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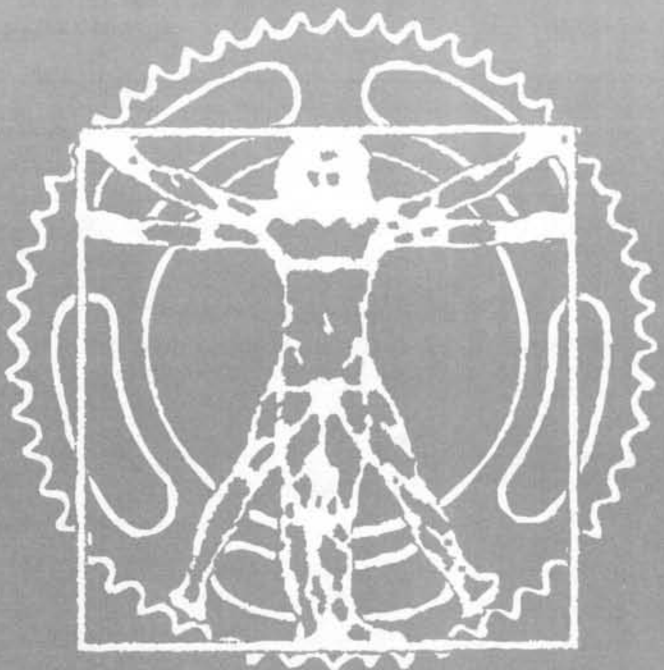

# HUMAN POWER

## TECHNICAL JOURNAL OF THE IHPVA

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Association
David Gordon Wilson, editor
21 Winthrop Street
Winchester, MA 01890-2851, USA
Phones: 617-729-2203 (home)
617-253-5121 (MIT); 617-258-6149
(FAX)
dgwilson@mit.edu (email)


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Additional copies of Human Power may be purchased by members for $3.50 each, and by non-members for $5.00 each.



We welcome contributions, preferably on a PC diskette, for Human Power. Send them to the editor at his address above. He would be happy to send guidelines on preparing contributions. They should be of technical or longer-term interest: news and notices etc. should go to HPV News at the IHPVA address above.

We are indebted to the authors, to Dot Cavignano, MIT, for transcription, and to Len Brunkalla and his volunteers, whose dedicated help made this issue possible.

*Dave Wilson*

## *In this issue*

### Off-road travel with a human-powered vehicle

Recumbent enthusiasts usually concede that their favorite vehicles are no challenge to mountain bikes off-road. Greg and Dwight Fisher make a strong case for their highly effective design of a two-person four-wheeled recumbent "Animas 96" (pp. 3-6).

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### My HPV - a long-range, practical, human-electric hybrid

Mike Saari believes that the combination of lead-acid batteries, a small motor, a human, and a streamlined recumbent constitute a combination that can yield a vehicle with a 500-km (300-mile) range. This is a well-thought-out argument backed by practical results (pp. 6 - 12).

---

### Lelystad report

The 1995 World HPV championships in The Netherlands were first cancelled by the original organizers and then rescued by Marielle Bakker and Sacha Knoop whose Herculean work produced a memorable week. Wouter Suverkropp writes a brief report on his experiences (p. 12).

---

### The "Extra-energy exposition: tests, symposium and races

"Extra-energy" vehicles are defined as those that could be propelled by human power alone, but can also be fitted with electrical power assistance (possibly solar) for hills, long range and so forth. Theo Schmidt reports on a meeting in Koln, including tests, classifications, regulations, and 1996 races (pp. 13-15).

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### "Pedeluxe" cyclecar

Michael Eliasohn discovered an article about a 1920s British HPV by Sidney Whitehead. Eliasohn found that Whitehead is still very much alive, and they worked together on the version of the article given here, with an introduction by Eliasohn that puts it into context (pp. 15-16).

---

### Greenspeed tyre testing

"Greenspeed" is the name Ian Sims gives to his range of environmentally friendly HPVs. In the course of developing these in Australia he carried out some simple but valid tests on the rolling resistance of tires (spelt "tyres" in civilized countries). He produced a table in which he gives the rolling losses of an extraordinary number of tires for several inflation pressures (pp. 17-18).

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### Wing sails for practical HPVs

Peter Sharp continues his campaign to bring us out of our shuttered thinking, especially with regard to using the wind, normally regarded as a bane to bicycling, for its potential benefit. It is one of those concepts that can be a little frightening until its advantages and disadvantages are squarely faced (pp. 19-20).

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### Human-powered aircraft for sport

Chris Roper reports on a conference at the Royal Aeronautical Society, London, on the possibilities of developing a sport around human-powered aircraft. A new Kremer prize is aimed at encouraging developments in that direction (p. 22).

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### Reviews

"The American bicycle" is "the first-ever color history of the American bicycle industry" and is given a favorable review by Michael Eliasohn (p. 16).

Oliver Zechlin has put around 2000 color photos of HPVs along with much other HPV-related information on a CD-ROM. Your editor comments happily on his first hour of viewing (p. 16).

Helmut Walle reviews a 1984 book on building fiberglass boats that he believes would give useful guidance to HPV constructors (p. 18).

Doug Milliken reviews a book that your first IHPVA president, Allan Abbott, and your editor worked on "Human-powered vehicles" (p. 21).

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### Editorials

This section is, for this issue, a broad survey of the range of high-quality publications now covering non-traditional HPVs (p. 23).

*Dave Wilson*

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# HUMAN POWER

Vol. 12, no. 3 Winter-spring, 1996 $5.00 ($3.50 members)


## Off-road travel with a human-powered vehicle

by D. Greg Fisher and Dwight S. Fisher


### SUMMARY.

The Animas ™ Quadracycle is a human-powered vehicle (HPV) designed for off-road applications as an alternative to fossil-fueled vehicles. Stability, ease of use, and a low negative environmental impact in the limited off-road recreational areas available were key considerations in the development of the Animas QC. It is a two-person, side-by-side, four-wheeled semi-recumbent cycle with both rear wheels driven and fully independent suspension. The fifteen claims of U.S. Pat No. 5326121 "Human-powered four-wheel on-/off-road vehicle" (D. G. Fisher, Tucson, AZ, July 5, 1994) address mechanical systems that reduce rolling resistance, optimize rider efficiency, and improve control of the vehicle. (World Wide Web URL is: http://www2.ncsu.edu/ncsu/cals/crop_sci/dsfisher/quadphot.html)


### INTRODUCTION.

Fossil-fueled all-terrain vehicles (ATVs) and four-wheel-drive automobiles have negatively impacted many of the natural areas available for recreation with off-road vehicles. The use of a viable off-road HPV would reduce the negative impact of vehicles on the environment. In designing off-road HPVs the two-wheeled "mountain bike" configuration would be rejected if it were not traditional. While the safety-related issues of a two-wheeled vehicle for on-road travel may be manageable, the inherent instability of the design becomes a dangerous handicap off-road. During a climb on an unfamiliar course, riders should naturally be able to stop safely and survey the course without falling over or coming off the pedals. In addition, during rapid descents with the possibility of hidden obstacles such as large rocks in grassy areas and patches of sand the vehicle should handle the obstacle without requiring extraordinary skill from the rider. In a recreational setting, many people prefer a tandem vehicle: however, a tandem mountain-bike configuration can aggravate the lack of stability and the common requirement of matched cadence is an additional safety risk on uneven terrain. The long wheelbase and low crank arms can cause problems when cresting a hill. Limiting the vehicle to two wheels makes sense only in a vehicle first developed for riding on the road and then adapted for off-road use without any real consideration of substantive redesign. In a design specific for the type of terrain that would be likely to confront an off-road vehicle, four wheels would provide for a stable, self-righting platform against side-to-side and front-to-back forces. Four wheels offers more stability than three wheels and results in only two tracks, permitting a straddling of terrain, as compared with three tracks for a three-wheeled vehicle.

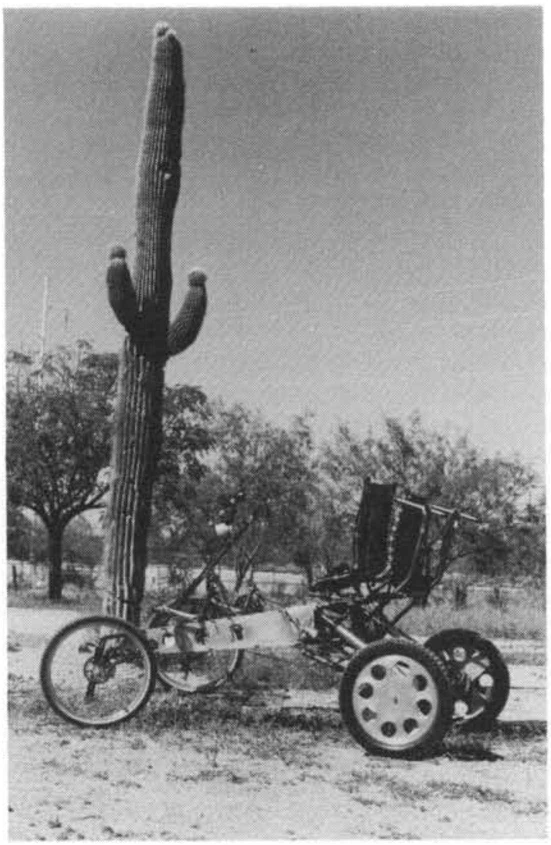

*Figure 1 The Animas 96*

Previous patented velocars in this same configuration include Nelson, Four-wheel Reclining Position Cycle, US Pat.No. 4,674,762; Pomerance, Bicycle for Two, US Pat. No. 3,836,175, and others. However, none employed suspension wheel travel or ground clearance of the magnitude required for the off-road environment. The human-powered moon buggy proposed by D.G. Wilson in the late 1960s for NASA's use on the moon was not designed to operate in the earth's gravitational field (Wilson, 1970). The upright riding position cannot be considered because of the aerodynamic losses when compared to reclining (Gross et al., 1983). The semi-recumbent position also gives a lower center of gravity and more sustainable riding.

Filling the gap between mountain bikes and the tube-frame sand buggy is a new class of vehicle developed over the last four years called the Animas QC. The Animas QC is a two-person, side-by-side, four-wheeled semi-recumbent cycle with both rear wheels driven and fully independent suspension. The fifteen patent claims address mechanical systems that reduce rolling resistance, optimize rider efficiency, and improve control of the vehicle. The design of the Animas QC draws upon pioneering efforts in the field of human-powered vehicles and incorporates airframe/aerospace technology with commonly available bicycle components.

### FRAME DESIGN

The Animas QC frame, to which all mechanical systems are attached, is comprised of four trusses, two of which lie below the riders, the others placed at an angle of 90° serving as structures loaded through suspension components. Materials used are steel tubing [seamless 4130 cromoly 22.2 mm (7/8 in.) diameter and 1.24 mm (0.049 in.) wall] mitered and MIG welded at the joints, supplemented by sheets of 1.65-mm (.065 in.) -thick aluminum alloy (7075-T6). Formed as a wrap-over to the underlying tube frame while in the annealed state, it is then heat treated to 482C (900 F), quenched, and maintained at 121C (250 F) for 24 hrs to bring up to a T6 state. These panels are attached to the tubing in aerospace fashion by the flush head Huck-Clinch blind rivet produced by Huck International.

## SUSPENSION AND BRAKING DESIGN

A recumbent HPV requires suspension, at least for rough terrain, because the rider cannot use his or her legs as a suspension component as is possible with an upright bicycle. Suspension allows impact with the ground to be spread over the entire frame and to increase rider comfort. Riders could be tossed about or could even be thrown without suspension and the suspension provides a more comfortable ride. With large amounts of wheel travel, the impact upon loose debris is reduced; thus less energy is lost in propelling the vehicle. The dynamic action of extension and compression necessitates suspension systems that are designed to maintain correct toe-in to reduce frictional loss through misalignment. Precise adjustment of camber and toe-in are an essential part of reducing rolling friction on the Animas QC whether on the road or off. This is accomplished by using the common spherical rod-end joint at all of the suspension-, steering- and control-pivot locations. The Aurora ALM-8, 12.3-mm (0.5-in.) male-threaded aluminum rod end is used because of its wide availability, light weight, and low cost. Eleven are used in the traditional manner, as well as four in a sliding configuration. These units, along with properly sized axle bolts, also serve as mechanical limiter fuses; i.e., components designed to bend instead of the chassis if

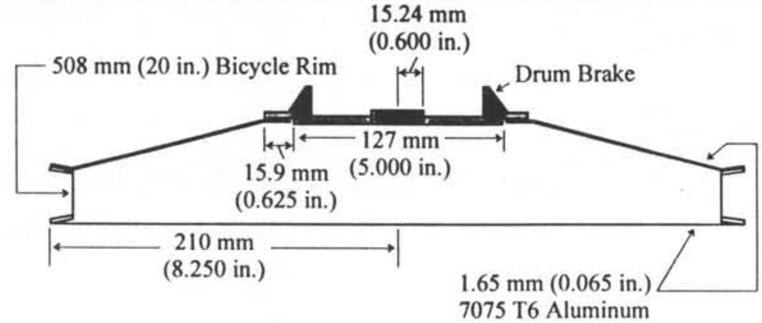


*Figure 2 Diagram of rear-wheel design*

the riders are regularly exceeding weight and suspension limits. Beyond that level of impact, wheels, front spindles, rear control arms, and frame ends, respectively, bear progressively greater weight.

