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REPORT OF THE WORKSHOP

ON

REHABILITATION ENGINEERING EDUCATION

Held

November 3-5, 1976

at

THE UNIVERSITY OF TENNESSEE, KNOXVILLE

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April 1977

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WORKSHOP ON REHABILITATION ENGINEERING EDUCATION

1.0 PURPOSE

The object of this workshop has been to formulate recommendations and guidelines for the systematic development of education, practical training, and certification programs in Rehabilitation Engineering.

1.1 Background

Recent estimates made by the Social Security Administration (SSA) and the Swedish Institute for the Handicapped indicate that between 10 and 12 percent of the population are handicapped.(1) Thus it is conservatively estimated that there are approximately 20 million handicapped individuals in the United States. The Social Security Administration indicates that of these approximately 8 million are either fully employed or limited in work activities and 7.5 million are unable to work at all. By deduction, the remaining 4.5 million must be juveniles or from the geriatric population. The loss of productivity plus the financial burden borne by the federal and state programs are estimated to be in billions of dollars. These financial burdens are in addition to personal losses suffered by the physically handicapped individuals resulting from their inability to participate in many aspects of life -- losses that cannot be measured in dollars.

A further conservative estimate is that modern technology can be potentially beneficial to at least 50 percent of this population (10 million people). Recent experience indicates that the judicious application of technology can have beneficial effects by increasing the level of independence of individuals, thereby reducing costs of care and increasing involvement in productive job activities. At present only a very small fraction of the country's technological capabilities are being effectively utilized to aid the physically handicapped.

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(1) Numbers in parentheses refer to references included in Appendix 5.2.

Prosthetics and orthotics have been the primary source of technological appliances for the physically handicapped over the years. Recent studies conducted by the Committee of Prosthetic Research and Development[2] indicate that approximately 4 million individuals directly benefit from prosthetic and orthotic services, which are provided primarily by the private sector. Thus there are approximately 6 million individuals who stand to benefit from additional types of technology that are presently unavailable to them.

Over the past 20 years a variety of federal programs have attempted to direct the advances in technology to the needs of the physically handicapped population. To date, the greatest successes have been made in the fields of prosthetics and orthotics. These advancements have come largely as a result of the close coordination, consultation, evaluation, and dissemination efforts carried out by the Committee of Prosthetics Research and Development of the National Academy of Sciences. These programs have appropriately been augmented by three subsidized schools for Prosthetic and Orthotic Education and the Committee for Prosthetic and Orthotic Education of the National Academy of Sciences. A major commitment to research and development in the fields of prosthetics and orthotics by federal agencies such as the Veterans Administration (VA) and Rehabilitation Services Administration (RSA) of the Department of Health, Education, and Welfare (DHEW) provided the funding base necessary to achieve these advances. In general, progress in other areas involving the application of technology to the severely handicapped has not experienced similar successes.

Throughout the 1960's attempts were made to transfer sophisticated technology developed by the National Aeronautics and Space Administration (NASA), the computer industry, and others into the clinical setting. This attempt at transferring advanced technology has met with several obstacles over the years which has reduced its effectiveness. The major difficulties stemmed from an inability of the involved disciplines to communicate effectively, and from the fact that there were not resources within the clinical environment that could effect the transfer in a manner that was acceptable to patients. Technology transfer is now rapidly improving through an expanded approach which has placed engineers, physicians, and related professionals together in a clinical setting to work directly with patient problems. This approach has been termed Rehabilitation Engineering and received a major program commitment by RSA beginning in its fiscal year 1972, and also more recently by the VA.

The broad objective of Rehabilitation Engineering is to enhance the lives of the physically handicapped through clinical involvement in a total approach to rehabilitation combining medicine, engineering, and related science and technology. Specific areas of concern have been delineated for rehabilitation engineering which distinguish this RSA program from the Biomedical Engineering Program of the National Institutes of Health (NIH).

The RSA plan called for the establishment of a network of rehabilitation engineering centers throughout the country. Since its inception in FY 1971, seven rehabilitation engineering centers have been established within complexes that combine medical and engineering resources with a commitment to rehabilitation services, research, and training programs. Each center has been charged with a core area of research with an obligation to function as a cooperating member of the national network for the purposes of information exchange, evaluation, and education. Also inherent in the rehabilitation engineering concept is the implied commitment that each center will strive to make technical advances, developed either externally or internally, available to patients. Finally, there exists a commitment within the national program to develop the necessary educational programs to train people to successfully carry out research, development, evaluation, and patient services, as they relate to the above stated goals of rehabilitation engineering.

Within the scope of activities of the existing centers significant success has been achieved in the established core areas of research. However, it is recognized that the further development and ultimate maturity of the rehabilitation engineering concept is dependent on the availability of adequately selected and properly trained persons to function as rehabilitation engineers. In spite of several attempts by RSA and the VA in recent years to stimulate the development of education programs in rehabilitation engineering, a formally recognized program for rehabilitation engineers does not exist in the United States. This workshop is a further expression of this concern, and has been organized in order to develop guidelines that will form, we hope, the basis for the systematic development of formal educational programs in rehabilitation engineering for both engineers and persons from other disciplines involved in rehabilitation engineering activities.

2.0 WORKSHOP FOCUS AND FORMAT

On July 28, 1976, a twelve member steering committee met to formulate guidelines for the workshop. It was immediately obvious that education in rehabilitation engineering could not be adequately discussed in a workshop setting by disciplines representing a wide variety of interests without some common interpretation of rehabilitation engineering in general. Therefore, the initial phase of the workshop was structured toward defining the scope of rehabilitation engineering, outlining the role of the rehabilitation engineer, establishing the extent of the need, and indicating the inter-professional relationships that should exist between rehabilitation engineers and the other rehabilitation disciplines. In order to provide further insight into the potential areas of employment and the ultimate need for rehabilitation engineers, it was felt necessary to explore and outline the organizational requirements and funding potential for a delivery system in rehabilitation engineering that would have national impact. Based on this background information, the final phase of the workshop could then be directed toward developing guidelines for rehabilitation engineering education, complete with recommendations for certification. Position papers from leading experts in the field would provide a further basis for discussion. Most of these papers are included in this report as Appendix 5.1.

An attempt was made to select workshop participants who would represent a wide range of interests in rehabilitation engineering. A breakdown of the final attendance list indicated the following participants according to discipline:

Engineering Educators	10
Rehabilitation Engineers	21
Administrators	1
Orthotists/Prosthetists	5
Physicians	7
Architects	1
Physiologists	1
Vocational Rehabilitation Educators	14
Research Physical Therapists	1

Representatives from the Department of Health, Education, and Welfare, the Veterans Administration, and State Vocational Rehabilitation agencies attended the workshop and served as resource people throughout the deliberations.

The two and one half day workshop was hosted by the University of Tennessee, Knoxville. The meeting followed the guidelines established by the Steering Committee. That is, solicited position papers were presented on the major topics previously mentioned and panel sessions followed each presentation with a set of guidelines to assist the panel in focusing the discussion. The proceedings of the panels from the first day were made available to each participant, thereby providing a common background prior to the second day's deliberations. In addition, panel chairmen presented the recommendations of their groups in plenary sessions which permitted further discussion and exchange of concepts.

Discussion of the broad aspects of rehabilitation engineering led to many diverse but valuable opinions, which appeared throughout the proceedings of each panel. These opinions have been condensed and appear as a composite statement in the Narrative section. It is anticipated that this composite statement will be useful to physicians, administrators, educators, prosthetists/orthotists, therapists, students, and others who are attempting to gain more insight into the new and developing field of rehabilitation engineering.

The primary purpose of this workshop was to formulate guidelines and consensus recommendations for the development of rehabilitation engineering education. These consensus recommendations appear in the following section.

3.0 RECOMMENDATIONS

Since the focus of the workshop was on rehabilitation engineering education, recommendations in this area were considered to be of highest priority. Although many valuable recommendations were made in other areas, they have been assigned secondary emphasis due to the focus of this workshop. The editors have not felt obliged to include all recommendations from all panels, but rather have included only those that represented a consensus opinion.

3.1 Major Recommendations

3.1.1 It is recommended that a three-year federally-sponsored pilot educational program be initiated and administered at three or four universities with experience in engineering and medical education combined with the availability of clinical resources in rehabilitation. The major focus of the program should be to provide the post graduate education necessary for the student to immediately assume a primary responsibility for the delivery of engineering technology to disabled patients/clients. The support for this program should be in the form of institutional training grants.

This highest priority recommendation is made on the basis that there is an immediate need for about 250 qualified rehabilitation engineers and a future estimate of approximately 2,000. Although a number of options were suggested (i.e., B.S. in engineering, plus short courses; second B.S. degree), it was generally agreed that rehabilitation engineering education should result in a Master's degree. A significant part of the graduate educational experience should involve a clinical internship during which time exposure is gained into the activities of other rehabilitation disciplines, plus active participation in solving patient problems, involving both adults and children. The education program should follow the general curriculum outlined in Section 4.4 of the Narrative portion of this report and be of approximately 18 months duration. The program should involve approximately equal exposure to both didactic and clinical training, depending on the background and experience of the individual. Student stipends should be consistent with other graduate engineering assistantships. It is anticipated that the training program would be open to students with non-engineering backgrounds on the assumption that they could acquire the necessary undergraduate background from an accredited engineering program to enter into an advanced program.

3.1.2 <u>It is recommended that a means be developed for the continuing education of rehabilitation engineers and other disciplines involved in rehabilitation engineering activities.</u>

Since no formalized continuing education program exists in rehabilitation engineering, it was deemed highly important that this be developed. It was further recommended that the continuing education courses should be in the form of short courses of three to seven days in duration. The costs should be covered by individual attendees. The courses should be held in rehabilitation engineering centers and/or universities or other appealing locations capable of offering either clinical or didactic experience as required. The courses should be coordinated through existing organizations related to rehabilitation engineering using as a model the continuing education programs of the American Academy of Orthopedic Surgeons and the American Academy of Orthotists and Prosthetists.

3.1.3 <u>It is recommended that a certification process be instituted in rehabilitation engineering to insure adequate consumer protection and recognition of the qualified rehabilitation engineer.</u>

It was felt that an individual should be qualified in a recognized field of engineering and then seek certification as a Rehabilitation Engineer after completion of recognized course work plus an appropriate length of time in practice, resulting in a "Board Eligible" rehabilitation engineer. The existing biomedical engineering societies should be approached to convene an appropriately constituted committee to consider the details of certification of rehabilitation engineers. Perhaps the American Board of Clinical Engineering would be an appropriate body to coordinate certification activities.

In general, it was felt that certification should establish minimum standards or requirements for rehabilitation engineers and that it should imply recognition rather than licensing. It is further suggested that an initial certification examination be required plus periodic continuing education experience in order to maintain certification. Future consideration of rehabilitation engineering certification should have adequate representation from other rehabilitation specialties, including prosthetics, orthotics, and medicine. The initial action on this recommendation should be to identify the peer group that will assume the responsibility for further developing the guidelines for certification.

3.1.4 <u>It is recommended that a national coordinating body be established to advise and serve various agencies of government with respect to the delineation and development of national and international programs in rehabilitation engineering. One function of this body would be to coordinate the systematic development of the educational program as outlined in the above recommendations and in the body of this report.</u>

Due to the small number of rehabilitation engineers in the field, it is premature to establish a national professional organization. It is, therefore, felt that a coordinating body or Board acting with strong interagency support could serve to implement and oversee the education program, plus coordinate the continuing education activities. It could also serve as a coordinating and advisory resource during early phases of the certification planning.

Included in the scope of this Board would be to provide advice on policy in areas of rehabilitation engineering including research, evaluation, training, and service delivery. This would be accomplished through activities of grant proposal reviews, formulation of policy recommendations, conducting of site visits, and initiation of special studies. Further operational activities of the Board would be to coordinate evaluation studies, conduct workshops and conferences, establish a centralized information referral system, and disseminate publications. The Board, acting with the full support of RSA, VA, DOT, and other governmental agencies, would assume the responsibility for planning and directing the development of the federally-sponsored rehabilitation engineering movement.

3.2 Secondary Recommendations

3.2.1 It is recommended that plans be developed and the appropriate action taken in order to establish a national system for delivery of rehabilitation engineering services to physically handicapped individuals of all ages.

It was stressed that the ultimate measure as to the success of rehabilitation engineering will be the extent to which its products enhance the lives of the physically handicapped. This implies a need for the following: a) the availability of qualified people necessary to implement technology transfer within clinical settings; b) adequate clinical facilities; c) the availability of technical services and components in a form that is acceptable to patients and clients; and finally, d) the means of purchasing these services and components.

3.2.2 It is recommended that a system for information exchange be developed to serve the needs of those now practicing rehabilitation engineering, and those seeking rehabilitation engineering services.

The information exchange system would make available information on materials, devices, current research, potential manufacturers and consumers' needs. Current research and development activities in the various rehabilitation engineering centers and other research facilities would be readily available to those in other centers, plus consumer advocates such as therapists, vocational rehabilitation counselors, physicians, social workers, and others.

