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A Technical Note

Tests of two new polyurethane foam wheelchair tires

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Abstract—The performance characteristics of four 24-inch wheelchair tires are considered; one pneumatic and three airless. Specifically, two new airless polyurethane foam tires (circular and tapered cross-section) were compared to both a molded polyisoprene tire and a rubber pneumatic tire. Rolling resistance, coefficient of static friction, spring rate, tire roll-off, impact absorption, wear resistance, and resistance to compression set were the characteristics considered for the basis of comparison. Although the pneumatic tire is preferred by many wheelchair users, the two new polyurethane foam tires were found to offer a performance similar to the high-pressure pneumatic tire. In addition, the foam tires are less expensive and lighter in weight than the other tires tested.

Key words: *acceleration response, compression set, rolling and wear resistance, spring constant, static friction, wheelchair tires.*

INTRODUCTION

Airless wheelchair tires offer important maintenance advantages over pneumatic tires. There is no need to check and adjust air pressure and there is never a worry about a flat or punctured tire. These are common inconveniences encountered when using pneumatic tires that reduce the wheelchair user's independence. Wheelchair users surveyed say that tires are the biggest repair problem for all kinds of wheelchairs (6). However, airless tires are unable to deliver better operating performances than pneumatic tires. This is true in the critical areas of ride comfort and rolling resistance. Characteristics such as these may outweigh the maintenance-free advantage of the airless tires for some users. The recent introduction of two new airless polyurethane foam tires is a great step toward reducing the performance gap between airless and pneumatic tires.

The purpose of this study is to quantify the engineering performance characteristics of wheelchair tires and to determine how the new polyurethane foam tires compare to conventional wheelchair tires.

Only four tires were studied because it was felt that a pneumatic tire and an airless rubber tire represent the two types of tires which were commonly available prior to the introduction of the polyurethane foam tires. The pneumatic tire tested was a gray rubber, nylon-cord-reinforced, nonmarking, tire with a rubber innertube (See **Appendix** for details as to source, price, etc.). The airless rubber tire tested was manufactured by extruding a polyisoprene polymer about a 3/8-inch polyethylene tube (**Figure 1**). The two styles of polyurethane foam tires tested were centrifugally molded and contain two or four nylon cords to hold them on the wheel rim. The centrifugal molding process causes a high-density skin, about 1/16-inch thick, to be formed at the mold walls: See **Figures 2 and 3** for

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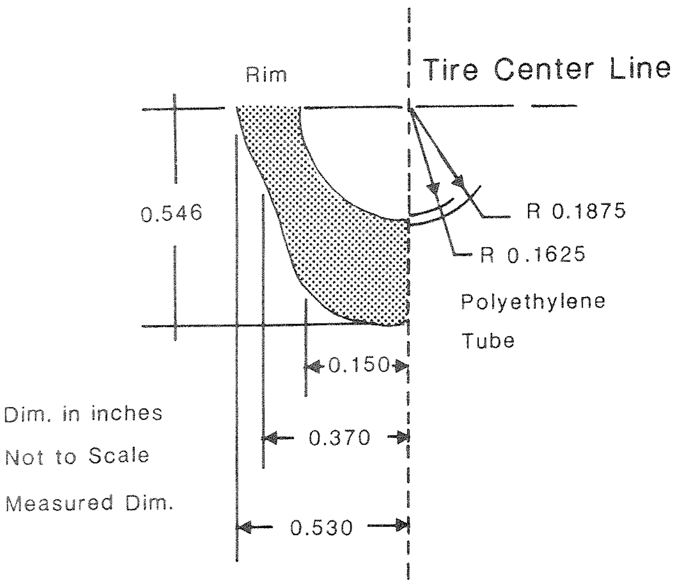

Figure 1.
Molded polyisoprene tire dimensions.

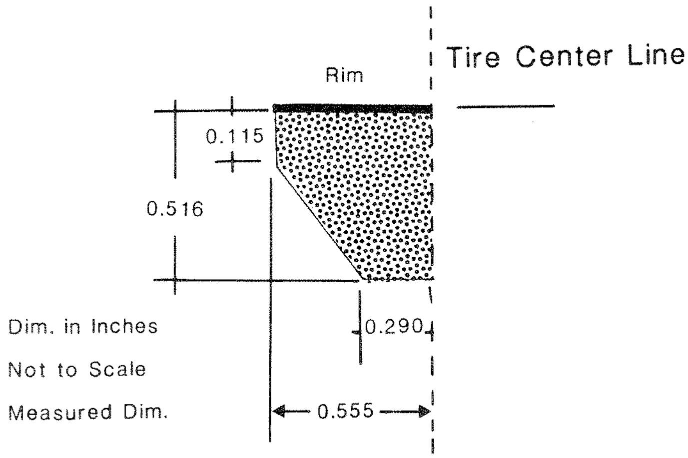

Figure 2.
Tapered polyurethane foam tire dimensions.

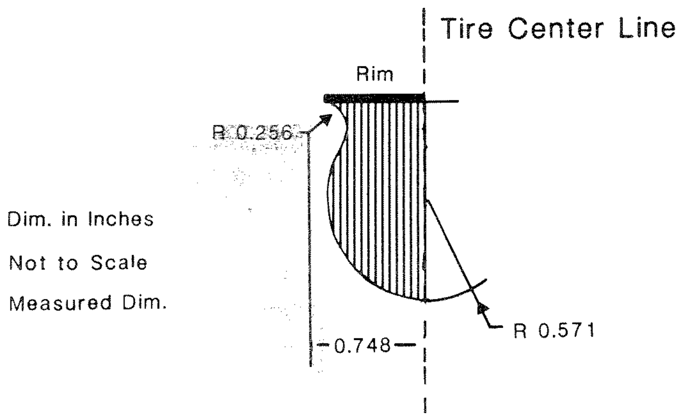

Figure 3.
Circular polyurethane foam tire dimensions.

dimensions, and the **Appendix** for other details.

A description of each of the performance tests, test results, and theoretical considerations are given in the following sections.

ROLLING RESISTANCE

The rolling resistance of each tire pair was measured using a treadmill and load cell test facility (4). Pairs of 24-inch tires were tested using a towed cart arrangement (**Figure 4**). The tire camber and toe were adjusted for zero degrees and measurements of towing force were taken at various speeds and loads. While most wheelchairs operate with some amount of camber, it does not have a significant impact on rolling resistance (4). The wheel bearings were adjusted for minimum drag; the measured bearing torque was 0.015 lb_f-in, which has a negligible effect on rolling resistance.

The rolling resistance of the pairs of tires varied primarily with load. The treadmill was operated at speeds of 1.5, 2.0, and 3.0 miles per hour (mph), and rolling resistance (towing force) was measured for loads of 85, 109, 133, 157, 181, and 205 pounds (lb_f) for each speed setting. The data are shown graphically in **Figures 5, 6, and 7**. The uncertainty in the rolling resistance force values shown is plus or minus 0.09 lb_f.

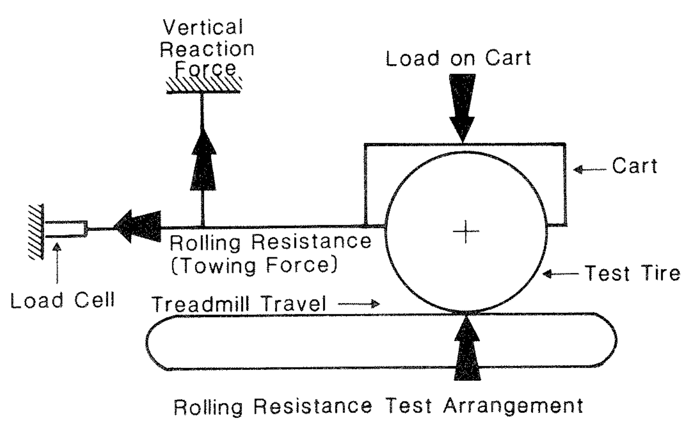

Figure 4.
Rolling resistance test arrangement.