For quadracycles, without the ability to lean into turns as would a bike, the four wheels receive higher side loading of the wheel/axle while at the same time may be supported only from the inside with a stub axle. Hub brakes are therefore a necessity because of the lack of a fork upon which brake posts (for rim brakes) are attached. The advantages of this layout include better side-to-side stability when the wheel centerlines are placed outside (instead of under) the riders. Serviceability benefits as no mechanical disassembly is required in order to do tire or tube replacement. A rear steering brake, similar to the cutting brake of a dune buggy/sand rail, has been incorporated in the design. For this application, the Arai-tandem-bike brake drum is used as an integral part of the rear wheels (fig. 2). With a fixed drive sprocket on the outside of the brake drum, formed panels of 7075-T6 aluminum alloy attach the drum to the 508.0-mm (20 in.) bike rim, the opposite side of the wheel being flat sheet (figure 3). The Bullseye rear hub is used because of 12-mm (.47 in.) axles and ease in converting to stub axle. With the brake drum threaded on the hub (where the freewheel would normally be) and all other parts held together by structural adhesive and solid-plug flush-head aerospace rivets either clenched or bucked, the wheel is capable of severe side loading. The use of 508.0 mm (20 in.) bike rims exploits the fact that 406.4 mm (16 in.) motorcycle tires may also be fitted, giving a wide variety of treads to choose from, ranging from 38.1 x 508.0 mm (1.5 x 20 in.) bike tires, up to 76.2 x 406.4 mm (3.5 x 16 in.) motorcycle trials tires. The advantages of motorcycle tread are extra traction and durability in the most severe conditions. The capability of controlling rear brakes independently of the front helps maintain steering contol. For example, biasing rear brakes left or right may aid in tight turns in loose material by dragging the rear wheel located to the inside of the turn.

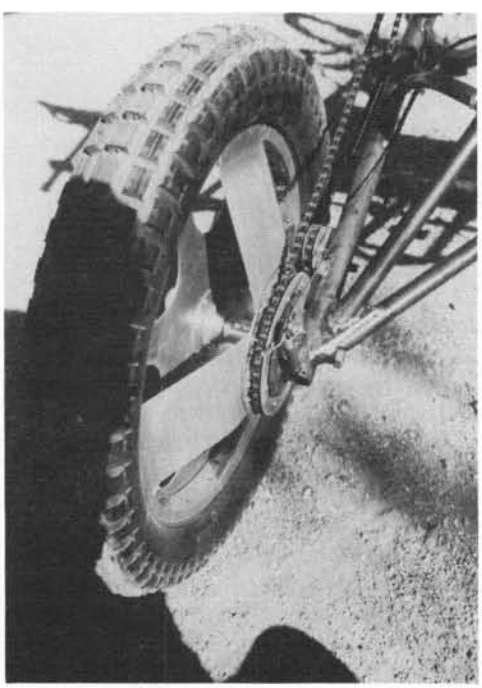

*Figure 3 Rear-wheel assembly showing drive sprocket and drum brake*

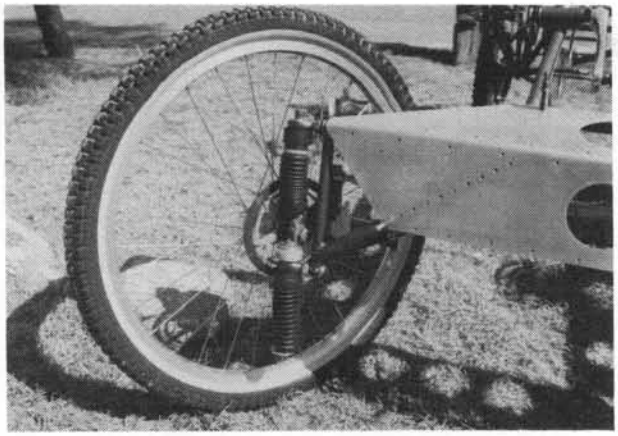

*Figure 4 Front wheel with disc brakes, suspension, and supplementary aluminum sheeting.*

Front wheels are 0.61 m (24 in.) Sun rims employing 32 DT Swiss spokes (figure 4). Hubs and disc brakes are manufactured by AMP, with floating rotors and calipers to minimize free-spinning drag. Axle-bolt diameter used in the AMP hub is 12 mm (0.47 in.) and was converted to stub-axle style by adding a rigid "crush sleeve" between the sealed bearing-cartridge units. Front tires are 55.0 x 609.4 mm (2.125 x 24 in.) IRC Trial Winners, only slightly larger in diameter than the 76.2 x 406.4 mm (3.0 x 16 in.) motorcycle trials tires used in the rear.

The rear suspension is designed to absorb irregular terrain with wheel travel (x) of approximately one quarter of the average vehicle track width (y) and wheelbase (z). Expressed as an equation $x=0.25(y+z)/2$ or, in this case, 0.3 m (12 in.). Rear suspension uses trailing "A" arms swinging from four rod-end joints oriented along a horizontal transverse line, 0.53 m (21 in.) ahead of the rear-axle centerline. This provides for large amounts of travel without either scrubbing the tires side to side or toeing in or out (bump steer). Three different mounting points on the rear control arms for shock/spring mounting change the leverage applied slightly, while also affecting ride height and compression limit. The "A" arms leverage at three to one against aluminum-bodied, nitrogen-gas, tube shocks with rod-end weighing 1.8 kg (4 lb) each (Marvin Shaw Engineering, Yarnell AZ). With an extended length of 0.39 m (15.5 in.) and compressed length of 0.27 m (10.5 in.), rear-wheel travel (theoretically) is 0.38 m (15 in.). Urethane extension limiters remove over 50 mm (2 in.) as do soft compression stops. Approximately 0.3 m (12 in.) of useable wheel travel is left. The spring rate can be increased by adding nitrogen through the charging port, a common service at many motorcycle/ATV shops. Also, the overall length of the shock is adjustable by threading the rod ends in or out to change ride height and compression limit without affecting the leverage ratio.

A "sliding kingpin" design of independent suspension provides a minimum of bump steer. Front spindles are constructed of 4130 cromoly shaft and MIG-welded tubing. Sliding vertically through four rod-end joints, a maximum of 102 mm (4 in.) of wheel travel is realized. Able to rotate around a vertical axis approximately 90 degrees left to right, lock to lock, gives a turning circle of 6.4 m (21 feet). High caster angle (16 degrees) reduces peak side loading in turns by leaning the front wheels into the turn and also returns to center (straight ahead) easily. The two front spindles are linked through a common transverse tie rod with the left side linked to the pilot's steering column shaft. Toe-out on turns is accomplished using standard Ackerman angles.

## SEATING

Seating on the Animas QC is semi-recumbent with quick-release adjustments that accommodate pilots and stokers ranging from 1.60 to 1.93 m (63 to 76 in.). Seat angle is easily changed from a more upright position for hill climbing to an extreme recumbent aero position with a slight loss of maximum leg length in the latter. The seats are manufactured by Rotator Bicycles (Santa Rosa, CA).

## DRIVE-TRAIN DESIGN

To maximize flow of energy to rear wheels, the wheel on the outside of the turn must be allowed to rotate more quickly or overrun the wheel on the inside of the turn. In the distribution of power between rear wheels, when traveling straight ahead the simplest solution would be to turn each of the rear wheels equally as in a locked rear axle. In turns, however, the rear wheels describe circles of different diameters and wheel skid would occur. Straight axles found in engine powered ATVs are far too energy inefficient for consideration on a HPV. A conventional differential has the ability to transmit even torque to both rear wheels during unequal wheel speeds provided either tire has traction enough to accept one half of the energy available. Above that level, one-wheel spin, or slippage occurs causing energy loss and inability to use all of the other wheels available traction. The "limited-slip differential" or simple friction clutches between spider gears also result in energy loss that HPVs can not afford. The Torsen-Gleason torque-sensing differential (if a lightweight version were made) might also be an option if the riders were in line as on a tandem bike but this would create a much longer wheel base or excessive overhang beyond the axles. The use of freewheels (one-way-drive ratchets with sprockets) at each rear wheel would require a fork and identical left and right rear wheels. In a stall situation, power from two humans will stretch the limits of durability of bicycle free wheels. The freewheel must be placed in the driveline ahead of the reduction to the rear wheels in order to decrease the peak applied torque.

In the Animas QC, to split the energy in an equitable fashion, "output free wheels" are employed. These units differ from "input free wheels" only in their orientation of drive direction being placed upon a common transverse driveshaft (figure 5). All wheel bearings, chain-tensioner idlers, and bottom-bracket shells are fully sealed Timken bearings.

The "input free wheels" are driven by chains; the "output free wheels"

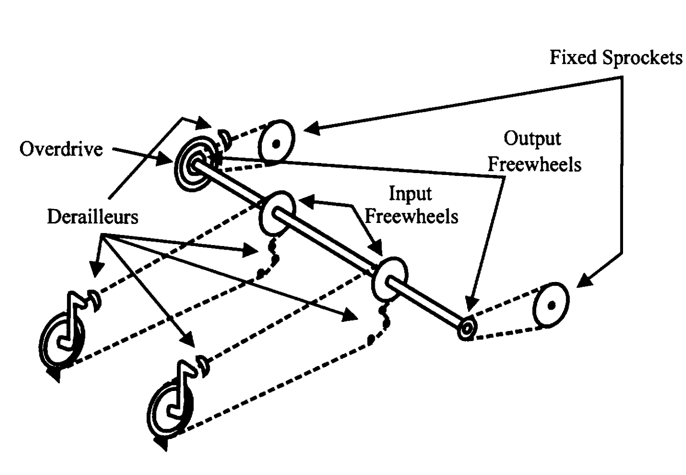


*Figure 5 Diagram of the Animas drive train*

drive chains going to fixed sprockets on the rear wheels. This arrangement allows either wheel to overrun the other and still drive both rear wheels without wheel spin in the event of loss of traction to one wheel. The use of two separate input freewheels allows dual cadence from independent selection of gearing by each rider. The ability to start or stop at will without the coordination of the other rider increases the effectiveness of the rider's production of power, similar to having two separate engines in different gears on the same vehicle. One rider may carry the load as the other gears down, lessening the chance of bogging down to a stop in an unmanageable gear. The availability of 21 speeds (3 x 7) for each side is given further range with a 3-speed "overdrive" on one of the output freewheels. The overdrive is used to propel the vehicle in one-wheel-drive for road speeds. This additional gearing affects both riders and is enabled by a separate derailleur. As the speeds increase in an overdrive gear, the opposite side's single-speed sprocket simply overruns through the output freewheel.

## USE AND OPERATION

First impressions during riding the Animas QC are somewhat contradictory because the elements of bicycle and automobile travel combine. New riders expect to lean into turns and instead feel the opposite take place. At the same time, automotive experience says that it is more car-like except for the lack of a body surrounding the occupants. Once accustomed to the new paradigm, confidence in one's ability to pitch from side to side without approaching roll-over builds. Then traversing otherwise dangerous (or formerly impossible) obstacles becomes more and more natural. Curbs, stairways, and rock impacts are soaked up by the long-wheel-travel suspension and many first-time riders repeatedly look back to verify what passed below. Long rides require more leg energy than most ordinary bicycles because of the greater mass and frontal area, but most riders report that they are compensated by the more comfortable seating, the ability to stop pedaling without dismounting, and lower loading of the knees and spine. The latter becomes more apparent when the terrain approaches the highly technical type of mountain-bike riding. Large drops of several feet are not difficult once the pilots grow confident of their vehicle and their own ability to shift weight to ease the impact. Maintaining momentum when terrain changes to soft sand or rock fields is the forte of the Animas QC, with its high-efficiency suspended chassis and flexible drive train.

Testing of the Animas '96 has been going on for two months and for 200 hours of severe use on rocky riverbeds with water as high as 450mm (18 in.) as well as sand and brush. On the road, a top speed of 40 km/h (25 mph) is possible for bursts, and 18-23 km/h (11-14 mph) average cruising speed.

## CONCLUSION

The Animas QC is an HPV designed for off-road travel with two persons and up to 45 kg (100 lb) of payload. The inherent stability of four wheels allows a margin of safety that is not possible with two- or three-wheeled vehicles. The use of widely available cycle and aerospace components gives excellent durability and ease of servicing or repair. Both recreation and utilitarian markets are potential users of this new technology.

## SUMMARY SPECIFICATIONS OF THE ANIMAS QC

Weight - 56.7 kg (125 lb) with motorcycle tires in rear
Width - 1.32 m (52 in.)
Capacity - 199 kg (440 lb) with 30% overload margin + 57 kg (125 lb) = 256 kg GVW (565 lb)
Wheelbase - 1.65 m (65 in.)
Length - 2.26 m (89 in.)

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Wilson, D. G. 1970. Human-powered space transportation. Galileo ?Volume?:20-26.

Fisher, Daniel G. US Patent No. 5,326,121; July 5th 1994; Human-Powered Four-Wheel On/Off-Road Vehicle; Tucson Az. (This patent covers various aspects of the suspension and drive train.)

*D. Greg Fisher, 4932 E. 3rd St. Tucson, AZ 85711-1258*
*Dwight S. Fisher, 7216 Bentley Circle Raleigh, NC 27604*

*D. Greg Fisher has been designing, building, and riding HPVs for more than 10 years. Dwight S. Fisher is his brother, an avid cyclist, and designer of the Animas WWW material.*

# MY HPV - A LONG-RANGE, PRACTICAL HUMAN-ELECTRIC HYBRID

by Michael Saari

## OVERVIEW

How could one design an electric vehicle with a 500-km (300-mile) range? This article describes a concept for an inexpensive, long-range electric vehicle.

It started with a simple idea. Aerodynamic, human-powered HPVs are clean and silent and optimized to produce maximum speed with minimum power. Electric vehicles are clean and quiet, but are limited by battery packs that hold too little power - hence limited range. Today's HPVs achieve 50+ km/h with less than 300 watts of power. Twenty kg of lead-acid batteries contain about 700 watt-h of energy. Put them together and voila! - a clean, silent electric vehicle. So I built one. The result: a long-range human/electric vehicle. But what's the operating range? This turns out to be a subtle question, and the final answer is surprising. Join me as we explore this question.

## CONVERSIONS

Non-metric readers: use the following handy approximate conversions.

| | |
|---|---|
| 20 kg | 45 lbm |
| 160 km | 100 miles |
| 10 km | 6 miles |
| 32 km/h | 20 MPH |
| 40 km/h | 25 MPH |
| 48 km/h | 30 MPH |
| 750 watts | 1 horsepower |
| 300 watts | 0.4 hp (typical sustained output for excellent athlete) |
| 75 watts | 0.1 hp (typical sus tained output for average non-athlete). |

## LEAD-ACID BATTERIES ARE GOOD ENOUGH

Today's electric cars have battery packs that last only an hour or so at freeway speeds, and thus are hobbled by a limited range of only 80 km or so. There are expensive, advanced prototypes that can achieve 160+ km, but none is in full production as yet. And while there have been numerous attempts to produce electric bicycles, ordinary (upright) electric bicycles typically have a range of only 8-24 km, i.e. less than a hour of use at 32 km/h.

