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

We are indebted to the authors, to Marti Daily and to Maggie Beucler, whose dedicated help made this issue possible. Dave Wilson

In this issue

COGITO-II AND THE DREAM-SHIP RACES

Any thought that the US or Europe still represents the center of the human-power movement has to be dispelled by the first paragraph of the account in the lead article in this issue of the winning of the 1993 "Dream-Ship" race in Tokyo. There were 30,000 spectators right there, and countless more on TV! (A similar number view the Japan International Birdman Competition, for gliders and human-powered aircraft). Tsuide Yanagihara and his co-authors discuss the design decisions they made to win the 200-m standing-start race against very strong competition, and compare these decisions with those made by Alec Brooks and Allan Abbott for the Flying Fish. This article is bound to be required reading for all future builders of human-powered hydrofoils.

FIN POWER AND THE THISTLE

Harold Bryan, a boat builder from New Brunswick, shares with us his study of the swimming actions of fishes and his application of those actions to human-powered boats. He relates his work to that of three predecessors who have reported their fin-propulsion projects in these pages, and gives details of some of his designs. He will undoubtedly inspire others to follow.

BUILDING ALUMINUM RECUMBENTS

Mike Eliasohn continues his series of wide-ranging surveys of technological directions with this collection of interviews, photographs and useful construction details. As with his other reports, Mike gives a balanced view and leaves the reader to decide. There are advantages and disadvantages to the use of aluminum (alloys) for recumbents, but, as one might expect, the builders don't altogether agree.

THE AERODYNAMIC ADVANTAGE

In "the unfair advantage?" Martin Staubach reports careful measurements of aerodynamic drag on a variety of bicycles, recumbent and otherwise, and two tricycles. He arrives at results which may be surprising to N. American readers, accustomed to having speed records fall to long-wheelbase machines. He points out that in Europe the short-wheelbase recumbent bicycle is king. Read and learn - and write to HP with your reactions!

A NEW INDEX

Your editor has rallied to produce the second index of his now-ten-year reign. In order to do so, the early issues of Human Power, which were produced on a rather random schedule and with inconsistent or no volume or issue numbers, have been labeled in as logical a manner as seems possible. This includes a previously overlooked early issue omitted from the last index and brought to our collective attention by a diligent reader. May more of equal persistence find areas where the present index could be improved. All it contains at present is a double entry for each article and each note or letter considered to be of special significance: one entry for the title or topic and one for the first author. It would be useful to have entries for all sub-topics within the articles, but the index would thereby become rather cumbersome. However, if there is a strong call for this to be done and volunteers willing to do it we would publish it.

A NEW FORMAT FOR HP

With this issue I'm trying a new arrangement. I often feel irritated when reading a newspaper at stories that start on page one and are continued on p. 34. I noticed that the journal SCIENCE seldom does that. With the last revision of its format, that publication also started summarizing its principal articles, and I liked that too. So you'll find my summaries of the main papers and articles right here on this page. And all of these principal articles will start on a new page and will continue on to the following pages until they end. The last pages will be filled up by reviews, letters and short items. Something has to be disjointed - we don't have advertisements to fill up pages as do many publications - and it seemed better that the letters and so forth be somewhat scattered than the articles themselves. The editorials also get relegated to a later position in the journal. Editorials are simply rewards to an otherwise uncompensated editor to allow her/him to sound off and feel more important in a "bully pulpit", and could well go last. Let me know if you like the new arrangement or hate it.

Dave Wilson

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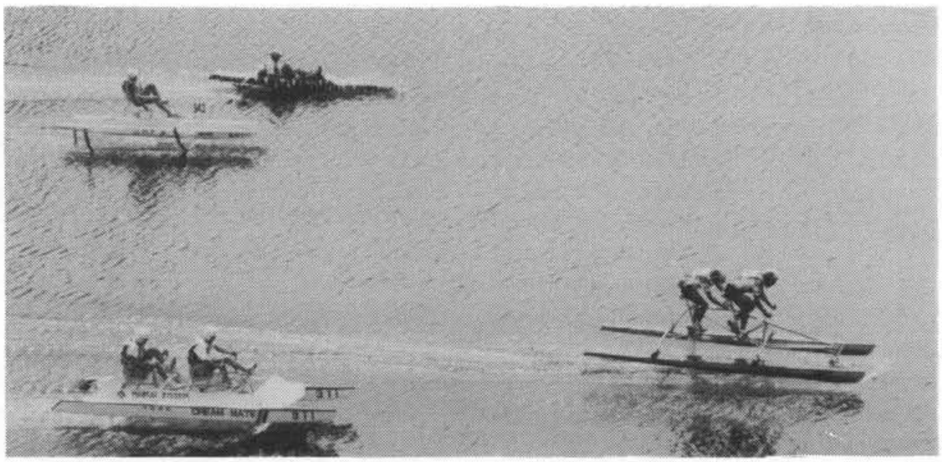

*Figure 1 The start of the final race.
From L to R: Crea Jr., Sindbad the Winner, Ushimado Speed, Dream Mate, COGITO II, and Phoenix II.*

COGITO-II: Dream-Ship Race Champion

by
Tsuide YANAGIHARA, Tokuzo Fukamachi and Takashi Motoyama

ABSTRACT

On August 1, 1993, the third "Dream-Ship Design contest" was held in Tokyo with over 30,000 spectators. The contest included a 200-meter standing-start human-power speed race.

The authors' team won the race with a new record time of 30.21 seconds by a two-man fully submerged hydrofoil named "COGITO-II" (fig.1). The design details of the champion boat are described here.

COGITO's DESIGN

"COGITO-II", shown in fig. 2 was designed expressly for simple construction. A fully submerged main foil hangs on a vertical strut to form an inverted T. A forward foil assembly also has a configuration of an inverted T, with active depth control and steering mechanisms. These foils are fixed to a tandem-bicycle-type frame of simple truss structure, and the frame is connected to a pair of pontoons by a pair of aluminum tubes.

There are several reasons to choose fully submerged hydrofoils. Hydrodynamic advantages like - low wave-making and induced drags, less liability to wave interference - are the principal reason. Structural simplicities comparable to surface-piercing hydrofoil are another reason. The biggest reason, above all, is that the mounting and dismounting can be done at one point, therefore it is very easy to adjust foil attack angle, and to deliver the boat.

The majority of competitors, however, employ surface-piercing foils. The authors' presumption for the reason is that they might have been worried about the lack of self-stability of fully submerged foils. The authors' knew, however, that a simple and practical solution was made some forty years ago by

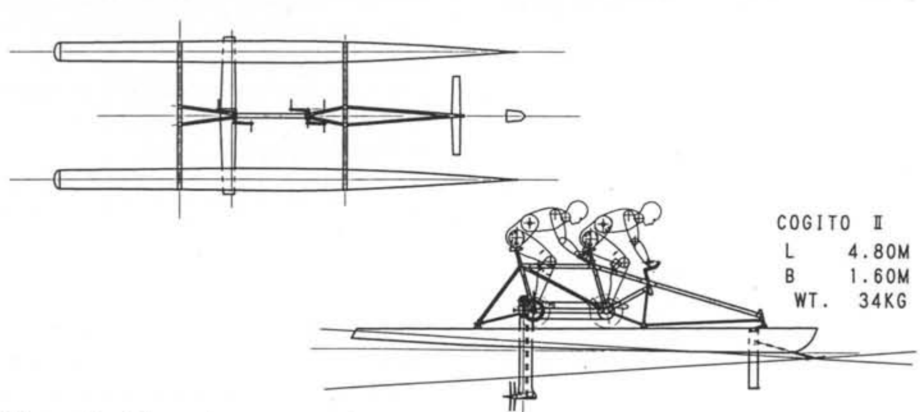

Figure 2 General arrangement

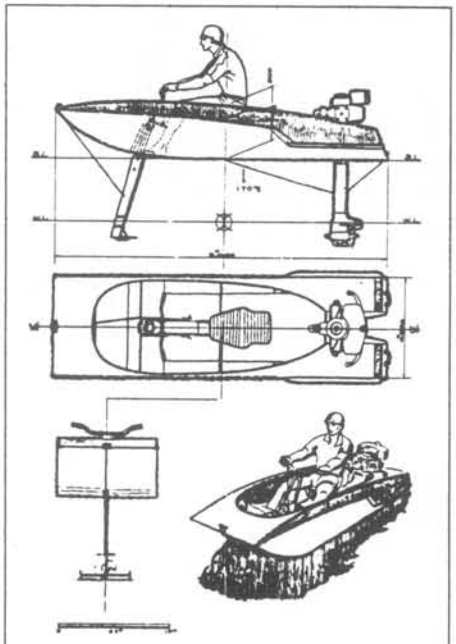

Figure 3 Horiuchi's hydrofoil boat

Kotaro Horiuchi, who developed a fully submerged hydrofoil boat with outboard motor shown in fig. 3, and drove it successfully on the water to convince the then-doubting onlookers.

The basic stability principle for his boat, and for the "COGITO-II" as well, is identical to that of a bicycle: by turning a handle-bar towards the inclined side proportionally to the angle of heel, the inertial force of the forward-going vehicle with its high center of gravity generates a righting moment. This series of actions is instinctive, thus imposing a low balancing load on the pilot.

To start initial design, the total mass was assumed to be 170 kg (hull: 30 kg, crew: 140 kg). The foil-load distribution was 20% to the canard and 80% to the main foil. The canard load is much higher than that of the "Flying Fish" (which is said to be 10%). The reason was that lighter front load was thought to cause excessive running trim during the take-off stage, which would result in course instability.

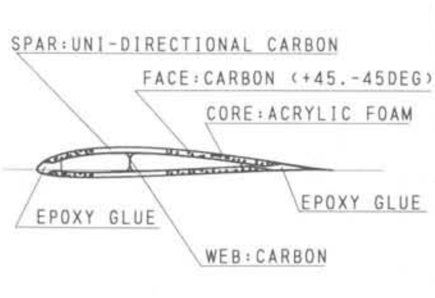

Figure 4 Main foil section

The wing areas were calculated by choosing the take-off speed at 3 m/s. (6 kt. approx.). An S3010 airfoil section was chosen for both of the foils (figure 4). A taper ratio of 0.4 is near optimum for achieving low induced drag, but we used a ratio of 0.6 to avoid the risk of tip stalling. The result of the drag calculation revealed that the wing area was larger than necessary. Nevertheless, the area was kept unchanged until the test run. It is easy to cut the wing tips to reduce the area, and it can be done whenever necessary.

Once easy take-off was confirmed, the tips were cut short twice during the trial tuning stage, and the final wing area was decided to be 0.224 sq.m and its aspect ratio was chosen to be 11.4. No higher aspect ratio was needed in this wing-configuration envelope since its wing-lift coefficient was quite small. In these circumstances, even a wing with twice the aspect ratio cannot contribute much to a reduction in total drag, because the higher the aspect ratio, the lower the Reynolds number. It therefore becomes a trade-off.

The length of the main strut was so designed that the foil is capable of keeping an adequate angle of attack at all times, from take-off to crossing the goal line. During the run the attack angle changes by seven degrees with its pivot point set on a surface follower of the depth controller. Figure 5 shows the detail of the controller. A spade-shaped surface follower made of carbon-fiber panel and tube is attached to the canard strut, to control the canard foil's attack angle automatically.

