Wheelchair development, standards, progress, and issues:  
A discussion with Colin McLaurin, Sc.D.

This discussion is presented by the Editors of the Journal in an effort to provide significant information about improvements in wheelchair design and evaluation of wheelchair standards, since this type of research is rarely reported in the current scientific/engineering literature. Dr. McLaurin is the Director of the Rehabilitation Engineering Center at the University of Virginia in Charlottesville, Virginia and is Chairman of the Technical Advisory Group (TAG) of the American National Standards Institute (ANSI), a private group representing the U.S. at the International Organization for Standards (ISO), which is responsible for developing wheelchair standards. Portions of this interview appeared in the July 1985 issue of the Journal.

DEVELOPMENT OF STANDARDS AND ALTERNATIVE SYSTEMS

Editors: What are your comments about automatic transmission systems such as the RESATRAN, designed and developed by James Reswick, Sc.D., and other alternatives?

McLaurin: Series wound motors are possible, as we discussed, but they still require the use of power trains or belts. Belts are inherently problematic because they can break and slip and then you’re out of luck. The University of Virginia REC is currently investigating a new controller which can provide up to 40 volts from a 24-volt battery; this should allow a reduction in maximum current. There is no doubt that a variable-speed transmission such as the RESATRAN makes better use of the motors. It is a matter of whether the extra cost and complication is worth it.


McLaurin: The meeting was very successful. All the points that the United States delegations wanted were approved: efficiency of brakes, energy consumption, overall dimensions, mass and turning space, determination of maximum speed, acceleration and retardation, climatic tests, obstacle climbing ability, test dummies, and the coefficient of friction for test surfaces.

The remaining work, which is scheduled for completion in 18 months is concerned with determination of seating dimensions, fatigue testing, and the dynamic stability of powered wheelchairs. In addition further testing is needed in Europe and the U.S. to determine acceptance values where applicable.

Editors: What is the difference between the standards now being developed and the standards which already exist?

McLaurin: The only existing standards in the U.S. are those used by the VA as acceptance standards. The ANSI and ISO standards are more general in nature and are being written to be acceptable internationally.

Editors: What countries are included in the ISO Committee which you chair?

McLaurin: UK, Sweden, Germany, France, Denmark, United States, Canada, and now Austria.

Editors: How about Japan?

McLaurin: They have sent an observer to previous meetings, but there were about 10 delegates at the Vienna meeting.

Editors: When will these standards be completed?

McLaurin: By the end of the three-year grant from NIHR [the National Institute of Handicapped Research]. The methods of testing should be available in a year or two — range values will take longer. The work under way is expected to be completed in 18 months time. Some work such as power and controls and strength for electric wheelchairs may require further time.

Editors: Who would actually do the performance testing for compliance with these standards?

McLaurin: I don’t know — perhaps the VA, perhaps
the manufacturer. Some foreign countries have their own testing agencies.

[Dr. McLaurin’s colleague, James Kauzlarich, Ph.D., informed the Journal that the Dutch have a library catalogue of wheelchairs which will be computerized. Dr. McLaurin also said that the Dutch and Swedes have their own wheelchair acceptance standards, but will adopt ISO when they are ready.]

Editors: Are any of the major manufacturers and consumers on the ISO Committee?

McLaurin: Yes. Ortopedia, Carters, Everest and Jennings, and Invacare are examples of manufacturers. Dr. Jordan (Germany), Langford (Canada), and Axelson (U.S.) are consumer representatives on the ISO subcommittee.

Another of Dr. McLaurin’s colleagues, Clifford Brubaker, Ph.D., was asked to comment on how manufacturers feel about standards.

Brubaker: Of course they resist anything that would require a change in their wheelchairs, but they are actively engaged in the development of these standards.

Editors: Why are U.S. wheelchairs made in the U.S.A. and not imported?