Because of this current situation, everybody believes that ordinary lead-acid batteries hold too little energy to be practical, *but they are wrong*. Here are the facts.

Lead-acid batteries have a specific energy of 35 watt-h/kg. Thus, 20 kg of lead-acid batteries contain about 700 watt-h of energy. (However, at fast discharge rates of one hour or so, most lead-acid batteries can deliver only about 60% of their rated capactiy.) Total motor efficiency of 50% is a conservative but reasonable assumption. So 2 kg of lead-acid batteries can deliver a net energy to the wheels of about 200 watt-h over a period of one hour.

*Photo 1 The converted Tour Easy*

Automobiles require power levels of about 7 - 40 kW, and peak power of about 70 kW. Bicycles require power levels of about 75- 400 watts. This difference is a factor of *one hundred!* Therefore

- 500 kg of batteries (35x500x0.5x0.6 = 5.25 kW-h) can propel an automobile at 40 kW for only 8 -12 minutes, after which the vehicle and passengers will be left stranded. Electric automobiles are thus hopeless or marginal with current technology. On the other hand
- 20 kg of batteries (35x500x0.5x0.6 = 210 W-h) can propel a bicycle at 75-300 watts for 0.7 to 2.8 hours, and human pedal-power is also always available.

However, upright electric bicycles have been commercial failures, as they require about 300 watts to travel at only 32 km/h and thus are also range-limited to 20 km or so at that speed. On the other hand, aerodynamic electric bicycles are totally feasible because of their significantly reduced power requirements.

## DESIGN SUMMARY

Thus, I assembled an aerodynamic electric recumbent bicycle in early 1994, using my ten-year-old Tour Easy with wheel covers, a new front fairing and surrounding body stocking, plus an add-on electric bicycle-motor kit from ZAP Systems (US:800-251-4555) and 20 kg of sealed lead-acid batteries. ZAP uses dual motors (about 250 watts each) with a common drive shaft/roller that presses directly against the front tire, and a simple three-speed on-off controller. The standard ZAP system has a top speed of 32 km/h but I wanted to achieve 50+ km/h, so I adapted the ZAP system (with a larger drive roller) for a lower torque but higher top-end speed. To avoid the need for shocks and a general vehicle redesign, I limited the battery weight to <25 kg. To maximize the range (and also to avoid vehicle redesign), I limited the vehicle design to a maximum speed of 50 kph.

My early results are encouraging. Even with my current aerodynamics (unrefined) and my current friction-drive system (inefficient), I can travel about 32 km at 40 km/h without pedalling. With only light pedalling at 40 km/h, I can make it about 40-65 km. With stronger pedalling or at slower speeds the range is even greater. (How much greater? Read on...) This is good enough to serve as a practical, clean, inexpensive car-alternative for many or most trips (including "no-sweat" commuting by the average, non-athletic Joe like myself). I hardly ever use my car anymore, and I don't miss it!

I also carry a lightweight battery charger on the bike. With midday battery charging, doubling or tripling these range numbers is a routine, daily event. I use ordinary electrical outlets, drawing about one penny's worth of electricity per hour. (A strategic "battery stash" for quick battery changeout can be used for yet another instant doubling.) But hang on, it gets better!

**CALCULATED RANGE**

I decided to see if I could file a patent on the design, and calculated some theoretical range values for this system. To my surprise, I started getting calculated range values at speeds of 32-40 km/h of 200 km, or 800 km, or 18,000 km - very strange! What's going on here? Oh, of course! With good aerodynamics and a speed of under 32 km/h, human power alone can sustain the speed. With a motor-assist current of zero, the "powered range" value at that speed is unlimited. Hmmm... How can one talk intelligently about the "range" of an electric-assist bicycle since the answer is always "unlimited" below a certain speed? The key is always to specify the speed at which the range is measured.

The physics of aerodynamics tells us that a vehicle speed increase of 2x causes a drag increase of 4x, and a power increase (force times distance) of 8x. The result of a 2x speed increase is a net range reduction (assuming finite fuel) of 4x. Range values are thus meaningless unless speeds are also specified. Anybody who quotes range values without specifying the measured speed is simply blowing smoke.

Aerodynamic drag at a given speed is directly proportional to the $C_dA$, or "effective frontal area" for that vehicle. Here are several typical values for $C_dA$ in $m^2$.

| | |
|---|---|
| Upright bicycle | 0.5 |
| Racing bicycle, full crouch | 0.25 |
| Semi-streamline recumbent (such as my prototype) | 0.125 |
| World-class streamlined HPV | 0.06 |
| Gold Rush HPV former speed champion | 0.04 |

Let us compare two vehicles, identical in all respects except that one has a 2x aerodynamic improvement over the other, i.e. half the aerodynamic drag at any given speed. With no change in speed, the total power requirement will be reduced by 2x. How much will this 2x aero

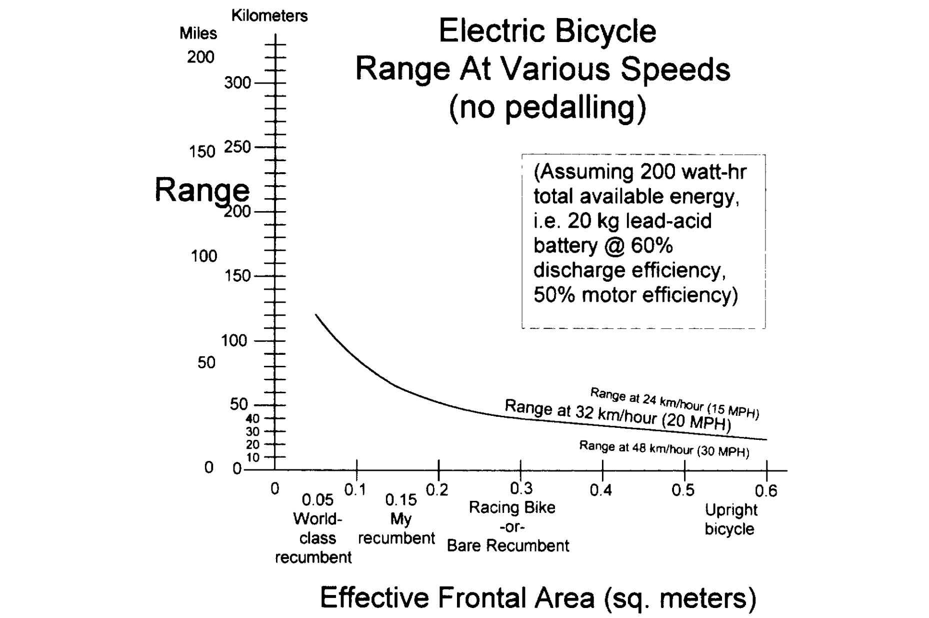


*Figure 1 Power required to maintain various speeds as a function of vehicle aerodynamics*

improvement improve the range of the second vehicle? (The aero improvement can generally be used either to increase the range at a given speed, or can be used to increase the available top speed. But the possible speed increase is proportional only to the cube root of 2, i.e. 1.26, or a 26% speed increase.)

For simplicity, this analysis will keep the vehicle speeds constant and focus on the range improvement at that given speed. Let's calculate the range improvement for several variations of bicycles/HPVs, electric vehicles, and human-electric hybrid vehicles. We will specify 30 watts of rolling resistance at 32 km/h in all cases.

**BICYCLE or HPV**

Range is unbounded in all cases, but aero improvement can either reduce the athletic level required or can yield a small speed increase.

For an ordinary upright bicycle (0.5 $m^2$ effective frontal area) at 32 km/h, the power is (210+30)=240 watts, giving an "unlimited" range with a strong athlete [limited, of course, by the need for food and sleep - ed].

For 2x aerodynamic improvement, e.g. a racing bicycle with full crouch, the power is (105+30)=135 watts, giving unlimited range with a "regular" athlete.

For a 4x improvement (0.125 $m^2$) e.g. semi-streamlined recumbent, the power required is (52+30)=82 watts, allowing unlimited range by a non-athlete.

**ELECTRIC VEHICLE**

Let us specify 20 kg of batteries, for 350 (20x35x0.5) watt-hours of net capacity. (Then reduce by discharge efficiency which varies from 60% to 95%, depending on discharge rate.) See figures 1 and 2. Each 2x aero improvement applied to an electric vehicle (without human power) will generally cause a range improvement of a full 2x. (The constant-rolling-resistance factor tends to be offset by the improved discharge efficiency at slower discharge rates.)

For an ordinary upright bicycle (0.5 sq. meters) at the chosen speed of 32 km/h and a battery efficiency of 60%:
power=240 (210+30) watts;
battery life=0.88 hours; and
range=28 km.

For a 2x aero improvement (0.25 $m^2$) e.g. racing bicycle, full crouch:
power=135 (105+30) watts;
battery efficiency=70%;
battery life=1.81 hours; and
range=58 km.

For a 4x aero improvement (0.125$m^2$) e.g. semi-streamlined recumbent:
power=82 (52+30) watts;
battery efficiency=80%;

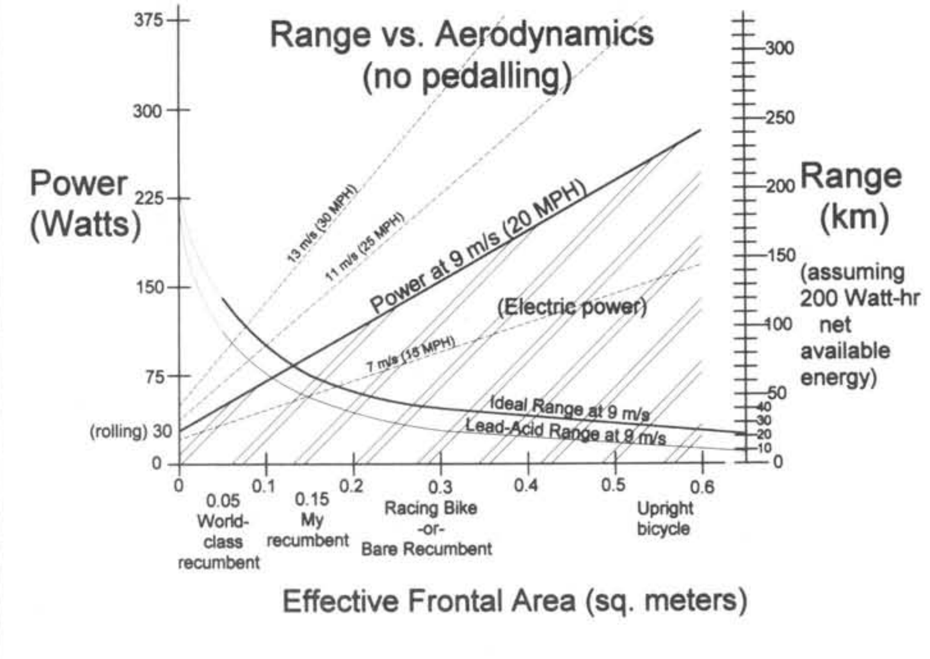


*Figure 2 Range of an electric bicycle at various speeds with no pedalling*

battery life=3.41 hours; and range=109 km.

So far, so good. A range improvement from 28 km to 109 km (compared to an upright electric bicycle) is quite a significant increase - and it didn't even require world-class aerodynamics.

Maximum range at 32 km/h for a world-class streamlined HPV with 20 kg of lead-acid batteries and no human power: 115-200 km. With 20 kg of more-expensive Ni-Cd batteries the range improves to about 360 km. This range capability already surpasses nearly all other electric vehicles in existence today.

But wait, it gets even better! What happens when we factor in some human power?

### HUMAN-ELECTRIC HYBRID

Aerodynamic improvements to an electric bicycle yield variable range increases, WHICH CAN BECOME ARBITRARILY LARGE at certain speeds. Let's specify 20 kg of batteries and a speed of 32 km/h (as before), plus 75 watts of human power (a level which can be sustained for many hours by a typical non-athletic person.)

For an ordinary upright bicycle (0.5 $m^2$):
total power=240 (210+30) watts;
human power=75 watts;
electric power=165 watts;
battery efficiency=65%;
battery life=1.38 hours; and
range=44 km.

For a 2x aero improvement (0.25 $m^2$) e.g. racing bicycle, full crouch:
total power=135 (105+30) watts;
human power=75 watts;
electric power=60 watts;
battery efficiency=90%;
battery life=5.25 hours; and
range=168 km.

For a 4x aero improvement (0.125$m^2$) e.g. semi-streamlined recumbent:
total power=82 (52+30) watts;
human power=75 watts;
electric power=7 watts;
battery efficiency=100%;
battery life=50 hours; and
range=1600 km (!!)

Another way to view this somewhat bizarre result is to consider figure 3. Notice that as the improved aerodynamics approach the intersect point (where the size of the cross-hatched region approaches zero), very small additional aero improvements can yield large reductions in the residual electric power required (40 watts down to 10 watts is a factor of four improvement - see points "a" and "b" on the graph.) This directly yields very large increases in "powered-range" values.

Thus it is easy to design an electric vehicle with a 500-km range for an average (non-athletic) human. Just add an electric motor to any bicycle! The only question remaining is at what speed you will travel the 500 km. The answer is determined by battery weight, motor efficiency, human-power contribution and especially vehicle aerodynamics.

For instance, let's specify 20 kg of lead-acid batteries (700 watt-hours), 50% motor efficiency, 100% battery efficiency and an average human rider putting out 75 watts.

With an upright bike, you can travel indefinitely at about 19 km/h (human power only), or 500 km at 22 km/h (with an additional 15 watts of electric power). With a moderately-streamlined recumbent, you can go indefinitely at 29 km/hour, or 500 km at 35 km/hour (with an additional 25 watts of electric power). And with today's world-class streamlining, a 500-km range at 50 km/h (75 watts human power + 35 watts electric power) seems well within reach. This design shatters the "range limit" for electric vehicles.

### RIDING BY NON-ATHLETES

In contrast to most bicyclists, most ordinary people do not look forward to exercise. But there is another curious effect I've noticed while riding my prototypes. Since my goal was to maximize the range at useful speeds (up to 50 km/h), part of my strategy was to minimize battery drain by restraining overall power consumption to a maximum of 400 watts. The net result is a system which can accelerate (slowly) from a stop up to cruising speed with no pedalling, and can maintain 40 km/hour with no pedalling.

