REPORTED ABROAD*

GERMAN DELEGATION'S REPORT ON RUSSIAN ARM

The Nov. 1964 issue of Orthopädie-Technik contains a report by Dr. F. Blohmke, Federal Ministry of Labor and Social Affairs, Bonn, Germany, of a visit by a group of German prosthetic experts to study the Russian arm. A summary of this report is herewith presented.

1. General Travel Report

From July 29 through August 5, 1964, a delegation of German experts, sponsored by the Federal Ministry of Labor and Social Affairs (BMA), visited the U.S.S.R. to investigate a request by the V.O. Lizensintorg firm, Moscow, to negotiate a licensing contract for the production of the bioelectric arm prosthesis.

On July 30, the Delegation had its first meeting in the Ministry of Foreign Trade with Lizensintorg representatives, Vice President Borisenko, Chief Engineer Kulinitsch, and Director of the Export Division Perekhodtsev. According to the statement of these representatives, the firm concerns itself with the sale of patents of Soviet inventions, the licensing of their use, and the buying of foreign patents. These transactions finance the firm, which is not subsidized by the government, thus the license fees must not be considered as covering developmental costs of an item such as the bioelectrical prosthesis but merely as a token of acknowledgment.

During the detailed discussion as to who should be the German contract partner, it was pointed out that, in contrast to the national orthopedic workshops of the U.S.S.R., the orthopedic workshops of the Federal Republic were private enterprises, although the orthopedic care of the war disabled is financed by the Republic. A Russian license contract would therefore have to be made with a German private company, most likely a manufacturer of orthopedic appliances.

The German delegation stressed the humanitarian importance of the orthopedic aid, and presented films and slides to emphasize their desire for an exchange of scientific information as well as for commercial discussions with Russian researchers.

Mutual proposals on program planning concluded the session.

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*Based chiefly on translations by Dr. Gabriel Rosenkranz, Medical Consultant to the VA Prosthetics Center.

On the same day, the Delegation was received in the Ministry of Social Service of the Russian Socialist Soviet Republic by the Assistant Secretary Malachov and Prof. Popov, the director of the Central Prosthetic Research Institute in Moscow, for a thorough discussion. In the Russian Soviet Republic with a population of 100,000,000 there are about 360,000 disabled, who require 180,000 prosthetic, orthotic, and orthopedic appliances annually. Each amputee has both a cosmetic and a work prosthesis, which are used for at least two years before replacement.

Governmental workshops are responsible for the production and procurement of these appliances. These workshops, normally employing 50 to 80 workers, produce all kinds of aids, including orthopedic shoes, artificial eyes, wheelchairs, etc. The workshop in Moscow, with 600 employees, is the largest in the U.S.S.R. The workshops, which number 15 in the Russian Republic, are usually connected with a hospital that has an amputee training school. Prosthesis fitting in remote areas is done in mobile workshops.

In the construction of lower-extremity sockets, no plaster of Paris was used (with few exceptions), but experimental sockets of synthetic material were used in various forms and sizes.

The orthopedic technician is taught in a specialized technical school in Leningrad. His specialized training begins upon graduation from high school at the age of 16 to 18 years and lasts four years. Prerequisite courses in other arts or sciences are not required. Postgraduate training is given at an appropriate institute.

On August 1, 1964, the German delegation was received in the Central Prosthetic Research Institute in Moscow. Each participant was given the opportunity of trying out any prosthesis that interested him. Later, the Delegation presented German films, which met with the unanimous approval of the Russian members of the Institute. The discussion that followed further improved direct contact between the experts of the two countries.

In the Institute for Prosthetic Research in Leningrad, the Director K.T.H. Strukov, Technical Vice Director K.T.H. Voroncov, and Medical Vice Director K.T.H. Shulak demonstrated an electric prosthesis and one of their first models of a pneumatic prosthesis. The below-elbow bioelectric prosthesis was controlled by pronation and supination of the stump.

The applause and discussion that followed the German films clearly proved the international interest in the exploration of humanitarian problems.

