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Human Power
The technical journal of the International Human-Powered Vehicle Association
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Additional copies of Human Power may be purchased by members for $3.50 each, and by non-members for $5.00 each.

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

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

Dave Wilson

In this issue

The Japan International Birdman Rally, 1995

Harry Clark Higgins recounts his impressions of this amazing event, the greatest celebration of HPVs in the world. He also offers guidance on the avoidance of structural failures in human-powered aircraft and gliders by specifying some simple tests (pp. 3-6).

Recumbents in racing

A refreshing new view by a very experienced insider in the established bicycle-racing arena, Les Earnest, on why recumbents were banned from racing in the 1930s and why innovations are sometimes accepted without question and at other times are rudely rejected, makes complete sense out of something that has puzzled many(p.6).

Measuring HPV drag forces using an on-board microcomputer

Angus Cameron gives a "high-tech" method of taking data in the most-popular method of measuring drag for wheeled HPVs: the coast-down test. He lists the equipment needed, the form of programming, and some samples of data taken (pp. 7-11).

Octogenarian bicyclist, II

Ron Beams follows his story in the last issue - of someone who came late to bicycling, and who designed his own recumbent tricycles. Here he gives some reasoning behind the choices he made, and some details and photographs, besides some philosophizing appropriate for someone of his years (pp. 12-15).

The human-powered rail event at the Eurochampionships at Laupen, Switzerland in August 1994

Our HP European associate editor, Theo Schmidt, describes the first competitive event for HP rail-cycles at HPV meetings. (He also organized it). This was of great interest to your editor, who has made no secret of his belief that the HPV land-speed record will be set by a rail vehicle (on special rails) (pp16-17).

Putting the IHPVA in high-gear: shifting paradigms

Peter Sharp continues his dedicated campaign to liberalize our organization in the direction of allowing many classes of vehicle technology to co-exist. He believes that we are missing vital opportunities by outlawing most cases of storing energy and of using wind-assist. Your editor agrees with him and plans to write an editorial in support (pp. 18-21).

Velocity: a user report

Theo Schmidt, writing now as our VP of hybrid vehicles, is highly enthusiastic about an AHPV, an assisted human-powered vehicle, designed and manufactured by Michael Kutter and called "Velocity". A principal difference with other approaches is that the two power inputs are connected in series through a differential gearset. This innovation confers many advantages, Theo maintains (pp. 21-2).

Letters

Eugene Villaret believes that going to a tricycle design just because it is sometimes difficult to get started on a recumbent bicycle is illogical. He gives his design of a pedal modification that enables him to start rapidly (p. 15).

Theo Schmidt writes with regard to his plea for agreement on simple rules for hybrid vehicles (p. 17).

Reviews

"Handbook of Composites" is briefly noted: it is not a new book, but seems to have become a standard work (p. 11).

"Race-car vehicle dynamics" is found to have useful applicability to wheeled-HPV design, particularly in respect of tire behavior, suspension, damping, steering, and aerodynamics (p. 15).

"Bike Cult, the ultimate guide to human-powered vehicles" by David Perry is a compendious paperback about all kinds of social aspects of bicycling, and some science and engineering. There isn't a great deal on HPVs as a separate class, but it's a bargain just the way it is (p. 22).

Editorials

A tribute to Marti Daily and to incoming president Len Brunkalla; who and what are good on hills; and a congestion-pricing experiment for motor-vehicles that might bring much better conditions for HPVs (p. 23).

Dave Wilson

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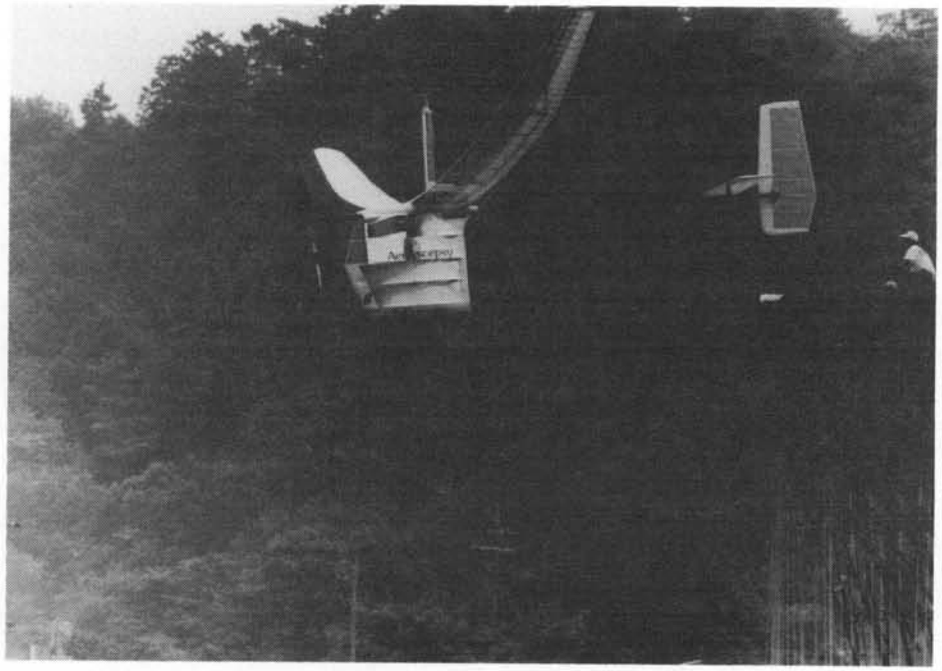
THE JAPAN INTERNATIONAL BIRDMAN RALLY - 1995

Harry Clark Higgins



The winning HPA Aeroscepsy at take-off
Photo courtesy Yamaha Motor Co. Ltd. and Toshio Kataoka

Akira Naito, retired professor of aeronautics at Nihon University, brought his human-powered helicopter, Yuri-1, from Japan to Seattle in August of 1994 to fly at the Museum of Flight/AIAA Human-Powered Aircraft Symposium. Norikatsu Ikeuchi flew it for 24 seconds, setting a world record for endurance, and Ward Griffith flew it for 8 seconds to be the first woman to achieve flight in a human-powered helicopter. Naito and I became friends: he invited me to come to Japan to see the Japan International Birdman Rally in July, 1995. I jumped at this opportunity, and spent two weeks in Japan. I won't discuss this amazing adventure except to tell you what I saw at the Rally.

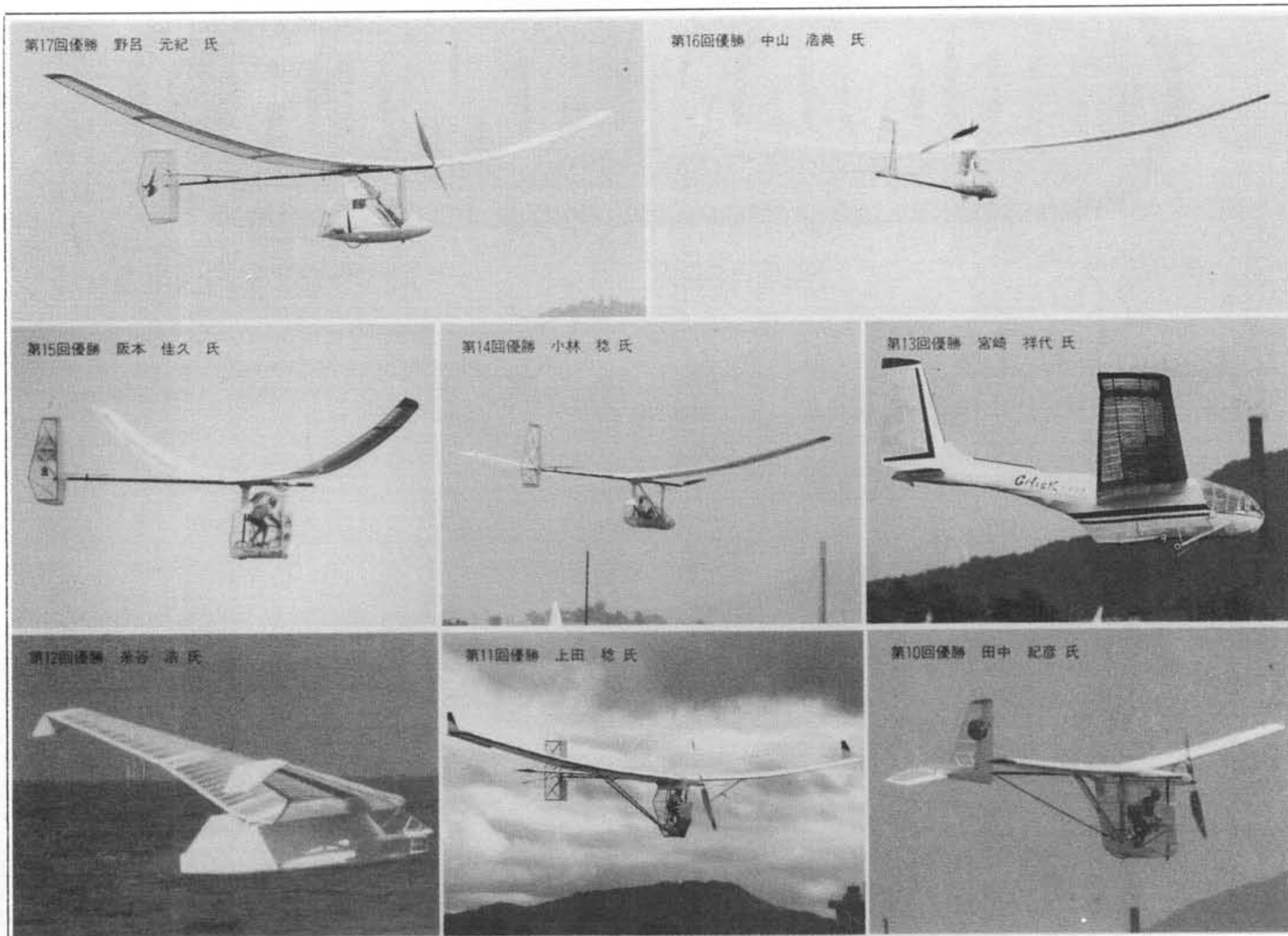
For those who have neither been there nor seen the video tapes of this competition let me describe it. Every year the Japanese build a pier out over Lake Biwa at Matsubara Beach near Hikone. The pier is ten-meters high, and there is a platform on the top ten-meters long. Prizes are given to the people who can run down this platform, jump off the end, and get farthest across the lake. The prizes are not trivial: first place gets one-million yen (about $10,000). They have three categories: women in gliders, men in gliders, and human-powered airplanes. In 1995 the contest was held on the last Saturday in July. It is a one-day show: it runs on schedule - rain or shine, wind or calm.

This has been going on since about 1977. It is sponsored by the Yomiuri Telecasting Corp. and the TV influence is pervasive. Everything happens on schedule and on camera. Akira Azuma, an emeritus professor of engineering at Tokyo University and a major spokesman for the contest, told me that although all of the aircraft land in the water (they are required to land in the water!) and most crash, no one has ever been hurt. This is comforting to know. I doubt that any machine has ever survived the water landing and subsequent retrieval without major damage.

Most, but not all, of the contestants are young people and each entry appears to be a team effort. Large contingents of supporters led by a cheer leader send each machine off with loud enthusiastic cheers and yells. Ignorant of Japanese, I was not able to identify most of the groups - but familiar industrial names were common and several teams were from prominent universities.

I counted 53 launches: 9 women's gliders, 23 men's gliders and 21 human-powered airplanes. Of these machines, 35 (66%) failed to achieve stable flight with 19 (36%) failing structurally. Please believe me, these were not backyard-built, styrofoam, plastic-sheet-and-duct-tape contraptions. The most primitive were built with much skill and art. Most of the machines had very large spans. There were canards and tailless examples. The man-powered airplanes tended to look like the MIT Daedalus. There was one example with a counter-rotating propeller.

Nearly every conceivable type of airplane accident excepting fire was seen. No one got high enough to produce a fully developed spin but I saw examples of the center of gravity being outside of control limits, both fore and aft; inadequate control power about all axes; spiral divergence; pilot-induced divergent oscillations; mechanical failures of the propulsion system; and a mid-air



Some of the entrants in the 1995 Japan International Birdman Rally (from the results booklet)

collision between a glider and a boat. Of the 19 structural failures most were simply the wing or tail breaking off. There were also examples of chordwise bending failure, torsional divergence and (if I'm right) one case of divergent flutter.

Although most failed, those who survived and reached steady, trimmed flight were beautiful to watch. The successful gliders usually flew long distances a few inches above the water exploiting the ground effect (water effect?).

The winner among the men, Shouji Sasaki (Japan control-line model-aircraft champion) flew 329 meters, a glide angle of 33/1. I thought this a truly remarkable performance considering that much of that vertical 10 meters was lost accelerating up to flying speed in addition to the adverse effect of operating at very low Reynolds number.

Mr. Itoya was favored to win the men's glider event, but he had a bad launch, dragging his left wing on the lip of the platform. His beautiful tailless glider was yawed about 90 degrees off course. To avoid flying onto the crowded beach (where I was standing) he dove into the water. The winner of the women's glider event flew a beautiful trimmed flight except for a slight left-wing-down attitude that developed into a graceful spiral to the left and a gentle landing with the left wing tip in the water and the glider pivoting in a wide circle.

The human-powered event was a dramatic improvement over previous Rallies with three machines exceeding the existing record. Hironori Nakayama flew the Yamaha 'Aeroscepsy' 8.764 km for a new Rally record. His flight was a long, deep curve actually much longer than the official straight-line measurement.

The 'Sky Goku' was a strong second at 6.4 km and the entry from Nihon University (Naito's school) flew 5.4 km. These three airplanes were definitely world-class and to see them committed to water landings and destructive retrievals was discouraging. I have been following the Rally for several years. Friends in Japan have sent me tapes of more than a dozen contests and I have always felt that many of the crashes were unnecessary. When Professor Naito invited me to visit I thought of what I might do to lessen the carnage.

