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HUMAN POWER

THE TECHNICAL JOURNAL OF THE IHPVA

Volume 5, No. 2 Summer 1986

ISSUE NO. 16

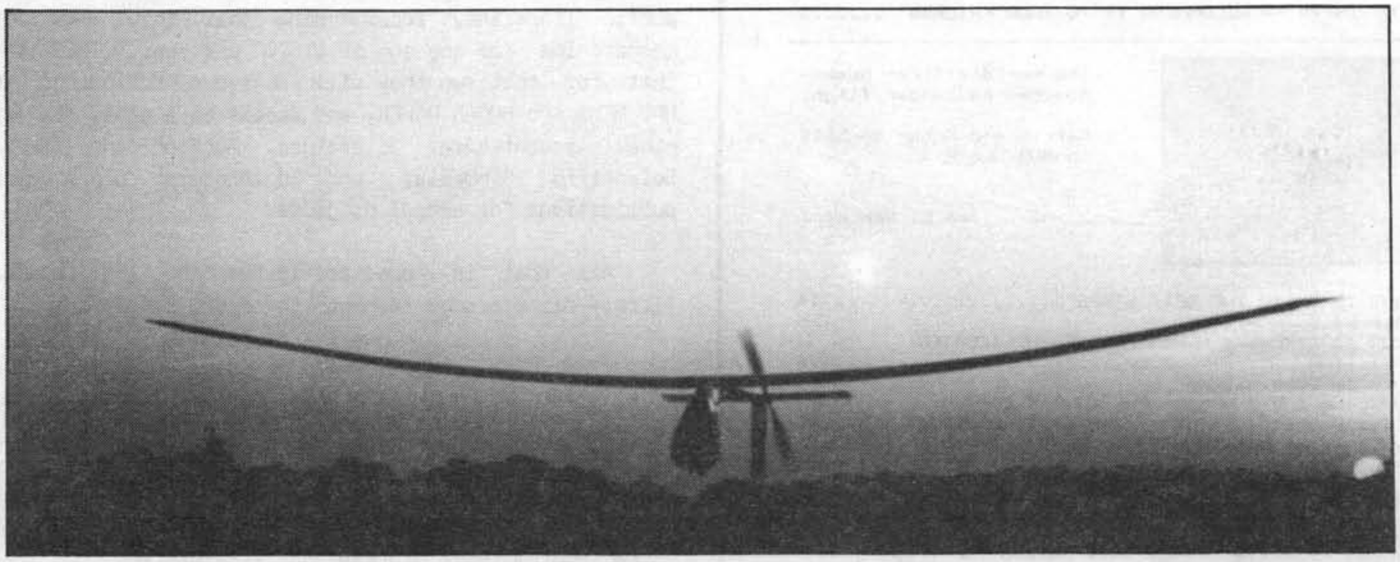

Photo: (c) 1986, E Schoberl

MUSCULAIR 2 Human-Powered Aircraft

THE MUSCULAIR 1 & 2 Human-Powered Aircraft and their optimization

E. SCHOBERL

(transl. by Heinz Altherr and Dave Wilson)

The era of human-powered aircraft began over fifty years ago with the 235-m flight of Haessler Villinger's "Mufli". When Henry Kremer offered his prize in 1959 for a one-mile flight over a figure-of-eight course, it took almost two decades, and major developments in materials, technology and methods, for the prize to be won. Bryan Allen succeeded in completing the one-mile figure-of-eight course first, in 1977, in MacCready's Gossamer Condor, and conquered the English Channel in 1979 in the Gossamer Albatross, making two incomparable milestones in the history of flight.

Without the extremely light and high-strength composite fiber materials, films and pressure-resistant foams, and without the aid of computer-developed high-lift-drag airfoil profiles and the high-efficiency propellers designed by Prof. Larrabee, these developments would not have been possible.

THE MUSCULAIR TEAM AND ITS CONCEPT.

Encouraged by the remarkable successes of solar-aircraft development and stimulated by MacCready's work, Gunter Rochelt, from Munich, and his friends announced the start of a human-powered-aircraft project in 1984 and set out to win the figure-of-eight Kremer prize still available to non-Americans, and the Kremer speed prizes, the third series of prizes Henry Kremer had offered. A basic concept was quickly decided upon: a conventional unbraced high-wing monoplane with laminar-flow-profile airfoils, a fully profiled faired hanging cabin, a balanced rudder and a pusher-propeller. The machine would have to be constructed of the lightest possible materials, with very high profile accuracy and surface finish in order to attain the highest possible speed with a minimum power requirement. The plane had to combine excellent stability with good controllability in order to give the pilot precise control while simultaneously putting out his maximum power. These contrary requirements seemed at first to be irreconcilable.

The task was all the more interesting because Rochelt's seventeen-year-old son, only an average athlete, had to win the speed prize without the aid of energy storage (which would have been allowed under the Kremer rules). Only with the most careful optimization of the aerodynamics, ergonomics, method of construction, flight and meteorological conditions would this be attainable.

The power requirement of an aircraft depend essentially upon the drag of the aircraft components, the induced drag, and the propulsion efficiency. The drag of the aircraft itself can be kept small by employing a low-drag profile, especially one with laminar flow over much of the airfoil, by small surface areas (wings and controls) and by the avoidance of flow disturbances. The induced drag can be minimized through the use of the smallest possible all-up weight, a large wing span, high flight speed, and the best approximation to an elliptical lift distribution.

HUMAN POWER - THE TECHNICAL JOURNAL OF THE INTERNATIONAL HUMAN-POWERED-VEHICLE ASSOCIATION
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April 15, 1986

HUMAN POWER, Spring 1986

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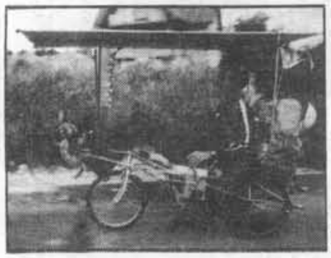
EDITORIAL

The world's first human-powered passenger flight

Katrin and Hdger Rochelt in MUSCULAIR 1

(c) E. Schoberl



Solar/Human powered vehicle Theo Schmidt, 1985

Well packed for trip -- Switzerland to England. (Helmet was taken off for show as they are extremely rare over here)

Photo by: Christoph Laser

A possible obstacle on Theo Schmidt's planned London to Paris pedal

EDITORIAL

HELP THE IHPVA - RECOMMEND IT TO YOUR FRIENDS!

Human power is a topic that generates a great deal of interest. Yet the IHPVA is limited in getting our message out mainly because we have such a small (well under two-thousand) number of paying members. And our numbers are actually decreasing. Let's change that!

Recommend that your friends join. In particular, write to the craft or physics teachers of your local secondary and high schools, and the directors of your public libraries, recommending that they take out memberships for the sum of $15.00 per year. Tell them that for that sum they will receive subscriptions to HPV NEWS and HUMAN POWER, and access to a great deal of other sought-after literature. Mention the IHPVA Scientific Symposia, and Ed Roeters' plans and publications for school projects.

All that is necessary is for the individuals, library directors or teachers to send $15 (US) to:

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PO Box 2068
Seal Beach, CA 90740.

If each one of us does our part in spreading the word, we could have ten-thousand subscribers in two or three months, more professional services and publications, which would in turn attract more to our ranks. Let's do it! Let us know of your success. We'll publish an honor roll of those who have recruited the most people and institutions. We'll count your gift subscription to your old school as a recruitment: the school will probably want to renew when the time comes.

(End of editorial)

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RIBLETS FOR TURBULENT DRAG REDUCTION

Riblets are low fins approximately aligned with the airflow. Studies at NASA and elsewhere have shown that a drag reduction of around 7.5 percent could be achieved on a surface having a turbulent boundary layer. As Bruce Holmes of NASA Langley pointed out (HP vol.5 no. 1 p 7), the fairing of an HPV might have just over half of its surface in natural laminar flow, giving a low drag. The turbulent drag on 45 percent of the surface would contribute about 65 percent of the total drag, so that a reduction of 7.5 percent is significant. Holmes was advocating a larger reduction in drag by using suction at the surface (eg through a porous skin) to maintain laminar flow. Using riblets would be a less-complex but partial solution.

The optimum shape of the riblets was found to be of a vee-form, having a height, h, given by:

$$\frac{\text{(h*free-stream velocity)}}{\text{fluid kinematic viscosity}} = \frac{13}{\text{(0.5*skin-fr.coeff)**0.5}}$$

The optimum spacing, s, is 15/13 times the height. I presume that the skin-friction coefficient is that for turbulent flow before the application of the riblets, and could be estimated from a plot of flat-plate data given in most fluid-dynamics texts, against a Reynolds number based on the length of the surface from the vehicle nose.

For more information, see "Optimization and application of riblets for turbulent drag reduction", by M. J. Walsh and A. M. Lindemann, NASA Langley LAR 13286.

Dave Wilson

GOSSAMER CONDOR AND ALBATROSS CASE STUDY

Paul MacCready has provided the IHPVA with copies of an excellent 60 page monograph on the design and execution of the Gossamer Condor and Albatross Human-Powered Aircraft. The document, authored by James D Burke, is one of a Professional Study Series published by the AIAA (American Institute of Aeronautics and Astronautics). Included are 18 large photographs or diagrams along with 30 pages of textual material. As a bonus, the paper includes 13 pages of detailed drawings by Pat Lloyd -- which originally appeared in the british Aeromodeller Magazine. IHPVA is offering this monograph to members for $US 10, postage included. Any profits, after reimbursing Paul MacCready for his costs, will go to the IHPVA treasury.