The morning of the last day was devoted to a visit of the Central Institute of Orthopedics and Traumatology in Moscow. It is a well organized clinic which was opened in 1963 under the direction of Prof. Volkov.

During the final negotiations with the Lizensintorg firm that afternoon, in which the Russian representative, Director of the U.S.S.R. Trade Office in the Federal Republic, Engineer, W. Trebenko, also took part, the Lizensintorg people presented a contract proposal and implied that after the German Delegation read it, they were prepared for further negotiations.

The Germans emphasized that their highly developed pneumatic prosthesis had a strong trading value, which should not be underestimated; they also repeated their offer to permit Russian experts to visit at any time the orthopedic workshops and clinics in Munich and Heidelberg.

The Delegation of Experts made every effort, through observation and experience, to gain insight in a few days into the development of orthopedic technology in the U.S.S.R. If these efforts prove successful, it is partly due to the fact that the members of the delegation had had professional and personal intercommunication for decades. The fulfillment of this concentrated program would not have been possible without the energetic support of the numerous assistants in the official departments. The German delegates extended their particular thanks to the German Embassy in Moscow, who, they said, not only splendidly helped in the smooth running of the official program but also imparted to the delegates an unforgettable impression of the grandeur and uniqueness of Russia.

2. Central Prosthetic Research Institute in Moscow

On August 1, 1964, the German delegation was given the opportunity of visiting the Central Prosthetic Research Institute in Moscow, and there to form their impression of the design and function of the bioelectric prosthesis. Unfortunately, the amputee assigned to demonstrate the prosthesis, was not present but, in his absence, the participants themselves could examine the electrodes and study the functions of the prosthesis, such as opening width, gripping power, fist closure, and speed of action. The absence of the amputee was thus not considered a disadvantage since the discussion of construction principles was more relevant with the participants manipulating the prosthesis themselves than if they were merely watching the amputee use the prosthesis.

In its present form, the bioelectric prosthesis conformed quite closely to the illustration shown in the Lizensintorg catalog. The bioelectric prosthesis, covered with a cosmetic plastic glove, consisted of a hollow plastic hand with the four fingers in medium flexion position and a movable hollow plastic thumb. It was not learned which material was used for the hand shell.

A small, high-speed electric motor of about 3 cm. radius and 2⅓ cm. height was set within the body of the hand.

Gears opened and closed the thumb to contact the tips of the second

and third fingers, producing a gripping strength of 1.3 to 1.5 kg. By means of multiple fist-closing impulses, the free play within the gears could be overcome, producing a maximum gripping force of 2 kg. A cadmium-nickel storage cell, encapsuled in plastic, served as power source; it weighed 320 g. and required recharging every 2 to 3 days on 127 or 220 volt alternate current.

Hand closure or opening of this below-elbow prosthesis was controlled by myoelectric currents, which were picked up by means of two electrodes from the flexor and extensor musculature near the elbow; a third neutral electrode was applied to the skin close to the ulna. The necessary potential of the myoelectric currents was 20 to 40 microvolts. For better contact, the small electrodes were slightly moistened. They had to be pressed against the flexor and extensor muscles to retain the contact. The contact pressure of the electrodes was about half as strong as that required by pneumatic valves, which are mechanically controlled by muscle tension. The myoelectric currents picked up by the electrodes were amplified to a point where the motor was switched on for hand closure or repoled for opening. The amplifier was transistorized, weighed about 120 g., and was the size of a cigarette box, 8.2 x 4.6 x 2.1 cm.

The electrodes were fastened with contact springs in the plastic stump socket, which was attached to the arm by means of bars through a cuff on the upper arm.

To summarize, the demonstrated model of the electroprosthesis consisted of three electrodes, a transistor amplifier for reinforcing the myoelectrical potentials, which actuated a small motor which, in turn, moved the thumb toward the four rigid artificial fingers (by means of reduction gears) with uniform velocity and gripping power. The bioelectric prosthesis is useful only with medium length or long below-elbow stumps. A bioelectrically controlled rotatory wrist joint had not been developed. Short above-elbow stumps or shoulder disarticulations cannot as yet be fitted according to this principle, because myoelectric elbow joints are not available.