3.2.3 It is recommended that the scope of RSA - Rehabilitation Engineering be expanded to provide increased effort toward solving problems of both pre-adults and geriatrics.

With geriatrics the goal should be to prolong independence of mobility and self-care in the community to the extent that it is economically feasible. Appropriate application of technical assistance can substantially reduce in-hospital costs, plus reduce the cost for attendent care in the community.

For pre-adults with severe congenital or acquired disorders, the goal should be to initiate technical research, service, and education projects that would support habilitation and rehabilitation programs that begin at early age, and provide continuous assistance throughout the developing years on into adulthood. These projects should be closely integrated with the medical, therapy, educational, vocational, and life goals for the individual.

3.2.4 It is recommended that the scope of the Veterans Administration, Rehabilitation Engineering Program, be expanded to cope with the needs of their growing geriatric population.

As with the civilian population living at home, life can be prolonged and made easier for the family, mobility in the community and independence enhanced, thereby contributing to the quality of life of the individual by reducing the need for hospitalization and similar institutional living. In the hospital or institution independence can be improved and attendent care simplified with appropriate engineering systems and devices.

3.2.5 It is recommended that a federally-sponsored "Rehabilitation Engineering Week" be held to enhance the national visibility of Rehabilitation Engineering.

It is anticipated that this concept would be supported by the existing rehabilitation engineering centers, the VA, NASA, consumers, and others, with appropriate participation from congress and other federal agencies. The goal of such a meeting would be to illustrate the potential of rehabilitation engineering to positively affect the lives of hundreds of thousands of handicapped individuals. This rehabilitation week would facilitate the exchange of information, the development of plans for future action, and provide the opportunity for continuing education.

3.3 Recommended Action for the Pilot Education Program

The following action plan has been formulated by the Editorial Committee based on the workshop proceedings, recommendations, and the tone of discussions held throughout the workshop.

(a) An ad-hoc committee on rehabilitation engineering education should be formed immediately to formulate specific guidelines for curriculum content, internship program, cirteria for institutional participation, entrance requirements, student selection, and program evaluation.

(b) Funding support of $1.5 million should be obtained and administered by RSA/OHD - Rehabilitation Engineering Program in order to conduct a three-year pilot education project for training rehabilitation engineers as defined in this report. These funds should not in any way deplete the resources available for prosthetic and orthotic education.

(c) Proposals should be solicited from universities which have demonstrated commitment to engineering and medical education combined with the availability of clinical resources necessary to provide a meaningful internship experience. Rehabilitation engineering centers should be given high priorities as applicants.

(d) Three to five universities should be granted support at a level of approximately $100,000 each per year for three years to provide graduate educational experience to about five students per year per university (i.e., a maximum of 25 new students per year for three years).

(e) The Veterans Administration should investigate the possibility of training rehabilitation engineers in their rehabilitation engineering centers and appropriate academic institutions following the guidelines of this report.

(f) In addition to post-baccalaureate training and education for engineers, specific consideration should be given to the provision of specialized engineering education for other health peers such as therapists, prosthetists, orthotists, as an alternate route into rehabilitation engineering.

(g) Support of this program should be in the form of institutional training programs rather than direct support to individuals, or through research grants.

3.4 Recommended Action Plan for a National Multiagency Coordinating Board on Rehabilitation Engineering.

(a) Rehabilitation engineering staff officials in the Rehabilitation Services Administration and the Veterans Administration should take immediate steps to establish a Rehabilitation Engineering Coordinating Board. Its purpose would be to advise governmental and non-governmental agencies in this area, inform the general public of rehabilitation engineering programs, and carry out the responsibility for planning, developing, and monitoring a national strategy for research, clinical evaluation, training, and service delivery in rehabilitation engineering.

(b) The Coordinating Board should consist of representatives from the various governmental agencies and departments such as: The National Institutes of Health, the Bureau of Education for the Handicapped, the National Bureau of Standards, the Department of Housing and Urban Development, the Department of Transportation, the National Aeronautics and Space Administration, the Defense Department, and the Energy Research and Development Administration.

Non-governmental participation would also be crucial and must be integrated on the Board membership. Representatives would be from organizations of and for the disabled, individual consumers, industry, health and scientific professions.

Also, representation from the service delivery sector, such as state vocational rehabilitation agencies and Veterans Administration hospitals would be included on the Board.

(c) In time, it is envisioned that the proposed ad-hoc Rehabilitation Engineering Education Committee would become one of the standing committees of the Coordinating Board.

(d) Through the rehabilitation engineering center network, the media, activities throughout the Veterans Administration, the State Vocational Rehabilitation agencies, and via conferences and workshops, a high level of effort should be initiated to inform a vast cross-section of potential employers as to the advantages of rehabilitation engineering, and the problem solving potential of the rehabilitation engineer. Universities funded for rehabilitation engineering education should be requested to participate in this activity.

(e) In the third year of the project a critical evaluation should be carried out. This evaluation should provide documented recommendations for program modification plus specific plans for program continuity, considering the growth of the job market, desirable rate of program expansion, and the need for continuing financial support.

(f) Preliminary discussions should begin in the first year in order to lay the ground work for a certification program, which may not be totally implemented for five or more years from now.

(g) The ad-hoc Education Committee should begin to formulate plans immediately, complete with course topics, for a series of short term continuing education courses in various areas of rehabilitation engineering. The initial step should be to identify which societies or associations this activity should be affiliated with in the conduct of these courses as well as the development of the entire rehabilitation engineering education program.

4.0 NARRATIVE

Rehabilitation engineering was conceived as a practical means of bringing tremendous technological resources to the aid of physically disabled individuals. Based on practical experience gained in the prosthetics and orthotic professions, the concept involves the creation of a new professional who has engineering competence together with sufficient health care experience to enable effective patient interaction and communication with other health peers. The concept also includes the development of a delivery system in which rehabilitation engineering can be effective. Although the development of the system is essential for the delivery of engineering technology, the prime concern of this workshop was the training and education of personnel, particularly the rehabilitation engineer.

It is believed that the availability of such trained personnel and the development of a delivery system will have an enormous impact on increasing the independence, the productivity, and quality of life of our disabled population, and in many instances decrease the spiraling costs of health care.

4.1 The Profession

It is evident that the scope of rehabilitation engineering must be broader than the traditional focus of prosthetics/orthotics in order to be responsive to the needs in all aspects of a handicapped individual's life, i.e., education, vocation, daily living, recreation, and creativity. It was felt that rehabilitation engineering activities could be carried out anywhere that consumers require the services. Some examples are: rehabilitation hospitals and centers, special and public schools, industry, special living environments, research laboratories, insurance companies, vocational rehabilitation staffs, consulting services, government health departments, advisory boards, teaching programs, standards committees, and private charitable organizations.

That is, rehabilitation engineering should be considered in its broadest sense to mean the application of science and technology in a total approach to rehabilitation to improve the quality of life for the disabled person.

Rehabilitation engineering should be responsive to the needs of handicapped people of all ages. In particular, it was emphasized that the rehabilitation of youth should begin as early as possible in order to establish the proper confidence, emotional growth and maturity necessary to lead a productive and rewarding life and enhance their potential as human beings. Successful vocational rehabilitation for the young adult is much more likely if he or she already has learned to deal successfully with the handicap in earlier years.

It was agreed that a crucial element in the evolution of rehabilitation engineering is the establishment of an educational program which would generate individuals capable of "getting the job done." Within the hierarchy of engineering education, rehabilitation engineering can be considered as a subspecialty of biomedical engineering, as detailed in the appendixed paper entitled, "Some Thoughts Relative to the Rehabilitation Engineer," by James B. Reswick.

Throughout the discussions several approaches were followed in order to arrive at the number of rehabilitation engineers that are required to undertake this tremendous challenge. Based on these discussions, approximately 250 are required today, 1,000 in five years, and 2,000 in ten years.

4.2 Role of the Rehabilitation Engineer

The term "rehabilitation engineer" apparently has different meanings and connotations to different groups of people and these differences existed among various participants in the workshop. However, after considerable discussion, the consensus of opinion seemed to support the following definition.

A rehabilitation engineer is a person having identifiable competence in engineering with additional specialized training and experience which enables him or her to:

(a) Participate in patient care as a member of the interdisciplinary group responsible for health care delivery to disabled persons. This includes

- application and modification of existing systems or devices for the disabled patient; and
- conceiving, designing, testing, and evaluating innovative systems or devices for patients.

(b) Recognize and publish the results of experiences of interest to other rehabilitation engineering groups or colleagues and other health care professionals.

(c) Collaborate with industry on commercial evaluation of systems or devices.

There is considerable latitude for specialties to develop within the confines of the above definition; areas of emphasis would depend upon both the work environment (nature of facility, types of patients served, etc.) and the particular background and interests of the rehabilitation engineer. However, there was a general consensus among the participants of the workshop that a rehabilitation engineer must be able to effectively participate as a member of a rehabilitation team (whose members might be drawn from such specialties as medicine, physical therapy, occupational therapy, prosthetics, orthotics, vocational rehabilitation, social work, environmental design, etc.). In addition, the rehabilitation engineer must have a rather broad background in engineering with some particular area of emphasis (the most often mentioned was electro-mechanical design).

The rehabilitation engineer should use his or her knowledge of developments, techniques, and engineering design to aid in the solution of rehabilitation problems in such areas as patient environment, patient treatment programs, and patient devices or apparatus. He or she should be aware of the state-of-the-art and help assess patient needs. The rehabilitation engineer should aid in evaluating the advantages and limitations of various rehabilitative devices (and thus help to determine their applicability to a particular problem), determine when an existing device should be modified and/or when special devices should be constructed "in-house," and be able to effectively communicate with other engineers and with technicians in order to call upon their particular specialties in solving problems using existing technology and devices, or in designing new devices to meet particular needs. Some additional activities in which rehabilitation engineers might participate include those in:

(a) education and training,

(b) dissemination of information,

(c) consumer safety, and consumer advocacy,

(d) research and development.

The rehabilitation engineer should always exercise moral and fiscal responsibility, and feel ultimately responsible to the consumer. It should be emphasized that a rehabilitation engineer is an engineer -- not a prosthetist, an orthotist, a physician, a physical therapist, or an engineering technician.

To carry out the above prescribed functions, a rehabilitation engineer must have certain resources available. The extent of the support resources are dependent on the types and numbers of patients being served. Generally, a rehabilitation engineer should have three to four support technicians plus secretarial assistance, and a sufficient shop backup so that most of the devices can be fabricated or modified on site. Ideally, his or her activities should take place within a setting that will be conducive to natural communication with the other involved disciplines, in which the engineer's presence as an active member of the problem solving team will be constantly reconfirmed.

There was discussion which suggested a possible need for a third level individual -- a rehabilitation engineering technologist. This person would essentially be "the hands" of the engineer, working directly with patients under his direction. However, this concept was not supported on the basis that it is neither necessary nor desirable to have a technician acting as the interface between the engineer and the patient, as direct patient contact should remain the primary responsiblity of the engineer. Also, the additional technical skills usually required are already available in the form of machinists, electronic technicians, draftsmen, etc.

4.3 Relationships with Peer Professionals and Consumers

The practicing rehabilitation engineer at one time or another has to interface with approximately 15 different peer professionals -- and do so without offending those who basically resent his or her intrusion.

Within the sphere of the traditional rehabilitation process, in which the rehabilitation engineer functions as a member of the clinic team, it was recognized that the engineer would assume equal status to other professionals on the team -- with the physician retaining the ultimate responsibility for patient welfare. As the scope of rehabilitation engineering develops to encompass more areas of activities outside of the established rehabilitation process, the engineer may function in a consultant capacity, on a "fee-for-service" basis, and assume legal and ethical responsibility for the services provided.

As previously mentioned, a rehabilitation engineer usually functions as a member of a rehabilitation team made up of various specialists who, from an administrative and organizational point of view, have "territorial boundaries." However, boundary crossing should be encouraged since the more familiar an individual becomes with the total problem area the more effective will be his or her contributions toward solving the problem.

Since the fields of prosthetics/orthotics have long served as the major contributors of technology to the rehabilitation process, rehabilitation engineers may possibly be interpreted as an encroachment upon achievements made, and future developments of the prosthetic/orthotic profession. It was recognized that these fields have both common and unique areas of contribution to make to the lives of the handicapped. It was agreed unanimously that rehabilitation engineering should in no way supplant or infringe upon the growth of prosthetics and orthotics. Rehabilitation engineers, unless having had certification in prosthetics/orthotics, are not competent to provide prosthetic/orthotic devices to patients. However, they can have a technical area of expertise that, when combined with a basic understanding of the field of prosthetics/orthotics, can serve as a valuable technical resource, especially when application of more sophisticated technologies is indicated. In general, it was felt that in clinical activities that are clearly within the realm of prosthetic and orthotic experience, the rehabilitation or research engineer would assume the role of consultant. In other technical areas the rehabilitation engineer would assume the primary responsibility for technical delivery and call upon prosthetists and orthotists as consultants. Of course there will be "gray areas" and the responsibility for different aspects of a patient's technical program may shift between the disciplines, depending on the type of patient, the course of the patient's improvement, and the point in the time-continuum of the individual's rehabilitation process.

