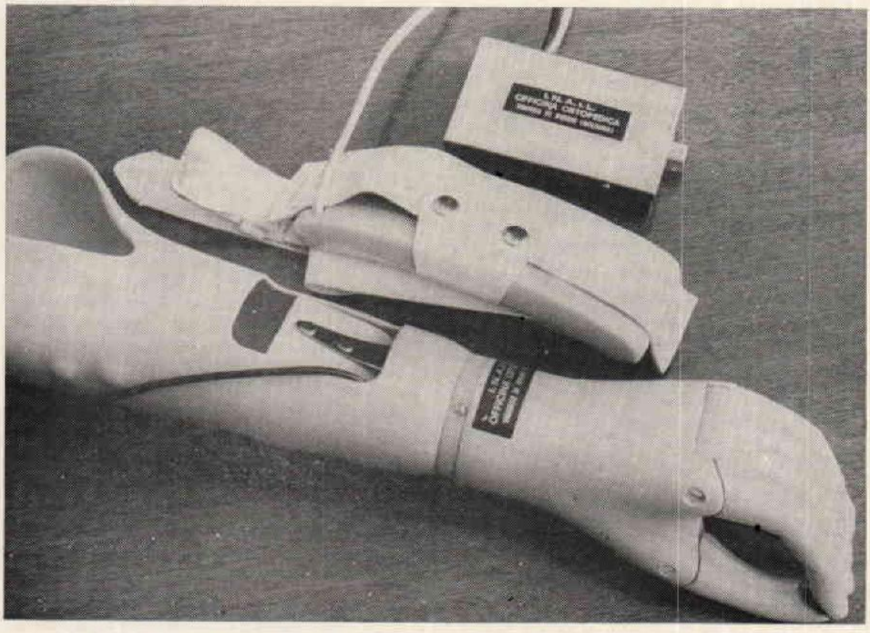
EDITOR'S NOTE: The following article was presented at the AOPA National Assembly in Colorado Springs, Saturday morning, September 4th, 1965. Otto Bock Orthopedic Industry, Inc. of Minneapolis, is distributor of the I.N.A.I.L. system. Questions relating to the component parts and availability of the system may be referred to them.

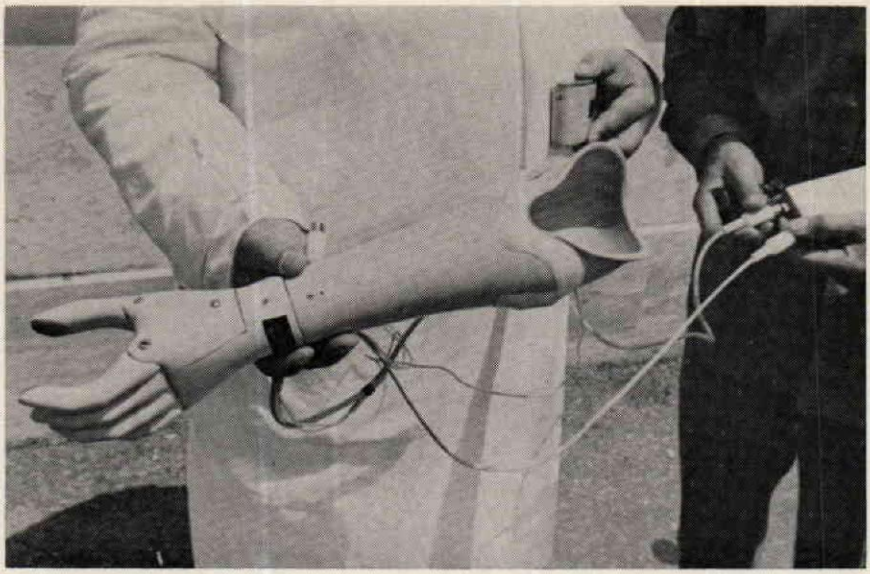
I appreciate the opportunity to speak before this group of American Orthopedic Specialists on the subject of I.N.A.I.L. Myo Electric Prosthesis.

I shall enter immediately into the subject dealing with the details and technical characteristics of the prosthesis itself. First of all, I should like to explain the meaning of the expression "Bio-Myo-Electric."

The term "bio-myo-electric" derives from the Greek "bios" meaning life or body and "mios" meaning muscle. From this it may be understood that muscular current is being utilized to operate artificial limbs. Here is how it works.



I.N.A.I.L. System: Prosthesis, battery pack, and amplifier



View of B/E Arm, Hand, and Amplifier and Battery Pack (complete system)

The central nervous impulse originating from the brain travels along the neurone causing muscular contraction. At the level of the neural plate and the tendons this impulse generates high frequency electrical waves of very low potential.