However, even leisurely human pedalling nearly doubles the available power, as it is easy to put out 300-400 watts or more in short bursts. A little pedalling greatly helps with

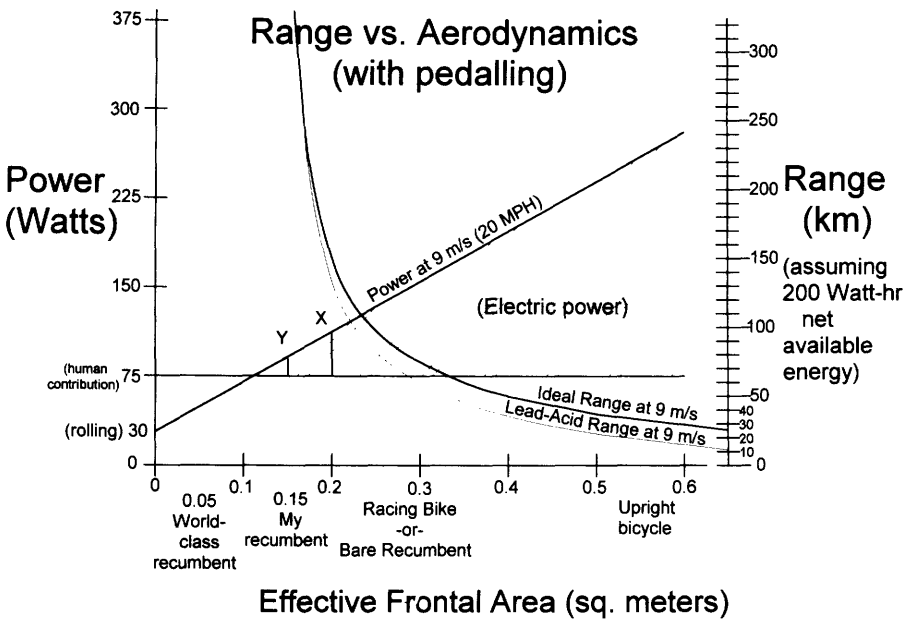


*Figure 3 Hybrid human-electric vehicle range with 200 W-h of net battery energy and 75 watts of human power*

acceleration, boosts the top speed, and greatly extends the range (to arbitrary distances at slower speeds). A quick burst of pedalling boosts the speed from 40 km/h to 50+ km/h. Even after pedalling stops, the electric motor maintains that higher speed for a long time (taking 30-60 seconds to slow back down to 40 km/hour).

The vehicle thus entices, encourages and rewards even small amounts of pedalling, while never requiring it. It is the perfect vehicle for "couch potatoes", who never want to exercise but could really benefit if they could be induced or tricked into a few pedalstrokes here and there.

## QUESTIONS AND ANSWERS

➢ Why not just use streamlining to sustain 32 km/h with human power alone? Why bother with the batteries and electric motor? My answers:
1) human power plus streamlining gets you to 32 km/hour on level ground, but to achieve 40-50+ km/h requires electric assistance;
2) streamlining alone is of little or no help on hills or for starting acceleration, and instead is a weight penalty in those cases; and
3) the motor allows the flexibility of either pedalling or resting.

➢ Why not add a gasoline motor instead? My answer: conventional motorcycles serve a useful niche and are already well-developed. Electric-assist bicycles are cleaner, quieter and lighter than motorcycles or mopeds, and thus can be taken places (bike paths, nature trails, some buses, trains, living rooms) which are inaccessible to other motor vehicles.

➢ Aren't hybrid human-electric vehicles supposed to be 75 watts (1/10 horsepower) maximum, and at least 50% human powered? My answer: this argument seems to be based on philosophy rather than on real engineering. Since it is feasible to carry up to 800 watt-hours of battery power, a power restriction to 75 watts is unnecessary. I have thus ignored this "standard" recommendation.

➢ Isn't it best to couple the electric motor to the pedals? Shouldn't the design require some minimum human power (referred to by P. Ernst as the "No Potatoes, No Dessert" principle)? My answer: this is certainly a simple and appealing user-interface design. However, in order to solve the electric "range problem", it is necessary to maximize the efficiency of all available power sources. Electric power is most efficient by using a smaller lightweight motor, continuously running at an efficient power level. Human power, on the other hand, works quite nicely in "burst mode", i.e. infrequent high-power bursts with rest intervals of very low effort in between. Everyday use requires some of both, but the best mix is electric=continuous, human=intermittent - not the other way around. A fixed coupling makes both power sources less efficient.

➢ Isn't it best to restrict the motor to occasional use, i.e. hill-climbing? My answer: this means you have to carry extra unused weight on level ground. It is more fun to go fast, especially on level ground! I obtain good results by running the motor full-time and restricting my muscle-power to occasional use. And using the motor on level ground gives quite a nice speed capability - faster than any other bicycle.

➢ Should this be categorized as an AHPV, an EAHPV, or a HAEPV (human-assist electric-powered vehicle)? How should this be classified for racing? How much battery should be allowed? What about regenerative brakes, etc.? My answer: I am more concerned with usefulness than records. But for the die-hard racing crowd, I propose a new category of "practical vehicle" race, called the "crowded cross-town errand test". Set up the test as one or several simple trips across town (10-100 km) to pick up and return a bag of groceries. No special routes or traffic restrictions, and no vehicle restrictions whatsoever (except for possibly disallowing the use of gasoline) - just get there and back on ordinary city streets in typical stop-and-go traffic. If you think your regenerative brakes, etc. will justify the extra weight, fine. If you think that solar panels will help, fine. A several-hour or overnight battery charge before the race should be allowed as well. (I'll admit to a bias here. The basic vehicle described here would have a good chance to win such a race against *all* non-gasoline vehicles. And with heavy traffic, it would probably beat out an ordinary car as well!)

➢ Don't we need better batteries before electric vehicles will ever become practical? My answer: NO! This design proves otherwise.

**RESULTS FROM DAILY USE**

In general, I never use my car anymore, as the "eBIKE" is both more fun and more practical. No more traffic jams, no more parking problems, no more expensive gasoline/maintenance/ insurance/ accidents/ new-car depreciation/ smog checks/tickets/ repairs/tuneups.

It's perfect for commuting (recharge at work), errands (free and easy parking) and all-around use. Traffic jams, one-way streets, construction, etc. don't slow me down one bit, as I freely use road shoulders, bike lanes, sidewalks and crosswalks as appropriate. The "body stocking" protects against rain and cold. Side panniers (normally stowed) can carry lots of groceries and stuff. Bulky items can be stuffed behind the seat - the body stocking holds such items in place and conceals them from prying eyes. I also carry along a backpack (worn on my front) for even more load-carrying capacity.

It is like the ideal "dream" bicycle, where every trip is downhill! I coast to most destinations, always wear ordinary clothes, and I simply blast past every bicyclist I meet without even trying! Brains are faster than brawn.

**SAFETY**

After riding my prototypes for over a year now, I am confident that this is a safe, practical design.

The blue body stocking is striking during the daytime, and cars consistently give me a wide berth. At night, the 55-watt headlight lights up the entire front fairing as well as providing lighting overkill for the roadway ahead.

It is significantly easier to coexist with city traffic when you are going close to the same speed yourself, whereas ordinary bicycles are dangerous in the same situation because of the cars' higher overtaking speeds. And we all know how low-down, feet-first recumbents are better in a crash than "head-firsters". This is even more true at 40-50 km/h than at 25 km/h. The Easy Racer positions the rider's head at eye-level with car drivers (not super-low as do some recumbents), so good two-way visibility results. Easy ground access with my feet has already prevented several potential spills.

The other interesting safety aspect has to do with the safety of others. Regardless of the vehicle you are using, you are at risk whenever you go out on public roads. No vehicle design can completely eliminate this risk. The other component, however, is this: whenever you get behind the wheel of your automobile, you are also putting the lives of other people at risk. Many car drivers don't think about this very much, but they should. Riding my electric recumbent gives me a wonderful feeling, knowing that I am not endangering other people's lives every time I go to the store.

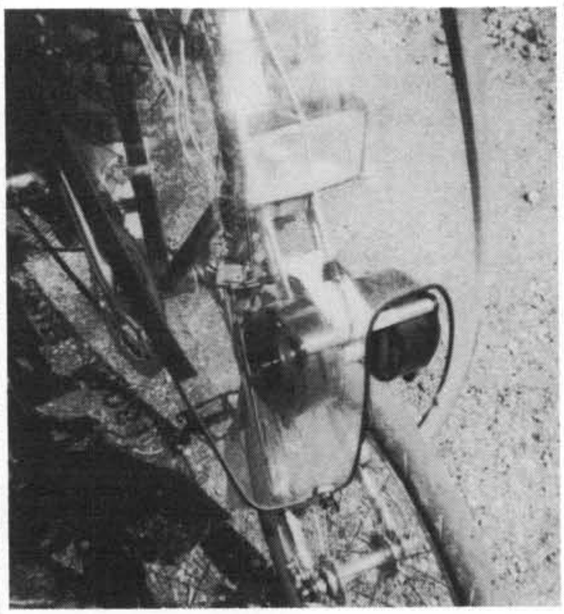

*Photo 2 Close-up of the drive*

**HILL-CLIMBING**

Even the most aerodynamic bicycle is slow when going uphill, where the principal limiting factor is overcoming gravity (not air resistance). And if a vehicle goes uphill at 10 km/h and downhill at 70 km/h, the net average speed is still only 18 km/h. This is one reason why streamlined recumbent bicycles are still not in widespread use.

My design, with a 500-watt peak power output, simply blasts up and over most hills. It can maintain 25-30 km/h up virtually any hill (although I usually pedal a bit to help out). Then I can coast down the other side and regenerate some of the energy back into the batteries. Hills have only a slight net effect on powered range and average speed. Overall, I can maintain a solid 32+ km/h speed average for nearly all trips, and I never sweat! (Unless I want to...)

**TRY THIS AT HOME**

I encourage you to try this out for yourself. Start with your favorite recumbent (short or long wheelbase, above- or below-seat steering) with as much streamlining as you can manage to get. Then add some batteries and a motor/controller. I recommend 10-25 kg of batteries, to keep the feel, convenience and portability of an ordinary bicycle. Use sealed lead-acid ("gel-cell") batteries - they're maintenance-free and safer than wet-cells because they can't spill. Or, use NiCad batteries (for about twice the watts per pound and faster recharging) or newer technologies if you can afford them and are familiar with their quirks (e.g. never charge/discharge NiCad cells in parallel because unbalanced currents will result). I recommend 200-800 peak watts of electric motor, to provide useful electric power for at least one or two hours. (I don't have a specific motor/controller recommendation; the ZAP system is good but not ideal.) Gear the motor for useful power up to 50-55 km/h. (Faster than this will burn power too quickly unless you have world-class aerodynamics. I have a stock of oversize drive rollers for ZAP which I can provide to tinkerers.) A good hill-climbing gear for your motor is also handy, but not crucial. Tweak your aerodynamics as much as you can without making the vehicle impractical. Aerodynamic improvements yield exaggerated, non-linear improvements to the total range available at any speed.

Finally, try to follow local laws regarding high-speed electric bikes (if you succeed in determining just what they are - not a trivial task). Otherwise, just do whatever seems safe and friendly. Smile and/or wave as you pass all the sweating bicyclists and backed-up cars.

**COURTESY NOTICE**

My patent application has been filed. If my claims are allowed, I intend to license this design to all interested parties for a reasonable fee. (If this design is successful and gets produced by the millions, I intend to get my fair share of the profits.) Anyone can experiment on her/his own for free, of course. I will be happy to share my knowledge and provide design advice to anyone who asks. But if you decide to start selling vehicles using this design, come and talk to me first. My goal is to encourage, not restrict, the widespread use of human-electric hybrid vehicles. I firmly believe that this design approach is the answer to the long-standing puzzle - how to build a practical electric vehicle.

**SUMMARY**

Electric cars are still struggling with the problem of limited range. Everyone believes that advanced battery technology and advanced vehicle design are necessary to enable practical electric transportation. Electric bicycles have been tried repeatedly, but previous designs missed the mark. Previous electric bicycles could not achieve sufficient range to be practical, because their poor aerodynamics wasted the limited battery energy.

A streamlined recumbent bicycle, fitted with an electric motor, goes fast enough and far enough to become a realistic replacement for the conventional automobile in the majority of trip situations. A typical family, with a single automobile and one or several electric recumbents, will not only gain greater mobility for less cost. It will also be helping to reduce dramatically both energy consumption and air pollution - so we can all breathe easier.

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Michael Saari saari@aol.com
MIKE'S eBIKES (415) 493-7633
2270 Yale St., Palo Alto, CA 94306

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*Mike Saari escaped from Caltech in 1977 with a BS in Engineering . Since then he has worked in computer hi-tech, doing VLSI chip design, video-game design, home robotics development and various software projects. He has been on a long-term (self-financed) sabbatical since December, 1993 to pursue two hobbies/passions. One passion is a systematic study to revolutionize group decision-making, including sensible voting methods, a practical replacement for Robert's Rules of Order which works equally well for any group size, and a resolution of the famous "Arrow's Paradox" of voting. His other hobby/passion is aerodynamic recumbent electric bicycles. He now has three working electric bikes in his garage and conducts test rides on demand. His car has been non-functional since May, 1995.*

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## Lelystad report

by Wouter Suverkropp

*(reproduced with permission from hpv@sonoma.edu)*

I went to the 'world information day' in Lelystad to start my mini-tour in Europe. On the way a chap on a very neat, compact low bike pulled up next to me. We rode the last 50 km to Lelystad together. He turned out to be the director of Fiets magazine *(equivalent to Bicycling in the US)*, just returning from a bicycling vacation in Ethiopia!

The main building was inside the criterium circuit. Many HPVs were parked outside, some home-built, some commercial.

There was a French gentleman of 73 on his HPV, built in 1950. It featured full suspension, intermediate gears, and a wire-driven speedometer. He was very enthusiastic and told us he knew of more people with old HPVs in France. One of the children of frame-builder Meindert Valenteijn, Joeri (6), was riding around on his FWD 1F2R middle-steering trike.