No significant discussion was held relative to the relationship between the rehabilitation engineer and other members of the rehabilitation team. However, as a member of the team, the rehabilitation engineer must be prepared to act in a liaison capacity with other engineering or related activities such as research, education, manufacturing, and evaluation.

In the realm of research and development it was recognized that the traditional territorial boundaries have much less significance, and the individual chosen to lead a program or project is related to the nature of the project, demonstrated leadership qualities, and a willingness to accept the responsibility for insuring the project is carried out within a predetermined time frame. That is, a therapist, physician, prosthetist/orthotist, or engineer could qualify to be a project leader as the situation warranted.

The rehabilitation engineer should at all times remain sensitive to the needs of the patients. He or she must attempt to gain insight into human behavior, particularly relative to the pressures and hardships experienced by the handicapped in their daily lives, and inject these realities into the technical goal-setting process. The engineer must at all times be cognizant of the intricate balance between cost and real benefits derived, and be prepared to withhold technology when the cost is prohibitive.

4.4 Formal Rehabilitation Engineering Education

There was general agreement that rehabilitation engineering education should occur at the post-baccalaureate level; that is, a person should have a bachelor's degree in engineering and, hopefully, some experience in working as an engineer before entering a rehabilitation engineering educational program. Certainly a program in rehabilitation engineering can be developed at the M.S. level, although some felt that a second B.S. in "health sciences" or a certificate program could provide the necessary background to become a rehabilitation engineer.

Regardless of the exact nature of the rehabilitation engineering educational program, there is general agreement that it should include a clinical internship program supplemented by course work in the following areas. (For further information and a sample M.S. program, see the position paper entitled "An Educational Program for Rehabilitation Engineering" by J. H. Forrester in Appendix 5.1.)

human anatomy and physiology
human factors engineering
biomechanics/kinesiology/perceptual psyche
sensory motors systems physiology
medical science (terminology/specialties review)
electronics and instrumentation
innovative design

engineering economy/law)
psychology and sociology)
social management) Optional as formal courses
communications skills)

An engineer who has majored in biomedical engineering as an undergraduate will likely have had some previous course work in some of the areas mentioned above. However, this person may be somewhat deficient in areas such as mechanics, electronics, materials, and mechanical/electrical design. It thus appears that educational programs should be somewhat flexible, at least until experience is gained in administering such programs.

In the educational program, the order of the course work and the professional requirements may be adjusted. For example, the masters level person may choose to do the internship period before all course work is completed and combine it with a clinically oriented masters thesis project. Alternately, clinical experience may be accomplished or begun while still an undergraduate (in the style of a physical therapist clerkship) if the student formulates his or her professional goals early.

As previously mentioned, there was general agreement that all rehabilitation engineering educational programs should contain an internship program from six to twelve months duration with the goal of receiving comprehensive exposure to disabilities. Internship should be performed under the guidance of a preceptor who is a functioning rehabilitation engineer and should include substantial contact with patients/consumers and all other ties of medical professionals, i.e., medical doctors, physical therapists, occupational therapists, prosthetists, orthotists, social workers, rehabilitation nurses, vocational counselors, etc. This should be a clinical "patient engineering" internship as distinct from involvement in a research project. Such experience will be necessary even for an individual who ultimately becomes a researcher in order to acquaint such an individual with the realities of clinical practice and the constraints they will impose on his or her research and development work. The program should also include an understanding of the appreciation of electro-diagnostic instrumentation, therapeutic modalities, etc. An individual study project with written report should be one requirement for completion of the internship. During the internship program the rehabilitation engineer intern should become competent in seeking out information, applying that information to the analysis of a rehabilitation problem, developing a plan toward solution of problems, and following through to a completion with a written report.

Two final points which are related to rehabilitation engineering education should be included in this section. First, it has been assumed throughout this section that the rehabilitation engineering education begins with a graduate engineer. This should not be interpreted as an absolute requirement, but rather that the individual has acquired the necessary background in fundamental engineering coursework.

A measure of this proficiency would be the successful passing of the Engineer-in-Training examination, which is the first step to becoming a registered professional engineer.

The second and final observation is that educational programs in rehabilitation engineering cannot be undertaken without additional costs to the educational institution. In addition, unless there is financial support for the students in such a program, the chances of attracting well qualified and interested students are greatly diminished. Since university budgets are already strained more than we would like to admit, and since the federal government is a large purchaser of health care and particularly rehabilitation services for disabled persons, it is suggested that federal support be made available for the initiation and continuation of several rehabilitation engineering educational programs. Support is needed not only for the student stipends and support of project work, but also for "released time" for faculty in order to devote a significant amount of time to properly plan and carry out an effective program.

It is suggested that federal support for rehabilitation engineering education be made available through institutional training grants as this form of support is most likely to provide stable, high-quality programs that are continuously under peer review.[3] These grants should serve to support staff, equipment, library facilities, and other appropriate expenditures needed to ensure the appropriate training experiences for the student.[3]

4.5 Continuing Education and Certification

Since the field of rehabilitation engineering is new and developing, it is strongly recommended that means be provided for continuing education of rehabilitation engineers. Courses could be either a clinical-patient experience or didactic, or both. The courses might be in the form of science or hardware fairs and/or workshops. Updating can also be accomplished by organized circulation of case studies via written materials or audio-visual cassettes.

Some of the areas related to rehabilitation engineering requiring periodic updating are communication, mobility, sensory and visual aids, orthotics and prosthetics, patient-machine interfacing, control systems fabrication and material technology, environmental control and instrumentation. The updating courses should be, at most, a week in length. These courses should be offered at Rehabilitation Centers and/or universities, industries, and other appealing locations. The continuing education programs of the American Academy of Orthopaedic Surgeons and the American Academy of Prosthetists and Orthotists should be utilized.

In order to insure adequate recognition and definition of the rehabilitation engineer, and to protect the consumer, it is recommended that certification of this profession be established. Such an individual should be licensed as an engineer and then obtain certification as a rehabilitation engineer after completion of academic courses and an appropriate length of time (to be established) in practice, making a "Board Eligible" rehabilitation engineer. Rather than establishing a distinct new society or independent board for establishing and determining qualifications, all means should be explored to establish such a board within the framework of an existing engineering society.

At this time it is difficult to designate the peer group to charge with establishing certification. One possibility is that the Alliance for Engineering in Medicine and Biology (AEMB) be requested to underwrite a meeting to convene an appropriately constituted committee to consider certification. International certification can be considered by the International EMB via AEMB. Some recommendations to AEMB regarding certification are:

(a) It should establish minimum standards or requirements for the rehabilitation engineer;

(b) It is to imply recognition and not licensing or registration;

(c) The applicant should have completed an ECPD accredited engineering B.S. program;

(d) Certification should also require additional educational experience relevant to rehabilitation including both patient-clinical experience and additional didactic courses;

(e) Certification should include an initial examination;

(f) AEMB should pay careful attention to the nature and requirements of "grandfather" certifications;

(g) When considering certification, AEMB should also include representatives from the American Academy of Orthotists and Prosthetists, and other professional groups who may not now be members of AEMB;

(h) Continued certification should include annual requirements for continuing education.

4.6 The Delivery of Engineering Technology

It was recognized that the development of a clinically-based system capable of delivering engineering technology is essential to the natural evolution of rehabilitation engineering. The full development of the rehabilitation engineering center network can serve as a nucleus for the delivery system; but in order to be truly effective it must reach far beyond the present activities carried out in the existing centers. Many factors were identified as essential components and concerns of such a system. The relationship between research and patient services, funding for patient services, availability of trained personnel, availability of suitably developed hardware, relationship to manufacturing and distribution, exchange of information, and the scope of prosthetics and orthotics in rehabilitation engineering centers -- are some of the factors requiring further clarification or development. A flow chart complete with a description of inter-relationships between the variables may be found in Appendix 5.1 in the paper entitled, "Rehabilitation Engineering -- A Delivery System," by Colin A. McLaurin.

It was noted that rehabilitation engineering services must be developed on the basis of a justifiable cost/benefit analysis. Rehabilitation engineering must look to the time when federal support is no longer available and programs must be sustained on the basis of reimbursement for services rendered. Therefore, appropriate fees-for-services should be developed and sources of individual or third party payment determined. This may mean that considerable time and effort will be required to educate the public, health officials, legislators, and the private sector as to the benefits to be derived from engineering technology. The recommended "Rehabilitation Engineering Week" could be most beneficial in this respect, and could prove to be an excellent launching point for the establishment of a comprehensive national network for delivery of rehabilitation engineering services.

4.7 Summary

This workshop on rehabilitation engineering education is only one of a series of workshops presently being conducted throughout the country. The resulting composite document will encompass many diverse topics and will serve to plot the course for the future development of the sub-specialty of rehabilitation engineering. In summary, this workshop has made recommendations for future action in four distinct but interrelated areas.

The urgent need for a formalized education program for rehabilitation engineers has been outlined, complete with an action plan for the initiation of a pilot education project involving three to five universities. This plan also includes recommendations for the certification of present and future rehabilitation engineers.

Recommendations have been made for the establishment of a nation wide system for delivery of rehabilitation engineering services. The proposed delivery network would augment the present research and development effort being conducted in the existing rehabilitation engineering program. In parallel with the development of the delivery system is the need for a systematic means of information retrieval and exchange. Identification of third party agencies prepared to purchase the specialized services rendered would be the remaining cornerstone necessary to ensure continuity and future growth of the rehabilitation engineering services.

The lack of research, development, and service programs that are committed to solving the technical problems of the pre-adult and geriatric populations was strongly stressed. Recommendations have been made to expand the present scope of the RSA/VA rehabilitation engineering activities to include the needs of these populations of handicapped individuals.

Last, but certainly not least, a priority recommendation has been made for the establishment of a multiagency coordinating board which would serve to coordinate all federally-funded activities related to the present and future developments in rehabilitation engineering. The formation of this semi-autonomous board is seen as an urgent and necessary step to assure a coordinated approach to the future development of the field. In order to represent the broad interests of rehabilitation engineering, the board and its subcommittees should be comprised of members from academic institutions, clinical programs, government agencies, and industry.

It remains to say that rehabilitation engineering services for those in need is an inescapable responsibility of society. The evolution of rehabilitation engineering as outlined in this report (and reports from other workshops) will result in a clinically-oriented network of technical resources that will have a tremendous positive impact on the lives of more than 15 million handicapped citizens in this country. The challenge that is now before us is to build on the present research and development effort and establish the resources that can transfer the developed technology directly to those we are pledged to serve through innovative programs of education, service delivery and information exchange.

APPENDICES

Appendix 5.1

POSITION PAPERS

Invited position talks were presented by the following individuals and are included herein:

- Colin A. McLaurin - "Rehabilitation Engineering - A Delivery System"
- James B. Reswick - "Some Thoughts Relative to the Rehabilitation Engineer"
- Anthony Staros and Saleem Sheredos - "The Rehabilitation Engineer"
- J. H. Forrester - "An Educational Program for Rehabilitation Engineering"

REHABILITATION ENGINEERING - A DELIVERY SYSTEM

Colin A. McLaurin
Ontario Crippled Children's Center

In any system there are two things to consider - the "players" and the lines of communication. In this system, the lines of communication for three major commodities will be considered - devices, information, and dollars. Each is presented separately in chart form on the following pages and only the main lines are shown to keep it simple.

The "players" are defined as follows. The Patient is not an object, but a real person with a chronic physical disability. He or she may be in a rehabilitation center but will have permanent residence in a Home which may be an institution and may have a paying job at a place of Work.

Lining up to help the patient is the rehabilitation team consisting of physicians and surgeons, therapists, teachers, nurses, prosthetists, orthotists, rehabilitation engineers, vocational counselors, etc. The rehabilitation engineer (RE) is part of the team, contributing information, joining in decisions, and delivering a useful product. In this chart he is included with his staff of technicians and students.

The RE may be part of a rehabilitation center or may be in private practice. At the present time, there are very few, but in the future there may be hundreds or maybe thousands, comparable to the number of orthotists.

Several Rehabilitation Engineering Centers (REC) have already been established. Each is associated with a rehabilitation center, a medical school, and an engineering school, and each will have expertise in one or more core areas of research, and some will have education and training programs for rehabilitation engineers.

In addition to REC related research has and will be conducted in other research projects involving both medicine and engineering.

Several Manufacturing and/or Distribution centers will produce the devices and components the rehabilitation engineer requires in fitting patients, such as environmental controls, mobility aids, communication aids, etc. These manufacturers draw on industry for parts and processes that are used in producing their products.

The picture is completed by considering the government agencies, insurance companies, and charitable organizations who ensure a cash flow to initiate and maintain the system.

The Device Flow is fairly straight forward. Industry produces raw materials and parts, the manufacturer converts these into products and kits which are fitted, modified, and serviced by the RE staff for the patient for use in his home or place of work. The flow is complicated when introducing new devices. Prototypes may be developed in REC's who approach manufacturers for experimental models that are distributed to other REC's and RE's for evaluation. Revision may be expected so there is some back and forth flow between manufacturers and RE's before the product becomes commercially available.