Electromyology has recorded these signals both in depth (muscular mass) and at the surface. We are interested in the surface, or contact derivation.

Through the use of electrodes and by exploiting the gain of a transistor amplifier; micro-relays and electrical circuits can be closed. Furthermore, using electrical or pneumatic power, one can thus obtain movements.

The two pairs of contact electrodes can pick up an electrical impulse as small as 20 - 30 microvolts (a microvolt is one millionth of a volt) from a dry normal skin surface overcoming even a fairly thick fatty layer.

The muscles of the amputation stump retain the property of emitting impulses strong enough to be picked up and amplified to the point of securing the closure of relays. Our transistor amplifier gives an effective gain of 40 to 100 thousand times and can be adjusted according to the need.

On a below-elbow prosthesis, two terminal relays operate the electrical circuits. A pair of electrodes placed over the flexor muscles close the fingers of the artificial hand. Another pair of electrodes placed over the extensor muscles open the hand. The action is smooth, accurate and, if desired, strong.

The sensitivity of the grip is such that the tips of the fingers can pick up an egg without crushing the shell, or lift a weight of 33 pounds.

An important feature of our design is the micromotor. It is of greatest importance that the micromotor begins to operate only if the muscle begins to contract. Thus, once the amputee has grasped an object, he does not have to concentrate on keeping the muscle contracted to maintain his grip.

With this type of prosthesis the stumps in which pronation and supination have been preserved can move freely since, by means of suitable calibration of the amplifying apparatus, the pronator and supinator impulses do not interfere with flexo-extension and therefore with closing and opening. At the same time, opening and closing can be achieved in both maximum pronation and supination.

A prosthesis for a person with the forearm amputated consists of: battery — amplifier — hand.

Battery—The battery supplies power for closing and opening the fingers of the hand and power for the operation of the amplifier. The consumption of the amplifier is very little whereas that of the motor is considerable. However, experiments have been carried out, always under strain, in which a minimum of 1400 movements and more have been obtained.

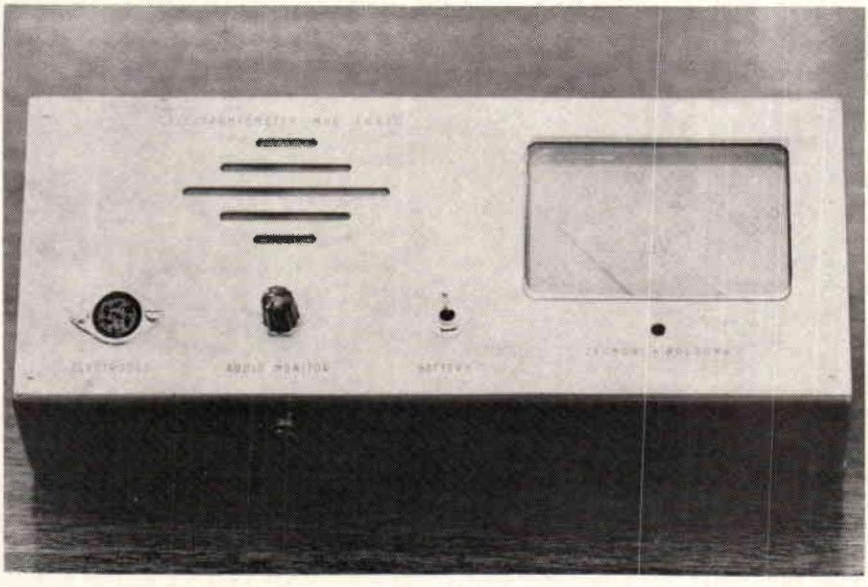
It is considered that the utilization of an artificial hand involves a series of about 400 movements a day. Therefore, the effective use of the hand is assured for at least two days before the battery requires recharging.

The battery, 6.8 x 2.4 x .65 inches (172 x 60 x 16mm) in size, can be recharged. It is slightly curved in shape so as to fit against the abdominal belt on which it is placed. It weighs 12.34 ounces (350 grams), and is made up of nickel-cadmium elements. Its average tension is 12 volts, and its capacity 0.45 amp. hrs.

The various components of the prosthesis are connected by special highly screened leads and plugs.

The Amplifier—The amplifier with transistors is enclosed in a casing measuring 4.15 x 2.4 x 0.8 inches (105 x 60 x 20mm) with a total weight of 4.6 ounces (130 grams). It is made up of two identical silicon transistor channels having a total gain of over 40,000.