McLaurin: Because, selection in this country is controlled by the prescription process. Medicare/Medicaid — third party payers buy nearly all of the chairs. You can pick up a chair made in Taiwan for $100 on the dock in Los Angeles but a third party won’t buy it. We know that European chairs are built like tanks, but are heavier. The French make better tires. More attention is given to seating in European wheelchairs. The international market for wheelchairs will probably develop in the near future, especially since ISO standards will give some assurance of quality.

RESEARCH ISSUES

Editors: Will you comment on the key areas of wheelchair research and development going on now and what impact this research is having on wheelchairs?

Seating/Ergonomics

McLaurin: It is important that a person fit into a chair correctly and that the chair suit his or her purpose. It would be ideal if a person could change seating position at will in accommodation with the environment at that time, for example, the ability to sit and shift position within the seat at will or to tilt the seating position forward.

The studies at UVA show that levers are a more efficient way to propel a wheelchair, compared with handrims. Recent prototypes for lever systems allow control of the wheelchair comparable to handrims and have the added advantage of allowing various gear ratios. They also prevent the hands from being soiled or damaged and promise to be especially functional for quadriplegics and others with limited use of hands.
Strong Lightweight Wheelchairs

McLaurin: The use of aircraft aluminum, chrome molybdenum steel, titanium or graphite tubes has brought the weight of sports wheelchairs to the 20 to 30 lb range. This seems practical for general use. The NASA/UVA composite wheelchair weighs 28 lb, and so far has endured 150,000 cycles on the torture machine without mishap.

Easier Seating Adjustment

McLaurin: No one would buy an automobile today that did not have adjustable seats. It is logical that similar adjustments should be available to a wheelchair user who spends up to 18 hours a day in the seat. Adjustments should be of two classes: one that allows adjustment to fit the person, such as in present foot supports, and one that allows adjustment to the seating and limb support system while using the wheelchair.

Reliability

McLaurin: We should be able to make a trouble-free chair. This is a difficult requirement because some people are much more rugged users than others. However, with the possible exception of tires, it should be possible to build a wheelchair that is trouble-free for the average user. This is particularly important for powered wheelchairs where the electric (wheelchairs) pose some real problems such as transistors burning out. We do build refrigerators that run for decades without any maintenance, why not electric wheelchairs?

Improvement of Battery Life Cycle

McLaurin: There are many ways to improve battery life cycle. The tabular plate batteries produced by Chloride have a guaranteed life of 1,000 cycles. A monitor being developed at UVA will act as a “fuel gauge” allowing the user to know the state of the battery chargers and avoid excessive discharge. Some new battery chargers do a much better job in preventing overcharge, which is one major problem in reducing battery life. Meanwhile, research is being carried on with more exotic material which may provide greatly extended life, although to date none of these has measured up.

Improvement of Tires

McLaurin: Tires are the main problem in rolling resistance on a hard level surface. High-pressure pneumatic tires provide very low resistance with a comfortable ride but require maintenance and do not wear well. Dr. Kauzlarich has developed a unique and simplified theory for tire design and it appears that solid synthetic tires can match pneumatics in rolling with greatly increased tire life. The ride may be compensated with spring suspension of the wheels, a concept pioneered by Gordon Stout in Berkeley several years ago.

Controllers

McLaurin: There are two aspects to controllers: the interface, of which the joystick is an example; and the electronics that controls the speed of the motors. In this second category, pulse width modulation is the common means for controlling the motors. In this method the supply of current is “chopped” anywhere between 400 to 20,000 times per second, and the power or speed is determined by how long the current is “on” each time it is “chopped.” These controllers rob the motor of efficiency, are bulky, expensive, and often subject to failure. Other types are under investigation to overcome these problems.

The use of microcomputers is a promising method for enhancing the interface aspects of the control system. These can be adjusted to provide a desired response to any type of input, from joystick to voice, and can be programmed to provide some degree of automation, thus relieving the user of some decisions and required inputs.