I saw also quite a few tandems. The M5 (rear suspension), the new Challenge (full suspension, 3900 guilders), and Ostrad back-to-back with super suspension, a Ryan, and a Rotator. To my surprise, only Challenge was well represented in the information hall. It had a full-colour attractive and informative brochure. Kingcycle showed its K3 and Beano.

The biggest recumbent shop in the Netherlands, de Liggende Hollander, had a test area. Here you could ask for a ticket, after which you could ride a Challenge Cirrus, an M5, an M5 hand-power trike, a Flevo Amigo and other machines. The shop also organizes recumbent-cycling vacations. Its display was very popular with people of all ages.

Many of the machines in Lelystad featured suspension. Mostly, front suspension was implemented using 20-in. forks from companies like Rock Shocks, RST, Rondt, etc. There were also home-brew constructions. On SWB tandems front suspension is almost mandatory in the interests of safety. Rear suspension was usually made using a pivoted rear fork and a polymer or oil-spring damper. I suspect that these are from mountain bikes, although they look like miniature car dampers *(shocks)*. This type of damping results in a light construction and a plush ride, as on the Sinner LWB, a fairly compact "Mochet-like" bike.

The criterium finals in the afternoon were spectacular, with machines zipping past at incredible speeds. It was won by a Bendtsen, a beautiful fully faired cleverly designed suspension bike. Unfortunately it cost over £3000.

Good sportsmanship was evident in the races and at the prize ceremonies. One hand-power rider from Germany could not race as there were not the minimum five participants in her category. She builds her own vehicles from a wheel-chair, and received a prize for her achievements.

The organization of Marielle Bakker and Sacha Knoop was an amazing team effort, and almost everything went smoothly. It was a great day, and I really enjoyed being there.

*Wouter Suverkropp@jet.uk*

*(Wouter Suverkropp works in Britain. He has offered to translate summaries of occasional articles from hpv nieuws, the super Human Power of the Netherlands. Thanks, Wouter! - Dave Wilson)*

## The "Extra-energy" exposition: tests, symposium and races

A review by Theo Schmidt

Following the lead of the World Solar Bike Race in Akita, Japan, Hannes Neupert and the "Umwelt-Exploratorium" Frankfurt organised another major event for solar cycles during the 1995 Intercycle Cycle Show in Cologne. Neupert attempted to gather all electric bicycles commercially made, as well as many individual prototypes, and to subject these to a standardized testing and racing procedure. Most of these vehicles were exhibited and a full-day symposium was held on September 15th, including the presentation of the test results and the dates of the four solar bike races planned in 1996.

The philosophy and definition of the Extra Energy vehicles was given as:

- lightweight vehicles which can be effectively propelled by human power alone; and
- vehicles with (electrical) power assistance in order to climb hills, to go a bit faster and further, and transport luggage without undue exertion.

*(This is thus a sub-class of AHPVs, assisted human-powered vehicles - ed.)*

Seventeen commercial and four individual designs were subjected to a series of tests with the aim of comparing the vehicles in everyday use. An additional nine prototype vehicles were presented but not tested, including two four-wheelers and a propulsive trailer.

### Technical tests

Johannes Doerndorfer presented the results of the Extra Energy technical tests. These consisted of:

- battery-capacity measurement at 200W discharge rate;
- energy measurement for a complete charge from 230 VAC;
- test drive for 14 km on more-or-less flat terrain;
- test drive for 5 km on a mostly 7% gradient (140-m altitude gain);
- stationary power measurements on a test rig; and
- a simulated test drive on a test rig.

All vehicles were equipped with a portable data logger measuring ten different values every 0.5 sec. such as speed, electrical data, temperatures, and the rider's pulse rate.

**Classification:** most vehicles were multi-geared bicycles with women's frames, NiCad batteries, electronically and twist-grip-controlled standard DC motors driving the rear wheel via chain and equipped with a mains charger.

There were also three mountain bikes, three recumbents, two faired vehicles, three tricycles, some lead-acid (gel) batteries, one synchronous and one asynchronous motor, two wheel-integrated motors, four front-wheel drives, five friction drives, five vehicles with simple on-off control and three vehicles with human-power-measuring sensors as motor controls. Half the vehicles had high-frequency electronic mains chargers and some had additional small solar panels.

All tests were conducted in hybrid mode. The basis for standardisation were repeated Conconi tests in order to determine the riders' pulse rates as an approximately linear function of power. This test starts at 80 W which is increased by 10 W every 30 seconds. The riders were then instructed to ride steadily at their 100-W pulse rates. Apparently rider mass was not standardised, so that the vehicles equipped with light riders would be at an advantage.

The main values of interest were speeds, ranges and energy consumption. These are given in detail in the syposium proceedings but the main results for the 14-km test drive are given in figure 1. This graph contains a good deal of information regarding typical operating conditions when pedalling at 100 W. Unfortunately one or two more operating points were not recorded, which would have allowed representing each vehicle with a curve rather than a point, useful for estimating range at different speeds. The single-charge ranges at the given operating points are between 25 and 30 km for most vehicles, the worst being 17 km and the best 76 km.

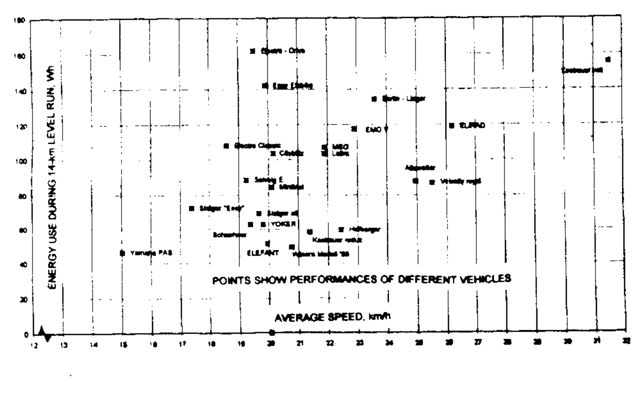


*Figure 1 Energy consumption in 14-km level run*

A similar graph (figure 2) for the hill climb emphasizes vehicle mass and drive efficiency more, aerodynamics less. The resulting altitude-gains possible on a single charge work out to approximately 300 m in the worst case and 600 m in the best case with an even distribution of the others in between.

### Design tests

Johann Rejek described a design test with the aim of determining public reaction to both the looks and the handling/performance of the vehicles. The necessarily subjective statements have no clear result other than that, so far, most manufacurers appear to see older people as their target market.

### Other symposium papers

Ingolf Merkel presented the method of the School for Art and Design at Halle, Burg Giebichenstein, for determining rolling resistance from deceleration data. Very low speeds are used, so that air resistance is negligible. The speeds must then be very accurately measured, which is done with a laser dilameter and appropriate software which allow very quick and easy measurements.

Frank Jamerson of the Electric Battery Bicycle Company, Naples, Florida, presented an overview of

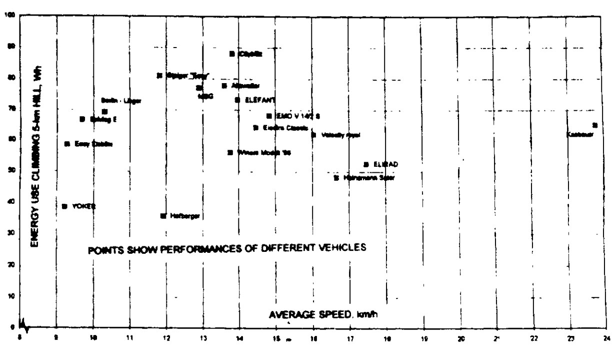


*Figure 2 Energy consumption for a 5-km hill*

suitable electric bicycle batteries, comparing the now available nickel-metal-hydride (40 Wh/kg now, up to 80 later) and future lithium-ion (100 Wh/kg) and lithium-polymer (up to 200 Wh/kg) batteries. Such batteries will permit present electric bikes to achieve a range of 80 km with a 6-kg battery pack.

Karl Lexow of Varta Batteries presented the case for standardised Ni-Cad battery packs. Varta's 10/RSH 7 is a 12-V battery with 7- to 8-Ah capacity weighing 2.4 kg (uses 10 F-cells = lengthend D-cells).

Uwe Tischer of Heinzmann Motors, Schoenau, Black Forest, presented Heinzmann's new wheel-integrated hub motor (standard 36 V, 270 W) with built-in 22:1 reduction gear. The efficiency is given as 70%, peaking at 77% at 150 rpm. A 24-V version is also available.

Michael Kutter presented his system of additive planetary gearing used in the Velocity (see elsewhere this issue) which permits a wide speed range with no gear shifts and allows a fixed-speed motor to work at full power both on hills and at high speed.

Ingold Schaefer, coordinator of the basic-kit class (see below), discusses Image-Perception Shift due to Extra Energy races. Power-assisted bikes are considered a young new product, ecological and forward-looking with a positive image. The product is easily presented and identified within a global process. Such vehicles could become widespread within a few years, certainly much faster than larger solar vehicles. The Extra Energy events are likely to augment the market forces considerably.

A panel discussion on legal requirements followed. These are different in every country and are regarded as stifling innovation by being unduly restrictive in most places. On the other hand some countries, e.g. Switzerland, are planning new vehicle classes of the type under consideration.

Freider Herb of the Technical University Berlin presented a mathematical model for dimensioning vehicle batteries with numerous examples.

Stefan Kilger presented the Carbike, a four-wheeler for two persons + luggage with sufficient motorisation to drive comfotably at 25-30 km/h. Because of the lightweight construction and pedal drive drivers are content with this speed, thus increasing safety for all road users in comparison to automobiles. In contrast to the more powerful Twike, Carbike is seen as an urban vehicle which can be produced more cheaply.

Prof. Eberhardt Scharnowski of the School of Art and Design, Halle, Burg Giebichenstein, gave a concise account for the reasons alternative vehicle concepts have not become popular. The School's answer is the vehicle project Half (Hallsches Leichtfahrzeug) under the formula 1/3 solar, 1/3 muscular, 1/3 battery. This allows a combination of performance and a design proclaiming a modern sporting ecological image likely to be popular.

### Extra-energy races, 1996

The following solar cycle races are to take place on four continents, the idea being that participants can go to the nearest one and not all four:
May 1996, Golden, USA
June 1996, Nuremberg, Europe
July 1996, Akita, Japan
November 1996 Adelaide, Australia (with the World Solar Challenge 3000 km!)

Two classes have been decided upon.

1. Up to 100 young persons between 15- and 20-years old on each continent may receive gratis identical solar basic kit components including a drive, a battery, and a solar generator. There do not appear to be any other rules for the Solar Basic Kit class other than an effective human-power drive.

2. The open class has two rules in order to exclude solar cars or electric bikes without autonomous charging capability: the solar generator must fit within a virtual box of 0.5 x 0.5 x 1.0 m, and the battery must weigh less than 20 kg.

Extra-Energy race-information packs (in German) including the exposition catalog and a PAL video of the 1995 race in Japan are available for a fee from:

Umweltexploratorium Frankfurt e.V.
Projekt Extra Energy
Eisenbornerstrasse 2
D-65929 Frankfurt am Main
Fax 069 3087334

Similar information in English should be available from World Solar Challange in Australia and World Solar Rallye in Akita, Japan.

*Theo Schmidt <tschmidt@mus.ch>*
*(Theo Schmidt is Human Power's associate editor for Europe and a prolific designer-experimenter.)*

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### Propeller-design program

Theodor Schmidt

Theo Schmidt's program PROPSIM5 (c), expanded by Christian Meyer, runs on Microsoft Quick Basic on the PC. It uses a Clark Y blade profile at optimum lift distribution (minimum induced drag). "The program may be used to get a desired prop by trial and error."

Theo has sent me a copy on a diskette. He is willing to have IHPVA members copy it for their own use (not, obviously, for sale). If you want it and live closer to me in Massachusetts than to Theo in Switzerland, write to me and I'll find the costs of copying and mailing a diskette. It's possible that I could send it by email.
*Dave Wilson: dgwilson@mit.edu*

## PEDELUXE CYCLECAR

by Sidney Whitehead
Introduction by Michael Eliasohn

There are cyclists who aren't deterred by the weather. Only a torrential downpour or blizzard keeps them inside.

A disadvantage of riding in bad weather, of course, is the extra clothing the rider has to wear to stay dry or warm, which may provide less than adequate protection. And riding a bicycle in icy weather carries with it the risk of falls.

Enter the velomobile, a.k.a. cyclecar or pedalcar -- a human-powered vehicle with three or four wheels and a body. The rider is protected from the elements and from falls on icy pavement.

The best current example is the three-wheel Leitra, which Carl-Georg Rasmussen has been manufacturing in Denmark since 1985. The 1994-95 Encycleopedia: The International Buyers' Guide to Alternative Cycling reported Rasmussen had ridden his own Leitra 200,000 kilometers. "The fairing acts as a rainproof cape [poncho], controlling the convective cooling of the body and keeping the feet warm and dry," it reported. "Carl has found that in the Danish winter, a light sweater over a T-shirt is sufficient to keep him warm."

Students of cycling history know, of course, that there are few truly new innovations in cycle design, and that's true of cycle cars. In the spring 1994 issue of the Tricycle Association Gazette, Sidney Whitehead wrote about one early example, the Pedeluxe, which he rode in the 1920s in England.

With permission of Mr. Whitehead and the Tricycle Association, his article is reprinted here. A few paragraphs of interest only to TA members have been omitted, and I did some slight editing. Mr. Whitehead furnished the photographs that are reprinted here. Now in his 80s, he was still riding his Ken Rogers tricycle until his recent move to very hilly Sidmouth, Devon, UK, although by now he may have fitted an electric motor to get back on three wheels.

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I wonder if I am the only Tricycle Association member who rode a recumbent tricycle back in the 1920s. No, not a child's one, but a machine made by the Pedeluxe Company. Enclosed (figure 1) is the company's advertisement.


*Figure 1: Pedeluxe Co. advertisement*

For several years I regularly went to school on it. On leaving school, a friend and I set off for Lands End [SW tip of England]. We got to within a mile or so of the Somerset/Devon border, then disaster. The aluminum front axle broke. To this point, it had taken us 2-1/2 days. On looking back, I feel this was pretty good going.

My friend had his bicycle and we switched from one to the other regularly. The Pedelux was loaded with our camping gear, spare clothes, etc. These items were far from lightweight as they are today.