I called Paul MacCready before my trip and we discussed at length the peculiar aerodynamics of these awkward beasts, especially the lateral-directional control problems that led to so many spiral divergences. He sent me papers on this subject by P. B. S. Lissaman, H. R. Jex and MacCready. From all this I gathered that lateral-directional control of these slow-moving machines with extremely large spans is dominated by two unusual factors: (1) virtual mass, the inertia of the air that participates in the flight of the machines, is large around the roll axis but much smaller around the yaw axis and (2) when yawing to the right, for example, the airspeed and dynamic pressure of the left wing-tip are much greater than those of the right wing tip.

For example, if the left wing is down, it is much easier to initiate right-yaw than right-roll. A down-going aileron will tend to produce greater response in yaw than roll. If the right aileron is down (the reverse of normal) the resulting yawing velocity will produce the desired rolling moment to the right. As I watched six gliders spiral into the water I couldn't help but think of Paul's remarks.

Thinking about the large incidence of structural failure I prepared a test plan for a simplified wing-bending-test (which is reproduced below). I took several copies of my plan with me and attempted to give a copy to the crews of each of the 19 machines that crashed due to structural failure. Unfortunately the plan was in English instead of Japanese and most of my contacts were without my interpreter. In those cases it was difficult to communicate my message.

I talked to both Naito and Azuma about my thoughts. I gathered that the Rally has little technical correspondence with the competitors. That is, there is no effort to ensure a minimum level of expertise in that group. I had expected there would be a technical session associated with the Rally such as is the practice at World Soaring Championships where the OSTIV boffins meet. The entry rules which I have seen are lengthy and in Japanese (which I do not read). I know that each machine is inspected before flight and passed by a team of experts but I believe the only consideration is safety for the pilot. The structure ahead of the pilot's face is always fragile foam and thin plastic sheets which obviously yield without injury even in the vertical dives.

Naito told me that the contestants break down into three groups: naive people with no technical support, sophisticated teams who start too late to do a complete job and teams of experts with plenty of time and support to do proper designing and testing.

I was greatly impressed by the tremendous amount of intelligent effort that the contesting teams expended, much of it ending in good-natured failure.

The management of the Rally was extremely professional with excellent facilities and sufficient skilled manpower to support the competition. The contrast with U. S. Regional Soaring Contests, with which I am familiar, was as night and day. My only regret is that so many of the accidents could have been easily avoided with a minimum amount of technical advice.

Why can't an American team take a crack at this contest? With resources such as MacCready and MIT available we clearly have the expertise to be competitive and I'll bet that transportation could be arranged. In the Seattle area Wayne Bliesner and Paul Illian are heavily involved in separate high-tech projects with human-powered airplanes. As I see it, the big technical problem is becoming airborne in 10 meters in zero wind. The emotional problem is the inevitable damage to the machine in the water landing.

It was a great experience and I feel honored to have been invited to attend.

Anyone interested in contacting Rally Management should write or call:
JAPAN INTERNATIONAL BIRDMAN RALLY SECRETARIAT
YOMIURI TELECASTING CORP.
2-2-33 Shiromi, Chuo-ku
Osaka Japan 540; Tel 06-947-2314
(from the USA: 011-81-6-947-2314)

A simplified bending-strength test of an airplane wing
by Harry Clark Higgins

How to select the test load

Select the design limit load factor (n), the maximum vertical acceleration that is anticipated measured in g's (one g is the acceleration due to gravity). I believe that 2.0 g's is appropriate for Birdman Rally operations.

2. Measure or estimate the gross weight (GWT) of the loaded airplane with the pilot and all equipment in place. Measure or estimate the weight of the wing alone (WWT).

3. The test load (TLD) to be placed on the inverted wing is
TLD= n(GWT)-(n+1)(WWT).
Properly distributed, this load will cause the same root-bending moment as experienced in flight at a load factor of n.

How to distribute the test load

The following approximate method makes two simplifying assumptions.

(1) The aerodynamic load is distributed spanwise proportional to wing area. In reality the aerodynamic load falls off to zero at the wing tip. (A precise method for distributing the aerodynamic load can be found in Abbott and Von Doenhoff, "THEORY OF WING SECTIONS", pages 10 through 15, Dover Publications, NY.)

(2) The mass of the wing is also distributed spanwise proportional to wing area. In reality the mass of a well-designed wing is concentrated inboard where the bending moments are greater.

Assumption (1) is conservative in that the test bending moments caused by this assumption will be somewhat greater than the flight bending moments when at the same load factor.

Assumption (2) is non-conservative. It will reduce the outboard test loads and therefore the test root-bending moments compared to the flight values.

The two assumptions tend to compensate for each other and the resulting error should be quite small.

Approximate method

1. Select the number of sandbags to be used to simulate the load. I recommend 20, 10 for each wing panel. The weight for each bag is then the test load divided by 20.

2. Starting at the tip, integrate the wing area inboard of the tip until that area is equal to one twentieth of the total wing area. Mark the centroid of that area as the position of the most outboard sandbag. Continue this process inboard until all 20 bags are located.

How to conduct the test

Although not essential, two jacks may be used, one under each wing about half way to the tip. If they are adjusted slightly clear of the wing then any structural failure will be checked by the jacks and major damage can be avoided.

If one jack is placed in very light contact with the wing it will tend to damp oscillations and keep the wing steady and approximately level during measurements.

1. Mount the wing inverted on a support at the centerline that will allow the wing to swivel.

2. Measure and record the height above the floor of each wing tip.

3. Add the test sandbags in symmetrical pairs starting inboard.

4. When all the sandbags have been added, measure the height above the floor of each wing tip.

5. Remove the sandbags in pairs starting outboard.

6. When all the sandbags have been removed, measure the distance above the floor of each wing tip.

Analysis

(a) Subtract the sum of the measurements of step 4 from the sum of the measurements of step 2 to get the total deflection caused by the test loads.

(b) Subtract the sum of the measurements of step 6 from the sum of the measurements of step 2 to get the permanent set caused by the test loads.

Divide the result of (b) by the result of (a) to get the ratio of the permanent set to the maximum deflection. If this ratio is less than about 0.02 the test has been successful. CONGRATULATIONS! If the ratio is much greater than 0.02 then the loads have caused substantial permanent set to the wing, probably by damaging the structure.

If this is the case, one should carefully examine the structure for local damage. Repair and reinforce any that is found. Then repeat the test until the permanent set is less than about 0.02.

Harry Clark Higgins was a WWII fighter pilot who spent his career as an aerodynamicist at Boeing. He is an active flight instructor and a glider pilot with two diamonds. The year after retiring he rode his bicycle from Seattle to San Francisco.

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Recumbents in racing

(Reproduced with permission from correspondence on "hpv@sonoma.edu")

Should cycle racing have stuck to the high wheelers and prevented the "safety bicycle" from competing in bicycle races? What about derailleurs for road racing?

As you probably know, the bicycle-racing establishment did prohibit the the use of "safety" bikes for a time, but were forced to accept them when the public voted with their pocketbooks and for participation.

The 1934 UCI ruling concerning Francis Faure's hour record of aprox. 45km (banning recumbents) was the equivalent of ruling against the "safety bicycle". The progression from high wheeler to safety bicycle represented a far greater performance improvement than the recumbent. The fact that Faure's record has since been exceeded with a conventional bicycle makes the '34 ban's basis suspect.

I don't think that the fact that that record has been exceeded is particularly relevant -- all records have advanced a lot since that time. However, as I'm sure you are aware, issues of this sort get decided in the political arena and seldom on the basis of logical principles.

It is clear that Faure broke the record fair and square. The reason that the rules were changed retroactively was that he was not a recognized cyclist and he had no connections in the cycling establishment. Consequently, the ICU found it necessary to declare that his machine was not a 'real' bicycle.

Compare that with what happened when Moser "broke" the hour record in 1984 using a disc wheel that clearly violated ICU rules. In that case, Moser was a recognized and established pro rider. More important, both he and the ICU president were Italian and the latter immediately gave a speech lauding Moser's accomplishment, so as to preempt the ICU Technical Commission, who are responsible for rule interpretations. Another factor was that the wheels Moser used were made by Campagnolo, which for many years had been generous in their financial support of the ICU.

Thus, in response to political pressures the ICU Technical Commission came up with the rationale that the disc wheel's surface is an essential structural element rather than a fairing. Not only was Moser's "record" recognized but the use of disc wheels became widely accepted, even though Campagnolo continued to make them out of spokes with an aero shell, making a mockery of the Technical Commission's ruling.

More recently, the outlawing of the "Obree position" last year fits this political model nicely. Obree lost because he was not an established pro and had no political support in the ICU.

I believe that bike-racing history would have been quite different if an established and politically connected rider had been selected to ride the Velocar in 1934, but history does not reveal its alternatives. Once a decision of this sort is made, it gets built into the structure of the organization in such a way that the only way to change it is to create a whole new organization, which is what IHPVA did. Of course, even that progressive body has picked up some baggage along the way that will probably never be discarded.

Even IF (and it's a big IF) unfaired recumbents have even a slight advantage in SOME events, they should be allowed because the '34 ruling was so transparent in its aim (in banning a specific technical innovation while ignoring prior ... more significant innovations) as to be absurd. Otherwise we should just stop all technical innovation and put bicycles into the same category as 12-meter yachts and rowing shells ... equipment useful for competition but not much else.

As I have pointed out, certain kinds of unfaired recumbents 'do' meet USCF standards. However, the only way to get a racing forum for a broader collection of unfaired recumbents is to either organize it yourself or wait until there is enough public demand so that other entrepreneurs will see the opportunity and develop it, if that ever happens.

While there may be a legitimate basis for complaining about unwarranted discrimination, simply grumbling about it isn't going to change anything. Just as the victory of the safety bicycle over the high-wheeler took place outside of the bicycle-racing establishment, so will most other significant advances in bicycle technology, though you may be able to slip a few of them in the "front door" if they can be made to look like minor changes and if you are politically well connected.

Les Earnest les@SAIL.Stanford.EDU

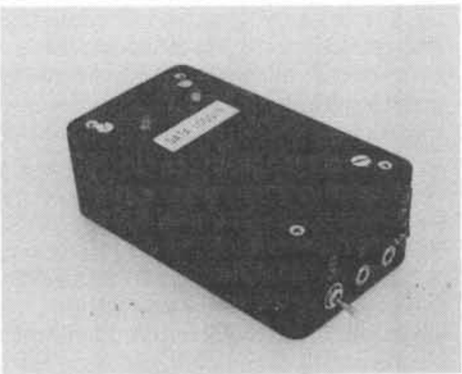
Measuring HPV drag forces using an on-board microcomputer

by

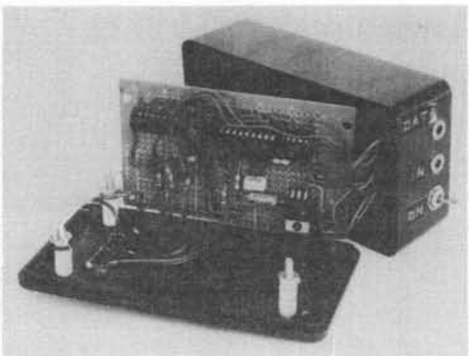
L. Angus Cameron

ABSTRACT

This paper describes the construction of an inexpensive data logger which was used for coast-down testing of human-powered vehicles. A graphical method of analyzing the velocity data for the product of drag coefficient and frontal area, CdA, and the rolling resistance, Cr, using a spreadsheet is presented. Some limitations of the method and suggestions for improvements are included.



Outside view of data-logger, showing the three LEDs, the sensor and output jacks, and the on-off switch



The components on the "perf" board with point-to-point wiring (and 9-volt battery just showing).

INTRODUCTION

When I started this project my objective was to develop a simple device to allow me easily to measure aerodynamic drag and rolling resistance on any reasonably level stretch of road. In addition I wanted to be able to measure the effects of small modifications such as adding fenders, panniers or fairings, or changing tires.

For those of us who don't have access to a wind tunnel, the practical alternative is to measure the drag forces indirectly by means of a coast-down test.

A coast-down test involves taking the vehicle up to the maximum speed of interest on a level surface and then allowing it to decelerate freely. The time rate of change of velocity is proportional to the sum of all the forces acting on the vehicle, including: air drag, tire friction, bearing friction, and any gravitational forces. (See the appendix).

Although the principles are well known (8) there have always been practical obstacles to readily obtaining numerical values, usually related to the cost and complexity of the necessary instrumentation.

It was therefore decided to start with the most inexpensive instrumentation available and to use simple graphical analysis and commonly available software.

The initial problem of choosing appropriate instrumentation was quickly solved when a colleague recommended Parallax's Basic Stamp computer.

The Basic Stamp is a module that contains a microprocessor, memory and related parts. The name reflects the physical size and programming language. It is now available in two different models, priced at $39 and $59 including a carrier board (as of summer 1995). The more basic model, the BS1, which I used, ran at 4 MHz and contained 256 bytes of electrically erasable program and data space. The pulse timer had a resolution of 10 microseconds.

The more powerful model, the BS2, runs at 20 MHz, has two-microsecond resolution, and has 2048 bytes of EEPROM. Both models come with a carrier board which includes battery clips, a PC connector for programming, and a prototyping area for adding additional circuitry. Software is developed for them on any MS-DOS computer using special software for editors and programmers. A kit including cables, documentation and application notes is sold separately. However the editor and documentation for the BS2 can be freely downloaded from the Parallax Web server at http:// www.parallaxinc.com.