Anyone who is thinking of designing an HPA, individuals who are facinated by the Gossamer saga, and those of us who just like to read about examples of innovative engineering should find this paper well worth its price. Send your orders to:

IHPVA, Dept AIAA
PO Box 2068
Seal Beach, CA 90740

Sincerely,

Paul R DesJardins
Executive VP, IHPVA

HUMAN-POWERED AIRCRAFT BOOK NOTE

There is much material in the following book that I think would be of interest to HPA designers and builders:

Unconventional Aircraft
by Peter W. Bowers
TAB Books, Inc
Blue Ridge Summit, PA 17214
1st edition, 1st Printing (c) 1984

Chapter 6, "Other Wing Shapes", might be especially useful if adapted to various HPA design function needs.

Sincerely,

Edwin G Sward
215 Cambridge Street
Worcester, MA 01603

PEDAL HEIGHT AND CROSSWIND EFFECT

CHARLES BROWN —

I've been working towards developing a fully-faired vehicle that could be used for commuting, and I'd like to share some of the things I've found out in person.

I become more and more convinced that placing the bottom bracket much higher than the seat results in a loss of power. It certainly gets uncomfortable. I have built two bicycles in this manner and both were slower than they should have been. This opinion is seconded, in a way, by relatively tall but fast vehicles, such as *Gold Rush* and *Bluebell*, which had their seats higher up and thus should have had more air drag. Yet they were able to beat some highly respected lower-slung designs, such as *Vector*, which had their cranks much higher than their seat. Studies of the *Vector* showed that rider Dave Gryllsw was producing 670 watts when he should have been able to manage 750 watts.

No matter how much I ride and try to get used to a seat-scraper my legs always feel a bit tired; I coast down hills rather than pedal. The feeling is like that experienced when one works for some time with one's hands above one's head, and they get tired. I believe it is due to a build-up of lactic acid in the bloodstream. I built one bike with a seat adjustable for height. To my tastes, I would not tour with a bike that had a bottom bracket much higher than 3 inches (80 mm) above the seat. One way to avoid this and still have a low seat would be to build a linear-drive vehicle. I tried twisting the chain in a figure-8 and having the pedals go backward so the legs pushed when they were in a lower position, but this felt unnatural and was extremely uncomfortable to pedal.

I wish someone had warned me how severe the crosswind effect is on a fully-faired two-wheeler! One of the highlights of my bicycle studies was speaking face-to-face with Gardner Martin. I was surprised to learn that he hadn't been able to do much about the crosswind problem either. I resolved to study the problem more closely. Crude tests showed the crosswind effect varies roughly with the square of distance above the ground; two designs can be compared for crosswind effect by cutting out their silhouttes in a mirror-image pattern (bottom to bottom) from a sheet of cardboard. Balance this along the ground line like a seesaw and the shape that rises has the least total crosswind effect.

The center of crosswind forces is called the center of pressure. Location of the center of pressure relative to the center of gravity is extremely important. Ideally, the center of pressure should be behind the center of gravity, so that crosswinds would steer the vehicle into the wind like a weathervane. This is unlikely to happen in the real world because the more streamlined a vehicle, the farther forward the center of pressure tends to be. On the really streamlined vehicles we build, the center of pressure can actually be ahead of the vehicle itself [How is this possible — Editor]. Correcting this by putting a fin on back, like the *Red Shift* vehicle, would require a large tail to do much good, increasing the side area and overall crosswind effect. The fin would add a lot skin drag, partially offsetting the advantage of the fairing in the first place. About the best we can do is to trim down the nose of the vehicle as much as possible. The *Gold Rush* has remarkably little fairing projecting ahead of the front wheel. It also uses a small front wheel of about 16 inches (400 mm) diameter. Stephen Delaire's *Rotator/Cargo Carrier* has part of its fairing turn along with the front wheel. Eric Andbergen's *Velerique* (Second Scientific Symposium, pages 104 & 106) has the front wheel between the rider's knees. The crosswind problem on fully-faired two-wheelers is so severe that, if you are going to build one, I recommend building it as low as you can, and keeping side area, especially in front, very low.

Charles Brown
22928 Oxford
Dearborn, MI 48124

Human Power for Hybrid Vehicles

THEODOR SCHMIDT —

Introduction

The present interest in the use of HPVs as practical vehicles has resulted in the appearance of a great variety of new machines. Although they are getting better all the time and some designs are already eminently usable, there is one barrier which obstructs every HPV, no matter how well designed: hills. The steep gradients prevalent in many parts of the world mean much sweat and low speeds in the best of vehicles and thus make these unattractive to a great part of the population. One answer to this problem is energy storage. Flywheels, compressed air, rubber bands, and batteries have all been examined, but all have low efficiencies and are relatively heavy and expensive. THis means that to be used effectively, some form of primary energy, other than human power, is desirable to precharge the storage medium. So have we gone full circle and ended back up with the automobile? Not quite: the use of human power automatically dictates a highly efficient low-powered design, everything the ordinary car is not. Some people in the HPV movement fear that involvement with energy storage and motors will lead to more fuel-efficient cars still powered by fossil fuels and in the end destroy the incentive to further develop HPVs. I would like to show in this article that this is, I hope, not so: there are so many advantages in using human power even in a basically powered vehicle that the only real problem is still that of upgrading the image of human power to people accustomed to seeing the world through a wind screen.

Specific advantages of hybrid propulsion over pure motor propulsion

(In this context, hybrid means human power plus motor power).

Cost:

For the same performance, the hybrid vehicle will be smaller, lighter, and thus cheaper and more practical.

Reliability:

Pedal mechanisms can be more reliable than any motor and ensure operation when the external power source is depleted (e.g. flat batteries).

Performance:

For the same cost or the same weight, the hybrid vehicle will usually be faster and have a faster and have a greater range.

Ergonomics:

Long-distance travel in any form is usually a pain, literally: car drivers get back and seat aches, so do motorcyclists. (Cyclists also get saddle sores and even recumbent HPV riders can have problems with knees and ankles when a great deal of effort is required). The driver of a correctly designed hybrid vehicle however gets enough exercise pedalling to prevent backaches or cold, yet never has to exert himself hard enough to feel uncomfortable. The steady excercise results in the production of endorphines, natural body drugs which result in a feeling of well-being.

Psychology:

Driving any motor vehicle at a safe rate is very often boring. Most people drive at a rate such that they get a certain level of mental excitement, but this speed is usually dangerous and is one reason for the appalling traffic statistics. (Europeans have much more difficulty driving at a safe speed than Americans) HPV and hybrid-vehicle drivers have no such problems: pedalling is fun and even slow speeds quite enjoyable. If you do feel bored or impatient you just pedal a bit harder!

These last two arguments are not theoretical but the result of my experiences with my hybrid solar-powered vehicle. Last summer I travelled from Switzerland to England (about 1000 km) and never felt tired, aching or sore, which I usually do when cycling or driving long distances. Although my vehicle has sufficient power to go fast without pedalling, I far preferred to pedal constantly, even if at times my legs were just going round contributing only a fraction of total propulsive power.

Safety:

The human-power part of the hybrid vehicle automatically restricts its mass, which will rarely exceed 100 kg, and puts an end to the ridiculous business of vehicles being designed to carry five or six people and mostly being used by one or two. An aerodynamic and slender vehicle with a smoothly rounded exterior presents less dangerous frontal area or sharp obstructions and in a collision will strike mostly glancing blows. These factors make such vehicles far less dangerous to pedestrians, cyclists, other vehicles, and the driver. Collisions with other vehicles will usually be elastic bouncings with energy being taken up by the subsequent sliding on the road rather than by the inelastic crumpling of metal and repeated roll-overs in car accidents.

Solar/Human Powered Vehicle. Schmidt/Muller 1985

Photo by Cristoph Laser

Pollution:

Although not nearly as environmentally benign as bikes or HPVs, hybrids driven by natural energy or even small amounts of fossil fuels are far better than present cars.

Advantages of hybrid vehicles over pure HPVs

Higher average speeds with less effort, especially in hilly areas. No aches and pains through heavy effort, little sweating. These factors will make hybrids more easily acceptable to many people who don't rate human power very highly or are below average fitness.

Good hybrid vehicles are initially quite expensive, even if running costs are low. This apparent disadvantage can however insure that they can still be used as status symbols and will also provide jobs for the many people engaged in the manufacture of gas-guzzlers when less of these are wanted. I hope that they will also educate and show the virtues of human power, thus perhaps also increasing the use of bikes and HPVs.

Hybrid electric/pedal vehicles

Electric power storage is so far the most popular because the necessary technology is widely available. Also, the primary energy source can easily be solar or wind energy as well as fossil fuels or mains electricity.

One characteristic of any powered vehicle is the fact that performance is higher the greater the weight ratio of the propulsion system to the payload: the exact opposite is desirable for efficiency. This is why automobiles weigh so much and require such huge engines to do so little. Ordinary electric cars also weigh a great deal as they start with an inefficient body and have to add huge amounts of batteries to move at all. The same principle applied to human power of course results in the opposite, lightweight efficiency, because the payload is mostly the power source.

It follows that a hybrid vehicle has two opposing directions of optimization which result in a well-defined optimum configuration for every set of performance requirements. This could be calculated or programmed, but often rule-of-thumb methods are used to choose the ratio of human-to-stored energy and human-to-motor power. Most electrically assisted bikes tend to use 150-250 watt motors which can propel you quite smartly on the level but don't help too much on the hills, which is just where they are needed most! Some vehicles such as the Sinclair C5, regard the small motor as the new propulsion unit and have an ineffective pedalling arrangement. I regard this concept as frustrating, as you can't pedal effectively when you want to but have to work very hard when you don't want to! I like to be able to pedal at any speed but have enough motor power to climb hills rapidly without straining. This requires a motor of 500-1000 W per person and a very wide range of gears for both the motor and the pedals. The way to use such a configuration is to engage the motor fully whenever there is any "up" in the way but to switch it off on the level or descending, where your own power is sufficient and the extra weight of motor and batteries doesn't matter much. The amount of batteries necessary will depend on the desired range and altitude profile. If you take half your body weight in lead-acid batteries, they will last you about 100 km on a medium hilly route without regenerative braking.

