CONTRIBUTION TO RESEARCH ON THE PROBLEM OF EXTERNALLY POWERED PROSTHESES FOR THE UPPER LIMBS

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In the field of externally powered upper limb prostheses, in a parallel way to what is done in the various world centres concerned with this very interesting subject we have been working last four years manufacturing prostheses with electronic hand for the B. E. amputees. In a special way two types of control have been studied, electromechanical and myoelectric, and two types of equipment have been manufactured:

(1) With myoelectrically controlled hand.
(2) With electro-mechanically controlled hand, by means of the stump pro-supination.

Our intention is to describe them more in detail in this paper.

Prosthesis with Myoelectrically Controlled Hand

It is composed of an electric hand, a frame for the forearm, a revolving wrist, a myolectric device, and a storage battery (Figs. 1 and 2).

The hand is of the traditional Otto Bock or Viennatone type, with pincers grip, and is covered with a cosmetic glove. The grip is obtained by the thumb in opposition to the forefinger and the little finger are passive and elastic, and do not create any limitation to the grip.

The forearm frame is in stainless steel sheet, and has been manufactured with consideration to the hygienic perspiration requirements of the stump and of the arm. Owing to its shape it allows a quick fitting to the limb and does not require suspension straps.

The anchoring arm band wraps the inferior part of the arm, but is open in front to allow the biceps to have the widest possibility of expansion, and is fixed to the humeral epicondyles to which it is suitably fitted.

This type of frame allows all the muscles to perform freely their activity and maintain their efficiency. In the arm and in the stump the deformations caused by the traditional prostheses do not occur.

The revolving wrist allows the hand of the prosthesis to have the movement of pro-supination operated directly by the stump; the

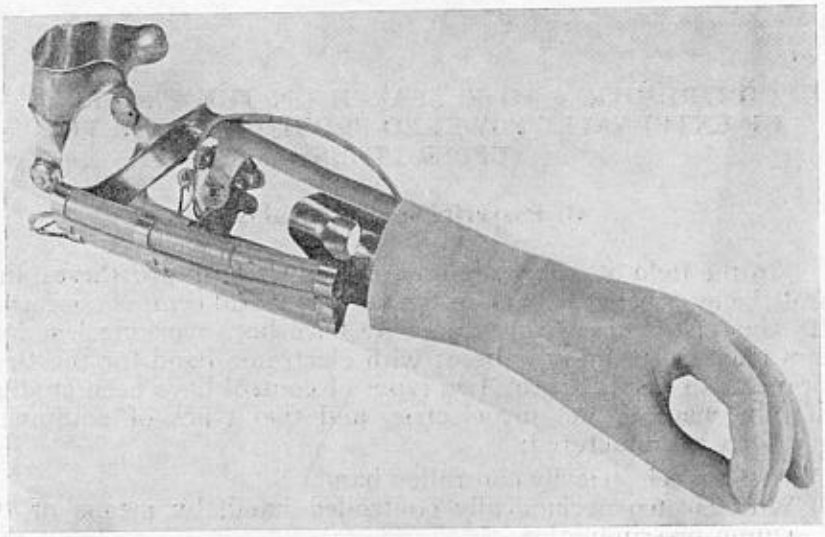

Fig. 1.

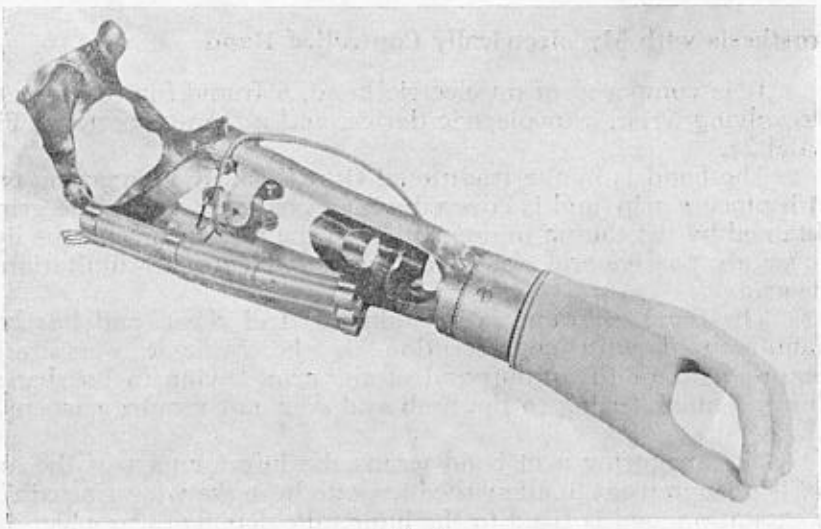

Fig. 2.

huge importance of this motion for an efficient and comfortable use of the prosthesis is known. Only if the stump is not capable of rotation, we resort to a stiff wrist.