The transistors are coupled in a special way so as to make it possible to amplify a band of frequencies involved in the myoelectric field. Frequencies above and below these vales are filtered out. In this way an amplifier has been achieved that cuts out disturbances due to house current dis-



Electromyometer used to determine optimum placement for electrodes

tribution as well as disturbances set up by the micromotor and broadcast transmissions. Through a potentiometer, the total gain of each single channel can be adjusted. This makes possible excellent adaptation of the prosthesis both as between individual and individual and, on the same individual, as between the electrodes placed on the flexor muscles or on the extensor muscles.

Hand—The hand, in plastic, is articulated at the junction between the metacarpal bones and the phalanges of the long fingers and of the thumb by means of ball-bearings; the fourth and fifth fingers are included in the movement of the second and third and are made of an elastic material. In the wrist cavity there is housed an electric micromotor which, through a reduction gear and a mechanical device incorporating screws and a slider with levers, operates the fingers. In particular this mechanism is made up of an electric motor with reduction gear and mechanical device in a single unit.

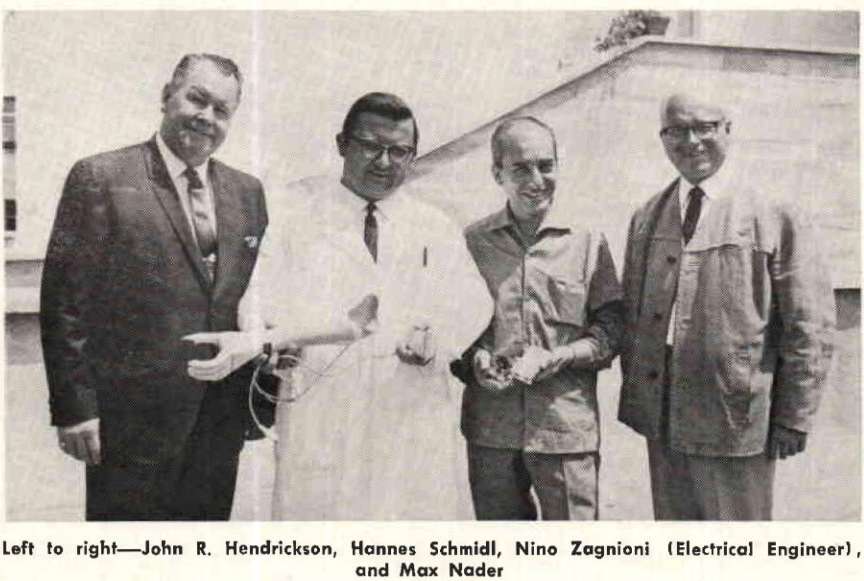
The micromotor operates on direct current and turns over at 15,000 rpm.

The total weight of the hand is about 12.34 ounces (350 grams).

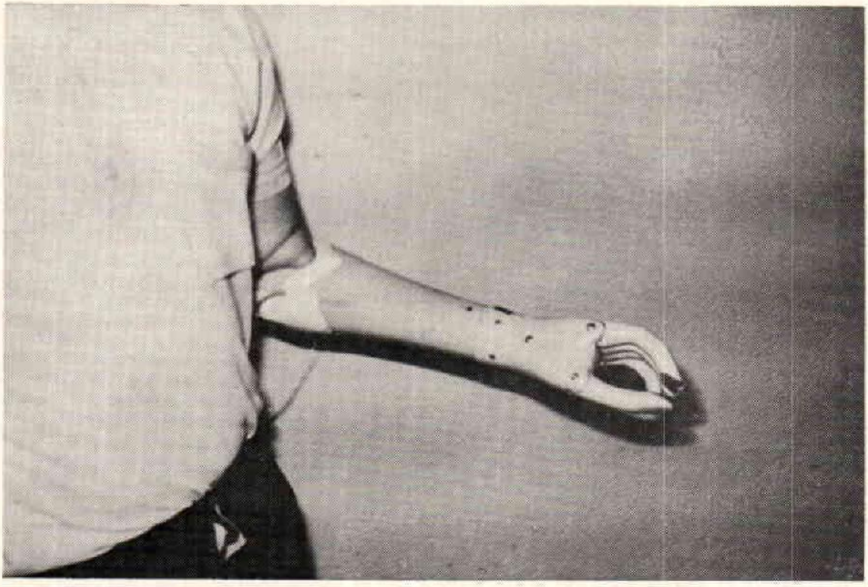
The strength of the grip at the tips of the fingers (measured by the dynamometer) reaches about 15½ lbs. (7 kgs), while with a pincer grip it can lift about 33 lbs.

To operate the prosthesis, the brain orders the flexor muscle to contract. This generates tiny signals called electro myographic, or EMG potentials. These EMG signals are picked up by the surface electrodes built into the socket of the prosthesis and amplified so as to run the small micromotor in the hand.

