Lead Article

Historical Aspects of Powered Limb Prostheses

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INTRODUCTION

People involved in work on powered limb prostheses may wonder if the history of this field is important. My answer is that one can learn a lot from history. Nevertheless, Hegel has said, "What history teaches us is that men never learned anything from it." Unfortunately, it sometimes does seem true in prosthetics that we have not always profited from past experiences. Too many aspects of the work are never published, and the multidisciplinary nature of the field produces papers in a broad spectrum of journals that are difficult to track. Books on the field are, unfortunately, not numerous.

The brief history that follows is by no means complete, and since some of it involves years that are within readers' memories, I apologize in advance for omissions that anyone may consider significant. The history is intended to entice readers to look more deeply into historical issues. It is also intended to give some perspective on the field and to dispel notions that powered prostheses are only recent developments of "bionic man" research. Wilson[50] has written a brief history on external power of limb prostheses and the handbook by Spaeth[41] contains an introductory chapter on this subject. Brief surveys are included in papers (e.g. Childress[10] or Bottomley et al.[7])

Powered limbs have existed for some seventy years. This roughly corresponds with the history of powered hand tools and other powered technical devices used so widely in modern society (e.g. airplanes, automobiles, etc.). This is not surprising since technology in most fields tends to mirror the state of technology generally. The history of powered limbs is also comparable in length with the history of an identifiable field known as "limb prosthetics."

I have chosen to consider the history of powered prostheses from a hardware viewpoint and from the viewpoint of important meetings and events. Control approaches, another viewpoint, are considered but not emphasized. Also, the perspective is from America.

PROLOGUE (1915–1945)

The first powered prosthesis, of which I am aware, was a pneumatic hand patented in Germany in 1915.[13] A drawing of an early pneumatic hand is shown in Figure 1. Figure 2 shows a drawing of what I believe to be the first electric powered hand. These drawings were published in 1919 in *Ersatzglieder und Arbeitshilfen* (Substitute Limbs and Work Aids).[35] This German publication illustrates the importance of history in prosthetics, containing ideas that are still being discovered today. Although the book *Treatise on Artificial Limbs* by A.A. Marks, published in 1901, does not contain anything about powered limbs, it too illustrates the importance of history in the field because many ideas put forward in it are also quite modern.

Powered limbs were probably not used to any significant extent between the World Wars, but CO_2 powered limbs were used by Weil as early as 1948.[28] Development work continued at Heidelberg during the 1950's under Marquardt,[28] and the Otto Bock Company became involved with the work about 1962. Laboratories at Munster and Hannover were also involved in this early work that led to clinical applications of gas powered prostheses. Part of Germany's prominent position in the prosthetics field can be traced to their early commitment to development work in the entire field of prosthetics.

Kiessling[23] was the major U.S. investigator involved with CO_2 powered limbs. Of course,

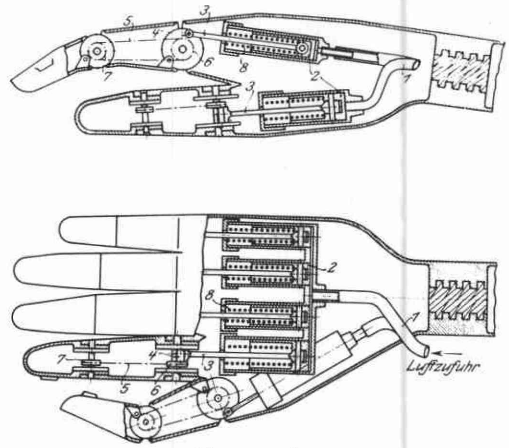


Abb. 178 und 179.
Preßluft-Hand.

Figure 1. Early compressed-gas powered hand (Perhaps the first powered prosthesis component). From *Ersatzglieder under Arbeitshilfen (Limb Substitutes and Work Aids)* 1919.

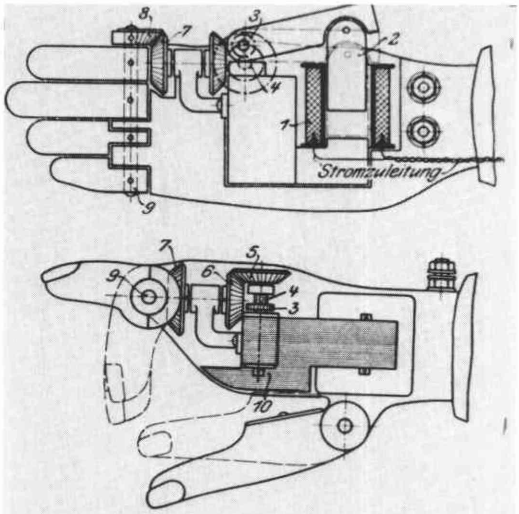


Abb. 180 und 181.
Elektromagnetische Hand.

Figure 2. Early electric hand component (Perhaps the first electric hand mechanism). From *Ersatzglieder und Arbeitshilfen* (Limb Substitutes and Work Aids) 1919.

the McKibben muscle[17] was developed in the U.S., but has been used mainly in orthotics.