The cash flow is more complex. Some is straight forward to the RE for services, who purchases components from the manufacturer who in turn buys from industry. How the dollars get to the RE is not so simple, but the sources are patients, insurance companies, and government. The cash flow may be directly to the RE or through the patient or through a comprehensive rehabilitation plan. The important thing is not just that the cash flows, but it flow quickly - no waiting for approval or snags regarding who is to pay. This suggests that some means for coordination may be required - an office, a pool of money, or perhaps just educating the various authorities.

Cash flow is also necessary for research and education which will be largely from government to REC's and other research projects.

One of the desired results will be more handicapped persons on the job earning money, paying taxes; but they also serve who only stand and wait - on themselves - and reduce the burden on government, institutions, and families.

Information is the cheapest and most valuable commodity of all. Without information, no one will spend the dollars to buy RE service and devices and no one can utilize the results of research. The RE learns of the patient's home and place of work; he also informs the patient of what is possible so the patient can participate. This and other information is shared with all other members of the rehabilitation team and contributes to the prescription or selection of devices and services.

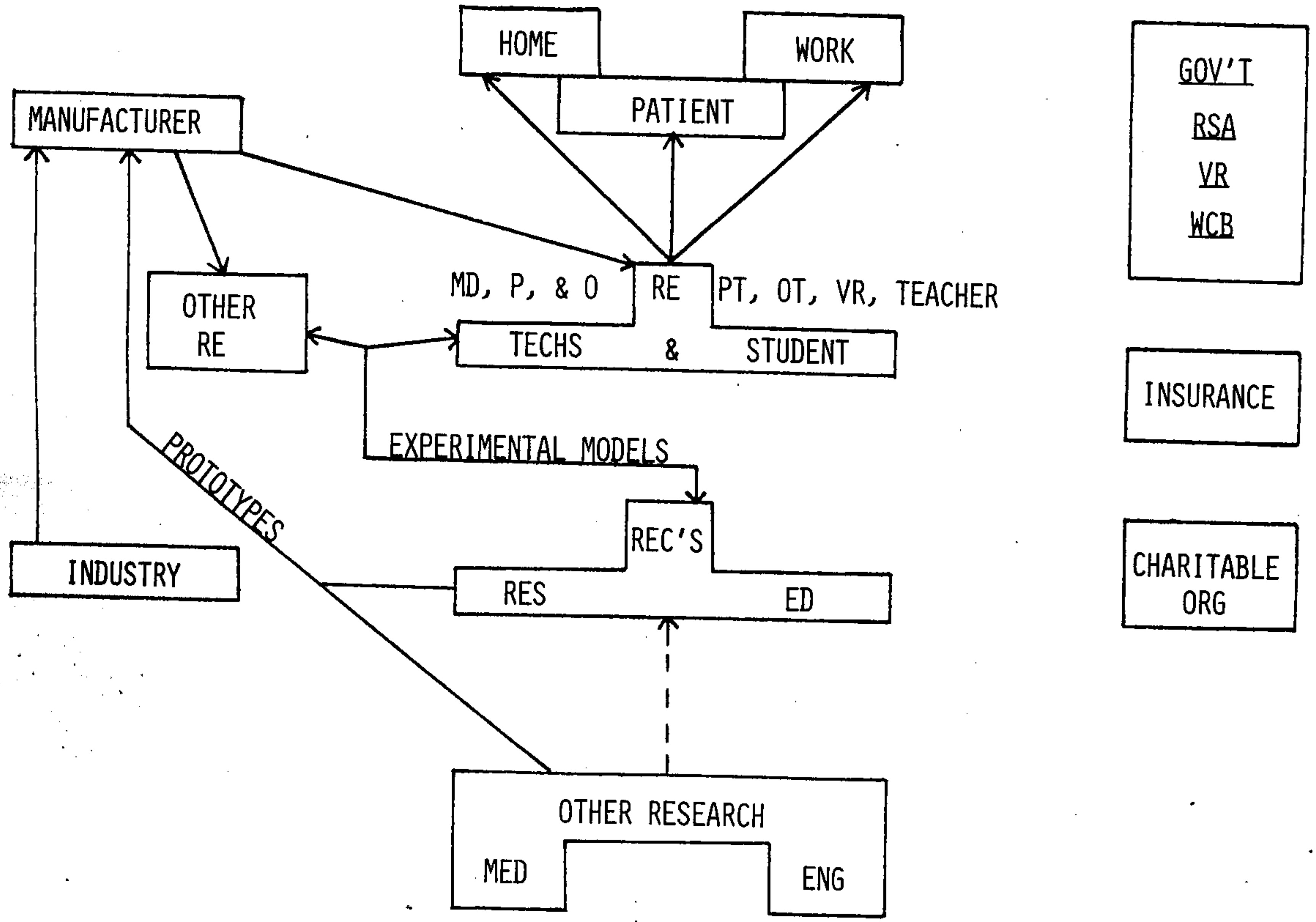
The RE to be informed also draws information from other RE's, from manufacturers, and from REC's. The REC's in turn are aware of related research in other centers and act as the main communication with government agencies and to a lesser extent with insurance and charitable organizations.

Information may be general, like demographic data, or very specific, like what type of communication aids are best for a teen age non-verbal athetoid. Also, the total amount of information is rapidly growing to such a level that an information center should be considered and established by the federal government in cooperation with one or more REC's. The function of the information center would be to collect, store, and disseminate all pertinent information in this field together with a duplicating service. To be truly effective, such an information service should be in contact with an evaluation program so that prescription criteria and comparative data could be included in the information package.

The System presented here is partly true, partly hypothetical; most of the players exist, certainly the patients do, but there are very few RE's. They must be trained at REC's or other educational centers, gain experience in patient service, and when fully competent, assist in training others. This cadre of professionals must also be matched in growth by the availability of manufactured components and both must be monitored to affirm their effectiveness. Again, there is a suggestion for national "management," at least to get the ball rolling. "Management" is perhaps too strong a word, but there is a need for "seeding," for coordination, and a unanimous voice.

The seed has been well established; it is time to plant, to cultivate, and in time to reap the benefits of a technology that helps the physically handicapped.

DEVICE FLOW


HOME
WORK
PATIENT
MANUFACTURER
OTHER RE
MD, P, & O
RE
PT, OT, VR, TEACHER
TECHS & STUDENT
EXPERIMENTAL MODELS
PROTOTYPES
REC'S
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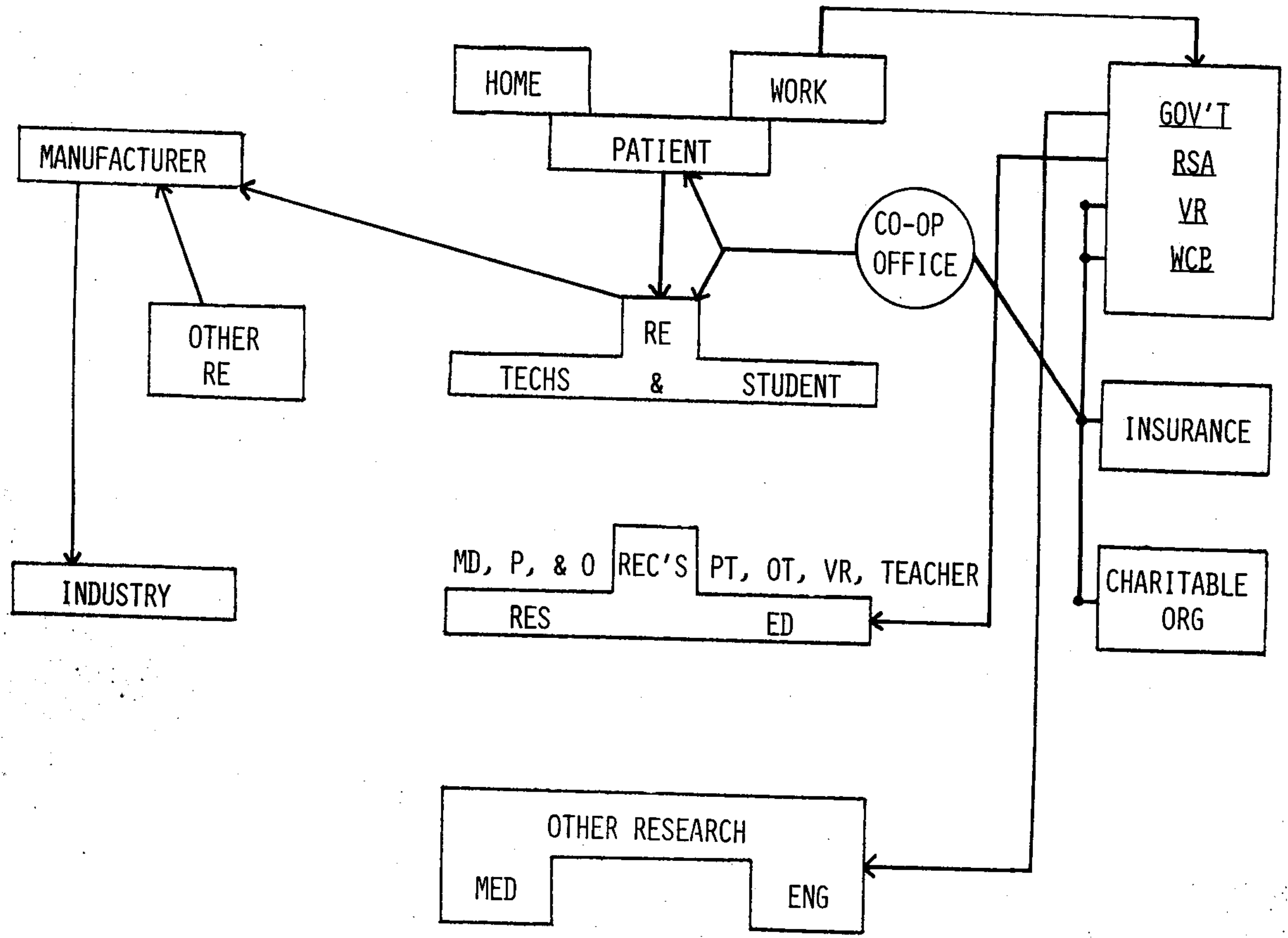
INSURANCE
CHARITABLE ORG

DOLLAR FLOW


HOME
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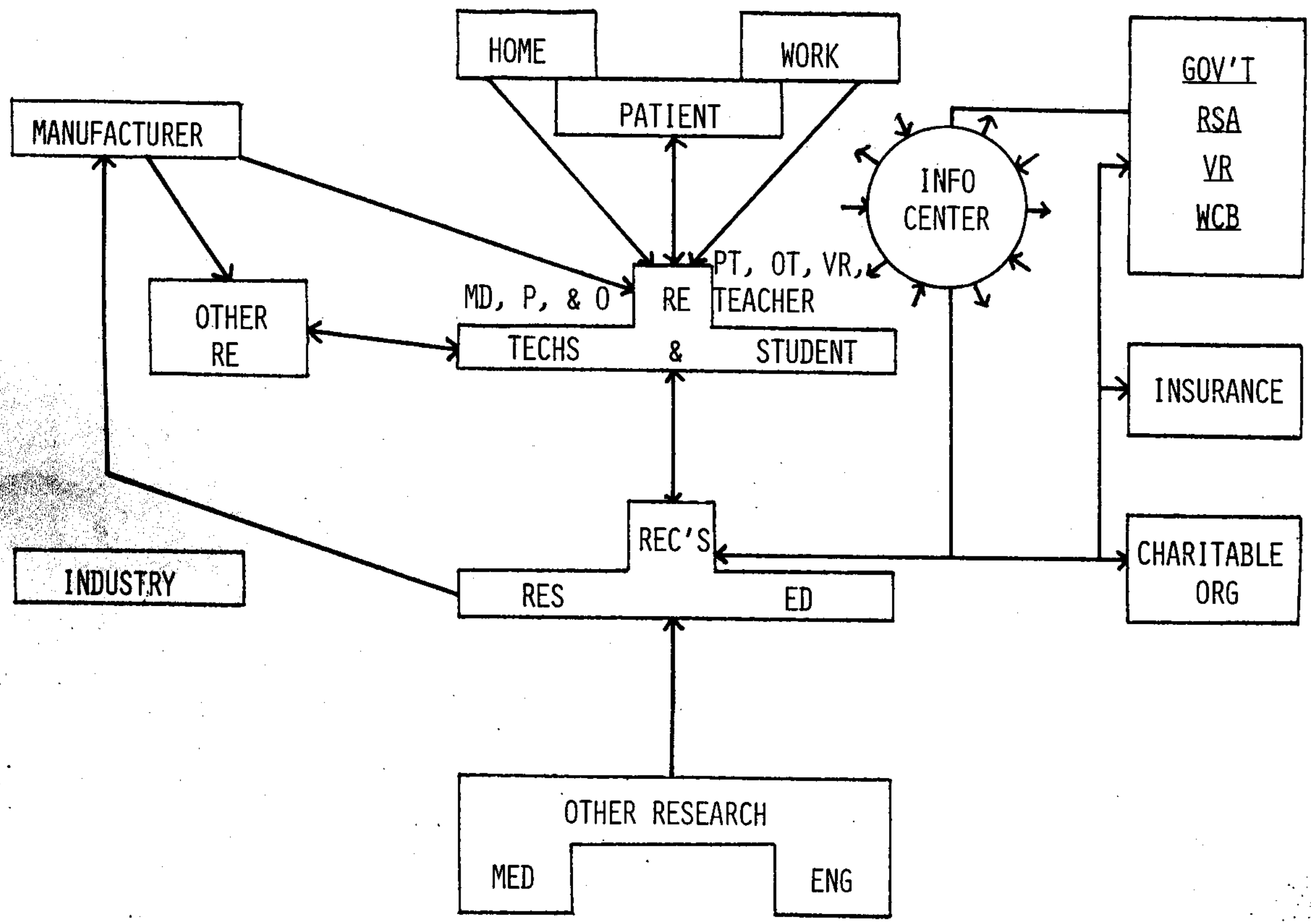
MED
ENG