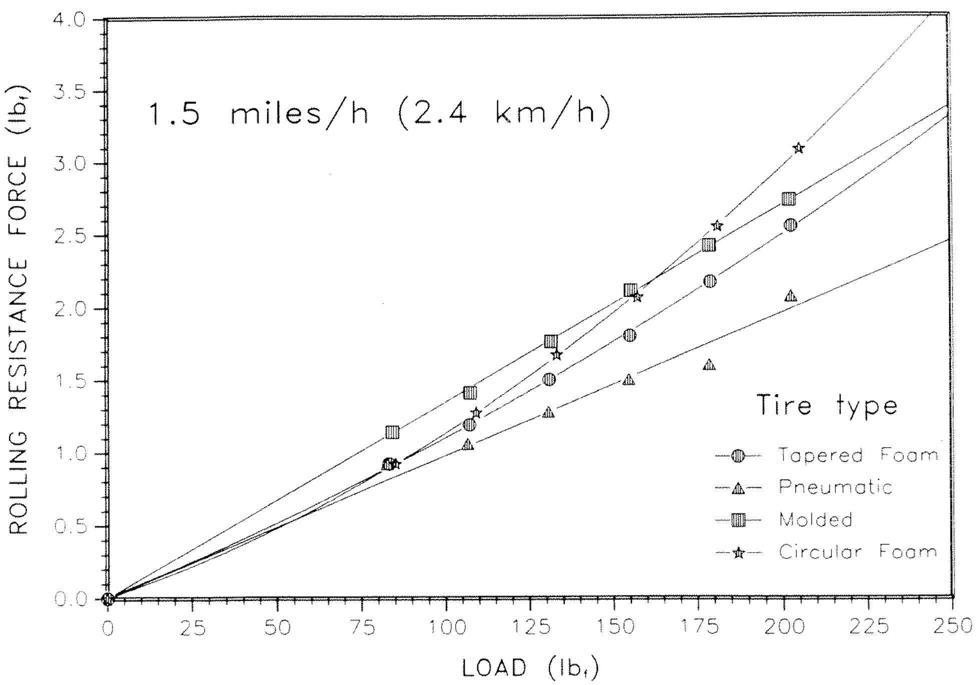

Figure 5.
Rolling resistance versus load (1.5 mph).

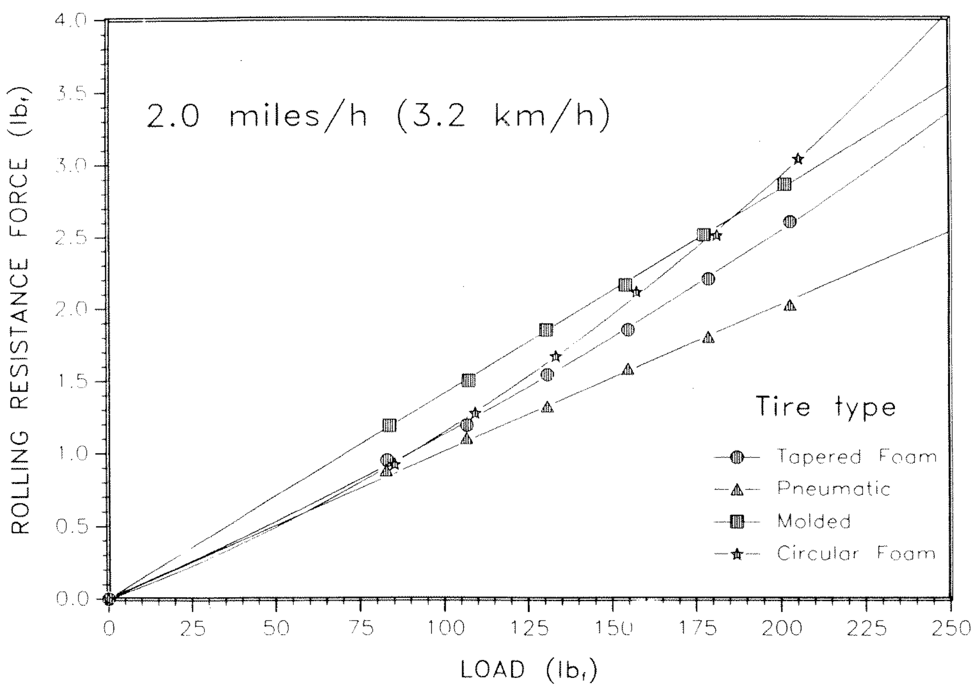

Figure 6.
Rolling resistance versus load (2.0 mph).

For 100 lb_f load (50 lb_f per tire) and 1.5 mph, **Figure 5** shows that the pneumatic tires have the lowest rolling resistance (1.0 lb_f, or 1/2 lb_f per tire), and the molded polyisoprene tires have the highest rolling resistance (1.4 lb_f). The foam tires have a rolling resistance of 1.15 lb_f. A wheelchair user operating at 1.5 mph and with 100 lb_f on the large wheels, and 100 lb_f on the caster wheels, would have to exert 15 percent more force to roll the polyurethane foam tires than the pneumatic tires, but 40 percent more force to roll the molded tires than the pneumatic tires. The latter analysis assumes the same data apply to the caster tires as the 24-inch tires, which is not strictly the case, but close enough

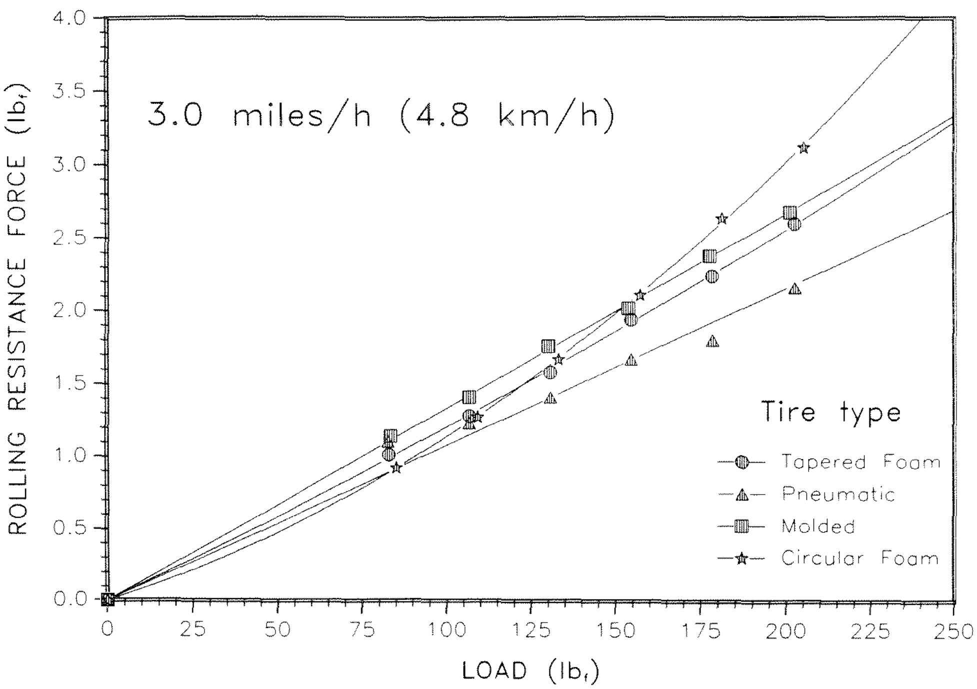

Figure 7.
Rolling resistance versus load (3.0 mph).

for practical considerations: See (3) for a more complete analysis.