The first, as far as we know, myoelectric prosthesis was developed during the early 40's by Reinhold Reiter, a physicist working with the Bavarian Red Cross. He published his work in 1948[33] but it was not widely known and myoelectric control was destined to be ''rediscovered'' in England, in the Soviet Union, and perhaps other places during the 1950's. Economic conditions in Germany after World War II prevented the work on myoelectric control from being continued there. Figure 3 shows a picture of the first myoelectric hand prosthesis which was probably used around 1943. The system was controlled by a vacuum tube amplifier and was not portable. The hand was a modified Hüfner Hand that contined a control electro-magnet. The system was heavy, large, and not battery operated; the idea was to use it as a

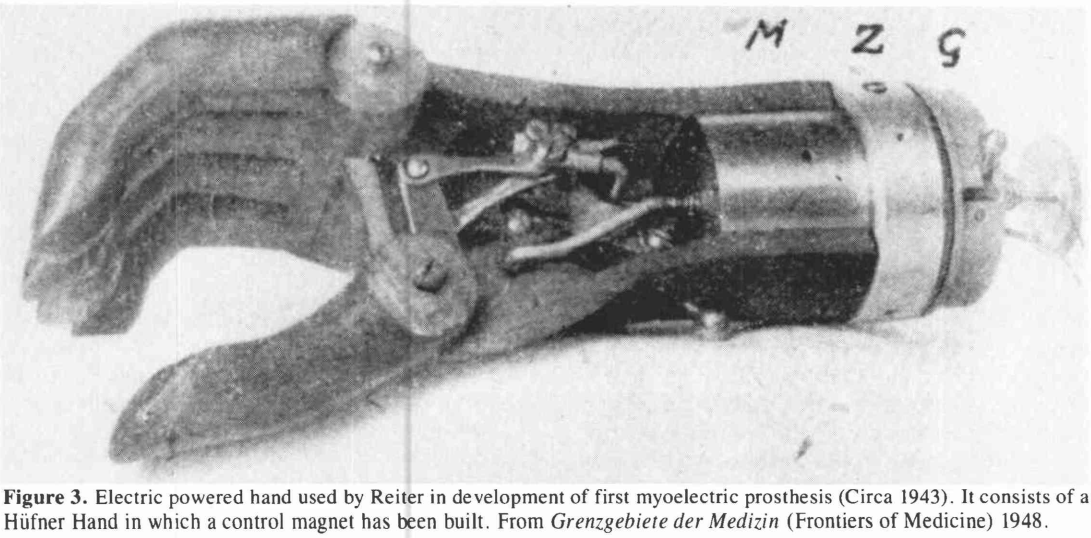
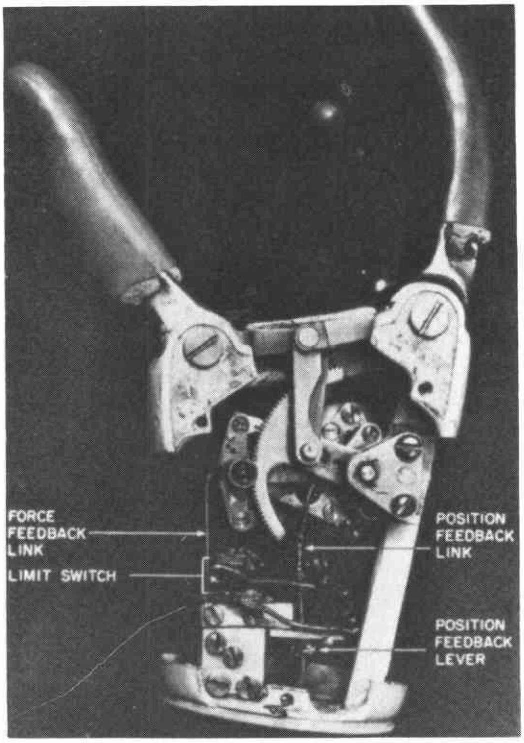
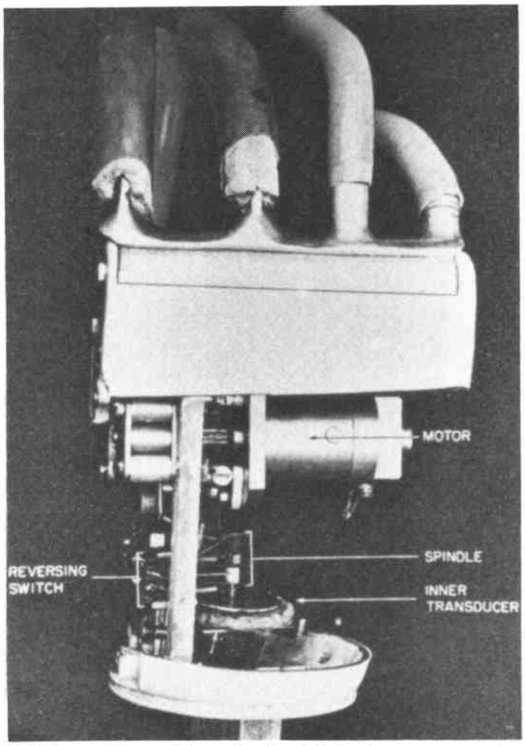


Figure 3. Electric powered hand used by Reiter in development of first myoelectric prosthesis (Circa 1943). It consists of a Hüfner Hand in which a control magnet has been built. From *Grenzgebiete der Medizin* (Frontiers of Medicine) 1948.





Figures 4a and 4b. Two views of the mechanics of the Vaduz Hand. Note position and force feedback links that connect to the inner transducer. This connects to an outer transducer (a bladder) adjacent to the residual limb in the socket. This voluntary-closing hand was activated by muscle bulge. It operated as a position servomechanism. It contained a gear shifting mechanism and a current cut-off mechanism. From *Bulletin of Prosthetics Research,* BPR 10-6, 1966.

special prosthesis at a work station. Reiter hoped that further development could make it portable.