Motors

McLaurin: The most common motor used in wheelchairs is the permanent magnet type. Ceramic and other exotic materials can improve the magnetics and hence the power from such a motor. These increase the cost of the motor and, like other magnets may lose their magnetism over a period of time. One of the difficulties in wheelchair use, is that the total volume of sales does not permit the design of motors for their specific use, and as a result the motors may not be ideal in performance or efficiency.

Other motors that may have application are series-wound motors, which use electric magnets instead of permanent magnets. The common electric drill is an example which illustrates the very high starting torque that is produced. The motors are cheap since they are mass produced; they are now being studied for wheelchair application.

Disk type or “pancake” motors offer high torque, but none are presently available in a size suitable for wheelchairs.
Velocity Feedback

McLaurin: In a typical wheelchair, directional control is obtained by varying the speed of one drive wheel with respect to the other. This requires some action on the part of the user on uneven terrain or a side slope. With velocity control, a tachometer or similar means, monitors the speed of the wheel and signals the controller which will ensure the required direction of the wheelchair under any conditions of terrain within the limits of the system. Velocity control is particularly important for users with impaired function and for wheelchairs with poor directional stability such as front-wheel drive, rear caster models.

Large Front Wheels to Accommodate Curbs

McLaurin: A powered wheelchair with large wheels in front offers advantages in mounting curbs and negotiating rough terrain. Furthermore, there is more front room between the wheels when compared to swivelling casters. However, such a chassis configuration, with the center of mass behind the main wheels is inherently unstable, and at speeds of 5 mph can easily spin out on a corner or fishtail on the straightaway.

Velocity control can provide the necessary dynamic stability, but the response of the control for a given speed is yet to be determined. A further disadvantage to front drive occurs in transferring, unless smaller diameter wheels are used.

Power Trains

McLaurin: The power train refers to the gears, chains, or belts that are used to connect the motors to the drive wheels. Properly lubricated and enclosed gears are preferred but are the most expensive. Spur gears, as in an automobile transmission, are very efficient but usually require 2 or more pairs to achieve the right gear ratio. Worm gears provide a suitable ratio and are quiet but rob the motor of some of its power.

Friction belt drives are commonly used because they are inexpensive, lightweight, quiet, and efficient. However, they can break or slip in wet weather, causing real problems for the user. Tooth belts as used in automotive timing belts prevent slipping and are quite reliable, quiet, and efficient.

The ideal power train would provide a variable gear ratio as does the RESATRAN, but this does add expense. It is interesting to note that designers of electric automobiles have avoided the use of such transmissions.

Specialized wheelchairs need to be developed for racquet ball, track, road racing, and general outdoor recreation.

FUTURE RESEARCH

Editors: What research and development beyond that currently underway at the University of Virginia do you see as being needed?

McLaurin: Our program has basically revolved around wheelchair R&D for the spinal cord injured. We would like to address the needs of other disabilities. Cliff Brubaker discussed his thoughts on the whole realm of new problems specific to the increasing numbers of geriatric clients in and out of nursing homes/hospitals. Should we be designing chairs that assist the able-bodied person's ability to manage the chair? Do we want to design wheelchairs that help an attendant to transfer a person from bed to chair to toilet to bath, etc.? Should wheelchairs be designed so that the seat system can shift a person into different positions to prevent pressure? We want to continue research in the whole area of human factors, automated wheelchair prescription, fatigue testing, determination of seating dimensions, dynamic braking and more reliable and efficiently powered wheelchairs.

Editors: Do we really know what the consumer wants in a wheelchair?

McLaurin: The PVA [Paralyzed Veterans Association] ran a survey in Paraplegic News which was really excellent. I would like to see an expansion of that survey that would really ask in-depth questions to the consumer. This is about the only information available on the needs of the wheelchair user in the U.S., with the exception of a recent survey regarding the need for dynamic brakes and an earlier survey by Gordon in Albemarle, Virginia and neighboring counties.

I think a national survey would enlighten researchers on the needs of wheelchair users as they perceive them, not as we the able-bodied see them.