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Human Power
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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 are indebted to the authors, to Marti Daily and to Julie Drennan (MIT), whose dedicated help made this issue possible. *Dave Wilson*

In this issue

New one-hour world record?

Bram Moens has a strong claim on a new record for faired bicycles (see opposite). At the time of writing the record had yet to be confirmed because of a "technicality" .

Energy consumption and tests of an AHPV

John Raine and N. G. Maxey fitted electric assist to the University of Canterbury's tricycle "Tricanter". They modelled the energy consumption and demonstrated the penalizing effects of hills even when regeneration is used. They concluded that an electric-assist AHPV gives good performance and is very pleasant to use in "niche" applications, particularly where hills are infrequent.

AHPV principles

John Tetz, a leading pioneer on and advocate of assisted HPVs, summarizes his key principles as a commentary on Peter Ernst's paper in the last issue of HP (vol. 11/3). Overall, his philosophy could be summarized as "occasionally assisted human power" for hills and other high-demand situations, and it differs from those who would like continuous assist modulated by human power input.

Peter Ernst writes a response to various comments on his paper.

AHPVs and "hups"

Izzy Urieli also comments on Peter Ernst's paper on AHPVs and John Tetz's principles, introduces the definition of a "hup" - a unit of human power - as 75 watts, and advocates consideration of clean Stirling assist engines.

HP watercraft speed prizes - a report

Doug Milliken, retiring VP Water, reviews the Du Pont HP Watercraft speed prizes and the IHPVA role in sponsoring and sanctioning the contests. He makes recommendations for us all.

International symposium on human-powered flight

Chris Roper, VP Air, gives a review of this extraordinary symposium and exhibition.

Aerodynamic effects of partial fairings

Steve Koren carried out comparative hill-coasting tests of "upright" and recumbent bicycles with and withour partial fairings. He found that the best partial fairing on a recumbent gave an increase of 3.5 - 4 mph (1.6 - 1.8 m/s) over an upright bicycle at about 30 mph (13.4 m/s). He found a bigger difference between a faired and an unfaired recumbent than between an unfaired recumbent and an unfaired upright bicycle.

HP lawn mowers

`Michael Eliasohn reports the encouraging news that the production of foot-propelled push mowers in the U.S. has approximately trebled in the last decade. He reviews past attempts to produce pedalled mowers, and concludes that opportunities beckon.

Letters

Among the letters necessarily (under the new layout) scattered throughout the issue are three by Mark Hack, Don Speck and Daniel DeBra on the IHPVA racing rules, partly responding to Peter Sharp's proposals in the last issue of HP; one on successes of a rowing-action bicycle from Ben Wichers Schreur; one from Gerald Pease on Pete Penseyre's 24-hour record; and one from David Damouth on friendly road signs. (*This is being written before I have done the final layout: it is possible that one or more letters will have to be held over until the next issue - editor)*

Reviews

Two substantial volumes of proceedings of symposia on HPVs have been published recently. One is of the fourth IHPVA scientific symposium in Yreka, CA in 1992, and the other is the second European seminar on velomobiles/HPVs in Laupen castle, Switzerland, in 1994. Two issues of Cycling Science are also briefly reviewed by your humble editor.

Tire and wheel standards; and bombs make peace

These are the two topics that your editor has chosen to mention in the editorials on p. 23.

Dave Wilson

HUMAN POWER

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ONE-HOUR WORLD RECORD CLAIMED BY BRAM MOENS: 77.123 km/h

Bram Moens with his M5 Carbon Low Racer

A new absolute world hour record for bicycles has been claimed by 1994 European champion Bram Moens on his *M5 Carbon Low Racer*. The attempt took place on October 1, 1994 on the high-speed car-tire-test track, 2.8-km long, in Lelystad, Netherlands, at an altitude of minus 7 m.

The attempt was part of the speed meet held by the Dutch HPV club. The former record holder was Pat Kinch in the *Bean*, at 75.59 km/h on the Lotus track in Millbrook, UK.

The type of bike now used was a fully carbon-fibre low-seat *M5* recumbent with a medium wheelbase, 26" front wheel and a 28" rear wheel. The fairing was also a 100-percent-carbon product designed and built by Derk Thijs and Bram Moens. The total weight of the bike plus fairing was 17 kg.

The average weather conditions during the record ride were

windspeed less than 0.1 m/s;
air temperature 13 C;
air pressure 1022 mb; and
air humidity 82%.

M5 is "meer meters met minder moeite", meaning "more meters with less stress" approximately. Bram Moen's address is:

M5 Ligfietsen, Brakstraat 11
4331 TM Middelburg, Netherlands
Phone 01180-28759.

Here are some additional notes on the record and its background from Ben Wichers Schreur via the Internet (wichers@knmi.nl).

"Late last month Bram tried to better Miguel Indurain's world hour record (53,040 meters) on an unfaired recumbent, but reached no further than 51,093 meters due to a mid-race dip. It was still a remarkable feat, comparing Bram's 350 watts to Miguel's approximately 450 watts, showing again the advantage of going 'bent.

Here is my two-cents worth re the UCI. My guess has always been that UCI forbade recumbents in record attempts when good-willing amateurs with superior technology started beating serious professionals, which in the eyes of the UCI degraded the status of the world record, and as UCI officials are all in it for status this would immediately affect their position. This attitude was perfectly exemplified by the a-posteriori banning of Obree's world-record bike, and reached a pitiful high in the banning of his saddles in the last world championships and finally his banning altogether because of his 'dangerous' posture (hips in front of the bottom bracket. Next time they will forbid the use of yoga to improve breathing, and Indurain's use of Ventolin against his asthma?). What I would like to suggest is that we get one of the really big 'uns (Indurain, Rominger) to have a go at the world record on a recumbent, by having the IHPVA and associated enthusiasts drumming up support and sponsoring. This would be great for 'bent publicity and might soften the callous hearts of UCI officials enough to allow for a 'hors category' innovation HPV world-record class. Or are we more comfortable cocooning in the IHPVA?"

For a profile and interview of Bram Moens, see HP 10/1/92/6.

ENERGY-CONSUMPTION MODELLING AND ROAD IMPRESSIONS OF THE ELECTRIC-ASSIST TRICANTER

by

J.K. Raine and N.G. Maxey

ABSTRACT

While the University of Canterbury Mk IV Tricanter HPV is being further developed for enhanced cornering power and stability, the earlier Mark III has been used as a test bed for both internal-combustion-engine- and electric-motor-assisted human power. This paper outlines the design of the electrically assisted Tricanter, which has a 250-watt D.C. motor powered by two 12-volt 17-ampere-hour batteries. Computer simulation of vehicle energy consumption with and without electric power assistance is also reported, based on the MkIV, for a Christchurch Bicycle Driving Cycle executed at various average speeds and road gradients. Results show the computed electrical-energy usage for the various driving cycles, as well as the proportions of Cycle Energy consumed in work overcoming inertial, rolling, aerodynamic and gradient resistances. Data relating to estimated battery discharge time for different driving conditions are also given. On-road performance of the battery-assisted vehicle is described.

INTRODUCTION

The definition of the boundary between a motor-assisted HPV (AHPV) and a moped, where the motor power considerably exceeds the human output, is not yet well defined. It seems generally accepted that the true AHPV has the human power as a major contribution, but within this class of vehicle different design philosophies may be followed. We would suggest that motor-assisted HPVs could be defined to have a motor power not exceeding 500 watts.

Abbott (1) used a 23-cc 2-stroke 750-watt engine geared into the rider's chainwheel, and with its throttle opened in response to rider effort, rewarding exertion and providing comfortable assisted cruising at speeds of around 60 km/hr. Tetz (2) on the other hand views the engine assistance strictly as an aid for hill climbing, with engine boost of around 150 watts geared to give a top speed of 17.7 km/hr.

Ernst (3) provides a good overview of AHPVs and makes a strong case for small-motor-assisted HPVs, favouring internal-combustion engines of 10 - 20-cc displacement producing about 440 watts rather than electric power, because of the weight penalty paid by electric-boost systems. Ernst indicates that realistic target total vehicle masses are 30 kg and 10 kg respectively for electric- and hydrocarbon-fuelled vehicles. He feels Stirling-engine power-assist systems would give an unacceptable weight penalty, although Urieli (4) makes a case for small Stirling engines.

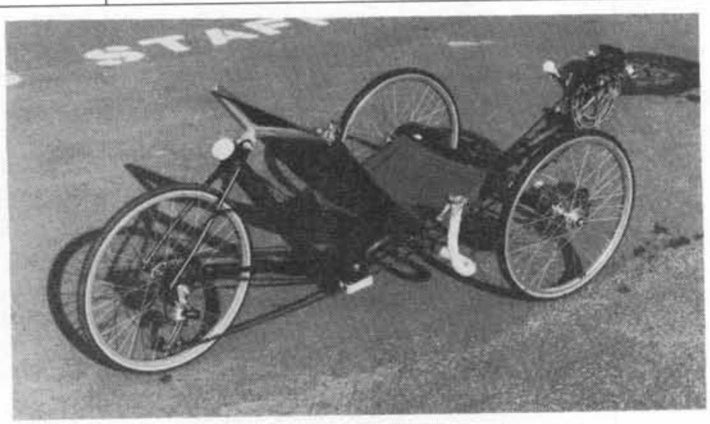

Figure 1 The Tricanter Mk IV recumbent tricycle

While electrically assisted HPVs (EAHPVs) at present have a weight penalty, they are quiet and in many locations can be truly emissions-free by recharging the batteries from hydro-electric-generated mains electricity or from local solar- or wind-power systems. They can also be very attractive where the vehicle operates on generally flat terrain. This is possible for much of the population in Christchurch, New Zealand.

This paper reports on the adaptation of the Tricanter HPV (5) to operate as an EAHPV. In parallel with design work for the motor installation, motor and controller performance-identification tests were done and vehicle-energy-consumption computer simulations performed. These activities and on-road vehicle performance are described.

DRIVE-TRAIN CONCEPT FOR ELECTRIC POWER ASSISTANCE

The Tricanter is a recumbent tricycle with two steered and braked 20-inch front wheels and a single driven 20-inch rear wheel. The chassis is of a simple cruciform type with a tubular steel backbone and front cross member. Dimensional details for the Mark III have been given by Raine and Amor (5). At about 18 kg the later Mk IV (figure 1) is 3 kg lighter than the Mark III but has the same wheel base of 1070 mm and track of 750 mm (shortly to be increased to 820 mm).

The Mark-III prototype is now an AHPV test bed. In 1992, as a B.E. student project, we fitted it with a 5-kW Honda Beat engine driving through an overrunning clutch onto an auxiliary drive sprocket mounted on the near side of the rear-wheel hub (6). The motor assembly with cooling system, battery, fuel tank, and controls added 24 kg to the 21-kg bare weight of the basic Tricanter Mark III. The available power easily drove the vehicle to 85 km/hr without any aerodynamic fairing, limited only by gearing and the 11,000-rev/min speed limit on the engine. This was a light-hearted exercise not intended as a proper AHPV. A much smaller engine would have provided an adequate power boost with lower added weight and safer, less dramatic performance.

The basis for our subsequent decision to use battery power was to achieve a higher cruising speed than is comfortable for the average healthy cyclist, with a range of 40 - 50 km, and a tolerable weight penalty.

The Mark III Tricanter in its present form has an 18-speed transmission with top gear equivalent to an 80-inch-diameter rear wheel (rear wheel rotation of four times pedal cadence), and bottom-gear equivalent to a 21.33-inch rear wheel. This gearing is low for high-speed riding. However the gearing still allows a strong rider to achieve speeds over 40 km/hr. In the EAHPV the rider can, with suitable gearing, provide reasonably high starting and acceleration torque, reducing the need for high motor torque at low speed. Energy-consumption calculations over the Christchurch Bicycle Driving Cycle (CBC) also indicated (7) that energy recovery from regeneration would not be more than about 20% of the cycle energy consumption, so regeneration was not specified at this stage.

For this application a small permanent-magnet D.C. motor with a pulse-width-modulating controller was considered appropriate. Whilst a motor of around 400 watts would have been preferred, a conveniently available 250-watt Polymotor from a Sinclair C5 tricycle was used. This motor has a 4:1 epicyclic-geared speed reduction to give an output speed at maximum power of about 900 rev/min. The chain-gear speed reduction from motor output to rear wheel is 2.45:1. A Dynamic Controls DS100 wheelchair motor controller was used.

Data given by Kyle and Caiozzo (8) for duration of human power output indicate that an average healthy cyclist can maintain about 270 watts over a 20-minute period. This is the duration of the Christchurch Bicycle Cycle, figure 2. For the bare HPV driven over the Christchurch cycle on a flat road in still air, the Cycle Energy Consumption, CE, of 138.7 kJ corresponds to an average power dissipation at the road of 134.3 watts allowing for drive-train losses (based on time spent moving, the 146 seconds spent stationary at intersections being subtracted from the overall cycle time of 1200 seconds). A 250-watt electric motor can therefore be used to provide the effect of a tandem rider.