Battery Charging

The primary energy source necessary to overcome the many inefficiencies in the system can come from a variety off sources

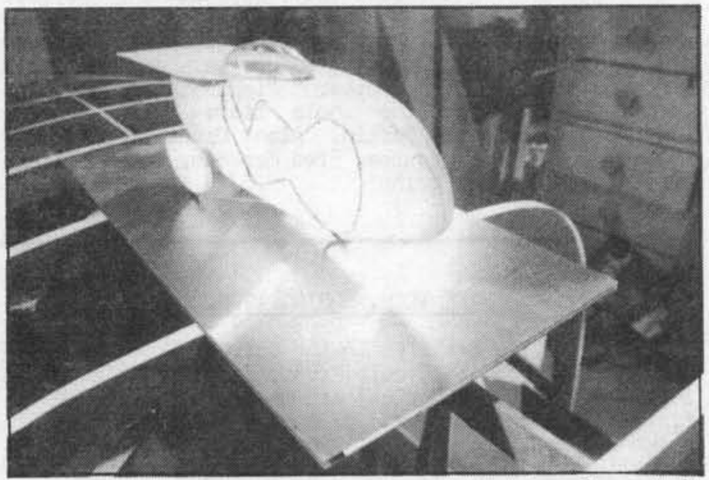
- Solar cells: this concept has resulted in an unprecedented boom in light-vehicle experimentation mainly in Switzerland, although countries like Australia or USA have more favorable climates where solar-powered vehicles could be a realistic transport mode.

- Wind generators: in coastal areas you could run your vehicle from a stationary large wind generator or from a mobile small one. You might also be able to sail your vehicle. (See Ref. 3).

- Mains electricity: this is the most widespread method. With the sort of efficient vehicles we are talking about, the amount of energy used is minescule compared to other uses and not a single extra power station would be needed if most gasoline cars were replaced by these (This is not the case for ordinary electric cars).

- Combustion fuels: a tiny low-powered gasoline or LPG generator could be optimised to produce less noise and pollution than a larger variable-speed motor. Small fuel cells could be developed or Stirling motors, which could burn any fuel.

- Regenerative braking - although this helps and was indeed the original reason for looking at power storage, the total system efficiency is too low to completely "flatten out" the hills, which in any case could be done only if one drove faster uphill than downhill and resisted the temptation to coast.



Concept of
a Modern Hybrid
Solar-Assisted HPV

Conclusion

The addition of a human-power train to light powered vehicles offers considerable technical, biophysical, environmental, and safety advantages. Such hybrid vehicles can provide near-auto-mobile performance even for non-athletes (though not for heavy load-carrying) yet operate extremely efficiently, lsuing little or no fuel. They can be used in hilly areas where pure HPVs are impractical and are more likely to find widespread public acceptance than these, thus also offering the benefits of human power to many people who would not ordinarily consider pedalling.

This is the logical vehicle type to fill the gap between the ultra-high-efficiency HPV and the ultra-low-efficiency but high-powered and load-carring ordinary automobile and is predestined for commuting, shopping, or light touring.

Such vehicles can be built with existing technology, and as the car companies refuse to build such or other lightweight vehicles, it is up to us HPV enthusiasts to make them and start new companies for their manufacture.

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2. Whitt, F.R., and Wilson, D.G., BICYCLING SCIENCE, Second edition, The MIT Press, Cambridge, MA 1982.

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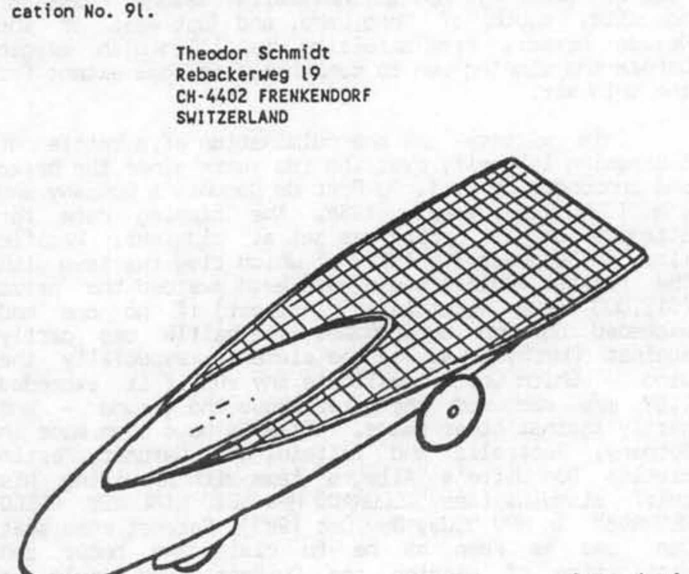


Concept of
a Modern Hybrid
Solar-Assisted HPV

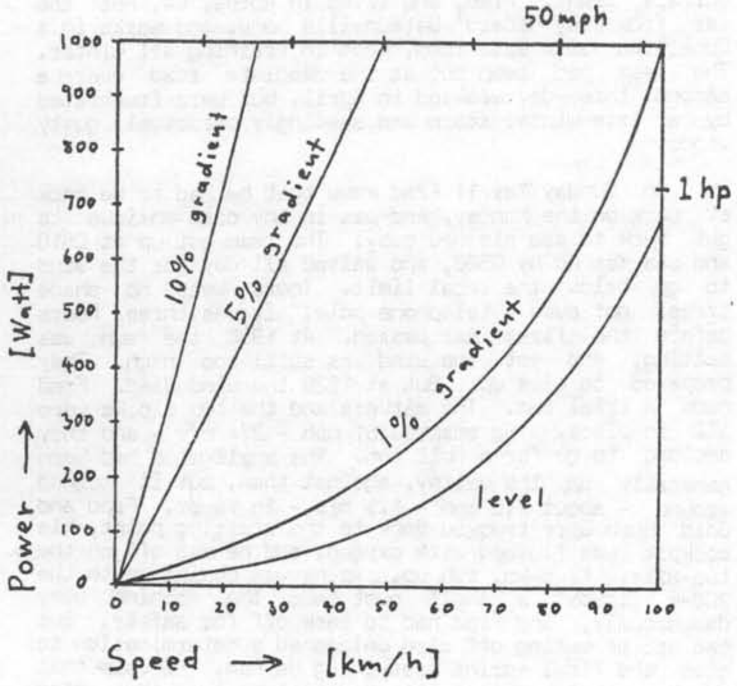


Fig 1. Power Requirements of a Vehicle having the values:
Coefficient of Rolling Resistance: 0.003
Effective Drag Area (Cd x A): 0.05 m sq
Total Mass including Rider: 150 kg

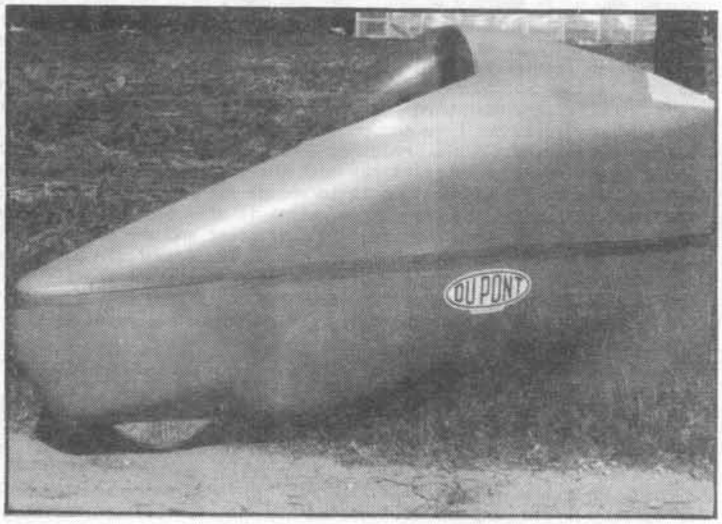
DU-PONT PRIZE WON!

Easy Racer, Gardner Martin and Fred Markham VICTORIOUS AFTER SUPERHUMAN EFFORT

At 2011 Pacific standard time on Sunday May 11, 1986 (0411 GMT, Monday), the Easy Racer team headed by Gardner Martin took the long-coveted Du-Pont prize of $18,000 to be awarded for the first human-powered vehicle to exceed 65 mph (29 m/s) over a 200-m course. Fred Markham, 29, who has helped make the Easy Racer team the most victorious in the short history of HPV racing, pedalled the new lightweight (31-lbm, 14-kg) low-area Easy Racer to an average speed of 65.484 mph (29.271 m/s). The team chose desert highway 120, 7800-ft (2377-m) up in the Sierra Nevada, east of Yosemite, south of Mono Lake, and just west of the Nevada border. Fred's fairing was filled with oxygen before the winning run to compensate to some extent for the thin air.

This victory was the culmination of a battle of increasing intensity over the two years since the prize was announced by E. I. Du Pont de Nemours & Company and the IHPVA in January 1984. The closing date for attempts on the prize was set at midnight, Pacific time, on December 31, 1987, at which time the team with the fastest vehicle would have been awarded the prize ($15,000 plus accumulated interest) if no one had exceeded 65 mph beforehand. The battle was partly against Murphy's Law and the elements, especially the wind - which would invalidate any run if it exceeded 1.67 m/s measured one meter above the ground - and partly against other teams. Attempts have been made in Germany, Australia and Britain, but Gardner Martin credits Don Witte's "Allegro" team with providing his chief stimulus (see "COLORADO HPV SETS NINE NEW SPEED RECORDS" in HPV NEWS, Nov/Dec 1985). Gardner knew that Don was as keen as he to claim the honor and distinction of winning the Du Pont, and would be running as soon as the Colorado high-altitude roads were open. After a gust had caused a 60-mph (27-m/s) flip and 200-ft (65-m) slide on a Markham attempt on the 1985 Columbus-Day weekend, Gardner designed and built "Gold Rush", lighter and with smaller frontal and surface areas. Fred, who lives in Aptos, CA, not too far from Easy Racers' Watsonville home, and works in a Cupertino auto sale room, kept in training all winter. The team had been out at the desolate road over a second three-day weekend in April, but were frustrated by a late-winter storm and seemingly perpetual gusty winds.