It is an interesting coincidence that the results of the first experiments with myoelectric control were published in 1948, the same year in which the development of the transistor was announced. Practical myoelectrically controlled prostheses required the transistor and its subsequent refinements.

Although Reiter conceived and developed the idea of myoelectric control in the early 1940's, others had the same idea later and apparently independently. The late Professor Norbert Weiner of Massachusetts Institute of Technology is reported to have suggested the concept around 1947. Berger & Huppert[4] presented the idea in 1952. Battye, Nightingale, and Whillis[3] at Guy's Hospital in London developed a myoelectric control system for a powered prosthesis in 1955 in what was for many years thought to be the first demonstration of this principle. That they were not first in no way detracts from their accomplishment. Soviet scientists were apparently the first to use transistors in a myoelectrically controlled prosthesis. The so-called Russian Hand[24] was the first semi-practical myo-electrical limb to be used clinically and was sold (although not widely used) on a license basis for application in Great Britain and in Canada.

THE EARLY YEARS (1945–1967)

As far as the United States is concerned, the year 1945 was a turning point in prosthetics. In January 1945, military personnel, surgeons, prosthetists, and engineers met in Chicago (Thorne Hall, Northwestern University) to consider what should be done about limb prosthetics. This meeting is recognized as the beginning of the prosthetics research and development program by the U.S. government. This program ultimately resulted in the establishment of the Committee on Prosthetics Research and Development (CPRD) of the National Research Council which guided work in the field for over twenty-five years. The post-war years saw tremendous advances in limb prosthetics in general, although powered prosthesis development was slow. During the period 1946–1952, Alderson, with the support of IBM and the Veterans Administration, developed several electric-powered limbs.[1] These IBM arms were impressive engineering achievements for the time, but they were somewhat difficult for amputees to use.

The Vaduz hand, developed during the early post-war period, appears to have been a prosthesis ahead of its time and one that contained antecedents of today's electric hands. A German team headed by Dr. Edmund Wilms settled in Vaduz, Lichtenstein after World War II to continue their prosthetic hand development work. They wanted to create a hand controlled by the muscles of prehension, which would operate on a portable power source. The hand they created is shown in Figure 4. It has been described by Wilms.[49] This hand had a gear shifting mechanism to enable it to obtain high gripping force from an electric motor while also having reasonable finger velocity. This is a principle used in current Otto Bock hands. The hand used a unique controller in which a pneumatic bag inside the socket detected muscle bulge through pneumatic pressure, which in turn operated a switch-activated position servomechanism to close the voluntary-closing electric hand. This principle foreshadows the concept of extended physiological proprioception (EPP) introduced by Simpson[39] (Figure 5). The complete system is shown in Figure 6.

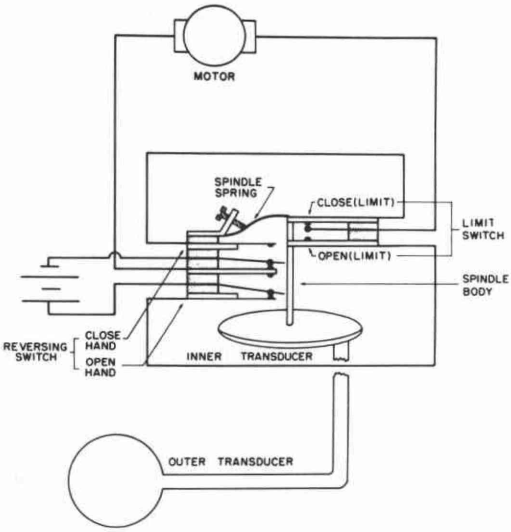


Figure 5. Diagram of control circuit for Vaduz Hand. Muscle bulge compresses the outer transducer, which causes expansion of the inner transducer, moving the spindle upward. This activates the switches that close the hand. A link with the output moves the switch assembly along so that the hand stops when the link movement corresponds with spindle movement. Force feedback opens the closing limit switch at some force level when the hand meets an object. This conserves battery power. From *Bulletin of Prosthetics Research,* BPR 10-6, 1966.