INFORMATION FLOW



SOME THOUGHTS RELATIVE TO THE REHABILITATION ENGINEER

James B. Reswick
Rancho Los Amigos Hospital

A proposed hierarchy or classification of engineering in medicine is shown in Figure 1 below:

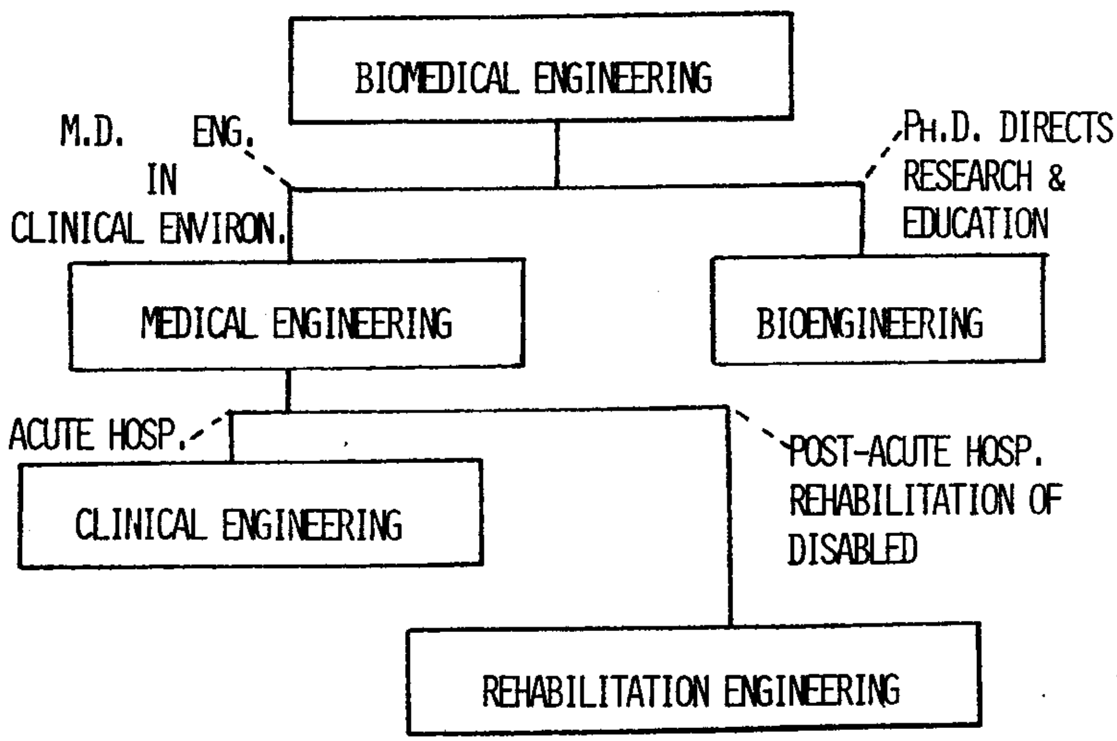


Figure 1 - Engineering in Medicine Classification

The above classification and the remarks which follow will reflect my biases and I readily recognize that many colleagues in the field might come up with a different formulation. I present it in the spirit of providing a point of departure for discussion.

The primary class for engineers working in medical and biological fields is Biomedical Engineering. The word "Biomedical" leads to a natural bifurcation into Bioengineering and Medical Engineering.

The Bioengineer

Again, apologies for over-emphasis. The Bioengineer is seen as typically the product of one of the many bioengineering educational programs in universities throughout the country originally supported through the Bioengineering Training programs of the General Medical Sciences Institute of NIH. These training programs, for the most part, originated within Electrical Engineering departments in engineering schools, with some Chemical, Mechanical, and other departmental influences. In only rare cases were medical schools involved deeply in the programs. While attempts were made to provide courses in anatomy, physiology, experimental methods in medicine and the like, the primary emphasis was on courses stemming from systems analysis techniques in electrical engineering, e.g., computer modeling, system parameter estimation, pattern recognition, systems analysis, etc. Where research or teaching experiments were made in vivo, they were almost always on animals in laboratories set up within the engineering schools.

The typical product of these programs is a Ph.D. who is trained to teach and lead research in biological fields with major engineering emphasis. Often his data come from previously published literature, from animal preparations and computer simulations. Less often are bioengineers involved in human subject research. The main point to be made here is that only rarely is the Bioengineer concerned with the care of patients in the clinical environment from other than the point of view of gaining data or testing models in his research. I hasten to add that there are many exceptional Bioengineers highly dedicated to care of patients and who have made real contributions to patient care. This is especially true of those M.D.'s who enter Bioengineering programs and those Bioengineers who later go on for the M.D. But the prime characteristic of the Bioengineer is his ability to contain his professional activities within his own efforts. Clearly he will relate to physicians and allied health people in many ways but he generally takes the major responsibility for whatever he does and often his work is done in laboratories not based in a clinical environment.

The Medical Engineer

The prime point of contrast between Medical Engineer and the Bioengineer is the need for the Medical Engineer to collaborate professionally and as a colleague with the physician in the clinical environment. His goal is to apply engineering in a direct way which improves patient care in the long run and often is directed to the specific problem of a particular patient. While the physician must maintain overall responsibility for patient care, the Medical Engineer often shares a major portion of this responsibility for a period of time. The Medical Engineer first of all must be a highly competent engineer in his field of specialization -- absolutely necessary to gain the respect and trust of his physician colleague -- and he should have some training in health science areas. But above all, he must be a person who can collaborate effectively at least with the physician and at best, as a member of an overall patient care team. This means that he needs, in addition to technical skills, those kinds of skills which are often related to management and interpersonal effectiveness. Often these are natural characteristics of one who is therefore drawn naturally to Medical Engineering, but these skills may be enhanced through formal training in the behavioral and management sciences.

The Clinical Engineer

At a third level of classification I have again bifurcated medical engineering into two perhaps more arbitrary functions. The distinction is drawn between acute medicine and post-acute or rehabilitation medicine. The title "Clinical Engineer" is gaining a good deal of use in the United States but I have confined this title to the Medical Engineer who focuses his professional activities toward the acute hospital. Among the activities of an acute hospital which require a high level of engineering input might be included the following;

1. Intensive Care Units
2. Coronary Units
3. Hospital computer information systems
4. Automation in Analytical Laboratory
5. Automation in Pharmacy
6. EEG, EKG, EMG laboratory diagnostic procedures
7. Radiological procedures, including scanning and image intensification techniques
8. Nuclear Medicine
9. Dialysis operations
10. Anesthesiology

All of the above activities now rely on advanced scientific methods and instrumentation. There is great room for innovation in design of new equipment and methods as well as a continuing need for trained persons to maintain equipment, instruct in its use, insure reliability in calibration and above all, to insure safety from electrical hazards. But the Clinical Engineer suffers the danger of being seen as a high level maintenance man. For such a person to spend his total time on call to perform routine repairs and inspections may be devastating to his professional development.

There is increasing awareness on the part of hospital administration and those responsible for budgeting and planning to include the Clinical Engineer as an important member of a hospital staff. While the Clinical Engineer is certainly involved with patients in a clinical environment, his prime focus is still on the technology which is used for diagnosis and therapy rather than the needs of a particular patient at a particular time. This is perhaps the major difference in emphasis between the Clinical Engineer concerned with acute medical problems and the Rehabilitation Engineer concerned with making the disabled person as effective a human being as possible.

The Rehabilitation Engineer

Thus we come finally to the Rehabilitation Engineer and rehabilitation engineering. Many of the activities listed above in the acute hospital are also obviously active in the rehabilitation or post-acute hospital, and the involvement of Rehabilitation Engineers in these activities may be assumed. But beyond such activities the Rehabilitation Engineer is more than any other Biomedical Engineer involved with patients on a continuing and active basis. He is concerned both with the development of new devices and the advancement of science as it relates to the rehabilitation of disabled persons, and with the needs of particular patients during their stay in the hospital. The Rehabilitation Engineer is most characteristic as a member of the patient care team which will include the physician, the allied health professionals, other technical professionals, as well as orthotists and prosthetists, psychologists, vocational counselors, social workers, and other persons concerned with the transition of the patient from the hospital to an effective personal lifestyle in the community. In many ways the Rehabilitation Engineer combines the characteristics of all of the Biomedical Engineers defined above but extends his interest and responsibility to include the whole process of rehabilitation from the time a patient is first medically stabilized to his successful return to the community. In this sense the Rehabilitation Engineer is more of a generalist than a specialist, and even more than the other engineers, needs propensities and skills in collaboration, team participation and ability to live with the ever present ambiguities in the complex processes where each patient's rehabilitation needs are different and the methods to meet these needs cannot be reduced to routine procedures.

THE REHABILITATION ENGINEER

A Proposed Job Description

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The (Clinical) Rehabilitation Engineer normally functions in and from a hospital setting, under the direct supervision of the Medical Director or the Chief of Staff to whom he is responsible (a) for a professional contribution which results in rehabilitation of patients with neuromuscular, skeletal and sensory dysfunction, and (b) for the maintenance of high quality extended care either in the clinic, the special extended care facility, or in the home.

The Rehabilitation Engineer is an expert on equipment, devices, aids, and environmental modifications to produce rehabilitation and high quality extended care. (See Attachment A.) With his detailed knowledge of such equipment and the processes associated with them, he has at least the following duties:

1. Participates in surgical and rehabilitation clinical team operations such as daily rounds, seminars, equipment committees, conferences, etc. on the same level as the prosthetist, orthotist, nurse, or rehabilitation therapist to assist in the evaluation of a patient's physical, psychological, and social needs with a view toward recommending elements of a complete prescription including implants, prosthetics and orthotics, mobility systems (including licensed vehicles), environmental controls, wheelchairs, communication devices, home modifications, job modules, etc. (Figure 1)

2. Follows up on clinical prescriptions by arranging for or performing the procurement, fitting or installation, check-outs, tests and quality assurances of devices and modifications where necessary and assists in or conducts necessary training of therapists and other professionals and patients in the use of the devices. (Figures 2A, 2B, 2C, and 2D)

3. Arranges for the maintenance and the replacement of defective devices in the clinic. (Figure 3)

4. Interviews patients and visits their homes and job environments as part of a medical or job development team or independently to