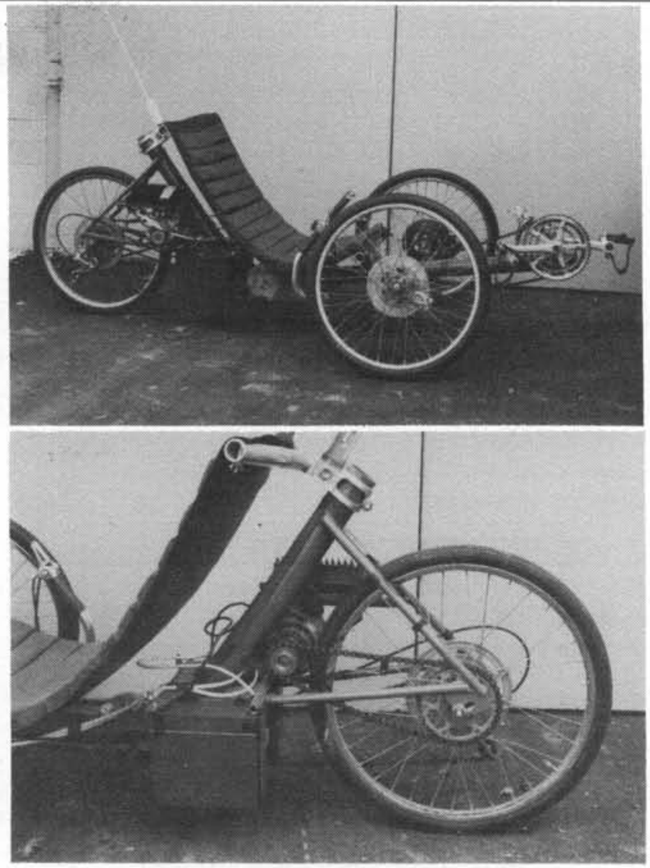

Figure 3 Views of Tricanter Mk III EAHPV with detail of battery installation and transmission

Two options were available for mounting the motor :

(i) chain-geared reduction onto the rider's front chainwheel shaft, such that the motor could spend a high proportion of its time at higher speed (therefore power) and greater efficiency;

(ii) chain-geared reduction through an overrunning-clutch/sprocket assembly driving on to an additional sprocket mounted on the near side of the rear drive wheel.

Arrangement (i) was preferred but it represented a more awkward installation, requiring a 10:1 speed reduction to match a comfortable pedal cadence, and with adverse effect on the vehicle weight distribution. The simpler rear-mounted option was therefore chosen, given that the major contribution of the electric motor was to be at cruising speeds and higher, where both motor and controller were more efficient.

To allow the rider of the EAHPV to pedal without the drag of the motor and transmission, a free-wheeling sprocket assembly was mounted on the geared-motor output shaft (achieved more easily than an installation onto the rear-wheel hub). The motor and battery mountings were fabricated in 1.2-mm sheet steel, the batteries slung from transverse brackets below the motor, as shown in the views in figure 3.

Several battery types were investigated (8) with regard to cost, discharge characteristics and energy density. The cost-driven choice was a pair of 12-volt GS Portalac PE12V17 sealed deep-discharge lead-acid batteries each of

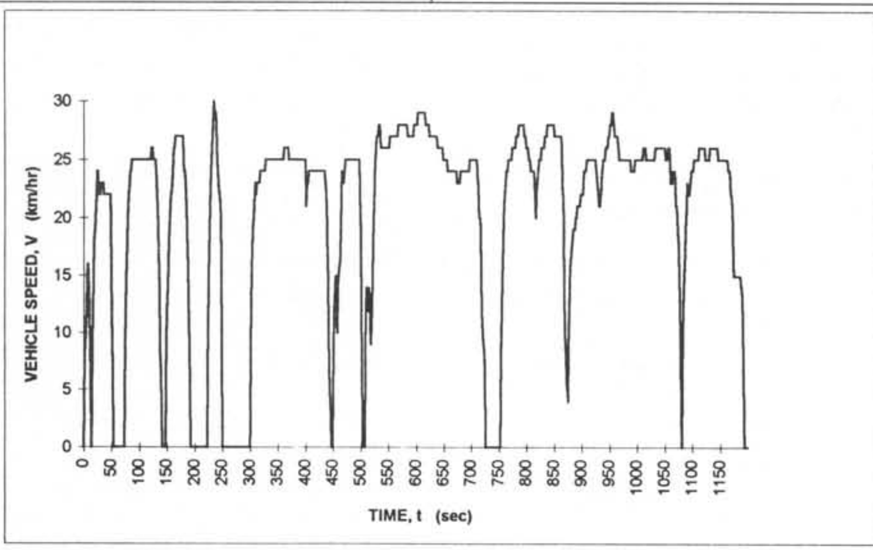

Figure 2 Christchurch bicycle-driving cycle

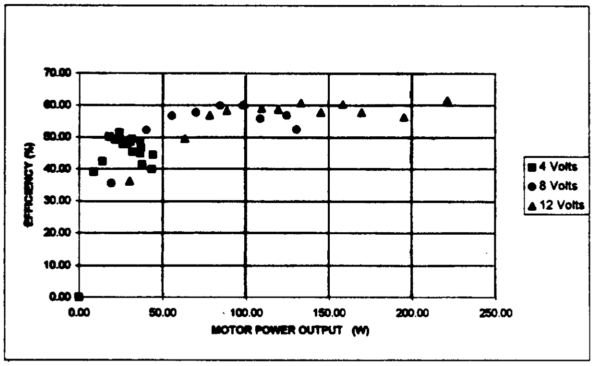

Figure 4: Electric Motor Efficiency versus Power Output

Figure 4 Electric-motor efficiency vs power output

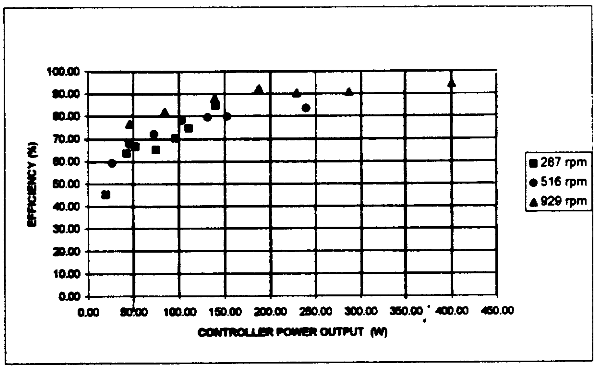

Figure 5: Controller Efficiency versus Power Output

Figure 5 Controller efficiency vs power output

17-ampere-hour capacity and energy density 35.2 Wh/kg. Total battery weight was 11.6 kg.

ELECTRIC-MOTOR AND CONTROLLER PERFORMANCE TESTS

Dynamometer tests of the electric motor showed that as torque increased (with increasing current) the speed at test voltages of 4, 8 and 12 volts drooped only slightly, indicating shunt-wound behaviour. This could produce high current and heavy battery drain if the rider demanded high speed from the motor when ascending an incline, and some form of current limit in the controller would be worthwhile.

Motor efficiency is plotted against power output in figure 4. At 12 volts the efficiency is fairly flat between 100 watts and 250 watts, just reaching 60%. The battery-discharge time, BT, varies roughly inversely as the discharge current. Portalac performance curves for the PE12V17 battery give, using an approximate binomial curve fit,

$$BT = \frac{600}{i} + \frac{420}{i^2} \quad \text{minutes} \qquad (1)$$

where I is the current drawn from the battery.

A steady motor power output of 250 watts, requiring a current of approximately 17 amps, would discharge the batteries in about 35 minutes. Reducing the power output to 150 watts gives a discharge time of about 60 minutes.

The Dynamic Controls DS 100 microprocessor controller was tested to determine its efficiency at various power levels. Figure 5 shows a graph of controller efficiency versus power output. Over the range where the motor approaches 60% efficiency the controller output is in the range 150 - 450 watts, where its efficiency is 80 - 90%, the higher efficiency being at higher motor speeds. It is clear from figures 4 and 5 that at low speed and light load the system efficiency will be low, eg. a typical overall electric drive efficiency to the motor-output sprocket of about 30%. It therefore appears that the most effective way to operate, allowing for the battery-discharge characteristics, is to work at around 60% of rated power and at high speed.

ENERGY-CONSUMPTION MODELLING OF THE URBAN COMMUTER DRIVING CYCLE

The road-load equation can be used in a simple form for HPV energy consumption in still air as follows:

$$P = ((C_R + \sin\theta)Mg + \tfrac{1}{2}\rho C_D A V^2 + M_e dV/dt)V \qquad (2)$$

P = power to overcome resistances to motion, W
M = mass of vehicle plus rider, kg
g = acceleration due to gravity, m/s^2
θ = angle of inclination of road to horizontal
C_R = speed independent coefficient of rolling resistance
V = vehicle velocity relative to the road, m/s
ρ = density of air, kg/m^3
C_D = aerodynamic drag coefficient of the vehicle
A = frontal area of the vehicle, m^2
M_e = equivalent mass of vehicle allowing for rotating inertias of drive train and wheels, kg, approximately 1.035M
t = time, seconds.

In the present work the rolling-resistance coefficient, C_R, was most accurately determined using tow testing at very low speed, and the aerodynamic-drag coefficient, C_D, was obtained from results of coast-down testing by Raine and Amor (5).

Details of the Vehicle-Energy-Consumption computer model (VECM) have been given by Raine and Amor (5). Using equation 2, the energy output required from the prime mover to complete the driving cycle (Cycle Energy, CE) is determined by taking the following sum over the digitised cycle:

$$CE = \Sigma_{cycle} P.t \qquad (3)$$

where t = 1 second interval.

Note: if P becomes less than zero at any time under deceleration, it is set to zero for the calculation in equation 3.

The model was run with the Christchurch bicycle driving cycle (5) as shown in figure 2 , and modified as described below. This represents a commuter journey across the city on almost flat terrain, about 20% of the distance being through city streets (office blocks), and the remainder through suburban areas (low-density low-rise residential buildings). There are ten sets of traffic lights en route.

Energy-consumption modelling focused mainly on a comparison of the EAHPV with and without an aerodynamic body, and several modest road gradients, at various driving-cycle maximum speeds. Given that the electric-drive system sits behind the driver's seat in a zone of separated flow, the same bare-vehicle aerodynamic drag coefficient, 0.92, was used for both the original vehicle and the electrically-assisted version.

A consequence of executing the driving cycle at a higher average speed is that the cycle effectively changes, only the distance covered remaining the same. To handle this a Pascal program was written to convert the Christchurch Bicycle Cycle (CBC) from a time to a distance base, including unchanged the lengths of time at rest at various traffic-light or intersection stopping points. Working with similar acceleration rates, new time-based cycles were calculated for several different top speeds. This

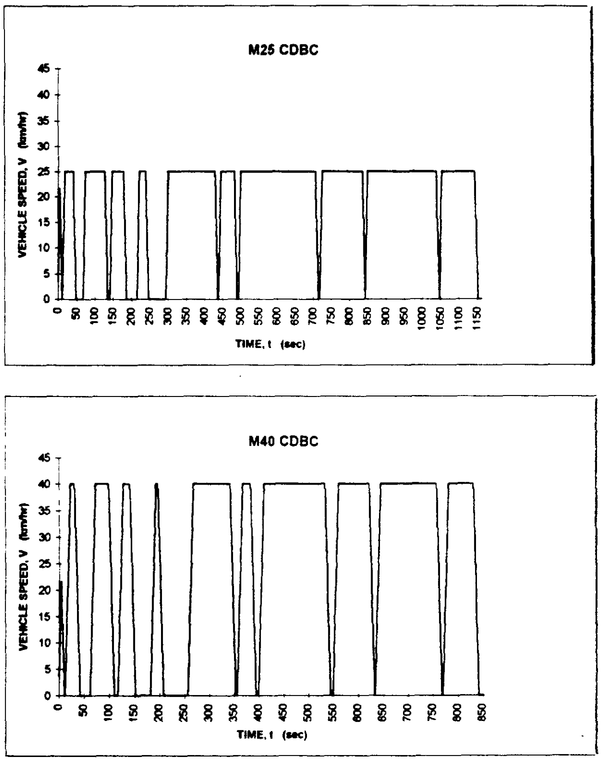

Figure 6 Distance-based Christchurch bicycle-driving cycle for maximum speeds of 25 & 40 km/h

results in a slight stylising of the original driving cycle as shown in Figure 6. A cycle top speed of 25 km/hr gives a value of CE for the Christchurch Distance-Based Driving Cycle (CDBC) within 1.2% of that for the original CBC. Each version of the CDBC was then imported into the VECM to study its corresponding Cycle Energy.

A transfer function approximately relating battery discharge rate to road-load power demand, and the corresponding controller, motor and transmission efficiency, was used to estimate battery discharge time as CDBC average speed increased. However, more knowledge of the actual motor-current draw during periods of acceleration would be needed for accurate predictions. In each of the electric-assist cases modelled, the human power input over the driving cycle is taken as that for the bare unassisted Tricanter over the reference Christchurch Bicycle Cycle.

RESULTS OF VEHICLE ENERGY-CONSUMPTION SIMULATION

The VECM was run at CDBC maximum speeds between 25 km/hr and 50 km/hr at 5-km/hr increments, and for gradients 0°, 1.5°, 3° and 6°. In each case computations were made for the EAHPV of

* CE cycle energy consumption, kJ
* ICE incremental cycle energy consumption, kJ; ICE = (CE - 138.7) kJ. i.e. the battery energy input, assuming unchanged human energy input.
* ICP incremental cycle average power, W, calculated as ICE/T' (where T' = total cycle time less time spent stationary)
* V_{av} cycle average speed, km/hr
* BT Battery-discharge time, min.

Over each cycle the VECM also calculates the percentage of the total cycle energy, CE, used overcoming each of: inertia, rolling resistance, aerodynamic drag and gradient resistance. These simulations were carried out and compared, for two electrically-assisted vehicles, at the 25 km/hr top speed CDBC only, with results for the basic bare Mk IV Tricanter HPV. Characteristics of these vehicles are shown in Table 1.