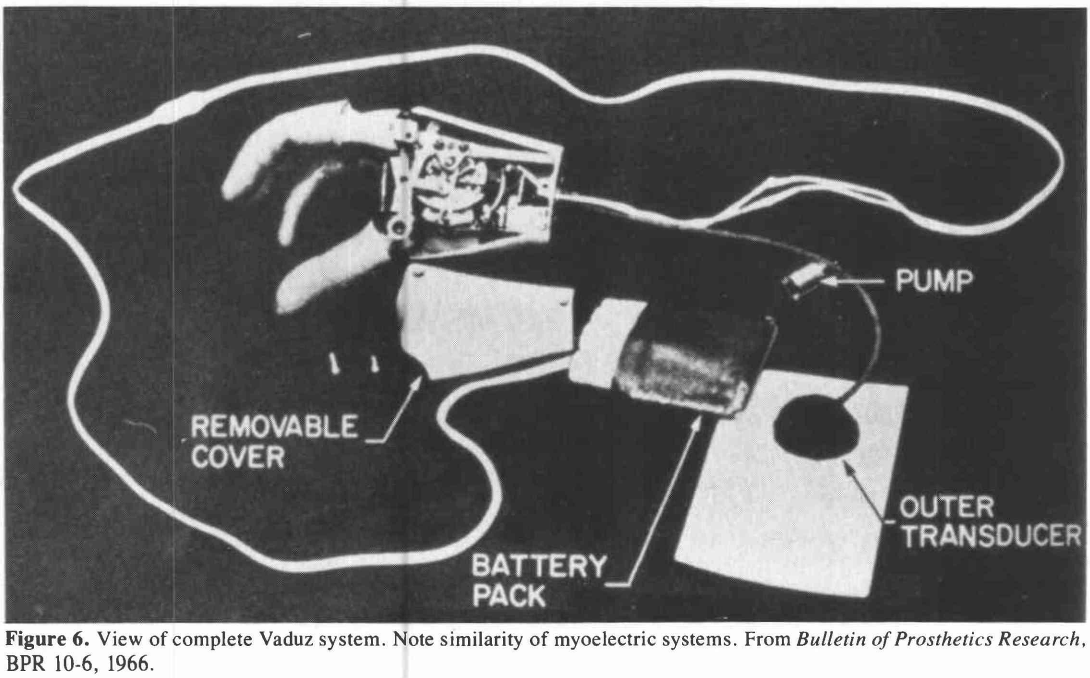


Figure 6. View of complete Vaduz system. Note similarity of myoelectric systems. From *Bulletin of Prosthetics Research,* BPR 10-6, 1966.

Lucaccini, Kaiser & Lyman[26] evaluated the Vaduz Hand. The center at the University of California at Los Angeles, under Lyman's direction, also evaluated the Alderson-IBM arm, the Heidelburg Pneumatic Prosthesis, and other externally powered systems, as well as conducting many control studies of their own.

After 1953, the Vaduz Hand was marketed from Paris and consequently was sometimes called the French Hand. It apparently was difficult to keep in optimal mechanical adjustment, but it must be considered as one of the most important ancestors of today's electric hands, and a hand that contained many novel and intriguing concepts. It was available through the mid-sixties.

The Russian Hand and Vaduz Hand were followed by an English Hand developed around 1965 by Bottomley.[5] This was the first myoelectrically controlled hand that exhibited proportional control (Figure 7). This prosthesis also contained several novel features for that period of time, such as internal force and velocity feedback and a unique myoelectric signal smoothing principle called "autogenic backlash," which produced a more or less consistent direct current (DC) output from the fluctuating myoelectric signal while not sacrificing time response.

The Russian Hand (Figure 8), Vaduz Hand, and Bottomley Hand were single-function devices and non-adaptive. During the early 1960's Tomovic suggested an adaptive, multi-articu-

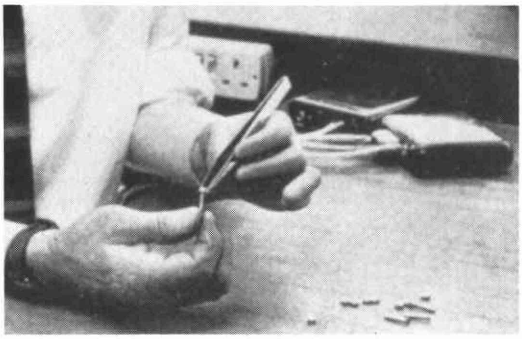


Figure 7. View of myoelectric hand developed by Bottomley in England. Note the two external packages on the table, battery on left and electronics on right. This was the first myoelectrically controlled hand that had proportional control. From *Science Journal* article by R.N. Scott, March 1966.

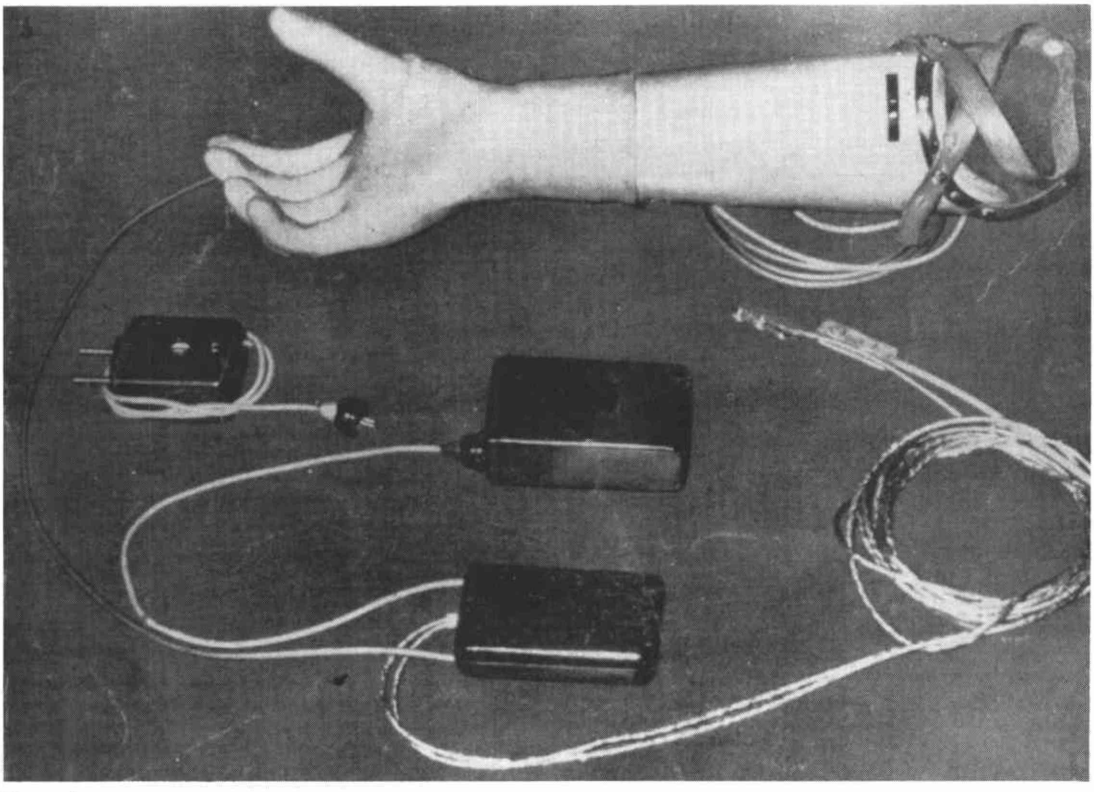


Figure 8. Photograph of Russian Hand. This was the first myoelectric hand that was transistorized and portable (Circa 1959). The external battery pack is shown in the center of the photograph. The electronic package is beneath the battery. The battery charger is at left. Note the long electrode wires and the prosthesis suspension straps. From *Science Journal* article by R.N. Scott, March 1966.