The myoelectric device is built in the wrist of the prosthesis, whilst the battery is composed of small cylindrical elements, fitted around the arm band or around the forearm band of the prosthesis, inside suitable containers. With this system the discomfort and awkwardness resulting from the placement of the device and the battery in a pocket or in some other part of the clothing of the amputee is avoided and, what is most important, there are no electric connection cables between the battery and the electric motor of the hand. Further to a remarkable advantage in duration and upkeep, it has been noticed that the amputees appreciate very much this arrangement which makes the prosthesis much more practical, both when they have to put it on, and when they have to take it off. Furthermore during the day they can change clothing without having to worry about cables or devices possibly contained in their pockets.

The control amplifier is composed of two identical differential amplifiers. The voltages that are created when a muscle is contracted feeding the differential amplification system, are remarkably inferior to the interfering voltages that practically exist in such a way to allow the perfect operation of the prosthesis in whatever normal ambient. The sensibility of the two amplifiers can be adjusted from the outside enabling the perfect fitting in each single case.

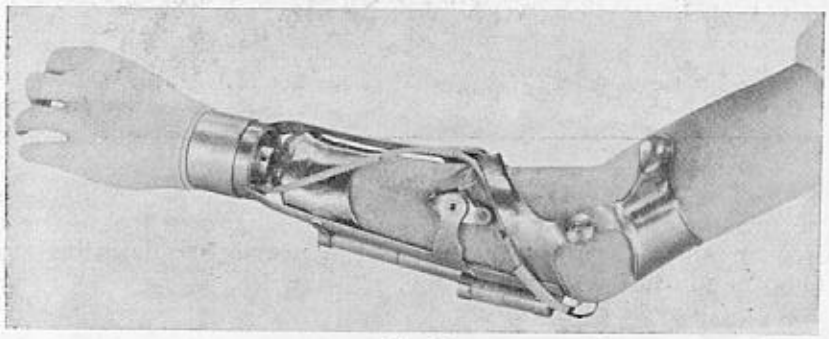

Fig. 3.

Two pairs of gold plated electrodes and a common electrode are used for the detection of the myo-voltages, derived from the muscular action, for the control of the flexion and extension motion of the fingers. They are fixed to the frame for the forearm, and are rested on the skin surface in correspondence to the muscles that are chosen, using the suitable instrument, bearing in mind, in each case, the possibilities shown by the amputee with reference to his amputation.

The charge of the battery lasts over 12 hours for an amputee who uses the prosthesis extensively.

The weight of the prosthesis is 1,150 grams, including the electronic device and the storage battery (Figs. 3 and 4).

Prosthesis with Electro-mechanically Controlled Hand by Means of the Stump Pro-supination

This prosthesis is suitable for stumps which have the pro-supination motion, but not sufficiently strong to revolve the wrist.

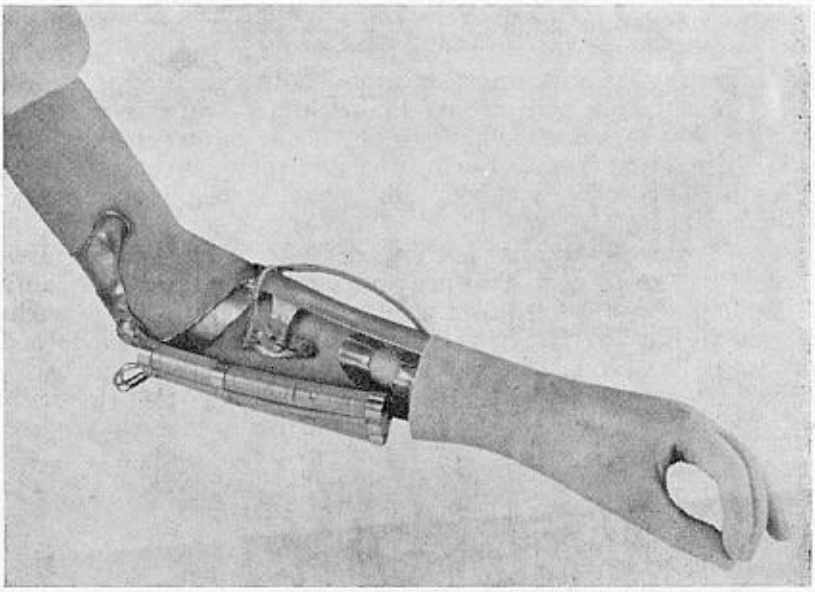

Fig. 4.