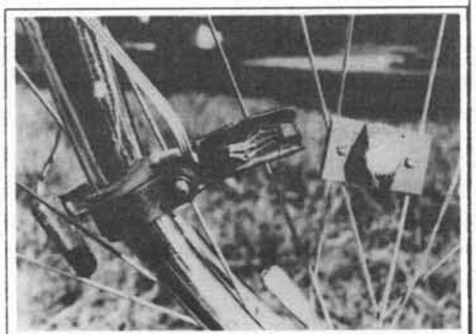
The analysis was carried out on a spreadsheet program. It consisted of deriving the acceleration from the velocity data, and using graphical analysis to find the product of drag coefficient and frontal area(CdA) and the coefficient of rolling friction (Cr). Details can be found in the appendix and reference 3.

Examples of coast-down testing with on-board computers have been published by researchers mainly associated with the automobile industry. (References 2,4,6,7).

Eaker (2) described the method used at General Motors Aerodynamics Lab. The on-board instrumentation measured the vehicle's velocity, dynamic pressure and wind direction every five seconds giving a total 23 to 24 data points per trial. Data analysis involved fitting an exponential curve to the experimental data and then computing the slope at a single point to find the total retarding force. The mechanical drag forces were found independently and subtracted to find the aerodynamic force. Cd was then computed by dividing the aerodynamic force by the product of the frontal area and the dynamic pressure.

The second method, developed by Passmore (6) at Loughborough University also used additional instrumentation to record wind speed and direction. The sampling rate was ten per second, giving 600 to 700 data points per trial. A sophisticated computer analysis was used to match velocity predictions generated by a mathematical model to the experimental data. In this way up to four parameters in the model could be found simultaneously, including aerodynamic drag, variation of drag with wind angle, rolling resistance, and of rolling resistance with speed.

These papers noted that accuracy and repeatability could be achieved with coast-down testing only with very careful control of all test conditions and even then large numbers of



The Hall-effect switch covered with black tape & mounted on the front fork. (The magnet is behind the fork).

test runs are required to obtain converged drag values.

HARDWARE

Magnetic sensor

The magnet and reed switch from

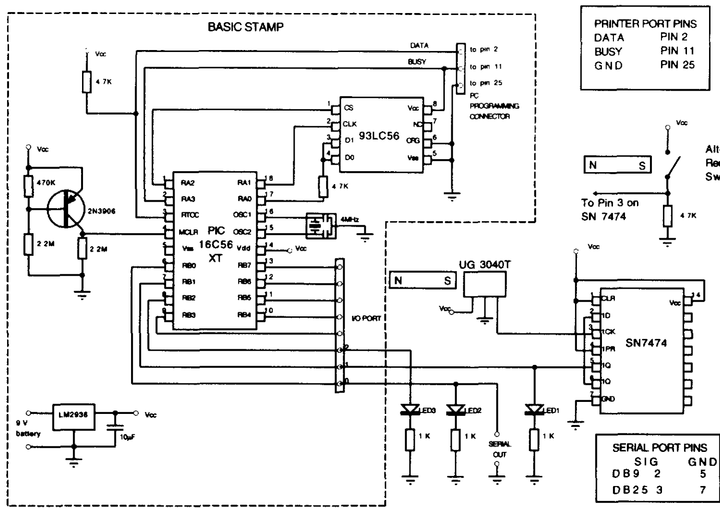


Figure 1 Schematic diagram of data-logger built around the Parallax Basic Stamp

an old bike cyclometer could have been used the trigger the computer. Not having one at hand I used the second option, a Hall-effect switch.

The Hall switch is a solid-state device which has the advantages of clean switching and fast response. Its only disadvantage is that it requires a three-conductor cable to connect it to the computer. It was taped to a thin aluminum strip 50-mm long by 10-mm wide that was in turn bolted to a plastic clamp that secured the assembly to the fork.

The magnet was a button-style fastened to a homemade plastic clamp with double-sided tape. The orientation is important because the Hall switch is polarity-sensitive.

The circuit

The logger was constructed on a prototyping board purchased from Radio Shack using discrete components and point-to-point wiring. The parts located within the dotted line on the schematic diagram now come preassembled on the module, thus greatly simplifying construction.

The SN7474 JK flip-flop was used to generate a pulse with a duration equal to the period of the wheel. With a single magnet on the wheel one of every two wheel revolutions was timed. The pulse width was measured using the microprocessor's 'pulsin' function.

The three LEDs were used chiefly for trouble-shooting. LED1 indicated proper operation of the sensor and input circuit. LED2 indicated when the serial output routine was functioning. LED3, not being dedicated to any single function, could be programmed as required. As shown in the diagram it indicated when the software was in the pulse-measuring loop.

The only external connections to the Basic Stamp were for the battery and switch, a three-conductor input jack for the sensor (signal, power and ground) and a two-conductor output jack for the serial connection to a PC.

The circuit was mounted in a plastic box measuring 120 by 66 by 40 mm.

SOFTWARE

1. Data logger

Table 1a is listing 1 of the current version of the data-logger program, written in Parallax PBasic.

When power is applied to the Stamp it always starts executing from the first statement. After initialization it checks whether the wheel is turning. If not it jumps to the output routine which dumps the contents of the memory to the serial port. Otherwise it loops within the measuring routine where it measures time as a 16-bit value and stores it in two successive 8-bit bytes before waiting for the next pulse. The wheel will make a complete revolution before the next trigger pulse occurs. When the memory is full the program jumps to the serial output loop and LED 3 turns off and LED 2 turns on. A single on-off switch controls all functions.

The non-volatile memory is organized with addresses ranging from 0 to 255. The program is located in the uppermost locations, between addresses 150 and 254. Address 255 contains the address of the last program location. Data are stored between addresses 0 and 150. A total of seventy-five data points could be stored at one time.

2. Communication on the PC

Table 1b is listing 2, which is written in MS QBASIC. The program saves the data to C:\ with a file name that consists of the date and time followed by the PRN suffix. For example the file C:\06281545.PRN was created on June 28 at 15h 45m. By following

TABLE Ia: LISTING 1 OF SPREADSHEET

```
'***** DATA LOGGER *****
'runs on the Basic Stamp
'allows multiple runs
symbol count = b2
symbol lastinst = b1
symbol byte = b3
symbol lo = b12
symbol hi = b13
w5 = 0
dirs=%00000001                      'pin 0 is output

'---------------------------------------------------------------
     read 255,lastinst
     b6 = lastinst - 1
     b7 = b6 - 2
     READ b6, count
'---------------------------------------------------------------
line1:
     b5 = pin1
     w5 = w5 + 1
     IF w5 > 256 THEN line4
     b4 = pin1 - b5
     IF b4 = 0 THEN line1       'is wheel turning?
'---------------------------------------------------------------
line3:
     pulsin 1, 1, w6                  'read pulse width pin 1
     low 2                            'green LED off
     IF count >= b7 THEN line4
     WRITE count, hi
     count = count + 1
     WRITE count, lo
     count = count + 1
     high 2                               'green LED on
     WRITE b6, count
     GOTO line3
     END
'---------------------------------------------------------------
line4:
     serout 0,N2400,(#lastinst,13,10)   '1 ASCII byte per '
                                        digit sep space
     FOR count = 0 TO lastinst
          READ count, byte           'read data at address count
          serout 0,N2400,(#byte,13,10)  '1 ASCII byte per digit
                                     'sep space
     NEXT
     WRITE b6, 1                     'initialize to one not zero
     END

'---------------------------------------------------------------
```

TABLE Ib LISTING 2 OF THE SPREADSHEET

```
'Runs on the host computer
'reads values from the logger and saves to a file named
'for the date and time

CLS
PRINT "opening the com port"
OPEN "COM1:2400,N,8,1,cd0,cs0,ds0,op0,rs" FOR INPUT AS #2
PRINT "opening the data file"
mn$ = LEFT$(DATE$, 2)                          'month
m$ = MID$(DATE$, 4, 2)                         'day of the month
h$ = MID$(TIME$, 1, 2)                         'hour of the day
t$ = MID$(TIME$, 4, 2)                         'minute of the hour
filname$ = "C:\" + mn$ + m$ + h$ + t$ + ".prn"
PRINT "data file name is  "; filname$
OPEN filname$ FOR OUTPUT AS #1
PRINT "waiting for the data, flip the switch on"

LINE INPUT #2, lastinst$
flast = VAL(lastinst$)
PRINT "address of the last instruction = "; last
lst = last / 2 - 1

FOR i = 0 TO lst
        LINE INPUT #2, hi$
        LINE INPUT #2, lo$
        time = VAL(hi$) * 256 + VAL(lo$)
        PRINT "time "; i; "= "; time
        PRINT #1, time
NEXT
PRINT

PRINT "######### DONE and saved to:  "; filname$; "  ###########"
PRINT
PRINT "********* remember to turn the switch off *************"
CLOSE
```

this convention each file has both a unique name and can be recognized by the Lotus 123 /File Input Number command.

The other point of note is that pairs of bytes are recombined into decimal values and stored with a carriage return and line feed. This format allows each value to be read into a single spreadsheet cell.

METHOD

The following example is of a mountain bike tested indoors in a basement corridor. The data logger was attached to the handlebar with a heavy rubber band. The rider quickly accelerated to 28 kph (7.8 m/s), settled into the saddle and then turned on the data logger. At the end of the run he switched it off. The data logger was then removed from the bike and taken to a nearby computer where the data were uploaded.

Table 2 shows a partial listing of the spreadsheet. The velocity in m/s was found by dividing half the wheel circumference (because there were two wheel magnets for this test) by the raw time and multiplying by 100 000. A curve was fitted to the data using /Data Regression using columns C and D as the X values and the raw velocities as the Y values. The equation of the curve in this case was V = 7.452046 - 0.05905 X + 0.000087 X^2, almost a straight line.

Figure 2 shows the graph of the raw velocity values together with the fitted curve.

In the remainder of the spreadsheet, column K contained the square of the smoothed velocities while column L contained the accelerations calculated from

$$a = (V1-V2)*(V1+V2)/(4*S)$$

A straight line was fitted to the acceleration data with /Data Regression function using the accelerations in column L as the Y values and the square of the velocities in column K. The equation of the line was:

a = -0.00282 V2 - 0.04713

from which CdA was found to be 0.487 m2 and Cr was 0.00480, using (an approximate) mass of 95 kg and wheel circumference of 2.2 m. Figure 3 shows the graph.

Reproducibility was tested with a mountain bike on an outdoor track under calm conditions. Tests were done in one evening, in one direction only, always starting at the same point and always using the same lane. The results are shown in table 3. The mean value of CdA was 0.521 m^2 with standard deviation of 0.040 m^2 (9.2%). The mean value of Cr was 0.0028 with standard deviation of 0.0036 (138%).

SOURCES OF ERROR

It is instructive to re-examination the mountain-bike data. They were obtained indoors on a level tile-covered concrete floor. Figure 4 displays the same data as figure 3 with the axes rescaled and the raw acceleration values included. The large magnitude of noise was caused by the differentiation of slightly noisy data. Small relative errors in the velocity data explode into large relative errors in the acceleration values. Because all timing devices display a certain amount of jitter, numerical differentiation will always produce relatively large scatter, in turn influencing the

TABLE 2: PART OF THE SPREADSHEET ANALYSIS OF A MOUNTAIN-BIKE TEST, INDOORS

```
         A      B      C    D    E      F          G          H          I       K      L      M       N           O         P          Q         R
1    circum           1.1        Cr=  -0.0047
2    mass              95        CdA= -0.4868
3               26.63
4       Time    Vel   Int   Sqd  Smooth----------------------------------- velsq   acc   reg lin----------------------------------
5      14870 7.397     0      0 7.452         Regression Output:             55.533                          Regression Output:
6      14915 7.375     1      1 7.393 Constant                    7.452046 54.658 -0.199 -0.201 Constant                     -0.04713
7      14935 7.365     2      4 7.334 Std Err of Y Est            0.050691 53.792 -0.197 -0.199 Std Err of Y Est              0.00109
8      15055 7.307     3      9 7.276 R Squared                   0.996848 52.935 -0.195 -0.196 R Squared                     0.99863
9      15257 7.210     4     16 7.217 No. of Observations               56 52.089 -0.192 -0.194 No. of Observations                55
10     15241 7.217     5     25 7.159 Degrees of Freedom                53 51.251 -0.190 -0.192 Degrees of Freedom                 53
11     15515 7.090     6     36 7.101                     Coeff1a  Coeff1b 50.423 -0.188 -0.189
12     15539 7.079     7     49 7.043 X Coefficient(s) -0.05905 0.000087 49.603 -0.186 -0.187 X Coefficient(s)-0.00282
13     15618 7.043     8     64 6.985 Std Err of Coef. 0.001649 0.000029 48.793 -0.184 -0.185 Std Err of Coef. 0.00001
14     15682 7.014     9     81 6.928                                    47.992 -0.182 -0.182
15     15949 6.897    10    100 6.870                                    47.201 -0.180 -0.180
16     16185 6.796    11    121 6.813                                    46.418 -0.178 -0.178
17     16353 6.727    12    144 6.756                                    45.644 -0.176 -0.176
18     16427 6.696    13    169 6.699                                    44.879 -0.174 -0.174
19     16580 6.634    14    196 6.642                                    44.122 -0.172 -0.171
20     16701 6.586    15    225 6.586                                    43.375 -0.170 -0.169
04-Sep-95  01:40 PM         UNDO                                         ep-95  01:40 PM         UNDO

K4: [W7] ^velsq
```

slope and intercept of the regression line. It can be seen how a small change in the slope of the regression line has a large effect on the value of the intercept.

Although the process of smoothing the data with a polynomial function before differentiation produced a smooth curve another source of error was introduced. The smoothing function must reflect an appropriate model of all the forces acting, otherwise the results will be biased an unknown amount. Any given smoothing function can be only an approximation to the true function.

When the random noise was smoothed using a five-point running mean the pattern shown in figure 5 was revealed. This pattern was consistent over several trials, caused by local variations in the slope of the floor. Any bias introduced by these surface ripples should cancel out if each trial were the average of two runs performed in opposite directions on a precisely defined path.

CONCLUSIONS

1. The Basic Stamp has proved to make an excellent data logger, combining ease of use with sufficient accuracy and low cost.