"COGITO-II" employs counter rotating propellers (figure 6). The system is not only more efficient than a single prop, but also is more desirable when you want a smaller wetted surface for the main strut. A smaller prop diameter allows shallower disposition of the prop shaft, and thus a shorter strut length. Moreover, a smaller pair of bevel gears can be used to deliver the required power, which gives a smaller frontal area of the gear case. The propellers are of the minimum-induced-drag type, designed by Larrabee's method (HP 3/2/84). Calculated propeller efficiency using the design blade L/D ratio of 50 was about 90 percent.

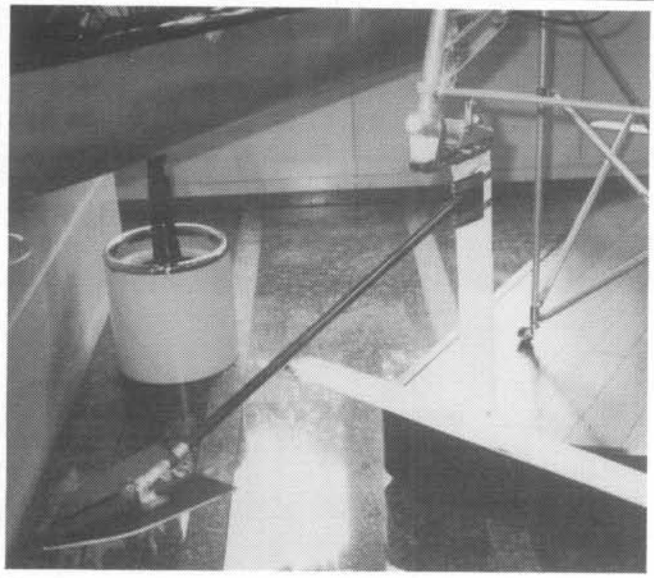

Figure 5 The skimmer-controller of angle-of-attack

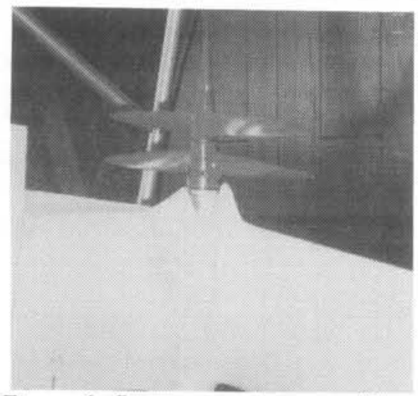

Figure 6 Counter-rotating propellers

COGITO's construction

The "COGITO-II's frame is constructed of aluminum tubes joined by rivets and welding. During the design stage, the use of carbon-fiber tubes was also considered, but the idea was given up due to the difficulties in connecting the carbon fiber with the aluminum gear box. Since normal bicycle-frame material was not available, A6061-T6 alloy tubes were used. This material is familiar to boat builders who use it for various sailboat spars.

Though it is strong as steel when heat-treated to T6, welding greatly reduces its strength. So special joint pieces (lugs) were made of A5056

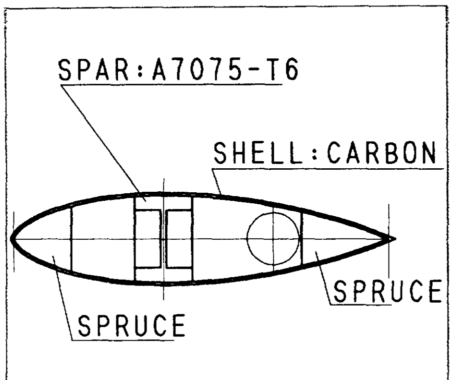

Figure 7 Main-strut cross-section

weldable alloy. Each A6061 tube was inserted in the lug sleeve and was fastened by several blind rivets to form a truss-frame component.

The main foil (figure 4) was made of pre-preg carbon fiber laminated in a pair (upper and lower) of female molds. As the foil is of cantilever construction, carbon fiber was the only choice to assure necessary strength and lightness. The foil spar is made of uni-directional carbon fiber, and the shell is of two-ply pre-preg 45-degree-bias carbon/acrylic foam/carbon sandwich construction to have sufficient torsional stiffness. The canard and its strut are of solid carbon fiber.

The main strut (fig. 7) was made of three parts: an H-shaped spar was made of aluminum (A7075) by machining, the leading and trailing edges are of shaved spruce, and the shell is of solid carbon bias laminate. Those parts are bonded by epoxy glue. The weight-strength ratio of spruce is as good as that of steel, and also its wide adhesion area was favorable for this application.

The pontoon hulls are made of A2024 aluminum-alloy sheet, 0.5 mm thick, and the decks of carbon-fiber pre-preg sheets (figure 8). To minimize the building time and cost, the half-round sections of the pontoons were formed by simply hand- bending the aluminum sheets, thus eliminated the use of any lamination molds. Before the construction, a one-twentieth-scale model was made to simulate the actual construction process. Consequently the pontoons were made in one day.

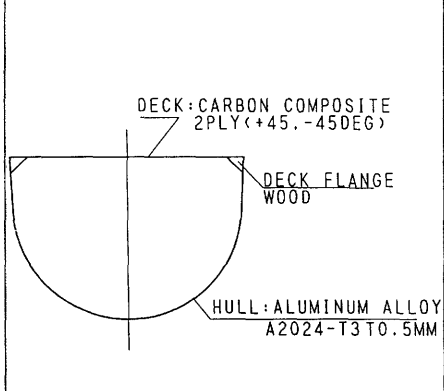

Figure 8 Section of pontoon hulls

The propellers are made of aluminum round bars. The boss was turned on a lathe and the blades were milled, then welded together.

DREAM-SHIP RACE - NEXT YEAR

Since the race rules are fairly simple (overall length less than 5m, beam less than 2.5m, and the crew two persons maximum.) and as this race is open to anybody who lives in Japan, more than 200 boats participated in the local elimination races this year. The final event in Tokyo (three-step elimination) was raced by 28 boats which survived the local eliminations and two seeded boats which were the last year's champion and the third (last year's second team didn't show up this year).

From this year on, a separate "students class" was made to give them chance to be honoured among "professional" shipbuilding-company teams such as Mitsubishi Heavy Industry, Mitsui Engineering and Shipbuilding, IHI, NKK etc. A total of six student teams survived the local eliminations.

The authors' team "COGITO", with only a handful of members, won the final race by beating the teams from those big companies. The reason which members believe is that they could integrate specialists in small-boat design and advanced composite technology, and they could employ master craftsmanship and expert riders.

In next year's race, the winning time will be definitely shorter than 30 seconds, and the "COGITO-II" design will become obsolete. The race will become more governed by athletic prowess than design skills because the performance level of the boat design itself may be overwhelmed under the current regulations.

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All the authors are colleagues at Yamaha Motor Company. Tsuide is a boat designer with an aeronautical-engineering background and a hobby of soaring. Tokuzo Fukamachi is a naval architect and amateur boat-builder. Takashi Motoyama is a specialist in advanced composites and is a holiday sailor. Toshio Kataoka, HP's associate editor, Japan, requested and transmitted this paper. He wrote of the authors: "Having been stimulated by the IHPVA events in the U.S., they decided to build their own boat to compete in the Dream-Ship competition. COGITO-II is a product of their individual skills and knowledge. They express their gratitude to the powerful riders Shunsuke Horiuchi, Masaki Kamimura and Disuke Chiba. And the editor is most grateful to all!

REVIEW
Recumbent Cyclist News

With the latest issue, no. 18, January/February 1994 RCN is being fully computer generated. It occupies a niche that is separate and different from our HPV News and Human Power. It is almost completely a consumer's magazine, reporting on manufacturers' developments and testing their products. In this issue there is an article comparing the Counterpoint Presto with the Easy Racer, for instance, by Ollie Deex. Generally the reviews avoid being outright critical of products, but usually one can read between the lines. Our own Michael Eliasohn, like the editor Bob Bryant a newspaper reporter, writes a review of the 1993 IHPSC. There is a photo and a discussion of the Cannondale recumbent with several contributors. Everyone believes that if Cannondale decides to take the plunge into recumbents, others will follow. Rick Pope reports on Interbike Las Vegas '93, and there is a home-builders' section. There are also a lot of advertisements by recumbent builders and others.

RCN is being mentioned increasingly as a source for buyer information when the popular press covers an HPV event, and, while we may wish that our IHPVA Source Guide would be regarded as the "bible", we must acknowledge that Bob Bryant and RCN are winning many converts to recumbent bicycling. A one-year U.S. subscription is $25.00: RCN P.O. Box 58755, Renton, WA 98058-1755

Dave Wilson

FIN POWER - SUCCESS COMES FROM COPYING NATURE

by
Harry Bryan

SUMMARY

The fin-powered concept described here was developed with almost no knowledge of other experiments with pedal-powered craft. My only model was the paddle-wheel boats that can be rented at vacation beaches and that show vast room for improvement. The drive system and boat we now build were conceived on a sailing voyage where time to think was the greatest gift.

The major inputs to the design process were: 1. fish caught and studied, 2. close observation of swimming fish at aquariums in Auckland, N.Z. and Monterey, California, and 3. the book How Animals Move which I studied at the public library in Honolulu, Hawaii. Unfortunately, I neglected to copy down the author and publisher of this work. When problems developed in the design process, solutions were usually found by returning to a study of fish anatomy.

Speed through the water has been important only if it contributes to efficiency at cruising speed. Reliability, relaxation, and ease of pedaling have been the guidelines.

PREVIOUS H.P. FIN BOATS

Early in the evolution of this design we used whales and dolphins (with their horizontal tails) as models. Einar Jakobsen has worked with this concept (Human Power vol. 5, no. 3 Fall 1986) as has Trond Oritsland (letters to the editor H.P. vol. 9, no. 2 1991). A horizontal-foil boat was built by Parker MacCready (H.P. vol. 5 no.3). Although this approach has proven to have potential, several problems exist which cease to exist or are easier to compensate for with the vertical fin which we have chosen.

ADVANTAGES OF VERTICAL FINS

For the horizontal fin, the center of oscillation must be at least half the distance the fin will sweep below the water's surface if the fin is to remain submerged. This means that some of the drive mechanism must be at this depth. This makes it susceptible to damage. Also, this drive mechanism (any underwater part which is not the fin) will contribute to drag.