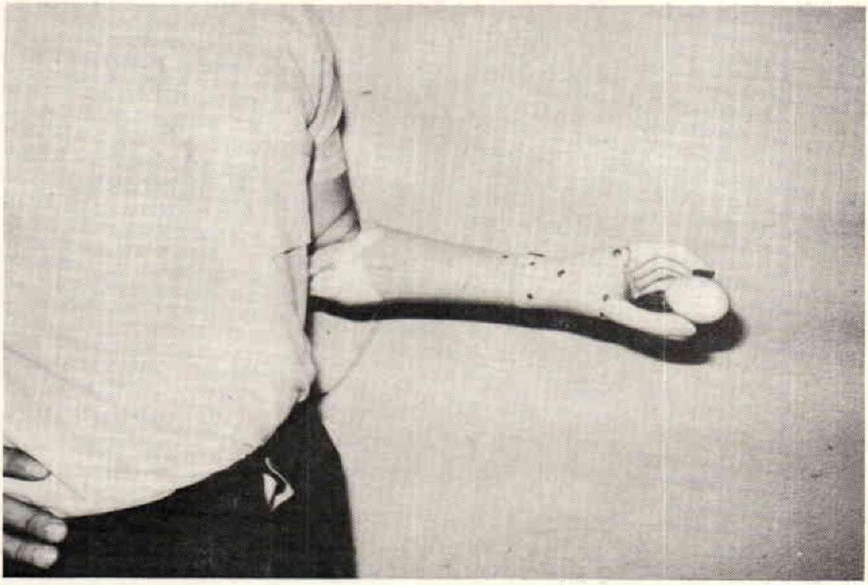
If the amputee wants a strong grip, he continues to order the flexor muscles to contract. Each command strengthens the grip until it reaches the maximum force. Conversely, when a light grasp is desired, the hand can be closed softly over the object. Ordering the muscle to contract further the amputee can progress from a soft grip to a strong grip thereby crushing or compressing any fragile or soft object in his artificial hand.



Left to right—John R. Hendrickson, Hannes Schmidl, Nino Zagnioni (Electrical Engineer), and Max Nader



I.N.A.I.L. Below Elbow Arm applied to amputee



I.N.A.I.L. Below Elbow Arm—Shows control possible by grasping an egg without crushing the shell

This particular prosthesis illustrates the principle of myo-electric control. It is possible, through attachment of other pairs of electrodes, to provide supination as well as pronation. In the case of an above elbow amputee, it will be possible to provide elbow extension and flexion.

We are at present organizing the mass production of the I.N.A.I.L. myoelectric prosthesis. At this stage modifications will be made to the external structure of the hand, which will be covered by a glove for appearance sake.

Myo-Electric and Pneumatic Control

Working with arm amputees using the Myo-Electric principle, it occurred to us that we might be able to combine the system with the Pneumatic System developed at Heidelberg, Germany.

This type of control, according to our research, would be of particular value to quadriplegics, especially in those cases where it is possible to apply an orthosis that can be operated by means of myo-electric impulses picked up from the facial muscles.

The special nature of these impulses makes it possible to obtain an extremely sensitive control exploiting the functioning parts of the body. Where it is not possible to apply electrodes to the facial muscles to operate a pneumatic control, an orthosis could not be used.

The possibilities of the application of Myo-Electric—Pneumatic Control are being studied at our Institute and we are convinced that they open unhoped-for horizons in the rehabilitation of the paralyzed.

VIETNAMESE REHABILITATION PROJECT ANNOUNCED

Dr. Howard A. Rusk, President of the World Rehabilitation Fund, Inc., has announced that the Fund is undertaking a major rehabilitation project for Vietnamese military and civilian disabled. The project is being financed by the Agency for International Development, U.S. Department of State, and will provide equipment and supplies to enlarge the present rehabilitation center in Saigon and to construct three smaller centers in the provinces.

AOPA member Juan Monros arrived in Saigon early in December to begin work as director of the prosthetics and orthotics portion of the project. Mr. Monros, who speaks English, French and Spanish, has conducted similar crash training programs in Peru, Brazil, Haiti, India and Ethiopia. One such project, sponsored by VRA and the World Rehabilitation Fund in 1962, has offered 1,000 sets of prefabricated brace parts to the new project.

Production of 500 artificial limbs and braces per month within a six-month period, and 1,000 per month by the end of the year, is the goal of the Vietnamese center. At present only about 60 new limbs and braces are produced each month. Prosthetic-orthotic equipment and supplies are being flown to Vietnam from the West Coast for use at the new center.

The estimated number of amputees in Vietnam varies from 10,000 to 35,000, and includes a large number of veterans wounded in the fighting against the French more than ten years ago.