2. With careful control of the test conditions and a sufficient number of trials, accurate reproducible results seem to be achievable.

FUTURE PLANS

The hardware is currently being redesigned around the Stamp II and an optical sensor, which will allow the data rate to be improved by as much as an order of magnitude. Assuming that timing jitter will remain small it is hoped that the variance from one run to the next will be reduced.

After the hardware is upgraded and tested the analysis method will be changed to a method similar to that described by Passmore (6,7). It neatly sidesteps the problems introduced by smoothing and differentiating the data at the expense of more complicated data-processing.

Once acceptable consistency has been achieved the model can be refined to include smaller effects such as the moment of inertia of the wheels.

Ultimately it is hoped to add wind-measuring instrumentation to the on-board package. This would give twin benefits. First it would allow outdoor testing to be done more easily. Second it would allow the effect of cross-winds on CdA to be measured.

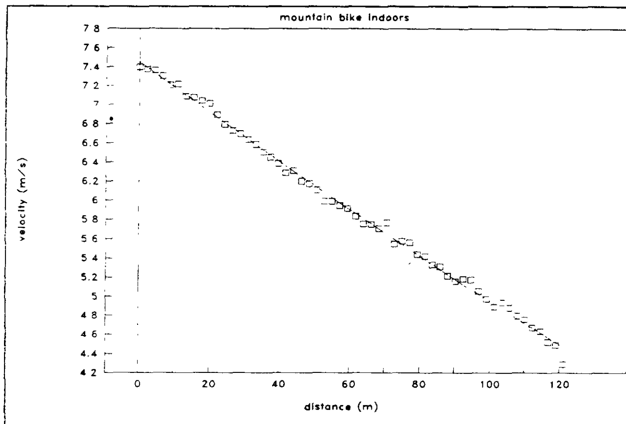


Figure 2 Raw velocity (column B) and smoothed velocity (column E) plotted as a function of distance

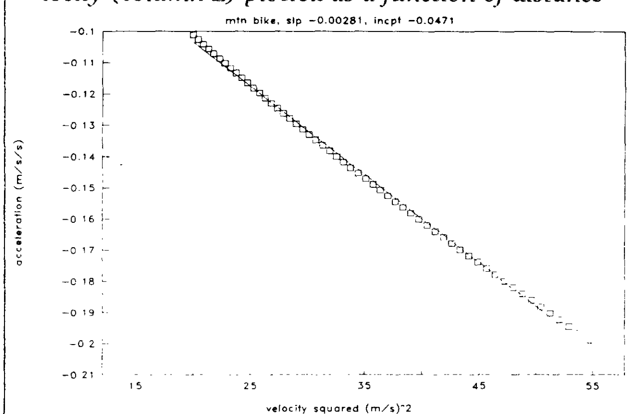


Figure 3 Acceleration (column L) and the regression line (column M) plotted against velocity -squared.

TABLE 3: MOUNTAIN BIKE TESTED ON AN OUTDOOR ASPHALT RUNNING TRACK IN CALM CONDITIONS

TRIAL NO.	VELOCITY km/h	C_dA (m^2)	C_r
1	44	0.543	0.0021
2	44	0.512	0.002
3	41	0.401	0.0043
4	43	0.567	0.0007
5	40	0.562	0.0004
6	38	0.572	0.0005
7	41	0.521	0.0019
8	40	0.533	0.0011
9	40	0.483	0.0138
10	43	0.521	0.0023
11	38	0.489	0.0028
12	36	0.557	0.0015
Mean		0.521	0.0028
Std. devn.		0.048	0.0036

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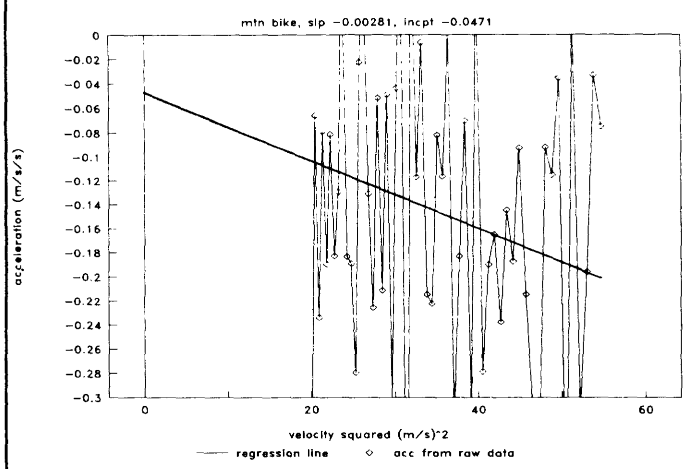

Figure 4 Scatter of acceleration values before smoothing

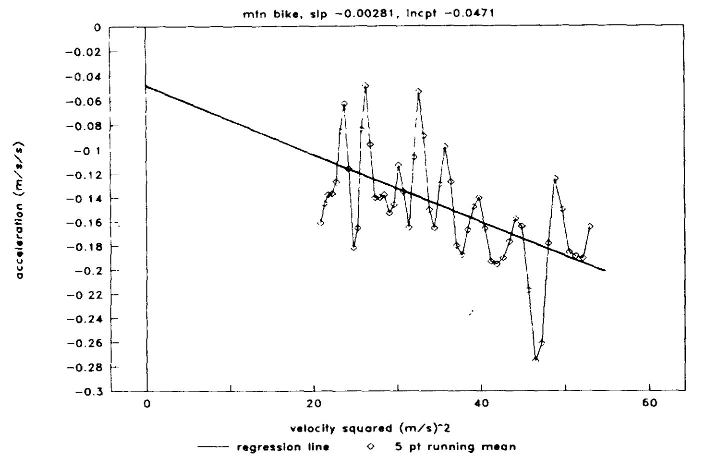

Figure 5 Scatter of acceleration values with five-point smoothing. The pattern reflects hills and valleys in the floor.

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APPENDIX I

The drag forces acting on a vehicle on a level surface can be described by:

$$F=1/2 \text{ rho } CdA\, v^2 + Cr\, m\, g$$

where rho is the air density (about 1.1 kg/m^3), CdA is the product of frontal area and drag coefficient, Cr is the coefficient of rolling resistance, m is the mass in kilograms and g is the gravitational acceleration, normally about 9.81 m/s^2.

The density can be found more accurately from the ideal-gas law:

$$\text{rho} = pM/RT$$

where p is the air pressure in pascals,
M is 28.9 kg/kmol for air,
R is 8314 J/kmol*K and
T is air temperature in Kelvin.

When only aerodynamic and rolling forces are acting the force equation becomes:

$$F=1/2 \text{ rho } CdA\, v^2 + Cr\, m\, g$$

If we plot force against velocity-squared the result will be a straight line with a slope proportional to air drag and intercept proportional to rolling drag.

By dividing each term by the mass (m) we get our working formula:

$$a=1/(2m) \text{ rho } CdA\, v^2 + Cr\, g$$

From a graph of acceleration versus velocity-squared the coefficients can be found as follows.

$$CdA=2\, m\, K1/\text{rho}$$
$$Cr=K2/g$$

where K1 is the slope and K2 is the intercept as found from the graph. The slope and intercept can be found without drawing a graph using the linear-regression function on a calculator or computer.

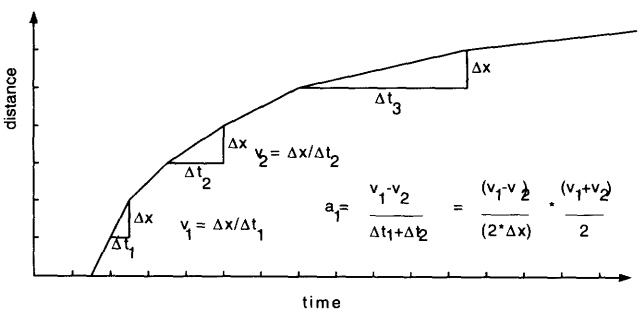

Figure 6 Calculating velocity and acceleration

APPENDIX II

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http:// www.parallaxinc.com.

Brief review

Handbook of composites
George Lubin, editor
Van Nostrand Reinhold, 1982

This book was strongly recommended by an HPV enthusiast as the bible for people working in composites, and he lent me his copy to examine. I am not qualified to judge the book's technological accuracy. The contributors appear to be RBS (real big shots) in their fields, so that I'm prepared to trust them. Rather, I was interested in its apparent usefulness in the two principal fields in which I am interested: HPVs and turbomachinery. It certainly seemed to bear out its owner's endorsement. Every topic in which I was interested I found easily in the index or the table of contents. When I read the entries on, for instance, raw materials, processing methods, design, high-temperature resins, or graphite fibers and composites, I found the treatment clear, succinct, and potentially very useful at my level of understanding. Much higher levels were also treated, but they didn't get in the way, as I find to my discomfiture in many, perhaps most, of the handbooks where I go for guidance and am often given gobbledegook.

I am happy, therefore, to lend my support to our colleague's endorsement of this very useful book.

It looks expensive: I hope that you can find it in your library before you decide that you have to purchase it. *Dave Wilson*

Octogenarian cyclists II

by W. R. E. "Ron" Beams

As promised in my previous article (HP 12-1 p. 16) I now tell how my interest in recumbents started and how it has progressed to date.

My years on two wheels finally ended a year ago when my prized Moulton AM14 was sold because I no longer felt safe on two wheels. Stability was lacking after riding recumbent tricycles. Have you noticed how some elderly riders have difficulty mounting and dismounting a bicycle and how prone they are to falling over?

With three recumbent tricycles in the garage I seldom make use of other alternative transports. Too impatient to wait for a bus and tricycles are not welcome on British Rail! Distant cycling events can still be reached by courtesy of cycling friends who have big vehicles.

Interest in recumbents has developed over many years and was started by the impact of the 1933 Velocar. Collecting news and technical paper cuttings has always been a hobby, some of them finding their way into scrap books.

In front of me is a scrap book of the first UK HPV event, in 1980, the Aspro Clear Speed Challenge, which gives a revealing insight into progress and developments from 1933 to the 1970 in the UK and USA. The first two pages have cuttings from UK "Cycling Weekly". That of 15 August 1934 carries a suggestion by A.C. Davison".....for a recumbent bicycle which could be made chiefly from standard parts". A well-known cycle maker, F.H. Grubb, made one and it appeared in a 25-mile time trial in 1934. A cutting of 15 April 1936 shows J. Henty who also followed the suggestion. Having a spare tricycle axle he built a workmanlike recumbent tricycle. It appears to be on 20" wheels, the posture upright on a seat almost over the rear axle. The front wheel, ahead of the crankset,was steered from under the seat by ".... handles that work in a back-and-forward direction". Henty is pictured in the voluminous "plus-4s" (breeches) typical of cyclists' wear of the period. He used the machine for commuting.

My own first efforts (marks 1 and 2) 40 years later were also based on standard tricycle configuration of wheels. The advantages and disadvantages of this and Ackermann format will be discussed later.

Back to the scrap book in which a page and a half from "Cycling" of 15 March 1969 shows Peter Duncan on a touring Grubb two-wheeler. He was an experienced 24-hour time triallist and he had "...no difficulty in topping 100 miles a day and on two occasions topped 150 with no exceptional effort". He toured in Scotland and Ireland and said "...The recumbents have provided me with a new dimension in cycling. On bike or trike I never quite lose the training-for-racing bug: the temptation to "hammer" *(pedal hard[1])* is always present. On the 'bedsteads' *(disparaging name given to recumbents)* I'm always content to relax and enjoy cycling".

In the early '70s I joined the (Southern) Veteran-Cycle Club and was occupied in restoring a small collection of old bicycles in addition to regular riding. This kindled an interest in bicycle history and engineering. The first of some second-hand tricycle axles was built up, sold and replaced by a Higgins *(prominent British maker of tricycles)* with a differential, and an early Higgins with an Osgear *(an alternative to the differential)*. All have since been sold and replaced by recumbents. At the same time I rode regularly with friend Chater who rode his own design of tricycle made by Higgins featuring wide track, long head tube from which the top tube sloped down to the seat tube. This proved unusually stable: I got a practical "on the road" knowledge of tricycle design.

Figure 1 Mark 1 design, 1977

In a scrap book of the "International Bicycle Touring Society of USA" (led by the late Dr. Clifford Graves) tour in the UK in 1968 there is a photo of Dan Henry of New York with his own design of bicycle. It featured springing, silk sew-ups and his stretched-canvas seat in place of a saddle. I did not know at the time that he was a recumbent enthusiast until I bought "The Best of Bicycling" edited by Harley M. Leete (USA) and found on pages 263-5 Dan Henry's May 1968 account of his recumbent bicycle. Again he used springing, 8oz. sew-ups and a webbing seat. He found "...speed and undreamed of ease and comfort", thus echoing earlier enthusiasts and foretelling what so many of us have found in later years.

In 1976 a young friend told me of a tricycle for sale".... suitable for an elderly gentleman". I bought it, sold the attached ladies bicycle for the price I paid, thereby acquiring a Higgins axle for free! At last my dream of building a recumbent became reality. Months of experiments followed using anything that came to hand including rudimentary tools such as hammer, chisel, files and electric drill. The axle was connected to an old Moulton frame cut down, a cafe-type *(slung)* seat fitted, bracket and drive installed and long handlebars giving direct tiller steering to the front wheel. At last the time came to join the Monday gang *(of fellow bicyclists)* and the revelation that the machine was not only comfortable but more stable than a tricycle, particularly on cambered roads. It was also awesomely fast downhill.

The 1980 scrap book contains photos of that machine (Mk.1) and it was much like Henry's except that the steering was above the seat and direct via long handlebars. Mk.1 was on the road regularly in 1978/9. When the first UK recumbent event was announced for 1980 I got together with fellow (S)VCC member Bob French, and we made some alterations in order to enter that event - so was born Mk. 2.