On Sunday May 11 Fred knew that he had to be back at work on the Monday, and was in any case anxious to get back to see his new baby. The team got up at 0510 and was set up by 0600, and waited all day for the wind to go below the legal limit. There were no shade trees, not even a telephone pole. It was three hours before the first car passed. At 1900 the sun was setting, and yet the wind was still too high. They prepared to give up. But at 1920 the wind died. Fred made a trial run. The markers and the two clocks were all in place. He reached 61 mph - 27+ m/s - and they decided to go for a full run. The small wind had been generally up the valley, against them, but it turned around - about 2.5 mph - 1.1 m/s - in favor. Fred and Gold Rush were trucked back to the starting point, his cockpit was flushed with oxygen, and he was off on the two-mile, five-km, run up. As he was coming up to the 200-m "traps" a small gust made the machine veer dangerously, and Fred had to ease off for safety. But the act of easing off also unleashed a determination to give the final sprint everything he had. He said that he knew that he was going very fast because the noise in the cockpit was deafening - much louder than ever before. The team rushed to catch him as he began blacking out for lack of air as he braked after the traps. But he had made it. Both clocks agreed: 65.484 mph.



The sleek lines of the new GOLD RUSH:
Weight: 14 kg 31 lbm Height: 1.3 m 51 in
Frontal Area: 0.46 m sq 720 in sq Width: 0.48 m 19 in
Est drag coeff: 0.09 Length: 2.4 m 96 in

Standard Tour Easy frame, but made of 6061 T6 Aluminum.
Fairing: Kevlar Wheel Disks: Mylar Windshield: Lexan
Wheel-gap Closures: Spandex

Remember when 50 mph - 22+ m/s - seemed out of reach? Fred Markham, two-time Olympic cyclist, was first through that barrier, too. What will the new goal be, now that Fred Markham and Easy Racers have set new levels of human performance? Let us give them a little while to savor their triumph before we - and possibly Du Pont - set another "impossible dream". Congratulations to the whole team: Nathan Dean, Gardner and Sandra Martin, Alan Osterbauer, Danny Pavisch, and, of course, Fred Markham, the fastest human-powered human being!

Dave Wilson

BIKE TECH, SPRING 1986.

Interesting articles in the current issue of BIKE TECH (vol.5, no. 1; Rodale Press, Emmaus, PA 18049, $11.97 annual subscription) are on molded composite frames; the metallurgy and design of chain drives; brake-pad heating; and muscle-power physiology. In its "newsline" it reports on two transmissions: Huffy's "Radialgear", a 15-speed expanding-chainwheel gear designed by Royce Husted; and the Bridgestone stepless hub gear, having a around the turn of the century, using a variable-eccentricity cam to operate one-way clutches driving the wheel. These join the wide range of unorthodox transmissions starting, perhaps, with the self-changing Deal Drive of three or four years ago. We hope that BIKE TECH or Frank Berto, who performs such beautiful tests on derailleurs and the like, will make some comparative tests on the efficiency, range, durability and weight of these new transmissions so that we potential customers can know which is worth considering for HPVs.

The propulsion efficiency can be improved through the use of a low-loss power transmission and the largest possible slow-running propeller.

THE WING DESIGN.

Since the profile and induced drag amount to about 85 percent of the total drag, a favorable wing configuration is particularly important.

In order to optimize the wing design it is essential that the following must be considered:

- the choice of airfoil section and the Reynolds no.;
- the wing surface area and aspect ratio;
- the lift distribution;
- the minimization of the low-speed-flight power requirements to about 200 watts;
- the use of the highest possible flight speed;
- a wing mass to give the highest strength and stiffness; and
- the most favorable stall behavior, forgiving flying characteristics, and good controllability (fast response of rudder movements of the total airplane.

The results of many trial calculations (figure 1) showed that in the total region of human-powered flight from low-speed long-duration flight to short-time high-speed flight the most favorable span and thickness distribution was given by a trapezoidal wing with a laminar-flow profile. In this way we arrived at an aircraft weight of 750 N for a small, fast plane to 650 N for a larger and slower craft, attainable with a light pilot and careful lightweight construction without the use of external bracing wires.

The span should not be allowed to increase much over 22m, since abnove this dimension the power requirement reduces only insignificantly, but the aircraft becomes hard to control because of its increased moment of inertia, even with extremely lightweight construction.

We chose for the airfoil profile the laminar shape termed FX 76 MP (man-powered), developed by Prof. F. X. Wortmann in 1976 for human-powered aircraft, figures 5 & 6. This was reckoned to be one of the best profiles in the Reynolds-number region of about 500,000, as it develops near-maximum lift over a wide range of lift coefficient (Cf = 0.7 to 1.2) despite the unavoidable profile variations that must accompany ultralight construction techniques, thus retaining its good-natured characteristics.

The World's First Human-Powered Passenger Flight (Katrin and Hoger Rochelt in MUSCULAIR 1)

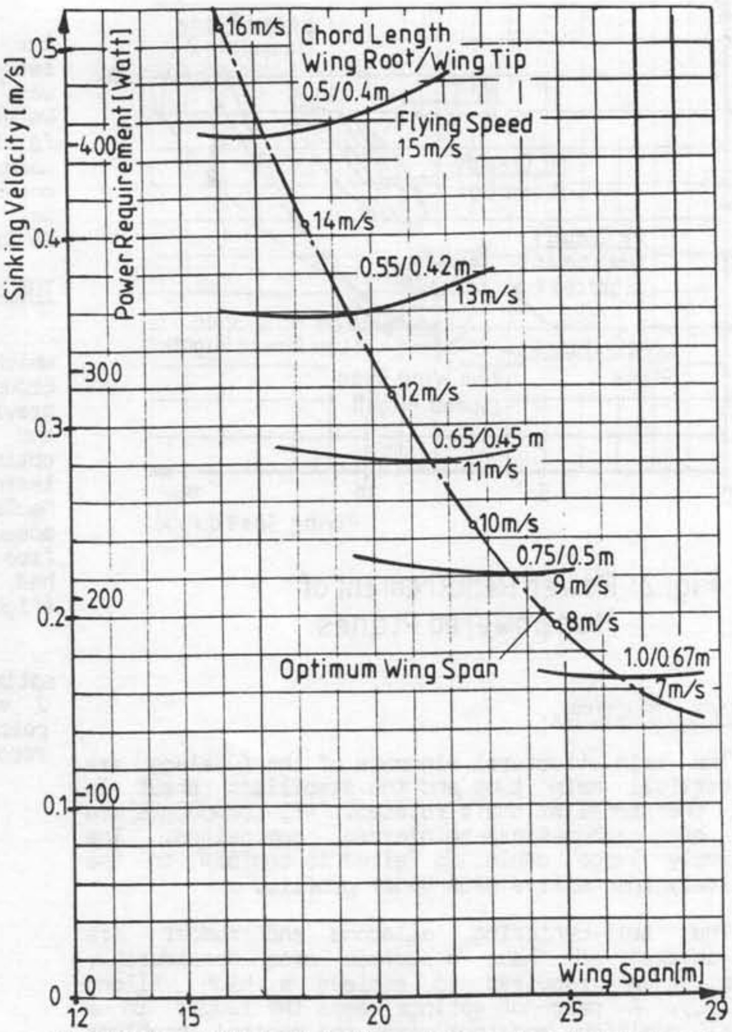


Fig.1 Minimum Sinking Velocity and Power Requirement and Optimum Wing Configuration of Man-Powered Planes

MUSCULAIR 1 AS AN ALL-PURPOSE AIRCRAFT.

Musculair 1 was conceived as an all-purpose aircraft to win both the Kremer figure-of-eight and the speed prizes without resorting to energy storage.

In the course of optimization calculations it became quickly obvious that the valuable aerodynamic concept and the wide operating range of laminar-flow profiles enabled both projects to be tackled with the same wing profile. In low-speed flight the lift coefficient was, at about 1.2, in the higher region of minimum profile losses; and in high-speed flight with Cf=0.75 in the lower region of minimum losses (fig.5).

For transportation reasons the wing was made in six parts, of which the main spar, designed for three times the static load, weighed only 8 kg. To avoid irregularities in the laminar-flow region the upper surface of the wing back to about 60-percent chord is covered with 4-mm-thick Styrofoam. The remainder of the surface is covered with Mylar film. Profile measurements on a finished wing section were conducted by Dieter Althaus in a laminar wind tunnel at the University of Stuttgart, and confirmed the good profile. It was found that it was the fine roughness of the Styrofoam surface that just brought about laminar-turbulent transition at the point wanted without a laminar separation bubble. This reduced the airfoil drag by about 10 percent.

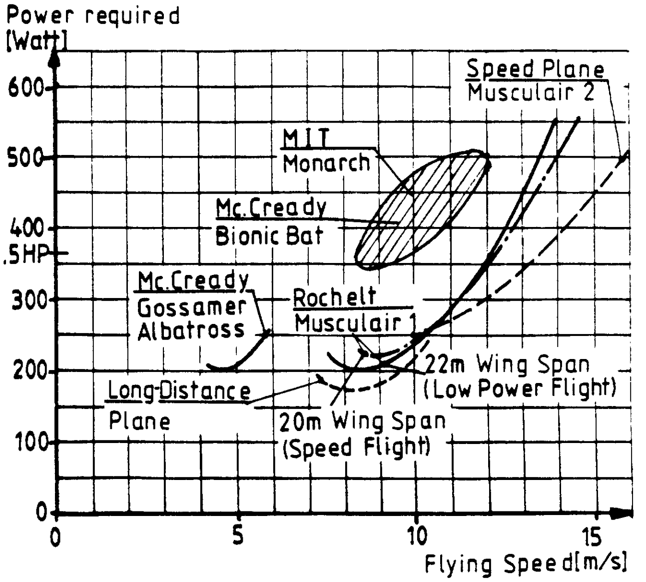


Fig. 2: Power Requirement of Man powered Planes

AIRCRAFT STRUCTURE.