The prosthesis is composed of an electric hand, a frame for the forearm, and a storage battery of the previously described type (Figs. 5 and 6).

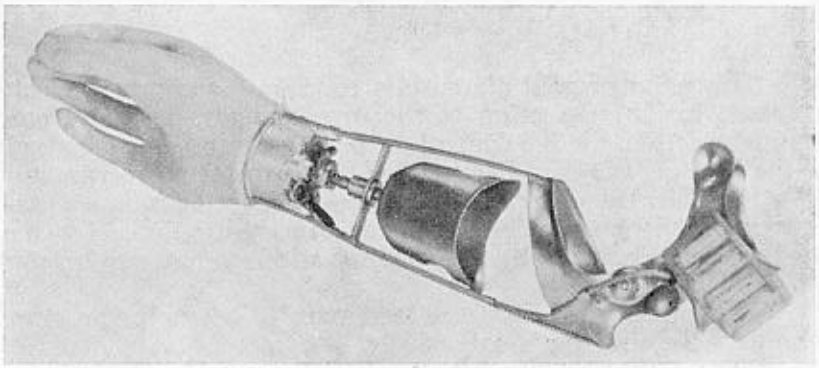

Fig. 5.

The wrist is not rotating and contains an elecronic device which controls the opening and closure of the fingers of the hand by means of the stump pro-supination. With supination the opening of the fingers is obtained at a constant speed; with pronation the

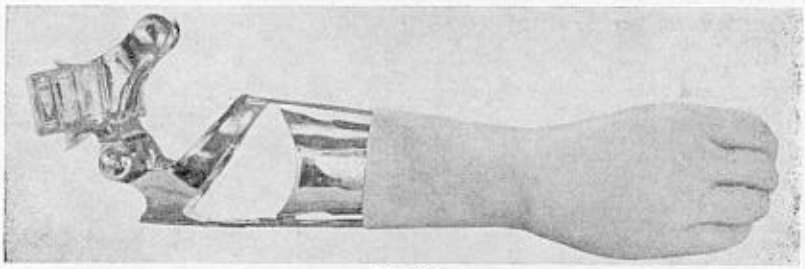

Fig. 6.

closure is obtained at a speed which is proportional to the angle of rotation. The adjustment is micrometric and no type of prosthesis with myoelecric control can allow such an instinctive and easy adjustment.

The rotation of the stump is resisted by two small elastic buffers; they allow the amputee to check the amount of the rotation and therefore the speed and the strength of the grip. Further, they return the stump to a well fixed rest position when the muscles that resist the buffers are relaxed. These systems allow the amputee to control his prosthesis more by instinct than by reasoning. This control system, as already said, unfortunately does not allow use of the pro-supination motion in the normal sense, but it is much

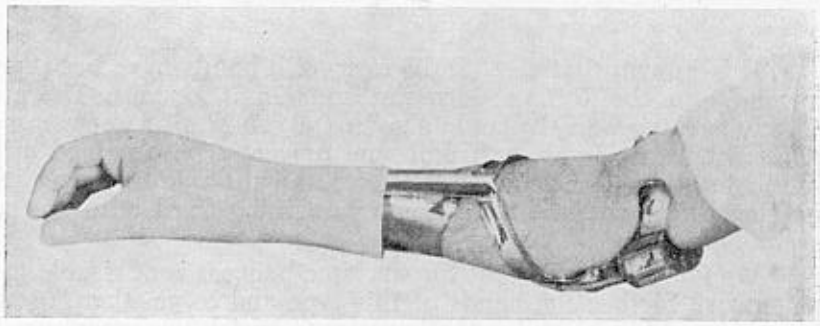

Fig. 7.

simpler than the myoelectric one, it is cheaper, and safer. We have repeatedly tested it with favourable results. The weight of the prosthesis is about 1,000 grams including the electronic device and the storage batery (Figs. 7 and 8).