lated hand with rudimentary sensory qualities. This resulted in the Belgrade Hand.[32] Although this hand was not used clinically to any great extent, it was used extensively in research laboratories and has had influence on robotic hand developments. In 1965, a Swedish research group began work on an electric hand which was adaptive and which had multiple functions (two types of grasp, wrist flexion-extension, and supination-pronation). This became known as the SVEN-Hand[19] (Figure 9). It also has been used extensively in research, particularly regarding multi-function control[18] and concepts employed in it are utilized today in Swedish developments.

Congenital amputations caused by the drug Thalidomide resulted in expanded interest in powered prostheses in the 1960's. Pneumatic systems by Otto Bock (hand, hooks, wrist rotators, and elbows) were fitted successfully, particularly in Germany by Marquardt,[28] to many children born without limbs. However, pneumatic systems never caught on well in the U.S. probably because of difficulties with the compressed gas. Cannisters of gas were expensive and difficult to maintain and distribute in the U.S. American laws also required steel cannisters, which added to weight. Pneumatic systems have low energy storage densities and this meant that multiple cannisters were required, particularly to supply the energy needs of adult prostheses. On the other hand, these systems have actuators that are light in weight, which are easily controlled, and which have natural compliance properties that keep them from being rigid.

Electric power can be stored more cheaply, more safely, and with greater density than gas power. Also, the control possibilities made possible by electronic circuits have given electrical systems an advantage. Unfortunately, the actuators (electric motors and gear mechanisms) tend to be heavy and may result in prostheses that are noisy and naturally non-compliant. They also have zero efficiency when activated in the stalled condition. Some of the negative aspects of electrical actuators have been overcome electronically in today's powered prostheses.

Electro-Hydraulic systems may be used in the future because they have the potential advantage of developing high torque in small actuators. However, cost factors for the special hydraulic mechanisms needed, along with technical problems, have restricted development work in this area thus far. Early work was conducted in Canada.[42] The Edinburgh arm has been converted to hydraulic power at a couple of centers in the U.K.

Research work on multifunctional limb prostheses flourished in the United Kingdom during the 1960's and early 1970's. Most notable among the developments were the Hendon Arm[29, 30] and the Edinburgh Arm.[39] Both were pneumatic, multi-functional limbs. Simpson used a position servomechanism control principle that he called extended physiological proprioception (EPP), a principle which enables control of multiple functions without excessive mental load on the user. This control technique has been shown to be a better information link between the body and prosthesis than "velocity" controllers.[15]

The Edinburgh Arm, which was pneumatic, worked in spherical coordinates from the shoulder and was controlled by protraction-retraction and elevation-depression of the two shoulders. If the arm was fitted on the right side, then elevation of the right shoulder elevated the hand about the shoulder joint. Protraction of the right shoulder moved the hand more distant from the shoulder (in a radial direction). Protraction of the left shoulder moved the hand medially, and elevation of the left shoulder supinated the hand. The wrist was linked to the shoulder and elbow so as to maintain attitude of the hand during shoulder or elbow motion. This made it possible to hold

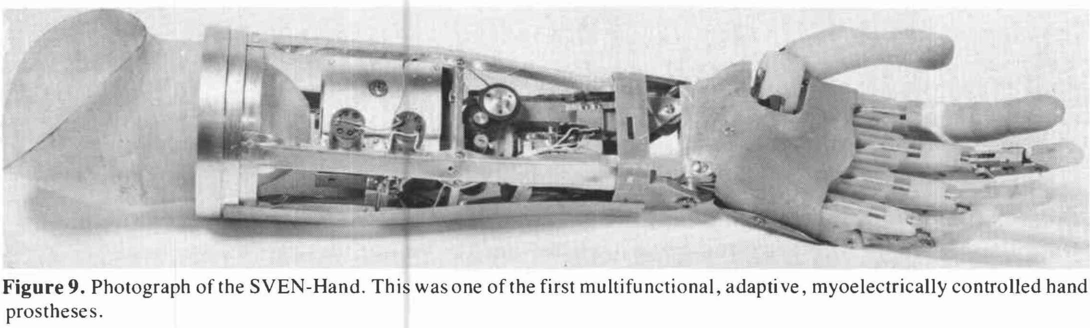


Figure 9. Photograph of the SVEN-Hand. This was one of the first multifunctional, adaptive, myoelectrically controlled hand prostheses.