The main structural elements of the fuselage are the vertical main tube and the stabiliser strut in which the propeller shaft rotates. All components are made of carbon-fibre-reinforced composites. The relatively large cabin is faired to conform to the relatively insensitive NACA 64021 profile.

The self-centering ailerons and rudder are Mylar-covered and have a surface area considerably larger than required to achieve a high flight stability. A pair of springs keeps the rudder in a neutral position and thus eases the control problems for the pilot.

The pedal-power train, which weighs only 450 g (in racing bicycles 1.2 kg is normal), transmits the power through a fine chain to the carbon-fibre propeller shaft, supported in four bearings, and back to the 2.72-m-diameter pusher propeller. At barely 100 rpm of the pedals the propeller runs at 230 rpm. The pusher propeller, developed in 1980 for a solar aircraft, has been modified for the special conditions of human-powered flight, but still has over 86 percent efficiency - see figure 9.

CONTROLS.

The control problem has been solved very elegantly, economically and ergonomically.

While a road racer forms a fixed unit with his bicycle and force is transmitted between the hands and the handlebars as well as between the feet and the pedals, the HPA pilot must keep his/her body almost immobile above the hips to allow the controls to be handled sensitively. Precise control is more important than the absolute maximum in power output. That a pilot experienced only in flying hang-gliders was able to control the craft at the first attempt can be attributed to the ergonomically designed joystick, which actuates all three control surfaces. When steering, the pilot has only to envision that he holds the wingtips with his hands, and twisting of the control surfaces will cause the plane to perform the desired manouevers. Sideways tilting of the control stick operates the ailerons, rotation about a vertical axis acts upon the main rudder, and rotation of the handgrips in the same way as opening the throttle of a motor-cycle acts on the elevators. A co-worker experienced only in model-plane flying achieved a 500-m-long clean flight on his first attempt.

FIRST GOAL ACHIEVED: THE FIGURE-OF-EIGHT PRIZE.

During the three-month period of construction of the aircraft, the pilot completed a training program set up by the Sports College of Munich. The first hop was accomplished at the Munich Military Airport at Neubiberg at the end of May, 1984. It was done without fairing on the pilot cabin. At the end of only two weeks of training, on June 18, 1984, the flight over a one-mile figure-of-eight course was achieved in 4 min. 5s, almost twice as fast as Bryan Allen's flight in MacCready's Gossamer Condor in 1977.

THE SECOND GOAL: THE KREMER SPEED PRIZE.

To also win a Kremer Speed Prize, the first of which meanwhile had been won by the Monarch student group from MIT, it was necessary to improve upon the previous speed by more than the required five percent, and the plane had to be aerodynamically refined and optimized. As a result of the test flights the pilot learned to fly the plane perfectly. Meanwhile, MacCready with the Bionic Bat had won the second Kremer speed prize by improving on the MIT speed by more than five percent. Both teams used energy storage and hence had approximately twice the peak power available (figure 2).

On August 21, 1984, pilot Holger Rochelt, in optimum conditions, flew the speed course in 2 min 31.38 s, improved MacCready's speed by seven percent, and for the first time established a speed record for human-powered flight without energy storage.

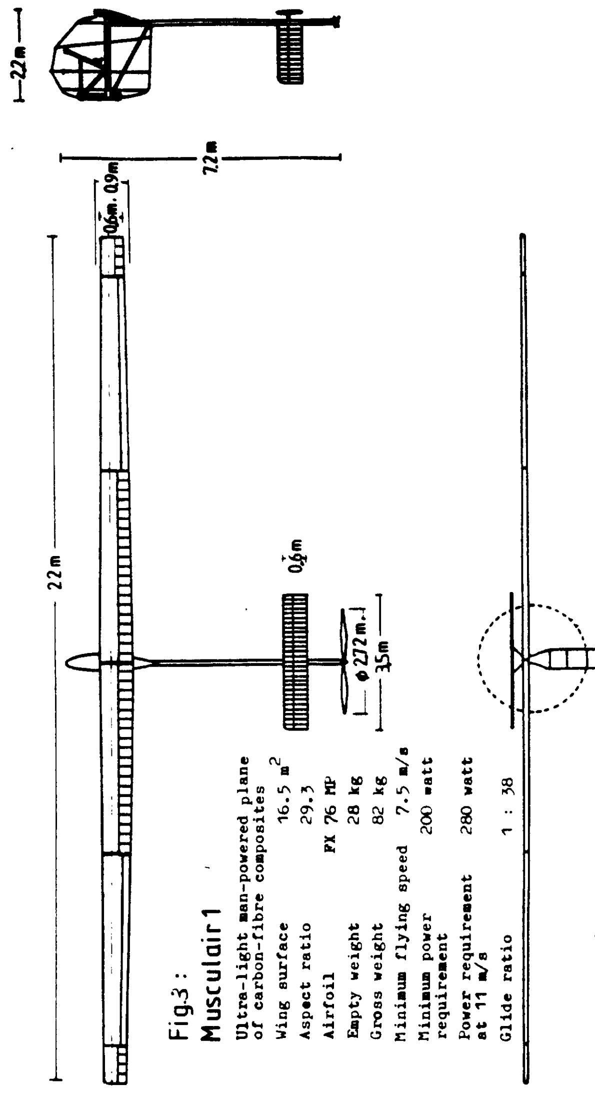


Fig 3. MUSCULAIR 1

Fig.3: Musculair 1

Ultra-light man-powered plane of carbon-fibre composites

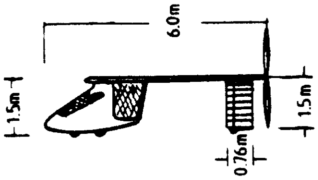
Wing surface	16.5 m^2
Aspect ratio	29.3
Airfoil	FX 76 MP
Empty weight	28 kg
Gross weight	82 kg
Minimum flying speed	7.5 m/s
Minimum power requirement	200 watt
Power requirement at 11 m/s	280 watt
Glide ratio	1 : 38

THE FIRST HPA PASSENGER FLIGHT!

Musculair 1 became an attraction at a few air shows and surprised everyone by demonstrating the astonishing manoueverability of such a large aircraft. To test the available reserves of the pilot and aircraft and to close off the 1984 flying season, Holger Rochelt on the last flight took along as a passenger his sister Katrin who, at 28kg, weighed exactly the same as the bare airplane. So on October 1, 1984 the first human-powered passenger flight in the history of aviation took place covering a distance of 500m at 5m altitude!

THE END OF MUSCULAIR 1 AND THE BIRTH OF A HIGH-SPEED SUCCESSOR.

When in the spring of 1985 Musculair 1 was involved in a traffic accident on the road and was heavily damaged, the idea arose of building an aircraft purely for high-speed flight. The large reserve capability and the good-natured flight characteristics of the all-round Musculair 1 led to the expectation of a significant increase in performance. The author's calculations showed that designing purely for a fast plane, a time of two minutes, which is 45 km/h (12.5 m/s) for the first 1500-m course, would be achievable without energy storage. This speed is significantly higher than the new MacCready speed of 37.7 km/h (10.5 m/s) of Dec 2, 1984. Based on the knowledge of the successful Musculair 1, the construction of Musculair 2 (figure 4) was relatively simple. Since proven concepts had only to be adapted for fast flight, we merely had to re-optimize the aerodynamics, mechanics and construction methods for the new conditions. The aerodynamicist Dieter Althaus of the University of Stuttgart modified and optimized the successful Wortmann profile FX 76 MP precisely for the high-speed conditions (lift coefficient 0.8 at Reynolds numbers of 600,000 inside and 400,000 outside) without reducing its good characteristics. To avoid torsional problems as were experienced in Musculair 1 and to achieve the accuracy and surface finish required for the laminar profile, the wings were covered with a 3-mm foam/fiberglass sandwich, and then covered with Mylar film (figure 7). The main carbon-fibre-reinforced spar was made in four pieces, and designed for three "g" weighed only 4 kg. Through the special design of the wing tips the intensity of the wing-tip vortex, and hence the induced resistance, was slightly reduced.



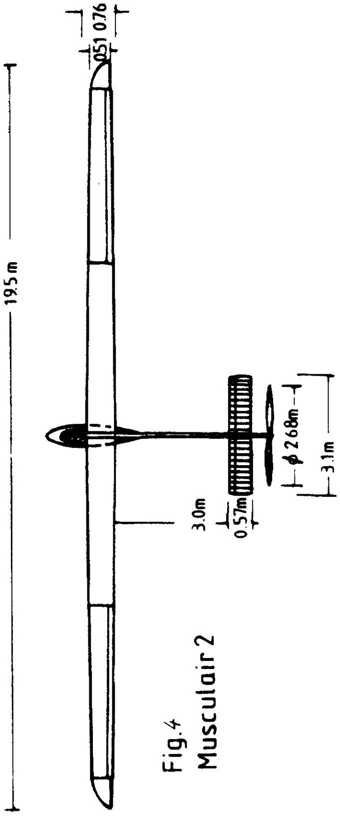


Fig.4 Musculair 2

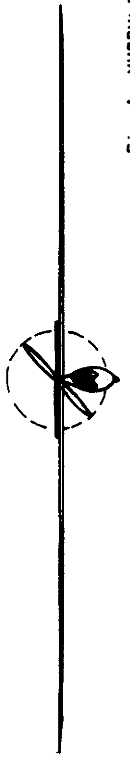


Fig 4. MUSCULAIR 2

SEMI-RECUMBENT PILOT POSITION AND ELLIPTICAL CHAINWHEEL.