Back again to the 1980 scrap book and we see that in the 200-metres

[1] *Your editor has attempted to define what might be unusual terms*

sprint the Vector did 46 mph *(21 m/s)*, the best UK machine 40 and our tricycle 30 in spite of a ghastly attempt at streamling. Amongst many features of this event was Bob French who was timed on his 50-ins (1270 mm) ordinary at 25 mph *(11 m/s)*! Although we marvelled at the engineering and took many photos there was to be a hiatus in my recumbent activity. I have a treasured photo of my wife seated on Mk. 2 at that event but sadly soon afterwards in 1981 she fell ill and died. My interest was in abeyance for several years until I reorganised my life.

There was another event in 1981, but I did not take an active part. At that event Mike Burrows rode his first Windcheetah at 42.84 mph *(19.15 m/s)* and UK machines began to challenge the Vectors 46/47 which took 1st and 3rd places by small margins. Our Poppy Flyer III was 2nd at 46.45 and two other British machines at 42 and 44 mph. In the road race at Goodwood the Vectors again led and the Avatar 2000 surprised everybody. The British machines again showed they were catching up.

Several years passed during which I kept in touch via the IHPVA, and later transferring to the BHPV club when that was formed.

Around 1986/7 I bought an old Holdsworth axle and met Clive Walton, a motor-racing engineer and keen cyclist who had built his own time-trialling bicycle which I admired. It led me to ask if he would build a recumbent tricycle for me. He agreed to do so. We set to work on what was to be Mk. 3.

Meanwhile I had broken up Mk. 2, an action I now regret as it would have been a good reference point for future building. In particular, my recollection of it is that it was quite stable.

Mk. 3 was again on tricycle format, pedals ahead of the 17-in Moulton wheel with rear wheels also of 17 in. Wheelbase was 40 in. (1016 mm) later reduced to 36 in. to place the seat nearer to the back axle to improve stability. I now think it is better to stay with conventional cycle wheelbase and use tandem tricycle track of 28 in. (711 mm) as a stability factor. Underseat steering superceded two other attempts The fibre-glass seat was from Peter Ross of Trice and I had it nicely upholstered in black vinyl. The lowest gear is 17 in but the gears never settled down as we realised afterwards the axle was made for a fixed wheel!

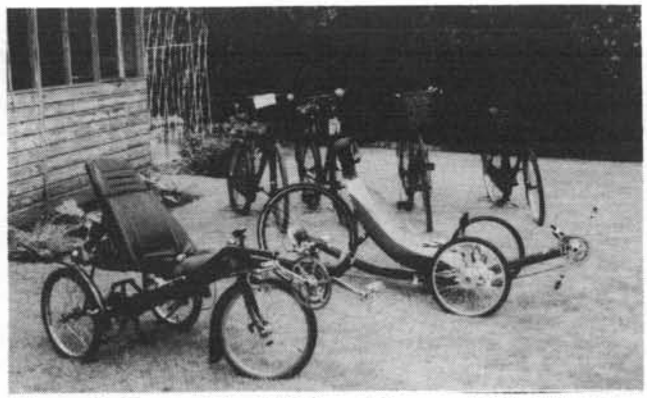

Figure 3 Beams Mk. III (L) and Burrows' Windcheetah (R); 1896 -1925 bicycles in background

This machine was used for day trips until a Windcheetah joined the stable. Then I "relegated" it to the function of shopping vehicle which it has been for three years. A large basket between the rear wheels takes my shopping and laundry and it covers about 20 miles (32 km) per month. Despite the oddity of its gearing it has proved ideal for shopping and has led to thoughts of a future machine based on 20" wheels with front-wheel drive via a seven-speed hub gear. With the seat at 18/19" instead of the 8/9" of the Windcheetah it is easy of entry and exit so necessary when stopping frequently. Mk. 3 is very economical - it takes the cast-off Moulton tyres from Windcheetah and Mk. 4! I believe the format has a future as a shopping, about town, inherently safe pottering machine with minimum maintenance.

Figure 2 Mk. 2 in Brighton, 1980

In early 1992 the Windcheetah beckoned and I visited Mike Burrows at his works in Norwich: he was assembling a batch of eight. He agreed to change the gearing to a Sun Tour Micro of 20/32/42T giving a range of 18.6 to 91 ins. He also found plastic knobs for the seat anchorage as it was necessary to remove the seat so that the machine went inside my estate car *(wagon)*. The Windcheetah was a revelation: it probably needs no description here as I expect the format is well known in the States. It is still a race-winning machine yet it can be adapted to be a fine day tourer. Mine is now equipped with a single-sided carrier with a pannier, sufficient for day use. Mudguards *(fenders)* are fitted and a very rigid mounting for a rear-view mirror. Only at the third attempt were we able to devise a mounting for the mirror that was vibration and breakage-free. These first-class fittings were arrived at only by experimental use and were designed and made by Clive Walton. There is nothing better than lengthy testing on the road to prove the suitability of equipment. I find the sole disadvantage of the Windcheetah is that so far I have not solved the problem of rain pouring down my waterproofs and soaking my nether regions before the water drains away through holes in the seat! Ah well, what cyclist worries about getting wet sometimes?

The Windcheetah is still my favorite machine. However, I gave up motoring in 1993 and felt an urge to have another machine built using front-wheel drive and steering. This led to new rough designs and a new partnership with Clive Walton. Interest in front drive was increased by the need to have a machine that could be dismantled and would fit into standard saloon *(sedan)* or hatchback cars for those friends without vans who could transport me to distant events. A year of work went into the final very satisfactory result. Mike Burrows rode it and declared it to be effective - praise indeed from an expert who doesn't hesitate to criticise! The steering is heavily damped so in straight-road use the hands rest lightly on the centre of the steering at a point where the Sturmey-Archer five-speed lever comes to hand. There is a slight side-to-side movement of the front wheel just as there is with an ordinary. Riding behind a standard tandem tricycle I noted the front wheel displaying similar side-to-side motion. I am sure readers will have noticed the weaving under pedal pressure when the Vectors accelerate. A bicycle front wheel also weaves although more from the need to balance than from violent acceleration. The seat is from the Windcheetah and at the same height and angle. The track is 28ins *(710 mm)*, a combination that, I think, has led to adequate stability for day touring. Its doubtful performance on a banked track and high-speed cornering means that this format is unsuitable for racing. The luggage platform is 15 in (381 mm) x 13ins (330 mm) and will take any number of variations of bags etc. The large rear Moulton bag fits and has been used to carry everything for a two-week tour. Although this machine is over ten lb *(4.5 kg)* heavier than Windcheetah I have been intrigued to find my daily average of between seven and eight mph *(3 - 3.5 m/s)* is about the same. A full specification and photos of Mk. 4 are available from the writer.

All three machines are now completely road-worthy and trouble-free for their purposes except for finding some solution to the wet-weather problem.

By coincidence as I write I have Allen Armstrong's article "Recumbent Tricycle Design" *(HP 12-1, p. 5)* in front of me and I comment as one without academic or practical engineering training. My designing is based on riding all types of three-wheeled machines and so is from "a seat-of-the-pants" aspect. It is good to find, from our different viewpoints, we are in agreement with so much in the field of day touring or commuting machines.

I offer the following comments based on 10,000 miles *(16,000 km)* of riding my own recumbent tricycles.

Track. Windcheetah has 23.5 in (597 mm) on Ackermann linkage and is amazingly stable. Allen's 29 ins (712 mm) ought to result in such stability that it would be almost impossible to lift a wheel. Note that I used 28 in on the rear wheels of Mk. 4 because a wider track appears to be desirable in that format.

Wheelbase. Normal cycle wheelbase of around 40 in (1016 mm) seems to be right and I question Allen's use of 50 in (1270 mm). Windcheetah at 39.5 in (1000 mm) and 23.5 (597 mm) track confers stability that has this machine regarded as a classic for racing and roadwork. Some machines provide alteration for leg length by a telescopic tube for mounting the bottom bracket. I think this would be Allen's best solution which would allow a shorter wheelbase. On Windcheetah the distance from front of seat to centre of front axle (I rode a 23 in (584 mm) bicycle frame) is only 5 in (127 mm), much less than appears from the TRk layout.

Braking. I endorse Allen's finding that separate braking is the best way of equalisation. On Mk.3 I use a double lever to operate the front brake and nearside rear with the other lever operating the offside rear. With standard cheap sidepulls this braking is very powerful. I have had none of the braking problems Allen describes.

Figure 4 (L-R) Beams' Mk 4, Mk 3, and Burrows' Windcheetah

Rear wheel. Here again I am mystified by his doubts. The 26 x 1-1/4 (ATB narrow) wheel on Windcheetah gives no trouble. Small wheels spoked 36 give no trouble - 17 in Moulton on Windcheetah and 3 x 17 in on Mk. 3. Mk. 4 has two 20 x 1-1/8 spoked 36 at the rear and gives no trouble. Riding with a CTC *(Cyclists' Touring Club)* group every week entails a good deal of riding rough tracks so lateral pressures on all wheels are considerable.

Performance. As an old 'un I potter at an average of around 7-9 mph *(3.5 m/s)*, uphill at 2-4 mph, downhill around 25-35 and more freewheeling than one can do on a bicycle. Aerodynamics play a part only downhill or against a strong wind. Weight and aerodynamics when downhill or on gentle gradients sometimes provide a welcome turn of speed so that I can leave my contemporaries behind! I am convinced the stability and comfort of the three-wheeler save energy. In comparing the factor of stability everybody forgets that bicycles, including the two-wheeled recumbent, are inherently unstable.

Comfort. It is a curious fact that I and other riders find Windcheetah more comfortable than Mk. 4 yet they share the same seat and cushion mounted in the same way as to distance from ground level and of angle. Why? It is strange when one remembers the 17 x 1-1/4ins tyre at 80 psi is unforgiving.

Finally a few comments on the future.

Assist engines. I met John Tetz here and had the benefit of a talk and took photos of his set-up. Here we are at present experimenting with a similar motor for my shopping machine. However, I ride most hills using gears under 20 ins and have on occasion been assisted by pushing or towing. I am beginning to wonder if "assist" is worthwhile. It is reasonably easy to climb hills by pedalling slowly on a very low gear at 2-4 mph i.e. walking speed - many of my contemporaries walk steep hills anyway. Time will tell.

The Demon Tricycle Recumbent is a new British introduction which uses only British and Continental material: 3/7 Sachs and Hope hydraulic disc brakes. I hope to report later on what should be an interesting machine.

Financing Research and Development. The motor industry spends billions on R&D - we need millions to be spend on developing recumbents. The perfection of the diamond frame has taken 100 years of development and the mould has been broken only by Alex Moulton, Mike Burrows and others - recumbents are at about the same stage as the diamond frame was in the 1890's!

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Book review

Race-car vehicle dynamics

by William F. Milliken and Douglas L. Milliken
Published (1995) by the Society of Automotive Engineers, Warrendale, PA
Reviewed by Dave Wilson

This beautifully produced book of 890 pages is already on its way to becoming the vehicle-dynamics bible for the motor-racing fraternity. It is written by two of our own. Bill Milliken started Milliken Research Associates just after the IHPVA was founded, and his son Doug joined the firm soon after he graduated from MIT (1977). Doug has had many roles within the IHPVA, but he is best known to us for his part in the program he, with input from his father, has worked on for Alex Moulton. It led to a succession of remarkable records for the revolutionary small-wheeled fully suspended Moulton, faired and unfaired.

While some of the book is irrelevant to the low-power low-Reynolds-number world of HPVs, a great deal is highly applicable. A major chapter (2) is on tire behavior, with chapter 14 having data on tire performance. The third chapter is on aerodynamic fundamentals, and chapter 15 on applied aerodynamics. Other chapters on suspension geometry, dampers and springs, wheel loads, and steering systems among others have applications to HPVs, particularly to two-track vehicles.

The book has a roster of big-name contributors assuring, if needed, its authority, and is beautifully illustrated and produced.

Dave Wilson

Letters

Starting recumbents

Reference article by Allen E. Armstrong, beginning on p. 5 of HUMAN POWER for Spring, '95: Vol. 12, #1.

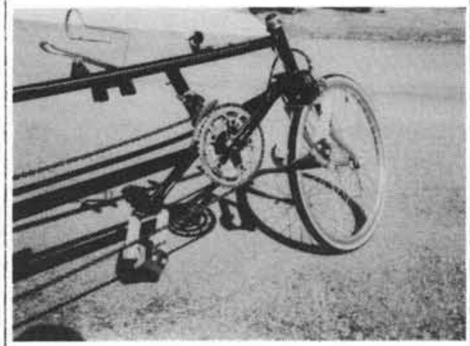
Mr. Armstrong repeats in his article an observation that occurs in HPV literature with some frequency: that recumbent bicycles are more difficult to start from a standing stop than "upright" bicycles; especially, he adds, if clipless pedals are used.

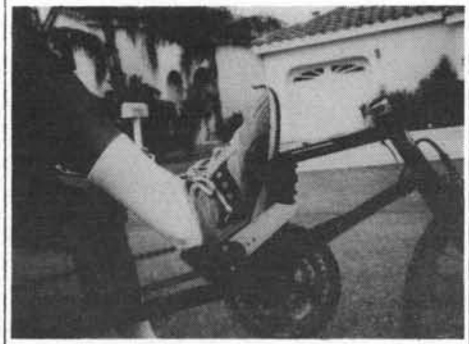
One of the generic distinctions that separate recumbent bicycles from uprights is their typically lower center of gravity. The trade-off advantage of course is their correspondingly lower wind resistance. But as evidence indicates that the toppling time of the shorter unstable structure will be less than that of an equally shaped and weighted taller one, so the recumbent bicycle may offer a fraction less time than the upright for its rider to get underway. And with the additional inherent recumbent characteristic that often positions the bottom bracket farther from the pavement than that of the typical upright, we may be looking at the root causes of the oft-cited observation noted above, and the two could well justify its implicit concern.