As the power demand on the batteries is variable, computation of battery-discharge time, BT, is at best approximate. However, an algorithm was inserted into our computation based on battery-discharge current, i, with the batteries in series driving the controller at 24 volts being given by

$$i = \frac{ICP}{24\eta_c\eta_m\eta_t} \text{ amps} \qquad (4)$$

where η_c controller efficiency, for which an interpolation formula was constructed from figure 5.

η_m electric motor efficiency, which was taken as 60%

η_t is the transmission efficiency from motor gearbox output to back wheel, taken as 95%.

The value of i from equation 4 is then used in equation 1 to give an indication of battery-discharge time.

Figure 7 shows curves of Cycle Energy against cycle average speed for the simulated vehicles at the various road gradients. On the flat-road 25-km/hr-top-speed cycle, M25, the difference between CE for the bare battery-assisted and human-powered vehicles, 18.7 kJ (table 2), is the energy drawn from the batteries simply to carry the electric-assist system on the vehicle over the driving cycle, and is about 13.3 % of the value of CE for the basic human-powered vehicle at this cycle top speed. Figure 8 shows that gradient is a dominant energy consumer, as noted in earlier sensitivity tests on the VECM by Raine and Epps (9).

Figure 7 also illustrates the expected large increase in the Cycle Energy with rising average speed, with the increase in CE at a much lesser rate for the aerodynamic-bodied vehicle. The assumed drag coefficient of 0.25 is optimistic for a commuter-touring vehicle

Table 1: Simulated Vehicle Characteristics

Characteristic	Mk IV Tricanter - (Bare HPV)	Battery-assisted Tricanter MkIV (Bare EAHPV)	Battery-assisted Tricanter Mk IV - aerodynamic body (Aero EAHPV)
Mass with 80kg rider, kg	98	118	130
Rolling Resistance Coefficient, C_R	0.006	0.007*	0.007*
Aerodynamic Drag Coefficient, C_D	0.92	0.92	0.25
Frontal area, m^2	0.45	0.45	0.50

* The EAHPV has mountain bike tyres of larger cross section and higher rolling resistance.

where it is likely that the rider may at least some of the time have an open cockpit, but we simply aimed to see what advantage might accrue from good aerodynamic design.

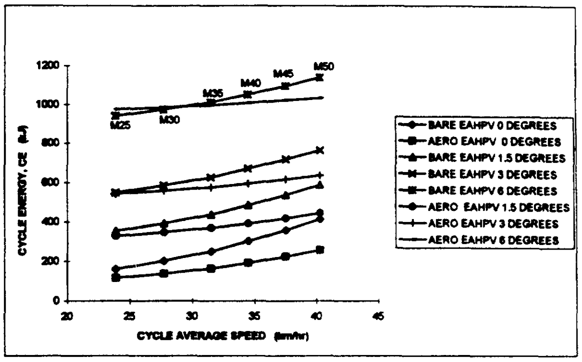

Figure 7 Cycle-energy results at various maximum driving-cycle speeds

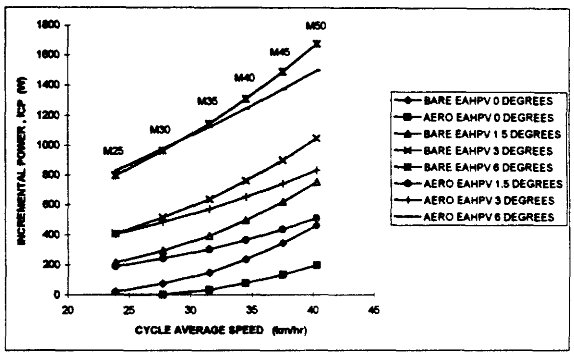

Figure 8 Incremental cycle power at various maximum driving-cycle speeds

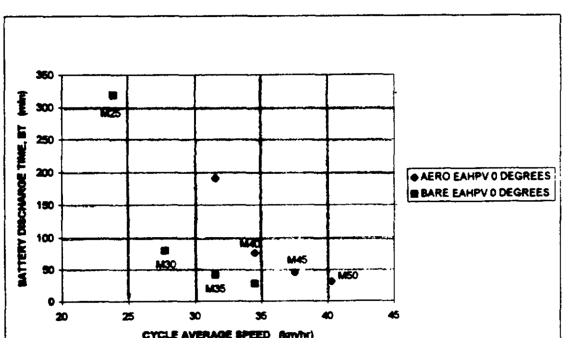

Figure 9 Computed battery-discharge times at various cycle maximum speeds.

Table 2: Proportions of Cycle Energy Used in Overcoming Various Resistances

Vehicle & Driving Cycle Characteristics			Breakdown of Cycle Energy				
Vehicle	Cycle*	0°	CE kJ	Inertia %	Rolling %	Aerodynamic %	Gradient %
Mk IV Tricanter	CBC	0°	138 70	19 71	26 69	53 60	0
Mk IV Tricanter	M25	0°	140 47	18 42	27 30	54 28	0
Bare EAHPV	M25	0°	159 14	19 58	32 51	47 91	0
Bare EAHPV	M30	0°	201 83	21 86	25 20	52 94	0
Bare EAHPV	M40	0°	302 33	25 50	16 05	58 45	0
Aero EAHPV	M30	0°	136 93	35 50	40.94	23 56	0
Aero EAHPV	M40	0°	191 76	44 29	27.88	27 82	0
Bare EAHPV	M25	3°	547 62	4.92	9 55	14 08	71.46
Bare EAHPV	M30	3°	584 38	6 68	8 82	18 54	65 97
Bare EAHPV	M40	3°	669 6	10 49	7 38	26 91	55.22
Aero EAHPV	M30	3°	557 21	7 72	10 19	5 87	76 22
Aero EAHPV	M40	3°	593 6	13 04	9 18	9 16	68 62

*M25, M30, M40 are respectively the stylised Christchurch Bicycle Driving Cycles (CDBC) for Cycle maximum speeds of 25, 30 and 40 km/hr. CBC is the original Christchurch Bicycle Driving Cycle.

Figure 8 shows corresponding curves of Incremental Cycle Power, ICP, for the battery-assisted vehicles. The average power demand with increasing average speed and gradient rapidly exceeds that available at the road (maximum about 237 watts continuous) from our 250-W motor. The implications of this are that a larger motor may be warranted and that the motor should preferably be geared into the rider's chain wheel for better impedance matching on hill climbing. However, this is only battery-assisted human power and it is unrealistic to consider high average speeds except on flat roads.

Figure 9 shows computed battery-discharge times and corresponding ranges based on cycle average speed. This figure very clearly demonstrates the advantage of a low-drag aerodynamic body. At the 30-km/hr top cycle speed the aero EAHPV uses less Cycle Energy than the bare EAHPV at 25 km/hr top cycle speed, despite the weight penalty of the electric power system and the aerodynamic body.

Table 2 shows a selection of Cycle Energy values and their breakdown into proportions used in overcoming inertial, rolling, aerodynamic and gradient resistances. These CE breakdowns are provided for several combinations of vehicle, driving cycle and road gradient. Points to note from the limited data shown in this table are the following.

(i) The human-powered Mk IV Tricanter on the stylised distance-based M25 cycle has a CE value and breakdown very similar to that for the original road-generated CBC.

(ii) Aerodynamic drag absorbs between about 48% (M25 cycle) and 59% (M40 cycle) of the Cycle Energy for bare EAHPV journeys on the level terrain. Whilst this is high for an urban journey, we have a high-drag vehicle configuration with CD = 0.92.

(iii) Addition of a low-drag aerodynamic body results in a much more even spread of work done against the three resistances on flat roads, aerodynamic work falling to about 28% of CE on the M40 cycle.

(iv) As noted earlier, gradients are a great energy sapper, even a moderate gradient like 3° (1 in 19) adding eg. 382.6 kJ, or almost 190% to the CE value for the bare EAHPV on the M30 cycle. Generally the gradient takes between 55% (bare EAHPV on M40 cycle) and 76% (aero EAHPV on M30 cycle) of the Cycle Energy on the 3° slope.

RESULTS OF ROAD TESTING - DISCUSSION

The Mk III Tricanter as tested had its front track increased from the original 750 mm to about 900 mm, with about 5° negative camber on the front wheels, and felt very stable. This sensation was enhanced by the low centre of mass of the electric drive system and batteries.

Drivers rapidly adapted to using the thumb-wheel potentiometer control for electric power at the handle bars. As the electric-system efficiency and power were low at low vehicle speed, we normally used it as a power booster once a speed of about 10-15 km/hr had been reached, providing improved acceleration and comfortable cruising under combined human and electric power input at 35-40 km/hr. Part-load cruising at around 20 km/hr on electric power alone was occasionally used. Riders commented that the EAHPV gives a pleasant sensation of much greater energy, or of assistance from a tandem rider, with little awareness of the quiet electric drive.

Calculations with equation 2 indicate that the bare Mk IV Tricanter with an 80-kg rider requires about 194 watts at 30 km/hr, and the bare EAHPV requires 436 watts at 40 km/hr. Thus, with a maximum motor-power contribution at the road of, say, 237 watts, and with human exertion equivalent to that needed to pedal the HPV at steady 30 km/hr, the EAHPV would reach about 40 km/hr.

Measurements of range to date have not been carried out under carefully controlled conditions. The longest day involved a return journey to an airport cruising at 30+ km/hr plus speed trials at the airport. At the end of the day 40 km had been covered and the batteries were low and would have given about 5 km more assisted riding. This range of 45 km corresponds to a battery-discharge time of about 100 minutes at an average driving cycle speed of about 27.5 km/hr in the computer-simulation output of figure 9. This seems to tally well with the driving experience.

A repeatable top speed of 46 km/hr was achieved on a level runway in fine weather and calm conditions, with a best one-way battery-assisted run of 50 km/hr by a recreational cyclist weighing 76 kg. Higher chainwheel gearing would have improved this figure as it was found that the unassisted bare Tricanter MkIV would briefly reach 50 km/hr (requiring 756 W). At high road speeds motor EAHPV is over the peak of its power curve and providing reduced assistance.

The computer modelling has shown that a low-drag body of modest weight would substantially improve the present typical battery range of 40-50 km, although re-gearing would be required to match a higher available cruising speed to the electric-motor output speed. The earlier aerodynamic body tested by Raine and Amor (5) did not achieve a suitably low drag coefficient, but would have approached the CD = 0.25 figure used here if it had been modelled more closely on results of our wind-tunnel model tests which achieved a CD value of 0.13 for a fully enclosed body.

A higher average level of motor power output and efficiency during vehicle acceleration would be achieved if the motor output were integrated into the Tricanter transmission at the rider's pedal chainwheel rather than the rear road wheel. This might involve a modest penalty in weight and braking stability. On uphill work vehicle road speed would be low and matching motor speed to pedal cadence would be more essential to maximise the availability of the boost motor power. The results of figure 8 show that for regular hill work, a more powerful boost motor would be worthwhile, but the increase should not be great as an increase in battery weight should be avoided.

It is intended to enhance the power of the VECM program and consider journey types further before producing more results. It would be instructive to build into the program the effects on human and electric power consumption of:

(i) power and efficiency characteristics of the motor and control system,
(ii) the gearing configuration, and
(iii) optimal gear-ratio selection on tackling short inclines to maximise human and auxiliary prime movers efficiency.

CONCLUSION

This paper has reported the design and performance of a first prototype conversion of a Tricanter HPV to operate as an electric-motor-assisted HPV, which appears to be an attractive option on generally level roads where the weight penalty from lead-acid batteries is less significant. The 250-watt motor offered a useful performance enhancement with a range of over 40 km easily achievable.

We intend to build an upgraded EAHPV based on the Mk IV Tricanter, with a more efficient motor controller running in a torque-demand mode and a more efficient motor of 400 - 500 watts maximum power. While there is no doubt that a small lightweight gasoline engine is preferable for AHPV applications in terms of weight penalty, we see there being a niche for electric-motor-assisted drives for the type of application described here.

The vehicle energy-consumption computer modelling for different vehicle and driving-cycle configurations has underlined the advantages of a good aerodynamic body and the energy cost of cycling in hill country. Further enhancements of the VECM program are now intended.

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Letter: IHPVA racing rules

I found the summer-fall '94 issue of Human Power to provide plenty of material for thought by the IHPVA membership. Two articles really caught my attention: "Why your bicycle hasn't changed for 106 years", and Peter Sharp's open letter.

The first article provided plenty of insight into the mentality of the UCI.

Obviously they were in a period of maturation when the anti-recumbent rules were passed. And quite obviously there was a difference in opinions inside the UCI organization then, as there now appears to be in the IHPVA. For if it was not so, then the delegates to the 58th Congress of the UCI would not have had a majority vote favoring legaling Faure's record. But whoever got to select the members of the special technical commission, or the candidates to that commission, were obviously in the minority of the UCI delegates. This shows how politics can kill ideas and solutions to problems. And so IHPVA members should take note that active participation is what keeps an organization alive.

Now I read very carefully through the 1934 UCI rules and could not find anything that specifically banned recumbents. I guess that I have spent too many years reading about sailboat race rules and how the boats are made within the rules as far to the extremes as is possible. The UCI under the same kind of extremism of designs would have long ago discarded their 1934 rules. It is a very carefully worded set of rules that would disallow almost all non-diamond-frame upright bicycles, but a recumbent could be built that would satisfy the1934 UCI rules. It might not be the most efficient recumbent, but one could be built. The key rules state relative location of the crank to the ground, crank to the seat, and crank to the wheels. It does not ban the use of extensions on the crank, such as one might see in a linear design (rods to a crank located under the seat). Now I suppose that there have been plenty of rule changes since then that would make that one difficult.