Before we left, my father did not like the idea of us riding on West Country hills with only the rear-wheel brakes. He had B.H. Co's front hub brakes fitted. No doubt it was the extra weight we were carrying and the new braking force which caused the axle to fracture.

The basis of the machine was a central box section frame made of aluminum-faced plywood. The padded seat with full back rest was attached to the frame, but was adjustable fore and aft. Of course, one's main thrust was taken by the backrest.

*Figure 2 Other views of the Pedeluxe*

The wheels were 26"x1", with Dunlop "Roadster" tires. There was a normal Sturmey-Archer three-speed hub. The very long chain had a jockey pulley to maintain tension.

Steering was by car-type steering wheel. The actual steering mechanism was by bobbin worm and steel cable to the stub axles. The mudguards were attached to the stub axles, so moved as the wheels were turned. By undoing two wingnuts, the wheel assemblies would fold close to the body for going through a doorway [an idea modern tricycle builders might adopt - Eliasohn]

The original braking was by two separate roadster-type brakes operating on the rear wheel. ["Roadster" was used to mean "heavy-duty", whereas "sports" meant "lightweight" - ed.]. One was operated by a car-type ratchet lever, necessary for parking. The other was by foot, using one's heel, which was just about possible with one's foot still on the pedal.

Everything was assembled with "O B.A." [6-mm, about 0.25" - ed] nuts and bolts, my first encounter with this strange size.

The body was all-aluminum, with a car-type door. The front opened to reveal quite a commodious parcel space, this being over one's legs and feet.

There was a fully opening windscreen. This was just as well, for the screen was made of Celluloid and soon became yellow. I fitted a Bowden-cable hand-operated screen wiper. There was a proper car-style hood [top], for when it rained.

Most folks seem to think riding a (conventional) tricycle draws attention. They should have trundled a Pedeluxe. It virtually stopped the world and his wife. After this, riding my first real tricycle seemed quite tame.

[For the unknowing, the Tricycle Association is a British organization. Most of its members ride "real" tricycles, conventional upright cycles except for having two wheels in the rear. Most have diamond frames, 27-inch or 700c wheels and derailleur gears. Such tricycles are used for racing and touring: Eliasohn].

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*Michael Eliasohn, 2708 Lake Shore Dr., St. Joseph, MI 49085, USA*

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*(Michael Eliasohn is a long-time supporter of HPV activities in Michigan, a newspaper reporter, and a frequent contributor to Human Power.)*

## *BOOK REVIEW*

### THE AMERICAN BICYCLE

by Jay Pridmore and Jim Hurd

*Reviewed by Michael Eliasohn*

HPVers who believe the only way to pedal is horizontally can skip this book, and perhaps so can non-Americans, but for anyone else who has a general interest in the development of the bicycle, The American Bicycle is highly recommended.

The Classic Motorbooks catalog describes it as, "The first-ever color history of the American bicycle industry, from the early high-wheelers of yesterday to today's high-tech, lightweight wonders." (The publisher, Motorbooks International, is a sister company.)

The description is accurate. The only black-and-white photos are old ones. The majority of photos are in color, with most of them showing bicycles on display at the Bicycle Museum of America in Chicago. Co-author Hurd is co-founder and curator of the museum.

The book starts with the origins of the bicycle in Europe and the United States, from the wood boneshakers to high-wheelers to the development of the safety bicycle. There are photos of many interesting cycles, some of which must have been VERY difficult to pedal.

Included is the early history of organized cycling in the U.S., including the League of American Wheelman, now the League of American Bicyclists.

A very interesting chapter is, "Bicycle Racers: America's Early Sports Heroes," America's passion for bicycle racing as a spectator sport having lasted until the 1920s or so.

American bicycle manufacturers are reviving what these days are called "cruisers," fat-tired upright bikes with curved-tube frames. Such bikes made their debut in the 1930s and many fascinating examples are shown, along with a history of the Schwinn Bicycle Company. Some interesting tidbits: Schwinn manufactured motorcycles from 1911-31 and Evinrude, the outboard-motor manufacturer, produced a very stylish balloon-tire bicycle in 1937, complete with rear suspension.

The origins of other interesting bicycle "phenomena" are also traced: 10-speeds, banana-seat kids bikes, BMX and, of course, mountain bikes. Some of the early mountain-biking photos are very interesting.

Many general-topic bicycling books published in the U.S. still ignore recumbents or give them a very brief mention, so it's gratifying that Pridmore and Hurd devote 6-1/2 pages to the topic. However, what's included is disappointing. Of the five photos, three show ATP Vision recumbents (long- and short-wheelbase versions) and the other two show the Easy Racer Gold Rush streamliner and the Easy Gold Rush Replica with Zzipper and fabric fairing

The history is confined to the banning of recumbents from competition in the 1930s, the formation of the IHPVA and the efforts of Gardner Martin and Fred Markham of Easy Racers to win the DuPont prize for the first HPV to reach 65 mph. There's no mention that the record has since been exceeded.

A more glaring omission is no mention or photo of the Avatar. It and the Easy Racer were the pioneer manufactured recumbents in the U.S. around 1980.

The American Bicycle, $29.95, is available at bookstores or from Classic Motorbooks, Osceola, Wis., 1-800-826-6600.

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### *CD-ROM review*
### Oliver Zechlin's HPVs

*Dave Wilson*

This CD-ROM, in ISO 9660 format, is a cornucopia of HPV data, almost 600 MB according to Oliver Zechlin, the enthusiast who has put it together. His note to the IHPVA mailing list stated that we can expect about 2000 HPV-related JPG files (color photos); some movies (not playable on all computers); a 94/95 HPV digest archive; FAQs (frequently asked questions); and WWW pages. I've managed to look at about 40 of the photos in the last hours before this issue of HP must be completed, so that I cannot pretend that this is a true review. What I saw in this small sample was like a slide show of interesting vehicles at various meetings. The photos were generally of high quality and enabled one to study design details and to be impressed with the ingenuity and creativity that is springing forth in our movement.

It is $30 or £18 including shipping from Oliver Zechlin, Weimarer Str. 6, D-90491 NUERNBERG, Germany Email: OZ@oz.msn.sub.org

## GREENSPEED TYRE TESTING

by Ian Sims

Having reduced the frontal area of our HPVs by reclining the rider, improving the shape with fairings, and improving hill climbing by weight reduction, the next item on the agenda in our search for a 60-kph sporting, touring, commuting, shopping, pedal-powered machine must be rolling resistance!

HPVs often tend to use smaller wheels than conventional bikes for a variety of reasons. Sometimes smaller wheels are used for space reasons; sometimes to give a stronger wheel in side loading, e.g. trikes; sometimes for lightness. Long and loud are the discussions as to which are better - big wheels or small wheels!

Conventional wisdom is that large wheels roll better. In fact one could imagine that a large wheel would cope better with bumps and probably roll easier than a small wheel. On the other hand there is no denying the fact that a large wheel will cause more air drag than a small one. One Christmas a couple of years ago the question in the Sims household became "How much difference is there in the rolling resistance of large wheels and small wheels?", as we contemplated the design of our next vehicle for 1993 HPV Challenge.

Now some time ago, I had noted there was a lack of reliable data on rolling resistance of different tyres, and after trying a number of road tests to measure rolling resistance I could see why. There were just too many variables - e.g. rider position, road speed, wind velocity, gradient, vehicle set-up etc, etc.. So I had decided that a lab. test was the only way to go, and had managed to half-build a tyre-testing machine before the demand for trikes put a stop to it. Now the question seemed more important than more trikes!

### THE MACHINE

Power is absorbed as the tyre flexes in contact with the road, so I had intended to simply run the tyres, loaded, on a roller or drum. I contemplated using a very large roller to simulate the road, but that was going to be difficult to drive without power losses, and expensive. Likewise driving the wheel would involve losses. I decided to use a 4.5" diameter roller as it could be direct drive from a motor I had, and the relatively small diameter would accentuate the differences between tyres for me. So the 4.5"-(114-mm-) diam. roller was mounted directly on the output shaft of the motor, an ex-computer drive motor, approx. 20-volt D.C. and about 185 watts output (1/4 H.P.), for which I had efficiency figures. It was mounted on a bench, and an arm was built to hold the wheels over the roller, with a weight loading system designed to press the wheel into the roller with a force of 294 N (30 kgf, 66 lbf) - equivalent to the tyre loading on our trikes.

A pair of 12-volt batteries and an ammeter accurate to 0.001 amp. completed the test rig (see drawing). A number of wheels were built up on Suzue sealed-bearing quick-release hubs, and tyres were tested at a number of pressures (see table).

### RESULTS

After allowances for motor efficiency, the figures show the power absorbed by the tyre at a steady 30 kph. It is immediately obvious how much better they roll when pumped up hard! Many tyres showing HALF the resistance at 100 psi compared with that at 30 psi! It amazes me the number of people I see riding on half-flat tyres. They must enjoy the extra exercise! Anybody know of a good 200-psi hand pump?

Surprise, surprise! The SMALL-diameter tyres roll BETTER that the large ones! For instance, 20" slicks absorbed 20 to 25 watts vs 32 watts for two well-known 26" slicks!

I mentioned this to a Moulton man - no surprise! He showed me a paper by Alex Moulton. In trying to find out why his bikes were faster that ordinary racers, he did some careful tests inside an aircraft hanger and found that with the same tyre construction, section size, and pressure, 17" wheels rolled 6% BETTER than 27" wheels! Unfortunately he was unable to account for the difference, and I think a number of people did not believe the results. The reaction of the bike racing body was as you might expect - they banned them!

There are three possible explanations that I can think of. One is that with a smaller-diameter tyre there is less air volume in it, thus it will allow less deflection at the contact patch. Two, the smaller diameter means less surface area for heat dissipation so it runs hotter causing higher pressure and easier flexing. Three, the contact patch is more circular than the rather oval contact patches on larger-diameter wheels, and therefore, although the area of the contact patch should be the same with the same pressure, the CIRCUMFERENCE of the contact patch will be greater and the loss will be larger with the oval shape vs the more circular shape. Thus the line where the flexing takes place will be greater on the larger-diameter tyre, hence more power absorption, just as one can expect to get more absorption with a thicker-walled tyre! The last explanation has the most support from other people, and seems the most likely.

A greater surprise was the fact that the 20" x 1-1/8" 100-PSI Road Lites I got from the States at great expense were not as good as the fat 20" x 1.75" 90-psi Tioga slicks we had been using!! Another case of the round vs the oval? I guess I will have to do some calculations to see if the Road Lite's thinner profile and much lighter weight make up for the deficiency in rolling resistance - it is not obvious on the road!

Another surprise was that the cheap Taiwanese tyres performed better than the Japanese, American, or German tyres! And best of all was a 16" x 1.75" Indonesian knobby with the knobs ground off!

We are, of course, testing pneumatic tyres on a smooth, hard surface. Don't expect your mountain bike to go better in the mud or sand with smaller wheels! Even Moulton found his bikes were slower in sand! I guess the smaller-diameter tyre would sink lower, causing more work to be done displacing sand.

So there we have it: not only are we ahead on air resistance, strength, and light weight with small wheels, but we are also in front with rolling resistance!

[In response to a question from your editor, all wheels except the 16" wheels had 36 14-g spokes, and the 16" had 28. Also, the air drag of the spokes is very small compared to the rolling resistance, then the DIFFERENCE in air drag between large and small will also be small, so there will NO significant interference in the rolling resistance tests from spoke air drag.]

## GREENSPEED TYRE-TESTING TABLE

*Tests were done on a roller, to exaggerate differences, and to exclude road and rider variations. Figures show the amount of power ABSORBED by the tyre in watts: the more watts, the worse the tyre.*

| *Speed 30 kph; load 30 kg (294 N, 66 lbf)* | *(Power absorption in watts)* | | | | |
|---|---|---|---|---|---|
| **Tyre pressure, P.S.I. (14.7 P.S.I. is 1 bar):** | **30** | **50** | **80** | **100** | **115** |
| **Make, type, size, & pressure rating.** | | | | | |
| IRC Road Lite 20" x 1 1/8" R 100 | | 40.8 | | 27.0 | 24.5 |
| IRC Triathlon Duro 700c x 25 R 115 | | 51.5 | | 30.8 | 28.1 |
| LHR 20" x 1.75" Semi Slick (F2) R 50 | 62.7 | 41.6 | 28.9 | 25.2 | |
| Tiogo Comp Ramp 20 x 1.75 R 90 | 51.3 | 36.7 | 26.5 | 23.2 | |
| Road Lite retest | | | | 27.6 | |
| IRC BMX RACER Z II 20 x 1 1/8 R 85 | | 53.7 | 39.8 | 33.6 | |
| Specialized Fat Boy 26 x 1.25" R 100 | | 50.1 | 37.4 | 32.7 | 30.8 |
| Ritchey Tom Slick K 26 x 1.4 R 50-85 | | 50.1 | 36.6 | 32.0 | 29.3 |
| IRC Freestyle Pro 20 x 1.75 R 45 -80 | | 41.1 | 29.7 | 25.8 | |
| Cheng Shin Semi-slick 20 x 1.75 R 35 | 50.6 | 37.4 | 27.1 | 23.6 | |
| LHR Comp III copy 20 x 1.75 R 45 | 59.6 | 45.4 | 38.0 | 36.0 | |
| LHR Mountain Tread 20 x1.75 R 50-70 | 58.0 | 42.5 | 33.1 | 30.1 | |
| Tiogo Comp III 20 x 1 1/8 R 75 | | 50.1 | 39.8 | 37.4 | |
| Tiogo Comp III 20 x 1 3/8 R 40-45 | 42.5 | 35.8 | 33.3 | | |
| LHR Road Tread 20 x 1 3/8 R 65 | | 51.7 | 40.6 | * | |
| LHR Comp III copy 20 x 1 3/8 R 65 | | 46.9 | * | | |
| Kenda Road Tread 20 x 1 3/8 R 40 | | 50.4 | 39.0 | | |
| Tioga Comp Pool 20 x 1.75 R 30-90 | 50.1 | 33.3 | 23.5 | 20.0 | |
| IRC Freestyle 20 x 1.75 R 45 - 80 | 46.9 | 37.4 | 33.5 | | |
| Continental Goliath 26 x 1.6 R 35 - 65 | | 46.9 | 35.8 | 32.7 | |
| Cheng Shin Semi Slick 26 x 1.5 R 40 -65 | | 37.4 | 29.5 | 26.3 | |
| Kenda Semi Slick 26 x 1.95 R 40 - 65psi | | 46.9 | 37.4 | 34.3 | |
| Continental Super Cross 26 x 1.95 R 35-65 | 51.7 | 43.9 | | | |
| LHR Mountain Tread 26 x 1.5/1.75 R 50-70 | 45.4 | 37.4 | 35.8 | | |
| Vee Rubber 26 x 1.75 R 40 | | 45.4 | 38.2 | | |
| IRC Racer XI 26 x 1.75 R 45 | | 53.3 | 43.0 | | |
| Continental Grand Canyon 26 x2.125 R35-65 | 49.0 | 42.2 | 40.6 | | |
| Moulton - Wolber 17 x 1 1/4 R 70 | | 48.9 | 33.4 | 30.3 | |
| IRC Kik Super MX8 16 x 1.75 R 45 -55 | 51.6 | 36.3 | 29.8 | 29.0 | |
| IRC Kik Super MX8 16 x 1.75 R 45 -55 (with tread ground off) | 36.2 | 26.5 | 19.0 | 16.7 | |
| LHR Road Tread 16 x 1.75 R 50 | 61.8 | 44.6 | 35.9 | | |
| LHR Golden Dragon 16 x 1.75 R 50 | 61.8 | 44.5 | 35.3 | 31.4 | |
| IRC Kik Super MX8 16 x 2.125 R 40 -50 | 56.5 | 39.9 | 32.2 | | |

* these tyres lost shape at this pressure.