Rolling resistance on a smooth surface such as a treadmill belt is mainly due to the energy losses (hysteresis) in the tire material during rolling deformation (3). If the surface is rough, such as a concrete sidewalk, the rolling resistance will increase on the order of 50 percent. If the surface is a pile rug, the apparent rolling resistance can increase by as much as 300–400 percent (4). In order to decrease the rolling resistance on a smooth surface, the material of the tire must have a low hysteresis loss. The geometry of the tire will also have an effect on rolling resistance, as can be seen by comparing the two foam tires in **Figure 5**. Improving the rolling resistance of tires is a highly specialized area of tire design and is an area of study for the UVA Rehabilitation Engineering Center.

STATIC FRICTION

The coefficient of static friction for each tire type was evaluated using the loaded (85 lb_f gross load) test cart with wheels fixed to prevent rotation (**Figure 8**). A horizontal force was gradually applied at the base of the tires, and the force which caused slow motion of the cart (sliding) to begin was recorded. A coefficient of static friction was calculated using the following equation:

$$\mu = \frac{L}{R_1} \qquad [1]$$

where: μ = coefficient of static friction
L = maximum applied force
R_1 = measured vertical force at test tire

Calculated values for coefficient of static friction are shown in **Table 1**. The *indoor surface* values are for a smooth finished concrete floor which has been sealed and polished. These values are similar to those obtained on an asbestos tile floor. The *outdoor surface* values are for an exterior concrete sidewalk. The performance of the foam tire does not equal the performance of the pneumatic tire, especially indoors. Wetting the concrete floor made no significant difference in the measured values. The uncertainty in the values given in **Table 1** are plus or minus 1 percent.

There is an ISO standard, ISO 7176/13 (1), concerning the determination of coefficient of friction of test surfaces. This test involves the sliding of a block of test rubber over a number of surfaces that wheelchairs commonly roll on, and the procedure for calculating the coefficient of friction. Our data in **Table 1** shows that the material of the tire

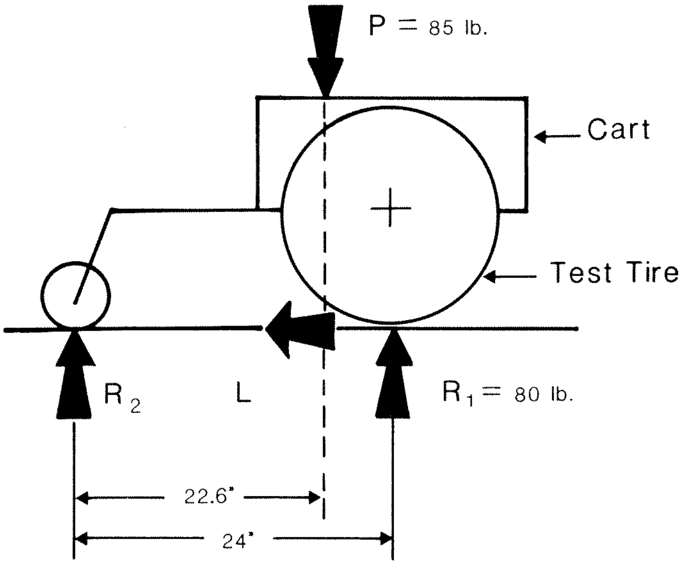

Figure 8.
Sliding friction test model.

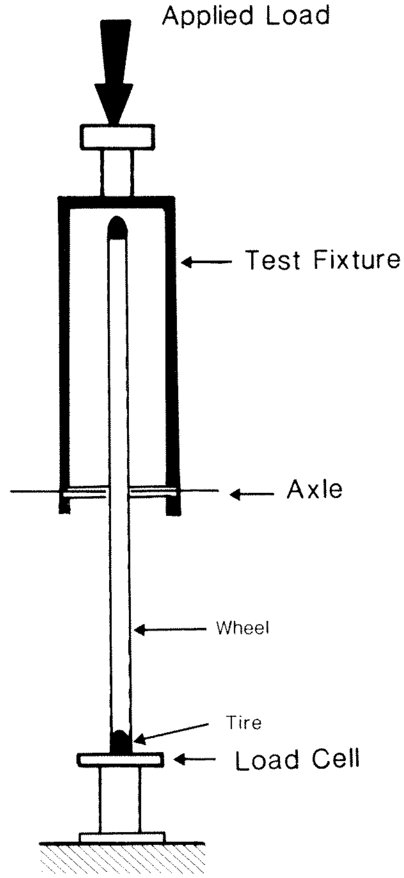

Figure 9.
Spring constant test schematic.

can make a significant difference in the coefficient of friction on the same surface.

SPRING CONSTANT

Spring constants were measured using a standard load-testing device (Instron® Model 1122 Universal Testing Instrument). A load was gradually applied to the wheelchair wheel with tire; and load versus deflection was plotted by the instrument. **Figure 9** shows the test setup. The spring constant was then calculated by determining the slope of the load/deflection curve at any load. In general, the spring constant was found to be independent of load over the load range of interest to wheelchairs. In order to determine the spring constant of just the tire, two measurements are required: first, the spring constant of the test fixture, wheel, and tire was determined; and second, the spring constant of the test fixture and wheel (without the tire) was measured **(Figure 10)**. For springs in series, it is well known (5, p. 35) that the overall spring constant, k, is related to the spring constant of the parts by:

$$1 / k = 1 / k_{F+W} + 1 / k_T \quad [2]$$

Thus, measuring the overall spring constant, k, and the spring constant of the fixture and wheel, k_{F+W} (fixture and wheel), allows the spring constant of the tire, k_T, to be calculated using Equation 2.

Tests were conducted for each tire in two ways. First, the force was applied along one of the solid spokes (**Figure 11**), and second, the force was applied between a pair of spokes **(Figure 12)**. Theoretically, the value of the tire spring constant should be the same regardless of which test position is used. This was not always the case and is commented on below.

Table 1.
Coefficient of static friction.

Tire type	μ (Inside surface)	μ (Outside surface)
1. Foam (both)	0.43	0.70
2. Molded	0.55	0.65
3. Pneumatic	0.65	0.78

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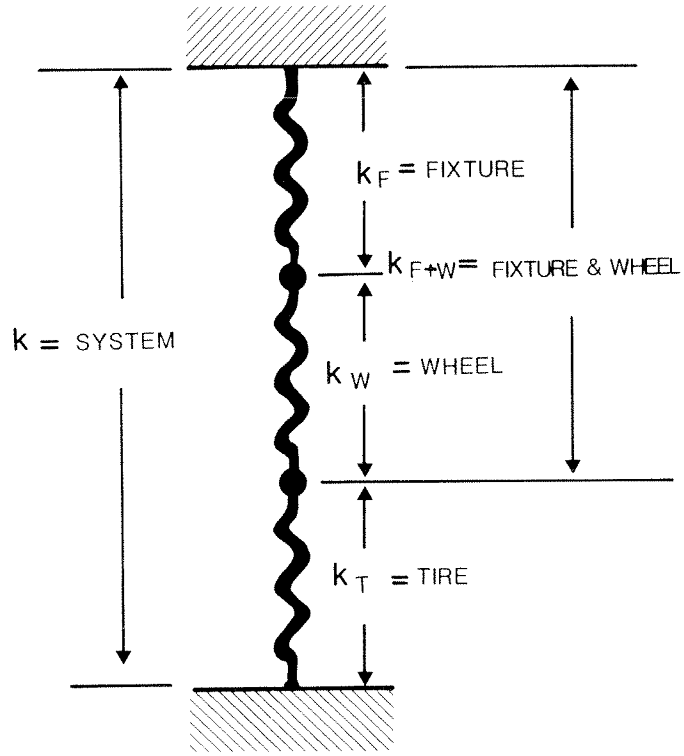

Figure 10.
Spring constant model.