But if the "culture" of the the UCI was not so ingrained into its membership, they would be doing the same design extremes as the sailors. I guess sailors are a more independent lot.

As for Peter Sharp's article, I agree with him on some of what he has to say. High-altitude records are fascinating but do not truly represent the ultimate speed record. Could't we use a formula to adjust for altitude? That way those who live in high-altitude regions do not need to go to the coast to run their machines. An altitude restiction would also impose a handicap on site location. I see no reason why we should not allow all present records, with adjustments made by formulas for all the conditions (altitude, slope, wind, or others) that were present, and allow the same in the future. The sites available for the speed championships are limited enough; let's not limit sites even more. For instance, would the '93 site at Yreka fit a 1000-foot elevation limit? I think not.

Do we have to create more categories of HPVs to meet desires of the membership or to "grandfather" in old records? No. What we need are specialty clubs within the IHPVA to be formed by interested parties with their own restrictions on HPV type (which I understood was already happening). If the type is successful with the public then the IHPVA will grow as new people discover the freedom of choices in the IHPVA. If the type is not popular then its club will wither and die and its membership will still find a warm welcome in the fold of the general IHPVA. As for me I think the present classes are sufficeint to cover all present and future categories of HPVs. Are energy accumulators a problem within the current IHPVA structure? No. Anybody can tell you that a flywheel will accumulate energy. But everyone seems to think that heavy bicycle rims are bad, yet they are in the strictest sense a flywheel and therefore an energy accumulator. The problem with heavy rims is control, braking, and acceleration. On a straight downhill run with a flying start, a heavy steel rim will give some return for its extra weight. I will let the PhD's figure out how much. It would be nice if they would publish a few of the necessary calculations in Human Power.

Therefore I think that energy accumulators should fit nicely within our present HPV categories. But that also would mean no "charging" of energy accumulators before a race. A race would have a distinct start time and end time. How a competitor used the intervening time would be up to them. And all vehicles and riders as raced would need to be weighed and surface areas calculated. These would be used in the formulas for conditions present at the site at race time, as I mentioned before. A little downhill slope? No problem, just insert the appropriate variables in the formula and let them roll. A stiff tail wind? Just do the same. The age of the computer is with us and this would be easy. In biology we dream of problems so easily solved. Of course race results without a computer could be a nightmare. As if they are not already a hassle for our dedicated volunteers on race day! But just imagine: no more waiting for the wind to let up, and no slight hill to prevent using an otherwise perfect course.

As for solar, wind, and other energy sources; that should be another club's specialty, one which the IHPVA has a few ties with. I would think that holding events together with hybrid and alternative-energy vehicles would help get HPVs more public exposure. Maybe the problem is more one that HPVers are a small group, but the hybrid enthusiasts are even smaller in number and nobody really wants them because they don't fit some nice neat category of power. If that is the problem, then maybe we could help the hybrid enthusiasts to create a sanctioning body for their special class of vehicles. They are some of the innovators in the IHPVA, so we should not be too harsh on them for wanting to show us ideas that may be alot of fun and practical.

Thanks for opportunity to give my opinion, and keep up the hard work.

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AHPV - A REVIEW OF PRINCIPLES

by John G. Tetz

Introduction

I appreciate the exploration in Peter Ernst's article, Bridled Assisted HPV's, and Unbridled Chances (HP 11/3, spring/summer 1994). Peter Sharp has also written several articles on assistance for human-powered vehicles and has extended the concept to include energy accumulators. Israel Urieli, a professor of Mechanical Engineering at Ohio University, is including AHPVs in his curriculum and is designing a Stirling engine specifically for AHPVs. Matt Weaver has included practical vehicles and energy storage in his comments (Draft Competition rules of the IHPVA):

> "I think we sense where things are naturally headed with this class of transportation (pure pedal power is simply not resourceful enough!).

The list of supporting statements continues with the many enthusiastic letters I have received from IHPVA members.

In the four years and 16,000 miles since I built a gasoline-powered assist for my P-38 Lightning / F40, I have witnessed an unprecedented interest in the "Motor". I can be showing the fully faired F40, which is an uncommon machine for most people, but when they spot the "Motor" all attention is diverted to it. I am known far and wide as the person with the "Motor". Even from those who profess to dislike it, the "Motor" commands the most attention along with the most verbiage. What this says to me is - even though on the surface there is resistance, down deep inside we want some form of help climbing hills.

The question is "but how out of the many possible ways is this to be accomplished?" My philosophy is to complement the ever-elusive efficiency and the overall elegance that is a bicycle. This kind of AHPV encompasses and integrates a group of key elements that can be described by four basic principles. Ignoring any one element creates a ripple effect - most often removing the concept from being an AHPV and places it back into the motorized-bike category - i.e. higher speed, more continuous motor operation - more pollution - large fuel supply - heavier - etc. This is contrary to the elegance of a bicycle. Previous motorized-bicycle designers have been seduced by the bigger, faster, easier growth cycle that we have been living with over the last 100 years. But this pholosophy has its disadvantages in the ecologically sensitive 1990s.

I find, from the comments and questions I am asked, that quite a few people do not fully understanding this AHPV concept. The following is a review.

Abstract

1. For most conditions of road inclination, typical humans do not require mechanical assistance; however, when required by steeper grades, such assistance is extremely critical to the well-being of the rider.
2. The addition of mechanical assistance involves a strong weight penalty when not used, due to the limited capability of a typical human to deliver power.
3. The foregoing observations (1) and (2) establish the conceptual framework of an AHPV, which encompasses and integrates the following key principles both in regard to steady effort, and in regard to recovery from heightened effort.

Principles

a. Maximize the use of available human power. The first principle is tied to human power capability. Most people can deliver about 75 watts for six to eight hours, which is the typical amount of power required to pedal a bicycle on flat ground at speeds of about 5 - 6 m/s (12 to 14 mph). However when asked to climb a steep hill (5% grade) and produce 150 -230 watts the time to fatigue can drop to as low as a few minutes. Even if the speed is reduced, the stress is still relatively high. It is imperative then to use all available human power but stay within a reasonable power limit to reduce premature fatigue.

The second principle

b. Minimize the weight penalty of the assist-power source to the rider for the lesser grades when assistance is not used. This is partially accomplished by combining the amount of power that an average human can deliver for the better partof a day (about 75 watts), along with just enough power from an assist source to climb a steep hill. This is the first step in reducing the assist-device mass to well below 4.5 kg, and preferably below 2.5 kg (generally for present gasoline-powered systems). The small size of the assist device is not capable of driving the AHPV up the steeper hills without help from the rider.

The third principle

c. Selection of a gear ratio that will support a range of speeds needed for hill-climbing. Gear reduction and slower speeds gives the means of further reducing the size and weight of the assist-power source to a point where it becomes transparent to the rider on the lesser grades. Gearing has been selected to give range of assistance down to 2.5 m/s for steep hills, or under conditions of heavy loads. With gearing set for 2.5 m/s the engine reaches maximum rpm at bike speeds of 5 - 6 m/s (10 - 12 mph). <u>This is ideal</u>. By the time the vehicle speed is up to 5 - 6 m/s the hill has leveled off to where the rider doesn't need assistance. Low top speed encourages infrequent use, and therefore high trip fuel mileage and low pollution. Low top speed should also reduce license and insurance requirements.

The fourth principle

d. Infrequent operation of the assist function - involved only as required for steeper grades. Since assistance is needed only on steeper hills, (typically about 10% of the trip distance in populated areas) a rider can travel well over 425 km/l (1,000 miles per U.S. gallon) (averages well over 1300 mpg are common). The criterion in measuring trip fuel consumption is the amount of fuel required to move the vehicle and the rider from point A to point B. Unlike heavy vehicles, an AHPV is not stuck using the power source more continuously. (Someday we will have to include the trip food consumption).

The phenomenally high fuel mileage has the critical advantage of not requiring a large (therefore) heavy fuel supply (350 ml, 12 fl.oz., is more than adequate for long-distance trips and a half of this or less for local trips) - thereby further reducing the power the operator must produce when the engine is not in use (again maintaining high biking efficiency). The small amount of fuel is adequate for assistance, but designed to be woefully insufficient for continuous use.

Pollution

The principle of infrequent assist use is a major factor in reducing overall trip pollution caused by the assist engine. Preliminary pollution calculations for a typical 16-km (10-mile) trip, show quite similar comparisons between 1992 auto exhaust emissions and the AHPV (average engine use of 10% of the trip distance). This is with present unclean two-stroke technology.

California Air Resources Board Title-13 pollution regulations are proposing pollution regulations that are driving small-engine manufactures to experiment with fuel injection, skip fire, higher fuel/oil ratios, overhead-valve four-strokes, and catalytic converters. These new engines will further reduce AHPV trip pollution. Infrequent use and low power requirements make alternative fuels and power sources ideal candidates for AHPVs.

Derivative benefits that follow from the above principles include the following.

a. A large percentage of trips are enjoyed in silence - typically 85-92%. Although a small engine may be noisy, it is generating this noise for a very short period of trip time. Assist noise has been unfairly compared to a silent bicycle. Yet we use these vehicles on roads that have high auto noise. The noise from automobiles traveling above 20 m/s, 45 mph, equals that of the assist-engine. Trucks of course completely drown out any assist noise.

b. Freedom to choose a wider range of routes. I have gone on trips and used the vehicle as everyday transportation in situations that I wouldn't think of doing without assistance.

c. Enhanced personal comfort during climbing, due to reduced power demand, such as less overheating. More cooling on downhills.

d. Higher steep-hill climbing speeds and higher average speeds on the flat and lesser grades due to less steep-hill climbing fatigue.

e. Last but probably the most important - maintaining a sense of personal accomplishment (this is a major feature of bicycling) due to limited assist operation.

An AHPV is not a motorbike. The label motorized bike or motorbike contains all the old concepts and biases that in the end restrict the development and acceptance of bicycles as alternative transportation. New concepts require new labels. The term AHPV denotes the concept rather than the power source or specific hardware implementation. The AHPV principles can be applied to most technologies. Indeed, the AHPV principles described herein are not limited to conventional engine technology and are expected to be applied soon with alternative power sources.

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Bridled AHPVs - response
by Peter Ernst

I have received many comments on my paper in HP vol.11/2, and would like to respond collectively here.

It was never my intention to nurture hopes of harnessing esoteric energy forms, e.g. exotic storage systems, revolutionary engines, etc. that may have aroused academic or laboratory notoriety. No: because time is really pressing, we must build now HPV assists relying on effective locomotive aids. Such combinations must guarantee muscle input first and foremost. Only thereafter assist energy may flow in, as a well-earned bonus, as in Yamaha's new 'PAS' bicycle-control principle. (Any practical test reports from Japan coming in 1995?)

I take exception to Yamaha's form of auxiliary energy (batteries) because assist systems must never burden our excellent ratios of payload to vehicle-weight. These are approx. 80 kg/10 kg = 8 for HPV sports, and 100 kg/14 kg = 7 for HPV touring. Lean bikes cannot afford to have feet of lead, unless we want to ridicule our given muscle-power contribution. At the worst, at unchanged human effort, progress may even become slower than before! That is, assist components must always justify their validity on an extended time scale, inclusive of captive 'gray' energy, hidden weight, service/repair costs, etc.. Hence, photvoltaic panels, electric batteries, windpower are out. Bitter as it may sound to puriests, but the option of a micro-tank plus combustion engine is the only immediate realistic asist alternative for the road. Here we come back to square one: does the IHPVA want to remain on closed racing circuits for another 20 years, or face road-realities?

Scenario 1: Imagine the car makers swinging to a new electronic breakthrough by placing all controls on the dashboard. A truly golden opportunity arises to motivate the driver's legs ecologically by turning a small control-generator in order to release ignition current - for fast overland-motorway runs, symbolic pedalling only; for slow urban-city crawling, an active pedalling rate.

Serious thoughts would precede short car trips. Unless they were for heavy loads, such short flings would surely get replaced by handy bikes, or free-lane public transit in tacky flow/parking coonditions. Mileage would decrease, cities would ag ain breathe....

Scenario 2: Imagine P.R. China's revolutionary traffic board acknowledging the merits of such electronics. But, after evaluating IHPVA (John Tetz) proposals/prototypes, it decides in extremis to cancel the presentation of the new People's car, replacing it instead with a new breed of bridled AHPVs with a 1+1 seat comfiguration (in view of widespread dismal car occupancy of only 1.1 - 1.3 people. Apart from a much better usage of road and parking space, the immense advantage rests with the average fuel consumption of about 600 km/litre (1410 mpgUS). This is about 1/50th of a car's needs.

Hard-boiled racing purists ought to use 1995 (the year of the IHPVA's 21st birthday and coming of age) for developing much-more-human scenarios, higher ethics, joining hands in solving remaining socioecolgic absurdities such as: Why are engineers on trains forced to use deadman's pedals, while drivers on open roads get by scot-free, absolved?