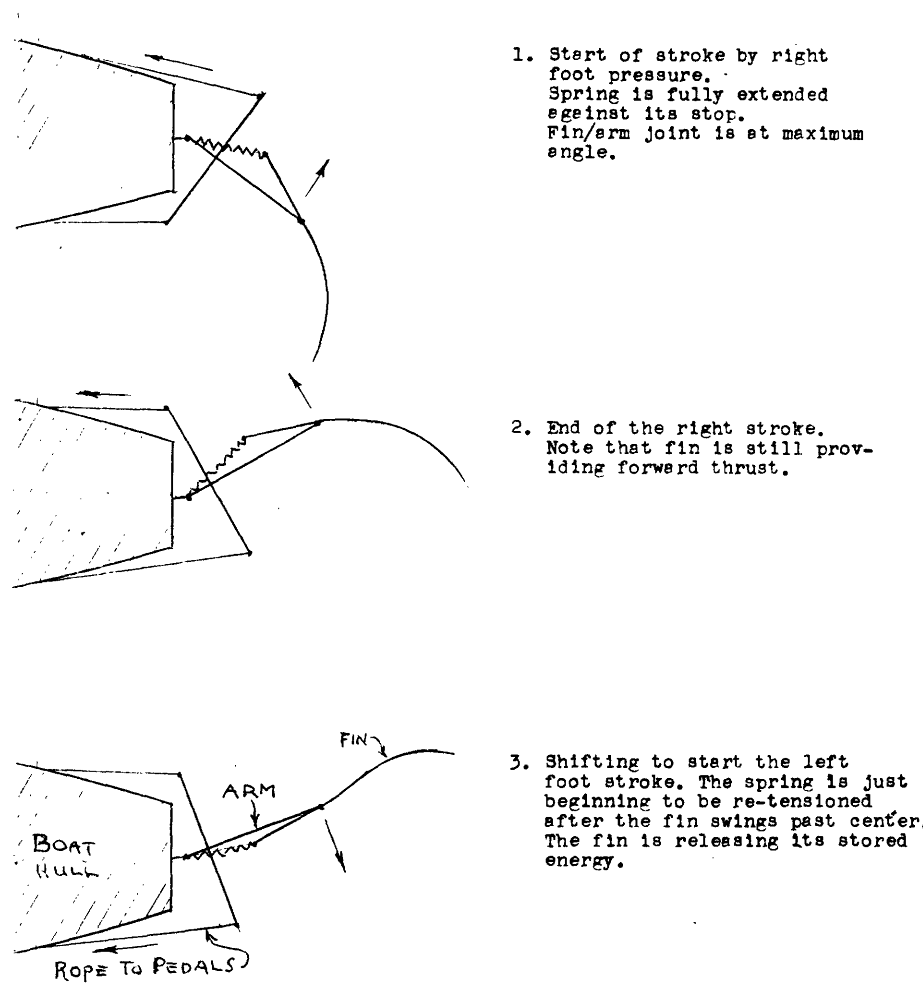


Figure 1 Stroke-drive diagrams

OPTIMUM STROKE

We have found also that with a displacement hull (canoe or kayak form) there is a greater efficiency in a slower oscillation of the fin sweeping a large area than in a shorter and quicker stroke. This motion seems best at 1:1 with the pedal stroke which greatly simplifies the drive system. A large swept area means greater depth of stroke with the horizontal fin which we see as limiting the area the boat can be used in. Our fin will kick up as does a small sailboat rudder when it encounters an obstacle or shallow water. It will swim over a shoal or through a patch of seaweed.

One other great advantage to the single vertical fin is that steering as well as propulsion is achieved with no additional mechanism. Once this last advantage was seen, we concentrated completely on the vertical fin.

DOUBLE VERSUS SINGLE FINS

Calvin Gongwer has experimented with double vertical fins (also H.P. vol. 5 no. 3). This may reduce the fin-induced rolling if the fins oppose each other, but steering would then be much more complicated. I will return to steering below.

USE OF FLEXIBLE FIN

The fin we use is quite flexible as we have made a conscious effort to match the characteristics of a fish. There appear to be definite advantages to this

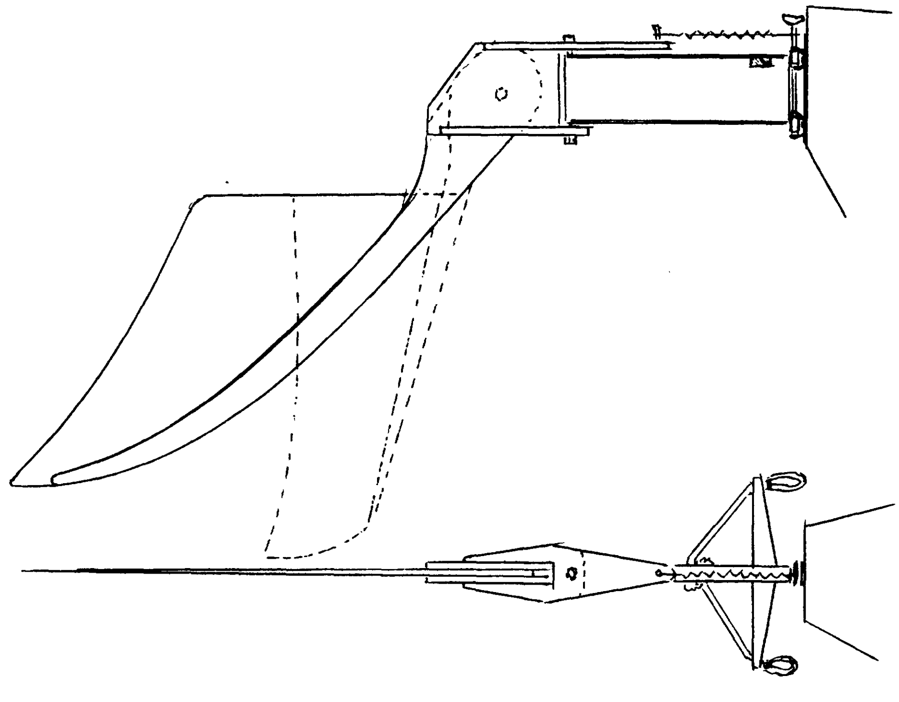


Figure 2 Fin construction details

over a rigid foil. As the fin swings to the side it bends and twists in reaction to water pressure. The more it can bend, the longer the stroke can be and still produce forward motion. The best construction seems to have a narrow but stiff leading edge and a quick change to the main area of the fin which is quite flexible. This is similar to a fish.

Even with a flexible fin, you cannot swing past about 30 degrees from the centerline of the boat and still maintain a favorable angle of attack. A more flexible fin would allow this, but when the fin is too flexible sufficient power cannot be transmitted to the water. We can increase the length of the arm to sweep a larger area with the same 30 degrees, but this gets clumsy and begins to make the boat look odd.

USE OF A FISH JOINT

Our solution to delivering more power without increasing fin area or arm length was to (once again) copy the fish. Just in front of the actual fish's fins we studied is a joint that is controlled by muscles and has a limit of bend at about 25 degrees from the centerline. We introduced this joint between the oscillating arm and the fin at its end, added a muscle in the form of a spring (which tries to keep the fin in line with the arm) and a stop in the form of a nylon cord within the spring which limits the joint to a 25-degree deflection.

Because the fin is now allowed to pivot 25 degrees as well as flex, the arm can be oscillated back and forth about 45 degrees and still provide thrust at its extremes. The spring performs three functions. First it makes smooth transition from the end of one stroke to the beginning of the next. Without the spring, part of the pedal stroke is lost as the fin shifts from stop to stop. The spring and the flex of the fin material both store energy which is released at this otherwise inefficient part of the stroke-cycle. The second function of the spring is to allow for light shallow strokes. If there were no spring and the arm were oscillated less than 25 degrees from center, the fin would just swing on its pivot and provide no thrust. The third contribution of the spring is to hold the fin far to one side if a tight turn is being made.

SPRING TENSION

The correct spring tension seems to be that which allows a cushioning effect as the spring is extended against its stop during moderate pedaling. Light tension is good for light pedaling but feels sloppy in a sprint. Heavy tension allows greater speed but is inefficient at slow and moderate pedaling. Our present "cruising" spring is 75 mm at rest and 150 mm extended. At this length the tension is 58N (13 lbf.).

FIN SHAPES

Six fin shapes have been tried so far. All have been able to push the boat at hull speed (about 2.2m/s, 5 m.p.h.). The improvements have been in reaching this speed with less effort, and in designing to eliminate stress points and consequent material failure.

The leading edge of the fin, which engages the cheeks at the pivot, extends nearly the whole distance to its tip. It is cut from two pieces of General Electric Lexan polycarbonate plastic. These are each 6 mm thick. Sandwiched between these is a single piece of 1.5 mm (1/6") Lexan forming the bulk of the fin. Early structural failure was partially attributed to the effect of the solvent glue (methylene chloride) used to bond the pieces together. Present practice is to use 3M 5200 polyurethane adhesive backed up by copper rivets.

Given a fixed area of fin needed to load the leg muscles efficiently, the choice of fin shapes goes from narrow and vertical to a shallow shape extending aft. The fish equivalent is from tuna to trout. The deep narrow blade will require a stiff leading edge. We use hardwood on the edge of this style of blade because it is stiffer than Lexan. It is the fastest shape. Its drawback is 150 mm (6") more draft (160 mm (24") rather than the average 450 mm (18"). Also, as mentioned, there is a bit more rolling with a deep fin.

As the fin design angles back more and more, its leading edge must become more flexible in order to provide forward thrust at the end of each stroke. Spring tension must also increase to counteract the leverage of the fin area as it moves aft of the pivot. The two fin shapes illustrated represent what we have found to be the practical limits given the present fin-drive mechanism and fin material.

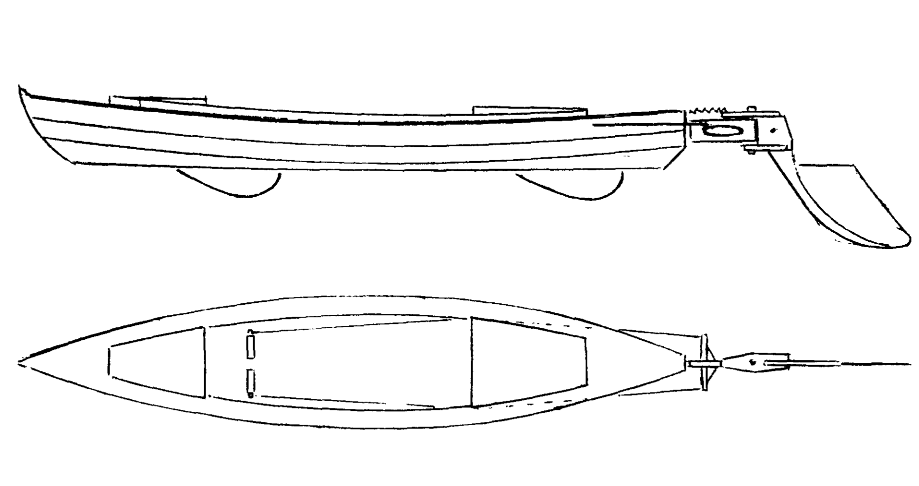


Figure 3 "Thistle" hull shape

PROTOTYPE HULL

The hull of the prototype, "Thistle", was designed to meet the needs and potential of the drive system. Its length is 4m (12'6"). Beam is 750 mm (30"). Two fixed fins are fastened to the hull. They correspond to the anal and pelvic fins of a fish. The anal or further aft fin opposes the tendency of the fin action to make the boat roll. More importantly it keeps the stern from wiggling due to the sideways force generated by the fin. The forward fin aids greatly in maneuvering. It gives a point to turn around when steering and keeps the bow from blowing away when the wind is on the beam.

This boat has proved to be easy to pedal for long distances and extremely easy to learn to steer. The feeling of control (both propulsion and steering), being all in the legs, gives the natural feeling of walking to water travel while freeing the hands for photography, binoculars, or fishing.

"Thistle" was designed to match the thrust and steering characteristics of the fin drive unit with a suitable hull form. She is small enough to be modestly light in weight and easy to carry on top of a car. Her layout allows for the semi-recumbent position best for pedaling, stability, and windage. The hatches at either end provide storage and flotation.