Values of k_T from averages of all values of each test resulted in the calculated values of tire spring constant shown in **Table 2**. Measured values of k_{F+W} are shown in **Table 3**. Note that the values of the tire spring constant for the tapered foam tire and the molded tire vary significantly depending on the wheel test position. However, the value of the tire spring constant for the pneumatic tire and circular foam does not vary much, about 6 percent, with wheel test position. This is due to the way load was transferred to the rim of the wheel. Consistent data are obtained for the pneumatic tire, which transfers the load only through the edge of the rim, since that is where the load was applied in determining the spring constant of only the fixture and wheel. The load is not transferred in this manner by either the tapered airless foam tire or the molded tire, but is transferred to the edge, side, and center of the rim. The circular foam tire fits the rim tighter than the tapered foam tire, and consequently gives more consistent results.

Table 2.
Tire spring constant.

Tire type	Spring constant (lb_f/in) % standard deviation in parenthesis	
	along spoke	spokes
1. Tapered foam	1603 (0.7)	1185 (2.9)
2. Circular foam	856 (0.08)	798 (0.02)
3. Molded	3976 (1.1)	2960 (4.1)
4. Pneumatic	694 (1.2)	654 (0.7)

If the wheelchair were operated over a continuously smooth surface, the user would not experience any jolting or bumping. However, real surfaces are not smooth, and each sidewalk crack, for instance, impacts the wheel and sends transient accelerations through the wheelchair tire and frame to the user. These short time accelerations are experienced by the user as forces that are unpleasant, and, if the accelerations are sufficiently great, they give the sensation of a very unpleasant ride. To obtain a relationship between ride and spring constant, we can examine the results of a calculation for maximum deceleration of a mass/spring system being dropped from a height h, as presented by Thomson (5, p. 102). Rewriting Thomson's equation slightly, the maximum deceleration is given by:

$$a_{max} = g[(2kh/mg) + 1]^{1/2} \quad [3]$$

In Equation 3, the spring constant, k, controls the maximum acceleration experienced by the mass, m, where g is the acceleration of gravity. Thus, the unpleasant forces that would be felt by a wheelchair user can be reduced if the spring constant of the suspension is lowered. Examining the data in **Table 2**, we see that the pneumatic tire has a very low spring constant, and it is well known that pneumatic tires on wheelchairs give the most comfortable ride. **Table 2** shows that the molded tire has a high spring constant, which is the reason these tires are considered to give a harsh ride. Of the tires tested, the new circular foam tire has a spring constant nearly as

Table 3.
Fixture/wheel spring constant.

Wheel type	Spring constant (lb_f/in) % standard deviation in parenthesis	
	along spoke	between spokes
1. Everest & Jennings	8791 (4.3)	4191 (4.0)
2. Invacare	8102 (6.9)	5296 (2.6)

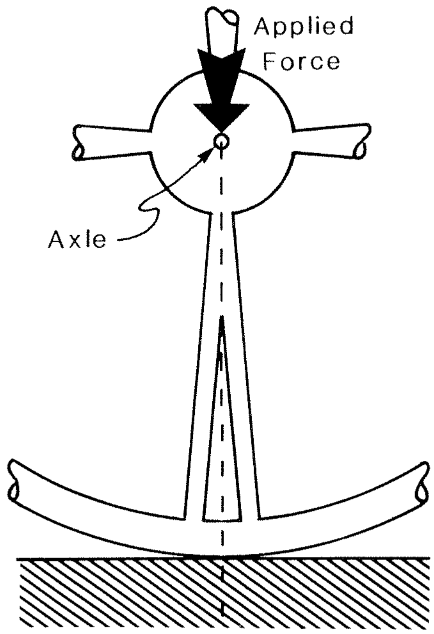

Figure 11.
Test along spoke.

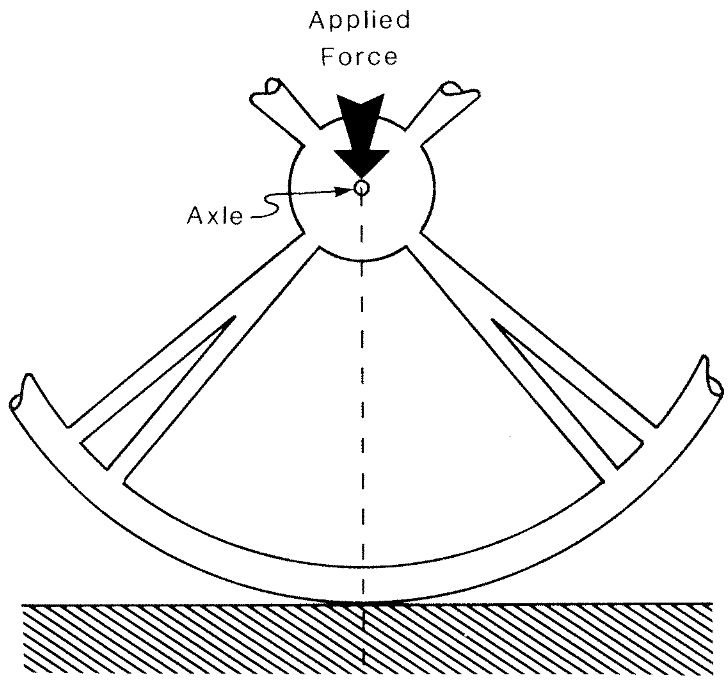

Figure 12.
Test between spokes.

low as the pneumatic tire, and it should give a ride that is almost as comfortable as the pneumatic tire. In the section on impact we will see that these predictions are verified.

ROLL-OFF

When a wheelchair turns a corner, the side forces on the tire can occasionally cause the tire to roll off the rim of the wheel. This usually occurs with high speeds and sharp turns, when using some of the newer airless tires. High-pressure pneumatic tires are not known to roll off the wheel rim, so only the airless tires were tested.

Roll-off was quantified by measuring the roll-off angle. The roll-off angle was determined by towing the cart with the toed-out tire pair on the treadmill (**Figure 13**). The toe angle was varied and the tire inspected for roll-off. For a given angle of toe, if the tire separated from the rim to such an extent that the tire did not return to its normal position on the rim when the toe angle was reduced to zero, a failure would be recorded. The maximum angle of toe that can be tested with the apparatus was 12 degrees. No roll-off failures were recorded for either the foam tires or the molded tire up to the 12-degree maximum.