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Comment on the article by Peter Ernst, "Bridled Assisted HPVs, Unbridled Chances"

H P, spring-summer 1994, vol. 11/2

by Izzy Urieli

Peter Ernst is to be applauded for bringing up the controversial subject of AHPVs, which has lain dormant since the sequence of articles by John Tetz in 1991(1). The adjective "Bridled" is so important to the concept of AHPVs that we might consider coining a new acronym "BAHPV" to emphasize this point. On discussing the article with John Tetz we both agreed that the amount of "bridling" suggested by Peter does not go far enough. He has suggested a maximum assist speed of 25 - 30 kph (16 - 19 mph) with a peak power of 440 W, and we feel that the single-purpose nature of the assist requires an assist speed of around 14 kph (9 mph) and a power of 150 W. This is not an arbitrary choice, and I will attempt to justify it below.

I first wish to formally define the unit "human-power", or hup (as opposed to horse-power, or hp). Refering to the landmark paper by Douglas Malewicki in 1983 (2) we define 1 hup = 75 W, or the amount of power that a healthy human can sustain for 8 hours before exhaustion. Thus 1 hup is approximately one tenth of a horse-power.

Consider now the power required to drive a hpv at a steady velocity V (3):

$$\text{Power} = 0.5\rho\,(V + Vw)^2\,V\,CdA + (Cr + \text{slope})\,m\,g\,V$$

where:

- Power is the drive power (W)
- ρ is the air density (1.18 kg/m^3)
- V is the hpv velocity (m/s)
- Vw is the wind velocity component (positive for headwind) (0 m/s)
- CdA is the effective frontal area, being the coefficient of drag (Cd) multiplied by the frontal area (A) (0.4 m^2 - unfaired SWB touring recumbent)
- Cr is the coefficient of rolling resistance (0.005 - high-quality tires, smooth asphalt)
- slope is the road slope (elevation / distance)
- m is the total mass (rider + hpv) (90 kg)
- g is the acceleration due to gravity (9.81 m/s^2)

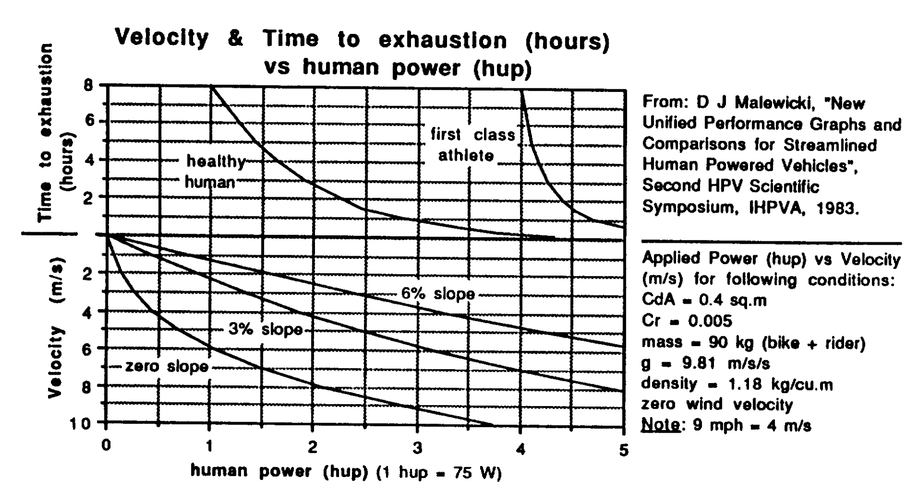
In order to match the hpv velocity to the maximum duration of human effort for various slopes, we plot Malewicki's data together with the above equation using "human-power" as a common axis, as shown below. Note that our curve has been plotted for a specific hpv operated under specific conditions, and can be plotted for different machines and conditions as required (4). Values of CdA (and Cr, for that matter) can be obtained by experiment, as indicated in Nickolas Hein's "Hill climb/descent simulations" (5). Notice also that velocity is given in m/s. This is consistent with SI units, and saves having to continually juggle between mph and kph as we cross the Atlantic. I also find it more pleasing to contemplate the number of meters that I ride in one second. Miles or kilometers tend to overwhelm and discourage me, especially when they are gleefully announced during the last leg of TOSRV ("only 15 miles to go!"). There is an extremely convenient conversion between mph and m/s that we can use:

9 mph = 4 m/s (approximately)

The plot should be used as a nomogram. Thus choosing a velocity of say 6 m/s (13.5 mph) we find that at zero slope we require 1 hup, and following up to the "healthy human" curve we can sustain that level for the full eight hours duration. A 3% slope at the same speed requires 3 hup, and we become exhausted in less than an hour. As the slope increases to 6% we have no option but to reduce our speed to less than 4 m/s, and we still become exhausted in less than an hour. If we could invoke an assist device to provide 2 hup (150 W), then in both cases above we would continue to provide our 1 hup of effort - which is the reason why John Tetz is able to travel across the US with such ease, previously in his unfaired P-38 and currently in his fully faired F-40. Restricting the engine power to 2 hup has an added advantage - less fuel, less bulk and less weight.

Why do we we wish to restrict the speed range? From our graph we see that using our assist on zero slope we could sustain more than 9 m/s (20 mph) for a full eight hours! Unfortunately the peak power of a heat engine is available only over a restricted rotation-speed range, which is why your motorcar is encumbered with a gearbox. We have a choice - either 4 m/s up a 6% slope, complicate the system with a gearbox, or relocate to the flat Netherlands. We have chosen the former. If you wish to upset John Tetz, then ask him (as some poor soul did) to fire up and demonstrate his engine assist on the flat parking lot of the Redwood Acres stadium in Eureka ... "You have totally missed the point! If you seriously want a demonstration then join me in climbing a hill..."

At this point I would like to consider the statement by Peter Ernst: "Stirling engines are too bulky and complex for our niche". Having done research and development of Stirling engines for many years, I would like to



Velocity and time to exhaustion (hours) vs human power (hp) accept this as a challenge. Andy Ross has been designing and building small Stirling engines for the past 20 years, mainly using a unique mechanism called the Ross yoke drive. He has recently published a delightful book on the subject "Making Stirling Engines" (6). I have recently teamed up with Andy Ross and Gary Wood, who invented a balance mechanism for the Ross yoke drive. We are in the process of developing a 2-hup Stirling engine specifically for hpv assist. At this stage we estimate that the engine mass will be less than 2 kg (lighter than the McCullogh engine used by John Tetz and only slightly more bulky). It is true that we normally require water cooling of the engine, and we are evaluating different cooling options. In the configuration that we are developing, Stirling engines have much to offer for this application:

1) Relatively quiet (no valves) and minimal vibration (Wood/Ross balance system)
2) Controlled external combustion. We will initially test the system with a propane burner. Because of the inherent high engine efficiency a miniature plug-in propane cylinder can be used. Ultimately we would like to develop a compressed natural-gas burner - one can envisage a modified bicycle pump which can be used to either pressurise the engine (or the tire) with its working fluid (air), or compress the natural gas directly from the methane generator.
3) Simple control. There will be two burner states for this two-speed device, "idle" and "run", a burner piezoelectric start switch, hot-cylinder temperature indicator, and a mechanical starter. The engine will be connected to the rear wheel through a centrifugal clutch, a gear reducer, and a chain drive to the inner cog of the freewheel mechanism.

We hope to bring our prototype to the IHPVA meeting in Eindhoven next August. Is there any possibility of holding the Fifth Scientific Symposium at that meeting? (Another challenge!)

References and resources:

(1) John G. Tetz, a sequence of articles describing AHPV experiences using a McCullogh 21-cc two-stroke engine. HPV News issue No. 8/2, 8/5, 1991. *Together with the many letters these make extremely interesting background reading. Also refer to his paper "AHPV: A Technical Description", Presented at the Fourth Human-Powered-Vehicle Scientific Symposium, IHPVA, California, 1992.*

(2) Douglas J. Malewicki, "New Unified Performance Graphs and Comparisons for Streamlined Human-Powered Vehicles", Presented at the Second Human -Powered-Vehicle Scientific Symposium, IHPVA, California, 1983. *A landmark "must-have" reference paper.*

(3) Danny L. Pavish, "Simulation of the Gold Rush 200-m Sprints", Presented at the Third Human-Powered-Vehicle Scientific Symposium, IHPVA, Vancouver, Canada, 1986. *A lucid description of the differential equation leading to the power/speed relation given above.*

(4) Izzi Urieli, "hupPlot", *a convenient menu-driven computer program for solving the power/speed relation given above. Allows an interactive character plot before creating a data file for importing to a spreadsheet or graphing application (the plot above was done using "CricketGraph"). Also uses the "bisection" method to solve for velocity as a function of applied power. There is also a text file of data points taken from Malewicki's "Long-Term Human-Power Capability" (0 - 8 hours) graph as used for the "Time to Exhaustion" plot above. Available for Macintosh computers from the author (free - simply send a blank 3.5" double-density disk - its my way of starting up an informal AHPV SIG).*

(5) Nickolas Hein, "Hill-climb/descent simulations", HPV News, July 1994. *A table of simulation results comparing the performance of six representative hpvs. Describes a level coast-down test for obtaining values of CdA introduced by Chester Kyle at the 1992 IHPSC practical-vehicle contest, but does not give any details. It would be useful if someone (Nickolas?) would provide details of practical approaches to determining CdA and Cr (for the rest of us without a wind tunnel).*

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Letters: SCUBA gear?

Peter Sharp raised the scenario of a top-speed record set in the extreme-altitude plateaus of Tibet using SCUBA gear for breathing. SCUBA supplies merely ordinary air at ambient pressure. Unless used inside a pressurized cabin, this would accomplish nothing beyond eliminating need for ventilation scoops. SCUBA would be more applicable to saving commuters in downtown trffic from carbon-monoxide headaches.

However, an oxygen tank would boost aerobic output at any altitude. Does the IHPVA need to disallow oxygen tanks, styofoam cups of liquid oxygen, flushing an all-sealed fairing with oxygen, or pre-breathing oxygen before events? So many ways to cheat . . .

Don Speck, 115 Felix Street, #3
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Rational records?

The optimization of a vehicle and rider is central to the challenge of HPV records. Loss of oxygen with altitude is a trade-off with decreased drag. All records should have the altitude specified however, and perhaps steps of 500m could be used t provide sub-categories. Too bad for the lowlanders, but there is excitement in the altitude trades I'd rather not see lost.

Gradients are another question. There is less trade-off for optimization. Let's keep what we have for continuity - no changes up r down.

Peter Sharp's article in Human Power 11-3 summer-fall 1994 is excellent discussion. A no-human-power division with say 2% slope maximum would optimize technology for speeds - say 20 m/s (45 mph) which are close to those that might be used by faired commuting vehicles and would put a better balance on rolling-friction improvements and aerodynamics.

I think that there are better ways to encourage a variety of competition like some Peter suggests than to discontinue a time-honoured competition.

Daniel B. DeBra, 630 Stardust Lane,Los Altos, CA 94024, (from a response sent to John Kingsbury about his survey).

Human-powered watercraft: a status report

Doug Milliken

It's been over a year, and the spray from The Du Pont Human Powered Watercraft Speed Prizes has mostly settled. Not the spray from the vehicles (the fast ones didn't leave much) but what was learned from the contest -- by competitors, officials, and the IHPVA as the sanctioning and promoting organization. This article summarizes my view of how it started, what happened and where HP Watercraft might go from here. Along the way I learned a lot about running contests and I'd like to get some of that down too, looking toward the day when IHPVA runs another big contest.

Brief history

My previous article on the Du Pont prizes [reference 1] described the process of setting up the contest and the many people who contributed. It also properly credited Allan Abbott and Alec Brooks with the first demonstration of a fast HP hydrofoil, the *Flying Fish*, and their dramatic slide show at the Indianapolis Speed Championships in 1984. Not mentioned in the earlier article was Brad Brewster's bachelor's thesis [2] (written under Dave Wilson's supervision) that indicated that a HP hydrofoil could be built. There were several popular articles written in the embryonic period of HP watercraft design [3, 4, 5] that give a flavor of the thinking at that time.

To make a long story short, [1] ended with a prediction that the contest would be won in 1990-91. While the "symbolic barrier" of 20 knots (10.37 m/s) was not broken as I had expected, MIT's *Decavitator* went 18.50 knots (9.53 m/s) in the fall of 1991. This speed was not exceeded during 1992 (the last year of the contest); thus the MIT team led by Mark Drela, Marc Schafer and Matt Wall was the Grand Prize winner [6].

The contestants

Besides the two teams mentioned above, the other serious significant team mind was Sid and Steve Shutt's *Hydroped*, based on their hydrofoil-sailboat experience. The major players (formal entries for the Grand Prize) were very few. In hindsight, this can be easily explained: the 20-knot speed predicted by [7] and used as the Grand Prize goal is hard to achieve. The teams that made headway all had a great deal of previous experience (often professional) in related fields such as hydrodynamics, aerodynamics and/or advanced composite construction.

A number of novel ideas were tried, but the contest winners all used combinations of existing technology, albeit with a great deal of cleverness and refinement. Hydrofoils and propellers were eventually used by all the fast machines. While the rules allowed hovercraft, only one *(Dragonfly)* was in existence before the contest and this was not developed during the prize period. Parker MacCready's flapping-wing machines (culminating in the *Preposterous Pogo Foil*) are probably the closest humans have come to imitating bird flight, given the various attempts at building ornithopters over the last centuries. I am aware of several attempts to build hydroplane-style craft that would "skim" over the water riding on a trapped bubble of air, but none of these (again to the best of my knowledge) were able to get up "on the step" with human power.

From my vantage point, no one team made an all-out effort to exceed the 20-knot goal that we set up as part of the contest. While I had hoped that 20 knots would be broken to end the Grand Prize contest, the structure of the rules (fastest in the four-year period) allowed competitors to play a waiting game. By all-out effort, I mean developing a really good vehicle, training an elite athlete to skipper it and finally setting up private record attempts to give the most advantageous operating conditions for the particular craft. Each team had good reasons for their level of effort and I have been told that, behind the scenes, teams that appeared to be quiescent were in fact working quite hard (but not advertising/tipping their hand to the competition). I still think that 20 knots is possible!