Another electrically powered prosthesis that has been the subject of our studies, is the forearm prosthesis with multi-functional hand. We have manufactured the following two models:

(1) *With myoelectrically controlled multifunctional hand*

(2) *With electro-mechanically controlled multi-functional hand, by means of the stump pro-supination.*

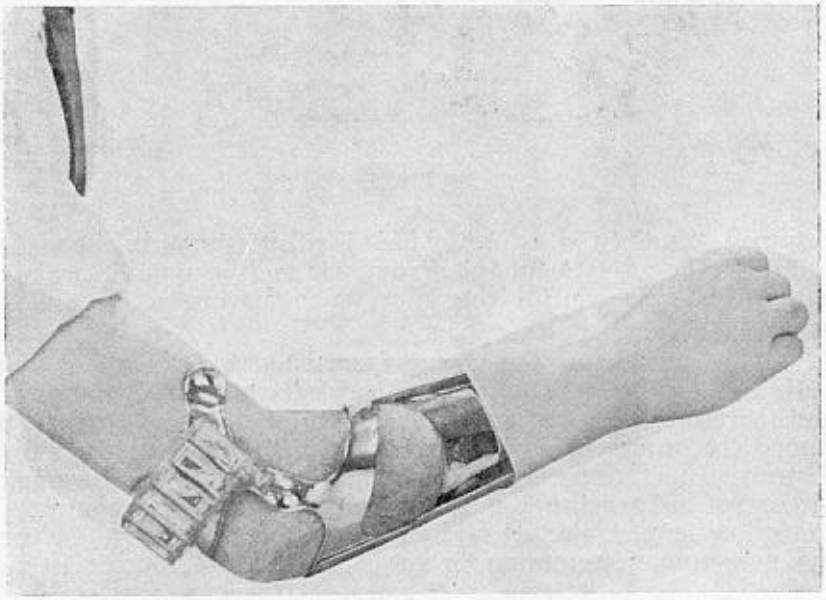

Fig. 8.

It is known that electrically energized hands have been made, especially in the U.S.A., Germany and Great Britain. There are already two types in the trade also in Italy, both of foreign import. In them the grip is of the traditional pincers type obtained by the thumb in opposition to the forefinger and the middle finger, with the ring finger and the little finger remaining fixed with the palm of the hand.

We feel convinced that for the time being it is advisable to try to improve further the hands of this type and to get them used all over the world more and more, in order to enrich the experience and to find more positive suggestions, dictated by the practical use of the systems studied. For this purpose it will be advisable to establish, in a collegial international seat, the series of the tests suitable for an objective comparison of the various types of hands and of complete prostheses on the basis of the functional capacities of the patients, of their tolerance, and of their resistance to wear.

However we also think that in the meantime it is advisable to continue to try to find radically different solutions, that in a more or less far future might bring substantial advantages.

In Italy we do proceed in this way at present doing the research aiming to give a greater functions to the hand, by means of motions that are similar as compared to the ones of the natural hand. Through this program a prototype has been manufactured in our Institute, although not having yet sufficient practical requisites for having it manufactured and sold on a commercial scale, represents the initial step of an experimental work on a limited number of patients which we hope will give positive results and will be a real contribution.

Our multi-functional hand, which represents the important part of the latter group of electrically powered prostheses that we have reviewed, has some very similar peculiarities to the ones of the Yugoslav hand of the Pupin Institute of Belgrade; however it substantially differs from it in the mechanism.

We cooperate with the Pupin Institute, having reciprocal exchange of technicians and of ideas, trying to obtain, even with two different mechanical solutions, a type of hand which has at disposal greater degrees of function than those available now. It should be possible in the future to make a final choice on the basis of the experimented use, and on the basis of the comparison tests.

Our type has the following specifications:

— All five fingers are articulated to provide the grip.

— All the fingers, with the exclusion of the thumb, have the three phalanges articulated between them with a coordinated motion, in such a way that they reach a reciprocal position which is very similar to the one that they have in the human hand in the various steps of flexion in which the fingers are during their motion of closure for closing or for opening.

— The configuration of the pincers type grip is obtained by the thumb in opposition to the forefinger and the middle finger; in it the ring finger and the little finger are only partially flexed and stop automatically before reaching the object gripped by the other fingers. (Figs. 9 and 10).

— Further, it is possible to perform the fist (ball), or the pipe-type grips; in them the object is gripped by all the five fingers which adapt their position to the shape of the object itself. The fingers have a high degree of independence from one another (with the only exception of the forefinger and of the middle finger that move together) and therefore each can adapt their position to the shape of the object, in an obviously similar way to that of the human hand (Figs. 11 and 12). The grip is especially efficient, good distributing forces being obtained. This is the most peculiar and practically appreciable advantage of this solution.