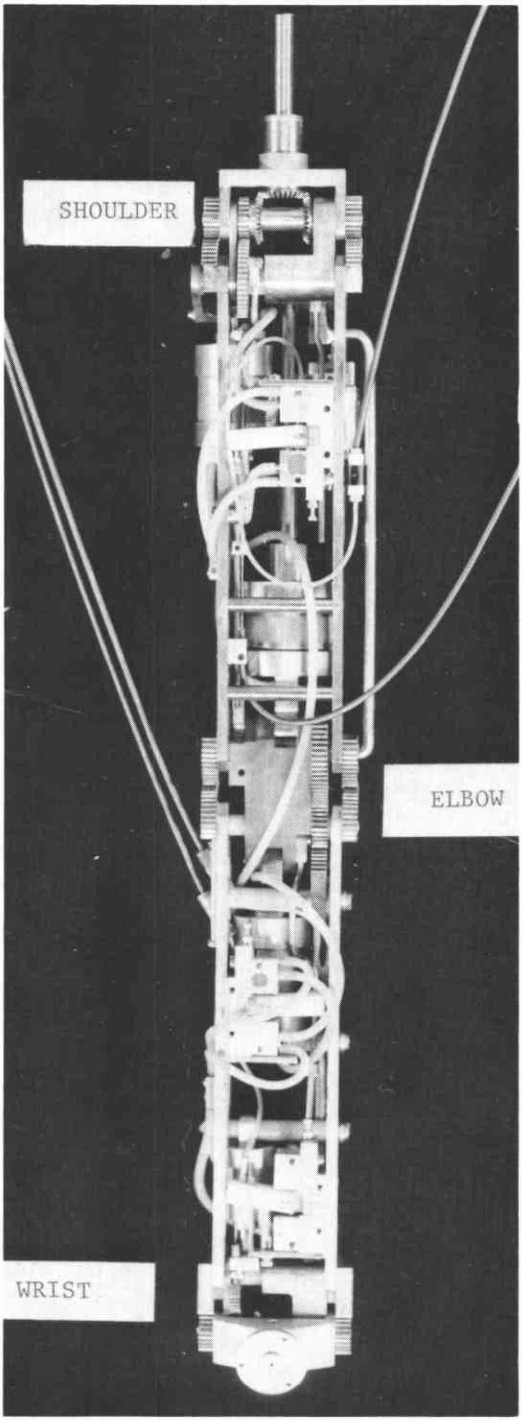


Figure 10. Photograph of the mechanism of the Edinburgh Arm, developed by D.C. Simpson. This CO_2-powered limb had four degrees of freedom (five if the terminal device was included) and kinematic coupling of the wrist to the elbow and the shoulder. It used spherical coordinates and was controlled by position servos that mechanically linked shoulder girdle position with prosthesis position. It is one of the most complete powered arms ever developed.

a glass of water without worrying too much about spilling the contents during arm movements. Carlson[8] has called this kind of joint coupling, "kinematic coupling." Opening and closing the hand or terminal device of the arm was controlled by a switch through some other motion of the body. The arm was complex and difficult to keep functional on active children but the control was remarkable. Children operated its multiple functions naturally, without much training, and seemingly without too much mental load. Figure 10 shows the mechanism. Less complex (and less functional) all-electric EPP-type controllers are now under study in the U.S. and Scotland.

Proceedings of meetings form an excellent historical record of powered prostheses. The first meeting of consequence in the U.S. concerning powered prostheses was held at Lake Arrowhead, California in 1960,[43] and was sponsored by the National Research Council. The second major meeting of this kind in the U.S. was held in Warrenton, Virginia in 1965[45] with considerable international input. Subsequently, the Committee on Prosthetics Research & Development (CPRD) held regular meetings related to applications of external power in limb prosthetics, and the reports of these meetings form a good record of U.S. activity in this field.

Myoelectric control received a major boost in America through a 1966 symposium in Cleveland, Ohio (Case Western Reserve University) entitled "Myoelectric Control Systems and Electromyographic Kinesiology." Bottomley demonstrated his elegant myoelectric system at that meeting. The meeting was also attended by Professor Robert N. Scott of the University of New Brunswick. Scott headed a group that developed the first myoelectric control mechanism in North America.[14]

A Yugoslavia-based conference, around 1963, called "External Control of Human Extremities" was followed by a similar conference in Dubrovnik, Yugoslavia and this international conference has been held there every third year since 1966. The Proceedings of the "Dubrovnik Conference," as it is often called, are a singular record of international developments in powered limb research and development since the early sixties.

Three other symposia produced significant early publications. The symposium on "Basic Problems of Prehension, Movement and Control of Artificial Limbs"[44] organized in London in 1968 by the Institution of Mechanical Engineers contains a wealth of information on powered limbs. The "Dundee Conference" held in Dundee, Scotland in 1969 resulted in the book *Prosthetic and Orthotic Practice*.[31] It covers prosthetics generally but has a fair amount of material on powered prostheses. Finally, the Swedish conference of 1974[46] produced a book that concerned early research and development work on powered prostheses and orthoses.

GROWING UP (1967–1977)

I have selected the decade of 1967–1977 as one of "growing up" because 1967 is about the time it became possible to purchase a powered prosthesis commercially in the United States, and it was approximately 1977 before powered upper-limb prostheses began to take on some real clinical significance (i.e. larger numbers of clients fitted).

The Viennatone Hand was the first commercial system available in the U.S. This hand came about as a result of Otto Bock Orthopedic Industries, a German prosthetics company, and Viennatone, an Austrian hearing aid company with expertise in electronics. Shortly thereafter, Otto Bock developed their own myoelectric system and a new hand mechanism. The Viennatone and Otto Bock Hand mechanisms (both designed by Otto Bock) have been altered somewhat through the years, but their basic appearance and design principles remain essentially unchanged.