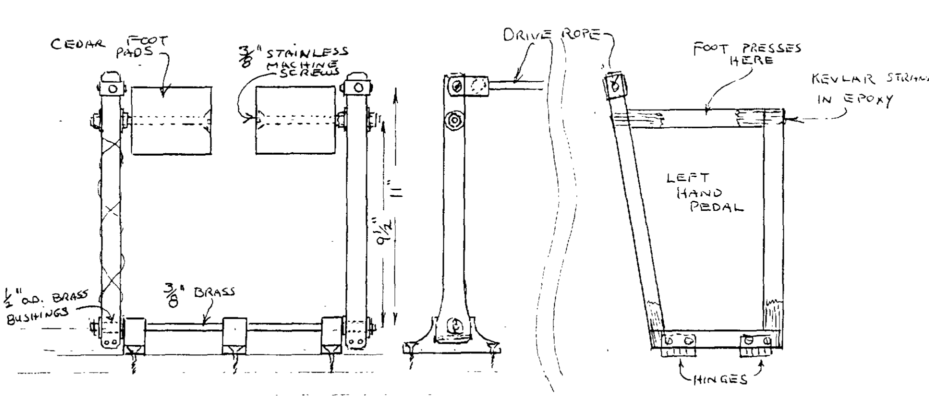


Figure 4 Two alternative pedal types.

PEDALS AND ROPES

Low-stretch-polyester ropes transmit pedal motion to the fin-drive mechanism through plastic tubing built into the hull. The pedals are reciprocating (rather than rotary). They pivot on bearings fastened to the inside bottom of the cockpit.

Steering is achieved by either coasting with one foot depressed or pedaling with the fin to one side or the other.

The drive unit itself has changed little at all since its building. To mimic its motion, wave you arm from side to side in a slow, horizontal handshake. Let your hand be like a fish's tail. Thus, the pintle joint becomes the elbow joint, the second pivot just in front of the fin becomes the wrist joint. The solid piece between these hinge points is the for arm. The tilt-up "rudder" cheeks and the fin itself are referred to as the fin.

Look at the drawing of the boat from above. Imagine pressure applied by the right foot. The drive rope (which passes through a polyethylene tube from the cockpit then out through the hull near the stern) pulls the forearm to starboard. The fin does not want to be moved sideways, so there is a twisting at the wrist joint. This causes the arm extending forward from the fin cheeks to move off centre, which movement is resisted by the spring connected from this forward fin arm to the elbow-joint pin. The harder you push on the pedal, the more deflection there is until a doubled nylon starter-cord stop inside the spring comes taut. This stop is at approximately 25 degrees. A fish's tail (a dorado's at any rate) seems to come up solid at the same point.

The fin itself is now in the best position to impart forward motion, and it now moves to starboard following the forearm. The flexible parts of the fin bend which makes a more efficient shape. This bending also stores energy.

At the end of the stroke, the energy in the flexed fin is released while the left foot causes the forearm to start back to port. Without the spring, this motion reversal is sloppy. Also, the spring makes light, shallow pedal strokes possible where the stop angle is not reached. Steering is crude without the spring as well.

Spring tension with the fin shapes illustrated seems best between 10 and 20 lbf measured with the spring extended to its stopped length.

The unit will go through heavy weed or over floating rope without fouling.

I believe this concept will be at its best for fishing, bird-watching, photography, or just as a pleasant way to get some exercise. It is a complicated oar but a very simple outboard motor.

FIN-DRIVE DETAILS

1. Forearm- 3/4" oak with 1/8"x 1" stainless steel screwed to the top and bottom. Bearings made from drilled-out 1/2" s.s. rod are welded to the front of the flat stainless while the other end is drilled for the 1/4" wrist bolt.
2. 1/8"x 1" stainless steel.
3. Spring and nylon stop. Collapsed length is 5". Extended length is that which allows an angle of 20 to 30 degrees between fin and forearm. Spring

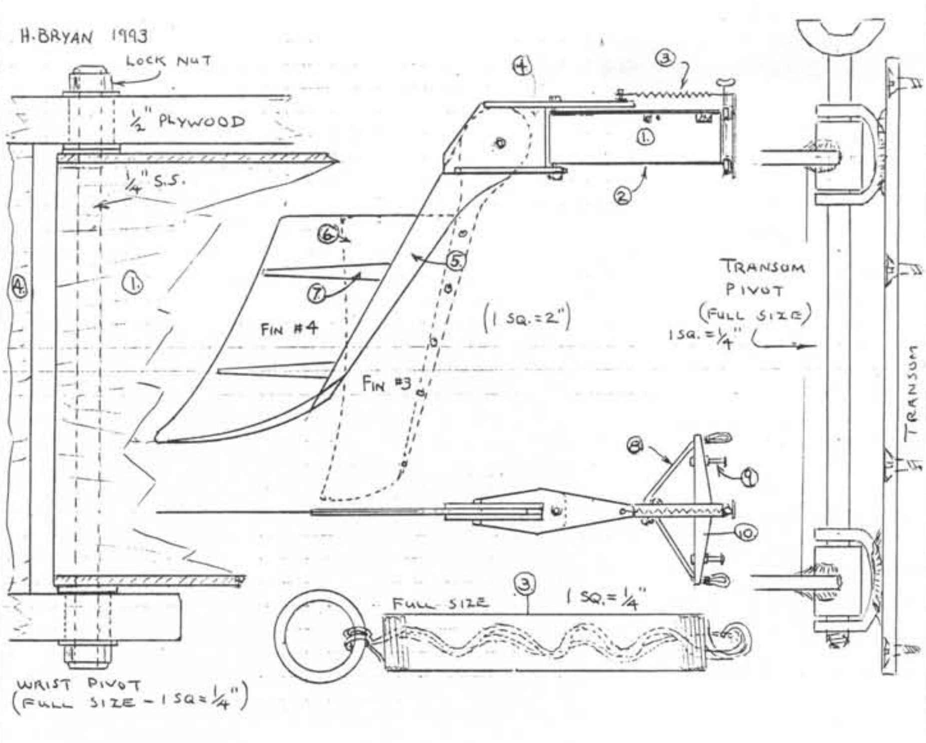


Figure 5 Fin details

tension is between 10 and 20 lbf. at full extension.

4. Fin cheeks. Made of 1/2' good-quality plywood glued and sealed with epoxy. There are 5 pieces to this assembly, two side pieces (cheeks) a filler in between these, a lower piece designed to withstand spreading of the cheeks, and an upper piece similar to the lower but extending forward of the wrist joint to engage the spring.

The upper and lower pieces have bearings for the wrist joint made from drilled out 1/2" s.s. rod. These bearings are epoxied into oversized holes.

5.,6.,7.

These references describe the parts of fin #4.

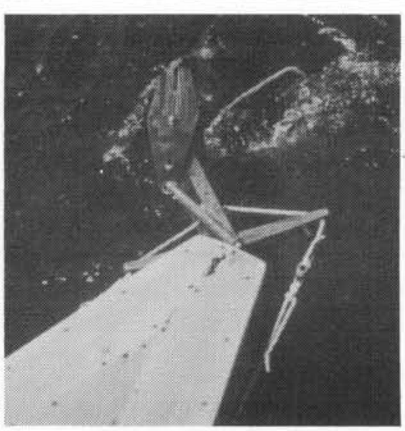


Figure 6 Fin mechanism (Photo: Mark ABB)

Fin #1 was much too stiff and consequently very inefficient. Fin #2 was much better, but its leading edge was still too wide. Fin #3 has a leading edge of ash. It is 3/8" thick. This ash is split with a bandsaw from its tip and 1/16" Lexan plastic is laminated between using polyurethane caulk and rivets. This fin works well and is capable of pushing Thistle at 5.3 m.p.h.. Because the ash is quite stiff, it should be used on a nearly vertical fin.

Fin #4 is laminated totally from Lexan. Its leading edge is two layers of Lexan. One-sixteenth Lexan is laminated between for the back of the fin. The number seven on the fin details sheet refers to stiffness as this fin shape was too flexible when first built. The shape and number of stiffeners customize the flex of the fin. The stiffeners on the lower edge are on both sides and overlap the leading edge to form a continuous reinforcement.

A sharp, lightly set block plane will shape Lexan.

The glue used is methylene chloride. Work fast with spring clamps. I understand that this is nasty stuff. Use gloves and excellent ventilation at a minimum.

Fin #4 draws less water than #3 for the same area. So far it seems very strong and can take scraping on a rocky bottom.

8. 5/16" low-stretch braided yacht rope. The power transmission ropes are the same size as these short ropes on the forearm. They have snap hooks seized to their ends to engage the seized eyes at the end of the yoke. (10).

9. 1/4" carriage bolts come up against rubber pads on the hull serving as stops to prevent damage to the elbow joint from over pedaling.

10. 3/4" tapered oak or ash. This sits in a notch in the forearm and is itself notched out 3/16" on its lower edge so that it is keyed in place.

DEDICATION TO HP

The fin-powered concept has been great fun to develop. There is a unique feeling of oneness and control between operator and boat. We offer this design knowing that it works well in its present form, but knowing too that tinkerers and experimenters will be able to make steady improvements in materials and design.

Figure 7 The "Thistle" in action

Please feel free to copy any part of this concept. We hope you will give us credit where it is due and share your experiences with us.

Harry Bryan is a professional boatbuilder and instructor in boat-building. His goal is to compete in the marketplace while steadily decreasing dependence on fossil fuels. A hand-cranked drill press, pedal jig saw and grinder, treadle band saw, and a heavy dependence on traditional hand tools are steps along this path. .

Harry Bryan, R.R. 4, St. George,
New Brunswick, EOG 2YO, CANADA

BUILDING ALUMINUM RECUMBENTS

by
Michael Eliasohn

"I want to build a recumbent, but I don't know how to weld."

"I want to build a recumbent, but I don't have space for a workshop."

There is a way to build recumbents without welding or a fancy workshop. Several home-built examples exist of recumbents -- two- and three-wheel --- made of aluminum tubing that was bolted, glued, screwed and/or riveted together.

SUCCESSFUL EXAMPLES

Have doubts about the technique? All-aluminum Linear recumbent bicycles have been manufactured in Iowa, U.S.A., since 1984. The only part of the frame that is welded is the fold-down rear fork. Everything attached to the rectangular main frame tube is bolted or clamped and bolted, with Loctite holding the bolts in place.

Linear Manufacturing owner Steve Hansel said he is unaware of any frames having ever failed. Melanie and James Finney-Pot of Iowa City, Iowa, rode Linears around the world in 1989-92. Hansel said nothing broke during their 12,000-mile (19,312 km) journey.

The idea isn't new among HPVers. An article by Chris Dreike in the fall, 1979, issue of Human Power described aluminum-bonding techniques used in building the frame of White Lightning, a two-rider recumbent tricycle which was the first HPV to exceed 55 mph (88.5 kph).

Hamish Crawford of Calgary, Alberta, Canada, wrote an article that appeared in the April-May, 1984, HPV News about building a no-weld recumbent bicycle. He later sold construction plans for it and a side-by-side two-rider recumbent tricycle, which also didn't require welding.

Keith Kovar of New York City has built seven recumbent tricycles in his New York City apartment. Everything is held together with bolts except for some sections that don't require great strength, which are assembled with pop rivets. As can be seen the photos, Kovar has built some complex structures.