The semi-recumbent position of the pilot was expected to result in an improved energy balance. The pilot cabin could be made smaller and held to a truer profile through the use of a superlight fiberglass-sandwich fairing. We have not yet established the optimum sitting position of the pilot at which he could deliver high power and yet is able to pilot accurately. The pedal power output was improved by about 5 percent through the use of an elliptical chainwheel. Proven components like the controls, the rudder configuration, and the pusher propeller were used without modification.

With a multitude of clever solutions, Gunter Rochelt was able to realize a very simple clean construction, functional down to the last detail, and highly efficient aerodynamically. With the most economical use of materials, and an almost stingy application of epoxy resin, the Musculair 2 weighed, ready to fly, 24 kg (figure 4). At the very beginning of the flight tests in September 1984, it was apparent (not really unexpectedly) that the airplane, in contrast to the good-natured Musculair 1, could be flown safely only with a fast powerful flight of about 250 watts pedal input, and then was very sensitive to control inputs. Shortly afterwards Musculair 2 was heavily damaged in a crash landing at an air show, but could be rebuilt in a little over a week.

MUSCULAIR TECHNICAL DATA.

PLANE	MUSCULAIR 1	MUSCULAIR 2
Type	HP all-purpose	HP speed plane
Builder	Gunter Rochelt, Munchen, W. Germany	
Construction	High-wing monoplane with rear prop.	
Span	22m (20m for speed)	19.5m
Length	7.1m	6.0m
Fuselage height	2.12m	1.5m
Wing area	16.5 sq.m.	11.7 sq.m.
Aspect ratio	29.3	32.5
Airfoil	Wortmann FX76 MP root 16% thick tip 14% thick	FX76 MP modified by Dieter Althaus
Empty weight	28 kg	25 kg
Flying weight	82 kg (with passenger 110 kg)	78 kg
Wing pressure	49 N/sq.m.	65.4 N/sq.m.
Min.flying speed	7.5 m/s	10.0 m/s
Min.power at speed	200 W @ 8.5 m/s	250 W @ 10 m/s
Full " " "	265 W @ 11 m/s	315 W @ 12 m/s
Min. sink rate	0.22 m/s	0.27 m/s
Max. glide ratio	1:38	1:37
Propeller	Solair 1 mod. 2.72m dia.	2.68m dia.
Materials for both:	"Sigri" carbon fibre "Rohacell" foam "Styrodur" foam "Conticell" foam "Bakelite L20" epoxy resin "Mylar" film.	

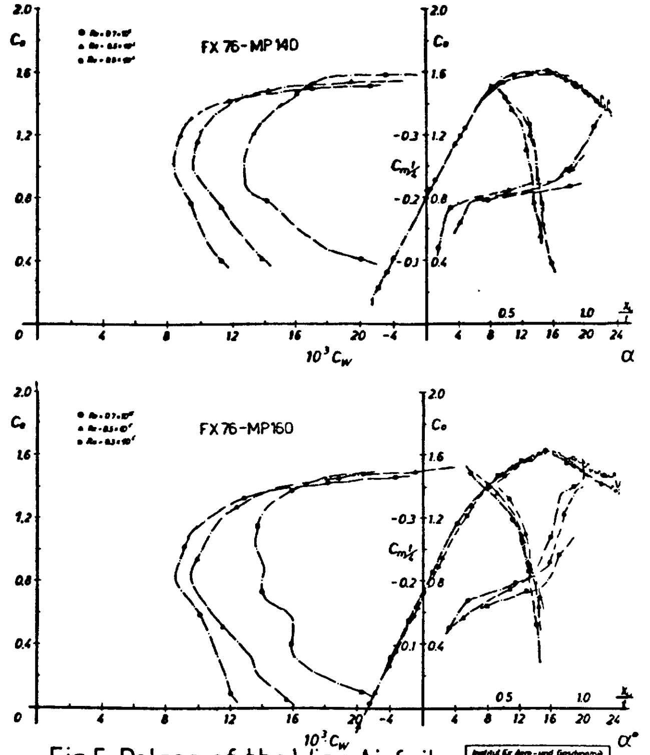


Fig.5: Polars of the Wing Airfoil

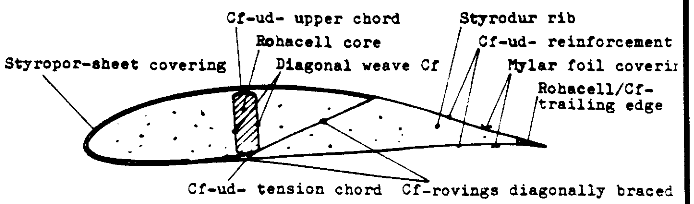


Fig.6: Wing structure of MUSCULAIR 1 with WORTMANN - airfoil FX 76 MP (man powered)

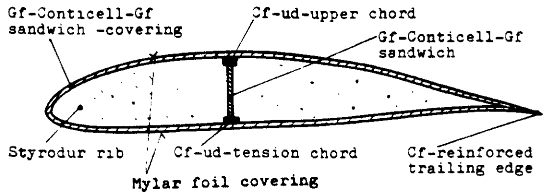


Fig.7: Wing structure of MUSCULAIR 2 with WORTMANN- airfoil FX 76 A, modified by D. Althaus

A NEW KREMER SPEED PRIZE.

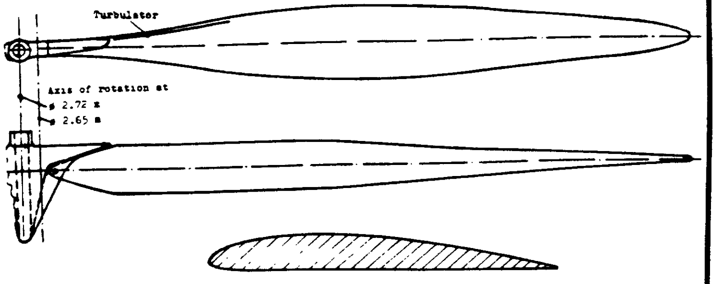
Unusually beautiful fall weather allowed continuation of the test flights. On October 1, 1985, Rochelt achieved a new speed world record of 2 minutes 21s at the airport of Oberschleissheim, near Munich, but could not better MacCready's speed by the required five percent. On the following day, a bicycle racer started working on the pilot two hours before the start to get him physically and psychologically ready for the tough job ahead, and brought him into super form. The course selected was a long loop over the runway such as to make best use of the minute early evening thermal uplift. Hence Holger Rochelt was able to increase, under the most favorable conditions, the world speed record and the Kremer speed prize to two minutes and two seconds, or 44.26 km/h (12.3 m/s).

Fig. 8 :Propeller

Type SOLAIR I mod.
Computation and design E.Schöberl
Minimum induced loss design and operation in turbulence as rear prop.

Design data for Solair I (measured values)		
Diameter	2.65	m
Pitch appr.	2.5	m
Thrust at	120	N
Flying speed	11.7	m/s
Power absorbed	1700	watt
Efficiency	82	%

Modification for Musculair 1		
Diameter	2.72	m
Thrust at	21	N
Flying speed	8	m/s
Power absorbed	195	watt
Efficiency	86	%
Pitch-angle adjustment	-1.5	°



Prop. airfoil Göttingen 795/796; 10% thick

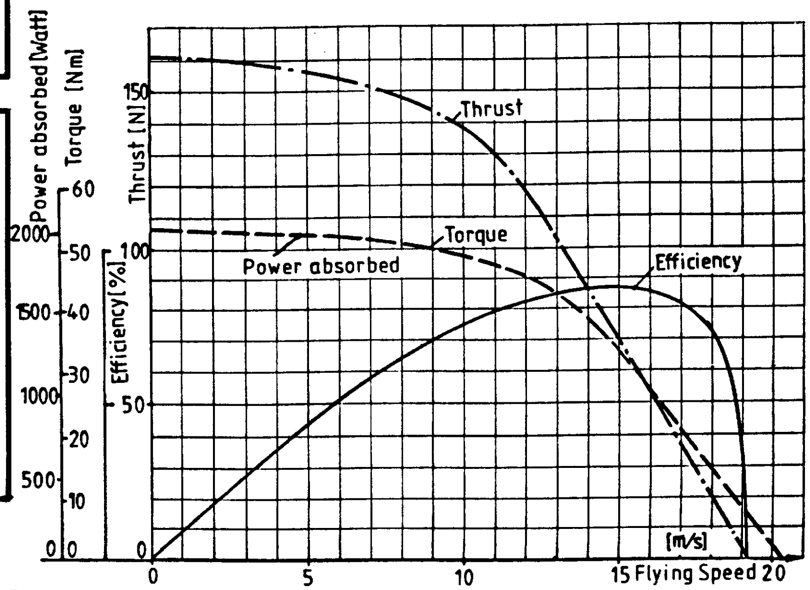


Fig.9: Propeller Operation Graphs at 360 rpm [Wind Tunnel-measured]

RECOMMENDATIONS FOR FUTURE HUMAN-POWERED FLIGHT.

Nobody had expected this vast improvement from an amateur team unsupported by any large, wealthy sponsor. It would be difficult to improve upon this achievement with justifiable effort without resorting to energy storage. If one evaluates the possibilities of improvements in aerodynamics, aircraft technology, ergonomics and flying techniques of fast flight, it seems that without energy storage 50 km/h, approx 14 m/s, is already achievable, and 100 seconds for the 1500-m course is certainly reachable.