The present system of electroprosthesis has no feedback features, neither for finger position nor for grip strength.

The pneumatic prosthesis, which is used in Germany for all amputation levels, gives the amputee a sense of feedback since the gripping power is proportional to the muscle tension applied on the valves.

The simplicity of the construction of the Russian hand, limited to moderate hand opening and closure speeds and an almost constant grip force, insures minimum mechanical breakdown; however, the gripping strength of the electrohand was only about one fifth that of the German pneumatic prosthesis.

A compromise is always necessary between the cosmetic and functional features of an artificial hand. The bioelectric hand looked good, but the

rounded finger caps of the opposing three fingers were relatively unsatisfactory for working purposes since a firm grip was not possible.

After a thorough examination of the bioelectric prosthesis and a discussion of its construction principles, the Delegation was given the opportunity of inspecting the Institute itself. Electronic circuitry for the prosthesis was tested in a special laboratory. Functional endurance tests were run and evaluated on every part used in the prosthesis. In a different laboratory patients were seen wearing electrodes for training in myoelectric control. These exercises were exactly the same as those practiced in the training for pneumatic valve control by means of muscle tensing; the problems of faulty control caused by involuntary associated motion of these muscle groups during arm movement under load are similar in both the bioelectric and pneumatic prostheses.

In another much larger laboratory, biomechanical studies of gait were in progress, such as electromyographs, treadmill, force plates, and similar methods. The studies were the same as those carried out at the Max-Planck Institute in Germany and at the Institute for Biomechanics in California.

3. Prosthetic Research Institute in Leningrad

The purpose of the Leningrad trip was to learn something of the present developmental status of the pneumatic arm prosthesis at the Institute for Prosthetic Research in that city, in order to be in a position to compare the Russian pneumatic prosthesis with their bioelectric BE prosthesis and also with the German pneumatic prosthesis.

The director, K.T.H. Strukov, and his co-workers stated that the development of the Russian pneumatic hand was in its early stages, but that nevertheless, he would show the Delegates everything of interest. In Leningrad, in contrast to the work in Moscow, construction of above-elbow prostheses for difficult amputation stumps had just begun. The Heidelberg arm was known only through the literature, and practical experience and tests with the German pneumatic prostheses were lacking. Right after the war, conventional arm prostheses were preferred because of the large numbers of amputees. Now, efforts are being made, through the use of synthetics, to reduce the weight of the prosthesis and to increase its stability. Conventional below-elbow and above-elbow plastic (polyamide) prostheses were shown in which interchangeable terminal devices (hooks and plastic-gloved prosthetic hands) could be mounted. In addition, the above-elbow prosthesis could be dismantled at the elbow joint and a device for mounting a shovel, or similar tool, could be attached. The interchange of pneumatic with conventional parts was not yet possible although, in Leningrad, a kind of building-block system was used for shortening and lengthening prostheses.

The Germans pointed out the advantages of standardized parts so that a pneumatic arm could be interchangeably fitted with a gripping hand, a work hand, or a cosmetic hand.

The German Delegation felt it remarkable that the Leningrad hook had no thumb. The passively closing and actively opening hook was activated by a shoulder pull harness. In a reverse joint, situated in the forearm of the prosthesis, the pull was transmitted to a pressure rod. The opening of the hook or of the prosthetic hand was achieved by a distalward moving rod. With this design, it would probably not be difficult to activate the Leningrad hooks and hands pneumatically if the pressure rod were driven by a CO_2 servomotor. The overall length of this arrangement, however, precluded its use with medium long and long below-elbow stumps; it would also be extremely difficult to install an active pneumatic hand rotation unit in the lower portion of a below-elbow prosthesis. Although a pneumatic wrist rotation joint had not yet been developed for the Russian pneumatic arm, the Russians considered it of great importance.