He assembles his trikes with bolts only -- no adhesive -- so they can be taken apart and reassembled. The 1993 International Human Powered Speed Championships were the 10th IHPSC Kovar has participated in. He flies to the events and in 1993 came to the Speed Championships with two disassembled trikes inside one plastic bicycle-carrier box. Reassembling them took about four hours each.

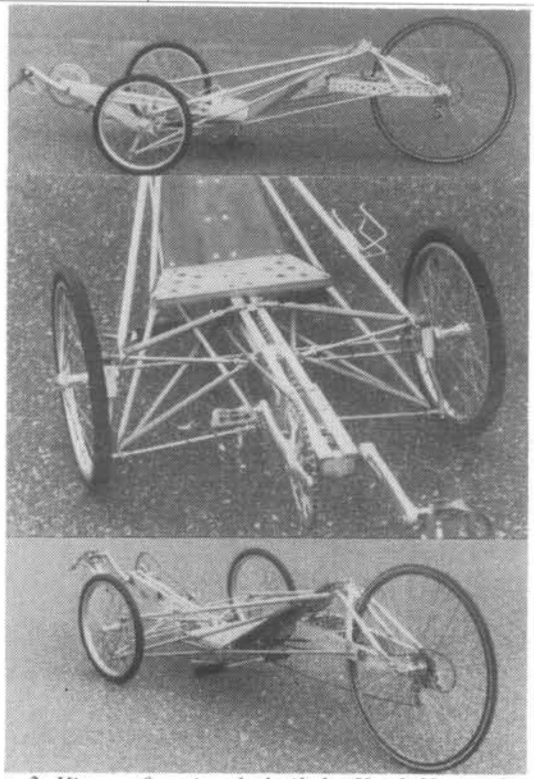


Figure 2 Views of a tricycle built by Keith Kovar, his seventh. It's held together with bolts and rivets. No adhesives are used, so that it can be easily assembled/disassembled. (Photos: Mike Eliasohn)

His newest trike weighs less than 35 pounds (15.8 kg). The large "tubes" used are 1/8th-inch- (3.2-mm) wall, 3/4-by-1-1/2-inch (1.9 x 3.8 cm) channel, with one of the long sides missing. Kovar said it's easier bolting everything together using channel, rather than rectangular (four-sided) tubing. The bottom bracket is a sealed assembly, with the sleeve of the assembly fitting between the two channels.

The round tubes used by Kovar are mostly 6061-T6 0.035-inch (0.9 mm) or 1/16th-inch (1.6-mm) wall, ranging from a 1/2 inch to 1 inch (13 - 25 mm) in diameter. He finds that's the maximum size he can use and flatten the ends in a vise and then drill holes through the flattened parts for bolting together.

Kovar's tricycles aren't ridden much outside of the IHPSC. If they were, that is, on the street, he said he might replace aluminum struts with steel and substitute steel for aluminum in some other places for added strength.

Jonathan Woolrich of Surrey, England, has raced his Lazy B short-wheelbase recumbent at the 1992 and

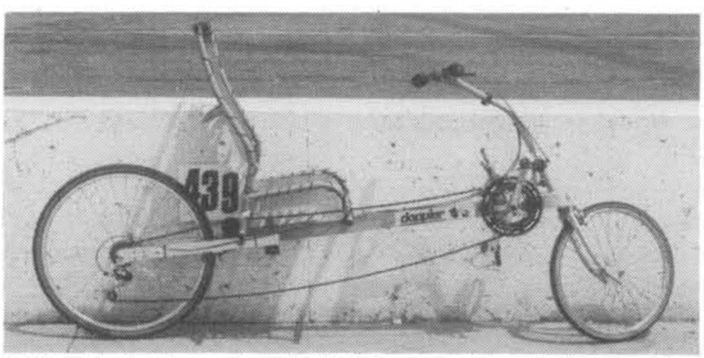


Figure 1 The all-aluminum Doppler TM-3, manufactured by Peter Heisch and Mark Swartz. All joints on the front end are welded. Rear swing arm is held together with epoxy. ------------- (Photo by John Riley).

DOPPLER BICYCLE

by Michael Eliasohn

With its aluminum frame, cantilever rear hub and integrated suspension, Peter Heisch of Doppler Cycle Technologies has made one of the more innovative recumbents around. Heisch, of Kitchener, Ontario, Canada, raced his machine in the 1992 and 1993 Great Lakes HPV Race Series.

Peter said after having built long- and short-wheelbase recumbents, he decided to combine the virtues of both into a medium-wheelbase bike -- good high-speed stability with reasonably responsive slow-speed turning characteristics.

Figure 1: Peter Heisch on the 11-kg Doppler. Short handlebars require a lean-forward riding position. Main frame tube extends ahead of head tube to support fairing.

His goal was to make it as light and low as possible, with as short a wheelbase as possible while having the cranks behind the front wheel. The result was a bike that weighs 23.75 pounds (10.8 kg), with a wheelbase of 57 inches (144.8 cm).

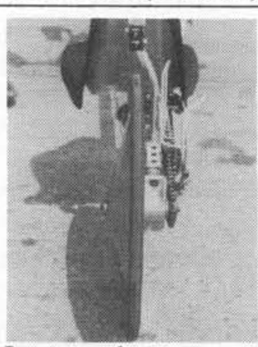


Figure 2 Rear view showing one-sided rear-wheel support. The spoke cover is carbon fiber.

The main frame tube is a 1x2" (25x50-mm) rectangular 6061 aluminum tubing, with 1/8th" (3.1-mm) wall, a common extrusion in North America. Peter is lightweight, so this size of tubing provides adequate rigidity, but major changes to the frame structure would add stiffness for heavier riders. However, this Doppler was designed to the minimum in all respects, as its sole purpose is racing under controlled conditions.

Contributing to the light weight is the form-fitting seat made of a Kevlar, carbon-fiber, and fiberglass composite. Thin foam padding was added for comfort, with a cloth cover.

Peter's choice of wheels and drive train contributes to the short length. The rear wheel is 20x1-1/8" and the front 17x1-1/4". Because the Doppler is intended only for racing, gearing is limited to five speeds with a range of 90-150 inches. (Yes, 90!)

The drive train has two stages, with a single front chainwheel of 36 teeth. Peter wanted a small chain ring in order to get the crank assembly as far forward as possible without having to worry about it overlapping with the front wheel during slow-speed turns.

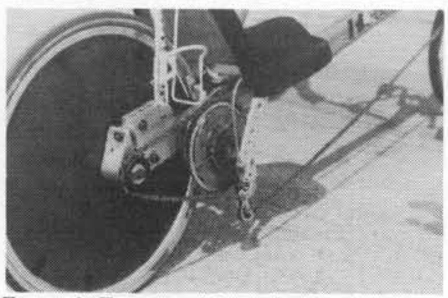


Figure 3 Five-speed free-wheel and a 43-tooth sprocket make up the intermediate drive, which runs to a single rear sprocket. Mountain-bike rear suspension allows 13 mm travel.

A freewheel and derailleur complete the first stage, with the freewheel assembly mated to a 43-tooth drive sprocket. This sprocket drives the second stage, which consists of a BMX single freewheel fixed to a shaft rotating in a sealed bearing assembly. Peter machined the entire rear assembly, including the axle housing, shaft and hub, from solid aluminum stock.

The rear wheel is supported on the right side only. The cantilever arm pivots, compressing against a small rubber isolator allowing just enough travel (less than a half-inch -- 12 mm) to absorb road shock.

The hub assembly utilizes a unique lock-out device to secure the wheel to the swing arm. That allows the rear wheel to be quickly removed without disturbing the chain.

All construction was done in the Doppler machine shop by Peter. Everything is bolted or riveted together and glued, using a two-part adhesive. Nothing is welded, thus maintaining the original strength of the aluminum without the need for heat treating.

For 1993, Peter built a temporary fairing for the Doppler, consisting of thin plastic sheets over a framework made of aluminum strips. As of when this was written, he was constructing a Kevlar fairing.

Peter and partner Mark Swartz have utilized the technology from this and other Doppler prototypes to begin manufacturing the Doppler TM-3 for sale. It's also all-aluminum, with the only welding being the head tube and front derailleur mount to the 2-inch (50-mm)- square main frame tube.

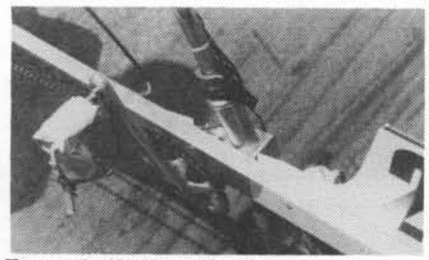


Figure 4 Aluminum head tube and bottom bracket (on centerline) are glued and bolted inside aluminum mounting blocks that are bolted to the offset 25x50-mm frame tube.

Unique features are rear suspension, which allow about 1 inch (25 mm) of travel and two-way adjustable handlebars. Three wheelbases are available, ranging from approximately 64-67 inches (1.63-1.70 m). Weight is 29 pounds (13.2 kg). The front tire is 20x1.125"; the rear 26x1.25". A sling seat is standard, but a molded composite seat with foam padding apparently is available.

Figure 5 Prototype, with all-aluminum frame, carrier rack attached to seat and rear suspension, of the Doppler TM-3, now being manufactured by Peter Heisch and Mark Swartz.

For more information, contact Doppler Cycle Technologies, 52 Walnut Street, Kitchener, Ontario, Canada N2G 1P6; telephone 519-579-5103.

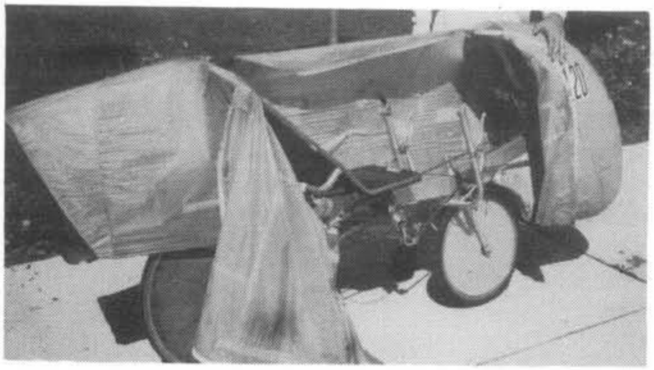


Figure 3 Jonathan Woolrich's Lazy B. Bolts and epoxy hold everything together. Fairing is riipstop nylon with a fiberglass nose piece. (*Photo: Mike Eliasohn*)

1993 IHPSC, as well as in England. Built especially for racing, it uses a 24x1-inch back wheel and 17x1-1/4-in front. Wheelbase is 38 inches (965 mm). He estimated the weight at 35 pounds (15.8 kg), including the fairing, which consists of a fiberglass nose piece and ripstop nylon.

The main frame is rectangular aluminum tubing in two pieces, with the forward section sloping upward. To connect the two pieces, Woolrich started with a solid aluminum block. He machined away the edges at both ends (see drawing) so that the block served as an internal lug for both sections. The block was glued into the square tubes using Loctite. (The author neglected to ask Woolrich if bolts or screws are also used.)