— The electronic devices that are used for the operation of the hands are suprisingly reliable but we cannot exclude the possibilities of malfunctions. The amputee might therefore find him-

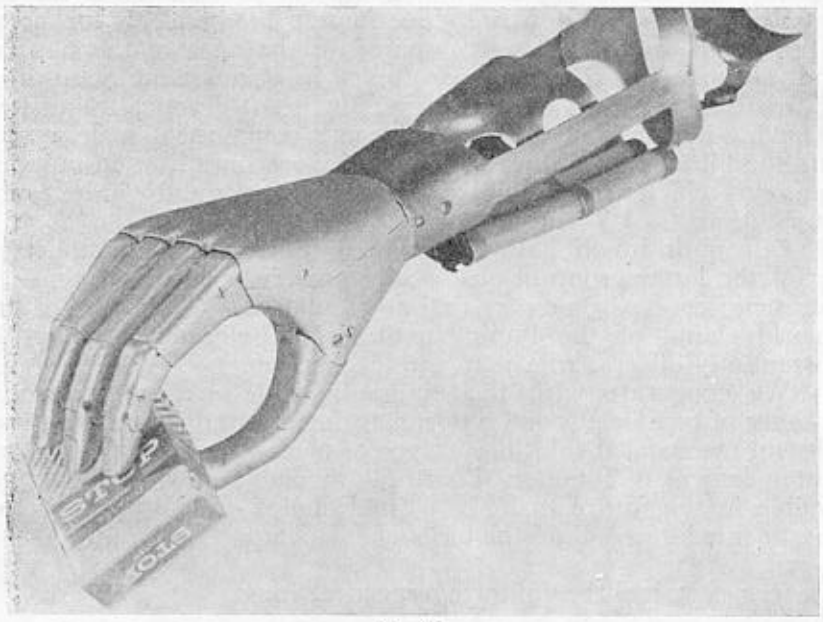

Fig. 9.

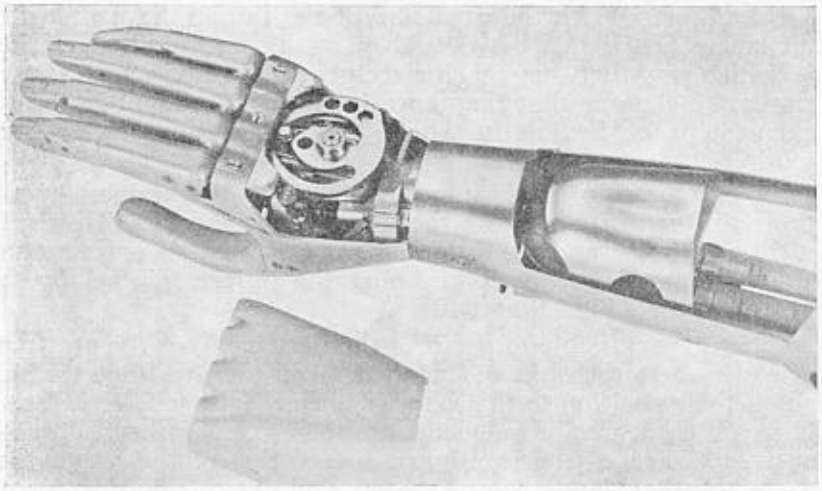

Fig. 10.

self in the position to have grasped an object without being able to get rid of it, not having the capacity to release the grasp

owing to an electric failure. This even might be unpleasant and sometimes even dangerous. Our hand, with a solution that has to be considered unique in the world, has therefore been sup-