Figure 1

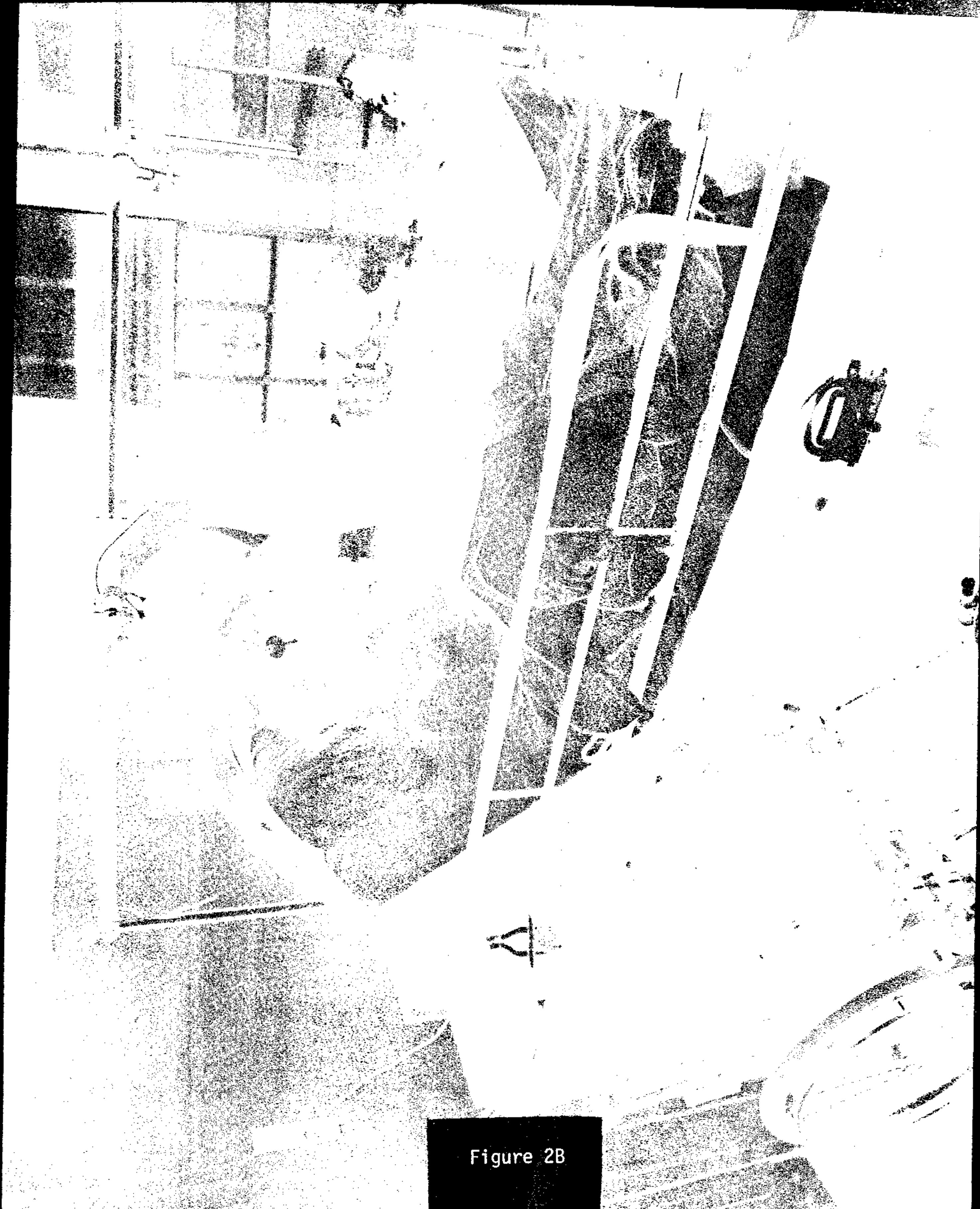

Figure 2B

Figure 2C

Figure 2D

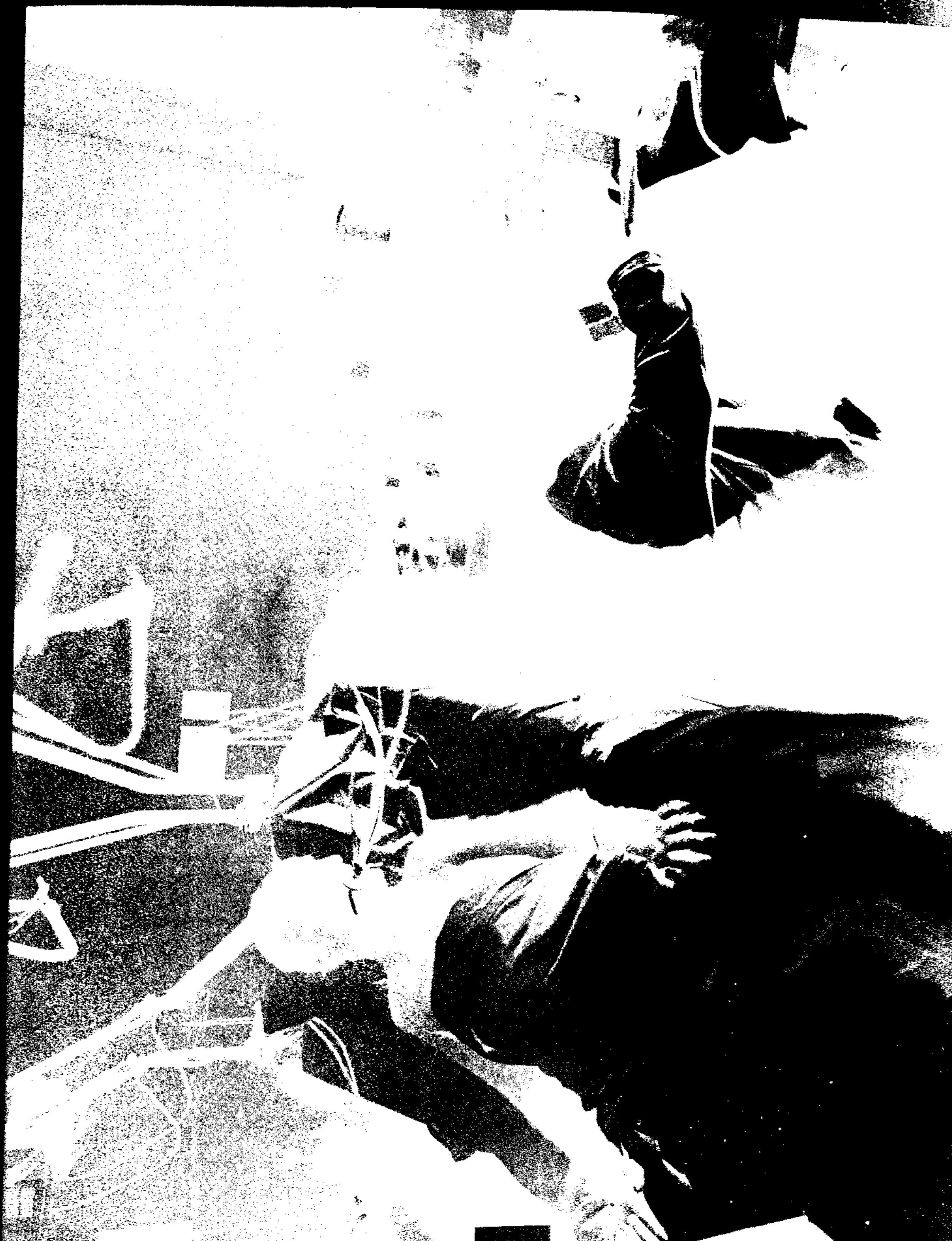

Figure 3

analyze total needs, and to recommend (and design and build, if necessary), and install prescribed devices. Arranges for or personally provides maintenance, repair, and replacement. (Figures 4A and 4B)

5. Conducts carefully controlled evaluation studies using laboratory tests and clinical or home trials to determine the functional attributes, safety, and cost benefits of new devices and processes. (Figures 5A and 5B)

6. Maintains an engineering laboratory and a rehabilitation engineering library including manuals on installation, repair and maintenance of equipment for use by patients. Uses these facilities to support his clinical and home care work with patients. (Laboratory facilities should be sufficient for simple tests including such equipment as voltage meters, hardness testers, measurement gages and the like.) (Figure 6)

7. As needed, develops, designs and builds, or supervises the construction or modification, to provide special adaptive architecture, equipment, furnishings or controls. (Figure 7)

8. Teaches rehabilitation engineering subjects by lecure and laboratory supervision or by preceptorship, usually through affiliation with an academic institution. (Figure 8)

9. Participates in miscellaneous health care facility management activities such as the special administrative, safety, and personnel committees. Is active on the clinic's research committee.

Special Qualities

In order to fulfill the duties described above the rehabilitation engineer should have at least a Bachelors Degree in Mechanical or Electronic Engineering. He must also demonstrate an interest in people particularly the patients for whom he must provide care. In this very significant role, he must develop a rapport which is empathic and sincere. He must also involve himself in the hospital management setting staying close to hospital administrative efforts, especially becoming involved, both informally and formally, with key administrative support activities such as procurement and finance.

He will need to maintain his knowledge of specialized equipment by repeated contacts with manufacturers, by visits to other installations providing this kind of service, and by participation in national societies grouping his colleagues. He should also maintain close contact with the societies and institutions of his medical and paramedical colleagues, particularly those in orthopedic surgery, rehabilitation therapy, and prosthetics and orthotics.

(Two case histories of a rehabilitation engineer's role in serving patients are given in Attachments B and C.)