*Ian Sims makes GREENSPEED recumbent bikes, trikes and HPVs at 69 Mountain Gate Drive, Ferntree Gully, VIC 3156, Australia.*
*Phone: +61 3 9758 5541; FAX: +61 3 9752 4115*
*email: greenshp@ozemail.com.au*

*Book review*

### Fiberglass boats

John Arthur Roberts

ISBN 0-393-03291-4, published by W. W. Norton & Co., Inc. New York, 1984

*Reviewed by Helmut Walle*

This is another book on composite materials that I found while browsing the library. (I work on glass-fiber communications...)

The focus of the book is (as the title says) on boat building. But after a first glance followed by quickly digesting the first two chapters I consider it to be quite useful for people (like me as an EE) with a lack of knowledge on how they should work with FRP materials.

The book contains no theoretical or scientific ballast (nothing against science: I produce aspects of science that are somewhat far off the real world myself), but the basic properties of various resins and fibers are explained. What is more important to me is that working techniques - including industrial series production - are described.

Of course, as it is a book on boats, parts of it have to be translated to make them applicable for HPVs: for instance, laminate thicknesses of up to 2 inches (50 mm) are commonly mentioned. But the book is really easy to read and contains lots of useful information for composite newbies; perhaps a third of the text is of interest only to boat people (for example the section on how to find a qualified marine surveyor). And, of course, some arguments must be interpreted for other contexts: while cost may be a decisive argument for not using epoxy resins and carbon fiber in a boat, this might be different for a bike frame that does not contain much material but many working hours.

The book contains some 25 photographs and about the same number of figures, and some tables with compilations of basic material properties etc.

I think I will enjoy further reading.

*Helmut Walle, TU Hamburg-Harburg*
*walle@tu-harburg.d400.de*
*Digital Communication Systems*

**WING SAILS FOR PRACTICAL HPVs; A DESIGN CONCEPT**
by Peter A. Sharp

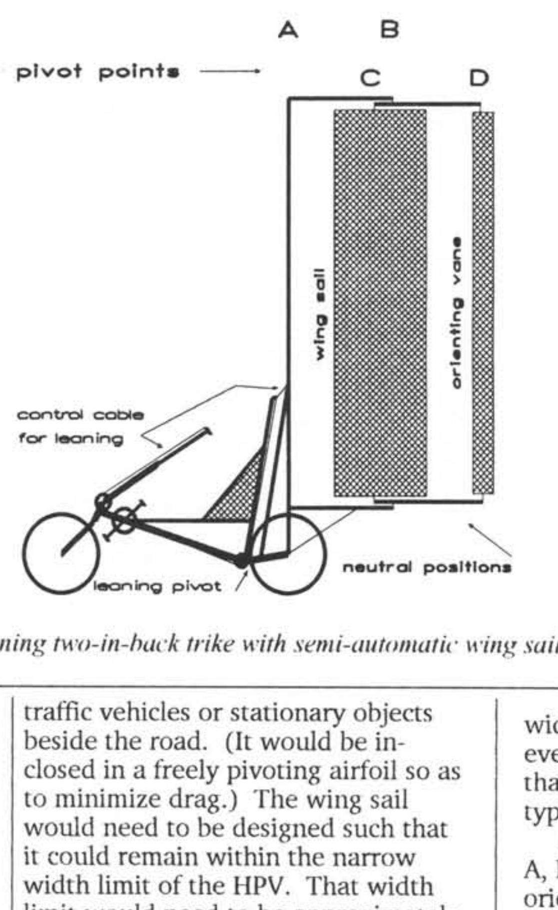
It is quite likely that future car and truck designs will incorporate wing sails of various configurations. I would like to see HPVs lead the way in making use of wind assist devices, since HPVs are the vehicles which are most in need of that assistance.

Wind assist for HPVs is analogous to thermal assist for birds. They can fly far on muscle power alone, but they can fly much farther by making use of rising winds when they are available. Wind energy is all around us, and free for the taking. We live in a sea of wind. HPVs can not afford to waste it. Wasted wind energy is wasted human energy. HPVs have always been helped or hindered by the wind to some degree, but this relationship has usually been haphazard and inefficient. We can fight the wind (conventional bikes), waste the wind (streamlined HPVs), or we can ride the wind (wind assisted HPVs). Like paved roads and gradients, the wind is a given. Our challenge is to learn to ride the wind as well as the roads. HPVs without wind assist devices will eventually be considered inefficient and obsolete.

The main problem in applying wind assist to practical HPVs has been a lack of stability, given how narrow HPVs must be if they are to be compatible with urban traffic. Small landsailers with pedals, which are very low and very wide for stability, can be quite fast, and they are safe enough for riding on rural roads. But they are not compatible with urban traffic. It may be possible, however, to design practical wind assisted HPVs (leaning tricycles, bicycles, and tetracycles) with a narrow track and a higher (recumbent) seating position, combined with somewhat smaller sails or wing sails. Adequate stability could be achieved by leaning the rider, or the entire HPV, into the wind. (A large sail, like the Bodisail, would be unsafe in traffic.)

For instance, see the accompanying illustration. A tib (two-in-back) tricycle could be constructed such that it permitted the rider and the front wheel to be leaned to windward, so as to balance the side force of a vertical wing sail. The wing sail would be held upright by the rear wheels, and it would not lean. The rider would activate the wing sail and lean himself into the wind only when traffic conditions provided sufficient room to do so safely. The goal here is safe wind assist to increase the average cruising speed of practical HPVs, not maximum speed. When the lack of wind, or an unfavorable gradient, prevented him from flowing with motor traffic, he would remain upright and keep to the right like a conventional HPV, and the wing sail would simply weathervane (point into the apparent wind).

A wing sail mast, mounted behind the rider, and supported by the rear wheels, would remain upright so that it would not make contact with other traffic vehicles or stationary objects beside the road. (It would be inclosed in a freely pivoting airfoil so as to minimize drag.) The wing sail would need to be designed such that it could remain within the narrow width limit of the HPV. That width limit would need to be approximately 1 meter or less in order to be compatible with urban traffic. The maximum track would need to be about the same as other practical tricycles - roughly .8 meters, or about 32 inches.



*Leaning two-in-back trike with semi-automatic wing sail*

This type of leaning tib tricycle would permit the rider to sit high enough for good vision while riding in city traffic. The rider's higher seating would be to his advantage when leaning, since it would enable him to shift his center of gravity farther toward the windward direction. The rider would control his leaning angle by pulling the handle bars backward, using a sliding steering column or a similar mechanism. Pulling back would pull a control cable so as to create an extensible connection between the top of the rider's seat and the mast. The rider would lean himself to windward to counterbalance the tipping force of the wing sail, and he could also pull himself upright quickly.

A bucket seat would be used to keep the rider in place when he was leaning to balance wind pressure on the wing sail. The pivot joint for the forward part of the frame (including the front wheel, pedals, and the rider's seat) would be located below and behind the rider. The pivot axis would probably be on a line extending from the ground contact point of the front tire to approximately the middle of the rear axle. The front fork would be designed to provide neutral steering when leaning. Leaning would also permit fast cornering without tipping, despite the high center of gravity, as has been demonstrated by previous leaning tib trikes.

The rider, when pulling back on the handle bar, could exert considerable force, since this movement would approximate a rowing motion. Also, the rider's lean angle would be preset to an adjustable limit, such as 45 degrees left or right, or more when racing on a closed course. When conditions permitted, he could lean far enough to approximate the stability of a much lower and wider landsailer. The sail area, however, would probably be less than half that of a small landsailer (which is typically about 33 sq. feet).

Note that there are pivot points at A, B, C and D. The wing sail and its orienting vane would remain almost entirely within the track width of the HPV during normal operation. When the wing sail and the orienting vane were in their neutral positions (shown), they would be free to rotate 360 degrees into the wind around their respective pivots, C and D, without extending beyond the width of the HPV. The wing sail has three positions: a neutral position behind the rider (shown), and two active positions - with the wing sail rotated around pivot A (the mast) to a position approximately above either the left or right rear wheel, whichever is to windward. The rider rotates the mast and support arms AB about 70 degrees, and thus swings the wing sail to the windward side, over that rear wheel. Then the rider locks the orienting vane parallel with the support arms CD. And finally, the rider then activates the wing sail so as to create its angle of attack, and aerodynamic lift. Once activated, the orienting vane would automatically maintain the wing sail's angle of attack. This variable sail positioning would provide the advantages of less turbulence, a low center of pressure, and more resistance to tipping. It would also cause the resultant force vector of the wing sail to point approximately through the center of gravity of the rider, so as to minimize yaw. (This relationship is similar to that produced by the Bodisail.)

When the wing sail was in its neutral, rearward position, the pivoting arms AB, and CD, would be held there by springs or bungee cords. But the wing sail and the orienting vane would be left free to rotate 360 degrees on their pivots C, and D, respectively (at about 1/3 cord), and would merely face into the wind, creating no lift and minimal drag. Consequently, the vehicle could be parked safely without removing or lowering the wing sail. In its neutral position, the wing sail would help to smooth out the air flow behind the rider, thus acting as a rear fairing.

The rider would control the wing sail with left and right control levers mounted on the steering column. Each lever would have 3 successive positions: an "off" (neutral) position, a "shift the wing sail to windward" position, and an "activation" position to create the angle of attack of the wing sail. Releasing the control lever would first eliminate the angle of attack of the wing sail, and its side pressure. Springs would then return the wing sail and the orienting vane to their neutral, rearward positions.

For extra safety, a tension spring would be used as part of the activation control cable so that the wing sail could automatically dump excessive wind pressures caused by strong gusting. Land sailers (and catamarans) tend to accelerate rather than tip, when responding to wind gusts. But HPVs would not always be able to accelerate - as, for instance, when riding behind slow traffic, when braking, or when climbing a steep gradient. Consequently, they would need to be able to dump excessive wind pressures quickly and automatically. The safety spring would permit the wing sail to reduce its angle of attack in response to excessive wind pressures, thus dumping the energy of strong gusts, so as to prevent the HPV from tipping if the rider failed to quickly release the control lever. Even so, extra caution would be required on slippery surfaces to avoid skidding sideways.

An even smaller version of the semiautomatic wing sail might be combined with a standard or recumbent bicycle, and used for commuting or road racing. A short mast could, for instance, be fixed to the back of a recumbent rider's seat, and the wing sail controls could still be mounted on the handlebar. An appropriate bicycle would probably have a small rear wheel in order to keep the wing sail as low as possible, so that leaning would not extend the top of the wing sail too far to either side. Note that the wing sail is counterbalanced by the orienting vane, around pivot point B. This is so that if the wing sail is leaned to the side, as on a bicycle, gravity will not inadvertently change the angle of attack of the wing sail.

A smaller semiautomatic wing sail could also be used on a tetracycle (still only a concept). (A tetracycle is essentially a cross between a bicycle and a tricycle. The diamond wheel configuration uses castored outrigger wheels on outrigger arms that are lowered independently by pulling back on the same side handlebar, so as to control lean independently from steering.) However, on a tetracycle, the wing sail must not be held upright against strong winds by using the down wind outrigger wheel. That is because the front wheel and the down wind outrigger wheel would create a tipping axis. That tipping axis could cause the rear wheel to lift enough to slide sideways in response to strong winds. For the same reason, landsailer tricycles do not use a tif (two in front) wheel configuration. But ridden appropriately, a tetracycle would let the rider lean into the wind like a bicycle, while also providing protection against falls or swerves in response to momentary instabilities caused by the wind or other traffic. In other words, a tetracycle could still track straight even if a sudden gust tipped it away from the wind, since steering and leaning could be controlled independently.

In addition to a wing sail mounted behind the rider of a tetracycle (or bicycle), another small wing sail might be mounted ahead of the front wheel. It would function similarly, but would not swing to windward. (For an illustration of such a wing sail, which would utilize "Weaver stabilization", see my article, "An Aerodynamic Stabilizer for Bicycles", HP, vol. 10, no. 1, Spring-Summer, 1992.) This front wing sail would, it is assumed, automatically tip the tetracycle and the main wing sail into the wind in response to gusts.

**Caution!**

Combining a wing sail with a narrow HPV is potentially dangerous, especially in traffic. Experimenters should therefore start with very small wing sails, no more than 0.2 sq.m. (2.0 sq.ft.) and should acquire considerable experience before advancing (in small increments) to larger sizes. Small experimental wing sails may be made by gently folding a sheet of plastic, such as polycarbonate, and stapling or pop-riveting the trailing edge. Other internal bracing can be added as needed. The aspect ratio (span divided by the width in the flow direction or chord) should probably be between 4 and 8, say 6.