With aerodynamically sophisticated ultralight construction methods, one can build relatively small and yet superlight human-powered aircraft for endurance and for long-distance flight, that can fly with less than 200 watts, approx 0.25 hp, and at almost 30 km/h, 8.3 m/s. This kind of airplane, similar to the Musculair 1 concept but with many improved details, with a wingspan not over 24 m, can be built with 30-kg total weight, such that it is easy to control and has good-natured flight characteristics. Because of the higher flight speed, this type of airplane does not react so sensitively to gusts, and can make headway even against light headwinds. For the Daedalus project, for which the 96-km-long stretch from Crete to the Greek mainland has to be conquered, this is especially important, since in the Aegean Sea one has to be prepared for sudden winds, one of the reasons why this area is also a famous sailing region. An airplane built for the Daedalus project should preferably be designed for barely 30-km/h cruising speed at approximately 200-watts power requirements rather than for minimum power requirements at slow speed, approx 150 watts at 23 km/h, so as not to be doomed by an upcoming light headwind.

The development of human-powered helicopters is, because of the high power requirements and the difficult stability and control problems, very difficult. The author calculated a minimum rotor power requirement at low rpm without lift at about 200 watts. That power for example was sufficient to enable the MacCready Gossamer Albatross or the Musculair 1 to fly. Even at low flight altitude and with the strong help of ground effect, the power requirements would be nearly doubled, such that the author does not think that it would be possible to have long or high helicopter flights. It therefore does not seem to be likely that anyone will achieve a breakthrough in the near future, a circumstance which for real enthusiasts is a large challenge.

THE KREMER INFLUENCE.

The prizes donated by the British industrialist Henry Kremer were worldwide a great incentive for the development of many human-powered aircraft. They gave new impulses to the largely neglected area of low-speed aerodynamics between model airplanes and gliders, and to the precise design of high-strength ultralight construction. They also helped to develop the technology required for the unmanned aerodynamic highly efficient ultralight aircraft with solar or hybrid power, used for example for the economical transmission of news and which can remain aloft in the stratosphere for weeks or months.

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** FLASH **

MUSCULAIR will be at EXPO 86
12th IHPVSC in Vancouver, BC
24-31 August 1986

(c) 1986 E Schoberl

HOLGER ROCHELT RIDING MUSCULAR I

HPV AND BICYCLE RESEARCH IN GERMANY.

This is an all-too-brief review, limited by my all-too-uncertain knowledge of German, of an "extra" issue of PRO VELO, the bicycle magazine of Germany. The issue was edited by Dr. Herbert F. Bode from the papers given at a symposium of research on bicycles and other light low-energy-use vehicles at the University of Oldenburg on September 27-28, 1985, and co-sponsored by the Union of German Bicycle Clubs.

Herbert Bode himself opened with a review paper on the line of development of the concept of the bicycle, posing the question "Is the bicycle incapable of being improved?" He gave the answer as an emphatic "yes!", but pointed out that for full "high-tech" application the involvement of major industrial concerns is necessary.

Rob van der Plas called for a refinement of the criteria for various user-groups and for various purposes in guiding future developments. Anne Modershohn called for criteria for all-weather vehicles that had the comfort and convenience of bicycles, with improved capability of carrying luggage, but being able to being carried into the house or office.

Gunter Fieblinger discussed the possibilities of fitting bicycles with small motors, equivalent to riding always with a tail-wind, and asked that the practical advantages be considered without an ideological bias towards pure human power. These possibilities were also discussed by Paul Schondorf, developer of many practical HPVs, who gave a long list of quantitative specifications. A group from the University of Oldenburg, including Falk Riess who, I believe, heads the "working group on bicycle research", gave the history of development of the Oldenburg light vehicles and the problems encountered. Unfortunately for this unskilled translator, there were no illustrations with most of the paper summaries, so that we can't do justice to much of the creative work.

A "mini-symposium" concentrated on specifications and needed research on bicycle braking systems.

The retail price of this special issue is 6 marks, plus postage, obtainable from ProVelo Buch- und Zeitschriften-Verlag, Am Broicher Weg 2, D4053 Juchen, West Germany.

Aspects of stored-wheel response

JIM PAPADOPOULOS —

In this short comment I'd like to summarise some salient aspects of bicycle-wheel mechanics, as suggested by the evidence currently available.

1. Spokes cannot carry a net compression, but their prestress permits them to resist an increment of compression with full tensile stiffness (as detailed in Ref. 1). This means that we can treat tensioned spokes as springs for small shortenings as well as lengthenings - as long as the added compression doesn't overcome their tightness and make them slack.

2. Spoke failures are usually caused by the crack growth arising from many cycles of stress increase and decrease (i.e., fatigue: spoke fracture surfaces often show rust and typical fatigue markings), but we can't say whether the damage is mostly caused by many small stress variations or a few large ones, how important is the maximum stress reached, or how well different brands hold up. Permanent lateral rim deformation, or wobble, has not yet been explained - its occurrence seems unrelated to lateral load magnitude.

3. The rim is very flexible (compared to the spokes) in radial deformation, so radial forces acting on the rim are essentially passed on to a few (3 or 4) nearby spokes, the closest of which feels as much as 30% -40% of the applied load. Consequent spoke-shortening is much too small for a rider to perceive, so a wheel's radial deformation is irrelevant for suspension considerations. (See Refs. 1,2,3) Though this description may have been confirmed only for undished wheels, there's reason to believe it applies to dished wheels almost as well.

4. In the tangential direction, the rim is considerably stiffer than the spokes, so a single tangential force (usually the force from the road due to a hub torque - as when pedalling hard, or hub-braking) makes the rim rotate around the hub more or less as a rigid body. The only surprise is that ahead of a tangential force, increased rim compression causes a slight elevation of spoke tension -with a corresponding decrease behind the force. (See Refs.1,3) Hub design and spoke pattern can make a large difference in maximum spoke force engendered by a tangential load, but even the weakest commonly available design (small flanges, slender barrel, cross-three) while I expect it may increase tension in some spokes by as much as 50% -100% of the tangential load, is unlikely to find usual tangential loads causing as much stress-change as the radial loads due to rider weight. A possible exception is if the bicycle is used primarily in a high-torque (low-gear) situation, such as towing a heavy trailer in the mountains.

5. Rim-braking loads also seem to be gentle to the spokes (See Ref. 2). Roughly speaking, it appears as if a hub-load is being supported by spokes from a rigid rim. I'll neglect it henceforth, but if it is ever proved to be important, several aspects of this review will require modification.

6. In lateral deformation, which is by far the most complex case, the rim is fairly stiff compared to the spokes; however, it is not correct to imagine the rim moving sideways or even tilting as a rigid body. Because it is curved, not straight, twisting gets into the act. (To see one effect of rim twist, compare an unbuilt sewup rim to an unbuilt clincher rim - the traditional type without a hollow cross-section. Holding each rim at 9:00 and 3:00, and pressing 12:00 and 6:00 against a vertical post, the clincher rim will be found to deflect much more. Its cross-section is about three times stiffer in lateral bending, but only 1/8 as stiff in torsion -this is what accounts for the increased flexibility). The result of rim bending and twisting in current wheels is to induce the rim of a built-up wheel to deform in a lopsided potato-chip fashion (that is, with a lateral load applied at 6:00, points at 3:00 and 9:00 move in the direction OPPOSITE to the load, and 12:00 moves in the SAME direction as the load, though considerably less). Rim deformation also doubles the maximum spoke-stress increase, compared to what it would have been with a rigid rim: in a current wheel, a number of spokes near the point of application of a lateral load have their tensions changed (either up or down) by about twice the amount of the load. This is likely to be the cause of the highest tensions a spoke will ever experience, since lateral forces are frequently up near 130 N (30 lbf) from bicycle lean alone, and might be considerably higher in steering maneuvers. Again, very limited evidence suggests that wheel dish doesn't affect this picture much. (Ref. 3 gives a brief account of the theory. The information on spoke tension due to side loads comes from my own measurements of spoke stretch with a dial-indicator, and also from comparison of plucked notes with the note of a reference-spoke supporting an adjustable weight. Note that spoke-creak or brake-rub can be used to show that steering maneuvers give front-wheel lateral forces at least comparable to those from leaning; also I once measured a lateral force of 265 N (60 lbf) in a violent steering maneuver at 4 m/s (10 mph), though instrument calibration was not confirmed.)

I'll conclude this list of comments with a couple of observations. First, you can get a sense of how much different spokes are affected by the various rim loads by getting an accomplice on a bicycle to stand on the pedal, sit in the saddle, lean the bicycle, roll forward, etc., while you repeatedly pluck and listen to a selected spoke (it helps if at least the spokes to be plucked are not laced and not very tight; also comparison with a piano may help if your sense of pitch is poor). Second, it may be most helpful to think of a bicycle wheel as a long, bendable, twistable, curved rod (or beam) held in place by 36 springs anchored in a firmly-held hub. Forces in any direction applied to a point on the rim always produce the greatest effects in spokes nearby.

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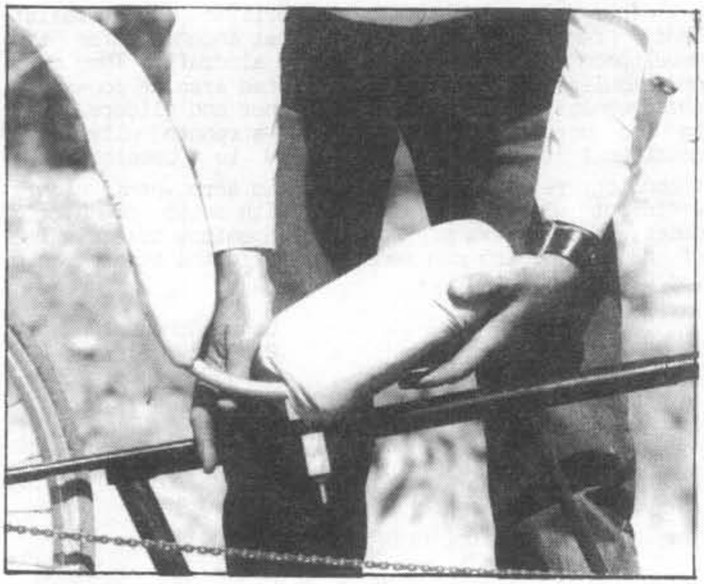
(Jim Papadopoulos prepared this note when I asked him to review a book on spoked wheels. Jim has just joined the mechanical-engineering faculty at Cornell and intends to be seriously involved in HPV research - Dave Wilson)



GETTING PRACTICAL - Recumbents on dirt roads

JIM ROBERTS —

The jury is still out on the viability of current recumbents on dirt roads. Ruts, washboard, gravel, the usual brain-dead car/trucks, dog packs and the unique characteristics of the bikes make for a courageous or foolhardy tight-rope ride.