Figure 4A

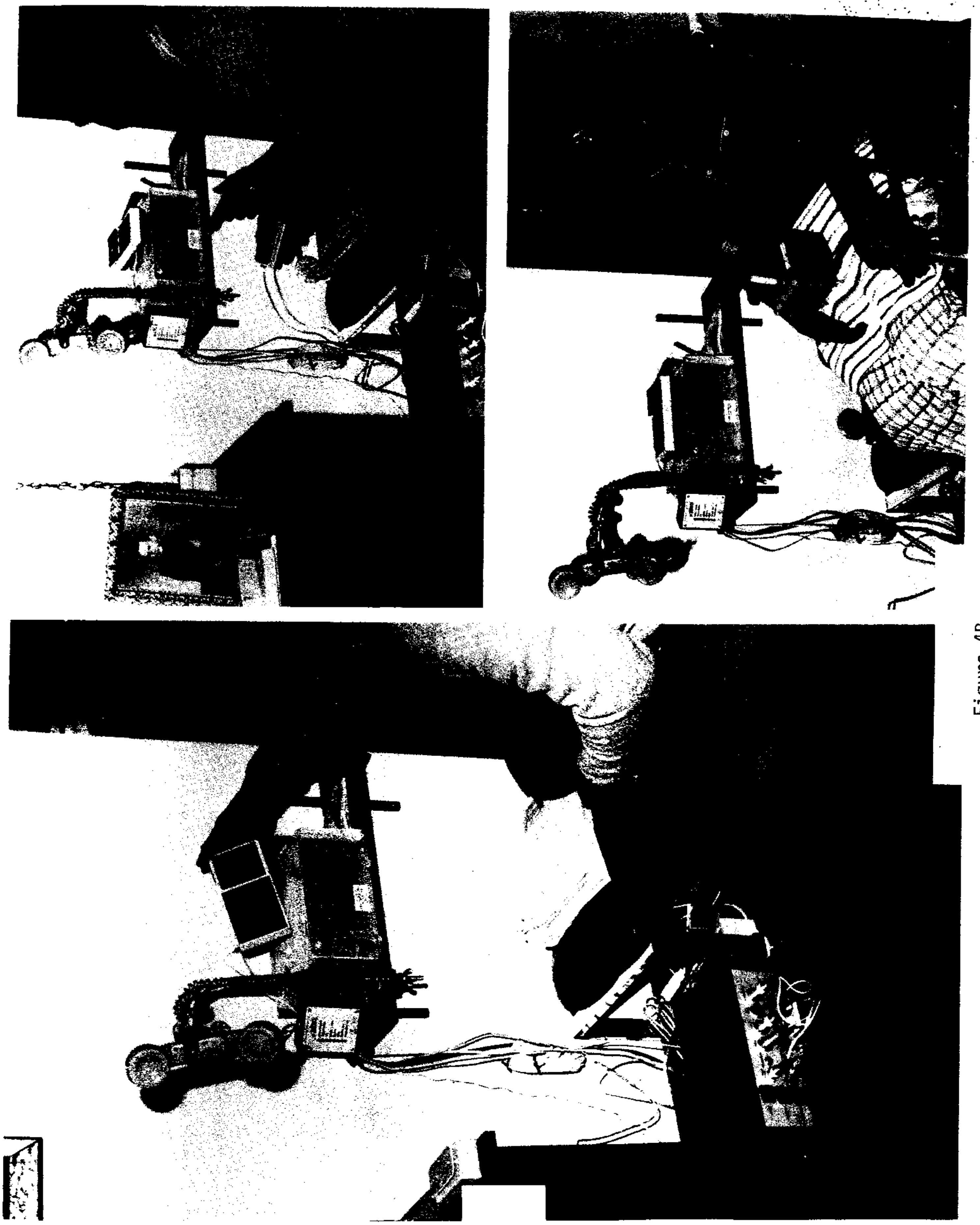

Figure 4B

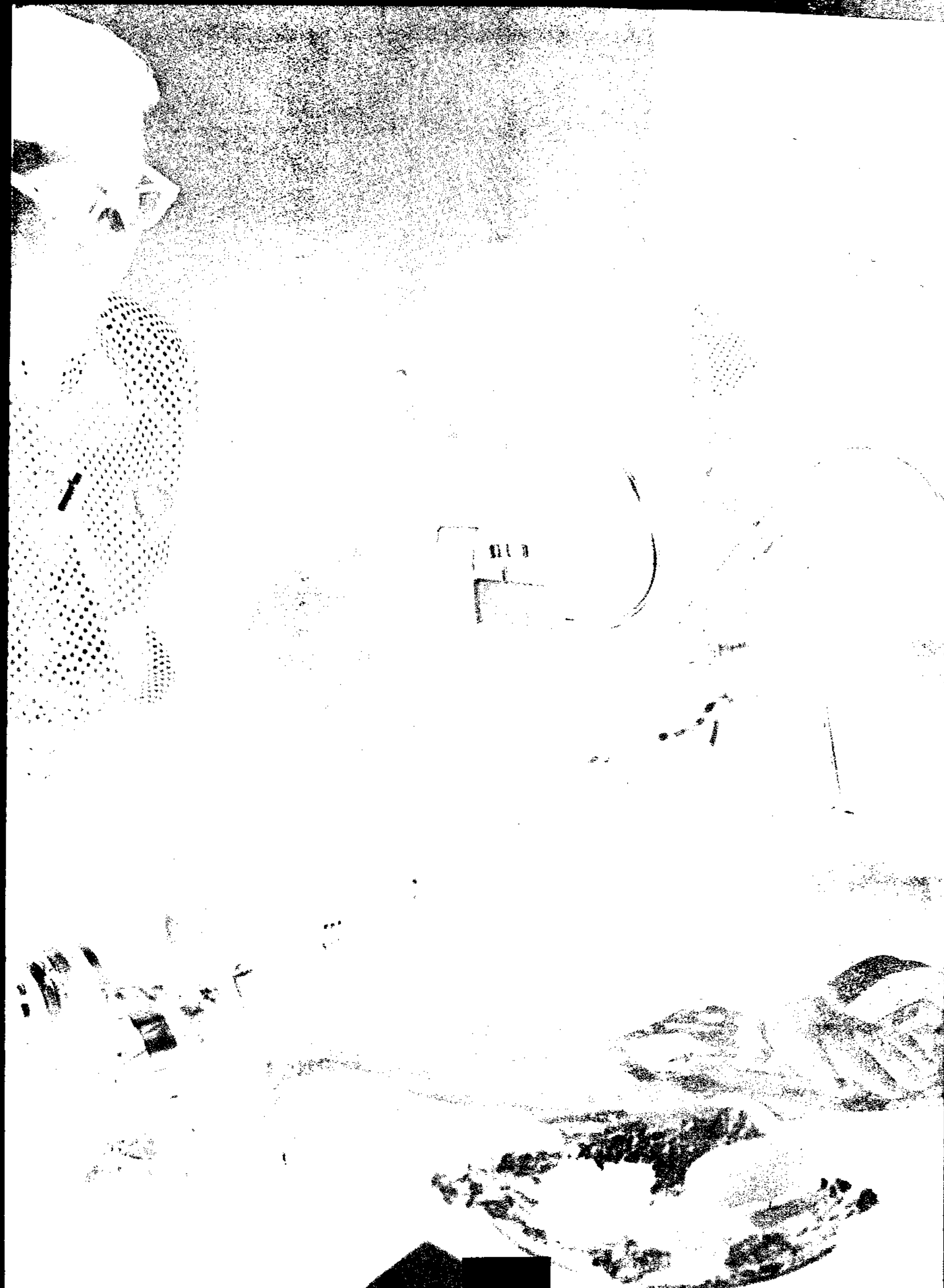

Figure 5A

Figure 2A

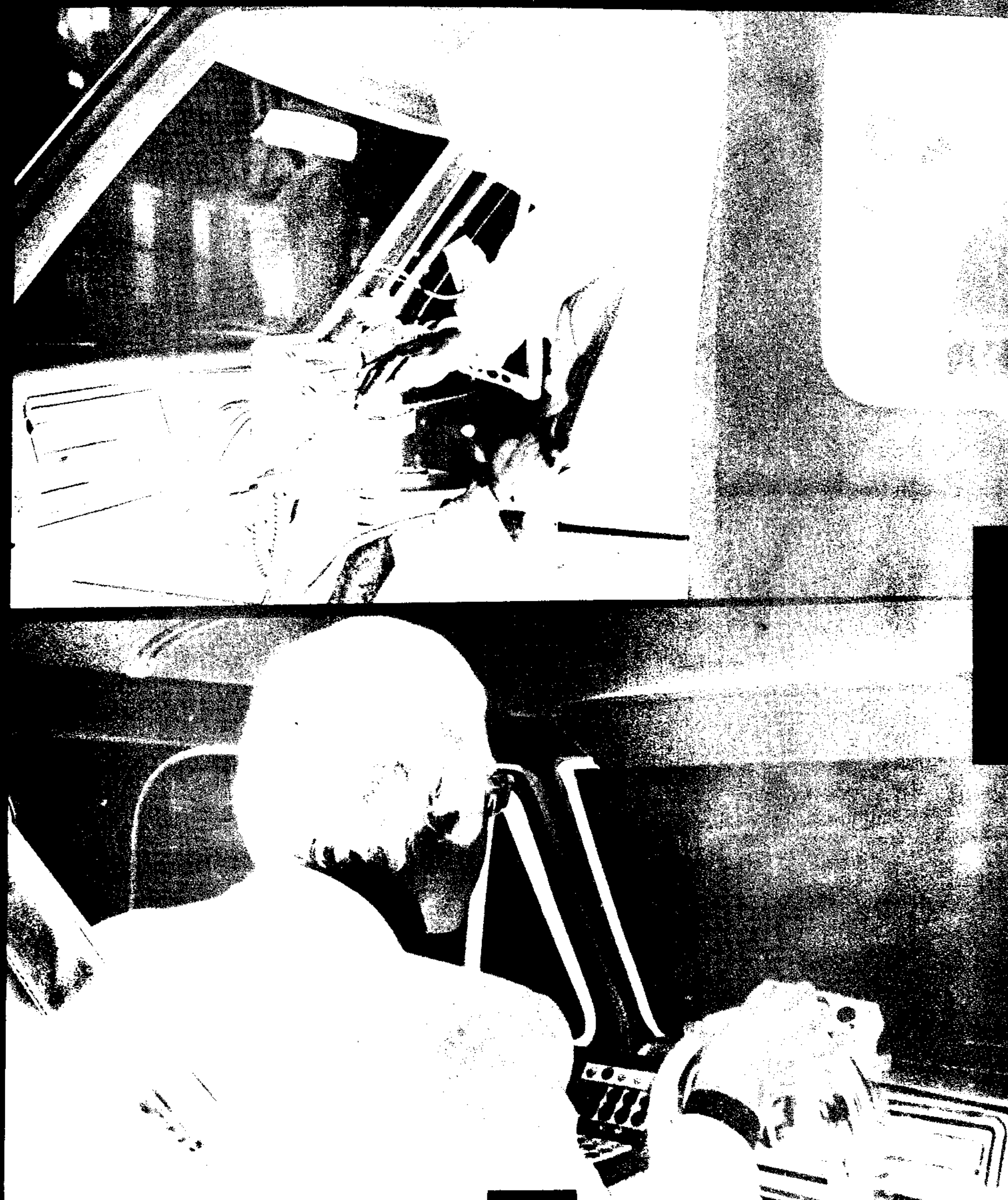

Figure 5B

Figure 6

Figure 7

Figure 8

ATTACHMENT A

REHABILITATION ENGINEERING

EQUIPMENT, DEVICES, AIDS

Below are some examples of the classes of equipment, devices, and aids presently available for the Rehabilitation Engineer's use in the clinic and in the patient's home and transport system.

ARCHITECTURAL AND HOME AIDS: Ramps and lifts for the home, special furniture and tools, etc.

MOBILITY AIDS: Hand, chin, vocal, and pneumatic switch controlled indoor and/or outdoor wheelchairs or powered standing ambulators. Blind mobility aids such as the Pathsounder, Laser Cane, and the like.

AUTOMOBILE SYSTEMS: Adaptive equipment, aids and modifications to automobile and vans, e.g., mechanical or servo hand controls, wheelchair lifts, powered doors, ramps, CB radio, etc.

BODY SUPPORT SYSTEMS: Special beds, mattresses, wheelchair cushions such as air, water, foam and "mud" support media for the prevention and care of decubitus ulcers. Devices to support the patient while sitting in a wheelchair.

LIFTS/TRANSFER AIDS: Hydraulic, mechanical or electrical lifts for transferring patients into and out of beds, wheelchairs, baths, or vehicles.

ENVIRONMENTAL CONTROLS: Systems to allow severely disabled patients through a single input control, e.g., hand, sip-n-puff, eye-movement, vocal or chin control, to operate a nurse call, alarms, a telephone, bed controls, television/radio, tape recorders, and security systems usually consisting of a closed circuit television, intercom, electric door release and telephone.

PROSTHETICS/ORTHOTICS/ORTHOPEDICS: Hydraulic and myoelectric prostheses and electro-mechanical or pneumatically controlled externally powered orthotic systems, pneumatic orthosis for the lower limbs and electrical stimulation of paralyzed muscles to prevent contractures and/or obtain function. Implants for neuromuscular and skeletal dysfunction.

COMMUNICATION AIDS: Telephones, typewriters, emergency dialers, message communicators, reading machines, as well as voice synthesizers for those with no or impaired speech or for the blind and deaf.

ATTACHMENT A

<u>ACTIVITIES OF DAILY LIVING</u>: Feeding aids and special clothing and bathing devices.

<u>RECREATION</u>: Modified pin ball and other electronic games which can be operated pneumatically and/or by hand to allow the handicapped indidual to compete with other handicapped or non-handicapped persons.

CASE HISTORY OF F.A.

F.A., a middle aged male, was first diagnosed as having Multiple Sclerosis in 1968. His condition degenerated with time; he came to the Castle Point VA Hospital in June 1973. His admission then was for bilateral gluteal ulcerations. His overall condition was described as spastic quadriplegia. The medical staff then looked to the rehabilitation engineers for processes or devices to provide (or increase F.A.'s) independence, mobility and sitting tolerance.

A hospital model environmental control system was prescribed, procured, installed, F.A. and the nursing staff trained, and the system maintained by the rehabilitation engineers. This system allowed him to operate the nurse call, three bed functions (head, foot, height position), radio, television, fan, lamp through puffing or sipping on a single pneumatic tube. The gooseneck support containing the tube is attached to the head section of the bed to allow continuous positive control over the system.

For mobility a two-tube pneumatically-controlled electric wheelchair was prescribed and procured. Puffing or sipping on the two tubes in various combinations allows him to drive the wheelchair at a predetermined speed with speed adjustable by an attendant which facilitated F.A.'s training on the use of the controls. In order to help F.A. maintain a fairly good posture and sit in the wheelchair for several hours without pressure sores developing on the buttocks, the rehabilitation engineers offered for prescription and then procured a custom-molded (commercially available) wheelchair body support.

ATTACHMENT C

CASE HISTORY OF B.F.

B.F., a middle aged housewife, was involved in an automobile accident in November 1971. The accident resulted in a fracture dislocation of the fifth cervical vertebra, with complete posterior displacement in relation to C-4 and C-6. She was rendered an immediate quadriplegic at the C-5 level. Further evaluation showed sensory loss at the level of C-7.

B.F., a female veteran, received her medical care and rehabilitation at the VA Hospital, Castle Point, New York. During that program and after her discharge to home, rehabilitation engineers from the VA Prosthetics Center supported the rehabilitation team by evaluating her home needs and by procuring, fitting or installing, and maintaining and updating special devices to increase B.F.'s mobility, her control over appliances and independence in feeding.

While in the hospital an environmental control system was prescribed as well as a pneumatic-controlled wheelchair and a myoelectric externally powered prehension orthosis with a ball-bearing supportive type feeder. The environmental control system she used in the hospital allowed her to operate the three functions of her electric bed (head, foot, and height position), the nurse call, an audio-visual alarm mounted in the hallway, a lamp, a radio, and a television (ON/OFF and channel selection). Her control over this system was by puffing or sipping through a single tube.

She uses a similar system to operate her wheelchair. There she uses a three-tube control, one for on-off, the same one for speed control, and the other two for wheelchair direction control.

The myoelectrically controlled prehension orthosis with a ball-bearing supportive type feeder was prescribed by the team as the best combination to add to her independence in daily activities such as feeding and reading. The rehabilitation engineers helped determine which of the available externally powered systems available would best suit B.F.'s needs. These were procured and checked out by the engineer and by the orthotist on the team, who then provided the fitting of the system; both worked with the occupational therapist in training B.F. in using it.

During the discharge planning for B.F., the rehabilitation engineer worked with the nurses, social workers, and therapists in a team effort to evaluate needs at home, with the patient's family needs included. A home-type environmental control system with basic appliances was initially prescribed. Ramps were recommended for accessibility in/out of the house. It was agreed that she would continue to use her electric wheelchair and externally powered orthoses at home.

The Home Environmental Control System initially consisted of a telephone, intercom, bed-controls, lamp, audio-visual alarm, and television. She operated these appliances in the same manner as the hospital system, that is by puffing to obtain a particular channel and sipping to turn the channel (appliance) ON/OFF. The following appliances were subsequently added: curtain operation, radio (ON/OFF, channel selector, volume), video camera outside the house with the monitor at her bedside and another for either outdoors or elsewhere in the house, an electric door latch release and a telemetry actuator system to allow her to operate these appliances from anywhere in her home while in the wheelchair.

The rehabilitation engineers were responsible for processing, testing, installing, training B.F. and her family, thence maintaining and updating this whole system.

AN EDUCATIONAL PROGRAM FOR REHABILITATION ENGINEERING

J. H. Forrester
The University of Tennessee

Introduction

The quality of life for the physically disabled will be improved if their disabilities can be minimized. Quite often an important factor in this process is that of providing an assistive device to the disabled person to aid in mobility, communication, or other activities of daily living. The rehabilitation engineer, as part of a rehabilitation team, should aid in assessing the disability and in determining assistive equipment specifications, evaluate the feasibility of using available equipment or modifying it for the specific application, determine when a new product or device should be developed, direct this development when it can be accomplished "in house," and, finally, be able to complement the process of providing the disabled person with an assistive device when it is technically and economically feasible to do so.