The demonstrated pneumatic above-elbow prosthesis had a mechanical elbow joint, a passively adjustable wrist unit, and a pneumatic servomotor that actuated the hand. The servomotor was called a diaphragm pump by the Russians. This diaphragm pump afforded a finely graduated gripping strength. The control valve was located on the upper part of the above-elbow socket and was activated by a shoulder-pull cable. The question of the German delegates as to whether it were a ball or needle valve remained unanswered, but they were told that feedback of the grip force of the hand upon the valve did not occur with the Russian model (contrary to the Heidelberg development). The need for feedback was recognized by the Russians. To explain the difference between the various pneumatic valve systems, the Germans sketched a diagram of the Heidelberg valve system, so that the design of the automatic feedback of the Heidelberg valves was clearly demonstrated.

The hand shell, especially the palmar surface of the fingers, did not satisfy the needs of a work hand. Cosmesis was very good, but practical effectiveness at work, in comparison with the pneumatic universal hand, the standard hook, or the three-finger hook, appeared to be inferior. A pneumatically or electrically activated hook had not yet been developed in Russia.

4. Central Institute of Orthopedics and Traumatology in Moscow

The Central Institute, under the direction of Prof. Volkov, is a large orthopedic traumatology clinic with about 600 beds. In 1963, a new building with 400 beds was completed, and more new buildings, including one with 200 beds for children, are planned for 1965. The Institute, in addition to the hospital, is comprised of a great number of theoretical

institutes, including Anatomy, Pathology, Histology, Limb Transplantation, Metallurgy, etc. Their task is to work in close collaboration with the hospital to further the development of orthopedics and traumatology. A Rehabilitation Center, which is about 50 km. from Moscow, is also affiliated with the hospital.

The Central Institute, with its 600 beds, is subdivided into 20 independent units. Each of these units is under the direction of a professor, who was a specialist in his field. The smaller independent divisions of about 30 beds are comparable to a station in a German hospital. At every division there were four more doctors, comparable to the German Assistant Physicians; thus, 100 physicians were assigned to 600 patients.

The Divisions were highly specialized; e.g., there was one exclusively for bone tumor and metabolic diseases of the skeleton, another for hip endoprostheses, and others for hand surgery, burns, nerve injuries, sport injuries, etc.

Specialist Professors concerned themselves exclusively with the development and application of a particular technique. There were regular conferences to coordinate the activities of the entire hospital, but the Delegates had the impression that though this overspecialization produced high accomplishments, the total supervision probably suffered. The operating room was well equipped; halothane was the anesthesia used, and a television camera was built into the operating light fixture.

At the departments for bone tumor, hand surgery, and endoprostheses, the German delegates were welcomed with the greatest friendliness, and the professional discussions were most animated. The Russian physicians displayed particularly great interest in transplantations. Deep freeze transplants were widely used not only of human bone but also of human nerves, skin, and whole joints. In the field of alloplasty, Vitallium was used. In hip surgery, head and socket prostheses were made of metal; artificial finger joints of metal were also shown.

Lively discussions ended the visit. Each member of the delegation received a number of Russian books, and in return the Delegates gave German books.

Prof. Volkov suggested an exchange of medical publications, and expressed his regret that the *Russian Journal for Orthopedy, Traumatology, and Prosthetics* was so little known in the German Republic. It was mentioned that this journal might be produced in English and German supplements, a suggestion that should be taken up promptly.

5. The Contract

The draft of a contract with the firm of V. O. Lizensintorg as license assignor took into account the fact that the contract was to be arranged with a private enterprise. Under the terms of the contract, it is agreed that:

a. For the duration of the contract the licensee will neither directly nor indirectly manufacture or sell similar prostheses or components which compete with the Russian prosthesis;
b. All prostheses or parts manufactured under the license must be labeled: "Made under license of the V. O. Lizensintorg of the U.S.S.R.," and this must be so indicated in all advertising;
c. The licensee must provide quarterly bookkeeping accounts on the production of prostheses and components;
d. The licensee must permit an inspection of production methods as well as the distribution data of prostheses and components.