My hope is that these concepts will help to expand our idea of what HPVs can be. For a dynamite 21st Century HPV, my current preference would be a streamlined tetracycle equipped with an accumulator and a wing sail. May the Aeolian Force be with you.

*Peter A. Sharp 2786 Bellaire Place, Oakland, CA 94601 ph.501-534-9540*

*Peter Sharp is an independent craftsman and inventor and a frequent contributor to Human Power.*

*Book review*

## Human-Powered Vehicles

Allan V. Abbott and
David Gordon Wilson *(co-editors)*
*Human Kinetics, Box 5076*
*Champaign, IL 61825-5076 USA*
*800-747-4457(US), 217-351-5076*
*8-1/2 x 11 in., 288 pp.,*
*Hardbound, $45.00 USA price.*
Reviewed by Doug Milliken

This book is long overdue. Finally, there is a proper reference that covers all aspects of human-powered vehicles including HPV history, human performance, design, vehicle performance, and even a bit of philosophy. The book is a combination of new work and revised/updated articles, many originally printed in IHPVA publications. There has been a need for a collection of the best articles from "Human Power" and "HPV News", and this book more than fills the vacuum.

The editors really need no introduction to the IHPVA audience -- Allan Abbott was the first IHPVA president and Dave Wilson also served in that position. They have both been IHPVA board members and long-time contributors to the human-powered-vehicle scene. As well as their own writing, they have drawn on experts from the HPV community to give coverage from a variety of viewpoints.

The book is broken down into five major parts which cover most of the over-twenty-year history of the IHPVA and a lot of related material. Part one starts with an introduction to the historical uses of human power, then moves to the physiology of human power production and the biomechanics of transferring human power to vehicles. The middle three parts cover history and engineering of the major classes of HPVs -- water, land and air. The final part collects some thoughts on the future of human-powered vehicles and ways that HPVs might be better integrated into industrial society.

The book includes bibliographies with each chapter and an overall index -- this will be the first place I'll look when I need to refresh my memory on any aspect of HPVs. Everything from details of different drive-train layouts to the difference between aerobic and anaerobic exercise is covered. The book is illustrated with about 180 high-quality line drawings and photographs; especially neat are the general-arrangement drawings of a number of HP aircraft.

*Human-Powered Vehicles* is an excellent read and an excellent reference/source book, even the material that was first printed in "Human Power" has been revised, corrected and/or expanded. Don't whine about the price, just get a copy -- you will use it for a long time.

A complete listing of the chapters and their authors follows.

Part 1: Human Power: An Introduction
- Chapter 1 Human Power in History.
- Chapter 2 The Human Engine.
- Chapter 3 Human-Power Transfer to Modern Vehicles.
  *(Chapters 1-3 are by Abbott and Wilson.)*

Part II: Watercraft
- Chapter 4 Human-Powered Water craft
  *Abbott, Alec Brooks & Wilson.*
- Chapter 5 Rowing Shells
  *Edward Van Dusen.*
- Chapter 6 The 20-Knot Human-Powered Watercraft
  *Alec Brooks.*

Part III: Land Vehicles
- Chapter 7 A History of Human-Powered Land Vehicles and Competitions
  *Chet Kyle.*
- Chapter 8 The Development of Mod ern Recumbent Bicycles
  *Wilson with Gardner Martin.*
- Chapter 9 Lightning Progress: An HPV Development Case History
  *Tim Brummer.*
- Chapter 10 Bicycle Aerodynamics
  *Chet Kyle.*
- Chapter 11 Aerodynamics Versus Weight
  *Dan Kirshner.*
- Chapter 12 Composite Materials
  *T. Scott Rowe.*
- Chapter 13 Drive-Train Design, and
- Chapter 14 Steering Design
  *both by Rob Price.*

Part IV: Aircraft
- Chapter 16 History and Present Status of Human-Powered Flight
  *Chris Roper.*
- Chapter 17 Gossamer Aircraft and Where They Lead
  *Paul MacCready.*
- Chapter 18 Conception and Optimi zation of Human-Powered Aircraft
  *Ernst Schoberl.*

Part V: The Future
- Chapter 19 Potential for a Major In crease in the Use of HPVs
  *Wilson.*
- Chapter 20 The Value and Future of Human-Powered Vehicles
  *Paul MacCready.*

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*Doug Milliken*
*[bd427@freenet.buffalo.edu]*
*245 Brompton Rd., Buffalo, NY 14221 USA*
*Tel: 716-632-6710 [1000 - 2200 EST]*
*Fax: 716-633-9283 [24 hour, auto-answer]*

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**Editorial note:** there's a risk of conflict-of-interest in publishing a review of a book co-edited and co-authored by the journal editor. Two people, unasked, offered to review the book: Doug Milliken offered first, and I accepted. Allan Abbott originated the idea of the book, and honored me by asking for me to collaborate with him. A large proportion, I believe half, of any royalties from the sale of the book are due to go to the IHPVA and the remainder will be split among the contributors and editors. One does not write books like this to earn a living. This is the eighth in which I have collaborated with others or written myself, Bicycling Science being far and away the most successful. If I took the total royalties received and divided them by the total hours I spent working on them, the average pay would be less than $1.00 per hour.

I wanted to let you know that you were not in danger of becoming victims of a scam!

*Dave Wilson*

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### Spaceframe Moultons

Doug Milliken brought a few copies of Tony Hadland's book to the USA from Britain and would be happy to sell copies to individuals in the US who want to avoid the overseas postage costs: his price is $35.00.

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## Human-powered aircraft for sport

Chris Roper, VP for Air, reports on a London conference in Jan. 1988 at the Royal Aeronautical Society

The late Henry Kremer maintained the hope that HPA would be able to compete with one another in a sporting event. The new Kremer competition is for a circuit in a fixed time around a closed course. Nothing new? Yes - there's a minimum-wind stipulation. Heretofore HPA have nearly all:

- operated mainly in still air;
- been unique prototype machines;
- had prizes as the only financial incentive for their creators;
- often terminated their existence, or at least been forced down, on encountering a gust of wind of magnitude that occurs in practice several times a day (i.e. they have not been weatherworthy); and
- been uncertificated.

For HPF to be a sport, all these must change.

All four speakers, and many of the delegates to the conference, were HPA pilots.

John Wimpenny, pilot of Puffin (1961), had studied available data on gusts at the relevant altitudes, and had made comparisons with the way in which sailplanes, hang-gliders, and projected HPA are affected by them. He had analysed the proportion of population and proportion of days per year vs. aircraft parameters when operation would be possible, and presented his results. He said that this might well be the last Kremer prize, because any machine that could win this competition could be put into production and the financial aspects would completely change. Also, once HPF moves into the public domain and is an everyday occurrence, certification will become necessary.

Wayne Bliesner, who has flown many HPA of his own creation, reported that his Marathon Eagle had rolled out and taxied. He has had to adjust the ailerons and the tail-wheel linkage. The Marathon Eagle is eligible for the Kremer Marathon competition. Winning of this competition would open the way to HPF becoming an Olympic-style sport.

Peer Frank, pilot of Pelargos, Musculair, and others, presented a list of past HPA contests. It is a short list: six events in the last ten years, and on no occasion has more than one HPA left the ground at any of these. Each year there are the Birdman Rallies in Japan and Britain, in which take-off is from a platform ten metres high. Peer showed us a video of the 1985 Japanese rally where a distance of 8 km was flown from the ramp. The day was exceptionally calm, and the team had experience of the rally in many previous years. Serious teams make test-flights from level ground, but the contest is from a pier over Lake Biwa. Every machine is destroyed on coming down into this fresh-water lake.

In both Japan and Britain there are always deliberately comic entrants. Also there are those who intend to cover distance but are just as much a flop as are the comics.

The organiser of the British Birdman rallies said that there have been few serious entries, hang-gliders at best, in previous contests. He is planning steps to encourage machines of greater wingspan that may cover greater distances. His rallies are held from various town piers over the sea.

Peer Frank explained that for HPA to fly safely in any weather from level ground considerable weight penalty would be involved. He had analysed the rate-of-climb that could be expected, along with gust loads and torsional divergence. This latter will become even more relevant if we hope to fly faster, over a range of speeds, or in a situation where we might pick up speed in a dive.

Nick Weston, pilot of Airglow, gave us preliminary results of the series of tests that the Airglow team are conducting to measure drag. They measure the pilot's output, and they also have data on the plane's drag and propeller thrust when it is driven by an engine. Recently they have fitted a wake traverse, which measures the local air velocity at various points just behind the wing. This can readily be computed to give a total momentum change. The assumption is that this represents the bulk of the aircraft's profile drag. The difference between this and the concurrently measured total drag is therefore the induced drag. Hence they hope to determine the effect of change of induced drag with height.

Also, a test-section of Airglow wing has been tested in a low-turbulence wind tunnel in Cambridge, UK. The behavior of the boundary layer of DAE 1335, developed by Mark Drela for Daedalus, was observed to be as anticipated.

What do we in the IHPVA want to happen with regard to human-powered aircraft for sport?

Which comes first: the events, the machines, the rules, or the people with bright ideas?

If you think that you are anywhere near an answer to these questions please contact me.

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*Chris Roper, 19 Stirling Court, Tavistock Street, London WC2E 7 NU, UK Phone from the US: 011 441 71 379 5611; FAX: 011 441 71 240 9816*

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*Copies of the conference proceedings may be ordered from the Royal Aeronautical Society 4 Hamilton Place, London W1V0BQ, UK, price £10 + postage, presumably. The entry forms and rules for the new Kremer competition may also be obtained from the Roy. Aero. Soc.*

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*Letters on this topic to Human Power will also be welcomed.*

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# Editorials

## A wealth of publications

*Dave Wilson*

Some time ago I jotted down a note that I should write an editorial glorying in the range of publications that now cover our young movement. This issue has also turned out to be one in which there has been little spare space for my reviews of some of these publications, reviews that have always been occasional, as space allowed. Also, I have had to "bump" some good articles to the next issue, and I would have felt guilty telling the authors that the work on which they had devoted much toil had been delayed, while I kept to myself a full-page "bully pulpit". Therefore, this editorial page will be a review of our "sister" publications (this term does not imply anything more than friendly association). I will, however, start with the other principal publication of the IHPVA.

### HPV News

IHPVA members are all familiar with HPV News, and no review by me is needed. I want, however, to give some background to our relative positions. At one time it was difficult to tell the difference between Human Power and HPV News. Current email to the IHPVA mailing list confirms that there is still a great deal of confusion. The general guidelines are that HPV News covers items of shorter-range interest, such as the schedules of meetings and races and their results, trip and tour reports, shorter reports of experiments and so forth, while Human Power tries to limit itself to technical pieces and reviews of longer-range interest.

Marti Daily, former IHPVA president, and the board of directors recognized that most IHPVA members join for the publications, and instituted a more-frequent publication of HPV News - up to twelve a year. The last editor, Len Brunkalla threw himself into this punishing schedule with enthusiasm. He may have been saved by being elected president of the IHPVA: many talented and dedicated former editors have been burned out by the demands of producing a major publication to an exacting schedule with little financial or human support. Give these wonderful people all the praise you can! Make the criticism entirely positive! Work toward increasing our membership from 2,000 to 10,000 so that we can afford a full-time editor+ association manager.

### HPV nieuws
### The British Human Power Club

Other national associations have their newsletters that often combine the functions of HPV News and Human Power. (A proposal to the IHPVA board coming from the Lelystad meeting in the Netherlands last year is to make the IHPVA the association of national HPV organizations, having no individual memberships, and to publish Human Power as a truly international journal, while each country or district would have its own HPV association). The newsletter of the Netherlands association is the most polished, with a glossy cover photograph, high-quality photos, graphics, and layout inside, and attractive advertisements. I have prevailed upon Ellen Wilson's knowledge of rudimentary Flemish and my own rudimentary German to review occasional articles, and some authors have been kind enough to translate their articles for Human Power. Wouter Suverkropp has recently courteously agreed to review intriguing articles I send him.

The magazine of the British Human Power Club is almost at the other extreme: very casual and chummy, with valuable nuggets sprinkled around. One feels sometimes when reading it that one is in the kind of small town where no one gives signals from their vehicles because everyone knows where everyone else is going. Many entries in past issues have been unsigned and unattributed and have contained inside jokes that have made me want a Wouter Suverkropp as a translator. Under John Kingsbury's editorship the publication is becoming more professional without losing its friendly face.

There are many other national and local publications, but I don't receive them: forgive me for not mentioning them. If the German magazine "Tour" is part of the HPV movement it is highly professional. I have made a long review of wind-tunnel tests it commissioned - it will be in HP 12/4.

### RCN: Recumbent Cyclist News

Bob Bryant started his publication in association with the IHPVA, but some problems, I know not what, cropped up and Bob went on alone. He kept his newspaper job and other sidelines to make ends meet, but has made enough of a success (but far from a financial killing!) with RCN that he and his wife Marilyn now work more-than-full-time on it. He and others carry out quite-demanding road tests of HPVs and publish test reports - seldom negative but one can read what is omitted, rather as in reference letters on students and former employees. The annual RCN Buyer's Guide is a valuable showcase of the amazing number and variety of HPVs now available. RCN brings many converts to our cause.

*(RCN, POB 58755, Renton, WA 98058)*

### Bike Culture and Encycleopedia

Jim McGurn, author of the acclaimed history "On Your Bicycle", and other luminaries formed the Open Road company in York, UK mainly to produce the very-high-quality publications Bike Culture (quarterly) and the annual Encyclopedia. These give publicity and recognition to non-traditional cycles, mainly recumbents and tricycle HPVs, but also to other types such as load-carrying cycles. The photographs and reproductions are always strikingly beautiful. These are "coffee-table" publications that are also technically sophisticated. They carry no advertising: I believe that manufacturers pay a fee to have their products reviewed. There is no other way such expensive publications could keep going. The editor and staff deserve high honor for their highly effective missionary work.

*Email: Peter@bcquedit.demon.co.uk; bikeculture@mailhost.net (US editor Dylan Macdonald, Open Road USA)*

*There were others I wanted to recognize. So many gems, so little space!*

*Dave Wilson*

**International Human Powered Vehicle Association**

P.O. Box 727
Elgin, IL 60121-0727
U.S.A.
(847) 742-4733