IMPACT

To examine the impact-absorbing ability of each tire type, the tire pairs were towed on the treadmill at a speed of 1.5 miles per hour with a cart

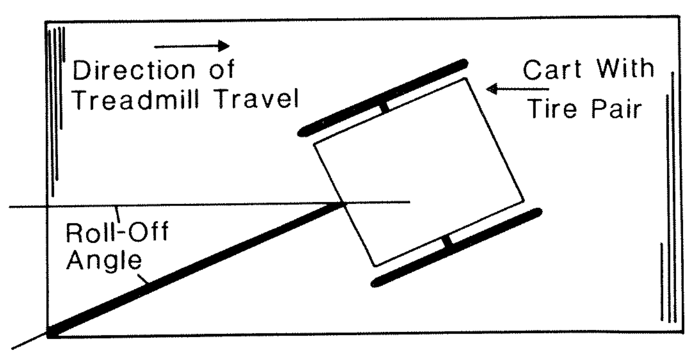

Figure 13.
Roll-off angle test arrangement.

load of 157 pounds. An ISO standard slat (2) was attached to the treadmill belt so as to impact both wheels of the cart at the same time. The acceleration response of the test cart, in both the horizontal (front to back) and vertical direction, was measured using piezoelectric accelerometer ($\omega_n > 100,000$ Hz).

Typical horizontal and vertical acceleration responses are shown in **Figures 14–21**. Both horizontal and vertical responses show two impacts (especially prominent on **Figures 16 and 17**). The initial one was the horizontal impact with the front of the slat, and the second one was the vertical impact with the ground when the tire drops off the back of the slat. Horizontal accelerations were compared by looking at response to the first impact, while vertical responses were calculated using the second impact. Acceleration responses are shown for the various tires in **Table 4**.

The foam tires, especially the circular foam tires, have a considerable reduction in peak horizontal acceleration over the molded polyisoprene solid tires. However, the foam tires could not completely match the pneumatic tires in this category. In the area of vertical acceleration, the response of the tapered foam tires is very similar to that of the molded tires, while the circular foam tires tend to behave much the same as the pneumatic tires.

The impact-absorbing ability of tires is controlled by two main factors: one is the hysteresis (**Figure 22**), and the other is the spring constant, as discussed in the section on spring constant. In **Figure 22** the hysteresis loss factor (circular foam) is given by the area enclosed by the load loop, divided by the area under the applied load line, where the applied load line is the compression line. The hysteresis is acting as a damper to absorb energy, and the square root of the spring constant controls the maximum acceleration response to a bump. Therefore, the impact-absorbing ability would be predicted to be greater for tires with higher hysteresis and a lower spring constant. For example, given the same materials, the impact-absorbing ability (low acceleration) of the circular foam tires should be greater than that of the tapered foam tires, because the spring constant of the circular foam tires is much lower than that of the tapered foam

Table 4.
Tire/wheel/load acceleration response.

Tire type	Peak acceleration (g's) Horizontal	Vertical
1. Tapered foam	0.41	1.57
2. Circular foam	0.52	0.48
3. Molded	0.89	1.67
4. Pneumatic	0.23	0.77

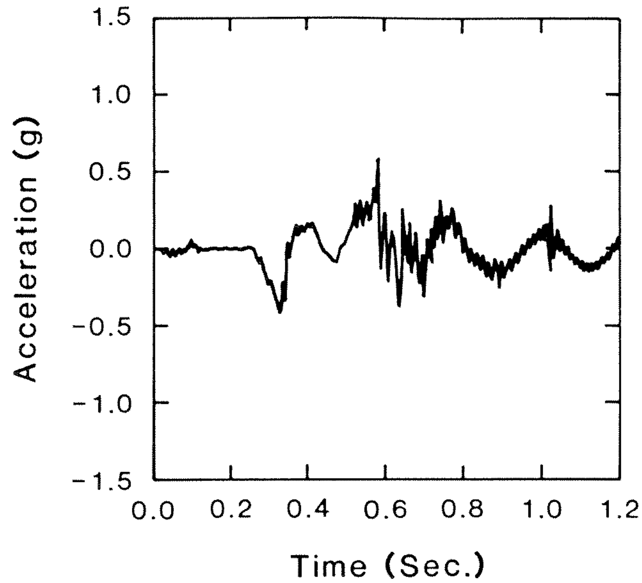

Figure 14.
Horizontal acceleration response: Tapered foam tire.

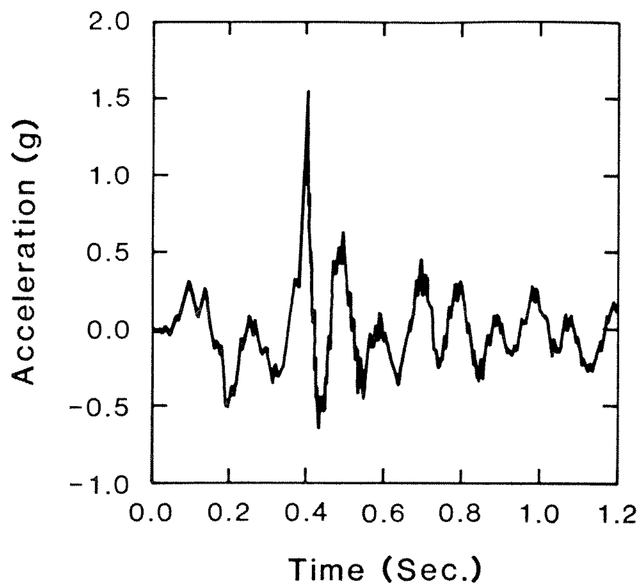

Figure 15.
Vertical acceleration response: Tapered foam tire.

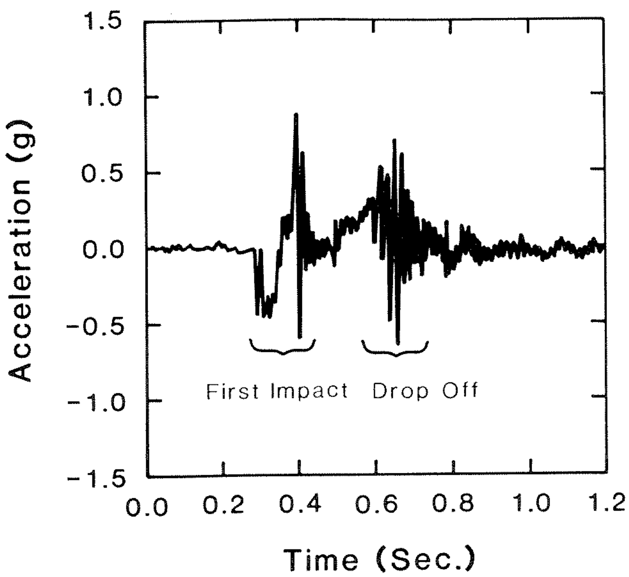

Figure 16.
Horizontal acceleration response: Molded tire.

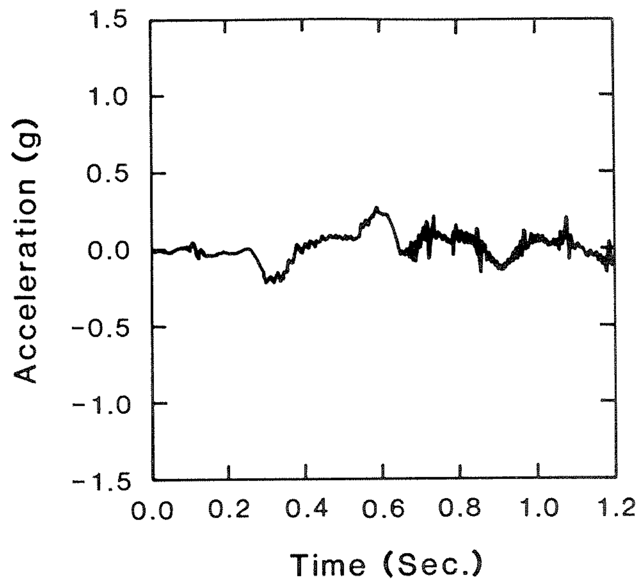

Figure 18.
Horizontal acceleration response: Pneumatic tire.