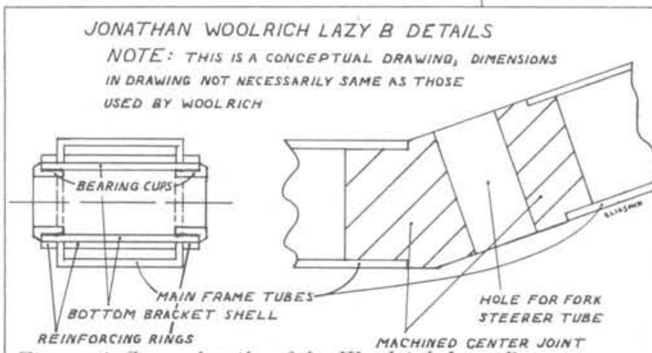


Figure 4 Some details of the Woolrich Lazy B. (Conceptual drawing only, not necessarily to scale).

A vertical hole drilled through the block serves as the fork tube. Woolrich made his own fork. Curtain rail was used for the rear stays. The bottom bracket runs through the frame tube. There's an internal support tube so that tightening the bearing cups doesn't crush the frame tube. (See drawing.)

The entire bike is bolted and/or glued together. "The whole thing is a bit more flexible than I would like," Woolrich admitted. He feels the construction technique is adequate for regular road use: "It's strong enough to race; strong enough for the street."

As of 1993, William Murphy of Carpentersville, Illinois, U.S.A., was still getting some of the bugs out of his full-suspension recumbent.

A noteworthy feature of this unique bike is the adjustable-height rear suspension, which enables the bike to be a "low rider," as shown in the photo, or a "high rider." As the latter, the main frame tube would be parallel to the ground. The head-tube angle, seat-back angle and the horizontal location of the bottom bracket are all adjustable. In addition, the rear swing-arm can be swung all the way forward for compact storage and transportation.

The swing-arm is made of 1x2-inch (25x50-mm) rectangular tubing with 1/8th-inch (32-mm) walls. A bottom bracket is used as the swing-arm pivot. Maximum suspension travel is 2" (50 mm). The main frame tube is 6061-T6 round aluminum tubing, 2" (50 mm) in diameter, with 0.065" (1.65-mm) wall. At the front end, the tube fits inside another tube with an inside diameter of 2" (50 mm). Epoxy and a bolt through the entire assembly holds it together.

The steel head tube is 1-1/4" (32 mm) outside diameter, around both ends of the head tube. The bottom clamp is bolted directly to the main frame tube. Steel rods run from the top seat-post clamp to the main frame tube, held in place at both ends by custom-made clamps held tight by bolts. The fork angle can be adjusted by loosening the bolts, which in turn loosens the rods. (See photo.)

A cartridge bottom bracket runs through an aluminum block, which is held to the main frame tube by aluminum straps. There is no front derailleur. Murphy said the bottom bracket hasn't moved while pedaling.

Everything is held together with bolts and/or Hexcel Safe-T-Poxy, which is normally used for building aircraft.

Murphy said when sitting on his bike, it bends a little, so he may stiffen the frame by adding triangulation. Using a thicker-wall round tube or a square main tube are other ways to create a stiffer frame.

BUILDERS' ADVICE

Here's some advice from the builders consulted.

Always use reinforcement where appropriate. For instance, if a bolt has to run through a tube, reinforce it by gluing a wood block or dowel inside the tube so that it won't be crushed when the bolt is tightened.

When expoxies are used, Swartz advised, roughen the surfaces to be bonded first, then clean them with methyl ethyl ketone, available at chemical supply stores. MEK is normally used as a catalyst for polyester resins. Don't use steel wool on surfaces prior to bonding or welding because steel particles may become imbedded in the metal, which can put impurities in the bond or weld. (Logical advice is following the instructions that come with the epoxy.) [Use gloves and good ventilation also: becoming allergic to epoxy, as I did through carelessly immersing my hands and arms in it, is highly unpleasant - ed.]

Murphy strongly recommends using high-grade bolts, grade A or better.

Some final comments from the author: first, for reasons of simplicity and brevity, I chose not to discuss the issue of using aluminum for bicycle

Figure 5 Bill Murphy's home-built recumbent. Head-tube angle, height, seat-back angle and bottom-bracket position are all adjustable. (*Photo: Mike Eliasohn*)

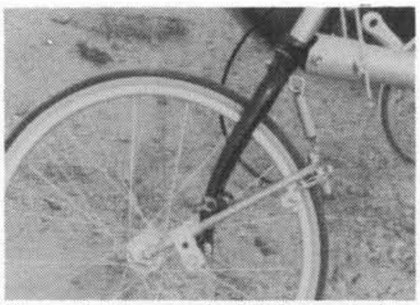


Figure 6 Front end of Bill Murphy's recumbent. Seat-post clamps are used on steel head tube. Bolt through top seat-post clamp holds clamps around steel rods. Bolt through main frame tube also holds clamps around steel rods, so head angle can be adjusted. Main frame tube, 50-mm dia., fits inside a reinforcing tube.
(Photo: Mike Eliasohn)

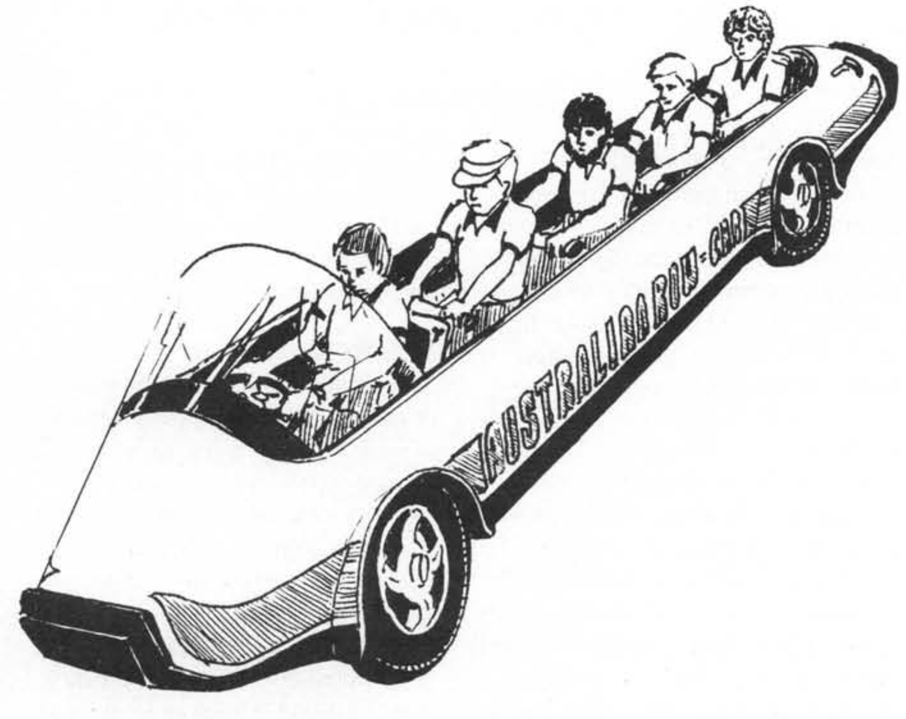
frames. Some experts advise against welding aluminum and I know one HPV builder who doesn't think it's safe to use aluminum even if it isn't welded. Obviously manufacturers of welded or bonded aluminum-alloy bicycles, be they uprights or recumbents, disagree.

It appears from the weights of the HPVs discussed in this article that using aluminum doesn't necessarily result in a vehicle lighter than a similar one made of steel. Presumably that's because of the thick-wall aluminum tubing used, plus all those bolts, rivets, etc.

And, if not already obvious, building a recumbent out of aluminum isn't necessarily simpler than welding or brazing one out of aluminum or steel tubing. For instance, for a single-main-tube recumbent, miter one end of the tube to the diameter of the head tube, then braze or weld the head tube on. Attaching the head tube to the main frame tube without welding will require clamps, bolts, and/or some other complex arrangement.

Michael Eliasohn, 2708 Lake Shore Dr., Apt. 307, St. Joseph, Mich. 49085, U.S.A.

Mike Eliasohn is a newspaper reporter, a long-time HPV enthusiast, and a frequent contributor to Human Power.



The Row-Car

LETTER

An idea for a row-car

[This is] an idea I had, about ten years ago. If perhaps you like the idea, then you certainly have my permission to develop it, and maybe even exploit it. Who knows? It could be to our mutual benefit.

Bob R. M. N. Tisdall (born 1907)
Ploughman's Folly, 42 Pringle Road
Nambour, Queensland 4560, Australia

(The construction sketches are, alas, not clear enough to reproduce here. The four rear riders are on sliding seats and pull on swinging levers. These are connected by a cable that goes around a pulley. A pawl engages a ratchet that is geared to the rear wheels. A spring returns the cable at the end of each stroke.)

(Bob Tisdall sent this to me after his daughter in Christchurch, New Zealand forwarded to him a newspaper clipping of me riding John Raine's Tricanter HPV. He was nice enough to write that he could trust me because he liked my face. He could be in a cult of one. He did agree to my using it in the letters section here. Dave Wilson)

REVIEW
SUSTAINABLE TRANSPORT

This magazine is published by the Institute for Transportation and Development Policy (616 Broadway, rm.616, New York, NY 10012). It has a strictly practical approach to giving assistance. It grew out of the "Bikes not Bombs" movement that shipped new and refurbished bicycles to Nicaragua and similar areas.

The September issue (no. 2) of this new publication features an article on "Mobility Haiti - non-motorized vehicles help hospital save lives". Much of it describes the work carried out by our own Matteo Martignoni, who is a vice-president of the ITDP. He worked with Glen Ray to train Haitians to service bicycles and other non-motorized transportation. Matteo also designed and developed the "Haitian Hauler", a human-powered ambulance, and the "Trailing Edge", a bicycle trailer that doubles as a hand-cart.

THE UNFAIR ADVANTAGE?
Drag measurements on HPVs

by
Martin Staubach

EARLY MEASUREMENTS

In 1988 I began measurements on recumbent drag coefficients. Due to my low student budget I decided to measure the drag-area product CdA by coasting down a hill close to my home town of Erlangen. There is a street with a long-enough constant slope, where you reach coasting speeds from 8 - 18 m/s (19 - 40 mph). I believed that the rolling resistance coefficient Cr could be neglected at these speeds, but I was wrong (mistake > 15%). To avoid this mistake I ran additional Cr measurements by accelerating to a low speed and coasting on a level floor in a closed building. The loss of kinetic energy was measured by a laptop computer that was mounted to the vehicles, and that registered the time for every rotation of a wheel and calculated the Cr coefficients.

The results of thus turning my back on low-cost equipment were Cr-coefficients with an error of about 30%, because the air drag could not be neglected. I combined the data of both measurements in my calculations to minimize the errors, but I was not able to get out CdA numbers with an error lower than 30%. The frustration rate rose.

The solution of these problems came this spring: in a recent Pro Velo issue (the magazine of the German HPV) a list of Cr coefficients was published with an error under 2%. These measurements were made by Thomas Senkel, member of a group of physicists at the Oldenburg university in northern Germany. He used a special tricycle with the same computer equipment as I had, but used much more efficient software. By reducing the environmental influences he was able to guarantee a maximum error of 2%, which is pretty good.

I used his figures to recalculate the data of my downhill-coasting measurements to get the vehicle drag-area coefficients CdA. The theoretical overall error of the following results is under 15%. Control runs showed that precision is even better.