Several teams (or potential teams) spent an inordinate amount of time fighting the rules of the contest--either publicly (in *Human Power/HPV News*) or privately (the correspondence is still in my files...) While defending the rules, I had some moral support from an experienced HPV land racer: his advice to disgruntled competitors was essentially "get back to the drawing board--the rules have been published and you aren't going to change them". In fact we didn't change the rules although there were one or two changes in procedure. With that said, all of the competitors and teams were easy to get along with, even under race-day pressure. Thanks!

Running the contest (and the yearly events)

In writing the rules, my lack of experience (and time pressure to finalize the contest) led me to make one major mistake: at the time that the rules were published IHPVA didn't really know how to time the 100 meters with automatic start/stop timing. In looking back at some of the notes from the Watercraft Prize ad-hoc Committee members, I can see that I was warned about this problem. If there is any one piece of advice I'd like to pass along to future contest directors it is very simple: <u>make sure that all the equipment for judging the contest is reliable, accurate, well understood, tested, and that a number of people are familiar with the system</u>.

IHPVA generally contracts with local promoters to run the IHPSC. The HP water craft were new and unfamiliar to most HPV race promoters. The result was that we usually didn't get the level of support that was required. Another bit of advice to future directors: make sure that there are enough volunteers available to run the event. If the event is new, most of the crew will probably have to come from outside the local area.

The Prize Committee members are ultimately responsible to the IHPVA. What makes a good committee member? Beyond the obvious requirements of interest and experience, consider the following: if the prize is small then the contestants' motivation may be assumed to be "for the glory". Thus relatively idealistic committee members are suggested. On the other hand, if the prize money is high, the contestants have "additional motivation". In this case I think the committee should include fairly "realistic" or "hard" members; with a big prize the "contest" aspect comes first, not the technology that may be developed.

This latter is only fair to the sponsor and the competitors (who will work as hard as they can, hopefully within the rules). We had an excellent Prize Committee--thanks for your help.

Rules

In the "Regulations and Conditions" [8] we defined a watercraft as using "control by reaction against the water". This had the result that several craft, including the Grand Prize winner, *Decavitator*, bore little resemblance to traditional ideas about "boats". There seems to be consensus that any future water contest should also require "propulsion by reaction against the water". At the time that the rules were written, the *Dragonfly* hovercraft was a contestant and Steve Ball's stated reasons for the air prop didn't really get into the speed advantages it might offer.

Future water rules should be more specific on timing (now that MIT has shown us how to do it optically) and on measurement of wind and current. While I personally have no doubt that the actual Grand Prize run was made in legal conditions, the wind-measurement procedure and its documentation were not adequately called out in the rules, and this was cause for later complaints.

Another approach to the whole question of "power from the environment" (i.e., wind assist) is to restrict contests to one- or two-day events. This avoids the whole concept of "fair conditions" that can be duplicated at a number of sites worldwide. Thus the winner on a particular day may well be the team that chooses to run at the most advantageous time. This is certainly true in other forms of racing (car, boat, etc.) where such variables as temperature, surface conditions and/or wind conditions have a big effect on times: part of the game is to second-guess the weather.

One of the goals in writing the rules was to formalize a protest procedure for contestants that was reasonable, and, most important, workable. The need for a protest procedure was established during the Du Pont Speed Prize for 65-mph on land. No official protests were filed in the watercraft contest, so the rules as written must have worked. However, there were a few complaints filed (see above) and a rewording that might make the procedure even more clear could include:

- Protests maybe filed only by official entrants in the contest. An entrant is defined as a team that has filed an entry with the IHPVA and paid the (typically nominal) entry fee to cover IHPVA expenses.
- There is no stigma attached to filing a protest; rather, a protest is a mechanism for opening up the actual detailed facts of an attempt to scrutiny by competitors.
- If no protests are filed during the protest period, the attempt is official and not subject to further attack (no double jeopardy for the team being protested).

I am open to comments on the above thoughts and will pass them on to the current IHPVA Rules Committee. The bottom line is that while volunteer officials will try their best to judge accurately, competitors should not trust the officials blindly and there should be a concise review (protest) procedure in place.

What did IHPVA learn?

Size and type of prize(s) -- Given the various comments that came my way I could say that the Grand Prize was too big. With $25,000 on the line (and no second place) some entrants took the contest too seriously and lost the sense of technological exploration that IHPVA tries to foster. At other times, I felt that the Grand Prize was not big enough--looking from the outside, it seemed that no team really tried everything possible to break the 20-knot goal. In contrast, the yearly contests (1989, '90, '91) had smaller prize money and the prize list paid down to last place. This latter system was well received by all: I don't recall any serious complaints.

So, you say, why not run future contests this way, with prize money for most entrants? The simple answer is that the money comes from a sponsor and, in general, the sponsor has a big say in how the money is to be spent. We were very lucky that Du Pont allowed us to distribute about one-third of their total gift over the yearly events.

Operating expenses -- In our agreement with Du Pont, money to run the contest came from interest on the prize money. We were lucky that the contest coincided with a big rise in interest rates and, by skimping a bit, IHPVA came out ahead in running the Grand Prize contest. Thanks to Dick Woodward, Du Pont picked up the operating tab for the yearly events: these events broke even.

Publicity -- If the goal is to really make a big splash, then much more advertising/PR work needs to be done. In hindsight, to do the promotion job right, it should probably be budgeted at an amount similar to the prize money offered. The two go together: with a bigger prize more money should be spent to get the word out. A good recent example is the HP Submarine Races promoted by H. A. Perry: they actually hired a professional promoter/advertising agency to plug their event with the result that they were eventually covered by National Geographic TV. In contrast, our contest PR got a paragraph mention in their magazine.

Contacts made outside the direct area of fast watercraft -- Perhaps the most interesting contact was from the Rockefeller Foundation. RF hired an independent researcher to put together a white paper on technology contests and I was interviewed on the telephone. Her final write-up makes fascinating reading. Most of the contests studied were underfunded (like ours) and thus required a "zealot" (a true believer) to run them. I had to agree that I must be a true believer in the possibilities of human power to put up with the demands of the director's job. This probably applies to most of the IHPVA volunteer staff!

We seem to be in the process of linking up with the HP submarine builders: witness the recent issue of *HP* on this topic and the recent San Diego event held with IHPVA sanction.

During the contest period, there were two extraordinary "outside" HP water achievements. Dwight Collins pedaled his screw-driven *Tango* solo across the North Atlantic (Newfoundland to England) realizing a childhood dream and also breaking the previous rowing records. Kenichi Horie, also in a pedaled, screw-driven boat, traveled from Hawaii to Japan. Videos were made of both voyages and aired on US/Japan TV.

In conclusion -- Did we contribute to the start of a new sport as I suggested in my previous article? I would say that the answer is a tentative yes, judging by the new pedal-powered craft on the market, e.g. the Eide Seacycle, Yamaha Waverunner and others listed in the IHPVA *Source Guide*. International interest is also high at this time with similar contests run in Europe (the Waterbike Contest) and especially in Japan with the first Japanese IHPVA sanctioned event, the Second All-Japan HPB races and the well-sponsored Dream Ship Contest (strangely, the DS Contest is open only to entrants from Japan). Unfortunately, the future of both of the Japanese contests is in doubt as they have lost their major sponsors.

In the making are two new vehicles that I am aware of: a fast monohull displacement boat and a "recreational hydrofoil" with lower power requirement. Both use water props and rudders. I won't steal the builders fire by revealing their names: both groups are well known to IHPVA members. Just watch these pages...

While there is no new watercraft contest in the near future, the goal of 20 knots has not been achieved. With or without a prize, I think that this sprint speed will be reached, but it may take a long time -- look at how long the *Gold Rush* 65+ mph record stood, and the commitment required by the *Cheetah* team to beat it.

At the 1994 IHPVA Annual Meeting in Eureka, CA, the Board of Directors elected Nancy Sanford as your new vice president for water. Nancy is the enthusiastic owner of an HP watercraft and brings her user's perspective to the job. I'm sure you will be hearing more from her. For me, it's been an enjoyable, educational, and challenging five years. Thanks again to all who helped out.

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Doug Milliken is the outgoing IHPVA VP-Water and director of the Du Pont Prize Committee. He also designed the shell for the Moulton 'Liner II HPV, holder of the flying 200-m record for "normal-riding-position" streamlined bicycles. He is a 1977 graduate of MIT and works as an engineering consultant, primarily on automotive handling.

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Letter: Pete Penseyre's 24-hr record

On Saturday April 15 1994, Pete Penseyres set a new solo 24-hour HPV record in Bakersfield on the Mesa Merin Raceway oval track. The 51-year-old veteran ultramarathon cyclist rode a Lightning F-40 968 km (601 miles). The previous 24-hour record, set by Wimpie Van Der Merwe of South Africa, was 904 km (562 miles).

Conditions at the Bakersfield track were not ideal, with temperatures of 38 C (100 F) in the early afternoons. The attempt at the hour record by Chris Huber riding the Cheetah was doomed to failure when the race organizers insisted on running the race for electric vehicles first while it was still cool early in the morning. Attempting to average 76.6 kph (47 mph) in the hot sun didn't work for the totally sealed Cheetah. Chris Huber does not deserve any criticism for throwing in the towel after a half-hour of fast laps.

I sincerely hope the HPV community will recognize the significance of Pete's 24-hour record in his old u nsuspended P-38 steel-fram F-40 commuter bike. Other practical vehicles claiming to be in the same league as the F-40 should prove it by shooting for Pete's record. Van Der Merwe's vehicle was a cost-no-object Mobil-Oil-sponsored special record vehicle, totally unsuitable for any practical use. Pete actually logged 611 miles on his precisely calibrated cyclometer. There was a question of whether the IHPVA officials had counted laps correctly. In any event, over 600 miles in 24 hours is a solo record Pete can feel proud of.

Gerald Pease, pease@courier1.aero.org (From his letter to the hpv@sonoma.edu mailing list, with permission)

Toshio Kataoka with the pedal-drive system of the HP helicopter he and his friends are building, with your editor on a visit to Osaka, Japan, on August 12, 1994
Photo by Kouichi Nakamura

The Human-Powered-Flight Inter nal Symposium organised by the Pacific Northwest Section of AIAA & held at the Museum of Flight, Boeing Field, August 26-28, 1994

Report by
Chris Roper

This is the first time that a series of lectures on HPA has been run alongside flight demonstrations. A variety of papers was presented and two world records were established during the demonstrations.

Comparable previous events

The Japanese International Birdman Rally encourages much building because it is known to be an annual event. Flights of appreciable length are made. Also it is good mass entertainment. But there is no formal series of lectures.

The Zapple Festival of Human Power was held at Milton Keynes, UK in 1985. The poster advertising this shows many bikes and boats and above them two HPA. In the event only one aircraft was brought to the rally, the Musculair II from Germany, which had not yet flown then.

Other than these, and the Jonathan events in France, there are no organised gatherings of HPA. Will there be another like it this century?

What didn't happen

Five flying machines which were expected did not appear for five different reasons. One had its funding cut, one a sick pilot, the pilot of antoher elected to go instead to the Birdman Rally, one was caught in a forest fire the preceding week, and one was not fully built. What also didn't happen was the sort of HPA flying we have been used to, namely fixed-wing machines competing to go a few percent further or faster.

The spirit of the event was more about helicopters and about collaboration. I was delighted to meet many old friends and to make new ones, and enjoyed the demonstrations and the presentations.

Dr. Paul MacCready gave the keynote speech, reminding us that our planet has limited resources, and that HPVs are one method of using them wisely.

On a historical note

John McMasters outlined the history of HPF from the British machines of the 1960s up to today.

Tuneo Noguchi reviewed the aircraft that have been built at Nihon University, one a year since 1963. That's thirty one - and counting.

Dr. Azira Azuma told us of other Japanese machines.

Bob Parks and Dave Watson recounted their experience with the Daedalus project.

Design tools

Professor E. Eugene Larrabee presented his minimum-induced-loss propeller-design method.

Nickolas E. Hein presented his computer program for analysing and integrating the forward and vertical motion of pedalled air and land vehicles. This program inputs, for land vehicles, the slope of the terrain and for aircraft the climb angle chosen.

Planes

Kazuho Kawai told us of his "Karura" ornithopter which is powered by rowing. The pilot sits in a novel design of sliding seat. Most of the wing is fixed: only the outboard panels flap. These are made torsionally flexible. Trailing tabs on these panels control their angle of attack during the flapping cycle. Kawai assumes zero lift from the flapping panels during the downstroke. He described how the sizes of fixed-span, total-span and other parameters were optimised using these assumptions as well as practical considerations. The "Karura" has yet to fly.

Kawai had conducted ergonometer rowing tests, and discovered, amongst other results, that with fit inexperienced rowers, for long duration the output was similar to that of cycling. For short duration, rowing produced less power. He suspects that the feel of the device, for example, whether or not the 'oar' is sprung forward, may affect power output.

Kotono Hori spoke about her project, a home-built plane with a professional approach taken by the team. Their goal was to prove that even an "amateur female pilot," as she described herself, can enjoy flying an aircraft, and that HPF is for anybody who wishes to try. She explained the design-optimisation process, and the training schedule which she undertook, including her early flight-training when runners steadied the craft with ropes--and how she then proceeded to become the first female HPA pilot in Japan.