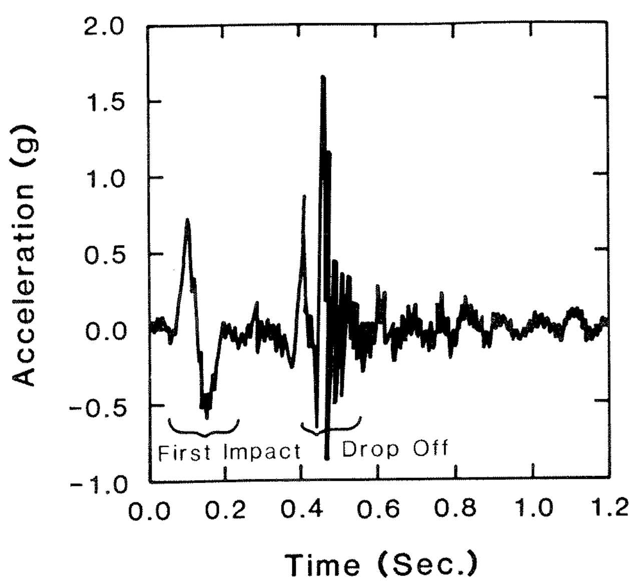

Figure 17.
Vertical acceleration response: Molded tire.

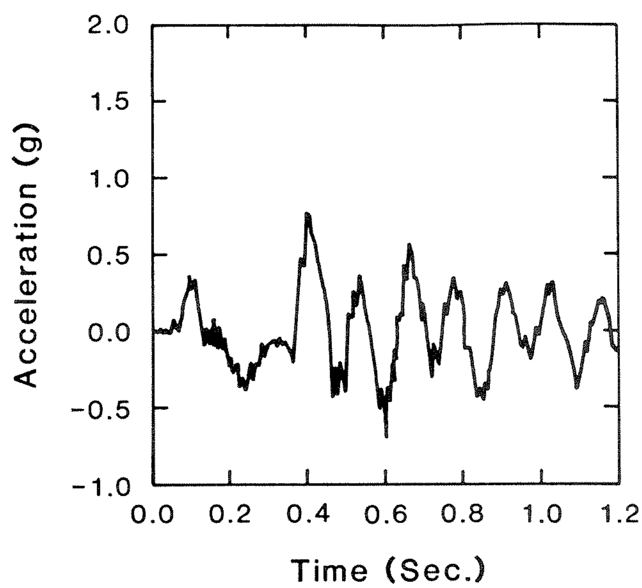

Figure 19.
Vertical acceleration response: Pneumatic tire.

tires (**Table 2**). This is found to be the case when using the vertical component of acceleration given in **Table 4**. The improvement in impact absorption of foam tires is very pronounced. In fact the peak vertical acceleration value for the circular foam tires is actually lower than that for the pneumatic tires.

WEAR

The wear resistance of the various tire materials was compared using a method similar to that described in ASTM D 1630-83 (Rubber Property—Abrasion Resistance). The following modifications and changes were made to the ASTM procedure. First, the abrasion test machine (**Figure 23**) directly

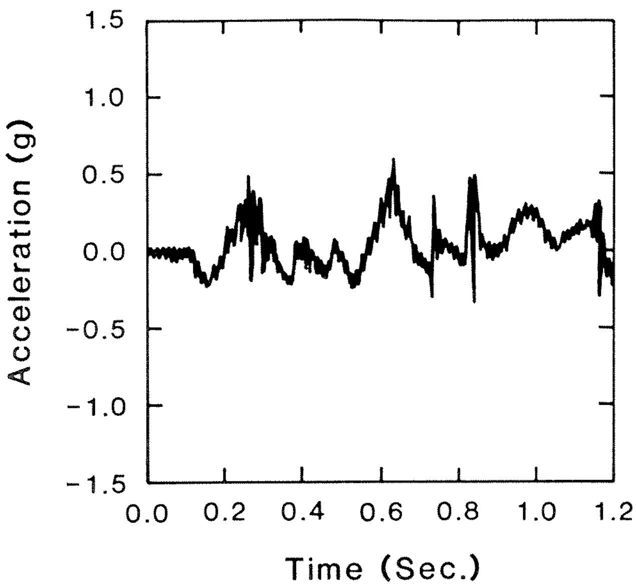

Figure 20.
Horizontal acceleration response: Circular foamtire.

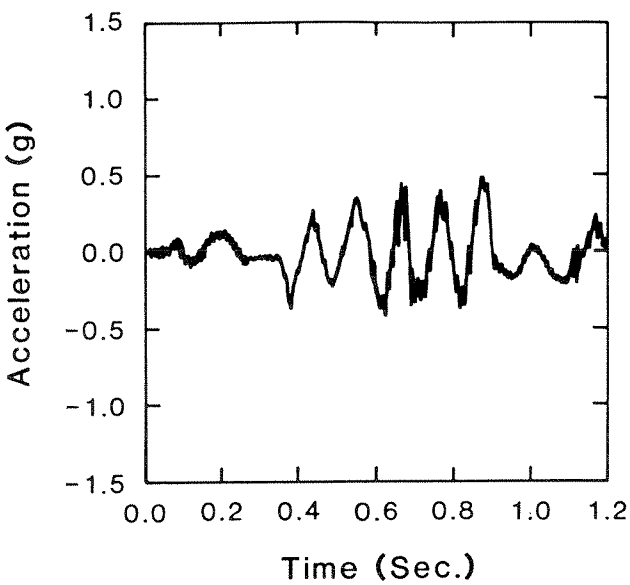

Figure 21.
Vertical acceleration response: Circular foam tire.

applied the load, and only one sample was tested at a time. Second, a coarse grit (#80) emery paper (aluminum oxide) was used as the abrasive. Third, an air suction system was the only method employed to clean the abrasive surface. Fourth, the exact surface speed of our abrasive wheel was 679 inches per minute (6-inch diameter wheel rotating at 36 revolutions per minute). Finally, a solid polyurethane material was used as the break-in compound and one of the reference compounds along with the National Bureau of Standards (NBS) reference compound. The standard compound was changed in part because ASTM states that, "misleading results are obtained in polyurethane compositions compared with the standard reference compound." This laboratory approach to wear testing has not been correlated with the results of actual tire performance, and, for this reason, and the fact that our test procedure for these types of compounds has not yet been perfected, the results of this test should be considered as a gross representation of relative wear characteristics.

Following the procedure of ASTM D 1630-83, an abrasive index was calculated using the following formula:

$$\text{Abrasive Index} = (R_1 / R_2) \times 100 \qquad [4]$$

where, R_1 = number of revolutions to abrade 0.1 inch of the test specimen, and

R_2 = average number of revolutions required to abrade 0.1 inch of a reference compound. R_2 is run before and after the test specimen run.

The abrasive indexes calculated for the various materials, using both reference compounds, are shown in **Table 5**. The polyisoprene material (molded tire) was found to be the most abrasion-resistant. **Figure 24** shows the relationship between wear depth and number of revolutions for the various materials tested. The uncertainty in measured wear depth is plus or minus 0.006 inches. The foam tires have a harder skin, Shore 70A, than the body of the tire, Shore 52A. In this test, the skin, which was less than 1/16-inch thick, wore away at approximately the same rate as the body of the tire.

Table 5.
Tire Material Abrasive Index.