THE RESULTS

As I am interested in aerodynamics of vehicles for everyday use, all measurements (except 4 and 12) were made in comfortable clothing (jeans, sweater). All vehicles (except 2, 3, 4, 12) were equipped with mudguards, carriers and lights. This is most common for everyday use of bikes in Europe. The figures measured in the wind tunnel of Ford in Cologne by Hans Christian Smolik in 1990 (Tour magazine 3/90) are similar to mine (16 - 18). As in these wind-tunnel measurements the wheels didn't rotate and test riders wore racing suits (unlike my tests) their figures should be lower. My measurement with Triathlon handle bars and racing suit are lower than the Tour-results despite having my wheels rotating. I can't explain this contradiction. Coasting-downhill measurements by Miller (20) and coasting-level measurements by Kukuk (19) are comparable to mine.
If you want to compare measurements, have a very close look at the testing conditions. Little changes of environmental parameters can have high influence. Better look twice at the comments to understand the figures!

If you compare a SWB-recumbent with (10) and without (12) this equipment, you easily see its high influence on aerodynamics. By wearing a racing suit and removing the mudguards CdA can be reduced by 12%. The biggest surprise was the triathlon bike (4). The CdA of 0.27-m^2 is very low. Even the SWB-recumbent with high handle bars (12) is hardly better (CdA = 0.25 m^2). Because all other recumbent measurements were made with full equipment they cannot be compared directly with (12) and (10). But you can subtract 12% as an estimation for clothing and equipment and get an idea of the figures for the racing versions. You would get 0.31 m^2 for a SWB-recumbent with low handle bars and 0.43 m^2 for the LWB-recumbent with low handle bars.

Figure 1 Martin Staubach at the start of the 1000-m race on the Munich Olympic velodrome during the 1992 European HPV championships.

If you compare SWB- and LWB-recumbents it is apparent why the European racing scene is dominated by the short versions. The LWB bikes (5) are ahead of the standard racing bike only in terms of comfort and safety (2 and 3). Only the SWB-recumbents (7 and 10) have real advantages.

To prove the effect of various equipment I measured various positions and fairings on the same SWB-recumbent. If you lay one arm on your body on a bike with low handle bars, CdA is reduced by 9% (8). If you mount a high handle bar, both arms are taken out of the wind and the gain doubles to 20% (10). Cause of this effect is the reduction of the frontal area A. A simple aerodynamically shaped bag made of fabric and standing on the rear carrier reduces the Cd coefficient by 20% (9). High handle bars and the aero-bag together didn't give an advantage in this case, because the bag was wider than my body and counterbalanced the effect of the high arms (11).

As expected a full fairing is the best means to cheat the wind. The CANARD-fairing reduces the vehicle drag-area of a SWB-recumbent to almost one third (CdA = 0.13 m^2) (13). With a frontal area of about 0.52 m^2 the resulting Cd-coefficient is 0.25. This is comparable to those of good cars. It is not better, because the head and parts of the vehicle are unfaired. The Danish LEITRA has a faired forebody, but unfaired front wheels. Its CdA is 0.24 m^2 (15), which is quite surprising for a fully faired vehicle. This is a figure that can almost be reached by an unfaired racing SWB-recumbent. But these vehicles can't be simply compared. The LEITRA is not designed for aerodynamics but first for weather protection and nimbleness on narrow roads.

COMMENT

The figures show that the streamlining efforts of the 80s have made standard bikes quite good. But unlike the recumbents the development of the racing bike (meeting the UCI rules) has already reached its peak. This peak was Mike Burrows' Lotus bike. I think this bike can't be improved further without violating UCI regulations. For recumbents this development has already taken place in the thirties, when Francis Faure beat almost everybody with his Velocar recumbent built by Mochet. The aerodynamics of this unfaired vehicle was even then better than today's best UCI bikes. One could think racing-bike developers had 50 years to learn from this but in fact they still aren't very creative. Most quantum leaps were made by unconventionally thinking people like Mike Burrows. It was a pleasure to see his good-idea bike win against the big-money wind-tunnel bike developed by the German FES in the Olympic Barcelona track races (even though it's not very patriotic of me).

We are lucky to work on recumbents, because we will not be unemployed soon. There still are many improvements to be made, as the development of the Z-frame SWB-recumbents show. Unfortunately I didn't have one of these low-to-the-ground machines for my measurements. See, there is still much work to be done!

Martin Staubach is a 25-year-old student of mechanical engineering at the Ohm Fachhochschule in Nürnberg. He was the second chairman of the German HPV association in 1992. As he has been active in the HPV scene since 1986 he had enough time to build some 30 recumbents and win a bunch of races. Among the recumbents was the well-known Z-2 prototype with full suspension and Z-2 fairing made of Kevlar/foam/epoxy sandwich. This and the CANARD fairing, Europe's most successful commercial full fairings, were developed by a team of five people from southern Germany. At the moment some equipment such as a carbon frame, front fairing and seat-ventilation system are in the making. In 1992 he opened Germany's first recumbent store together with his partner Bernard Klar. As there are many ideas and plans to be realized he wishes to retire at the age of 28 to get going on them. There are even some things besides bikes in life . . .

Martin Staubach, Holzschuher Strasse 8, D 90439 Nürnberg, Germany
Phone: 0911-266 343

IN FAVOR OF CARBON FIBRE

[This letter is reprinted, with permission, from the HPV Internet mail - Ed]

Having ridden a carbon-fibre bike for a couple of years now, I have to disagree with most of another [Internet] correspondent's comment that "carbon fibre doesn't generally buy you a whole lot". I agree that carbon fibre used as tubes with lugs doesn't buy you much. But monocoque construction, e.g. Kestrel, enables you to do things that have never been, and probably could never be, done with steel or aluminum. And far from being of interest only to racers, I think that the greatest payoff of CF (or any other advanced material) will be for real-world riders. Frankly, I've been surprised and disappointed by the structural conservatism of HPV builders.

Basically, my point is that advanced materials like CF can reduce structural weight dramatically, but only a portion of a bike's weight is structural. The greater the fraction of a bike's weight that is structural, the greater the payoff. Since real-world bikes (especially recumbents and HPVs) have more structure than racing bikes, using advanced materials will have a bigger payoff for them. A steel road-racing bike weighs about 24 lbf, made up of about 20 lbf of componentry on a 4 lbf frame. If CF cuts structural weight in half that would only save 2 lbf.. A steel LWB recumbent might weigh 10 lb. more than that racing bike with the same components, so CF might save 7 lbs instead of 2. And the all-weather HPV prototype Nick's been riding weighs about 90 lbf, say 25 lbf of components and 65 lbf of structure (including cardboard fairing) , so advanced materials could save 30-40 lbf. That's the kind of weight

VEHICLE DRAG-AREA(CdA) MEASURED BY COASTING DOWNHILL

NO.	VEHICLE DESCRIPTION	CdA m^2	IMPROVEMENT AGAINST: STANDARD BIKE	SWB RECUMBENT
1	Standard bike, TV	0,60	0	-71
2	Racing bike, RV, hands on brake levers	0,49	18	-40
3	Racing bike, RV, downhill racing position	0,42	30	-20
4	Racing bike, RV, RS, triathlon handle bars	0,24	55	23
5	LWB recumbent, TV, LHB, BBS -200	0,49	18	-40
6	LWB recumbent, TV, LHB, BBS -150, Front - Zzipper	0,36	40	-3
7	SWB recumbent, TV, LHB, BBS +60	0,35	42	0
8	SWB recumbent, TV, LHB, BBS +60 one hand on body	0,32	47	9
9	SWB recumbent, TV, LHB, BBS +60, aerobag	0,29	52	17
10	SWB recumbent, TV, HHB, BBS +60	0,28	53	20
11	SWB recumbent, TV, HHB, BBS +60, aerobag	0,29	52	17
12	SWB recumbent, RV, RS, HHB, BBS +60	0,25	58	29
13	SWB recumbent, CANARD full fairing	0,13	78	63
14	Tricycle KWADRAD II, TV, 2 front wheels, 1 rear wheel, BBS 0	0,43	28	-23
15	LEITRA tricycle	0,24	60	31

NOTES:

All measurement were made in street clothing (jeans, sweater, no jacket), except those with the designation of RS (racing suit).

The height of the test rider was 1,80m.

Designations

- TV Touring version (mudguards, carrier, light)
- RV Racing version (bike stripped)
- BBS Bottom-bracket height above seat in mm; negative figures means that BB is under seat.
- LHB Low handle bars under the seat
- HHB High handle bars
- RS Racing suit

Martin Staubach 1993

(Continued, a letter on carbon fibre)

savings that you can feel with every pedal stroke. And the kind of weight savings that can make the difference between a viable product and a dinosaur.

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LETTERS TO THE EDITOR

ADDENDUM TO "A CONTROVERSIAL ISSUE: HUMAN-ENERGY ACCUMULATORS FOR HPVs"

by Peter A. Sharp

The "one-minute rule" I proposed in HP vol. 10 no. 3 p. 19, which would allow competitors to accumulate energy for one minute before the start of most of the International Human-Powered Speed-Championship (IHPSC) events, requires an addition. If left exactly as proposed, the rule might encourage some competitors to abuse the rule. The problem is that competitors could use a particular strategy that would enable them to accumulate energy for more than the legal one minute, in both the drag-race and the top-speed events. Fortunately, this problem can be easily resolved without causing any complexities or inconveniences for the competitors.

The problematic strategy would be this: a competitor in the drag race could remain at the starting line after the starting signal, and continue to accumulate energy . His run would therefore have a larger elapsed time, but it would have a higher, and illegitimate, top speed. His strategy would be to sacrifice his elapsed time, and the race, in order to achieve an illegitimately higher top speed -- since IHPSC drag races are run primarily for top speed. This race strategy would violate the intent of the "one-minute rule" (which is to allow only one minute for human-energy accumulation -- a time limit which is consistent with real-world conditions for practical vehicles). A competitor in an IHPSC top-speed event could use the same strategy, with the result that the run would take longer, but the top speed would be higher. This too would violate the intent of the "one-minute rule".

A simple way to insure compliance with the intent of the "one-minute rule" is to require that top-speed runs and drag races be completed within an appropriate amount of time. Only the race officials would be concerned with this additional requirement. The time limit would be based on the time required to accelerate to the competitor's top speed over the specific distance of the designated course. In other words, the time limit would be proportional to the distance of the designated course, and inversely proportional to the top speed of a specific run. The time limit would also include two or three additional seconds to allow for the normal range of variations in acceleration profiles. The exact formula for the time limit would be determined by the rules committee, and would then be programmed into the timing device. As long as the competitors accelerated normally over the designated course, their runs would easily conform to this time limit. So the time limit would be of no concern to the competitors unless they attempted to accumulate additional and illegitimate energy. A run that exceeded a competitor's specific time limit would be disqualified.

No feedback would be given to the competitors regarding the time difference between the actual time used to make a specific legal run and the calculated time limit allowed for that run. The competitors would not be told how much time was left over, since doing so might encourage someone to attempt to accumulate a few extra pedal strokes' worth of energy before, or while, accelerating. Also, in order to further discourage any attempt to circumvent the "one-minute rule", disqualification of a run would occur if, for any reason, a race official suspected that illegitimate energy had been accumulated before or during a run. Two run disqualifications would disqualify a competitor from the event. Since use of the "one-minute rule" for IHPSC events would, in effect, modernize the definition of HPV (by promoting the use of human-energy accumulators), it is important that this updated definition be based on clear and strict standards. Including this time limit as part of the "one-minute rule" insures that all competitors will comply with the spirit of the competition, and that records will be reliable and unambiguous.