Peer Frank could not bring his "Velair 89" from Germany as hoped. This plane was designed in 1988 and built in 1989, flew at the Paris Air Show that year in a 12-knot wind and at other shows, and is still "in service" after 110 flights. In the Proceedings (ref. 1) he writes of the design and construction procedure of this successful virtually one-person project. He has charted the hours' labour for his first and second aircraft. Also published are plots of results of his in-flight tests collected by an onboard data-logger device. The plane is characterised by the bean-pod fuselage slung well below the wing.

Nick Weston of England spoke of his experiences in helping to build and in flying Airglow. This plane had much in common with Velair 89, both in design and in the team's circumstances (ref. 2). He showed results of their in-flight wake-traverse tests, which are continuing. In these, the local velocity is measured at a series of points behind the wing to provide a measure of the actual drag. Mark McIntyre has built a hot-wire anemometer for this that is proving useful in other applications.

Neal Saiki and William B. Patterson outlined the nine-year design and development process that led to the Da Vinci III helicopter at Cal Poly State U, San Luis Obispo.

Professor Akira Naito referred to the previous single flight of the Da Vinci III and described the work leading to his YURI 1 helicopter. He found in the literature five different theoretical formulae for ground effect, and conducted his own practical tests on models of previous designs, the Vertigo, the A Day Fly, the Papillon, and the Da Vinci III. The model of his own proposed novel four-rotor YURI 1 showed the highest ratio of thrust to power when in ground effect.

To smooth the torque output of the YURI 1, Naito chose an oval sprocket and a flywheel because these had proved themselves on other machines. On the second demonstration day we noticed a "tent" above the pilot which caught the draught from the rotors and billowed up to provide added lift. This is mentioned in the Proceedings as a "deflector." Naito admits that much is still unknown about the aerodynamics of HPH. He exhorts any would-be builder to learn from the mistakes of others. Norikatsu Ikenchi in the YURI 1 achieved a new duration of 25 seconds at the Symposium.

Whether the first man to "really" hover did so in the Da Vinci III or the YURI 1, there is no doubt at all who the first woman was. At 11 am on 25th August 1994, Ward Griffiths of Seattle, an American woman with no special training, became the first female HPH pilot. At her second attempt she hovered the YURI 1 for 8.6 seconds, observed by a substantial proportion of the HPA enthusiasts of the entire world.

Wayne Bliesner displayed his almost complete 12th aircraft, the Marathon Eagle, designed for the Kremer Marathon Competition. Following the original design in 1988, computer optimisation has included the airfoil, a third analysis of the wing and fuselage and particularly the junction between them. An entire wing mold has been made, and Bliesner noted what a huge task this was.

The Raven long-distance-aircraft, also designed in 1988, is also based in the Seattle area, and also the subject of much computer optimisation. The group has a sophisticated simulator which Paul Ilian described and displayed. The effect of gusts, pilot weight and propeller efficiency during take-off are being incorporated. The simulator, he explained, will be useful at every stage of the project. Building of the Raven is about to commence. Currently much effort is going into organisation of the team and its many sub-groups in order that the project will bring involvement to many individuals and organisations.

With all this activity in the Seattle area, it is sad to learn of the winding-up of the Flight Research Institute. Its functions will be taken over by the Pacific Northwest Section of the AIAA who so splendidly organised the Symposium with the Museum of Flight.

On display was the Curtis Barnes helicopter from Oregon. This is the group's third machine, and has twin 24-foot (7.3-m) rotors side-by-side below a gantry similar to that of the YURI 1, but with only two rotors, not four. Each rotor is a complete disc, with many blades around its circumference. A flight attempt was made, but trouble with the complicated hands-and-feet transmission precluded success.

Parker MacCready demonstrated the third version of his invention, the PogoFoil. This is a twin-float hydrofoil (NACA 4415) watercraft, of what is now conventional layout, with main foil and the usual front foils. But the drive-system is totally innovative. The rider stands on a fixed platform. Power is generated by the rider alternately bending and straightening both legs. The effect of this is to cause the main foil to operate on the same principle as a bird's wing or a fish's tail, producing thrust as well as lift. Power on the upstroke is provided by a spring which is charged on the downstroke. Control of this craft is very tricky. At planing speed it is necessary to do several things in quick succession. These include operating a pitch control, adjusting the spring and leaning forward. We were graced with demonstrations of the PogoFoil by Parker and his wife. Others present bravely and good-naturedly attempted to get it to plane, but neither Parker's father Paul, nor Kotono Hori succeeded in this.

The PogoFoil is of relevance to HPF because one of the current challenges is to take off from water. This presumably implies moving along the water initially.

How it felt

Let me illustrate this. Since there are conflicting accounts of who first flew the Gossamer Condor, I made a point of asking Parker MacCready. He said it was probably his brother Tyler, but he wasn't sure, and if he doesn't know then no one ever will. Then he said, "What does it matter? It was a group effort." That remark symbolised for me the spirit of the symposium. Human-powered flight is a worldwide group effort, and all those there from three continents are members of this group. For instance, we were all delighted to see an American woman fly a Japanese helicopter. In the past, HPF has been limited to fixed-wing competitions, where most of the activity at any one time would be in one country. There are still competitions to be won. By there is much more to HPF than that, and being together at an international gathering such as Seattle 1994 is one of the most enjoyable parts of it.

For more details of the items covered only briefly in this report, I recommend a copy of the Proceedings (ref. 1).

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Chris Roper is VP, Air. He is a pioneer in HP aircraft, having design and largely built Jupiter, an early British HPA.

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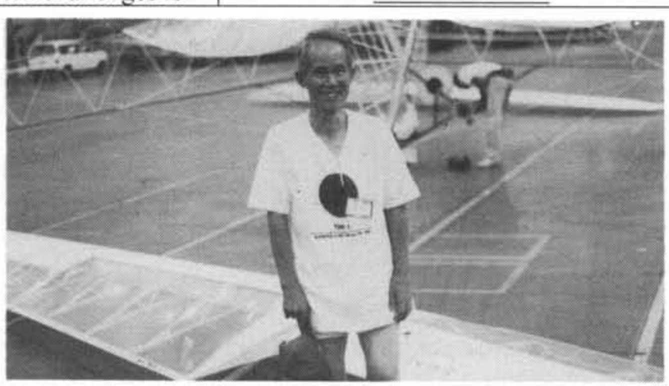

Lecturer (retired) Akira Naito designer and builder of the HPH Yuri I, about to attempt a flight, Seattle, September 1994
Photo by Chris Roper

AERODYNAMIC EFFECTS OF PARTIAL FAIRINGS
by Steve Koren

These are some data I collected on the effect of a partial fairing on a recumbent. I did a set of coast-down tests on a local hill, which gives roughly 13-m/s (30-mph) speeds if you coast down from the top.

I tested a standard upright bike, an unfaired recumbent, and a faired recumbent with three different fairing positions. The bikes and fairings used were as follows.

Uhigh: upright bike, Raleigh, about 16-kg (36 lbm) total, two Michelin Select 27" tires at 6.9 bar (100 psi) each; riding with the hands on brake hoods.

Ulow: same upright, but riding on the "drops". (Regrettably, I was not able to test "aero" bars).

Rnone: ATP Vision R40 recumbent (SWB/ASS), about 15 kg (34 lbm), one Fat Boy 26"x1 1/4" tire at 6.9 bar (100 psi), one Kenda 16"x1 1/4" tire at 6.2 bar (90 psi); no fairing.

Rlow: same recumbent with a Zipper Lexan fairing, with the top tilted horizontally so I was looking well over the top of the fairing.

Rmed: same recumbent with the Zipper Lexan fairing tilted out of horizontal so I was about at eye level with the top of the fairing.

Rhigh: same recumbent with the Zipper fairing tilted further out of the horizontal so that my entire forward vision was through the fairing.

Each of the recumbent tests was done twice with the results averaged. The upright test was done just once. The other possibly significant factor is that I'm not entirely sure the hill was long enough for me to reach terminal velocity. The hill itself is fairly long, but the steepest part where I reached the maximum speeds was very short.

All tests were done early in the morning with very little wind (just over 1 m/s, 3 mph, of steady crosswind).

RESULTS:

I estimate the magnitude of these experimental error at less than 0.5 mph.

BIKE	SPEED	TRIES	NOTES
Ulow	29.3 mph	1	(upright, drops)
Uhigh	29.0 mph	1	(upright, brake hoods)
Rnone	29.8 mph	2	(recumbent, no fairing)
Rlow	32.9 mph	2	(recumbent, low fairing)
Rmed	32.4 mph	2	(recumbent, med fairing)
Rhigh	32.6 mph	2	(recumbent, high fairing)

NOTES

* The fairing gives an increase in speed of about 3.5-4 mph over an upright bike when ridden on the brake hoods in the 30-mph speed range. At normal riding speeds, this is probably something like 2 to 2.5 mph. The speed difference between the partially faired recumbent and an upright with aero bars is probably small, but the comfort difference is huge. At speeds under about 17 mph, I doubt the fairing does anything for you at all.
* There is a bigger difference between a faired recumbent and an unfaired recumbent than between an unfaired recumbent and an upright.
* The fairing improvement is less than I had suspected it would be, but still quite significant. I am going to try this same set of tests on a windy day. I suspect the fairing will make a bigger difference then. I commute over this route every day, and it seems that my speed on this hill doesn't change much from day to day on the recumbent, whereas on my upright the speed ranges from 16 to 42 mph on the same hill depending on the wind conditions.

I also did another test, much less accurate, to see how fast the recumbent climbs compared to an upright. I have no way to measure power output directly, so instead I climbed a 1.25-mile-long hill with a pulse-rate monitor and held my pulse at the same rate on both bikes. I did this only with the unfaired recumbent and the upright, but did it at two pulse rates.

BIKE	SPEED	PULSE
Uhigh	16 MPH	180
Uhigh	12 MPH	150
Rnone	14 MPH	180
Rnone	11 MPH	150

Obviously this is going to be much less accurate than the coast-down test, but it appears that I climb about 1-2 mph slower on my recumbent than on my upright even though the upright is a little heavier.

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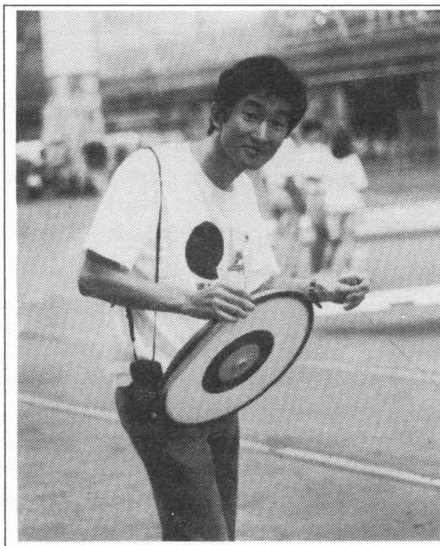
Steve Koren has been cycling for transportation for 15 years, including one month so far on an ATP R40 Vision recumbent. He currently works as a software engineer in Colorado.



Toshio Kataoka rewinding the spool of Yuri 1 at the Seattle symposium of HPF August 1994 Photo: Chris Roper

Letter: Friendly road signs

From a note on the Internet:
"Mark Frazier wrote 'There are a bunch of new road signs I've been seeing on roads around the Denver Tech Center. In fact, I can see one from my office window. They're big yellow diamonds with a symbol for a bicycle on them. Below, they read "Share the Road". It seems some progress is being made...'

"I saw these a couple of weeks ago along the coast in N. Carolina and/or Virginia - a long way from Denver, so whoever is distributing them must be national."

David E. Damouth;
damouth@wrc.xerox.com

Erratum

Michael Eliasohn sent a copy of the cover article and p. 842 from the December, 1933, issue of Popular Mechanics which has the photo of Marcel Berthet on p. 8 of HP 11/3/1994. The photo was taken in 1933, not 1951.

Lawn mowers
by
Michael Eliasohn

HPVers might take comfort in knowing that one of the oldest human-powered mechanisms is making a comeback.

The Chicago Tribune in its June 26, 1994, issue reported sales of foot-propelled push reel mowers in the United States are increasing. Sales by American Lawn Mower Co. of Shelbyville, IN have increased from 84,000 mowers in 1985 go better than 200,000 in 1993 and might reach 300,000 in 1994. In the 1970s, the company was making about 50,000 mowers a year.

ALM manufactures about 95 percent of the push mowers in the United States. The remainder are made by another company for use by professional groundskeepers.

According to the article, the first reel mowers were developed in England in the 1830s, so that the design is older than that of the pedaled bicycle. ALM has been making push mowers since 1895. At one time, almost 60 companies in the U.S. manufactured push mowers.

The comeback of the push mower is attributed to a desire for exercise, increasing sales of residential condominiums and homes on small lots, and concern over pollution. More than 35 percent of the pollution in the U.S. from non-road equipment comes, according to the U.S. Environmental Protection Agency, from gasoline-engine mowers.

Reel-type mowers are better for lawns than the common rotary blade used on most power mowers, which tend to tear grass rather than shear it. Reel mowers shear the blades between the rotating bade and the fixed cutter bar. "The shearing motion seals that grass as it's cut, retaining the nutrients and guarding against disease," the Chicago Tribune reported.

Although sales are increasing, foot-propelled mowers still have a very small share of the market. Power-mower sales in the U.S. total about 5-million annually.