It can be argued that the heart of the matter is in the span of time between the instant when at-rest three-point stance is relinquished, and sustained power delivery to the drive train begins. The normal getting-underway routine for recumbents is (with the brakes firmly applied) to reverse-rotate the cranks before take-off so that one of the pedals is just short of its highest point, and then to place the appropriate foot on that pedal. The anxious moment comes at the end of the first pedal stroke when the foot which has been on the ground is expected to find its relatively distant pedal and keep the cranks turning. With farther to go and less time to get there, the ground foot can ill afford to waste time on its journey. Add in the complication of clipless pedals (which require precise foot placement) and the exercise has the potential to become a nerve-testing matter indeed.

Mr. Armstrong deals with this problem by espousing the tricycle concept, with his machine's paired wheels leading the way. He accepts some notable weight and speed penalties but has indisputably met his goals.

If numbers of people find the problem to be of such magnitude as to drive activists like the estimable Mr. Armstrong to solutions significantly burdened with tradeoff liabilities, then it seems to me that attention might





profitably be drawn to a less costly solution that both fulfills its promise and is more readily available.

Getting-underway has never been a problem for me. My HPV, a "Tailwind" by the Lightning Cycle Company of Ohio, is of the long-wheelbase variety whose bottom bracket rides no farther above the pavement than do those of most uprights. And instead of succumbing to clipless pedals, I designed and had built a form of heel cup which allows instant entry/exit. Lightweight compatible pedals together with lighter shoes essentially cancel out the modest rotating-weight penalty, and I must say the results have been remarkably gratifying. At my age (71) I'm far from speedy, but as I am at full power while the young studs on their uprights are still busily clicking in, I derive considerable satisfaction on club rides at being almost always first across the intersection when the light turns green. I also find that uphill starts are no more challenging than they are on my upright.

In addition to the above, LWBs enjoy several more significant advantages over SWBs, all of them regrettably undersung in our hobby press. As for my "stirrups," other recumbenteers sometimes ask about them, but in spite of their obvious advantages and my demonstrations of their substantial energy-savings, I think most remain skeptical. A pity.

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The human-powered rail event at the Eurochampionships at Laupen, Switzerland in August 1994

by Theo Schmidt

For the first time, an event for rail vehicles was held at an HPV championship, in this case the European HPV championships at Laupen, Switzerland, in August 1994. Three categories were introduced.

1) Racing vehicles

The purpose of these especially aerodynamic vehicles is to achieve the highest speed possible in a 200-m timed section with a flying start. Theoretically higher speeds should be possible than on the road, as the rolling resistance of metal wheels on metal tracks is lower than that of rubber wheels on asphalt. Also, the rider is not required to steer and can concentrate fully on pedalling. However, there is added aerodynamic resistance due to the necessity to span both tracks at least with an outrigger (unless you have a gyro-stabilised monorailer!).

2) Practical vehicles

The purpose of this category is the development of vehicles that are suitable for transportation, e.g. as a tourist attraction, for rail inspections, for travel on disused lines, on private grounds such as factory sidings.

3) Kinematic sculptures

The purpose of this category is simply art and pleasure.

"Low-tech train", Laupen, Switzerland Photo: Christian Precht

Four teams showed up for the event, two with racing and two with practical vehicles. All vehicles were asymmetrical, i.e. using outriggers to one side.

Team Gridelli brought a very nicely painted faired vehicle with four wheels made from aluminium cycle rims. These didn't have the conical running surfaces and rigid axes of traditional rail vehicles. The Gridellis therefore attempted something completely new and discovered completely new problems to do with stability and vibrations. They also hadn't allowed for the fact that the track width is up to several centimeters wider in curves and "fell through" the track, damaging the rims. In spite of the rattling wheels, rider Gridelli junior achieved a credible 14.184 m/s, 51.063 km/h, on the timed section.

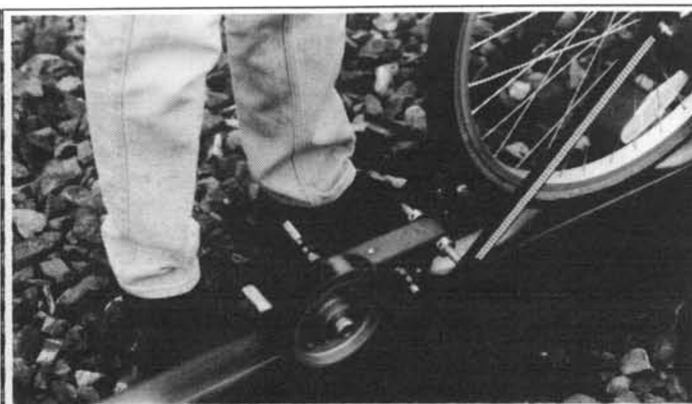
Katrin Ranger of the Low Tech Train team achieved 15.936 m/s, 57.370 km/h, and is the first holder of the world record in this category. Low Tech Train rolls on four wheels made of steel only a few mm wide. Further, four guide wheels are inclined and spring loaded to fit the inside edges of the rails. This vehicle was impressively engineered and has the potential for a higher speed. Apparently the single gear was not optimal. Also, part of the fairing had been lost and the tubular outrigger was unfaired.

In the practical vehicle class, Francoise and Bernard Magnouloux rode all the way from Paris with their convertible tandem. On the road this has a trailer for camping equipment which becomes the side-car/stabiliser on the rails. The Magnouloux are experienced touring cyclists (see HPV News March 1993) and have used their vehicle for thousands of kilometers on road and rail in the Canadian wilderness, where there are many abandoned tracks. Bernard has newly published a book about these trips (see below). On the rails, the tandem is guided by flanged rollers fore and aft. This works well on the straight, but not on tight curves and level crossings. The top speed is not very important on such a touring vehicle and a maximum of 7.00 m/s, 25.2 km/h, was recorded. The Magnouloux won a prize for riding the complete distance to Laupen under their own power.

Richard Stuart crossing the Coeur d'Alene river, Idaho, near his home

The prominent fourth entrant was Richard Smart, a true pioneer of rail-cycling. He has been developing rail-cycles for over 20 years and has covered many thousands of miles on disused tracks on the North American continent. He brought his newest design of guide system and outrigger fastened to a folding mountain bike, all carried as normal luggage by plane and train. The system, attachable to any standard bike, looks deceptively simple, but is very sophisticated: a magnet keeps the guide roller firmly on the rail in such a way that only the inside edge of the rail is needed. Thus level crossings and switches can be traversed with ease. The system works so well the single guide in front of the front wheel is all that is needed to keep the bicycle perfectly aligned on a single rail. The outrigger to the other rail uses a skateboard wheel and keeps the bike upright but otherwise has no constraints. Smart sells detailed plans for making his system and publishes the world's only newsletter devoted to rail-cycling (see below). The Smart rail-cycle easily won the practical vehicle prize, being the only vehicle to pass all switches and crossings without dismounting. Richard could even drive off the track at a crossing, turn around, and go back onto the track, all without dismounting. In spite of the refined construction, the top recorded speed was 7.39

"Low-tech train" at speed on the track, Laupen, Switzerland
Photo: Christian Precht



Closeup of Richard Stuart's magnetic guidance system

Francoise and Bernard Magnouloux on their rail-cycle tandem

m/s, 26.6 km/h. This has little to do with Richard's fitness but shows the effect that swinging legs have on an HPV: it starts to move from side to side at speed. When the permitted deviation sideways is about one centimeter at the most, the speed must be kept below a certain level to prevent derailing.

Richard later presented a superb slide show with historic rail vehicles and pictures of rail-cycles in magnificent scenery.

Befitting the punctuality of the Swiss rail travel system, the rail race was originally strictly scheduled, as there was only a relatively short time available between other HPV races and two steam trains were also scheduled to use the track in both directions. The practicality test for the two rail-bikes consisted in travelling the 1.5-km-long stretch from Laupen railway station to the start of the speed trail. Both teams enjoyed being officially dispatched from the station and traversing various switches, curves and crossings past hundreds of spectators and dozens of waiting cars! Dick Smart managed the stretch perfectly while the Magnouloux tandem had problems with curves. Arriving at the beginning of the flat and straight sprint section, the rail vehicles were confronted with nearly a thousand spectators, a good proportion of which were standing on the track. As the rail event organiser (and your scribe) had not organised a loudspeaker system, there was considerable difficulty in clearing the track and starting the high-speed sprints. The timetable was by now useless, but with the professional aid of the railroad company owning the track (Sensetalbahn), it proved possible to give each vehicle two runs, let the steam trains pass, and provide photo and film opportunities for the journalists. Finally Dick Smart was allowed to ride back to Laupen station, where all the vehicles were then displayed.

The track owners were pleased with the publicity and offered to make the track available for regular future events. Although the track is no longer used for passenger service, it is kept in good condition. This gives HP rail enthusiasts an almost unique opportunity to use a surveyed stretch of track, conforming with record requirements, legally. It is hoped to hold another event late in 1996.

Rules for hybrid vehicles

My "plea for agreement" in HP 12/1, proposing simple rules for hybrid vehicles within the IHPVA brought two responses. Paul Morningstar mentioned an article on an electric bike by Ely Schless with regenerative braking featured in Home Power Aug/Sept.

Peter Sharp sent many pages of material pointing out the futility of encouraging innovation by making rules including fixed precise definitions.

He proposes multiple classes containing working definitions which can be changed anytime as classes evolve or split up. Classes are created anytime enough people find it worthwhile. In a sense this has happened with electric bicycles. After many years of inactivity the Japanese races sparked off enough interest for the Extra Energy concept to be created (see elsewhere this issue). Already electric bike races are attracting sponsors and manufacturers aiming at tens of thousands sales of such vehicles, allowing professional promotion. So while we were talking, the IHPVA has been left behind here and there seems little sense in continuing to think about rule making in this context. The message seems to be: go ahead and build what you think sensible or fun and take it along to whatever meeting you want to, rules or no rules. If there are enough of you, you can make your own rules.

Theo Schmidt, VP Hybrid Power
<tschmidt@mus.ch>

"Pedalling unknown paths"

The Book Guild Limited, publishers of this book reviewed in HP 12-1, let us know that it is available for £8.95 (about $13.50) plus £2.50 surface mail anywhere or airmail for Europe, or £10 for airmail elsewhere.
25 High Street, Lewes, E. Sussex BN7 2LU, UK Fax (01273)476472

Putting the IHPVA in high gear: shifting paradigms

by Peter A. Sharp

Introduction

I have been perplexed by the resistance within the IHPVA to new HPV technologies, such as accumulators, wind-assist devices, and power-assist devices. That resistance to new technologies seems particularly out of place in the IHPVA. The IHPVA is, after all, a unique research-and-development organization founded on the principle of stimulating innovation through competition, using the least possible restrictions on technology. So I began to look for underlying structures or assumptions that might explain that resistance. What I found surprised me. There is a great deal of evidence to indicate that the primary cause of the resistance to change is, paradoxically, the use of an open (unlimited, unrestricted) class for land HPVs. The purpose of this paper is to explain why the open class is inherently flawed, and to recommend an alternative solution: multiple classes of equal status and unlimited number. They are the key to truly open competition and to unrestricted technological evolution. Multiple classes initiated directly by the general membership would maximize competition and creativity, and without causing disruptions to the existing records.

An historical example

The historical decisions of the UCI, the International Cycling Union, are instructive. The UCI's arbitrary prohibition against recumbents in 1934 may be ascribed to their using only a single technology class. At that time, the class excluded streamlining, but it was otherwise an open class for bicycles. Then along came Charles Mochet and his record-breaking recumbent bicycle. It was legal, but it represented a substantially different technology. If the UCI had allowed his record to stand, and had permitted recumbents to compete directly with standard bicycles, the effects would have been highly disruptive. Comparisons between past and future athletic records would have become difficult because they would have been based on very different bicycle technologies. So, in order to preserve the continuity of records, with their primary focus on athleticism, the UCI banned recumbents.

However, the UCI did have a much better alternative. It could have established multiple technology classes. To keep the emphasis on athletic ability, it could have added racing classes on various formulae for both streamliners and recumbents, plus racing classes for experimental vehicles. But it chose, perhaps without even considering those alternatives, to retain a single technology class. Once it made that choice, consciously or not, it was forced to exclude streamliners and recumbents so as to keep the primary focus on athleticism. In other words, the UCI's choice to use a single technology class is what made the IHPVA necessary.

The IHPVA's oversight

Many years later, the founders of the IHPVA inadvertently made the same mistake when they chose to use a single, open (unlimited, unrestricted) technology class. A truly open technology class seemed like a simple and elegant way to guarantee freedom from arbitrary restrictions like those imposed by the UCI. It is only over time that its inherent flaws become apparent.

The IHPVA was founded by a small group of experimenters who had been focusing on a relatively narrow goal: the improvement of streamlining for HPVs, using competition both as an incentive and as a way to compare their improvements. The experimenters included academics with backgrounds in science and engineering, so they had established simple rules (like the "no stored energy" rule) to eliminate confounding variables that might obscure the results of their streamlining experiments. However, when they decided to found the IHPVA, they apparently decided to give the organization a higher purpose and a more inclusive goal: the improvement of HPVs in general by stimulating diverse technological innovations through competition. The bylaws reflect that broader, more inclusive goal. The open class, however, was still focused primarily on the original, more narrow, goal: improved streamlining. Apparently, at that time, there was not much reason to suspect that a conflict might eventually arise between the narrower focus of the open class and the broader focus of the bylaws. At that time, the two focuses probably seemed to be congruent for all practical purposes since the most effective way to improve HPVs was to reduce aerodynamic drag.

But the issue of human-energy accumulators, which was first raised about ten years later (and about ten years ago), did focus some attention on that underlying conflict. Unfortunately, the IHPVA did not resolve the conflict between the open class and the bylaws at that time. Perhaps it was not recognized as such. Or, perhaps the IHPVA saw no apparent solution, or no need for a solution, other than the "compromise" that was chosen to resolve the problem. (The "compromise" was to allow accumulators only in events longer than one mile. Would we apply that "compromise" to streamlining?) Now, however, a solution to the underlying conflict is long overdue because it is retarding innovation in many areas. Fortunately, a simple and excellent solution does exist: multiple classes of equal status and unlimited number.