Tire type	Abrasive index (NBS reference)	Abrasive index (Polyurethane reference)
1. Foam	48	57
2. Molded	127	116
3. Pneumatic	19	28

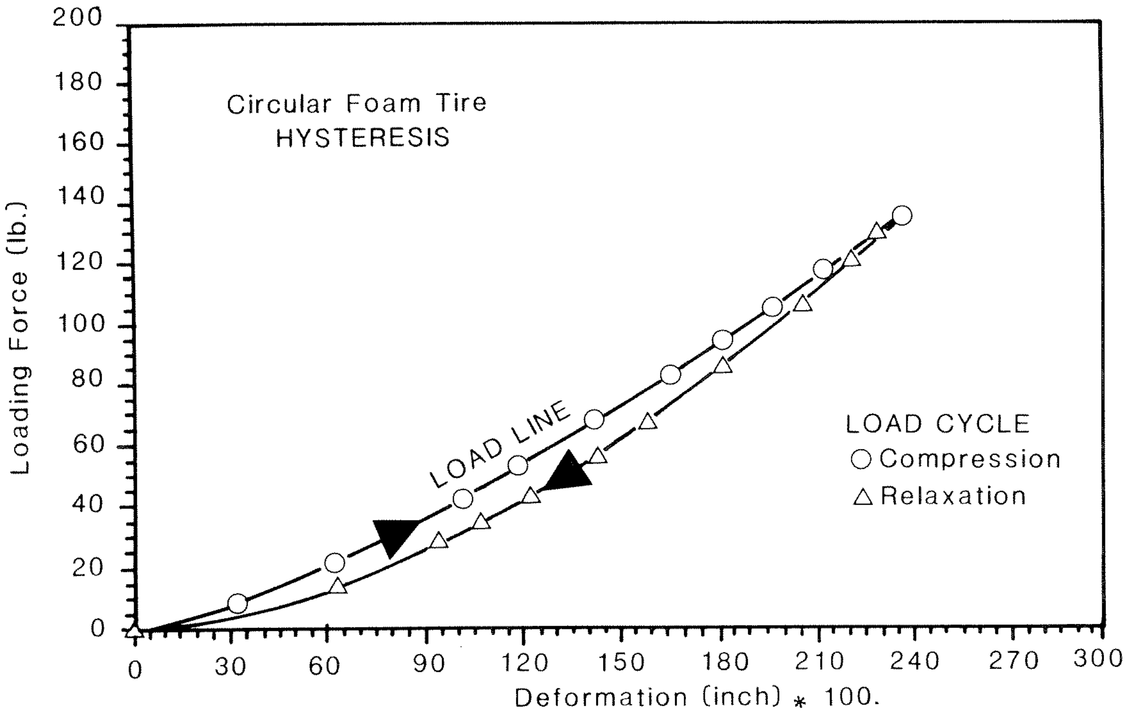

Figure 22.
Hysteresis: Compression and relaxation load cycle.

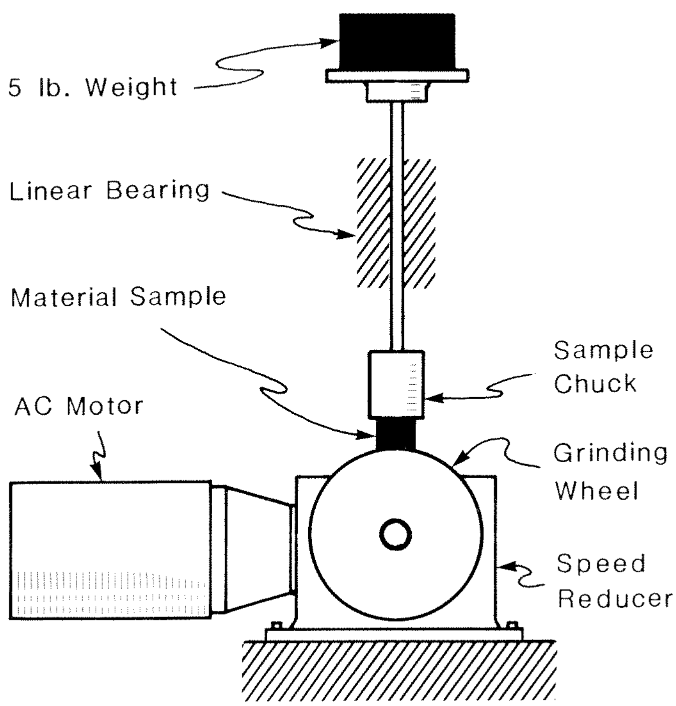

Figure 23.
Abrading machine.

COMPRESSION SET

When a material does not return to its original shape in a reasonable time after being compressed for a period of time, the effect is called compression set. The four types of tires were tested for their resistance to compression set following the procedure of ASTM D 395-85 (Rubber Property—Compression Set) Method B, Compression Set Under Constant Deflection in Air.

The ASTM test was modified as follows to make this test more applicable to wheelchair tires: 1) the tire was tested in place on its wheel (this was made possible by using the arrangement of **Figure 25**); 2) the compression anvil chosen was a 1/2-inch diameter rod similar to that used for most wheelchair parking brakes; 3) each tire was compressed 4.8 mm for 22 hours at approximately 72 degrees Fahrenheit and then released; and, 4) the maximum compression deflection remaining in the tire after 30 minutes was recorded and the compression set was then expressed as a percentage of the original deflection.

Table 6 gives the results of this test. It is interesting to note that the tapered foam tire significantly outperformed all other tires, and that

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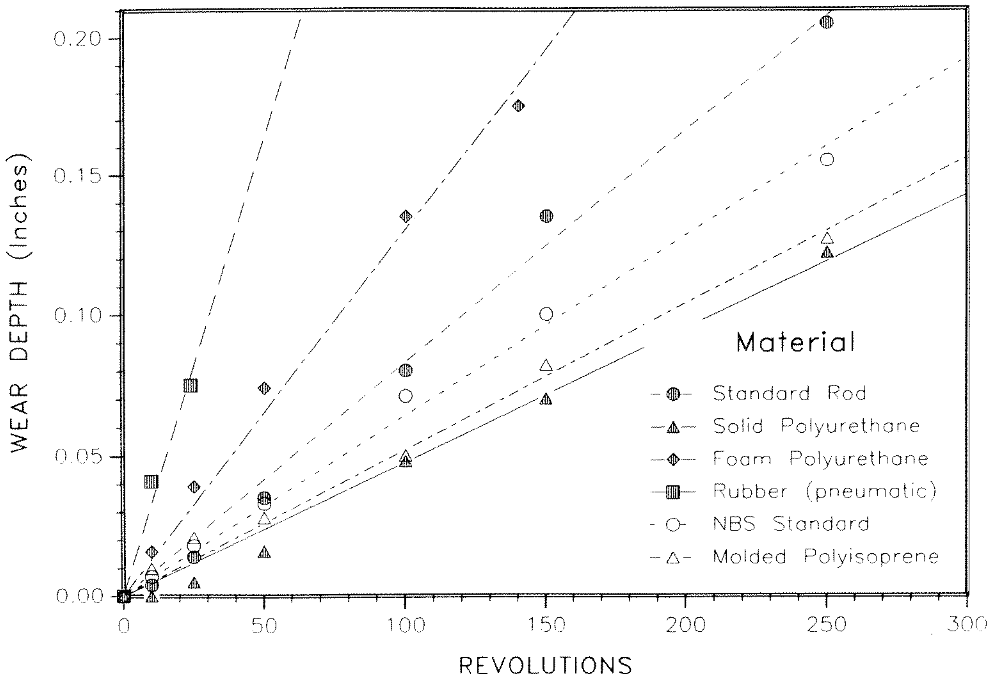

Figure 24.
Wear rate: Wear depth versus revolutions of the abrader.

the circular foam tire had a high compression set even though it was made from the same material. These results suggest that tire cross-sectional geometry is important to compression set.