In the "good old days," push mowers weighed as much as 50 pounds (22.7 kg) the Chicago Tribune reported. Use of plastic for some parts and other changes have reduced the weight of ALM's mowers to less than 30 pounds (13.6 kg) today. I wonder how much one made of titanium and carbon fiber would weigh.

There have been attempts at making pedal-powered lawn mowers and at least one example made it into production.

Bicycling Science: Ergonomics and Mechanics reported on one such mower. It was designed and built by Michael Shakespear in 1973 for his bachelor's thesis in mechanical engineering at the Massachusetts Institute of Technology. It used a reel mower between the two rear drive wheels, a Sturmey-Archer 3-speed hub gear and a single wheel in front. His mower was described in the book as "very heavy, but still gave easy cutting."

Wilson, in a chapter in Pedal Power in Work, Leisure and Transportation, described what would have been the second phase, which used two drive wheels in front and a single rear steering wheel. Cutting was to be done by something like a hedge clipper (non-electric, of course), that is, two "combs" sandwiched together, moving back and forth to shear the grass off between the teeth.

Rodale Press, which published the book, paid another MIT student, Lee Laiterman, to construct the mower. The author of this article has a vague recollection of a telephone conversation with Laiterman, in which he told me he constructed the tricycle portion of the mower and shipped it to Rodale, which was to add the mower assembly. Apparently that part of the project was never completed.

Now-defunct Cyclist magazine in April 1986 published a tongue-in-cheek review of the Cycle Mower, which was being make by Sunkyong Manufacturing Co., which I assume is Korean, although the article didn't say. It was being sold in the U.S. by Hammacher Schlemmer & Co., which sells merchandise in its own retail stores and by mail order.

Unlike the two pedaled mowers mentioned above, which used a recumbent seating position, the Cycle Mower rider was upright. There was a single 20-inch wheel in front and two 12-inch drive wheels in the rear. The rotary cutting blade and protective housing hung

The Cycle Mower - photo from the brochure (Sunkyong Manufacturing Co.)

beneath the pedals. The Cycle Mower weighed 63 pounds (28.6 kg).

Cyclist, which recruited U.S. Olympics cycling team member Thurlow Rogers to do the testing, complained the Cycle Mower was geared too low. It used a Shimano three-speed hub and Rogers supposedly had to spin at 100 rpm in top gear to get it moving above 1 mile per hour (1.6 kph).

With the small rear wheels perhaps 20 inches (50.8 cm) apart, the Cycle Mower didn't appear too stable.

Perhaps an HPV builder (amateur or professional) seeking a new technical challenge might tackle developing a practical pedal-powered lawn mower.

One possibility that occurs to the author is developing a tricycle, be it upright or recumbent, which would TOW the mowing apparatus, presumably a modified push mower minus the handlebars. It might be simpler to develop the gearing that way since it would be necessary to drive only one or two wheels, rather than having to drive the wheel(s) and the mowing machine. The gear system would have to allow shifting at very slow speeds or while stationary and reverse would be convenient.

Such a tricycle could also be used for other purposes, such as towing a cart to haul raked leaves or trash.

Which leads to another thought--a pedal-powered leaf raker.

References

Bicycling Science: Ergonomics and Mechanics (1974), Bicycling Science, Second Edition (1982), by David Gordon Wilson and Frank Rowland Whitt, MIT Press.

Pedal Power in Work, Leisure and Transportation, edited by James C. MuCullagh, 1977, Rodale Press, Inc.

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Michael Eliasohn wrote "It's too bad that Richard Ehrlich's article on his HP mowers in the July 1994 HPV News couldn't have appeared in Human Power. That was entirely my fault. I had his article typed up and laid out with illustrations, but apparently forgot to let him know that. He thought that I had ignored him and sent it to HPVNews. Apologies! Also, Michael sent me a copy of p. 46 from Mountain Bike Action, January 1995, showing a mountain bike with what seems like a standard "push" mower hitched behind it for towing.
- Dave Wilson

(Michael Eliasohn is a reporter and HP enthusiast who contributes his talents to giving us surveys of HP technology, e.g. on aluminum recumbents (11/1/94/10), cantilever hubs (10/2/92/9), FWD HPVs (9/1/91/11) and winning HPBs (8/1/90/8)).

Reviews

Safety and design - a review of the second European seminar on velomobiles/HPV, Laupen castle, Switzerland, August 25, 1994

The proceedings, bound in a handsome volume and very well edited by Andreas Fuchs and Theo Schmidt, arrived within a couple of months of the symposium. That is amazing efficiency! The papers are mostly in English with German summaries, with a few in German with summaries in English. There are 22 papers in three groups: safety, design, and miscellaneous. In a short review it is impossible to do justice to any one paper or even to mention all the papers.

Safety: the first and last papers of this section were typically thoughtful products of Theo Schmidt. The first cautions us against falling into the same line of thinking as with motor-vehicles, in which "safety" denotes the safety of the occupants, not of the other road users. His second paper relates speed and safety, pointing out that accidents are proportional to about the square of the average speed; injuries to the cube; and deaths to about the fourth power of speed. It is important, therefore, to avoid insulating ourselves from the perception of speed. W. Rohmert, professor from the Technical University of Darmstadt, and colleagues also contribute two interesting papers. One is on steering tests of a variable-geometry medium-wheelbase recumbent bicycle with negative trail. The most-favored configuration was a head angle of 89° and a negative trail of 59.5 mm, with a wheel diameter that appeared to be about 425 mm, (17"). The second paper was on the effects of different suspension characteristics on recumbent performance. There are two practical contributions by Len Brunkalla; three more papers on design aspects by Prof. Rohmert and Stefan Gloger; one by the creator of the Leitra, Carl Georg Rasmussen, on the characteristics of a practical fairing; and two on living with HPVs and without cars.

The seminar was organized by Future Bike CH, the Swiss affiliate of the IHPVA. Ask for the availability and price of the symposium from the secretary, Jürg Hölz, "Velomobile Seminar 1994", Spitzackerstrasse 9, CH-4410 Liestal, Switzerland.

Dave Wilson

Proceedings of the fourth international human-powered-vehicle scientific symposium, Yreka, CA, USA, August 6, 1992

Eighteen papers presented in Yreka in 1992 have been edited by Chet and Joyce Kyle and Jean Seay and nicely produced in a volume obtainable from the IHPVA. There are land, water and air sections. The land section has papers and/or presentations by Gardner Martin, Tim Brummer, John and Miles Kingsbury, Clive Buckler, and Doug Kliesch and Israel Urieli. Gardner Martin's presentation was humorous, whimsical and educational, and not all could be captured in the report of his presentation. The others were rather short accounts of sometimes-prodigious development efforts of various designs.

The water section contains just one paper, by Sid Shutt, with much useful information on the design and development of a practical HP hydrofoil.

The air section has two papers, by William Patterson and Terrance Hawkins, on how the problems of achieving HP hovering flight can be solved.

There are two other sections. One is on various aspects of physiology and mechanics, with papers on topics such as arm-power performance (Rick Powell) and the effect of body position on power output (Danny Too). The section on broad perspectives, actually section one, has papers on assisted HPVs by Allan Abbott and John Tetz, on transportation systems based on HPVs by Jim Kor and by your editor, and a look at the future of HPVs by IHPVA International president Paul MacCready.

Dave Wilson

Cycling Science vol. 6 nos. 1 & 2, fall & winter, 1994

It is good to see Cycling Science resume publication. It is a quarterly with a U.S. subscription rate of $22.97/yr from P.O. Box 926, Hightstown, NJ 08520. I will mention just two or three articles I found of particular interest.

The first article in the fall issue is by Ted Constantino and Rob Vandermark on titanium use in bicycles. It is the best review of the topic I have seen. The various alloys available differ significantly, and you should read this before you put down a lot of money on a titanium-frame bicycle. The best has a ratio of fatigure strength to weight that is twice that of 4130 chrome-moly steel. However, much titanium available is Russian, which has poorer specifications and quality.

In the winter issue the first article again drew my attention: tests of puncture-preventing products by Ronald Bowman et al. They tested regular and Kevlar-belted tires, "thornproof" tubes, and polyurethane tire liners. The differences among these when pierced with needles and two sizes of nails were, to me, astonishingly small. As a group, latex tubes were much more resistant to nails and much less resistant to needles than were the other products tested. The only products that were reported as performing well were puncture-sealing products, and these were not formally tested. I have been religiously buying Kevlar-belted tires, and this paper has come as a refutation of what I thought was established doctrine.

Dave Wilson

Editorials

Snakes and turkeys

If life is getting better, why, in the words of some long-forgotten philosopher, is it getting worse? The worsening aspect of life that is getting my attention at present is flat tires. I enjoy biking throughout New England winters, but crouching by the road removing a rear wheel and a tube with bare fingers on metal and rubber at -10 C does cool my ardor. I/we have just had two of these snake-bite-induced flats in three days.

Advertising tells us that tires are getting better. I buy those with Kevlar belts or layers, and I've tried polyurethane tread backing ("Mr. Tuffy") and sealing solutions inside the tubes. But I get far more flats than I/we used to (one of the flats was when Ellen and I were on a cold-night tandem run to see a friend in hospital).

I decided that I was getting the snake-bite flats because I didn't use a high-enough air pressure. I grew up with tires that carried the message "inflate hard". I learned that this was a phrase that could protect manufacturers from any liability. Tires could explode without warning at 5 bar, 73 psi. My modern tires have, typically, a rating of about 7 bar, over 100 psi, printed on the sidewall. I carefully adjusted the pressure of my air tank (I wasn't going to risk a pump) and admitted just under the rated pressure. There was a crack, a balloon as the tube came out under the tire, and a pop. The wheel rim had failed, bending out from the force exerted by the tire.

Why had the rim popped out, you may well ask? My prized Scott Superbrake had had a failure, and I had replaced it with a new Shimano 105 sidepull. This unfortunately came with brakepads that not only wore quickly in wet conditions, but which announced the wear in two unfortunate ways. One was through the incorporation of the end of the steel shaft buried in the brake pad and fashioned rather like a lathe tool. This rapidly wore a sharp groove around the wheel rim and produced the failure when I used a higher-than-usual pressure. The other way wear was signalled was when the pad wore through the sidewall of a new tire, despite my having positioned the pad carefully on the rim braking surface. Then I saw why the Shimano 105 is labelled a "dual-pivot brake": one arm is much shorter than the other, and when the pad wears the arm swings around through a sufficiently large arc to miss the rim altogether and to go into the tire.

It seems to me that another reason I'm having more flats than before is that rims now come with edges that are quite sharp. One doesn't have to ride over a sharp stone to get a pair of snake-bite punctures. One can get them through going over a smooth, round pebble or even a small tree branch. The edge of the rim is sharp enough to do the cutting.

I have another complaint about rims. When I was younger, I had bikes with well-defined rim specifications that fitted well-defined tires, and I never had trouble from misfits. Nowadays when I buy a 700 rim I have little idea what size of tire it will handle. Nor do many, probably most, of the bicycling public, to judge from correspondence on the HPV email network. I found the hard way when I replaced my defective rim and tire and had the new tube popping out from the new tube rather as does a TV plumber's buns from low-cut jeans. The rims I bought from Bike Nashbar didn't carry any size specifications whatsoever: I had to measure carefully to decide which were 700 and which were 27x1-1/4". I was using 35-mm tires, apparently too large for the particular 700 rims I had at that time.

The envelopes please! I want to hand out my turkey awards. Just as I don't like short-arm cantilever brakes because of the possibility that the pads will go into the spokes, so I will condemn short-arm side-pull brakes when they allow pads to go into the tire wall. In engineering design we talk of the desirability of products being "fail-safe" or "fail-soft". These brakes do not meet either test. Nor do brake pads that conceal a cutting edge that machines rim surfaces in highly stressed areas. It's also time that rim manufacturers and tire manufacturers came up with specifications on which combinations of tires and rims work together. And we need specifications of minimum rim-edge radius and minimum radial depth of braking surface to reduce snake-bite punctures and the likelihood of brake pads running off the rims into the tire or into the spokes. If the rims were simply curved out near the peripheries they would accomplish two purposes simultaneously: snake-bite punctures would be far less likely; and brake pads would be restrained from running off the rim into the tire.

If you agree with any of these complaints, write to some manufacturers and demand action. Most of these are potentially life-and-death matters.

Bombs not cars - or bikes

Here is a news item I took from The Economist of November 26, 1994, that has implications for us all. The IRA detonated a huge bomb in London's financial district in April 1993 causing death and injuries and about a billion dollars' worth of damage to buildings. The subsequent security procautions included a "ring of steel" that prohibited most traffic within its boundaries. The neighboring areas complained vigorously because they foresaw huge traffic jams as vehicles diverted from the blocked-off area tried to go around it.

What actually happened was that "the quality of life has improved: both streets and air are cleaner, crime has plummeted and commuting times have shrunk. The reason is simple. The security precautions . . have cut road traffic drastically. . . An even bigger surprise is that the neighbouring boroughs have withdrawn their objections. . ." The traffic simply disappeared.

This proves the rule that new roads don't cure traffic jams: they induce more traffic. Conversely when traffic is stopped, people don't drive in other directions: most find a better way of getting places, or, if their journeys are not all that necessary, they don't go.

I'm sure that a whole lot of driving is in this latter category. Big supermarkets and stores offer goods a few percent cheaper than the neighborhood store. As long as driving is virtually free it makes personal sense for many people to drive several miles to shop. If the several miles cost several dollars or had severe traffic restrictions they would use the neighborhood shops, and the quality of life would improve for all. We HPV people are probably keeping the local merchants going in any case. *Dave Wilson*

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