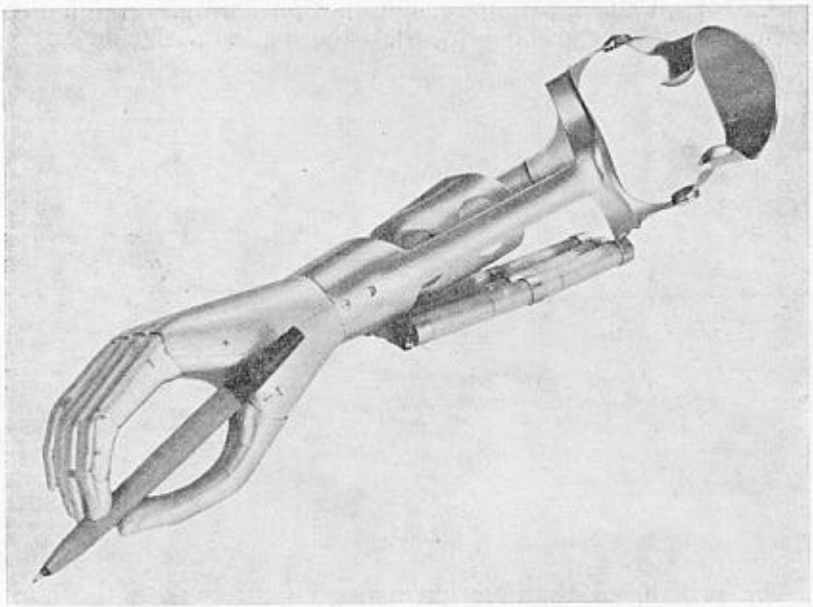

Fig. 11.

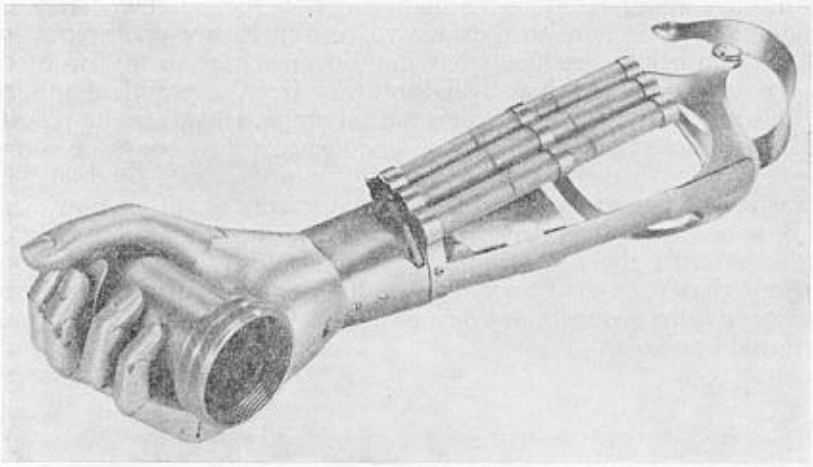

Fig. 12.

plied with a safety device by means of which, with a quick and easy operation, the amputee can disconnect the fingers from the mechanism, thus making them free to release the grip.

All these functional specifications have been obtained by means of an absolutely new type mechanism, the basic element of which is represented by a suitably shaped cam which orders the operation of all the most important motions, programming them according to the type of grip that the patients decide to use (Fig. 13).

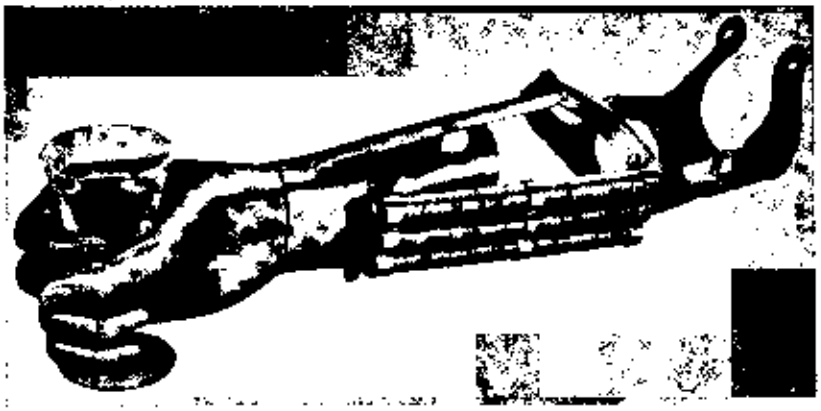

Fig. 13.

The prostheses that we have manufactured with the above described type of multi-functional hand, are similar to the ones manufactured with the uni-functional hands. The weight of the prosthesis is about 1,250 grams including the electric device and the storage battery. It is a little excessive, and in future prototypes we shall do our best to reduce it. It has however not to be forgotten that we consider ourselves still far away from a practical model, and that we are still in the experimental stage. However the results that have been reached until now encourage us to continue along this way; in fact we think that the hand manufactured by us has to be considered a good step, and that it may encourage other Institutes to follow our way. It is necessary, indeed, to intensify the fitting of prostheses with the already progressed uni-functional hands, but we think that it is also advisable to look to the future, trying to make even more evolutionary developments with emphasis on multi-functional hands.