DISCUSSION OF RESULTS

The two foam tires show improved performance over the molded tires in all but one area (wear resistance), and in some areas, have improved performance over the pneumatic tires. Specifically, the tapered foam tires appear to be more resistant to wear and compression set than the pneumatic tires. When costs are considered along with wear rate, the advantage of the foam tires is clearly indicated because it is twice as wear resistant; and the tapered foam tires are one-third as costly as the pneumatic tires (see cost data in the **Appendix**). Note that the advantage the molded tires have in this area decreases under the same cost versus wear comparison. In addition, the tapered foam tires provide the user with a 50 percent weight reduction over the pneumatic tires, a savings of 1.62 lbs for a pair of tires in this case (see weight data in **Appendix**). Also, the tapered foam tires have overcome the problem of high compression set that has continually plagued airless tires. The compression set of the circular foam tires is much greater than the tapered foam tires and almost the same as that of the pneumatic tires. This suggests that the volume of material compressed affects compression set.

Table 6.
Compression Set Test.

Tire type	% of Original Deflection
1. Tapered Foam	3.2
2. Circular Foam	11.1
3. Molded	21.2
4. Pneumatic	10.6

The two main areas of concern regarding performance, as generally indicated by the wheelchair user, are ride comfort and maintenance. The airless tires have a great advantage over pneumatic tires with regard to maintenance, but, due to their advantage in ride comfort, pneumatic tires continue to be preferred over airless tires. In the area of rolling resistance, an improvement of approximately 15 percent is still necessary before the foam tires will match the performance of pneumatic tires, and an improvement of greater than 15 percent at high loads is required for the circular foam tires to match

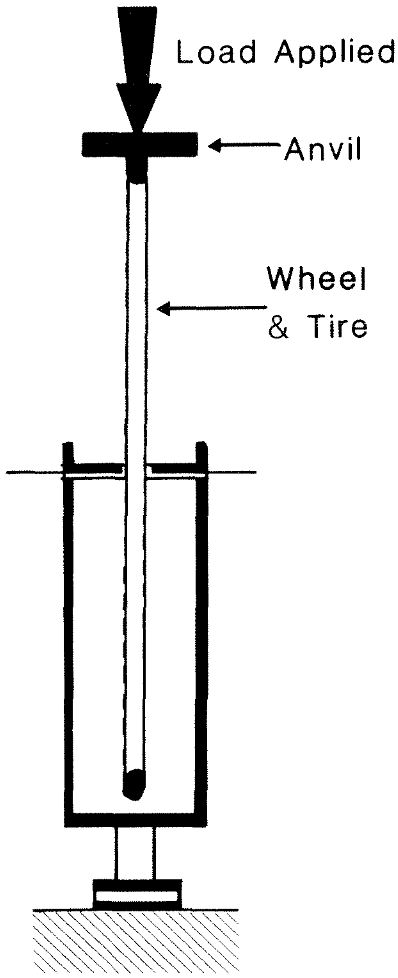

Figure 25.
Compression set test.

the performance of the pneumatic tires. On the other hand, the advantage for using pneumatic tires is reduced when they are not properly inflated (75 percent of rated inflation increases the rolling resistance by approximately 10 percent). The spring constant of the circular foam tires is within 19 percent of that for the pneumatic tires, and the lower the spring constant, the better the ride. A reduction in the spring constant leads to improved impact-absorption ability. Due to its higher hysteresis, the circular foam tire seems to have equaled the pneumatic tire in impact absorption without having to match the spring constant. It should be noted that this study assumes that the ride characteristics of a high-pressure pneumatic tire are the optimum condition, and, since the foam tires are such a dramatic improvement over the molded tire in spring constant and impact absorption, their ride may actually be preferred over the pneumatic tires by some users. As with any shock or vibration-absorption problem, the trade-off is between the actual motion the rider experiences, and the forces he feels.

While these new foam tires are unable to completely match the operating characteristics of pneumatic tires, they are a definite step closer to the goal of maintenance-free tires that meet the performance standard set by high-pressure pneumatic tires. The circular foam tires, in particular, should be considered as a viable alternative to pneumatic tires.

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REFERENCES

1. American National Standard: *Determination of Coefficient of Friction of Test Surfaces.* ISO 7176/13, 1987.
2. American National Standard: *Static, Impact, and Fatigue Strength for Wheelchairs.* ISO 7176/8, 1987.
3. **Kauzlarich JJ, Thacker JG:** Wheelchair tire rolling resistance and fatigue. *J Rehabil Res Dev* 22(3):25-41, 1985.
4. **Thacker JG:** *Measurement of Wheelchair Rolling Resistance.* University of Virginia Rehabilitation Engineering Center Report No. UVA-REC-107-83, Sept. 1983.
5. **Thomson WT:** *Theory of Vibration with Applications,* 2nd Ed., Prentice-Hall, 1981.
6. *Wheelchair III: Report of a Workshop.* Bethesda, MD: Rehabilitation Engineering Society of North America, 1982.

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APPENDIX

Two Polyurethane Foam Tires: Tapered section and circular section (See **Figures 2 and 3** for dimensions)

Manufacturer:	Captive Air, Inc. 2330 S. Susan Lane Santa Ana, CA 92704 Phone (714) 556-9000
Distributor: (tapered tire)	Everest & Jennings, Inc. 3233 E. Mission Oaks Blvd. Camarillo, CA 93010 Phone (805) 987-6911
Material:	Polyurethane Foam, two nylon cords at rim
Hardness Shore A:	72 (skin) 52 (body)
Cost to consumer:	Part 90000A01 $14/tire (tapered)
Weight/tire:	0.81 lbs (tapered)
Distributor: (circular tire)	Motion Designs 2842 Business Park Ave. Fresno, CA 93727 Phone (209) 292-2171
Material:	Polyurethane foam, four nylon cords at rim
Cost to consumer:	Part 386250, $22/tire (circular)
Hardness Shore A:	70(skin) 52(body)
Weight/tire:	1.18 lbs (circular)
Test rim:	Everest & Jennings, SS2 rim "Mag" style with seven spokes, plastic

Molded Polyisoprene Tire (See **Figure 1** for dimensions)

Manufacturer:	Daniel T. Moore, III, Co. 12819 Coit Road Cleveland, OH 24108 Phone (216) 268-1288
Distributor:	Invacare Corp. 899 Cleveland St. Elyria, OH 44036 Phone (216) 329-6000
Material:	Polyisoprene rubber molded around a 3/8-inch polyethylene tube
Hardness Shore A:	80
Cost to consumer:	Part B1210D-5, $41.60/tire
Weight/tire:	1.12 lbs
Test rim:	Invacare wheel & tire "Mag" style with 6 inner and 12 outer spokes, Mat.: aluminum

Pneumatic Tire

Manufacturer:	Carlisle Ribgripper, USA
Distributor:	Everest & Jennings, Inc.
Material:	Grey rubber, nylon cord
Hardness Shore A:	75
Cost to consumer:	Part WT-24P-T-137P-G $32.80 (tube $7.30)
Weight/tire: (includes tube)	1.62 lbs
Test rim:	Same as for the foam tire
Dimensions of tire:	24″ × 1-3/8 inches at 60 psig