In order to effectively carry out his/her function, the rehabilitation engineer must understand the present disability (or "where the patient is at") and how the degree of disability can be improved (or "where the patient should be taken"). This requires effective communication with other members of the rehabilitation team which would usually include the physician responsible for the patient as well as any physician or physicians responsible for special needs. Other members of the team might include nurses, occupational therapists, physical therapists, speech therapists, audiologists, orthotists, prosthetists, and social, psychological, and vocational counselors. For optimum effectiveness the rehabilitation team must work together, which requires that each member has an appreciation for and some knowledge of the other members' roles and functions. Effective collaboration requires professional maturity and mutual respect of all team members.

Criteria for an Educational Program in Rehabilitation Engineering

Once the role and scope of rehabilitation engineering have been defined, it becomes simpler (but still not easy) to set up educational programs to prepare students for employment as rehabilitation engineers. Certainly the nature of such programs depends upon interests and abilities of the faculty and students, as well as the environment in which the program operates (types of disabilities treated, facilities, etc.). Hopefully, however, we can agree upon some minimum background and experience required in a rehabilitation engineering educational program. As a starting point for discussion I would like to present some ideas we've had concerning rehabilitation engineering education here at the University of Tennessee. Certainly one benefit of such an understanding is that the term "rehabilitation engineer" might come to have a more uniform connotation among those persons involved in the total rehabilitation process.

Our basic premise is that a person trained as a rehabilitation engineer should be competent in his/her field of engineering specialization in order to gain the respect and confidence of other members of the rehabilitation team, as well as that of the patient and his/her family. If the criteria listed in the following paragraphs are accepted as reasonable expectations of a rehabilition engineer, then we feel that any educational program in rehabilitation engineering must be either a Master's or Doctoral level program which includes a significant internship period as part of the program. Furthermore, candidates for the program should have a bachelor's degree in engineering or be willing to take remedial coursework in mathematics and the basic engineering sciences required in most undergraduate engineering curricula. Our postulated general requirements of a rehabilitation engineer are listed below along with a brief discussion of how these requirements can be met.

(1) Because of the rather diverse activities in which a practicing rehabilitation engineer may become involved, he/she should have a broad background in the fundamental engineering sciences (statics, dynamics, materials, mechanics of materials, fluid mechanics, basic circuits, electronics and instrumentation, computer science, thermodynamics, engineering economy). Most of these subject areas are normally included in undergraduate curricula in engineering. The basic courses provide the engineer with the ability to understand some fundamental principles in each subject area, solve elementary problems, and to hopefully recognize when a specialist in a particular subject matter should be consulted.

(2) A second requirement is that a rehabilitation engineer should have some confidence and experience in solving design problems (which may involve testing and evaluation) involving analysis and synthesis which draws on material from several subject areas. Again, most undergraduate programs in engineering include a "design component" in the curriculum although it is often not emphasized as thoroughly as many engineering practitioners feel is necessary.

(3) A third basic requirement of a rehabilitation engineer is that he/she can work in harmony with other members of the rehabilitation team. Although it is difficult to "teach" someone to become an effective team member, and there is no substitute for a sincere desire to cooperate in reaching common goals, some courses in the behavioral and management sciences might help the students to expand their (hopefully) natural abilities in these areas. Again, undergraduate electives in social-humanistic areas may have provided the engineering student with some background in the behavioral and/or management sciences. Possibly some "key" courses can be identified at each institution offering a rehabilitation engineering program, and certainly an internship program can aid the student in developing these skills.

There are still more requirements of a program in rehabilitation and it is for this reason that the first degree in Rehabilitation

Engineering should be at the Master's Level.

(4) It is desirable for the engineer to have a fundamental background in several areas of particular interest to rehabilitation engineers. A core area of engineering course work might be selected from subjects dealing with properties and specifications of commonly used prosthetic and orthotic devices, metal and polymer fabrication techniques, theoretical analysis of stress-strain relationships, etc. There may be no "absolutes" in this core program, but possibly it can be agreed that four or five of these and/or other subject areas should be a part of every program in rehabilitation engineering. It is not suggested that a whole series of new specialized courses be developed except possibly a course entitled "Introduction to Rehabilitation Engineering," but that (in general) traditional well developed courses be utilized in a student's program.

(5) In addition to having a somewhat broad background, the rehabilitation engineer should be competent in his/her field of specialization. Thus it is suggested that each student identify a general field of concentration which may encompass one or more areas such as design, materials, testing and evaluation, bioinstrumentation, data reduction and analysis, systems analysis, pattern recognition, and image processing.

(6) Finally, a rehabilitation engineer should have a basic understanding of anatomy and physiology, as well as knowledge of the etiology, diagnosis, prognosis, and treatment of some common disabilities. He or she should have a knowledge of the activities and specialties at various rehabilitation centers. The engineer, as previously mentioned, needs to understand and have some knowledge of the functions of other members of the rehabilitation team, and to have had some experience in working with various team members as well as the disabled patient. Some of these criteria may be met in traditional ways in a comprehensive university. However, to maximize the educational experience while fulfilling the above requirements, it is felt that an internship program of approximately nine months duration in a hospital or other rehabilitation engineering facility is a necessary

and critical part of an educational program in rehabilitation engineering. As in other aspects of the educational program, there is room for a good deal of flexibility in the internship program. Its exact nature should be dictated by the student's background and interests as well as those of the "faculty" in the engineering school and the rehabilitation center or hospital. Ideally, the student would spend time in one or more facilities and not only gain experience in working with different medical and paramedical professionals and the disabled patient, but also gain experience and knowledge in such areas as prosthetics, orthotics, orthopedics, rehabilitative medicine, neurophysiology, physical and occupational therapy, and communcation aids. It is recognized that not all areas have been listed and that in a limited time period a student can assimilate only a finite amount of information and experience. Thus it seems reasonable to experiment with the nature of the internship program as long as its primary objective is satisfied — that of interfacing the rehabilitation engineering student with the patient-rehabilitation team. It is recognized, however, that the student's experiences from an internship program can be enhanced by proper selection of courses, short courses and seminars, and training aids which are made available to him/her during the internship program. Overall continuity and effectiveness can be facilitated by designating technical and medical directors at the rehabilitation facility and an educational director at the engineering school.

(7) As part of the degree requirement, the student should either write a thesis or a formal engineering project report (in those programs where a thesis is not required). The thesis or report would normally relate to a project encountered during the internship program and would be reviewed by the appropriate personnel at the rehabilitation facility as well as by at least one engineering professor in the student's academic department. This engineering professor, as well as at least one person at the rehabilitation facility, would have served as advisors to the student during the internship period.

Sample Program

It has been emphasized that rehabilitation engineering educational programs be implemented at the Master's level in engineering. However, this does not preclude the development of special courses and seminars in basic engineering principles and practices and in rehabilitation engineering activities for other members of the rehabilitation team. Indeed such communication should be encouraged, and perhaps some engineering students could become involved in these activities (in a small way) during their internship programs. However, the purpose herein has been to suggest a general approach for educating rehabilitation engineers. To emphasize some of these points in a general sort of way, a possible breakdown in the distribution of hours (based on four academic quarters in a year) is given below.

Proposed M.S. Program in Rehabilitation Engineering

		Number of Quarter Hours (3 qtr hrs = 2 semester hrs)	
		Thesis Option	Non-Thesis Option
1.	Mathematics, Computer Science	9	9
2.	Engineering Courses	18	24
3.	Related Courses (could include engineering courses)	3	6
4.	Anatomy, Physiology, Clinical Medicine	15	15
5.	Thesis	9	-
6.	Project	-	3
7.	Internship (credit included partially in items 4-6)	-	-
		54	57
		(36 semester hrs)	(38 semester hrs)

It should be noted that each of the above totals is nine quarter hours greater than the minimum number of hours required in traditional MS programs in engineering. This may not be unreasonable since 15 hours have been included which would not appear in traditional programs. It is expected that most students would require from 18 to 24 months to complete the requirements outlined above.

Appendix 5.2

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REFERENCES

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Appendix 5.3

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PM & R Journals

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BIOMEDICAL TECHNOLOGY PERIODICAL

Appendix 5.4

PANEL MEMBERS

REHABILITATION ENGINEERING EDUCATION WORKSHOP

Colin A. McLaurin, Co-Chairman
Robert E. Tooms, Co-Chairman

Panel Topic		Leaders	Session Attendees	
A - Scope and Objectives of Rehabilitation Engineering	1)	J. B. Reswick	P. Bach-y-Rita R. Cobbold R. Ehrle G. Hopkins	J. F. Jonas, Jr. A. Muilenburg S. E. Reger B. Scott
	2)	J. L. Cockrell	R. M. Davies H. Freiberger R. J. Johns A. J. Moore	G. Moskowitz O. E. Reece H. E. Thranhardt R. E. Tooms S. Traber
B - Role and Function of the Rehabilitation Engineer	1)	D. Childress	I. D. Dunmire R. Foulds R. Fulford J. Ray	S. Sheredos S. P. Simon R. Snelson G. Vanderheiden
	2)	J. Foort	R. Greene J. Leslie M. LeBlanc R. Nelson	B. Romich M. Rosen B. C. Simons R. Waters
C - Professionalism and Interprofessional Relationships	1)	J. T. Mortimer	C. H. Dankmeyer J. Kauzlarich D. Lehmkuhl J. Lyman	T. Porter M. Quigley C. Radcliffe G. Warren
	2)	M. Schnell	P. Cluff C. Compere J. Forrester R. Norris R. Pearson	J. Smathers G. Smidt W. S. Topham A. B. Wilson, Jr.

Panel Topic		Leaders	Session Attendees	
D - Manpower Needs and Rehabilitation Engineering Education	1)	J. Lyman	J. L. Cockrell R. Greene A. J. Moore	C. W. Radcliff M. Schnell B. C. Simons
	2)	B. Romich	R. Cobbold J. Kauzlarich M. LeBlanc	D. Lehmkuhl A. J. Moore
	3)	G. Hopkins	C. H. Dankmeyer J. Foort J. H. Forrester	J. T. Mortimer J. Smathers G. Smidt
E - Continuing Education and Certification	1)	R. J. Johns	G. Moskowitz R. Pearson T. Porter	M. Quigley S. Reger
	2)	A. B. Wilson, Jr.	P. Bach-y-Rita J. Ray M. Rosen	S. P. Simon W. S. Topham
F - Delivery Systems	1)	R. Waters	R. Fulford H. Freiberger A. Muilenburg	R. Nelson B. Scott S. Sheredos
	2)	R. Snelson	D. Childress P. Cluff I. D. Dunmire R. Foulds	J. Leslie R. E. Tooms G. Venderheiden
G - Program Organization, Sponsorship and National Visibility	1)	R. Ehrle	C. Compere R. Davies J. F. Jonas R. Norris	O. H. Reese J. B. Reswick H. Thranhardt G. Warren

Appendix 5.5

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Appendix 5.6

WORKSHOP AGENDA

WORKSHOP ON REHABILITATION ENGINEERING EDUCATION

Knoxville, Tennessee

November 3-5, 1976

Dr. Colin A. McLaurin - Co-Chairman
Dr. Robert E. Tooms - Co-Chairman

AGENDA

WEDNESDAY (November 3, 1976)

8:00 a.m.	Registration - University Travel Inn
9:30 a.m.	First Plenary Session - University Center, Crest Room Opening Remarks - Dr. William T. Snyder Dean Fred N. Peebles Mr. Joe E. Traub Dr. Colin A. McLaurin
10:00 a.m.	Formal Presentations (Moderator - Dr. Colin A. McLaurin) 1. Definition and Scope of Rehabilitation Engineering - James E. Reswick 2. Role and Function of the Rehabilitation Engineer - Anthony Staros
10:40 a.m.	COFFEE
11:00 a.m.	Formal Presentations 3. The Need for Rehabilitation Services - Maurice LeBlanc 4. Relationship between Rehabilitation Engineering and other Professions - Clinton L. Compere
11:45 a.m.	LUNCH
1:30 - 4:30 p.m.	Task Force Group Sessions - University Travel Inn A. Scope and Objections of Rehabilitation Engineering (Definition) B. Role and Function of the Rehabilitation Engineer (Employment and Responsibility) C. Professionalism and Interprofessional Relationships
6:00 p.m.	SOCIAL HOUR - University Travel Inn

THURSDAY	(November 4, 1976)
8:30 a.m.	Second Plenary Session - University Center, Shiloh Room Summary Reports of Task Force Groups A, B, C
9:00 a.m.	Formal Presentations 5. Implementation of Rehabilitation Engineering Programs - Colin A. McLaurin 6. Training and Education of Rehabilitation Engineers - J. H. Forrester
10:00 a.m.	Task Force Group Sessions - University Travel Inn D. Manpower Needs and Rehabilitation Engineering Education E. Continuing Education and Certification F. Delivery Systems G. Program Organization, Sponsorship, and National Visibility
12:00 noon	LUNCH
1:30 - 5:00 p.m.	Continuation of Task Force Group Sessions
FRIDAY	(November 5, 1976)
8:30 a.m.	Third Plenary Session - University Travel Inn Summary Reports of Task Force Groups D, E, F, G General Discussion Concluding Remarks - Colin A. McLaurin Joe E. Traub
12:00 noon	ADJOURNMENT OF WORKSHOP
1:00-3:00 p.m.	Meeting of Editorial Committee