Note that both the "one-minute rule" (for IHPSC events -- which use precise distances for each event) and the "six-minute rule" (for IHPVA sanctioned top-speed record runs, -- which use <u>unlimited</u> distances for acceleration) are variations on the same theme. Both use time limits, but the time limits are structured differently under the two rules. The "one-minute rule", by prescribing exactly how the time is to be used, would permit the efficiency of competing HPV to be directly compared with one another, and would provide a good indication of how well a particular accumulator design would function in a practical vehicle. On the other hand, the "six-minute rule" would permit a competitor to use the available time in any way she wished. This would encourage competitors to further explore 1) the tradeoffs between an accumulator's efficiency and capacity, 2) the balance between charging time and accelerating time, and 3) the balance between aerobic and anaerobic activity. In the process, we are likely to learn a great deal about the application of human power. Also, the differences between these two competition rules will probably lead a greater diversity in the types of accumulators that are developed. In my opinion, such diversity should be encouraged. My hope is that HPV of the future will be more efficient and much faster than we had ever imagined.

Peter A. Sharp, 2786 Bellaire Place, Oakland, CA 94601, USA

AN OPPOSING VIEW

As a graduate mechanical engineer with over thirty years of design experience, and as a founding member and past-president of a non-profit consulting association for which I chaired the development of the by-laws and associated rules and regulations, I have read with keen interest the dueling letters (and article) between Peter Sharp and Tim Leier.

In between the flights-of-fancy arguments presented, each has some valid support for his respective position. However, I feel Mr. Sharp is leaning too heavily on the IHPVA for a Good Housekeeping type of endorsement and Seal of Approval.

If he has some worthwhile designs by all means go for it and develop working models for demonstration and testing. But with regard to rule changes (a serious business requiring strong supportive evidence), to paraphrase the theme of Field of Dreams: if a sufficient number of designers ". . . build it (i.e. working models of meritorious performance) and they (IHPVA) will come (to change the rules)".

William J. Moriarty, P.E. 75 South Road, Hampden, MA 01036

CHEETAH MISCONCEPTIONS

I was one of the guys who designed and built the Dexter Hysol Cheetah. This is the bike that went 68.73 mph in the 200-m sprint on September 22, 1992. This bike has nothing to do with the Wind Cheetah. The Hysol Cheetah was custom designed and built from scratch mostly with composites. It does have a fully enclosed graphite fairing and would not be useful for commuting. We have no immediate plans to market the Cheetah or anything else for that matter. Just thought I'd set the record straight.

[Incidentally, the Cheetah was featured on the front cover and in an article in the October issue of Popular Science].

Please feel free to address any questions about the Hysol Cheetah to me. I'd be happy to clarify anything vague that is in the article. Send messages direct to my e-mail address.

James R. Osborn, Lawrence Berkeley Laboratory, JROsborn@lbl.gov
Phone 510 486-7052

(This was taken, with James Osborn's permission, from the e-mail hpv listing, and was a reply to some erroneous comments about the Cheetah- Ed).

1994 EUROPEAN HPV CHAMPIONSHIPS

The Swiss HPV association Future Bike invites you to the European HPV Championships, open to all HPV enthusiasts. They are from 26th to the 28th August in Laupen, a lovely little village, situation about 30 km WSW of Bern, our capital, and about halfway between Bern and Fribourg. The races include some Swiss "specialties" such as a mountain time sprint and a race of over 100 km for the racers and 50 km for the commuters. We are also organizing the first HP railroad championships! There is a level railway 2-km long near Laupen. For more information, contact me.

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E-mail:
100111.2117@compuserve.com

HPV ACTIVITY IN JAPAN

Prof. Naito's HP helicopter became airborne on December 5. In further trials on December 12 and 19 the truss frame connecting the four rotors broke. He plans to test again in February. I have sent you a video tape of the tests *[and I will be sending it on to the IHPVA library - ed].*

Aerocepcy's new HPA, Gokuraku Tonbo, crashed at the end of December during a long-distance flight.

Kinki University is constructing its first HPA. The total weight is only 25 kg. Scheduled first flight is in February.

Kyoto University is building a HP ornithopter. It has wings and tail in a conventional-aircraft style. A fixed inner wing will generate the lift, while the flapping outer wing produces the thrust. Unfortunately it made a ground loop and crashed during a HP towing test on December 12 1993. The team is rebuilding it for further tests in the spring.

I have good news about a race next summer: it will be in Lake Hamana and will be for solar boats.

RIM HEATING

I much enjoyed Dave Wilson's article on downhill braking and was somewhat surprised and edified at how low the speeds were for maximum rim heating. I suppose that I over-rated radiational cooling compared with forced-air cooling - but I'm no expert on cooling. The hoary advice to pump brakes to reduce rim heating is often repeated, without any analysis of the physics. It seems to me that whether or not this advice is good depends on the rate of heat conduction through the rim to the tire compared with the rate of cooling at the rim's outer surface. Since aluminum has very high heat conduction, I would think that pumping the brakes would give higher peak rim temperatures than steady braking. With hollow steel rims, the effect might be beneficial, though, because heat conduction to the tire is slower. Certainly, J. S. Forester's advice to use both brakes equally to reduce heating is good, but then Forester knows his physics.

John Allen, Waltham, MA, USA
(e-mail johna@cfa165.harvard.edu).

REVIEW YAMAHA LAKE RUNNER

In 1993 Yamaha introduced a pedaled catamaran called the Lake Runner, and made a short videotape widely available. It was discussed on the Internet HPV mailing list. Duane Klinge wrote that he owned a preproduction version called the Water Glider. It has hulls and seat made of Kevlar and weighs about 60 lbm. It will do 8 - 10 mph in a sprint but averages closer to 5 mph for normal cruising. The single gear is surprisingly simple and more durable that it appears on the video. He has had it out in small-craft advisories (30-40-knot winds) on 6-ft waves on Lake Superior, as well as using it on many lakes and rivers. "From what I have seen to date there is nothing that matches it for price, performance and stability".

Another writer, Dave O'Brien from Toronto, wrote that it seemed fun to ride, but he thought that the introductory price, $1700, was a bit steep.

EDITORIALS

Thanks!

In the first part of 1993 I was on sabbatical. I and you were lucky to have a volunteer to produce Human Power: Patrick K. Poole, late of the U.S. Navy submarine service and a professor at Annapolis. Pat has started a consulting company, and editing HP took a great deal of time from his business. We are very grateful. Pat undertook to produce two issues: vol. 10/3, principally composed of material that had come to or from me, and vol. 10/4, devoted almost entirely to HP submarines and the Third International HP Submarine Races in June 1993. He did a beautiful job.

Thanks also to John Raine of the University of Canterbury, New Zealand, who sent along a much-appreciated paper on the Tricanter in 1991, and subsequently asked me if I would be interested in an Erskine Fellowship there. It was my father's old university, and all I had to do was to get Ellen's agreement before replying enthusiastically in the affirmative.

I helped John in one course (we set the students to design a HP garden shredder) and taught another; Ellen and I got to know most of the energetic HP community, which is producing some very interesting designs; and we accepted a very generous offer from Dave Kelly to use his Gary Fisher mountain-bike tandem on a 1200-km tour around and over the Southern Alps. We had, as might be expected, a fantastic trip.

Wins and losses.

Cannondale's "trial-balloon" recumbent (a long-wheelbase machine with full suspension and above-seat steering) has many hoping that this is the breakthrough for which we have been hoping. Vic Sussman wrote on the e-mail network that recumbents seem to be catching on: "American Health magazine has a picture of Kathie Skewis' ReTrike and extols the virtues of 'bent biking. Dick Ryan's Vanguard is featured in Men's Health. And on October 17, USA Weekend, a supplement published by USA TODAY, will feature a small story about 'bents, illustrated with a small picture of a guy (me) holding up his Gold Rush Replica. USA Weekend has a circulation of 35-million . . which should make Bob Bryant very happy" (because the Recumbent Cyclist Magazine was listed as a source). And Popular Science had the Cheetah as its cover photo and lead article in October.

On the other hand, Bicycle Guide magazine has been sold again, and the new publisher announced that BG was going to concentrate on traditional sport cycling, and therefore less coverage of unconventional machines.

Rules

"Clever driving makes for a more interesting sport than cunning design". So ended an "Economist" comment on the increase in popularity of the IndyCar circuit and a decline in Formula One, which "has become too technological for its own good: the team with the latest gizmo fitted to its car invariably wins." Should we worry about this happening to HPV racing? The IHPVA was formed as a reaction to what were seen as restrictive rules for bicycle racing. Originally there was one IHPVA rule: no stored energy. Now we have a hodge-podge of strange rules ourselves, including the maximum favorable slope and wind to qualify a speed-record attempt, modeled after the conditions at the now-long-gone site of our early speed trials. And we have suggestions to revise the rules to make them more logical: Allan Abbott has proposed a new category of top-speed records and Peter Sharp proposes allowing stored human energy in some races. We should welcome all proposals. When I play tennis I marvel at how perfectly the court and net have been chosen to give no advantage for one type of play over another. There were decades of adjustments until that happy situation was reached. We can expect no less.

Near-custom bicycles.

Two developments from Japan could change the bicycle industry. Panasonic sells about 700,000 bicycles a year in Japan. According to an article by Trudy Bell in IEEE Spectrum, an increasing proportion of these are made to order through flexible manufacturing using CAD/CAM and robots. A customer orders a bike at a shop where her/his measurements and component preferences are noted, and every frame tube and angle is automatically cut and shaped and tack-fastened. A veteran craftsman accompanies the bike and works on the fine details. There are 18 models in chrome-moly steel, aluminum alloy and carbon fiber, and enough other choices to give over 11-million possible variations. The models do not, alas, include recumbents yet.

On another front, Yamaha is introducing its PAS: "power-assist system". It is a battery and auxiliary motor on a regular bicycle. The bike is ridden normally. When the PAS system is engaged the motor assists in proportion to the pedaling effort. The motor rated power is 235 W, so that it can match a hearty human-power input.

HPVs or VELOMOBILES

There are exciting developments in Europe. I have long been an advocate of rail-borne HPVs being the next speed-record setters, and the decision to hold rail-bike races in Switzerland this year (see letters) is exciting. There is also a move to use Velomobiles in place of HPVs. I'm not as enthusiastic about this switch, but grumpy old men were never able to stem the tide of popular change in language. HPV is descriptive. Some point out that "automobile" applies more to the HPV than to a vehicle powered by an engine, but it's too late to fight that battle. As far as Velomobile is concerned, the people's will will be done.

An index and a decade.

With this issue we are at last updating the Human Power index. It contains all the articles entered under the topic and under the principal author, and some letters and reviews. I did not include references to all the topics within each article: the length of the index would have become unwieldy.

I also included a summary of the issues of Human Power since it started with the winter 1977-78 issue; of the numbering system used; and of the editors. With this issue I am completing ten years in that post. I'm not trying to hang on to the position. There have been no rivals vying to take on a job that takes a great deal of time and some expenses and has no pay. If someone with a burning desire to do better does turn up, I'll happily hand over the reins. Meanwhile I enjoy working on something that I believe contributes to present and future human welfare: the effects of the HPV movement are all positive, as far as I know. And I'll try to do better. In July this year I go on emeritus status at MIT, which means, I hope, less unrelenting pressure from competing directions.

Dave Wilson

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