In the early days of myoelectric control (e.g. 1968), the battery or battery and electronics had to be worn outside the prosthesis, usually in a chest pouch, on a clip at the waist, or on a band around the humeral section of the arm. The wires and connections required by this kind of configuration led to failures due to wire breakage. There was also electrical interference on occasion. In addition, the components outside the prosthesis were a nuisance to fit and to wear.

In 1968, I was involved in fitting a college student with one of the first self-contained and self-suspended below-elbow prostheses.[12] The Viennatone Hand mechanism was used in conjunction with a myoelectric controller developed at Northwestern University. Self-containment and self-suspension are standard procedures for below-elbow prostheses today.

The Veterans Administration Prosthetics Center (VAPC) modified the Viennatone Hand mechanism and packaged it with a modified version of the electronic system developed at Northwestern. The VAPC contracted for this system to be manufactured by Fidelity Electronics, Ltd. and this system was marketed for a period of time.

An interesting electric powered hand of this period was the hand developed at the Army Medical and Biomechanical Research Laboratory.[34] This hand contained a "slip detector" in the thumb. The hand would grip to about 2 Lf_f at the finger tips. If the object to be held started to slip, the hand would automatically increase gripping force until slippage stopped.

Schmidl[36] was actively fitting many upper-limb amputees with myoelectrically controlled, powered limbs during this period and he achieved clinical significance with powered limbs well before this happened in the U.S. His center in Italy was also involved early in fittings of multifunctional limbs. Three-state controllers are used to control electric elbow, electric wrist rotator and electric hand from three muscle electrode sites. The Italian group has been at the forefront of progress in the fitting of powered limbs.

Engineers at Temple University-Moss Rehabilitation Hospital[51] were probably first to attempt multi-functional control of elbow, humeral rotation, and wrist using pattern recognition techniques on myoelectric signals from multiple muscle sites of the upper arm and shoulder. They had some laboratory success. Swedish scientists[2, 18] did similar work to control multiple functions of the hand (rotation, flexion-extension, and prehension).

The New Brunswick laboratory has played an active role in developing control methods for powered limbs in North America and is well known for three-state control design and development. They have also been active in research on sensory feedback[37] and the University of New Brunswick sensory feedback system is the only one available today, of which I am aware. Sensory feedback was examined by many research groups during the 1970's. I reviewed some of this work in an article appearing in the *Annals of Biomedical Engineering*.[9]

In the late 1960's and 1970's much experimentation and development were engendered in the field of external electric power. The Japanese developed a myoelectric powered hand.[22] MIT scientists designed the Boston Arm,[27] the first myoelectrically controlled elbow. The Ontario Crippled Children's Centre (OCCC) Elbow, a switch-controlled electric elbow was also developed in the late sixties, and is still in use. A number of electric elbows, the Rancho Electric Elbow (from Rancho Los Amigos Hospital) the AMBRL Elbow (from the Army Medical and Biomechanical Research Laboratory), and the VAPC Elbow (from the VA Prosthetics Center) also made their appearance in this time period. The Boston Elbow, AMBRL Elbow, and Rancho Elbow were evaluated by the Committee on Prosthetics Research and Development (CPRD).[16] Subsequently, the Applied Physics Laboratory in association with Johns Hopkins University developed a powered unit[38] capable of pulling the cable of conventional cable-operated, body-powered prostheses. It could be controlled by other inputs, such as from skin motion sensors, which were used with several fittings for high-level arm amputees.

The Boston Elbow was redesigned extensively to become the Liberty Mutual Powered Elbow,[48] available through Liberty Mutual Insurance Company. The Boston Elbow was also undoubtedly a stimulus to Jacobsen who did his graduate studies at MIT and who later developed the finely-crafted Utah Arm,[21] available through Motion Control, Inc. in Salt Lake City. Likewise this research at MIT influenced Hogan,[20] who today is developing an elbow in which elbow compliance is controlled by myoelectric signals.

The VAPC elbow was manufactured by Fidelity Electronics and used to some extent by VA clients. It was controlled by the VAPC pull switch.

The OCCC elbow (available through Electro-Limb in Toronto) has been a workhorse for many years. It, along with other elbows of its period, influenced Lembeck[25] in development of the NYU Elbow at New York University. This elbow is presently manufactured by the Hosmer Dorrance Corporation.

The OCCC has been a leader in the fitting and development of powered limbs. It is interesting how influential children's prosthetics programs in Germany, Sweden, Britain, and Canada have been on the field of powered prostheses. This is partially the result of government sponsored research programs directed toward amputations caused by the drug Thalidomide. Besides the electric elbow, the Ontario group have made small electric hands available through Electro-Limb for many years and their new electric hand is the latest evolutionary result of their continuing development work in this area.

Sorbye[40] in Sweden, pioneered the fitting of child amputees with myoelectric hands during the early 70's. His work stimulated the development of the Systemteknik Hand. His work also stimulated interest in the U.K. and an evaluation program there found myoelectric hand systems valuable for child amputees. This undoubtedly had an influence on the development of the Steeper child-sized hand.

When Colin McLaurin was at Northwestern University in the early 1960's he developed a "feeder arm" for the Michigan Area Amputee Center (MAAC) in Grand Rapids, Michigan. It was a kinematically coupled limb, designed to enable children with bilateral amelia to eat. A single electric drive mechanism at the elbow moved the terminal device from plate to mouth in a mechanically predetermined fashion. Subsequently, McLaurin moved to OCCC and was responsible for many developments there. Later, Dr. Aitken of MAAC requested the Prosthetics Research Laboratory at Northwestern to re-design the "feeder arm." The Michigan Arm resulted, which was a simple arm with electric hook and electric elbow similar in shape and function to one of Simpson's early CO_2 powered limbs. The electric terminal device for the Michigan Arm became commercially available through Hosmer Dorrance as the Michigan Hook. This was one of the first electric hooks to become commercially available. Of course CO_2 powered hooks had been used for many years. Also, it should be noted that Bottomley[6] designed a unique CO_2 powered hook in the 1960's that had many merits which were never exploited.