The open-class paradigm

The IHPVA's paradigm for its land HPV competition format is an open technology class. As paradigms go, it is relatively minor, but it does have important implications for the quality and quantity of HPVs, for the global transportation mix, and for the environment. The idea of the open class is to allow HPVs to use any legal technology for competition, to throw all HPVs into the same event, and may the best HPV win - a kind of "free for all", "survival of the fittest", or "king of the mountain" without subclasses or handicapping. Perhaps the image is one of a pyramid of HPVs scrambling over one another with the fastest HPVs making it to the top.

What is extraordinary is that neither the bylaws nor the competition rules make any reference to the use of an open class. It is simply taken for granted. That is often the case with paradigms. Once accepted, they seem like common sense. The competition rules are written so as to create, and to conform to, the open class, although that intention is only implied, not stated explicitly.

For example, the idea of the open class is only implied in this general (2.0) statement in the March, 1989 competition rules: "In general it shall be the intention of the IHPVA rules to avoid defining what type of vehicle may enter individual competitions, but to let the competition itself determine which type of vehicle is superior by a normal evolutionary process. Exceptions may be made if unavoidable (e.g., arm-powered vehicles). The spirit of these rules is to avoid inhibiting design innovation by not establishing unnecessary restrictions."

(Unfortunately, the rules that follow immediately establish unnecessary restrictions in direct contradiction to this spirit of the rules. However, they are not recognized as such. That is because they seem to be necessary in order to maintain the dominant focus on streamlining research.)

That general statement of intent sounds great; it is noble and realistic at the same time. But note how that statement sets up an ideal, open competition, and then acknowledges that "exceptions" to that ideal will have to be made. (Actually, "arm-powered" could be quite adequately treated as a rider subclass, so it is not at all an "unavoidable exception". But it serves to characterize "exceptions" as high minded.) Also, there is included no guideline as to how the ideal is to be implemented. That is taken for granted, even though a very different, and better, form of implementation could be used: multiple classes of equal status.

The IHPVA chose to throw everything into one pot, the open class, and then to make "unavoidable exceptions" when that did not work. This approach inadvertently puts a lot of power in the hands of those writing and enforcing the rules because it could permit just about anything, even the opposite of the original intention, as long as it were declared to be an "unavoidable exception" or a "necessary restriction". Consequently, anything that could disturb the status quo of open class might face a "necessary restriction" or might be made an "unavoidable exception". Justifying "exceptions" in the name of good "intentions" is usually a prescription for trouble. It lacks built-in checks and balances. Governing bodies with that power, even those with only the best of intentions, tend to use it, sooner or later, to justify the censorship or suppression of alternatives which they consider potentially disruptive to the existing order of things. In science, an "exception" is often a warning sign that part of a paradigm is incomplete or incorrect. Too many "exceptions" usually trigger a search for a better paradigm.

The open-class paradox

The resistance to new technologies in the IHPVA may be seen as an attempt to maintain the integrity, the status quo, of the open class. The open class places its primary emphasis on streamlining almost in the same way that the UCI places its primary emphasis on athleticism. Admitting fundamentally new technologies, such as accumulators or wind-assist devices, would require altering some of the most important events and records in the open class. In fact, each time a new technology came along, it might require that many of the records in the open class start all over again with new rules in order to accommodate that new technology. That would be quite disruptive to the records, which are almost universally records for basic streamliners (using only instantaneous human power under low-wind conditions). The continuity of the records serves to measure technological progress. If that continuity is broken to accommodate a new technology, then we lose our measure of progress because we are comparing apples and oranges. So no wonder such changes are resisted.

Therein lies a paradox. To defend the traditions and records of the open class, innovations must be restricted, even though the original reason for choosing the open class was to prevent restrictions on innovations. The existence of a paradox often indicates that one is using an inappropriate paradigm. The open class is self defeating. Its inflexibility is poorly suited to stimulating fundamentally new technologies. It has become not an open class, but rather an overly restricted class which does not comply with the bylaws of the IHPVA. In fact, it is now only a formula class for basic streamliners. While there is nothing wrong with having a formula class for basic streamliners, it is far from accurate to contend that it is an open class.

Unfortunately, the problems with the open class have serious implications for the IHPVA. If the open class is not fundamentally open, and does not comply with the bylaws, that could place the validity of the records in question. Records must be set in compliance with the rules. But if the rules are founded on underlying contradictions, if they are not in compliance with the bylaws of the sanctioning body, then the validity of both the rules and the records is open to challenge. In fact, if the competition format, the open class, does not comply with the bylaws, then the credibility of the IHPVA itself is open to question. Sadly, the open class is not living up to our original expectations. That is not to say that it has not stimulated much good work. It certainly has. The point is that it is doing far less than it could, and should, given the founding principles of the IHPVA as contained in the bylaws.

The bylaws and the open class

The bylaws are very inclusive with respect to what technologies can be used in competition. They permit all "non-stored-fuel" technologies, and even that limit is strictly applied only to records. The bylaws also make it the highest priority of the IHPVA to stimulate, and not stifle, competition and creativity, and to minimize restrictions. In contrast, the open class, with its priority on streamlining, uses rules that are restrictive of other technologies, such as the "no stored energy" rule (which prohibits accumulators), and the "human power only" rule (which prohibits a variety of wind-assist devices, such as Matt Weaver's aerodynamic stabilization technique, Specialized's three-spoke wheel which generates a net thrust in winds of a little over 10 mph, wing sails, etc.). The bylaws take priority. These rules are overly restrictive and do not comply with the bylaws. Consequently, they are not valid rules. Fortunately, a competition format based on multiple classes would solve this problem without requiring changes in these rules, since they would still be valid if applied only to classes for "basic" HPVs, like current streamliners.

The open class also imposes major restrictions on competition and creativity by what is not included. The nature of the events determines which technologies will be developed in order to win the events. Since the open class began with a dominant emphasis on streamlining experiments, the events are skewed to favor streamliners. There are, for instance, no official hill climbs, races requiring extreme maneuverability, races requiring extreme acceleration and braking, off-road races, relay races using teams of riders, or events and records based on standardized measurements of practicality. Conditions have been similarly restricted. One of the most important exclusions is that of windy conditions. Not specifying windy conditions (for some events and when available) has led to at least two delays in technological progress. One is that there has been little incentive to explore efficient wind-assist devices for propulsion, even though most vehicles in the future will probably use them. (For instance, we know almost nothing of what Randy Schlitter has learned, independently, from logging 20,000 miles in wind-assisted HPVs.) Another is that there has been little incentive to explore stabilizing devices to make streamliners handle well in gusting winds. (According to Peter Ernst, some European countries are concerned about letting streamlined HPVs on their roads, and Switzerland has already banned some kinds of streamlined HPVs because they weave too much in response to cross winds.)

Because the open class can have no official subclasses (except for "exceptions"), there are no official placements or records for unfaired or partially faired HPVs, even though they are, without doubt, "the best in technology" (a goal of the bylaws) for the majority of applications and for many (excluded) events. Reduced incentives are almost certain to result in reduced innovation. That is a basic assumption in the IHPVA.

The bylaws give equal status to speed, efficiency, and practicality. But to avoid practicality requirements for streamliners, which would inhibit their development, a separate and inferior subclass is used for practical HPVs. After 20 years, we still have no official rules for practical HPV competitions. Even worse, the evaluations of practicality are changed arbitrarily from year to year, and are often selected at the last minute due to inadequate planning. Imagine what the effect would be of having no rules for streamliners, and of changing the events each year and at the last minute. Practicality has been given a very low priority in the open class, and that is contrary to the bylaws.

The open class, which applies the same restrictive rules, events, and conditions to all technologies, is guaranteed to stifle innovation. If the open class were required to conform to the bylaws, then it would become unworkable. To be workable, it must circumvent the bylaws. So it is dependent upon restrictive "exceptions". What is needed instead is a competition format which would promote innovation in all areas (in compliance with the bylaws), while still preserving the traditional events and records with their dominant emphasis on streamlining. Multiple classes would achieve that.

Multiple technology classes of equal status and unlimited number

We can use multiple classes to accomplish everything that the open class was originally intended to accomplish, and without relying on restrictive "exceptions". Taken collectively, multiple classes would maximize innovation by minimizing restrictions, and they would place the HPV competitions and records on a legitimate foundation consistent with the bylaws. They would also provide a built-in system of checks and balances. For example, if inappropriate practices (such as the use of down slopes and [only] high altitudes for top speed records) could not be corrected by reaching a compromise within a reasonable amount of time, an alternative class could be created as a last resort.

Multiple classes would be like an ecosystem that would evolve in response to environmental changes. Each class would focus on a specific combination of technologies, its own niche. In principle, there would be no limit on the number of classes. That is the key to guaranteeing true openness and unlimited technological evolution.

In practice, the number of classes would probably be relatively few. A new class would be formed when a small number of members (say, 25) petitioned the board for official status. (A large proportion of scientific research is conducted by such small, informal groups.) The board would insure that the proposed class was consistent with the bylaws. Also, a "sunset clause" for classes, requiring renewal every five years, would minimize the book keeping by eliminating superfluous classes. There is no need to be concerned about spreading ourselves too thin, over too many classes, because classes could exist only to the extent that they were actively supported by a minimum number of members.

Each class would have its own records. The current records and record events would be reserved exclusively for "basic" HPVs, meaning HPVs using only instantaneous human power under low wind conditions. This would maintain the continuity of those records, and would avoid any confusion in the eyes of the general public. Races and record events could be held jointly by various classes. Some classes would have special events of their own, which would be designed to encourage maximum innovation within that class. An HPV could compete simultaneously in any classes for which it was qualified.

Not all classes would necessarily be represented at the annual championships. The number of events for a class would be proportional to the number of vehicles and volunteers representing that class. Since classes would often share the same events, the annual championships would probably look pretty much the way they do now, with only minor differences.

Multiple classes would avoid unproductive arguments over where to draw an arbitrary line to limit a technology, such as streamlining, wind-assist devices, accumulators, or power assist. Each class would set its own limits for research purposes. Using multiple classes would represent an agreement to disagree about controversial technologies, so as to stimulate, and not stifle, different avenues of research. This approach would fully accommodate both "purists" and "practicalists", without requiring either group to compromise its values or priorities.

One of the most important advantages of using multiple classes is that they would simplify the process of making rules and regulations. Many rules for a class would already be implicit in the definition of that class and its events. Also, the rules would be simpler because they could, if necessary, include restrictions that would not be valid if they were used in an open class. Since restrictions would function merely to define a single class, the unlimited collection of classes would still be entirely open and unrestricted overall. For example, a class for basic streamliners could legitimately prohibit human-energy accumulators and wind-assist devices. That would in no way prevent the formation of a different class (with different records) in which streamlining could be combined with accumulators and wind-assist devices. Each class would have limited objectives, thus making the rules and regulations simple and manageable. Only safety regulations, record validation requirements, and equal-opportunity requirements for riders might need to apply to all classes.

As an example of a potential class, here is a brief description of an accumulator class, with one record event. It would permit the rider one minute of unassisted pregenerative pedaling prior to the start, plus pedaling, regenerative braking, and regenerative suspension during the event.
Competitors would be responsible for demonstrating, unequivocally, that no additional stored energy was used during the event (batteries could be used if they could meet this requirement). The record event would be a "1-k Pylon Race", around two pylons spaced 100 meters apart, in each of two lanes, and all turns would be made away from the other lane for safety (following a figure-eight path). This race would have no wind speed, elevation, or overall gradient restrictions (since none would be necessary), and times could be measured using stopwatches. The track would be flat to within 0.2 meter (so as to avoid a bowl shape, which would function as a regenerative brake).

The goal here is to keep the event simple, safe, inexpensive, easy to run anywhere, and open to any kind of "non-stored-fuel" technology (plus "experimental" times for power-assisted HPVs, based on the average of two runs, one with and one without using the onboard power assist). This ten-leg race would require extreme acceleration and braking, maximum energy conservation, and exceptional maneuverability. In addition to the overall record, special records for various HPV subclasses (uprights, power rowing, etc.) could be used for incentives and comparisons. Technologies developed for this race would directly benefit practical HPVs.

A collection of multiple classes of equal status could include one or more classes that approximated the original idea of an open class. For example, one approximation would be a sport-cycle class that would permit all "non-stored-fuel" technologies to be used in all of its events. Plus, the events and conditions would be deliberately selected so as to require mutually exclusive design solutions. Conflicting demands stimulate innovation. The sport-cycle class would promote HPVs of exceptional versatility. It would be an especially interesting class because it would permit all other classes to compete directly against each other, with all having a reasonably equal chance of winning.

Conclusion

We are in the second golden age for HPVs, about a hundred years after the first. The IHPVA deserves the credit for reopening and expanding technological gold mines that were discovered but abandoned many years ago (streamliners and recumbents). Now our challenge is to design more sophisticated tools for mining those technologies, and for finding new gold mines in unexplored areas. Multiple classes of equal status would provide those tools. Since the future of the IHPVA, its records, and HPVs in general are at issue, reform is long overdue. We need to shift paradigms in order to put the IHPVA on a strong foundation so that its records will endure, its stature will increase, and its innovations will proliferate far into the future.

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Peter Sharp is an independent inventor and self-employed craftsman. He "is happily married to his Tour-Easy". He has had a continuing campaign to broaden and rationalize the directions of the IHPVA.

VELOCITY
A user report

by Theo Schmidt

Michael Kutter's electric bicycle VELOCITY is arguably one of the best production models around, at least in my totally biased opinion, being loosely involved in the project and also a satisfied customer. "Production" means there are about 20 of them, each one unique in choice of color and components. Prices range from about \$4000 to \$5500, depending on frame (Cannondale M500 to V2000), components and choice of batteries, i.e. either a lead-acid battery without charger or a nickel-cadmium battery with charger.