The contract provides, furthermore, that the parties mutually notify the contract partner of all changes and developments with no charge or delay. The license fee for a period of 8 years is set at 560,000 German marks; the fee for instruction in Russian language at 6000 German marks. Compensation for the delegation of Russian experts to Germany for the purpose of training German technicians, the length of stay, and salary, are to be negotiated in special contracts following the signing of the contract. The same conditions apply to the purchase of model prostheses.

6. Conclusion

The bioelectric prosthesis of the Central Prosthetic Research Institute in Moscow was not activated by shoulder pulls or arm musculature as in conventional prostheses, but utilized an external power source, namely, the electrical current derived from a cadmium-nickel storage cell. Myoelectric currents, generated through contraction of the flexors and extensors of the forearm, controlled the grasping movements; the myoelectric currents were picked up by skin electrodes and amplified by transistors. The electroprosthesis represented a development of scientific interest.

The model demonstrated seemed to function with sufficient reliability. If, indeed, the reliability of the Russian electroprosthesis proves superior to the Vaduz arm and the prosthesis developed by Kegel in Paris, this is, to a great extent (according to the German experts) due to its more primitive construction, which lacks certain functional features that are designed in the forementioned prostheses but which are not altogether achieved even in those models.

For full evaluation, the Russian bioelectric prosthesis must be compared with the German pneumatic prosthesis, which had been developed at the Orthopedic University Hospital in Heidelberg after World War II (see table).

As is apparent from the features listed in the table, the bioelectric prosthesis, although cosmetically acceptable, was very poor functionally. Furthermore, experience has shown that the number of externally powered prostheses used is limited since they are generally not worn by unilateral

amputees. For bilateral below-elbow and above-elbow amputees, however, the technically flawless German pneumatic prosthesis has proved its value for many years, according to the Delegation of German prosthetic specialists.

Evaluation of the Russian Bioelectric Prosthesis with the German Pneumatic Prosthesis

Features	Russian BE Myoelectric Prosthesis	German Pneumatic Prosthesis
Provision for BE stumps	Possible	Possible
Provision for AE stumps	Not possible	Possible
Provision for shoulder disarticulations	Not possible	Possible
Pronation of wrist joint	Not possible	Possible
Supination of wrist joint	Not possible	Possible
Feedback of grip strength	Not possible	Possible
Movable elbow joint	Not at present	Present
Movable shoulder joint	Not at present	Present
Normal gripping strength	1.3-1.5 kg.	10 kg.
Maximum gripping strength	2.0 kg.	Up to 20 kg.

BRITISH AND GERMAN REPORTS ON U.S.S.R. PROSTHETIC CENTERS (With Notes on the Bioelectric Arm)

Viewpoint of English Delegates to the U.S.S.R.

In May 1962, Mr. Norman Capener of Exeter, Professor Roland Barnes of Glasgow, and Wing Commander C. B. Wynn Parry of the Royal Air Force visited Russia under the auspices of the British Council. The following comments of this English group* on the Institute of Prosthetic Research in Moscow, and on electromyography as practiced in the U.S.S.R. are of interest, particularly in light of the German delegates' more recent report.

Institute of Prosthetic Research and the Bioelectric Arm

"This Institute is responsible for the design and development of artificial limbs and surgical appliances for the whole of the U.S.S.R. Associated with it is a centre for the training of amputees. The limbs we saw were not

*"A Visit to Russia," Proceedings and Reports of Councils and Associations. Excerpts reprinted with permission from the Journal of Bone and Joint Surgery, 45B(1):225-230, Feb. 1963.

superior to our own in any way. Two experimental limbs were of interest. One for the lower limb was essentially a light metal tube with joints at the knee and ankle, which was covered by a plastic material which gave the artificial limb a natural appearance and feel. There was also an experimental limb for forearm amputations. Impulses were picked up from the extensor and flexor groups of muscles in the stump and amplified 50,000 times by a small transistor; they were then passed to a small electric motor situated within the prostheses at the level of the wrist and operated by an accumulator.† The motor produced a massed flexion and extension movement of the fingers and thumb but was rather noisy. The grip was good and the prosthesis appeared to have possibilities but required much development."