The Michigan Hook was a stimulus for Lembeck at New York University to develop the Prosthesis Assist Device. Like the Michigan Hook and the earlier systems at Johns Hopkins, it pulls on a cable to open a voluntary-opening hook or hand against a resisting spring (e.g. rubber band). This form of electric power utilization in prostheses lacks control sophistication but has simplicity of design and operation.

Electric-powered prosthetic hooks have generally been thought to be desirable, particularly by Americans in the prosthetics field. During the mid-seventies, the VAPC developed an electric hook.[47] A few years earlier, Northwestern had introduced the synergetic prehension concept and the Synergetic Hook.[11] The VA purchased 12 synergetic hooks and evaluated them on VA clients. However, only recently has there been interest in commercial development of this prehension device for interchangeable use with electric hands.

Otto Bock developed the Greifer during the late 1970's. It is a novel prehension device that is interchangeable with the Otto Bock Hand. This device is valuable for persons engaged in heavy-duty activities.

The commitment of Otto Bock Orthopaedic Industries, Inc. to the powered limb field cannot be overlooked in any historical review. Without availability of Otto Bock hands, wrist rotators, and electronic control systems, much research work in this field would have been stymied for lack of components. Of course, without available commercial components that were backed strongly by educational programs and literature, and by repair and maintenance, it would have been impossible for practicing prosthetists to serve their clients well. Needless to say, Otto Bock, through research, production, education, and product support has made an unparalleled contribution to development for almost a quarter century.

THE PRESENT (1977–1984)

The last seven years has been a period marked not by experimental powered fittings in a small number of research centers or elite institutions, but rather by the clinical use of powered limbs by prosthetists practicing all over the country. This "coming of age" was vividly evident at the education seminar entitled, "Current Clinical Concepts of Electrically Powered Upper-Limb Prostheses" in Chicago in September, 1984 and sponsored by the American Academy of Orthotists and Prosthetists. This seminar, convened within a few hundred yards of where prosthetics research was born in the U.S., was not a seminar of researchers or a seminar directed toward particular products or particular methods; it was a seminar of clinicians involved with powered-limb fittings. Undoubtedly, this meeting was a milestone in the history of powered prostheses in this country.

An interesting aspect about this period has been the upsurge of clinical fittings of powered prostheses and the increase of commercially available powered components. At the same time, there seems to have been some reduction of research efforts in this area. It is an area that has received considerable attention over the last twenty-five years, and perhaps research is just gathering its breath for the next important push. Whatever the situation, the clinical results show that progress has been made. That this progress has been difficult and hard won with many setbacks, is an indication of the difficulty of the problem being addressed. Indeed, adequate replacement of the human hand and arm is one of the most difficult problems facing medical technology.

FUTURE TRENDS

From a technical viewpoint there will probably be movement to smaller electronic systems that have extremely low quiescent power. This will enable small power sources to be used when they are coupled with highly efficient prehension devices. Consequently, it may be possible to fit myoelectrically controlled, electrically driven prehension devices to partial hand amputees. Availability of wrist function should make this kind of fitting very effective. This new possibility with technology, coupled with the new surgical reconstruction techniques for the hand, should open up many new possibilities for rehabilitation of partial hand amputees.

There should be an increase in reliability and serviceability of powered limb systems. They will become more modular, as well as smaller and lighter.

Electro-mechanical components will become more efficient and will have improved dynamic performance. That is, they will be faster and more responsive to the desires of the amputee. New prehension devices, interchangeable with hands and hooks, will be developed.

Computer-based controllers will be used in artificial arms, particularly those for multifunctional control. The Utah Arm will probably be the first commercially available arm to contain a computer-based controller.

Prosthetists will develop better suspension techniques that minimize or eliminate harnessing in powered limb fittings. They will also, through case studies, develop fitting principles that will enable the various components to be fitted components to be fitted effectively, used appropriately in combinations, and used creatively with body-power.

I hope that new control strategies will become available which will enable arm amputees to use multifunctional prostheses without excessive mental load. When this may happen is difficult to predict.

SUMMARY

I have attempted to put powered limb components available today into perspective from an historical viewpoint. None of the devices used today appeared "de novo." All have been influenced by historical events and concepts, the state of technology, and prosthetics practice.

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Innovation and Improvement of Body-Powered Arm Prostheses: A First Step

by Maurice A. LeBlanc, M.S.M.E., C.P.

INTRODUCTION

Standard body-powered upper-limb prostheses have not changed significantly since developments in the 1950's which were spurred by World War II. They still employ aircraft technology using shoulder harnesses and steel cables for operation. If one looks at the *Manual of Upper Extremity Prosthetics* first edition (1952)[2] and the *Orthopaedic Appliance Atlas—Artificial Limbs* first edition (1960)[9] compared with 1985 state of the art, one will not find a great deal of change.

It is the consensus of several leading prosthetists in the U.S. that many arm amputees are being led into purchasing externally powered arm prostheses because they look more modern and "hi-tech." Present body-powered arm prostheses simply do not offer a good alternative. They look more archaic, and the shoulder harnesses are uncomfortable and restrictive.

Body-powered systems have more sensory feedback and generally are more functional (for unilaterals) than externally powered sys-