The VELOCITY has a relatively powerful motor, rated at 500W and controlled electronically by the pedals. A sensor counts the teeth of the pedalled chainwheel, resulting in a motor speed corresponding to a mathematical function stored in a PROM (Programable-Read-Only-Memory). This function determines the character or feel of the bike.

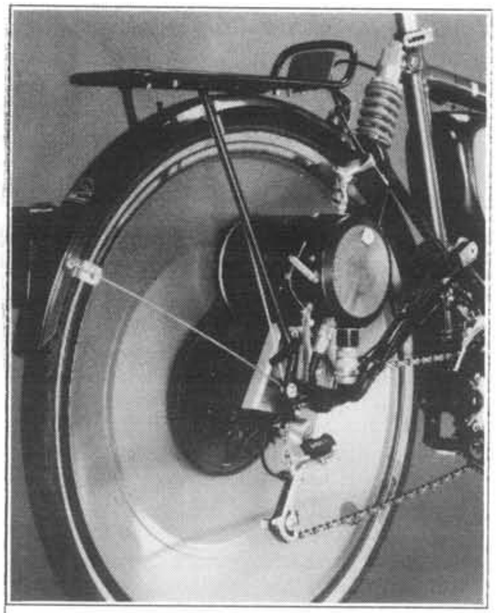
When you pedal slowly, the motor is off or at very low power and speed; as you increase your cadence, so does the motor speed. Motor and human input are coupled in series through a differential, i.e. their respective speeds are added, not their torques, as is the usual way. This results in a "servo" or "amplifier" effect, the virtues of which have been expounded by various people including Allan Abbott and myself. Mainly, you don't have to change gear from standstill up to 35 km/h (on the flat) (1 km/h = 0.277...m/s=0.6124 mph). Viewed this way, VELOCITY is an automatic continuously variable transmission.

The result is that the bike is great fun to ride and that you ride fast. Unlike most assisted vehicles where the motor is designed to help you up hills and works harder the less you work, VELOCITY's motor works harder the harder you work. This can be influenced by choice of gear and cadence. On short trips I pedal quickly and travel at about 35 km/h (about 22 mph) on the flat and correspondingly less on hills.

The VELOCITY drive simply adds 15-18 km/h to whatever speed you would pedal without assist. So if your normal speed is 20 km/h, this becomes 38 km/h, and on a steep hill where you might be pedalling only 5 km/h, this can become 20 km/h, four times faster! On very steep hills the motor is heavily loaded and becomes slower or even stops in extreme conditions such as with a very heavy rider on a very steep hill and a rather depleted battery. In this case it is possible to dismount and still have the bike pull itself and any luggage up the steepest hill at walking pace. This is done using a manual twist grip, normally unused. Riders are not tempted to use the twist grip rather than pedal in normal conditions, as is the case with most mopeds, because the top speed is then only a boring 18 km/h.

Most cyclists know that the bicycle is the fastest vehicle door-to-door in urban areas and even in the country for shortish trips. As this electric bike is faster than the average cyclist, it is logically the fastest vehicle there is, at least in places where there are shortcuts for cyclists not available to motorcyclists, as almost everywhere in urban and suburban Europe. I can certainly vouch for the truth of this statement in my riding, although I lose a few minutes by having to lock up my pride and joy more carefully than my usual old banger. I have measured average speeds on all my recent riding, which is hilly and suburban. This is almost always very near to 25 km/h, considerably higher than my unassisted riding or automobile trips door-to-door.

Another effect of using this bike is that I ride more than previously, simply because it is more fun. I also get a better workout, because the way the VELOCITY is programmed, someone like me actually tends to work harder. The extra exertion is not felt because of the feeling of speed and the much better cooling of the faster airflow. Viewed in this context, the VELOCITY actually amounts to a very cleverly



contrived portable electric fan! (Unfortunately if you don't remember to slow down a bit towards the end of your trip, you begin to sweat heavily the moment you stop.)

A great joy when riding in traffic is keeping up with the cars and overtaking the stinking mopeds, which are limited to 30 km/h in Switzerland. Fortunately the Swiss authorities take the view that this speed limit applies to the motor only, so that vehicles like the VELOCITY which add the pedalled speed on top can quite legally go faster than 30 km/h. The other effect is that it is possible for a rather unfit person like me to travel at speeds usually reserved for either fully faired HPVs or well-trained cyclists. (A fit rider in a faired vehicle is of course faster and has a much larger range.) For sheer versatility in traffic, the unfaired bicycle is however much better than the fully faired one. The conclusion of all this is that I have paid a large proportion of my savings to gain something that regular hard training would do better. My only comfort is that this is typical human behaviour and I thanks to my new toy I am actually getting more exercise and not tempted to get a car, whether electric or otherwise.

VELOCITY's NiCad battery is 24 volts and 10 Ah. This lasts for an hour's riding at full speed or in hilly country. The range is 25-40 km, depending on speed and terrain. To go further, it is necessary to slow down and choose a high gear (there are no gears as such on the motor, but 21 gears on the pedals). Or you can simply switch the motor off whenever it is flat and you're not accelerating: the bike's extra weight (total 33 kg) is then hardly felt if the tires are inflated hard.

This range is sufficient for most commuting trips. It is insufficient for longer two-way trips and touring. The battery case however has an integrated fast charger weighing only 0.2 kg and is easily detached from the bike and plugged into any 230-V socket. A full charge takes about two hours and uses about 0.4 kWh. The high-frequency charger monitors the rate of change in battery temperature and provides a reliable shutoff irrespective of ambient temperature and initial state of charge. The battery is also easily charged with solar cells but this is then unfortunately unregulated, so that fast charging is not possible without running risk of overheating. If the battery does become depleted, you can still get home in any case, as the pedal gearing automatically gets quite low. Or you can stop for a drink and a quick partial charge. I have found that if you ask nicely nobody minds giving the small amount of electricity - worth considerably less than a tip.

Public reaction to the VELOCITY is most favorable from cyclists who do a test ride and come back grinning and from many people who wouldn't dream of using one themselves but still think it a good idea. The least favorable reactions are from fit racing-type cyclists who understandably feel contempt for those whom they feel to be cheating.

Legally the electric bike is treated as a moped and as such must carry liability insurance (about $20 annually, ten times more than unmotorised bikes). Also a cyclist's helmet must be worn.

Kutter has also fitted out a Lightning and a Leitra with his system; however, I have never tried these. The VELOCITY project was possible due to Michael Kutter's single-minded dedication, generous sponsorship by the Swiss Department of Energy and some others, and a majority of customers prepared to pay quite a lot for vehicles still in the need of some development. The present stock of vehicles is nearly sold out and unrepeatable because Canondale no longer makes suitable frames. Contacts to potential manufacturers have so far not been successful due to their perception of an extremely small market segment for what is on average the world's fastest vehicle (average speed, average trip, average rider). It will probably be up to the large Japanese companies to sucessfully market useful electric bikes both desirable and affordable and perhaps save the world!

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Book review

Bike cult, the ultimate guide to human-powered vehicles

by David B. Perry
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Bike Cult is a large-format (8"x10", or about 200mmx250mm) fat, handsome paperback. There are almost 500 pages of the main text and illustrations, followed by over 70 pages of appendices including useful and arcane information (champions and records in various events, including HPVs; circus acts, biography, fiction, poetry, arts and music involving bicycles); "living and loving"; "bicycle mind"; and a comprehensive index. Alas for HPV enthusiasts, there are only a few scattered groups of pages on HPVs in the rest of the book.

It starts with a good history stretching from very ancient times to modern recumbents. Hardly anything in bicycling history is not disputed, but I could find no major transgressions that would excite a purist. One can always quibble on details (e.g. the author reproduces a drawing of a recumbent from something I wrote for the Rodale book Pedal Power and calls it the "linear-drive Avatar recumbent", which it wasn't. This raises the question of whether he was scrupulous in getting permission to use so many copyrighted illustrations. Many illustrations have neither acknowledgement of sources nor even captions.)

Part two has three chapters on human power output, physiology, and bicycling performance. Part three is six chapters on interesting aspects of bicycling around the world, called "bikeable planet". The fourth and last part is composed of three short chapters (public image, living and loving, and bicycle mind) under a title close to that of the book: "bike culture".

The blurb that came with the review copy stated that "Bike Cult aims to be The Whole Earth Catalog of bicycle culture". It succeeds. It also seems to me to be a bargain: $23.95 for 608 large pages full of information and fun. It's not a coffee-table book: there are no gorgeous color photographs to make one's noncycling friends gasp with amazement. It is something you will probably want to curl up with on long winter evenings to learn new aspects of the background of your favorite sport.

Dave Wilson

Editorials

The king is dead - long live the king!

Britons had a pride in being able to join in this cry, indicating a smooth transition from one monarch to another. Our long-serving (in two periods) former president, Marti Daily, is far from dead, but she has transferred the robe, sceptre and other accoutrements of the majesty of the office to Len Brunkalla.

Having been president of this august organization, I know that it is almost unmanageable. It started as a group of Californian enthusiasts who gathered periodically in a relaxed and friendly way to race and to discuss developments. When it began to spread into the rest of the U.S.A. there were complaints from what may have seemed like outsiders that the Californians were unwilling to give up control. (We've heard the same cries from the rest of the world about Americans). The annual speed championships first left California to go to Indianapolis, and Marti Daily was one of the local hard-working volunteers. Later she became president of the Indiana HPVA and then of the IHPVA as a whole. She was one of a series of non-Californians, of which number I was one.

The whole problem of running the IHPVA can be summed up in two words: poverty and communication. It was easy for a local group of friends. It was virtually impossible for people separated by thousands, often tens of thousands, of kilometers. Membership has stayed at below 2000, and dues are swallowed up by the two main publications. There are no funds for travel or secretarial help, and hardly any for phone and fax. Marti did far more than anyone previously in communicating by getting herself to meetings all over the country and to many places in Europe. (How she did this on the salary of an elementary schoolteacher is a story of sacrifice). She also did a phenomenal amount of writing and responding to letters and orders. She organized a wonderful network of volunteer help. We are grateful to her for getting the IHPVA stable and a going concern after a period when it seemed likely that it would shut down.

And now we cry "Long Live Len Brunkalla!" as we welcome our next president. As you all know, he has been an energetic editor of HPV News (a post he will relinquish as soon as he can find a successor). He is also the outgoing president of WISIL, the Wisconsin and Illinois HPV Association, the co-designer and constructor of the WISIL Missile Streamliner, which has won the race series at its first attempt. He has also been IHPVA booth coordinator at bicycle-etc. shows, and liaison with bicycling associations. His hobby is building HPVs, and he is a machinist. Len promises us an up-front full-disclosure administration. We wish him well, for his sake and for ours.

New rules for the IHPVA

Elsewhere in this issue I made space for another plea by Peter Sharp for a more-comprehensive change in the IHPVA rules. I did this for two reasons. The trite reason is that I had space that, at the time, I couldn't fill. The more substantive reason is that I agree whole-heartedly with Peter Sharp. He is a clear and original thinker whom we should not ignore.

I was caught up with the same movement that he identifies so well: a group dedicated to produce faster land vehicles trying for the 200-m flying-start speed trials. The rules for these trials had acquired a sacrosanct status. I remember with embarrassment trying to modify the rules to allow the runs to be recorded of a group of Britons who had borrowed cash to come to Indianapolis for their one glorious attempt at the record. The wind was usually above the minimum, so that the times for most runs were simply not recorded. They were appalled. They raced in all weathers and didn't see why we shouldn't. Likewise in this issue the Japanese Birdman Rally is run in all weathers, an extraordinary feat for fragile HP aircraft. We should have a class for running under the present rules (almost-flat course, almost-no wind, no energy storage) and other classes, as Peter Sharp suggests, for hill-climbing, wind- and possibly engine-assist, stored-energy races, and so on.

If, as Peter states, these are permissible under the bylaws, all that is needed is a group of enthusiasts wanting to compete under a new set of rules to propose these to the IHPVA president and board, and away we go to an exciting future!

Good on hills?

The Economist (here we go again) in reviewing this year's Tour de France, stated, in trying to explain why French riders haven't won the race for many years, "French riders fast on the flat are weak climbers; [when] strong in the mountains they do poorly in time-trials". No one has ever explained to my satisfaction why someone who is working her/his hardest on a machine with a wide selection of gear ratios (so that pedalling can be at the rate for maximum power or maximum efficiency) should be better when the bike is tilted up slightly than when it is horizontal, or vice-versa.

The same statement (the first of the above) is often made about unfaired recumbents: slightly better on the flat, much worse on uphills and much better on downhills. (There has recently been much correspondence on the subject on email). There are two obvious reasons for the recumbent's difference: they are usually considerably heavier than racing bicycles; and riders can't get up out of the saddle to "dance" on the pedals, as can the rider of a "wedgie". Doing so presumably rests some muscle groups while employing others. But these reasons don't apply to riders of conventional bicycles who do better on hills than their competitors on almost-identical machines.

There's another difference for recumbents. The German magazine Tour published some startling results of wind-tunnel tests, in which some (not all) unfaired recumbents came out badly. We've asked permission to reproduce parts of the article for the next issue. If we don't receive clearance, we'll give a full review of the tests.

Jam today, heaven tomorrow?

Supportive readers will remember that I am an enthusiastic supporter of road-pricing as a method of producing some balance of use on our roads. However, I have also noted that governments, particularly British and European governments, keep getting cold feet over what they believe the motorists' lobbies will do to them if they make serious moves toward having motorists pay something like tolls on regular roads.

Now there is good news from, of all places, the US. A new California road due to open in December will have an experiment in electronically collected congestion pricing: $2.50 vs 25 cents. If it works, I predict the system will spread like wildfire. This could be very good for the HPV movement.

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