Electromyography in the U.S.S.R.

"At each centre visited the opportunity was taken to investigate the work being carried out in electromyography. It is clear that by and large this science is less advanced in Russia than it is in Britain. Needle electrodes, for example, are not used at all and this therefore precludes the use of electromyography for the diagnosis of lower motor neurone lesions. Electrical stimulation techniques for diagnosis are widely used, but again they are out of date in our opinion; and furthermore the doctors carrying out these techniques and the doctors carrying out electromyography are usually different people and often separated geographically by a long distance within the hospital. Recording apparatus was primitive and nowhere did we see photographic records on film being made."

Development of Surgical Instruments and Prostheses in the U.S.S.R. and a Sidelight on the U.K. Way

"It (Institute of Metals, Moscow) is essentially a Department of Biomechanics with technical, experimental and clinical divisions. Its chief function is to test and develop instruments and internal appliances, which are not released for general use until thoroughly tested. The procedure is that a surgeon who is interested in a new instrument or prosthesis consults one of the engineers, who may see the operation for which the instrument is to be designed. A prototype is made and, if possible, it is tested in animals and changes are made in the light of the experience gained. It is then tested clinically on patients in the district hospital. Further changes are made if necessary and finally a prototype is released to the surgical instrument factories for general production. The quality of the work was impressive. The system of testing seemed superior to our somewhat hap-

†Ed Note: An accumulator is usually called a "storage cell" or simply a "battery" in the U.S.A.

hazard way of developing surgical instruments and prostheses, often without adequate tests."

INFLATABLE SERVO ACTUATORS

A. R. Mettam (Ministry of Aviation, Aeronautics Research Council Current Papers, Her Majesty's Stationery Office, London), during his service with the Ministry of Health, London, between 1958 and 1961, did some independent research on a practical artificial-muscle system.

To improve the force-versus-pressure relationship of fluid pressure Servo Actuators, he developed an actuator that utilized the whole wall surface of the working chamber in energy transfer, rather than the small area of a piston or a vane. One way this was done was by use of flat envelopes of flexible material that inflate into a cylindrical form. Mostly engineering applications were suggested by Mettam, however, in the case of skeletal muscle groups, two such actuators can be operated as mutual antagonists to give a double acting system.

Mettam also suggests that with suitable lobe design, the flexibility and bulging quality of human muscle under load could be duplicated with a muscle-motor, and if formed of an inert material such as "Terrylene" could be used as an internal prosthesis. Although Mettam admits the difficulty of implanting the fluid-pressure generator and providing for the necessary electrical signal, he points out the success already achieved with cardiac pacemakers.

He also suggested that by connecting the muscle-motor to a conventional flail appliance or to cineplastic tunnels, function of a paralyzed limb might be restored by utilizing residual myoelectric currents.

For powering hand or terminal appliance of forearms, particularly for bilateral amputees, the muscle-motor actuator could serve as a valuable aid. If myoelectric control is undesirable, squeeze-bulb-type fluid-pressure transmitters could be embodied within the conventional limb harness or within the arm socket wall.

The lack of orthotic-prosthetic tactile feedback might be overcome, according to Mettam, by using a pump-bulb in a thumb or finger-tip pad, connected to a muscle-motor by flexible tubing to produce a pressure stimulus on the stump skin through a simple lever stylus. The stimulus would be applied to a cutaneous innervation area common with that of the missing digits.

Mettam states that the extreme simplicity and economy of these actuators entitle them to consideration as alternatives to conventional fluid-pressure actuators in any low-pressure fluid servo system, whether physiologic, aeronautic, automotive (accelerator, brake, clutch linkage, window winding), or prosthetic.