One real killer is resonance, say twenty cycles per second. I live a mile off a paved road. Most of this mile is maintained by the county: at best, gravelled maybe once a year and graded every month or so, according to desperation of need. It is heavily travelled in all weathers.

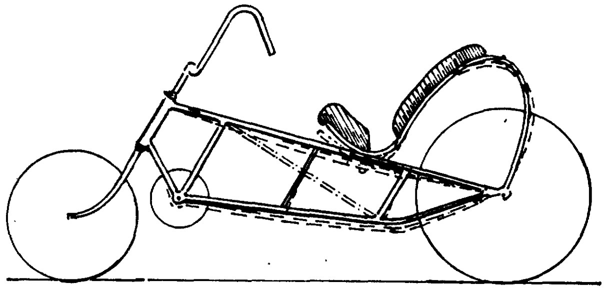
I built a good (read strong) Easy Racer recumbent out of a tall Fuji frame, opting for the parallel brace rather than the diagonal (see diagram). I wanted to build in the vertical flex I thought necessary for survival on these roads. It works to the limited extent of taking most of the grief out of rocks and holes. Performance on washboard is less predictable and you must choose your speed - that is frequency - with care. The resonance is induced by the gravel and builds as a harmonic in the bike frame. A fat twenty-six-inch (660-mm) tire and a suspension fabric seat might dampen these frequencies enough to prevent the collapse of my spinal discs. What I have at the moment doesn't do that job.

My experimental electrical-conduit (kink'n go) seat is a one-piece affair that cantilevers the bearing portion of the seat and arches the back to the rear axle, rather than making a column load out of the seat back; the back is thus preserved from direct kicks from the rear by structurally dissociated rear stays. The load-bearing sections are made from 1/8" (3-mm) plywood and plenty of Ensolite and foam. One important virtue is that the coccyx is completely free of seat burdens and well aerated. The lumbar arch is not vague, it helps avoid spinal compression and it allows limited 'back riding' in rough conditions. The design logic is good though unsightly and heavy in its present incarnation. It would be better as a composite structure. I'd also like to try the cushions used by air-freight shippers; these would certainly act to dampen the killer frequencies.

I was pleased to read Charles Brown's suggestions (HP, Fall 85) on frame design and his espousal of vertical flexibility. I agree that vertical flex is highly desirable and don't doubt that he can eliminate torque and lateral flexing from his minimalist frame, but he won't eliminate the vertical flexing that comes with high pedal loads. While he clearly regards frame flex as energy loss, I have my doubts. In my experience, a small amount of winding (torsional springiness) is advantageous. It does two things: first it takes the shock load out of the top end of the stroke and, second, it seems to extend the drive period at the bottom of the stroke (presumably as the frame and drive unwind). Winding experienced at the pedal actually comes from a number and combination of sources: vertical flex/suspension wind, drive-chain stretch, and torsional flex. To most designers these are all regarded as apparent losses. For the time being, I'd as soon see these frame molecules agitated. I grant that we are talking of no more than an inch (25 mm) of pedal travel in a long-crank, flexible Easy like mine. Brown will experience more winding, but he may also realize a net power gain to the wheel.

This may sound nuts to designers better educated than myself. But they will agree that slaving the human legs to rotary motion involves losses and system strains, especially in recumbent postures. I further believe that analysis of 'the running/climbing man' shows that the maximum thrust comes in about two thirds of the way through the power stroke and that this corresponds favorably with the stress lines and structure of legs and pelvis. I suggest that knee strain in recumbents results from working too hard past the flat spots at the top and bottom of the pedalling circle. That is where the unnatural loading occurs: too early a loading on the top leg and negative loading (read joint separation) on the bottom. Flexibility, if tuned, might deliver a winding process tailored to how the leg works best. It may well be, as far as I am concerned, that the principal contenders for the Dupont prize are employing 'winding' to advantage, knowing or unknowing.

In any event, the problem of 'compliance' with recumbents is real, if not for comfort and physical survival, then for efficiency. This point was well illuminated by Ray Wijewardine (HP, Spring '85): a recumbent bike with independent suspension allows for a twenty-percent reduction in energy requirement over that without on rough roads (saving energy otherwise lost in vertical acceleration). Nor has Ray complained of losses thrugh suspension or drive winding. I am bothered by the complexity and suggestion of dead weight when considering articulated suspension systems. I feel that the need for compliance and the damping of harmonics can be met by frames with graduated flexibility.



Roberts' Flexible Easy Showing Extreme Vertical Flex "Dissociated" Seat and Parallel Frame Base. (More Rigid Factory Type Diagonal Brace Shown as Dashed Lines.

Conventional bikes perform well in the dirt because the legs work perfectly as reflexive springs and dampers. Since it is the rider who makes up 80% of the "sprung weight" of the vehicle, this turns into "dead weight" when the rider is supine.

I sense a lot of anxiety about flexibility as it pertains to control. "Aren't we bound to suffer oscillation at speed with long, flat frames?" This would certainly be a legitimate concern for a 'high rider' or a conventional bike where the center of gravity is some distance from the drive/frame center line. But in 'low riders' we have a close proximity of forces and masses close to a common center; that makes it a different ballgame. Couldn't flexibility just as readily enhance control as destroy it? My point is that there may be opportunities here that have been viewed in the past as liabilities.

On the other hand, 'low riders' are definitely hard to control on less-than-optimal surfaces for different reasons. The unique characteristics of long-wheelbase, low-center-of-gravity control were well reviewed by Des Messenger (HP WInter '85): greater steering angles and greater lean, for a given turn. Very serious trouble on a dirt road. Add to this the short footprint (contact patch) of the 20" wheel, steep steering-head angle (Easy), light steering loads and you can just forget avoidance maneuvers; it wants to dig a hole much like a dull spade.

Sometimes I have the feeling that some of us are coming from way out in left field. We might doubt, for instance, that there will ever be a Dupont Prize for a Practical HPV (poorly cloaked challenge). You have to believe that there is a cultural entrenchment here that makes such a thing unlikely.

The 65-mph prize is going to be * taken with current technology, endowed with enough money, drive and peak conditions. The greater challenge, certainly deeper, lies with the practical HPV. Here we grapple with ambient physical and political realities. Practically speaking, I can't hack riding a bike while pumping dirty air and/or accounting for killer drivers of cars, uniformly blind drunk on disembodied power.

Let's face it, it's a dog's life for practical bikers in this country. In other parts of the world - let's say most of it -things are different. There, bicycling represents basic mobility, the prime object of liberation - through technology. In spite of universally inferior status, the bicyclist does maintain his right-of-way, as certainly as pedestrians do here (no snickering). The practical problem ultimately includes the where of it.

Maybe we should look to India or China to lay down the appropriate design parameters. You might believe a supine bike could be made entirely (hardware excepted) of bamboo, epoxy and silk.

Jim Roberts
The Wave Project
Chimayo, Box 408
New Mexico 87522

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* has been! Ed.

Some people want H.P.V.s, Others need them

HuDyN Vehicles of Indianapolis has brought two special people into the world of H.P.V. in the past year. They are both handicapped and are unable to ride regular bicycles.

Tom Price of Plainfield, Indiana was injured in an automobile accident several years ago leaving him with poor coordination and limited ability to walk.

One Sunday afternoon, Tom and his wife saw one of our HuDyN tricycles on the street and inquired about the vehicle. A test ride was arrainged and Tom was back under his own power for the first time in two years.

Construction was started on a new vehicle for Tom and within three weeks it was delivered to him. Special features included full lighting, saddle bags, a special rack for his walker and a mettalic burgundy paint job.

Tom's wife and doctor are very pleased with the pace of his recovery since he has been able to ride. After less than one year of H.P.V. riding, Tom's leg strength and coordination have improved to the point where he is able to walk without a walker using two canes instead.

Tom uses his vehicle for pleasure riding with his family and for commuting to the local swimming pool.

Frank Pottdorf of Indianapolis has only one leg. He contacted Indiana IHPVA President, Marti Daily about the availability of vehicles,so he would be able to continue some of his athletic pursuits. Marti suggested that he contact HuDyN and a successful test ride was arrainged. The red test vehicle was fitted with mountings for Frank's crutches and delivered to him within a week. One of the new locking shoe and pedal systems has been installed allowing Frank to easily operate the trike.

What a rewarding experience it has been for HuDyN to to be able to help these two guys get back on the road!

HuDyN makes major commitment to H.P.V. future

HuDyN Vehicles of Indianapolis, Indiana is investing in the future of H.P.V. by designing and building a special product just for H.P.V. The product is a special tire.

Tom McGriff of HuDyN Vehicles explains, "HuDyN has had a problem since we started building HuDyN trikes about 1 1/2 years ago. We just could not find a good 20 inch front tire. We talked to other builders and riders and they seemed to have the same problem. We could get a low tech, street, blackwall which was hard, heavy and not very round or we could get a high tech, lightweight,skinwall BMX type tire---------with knobbies (yuk) Neither of these tires offered us what we wanted so we decided to check into building our own tire."

Our specifications are: size- 20x1 1/4
type- skinwall clincher slick
rating- 90 p.s.i.
rim- standard 20x1 1/8 to 20x1 3/8

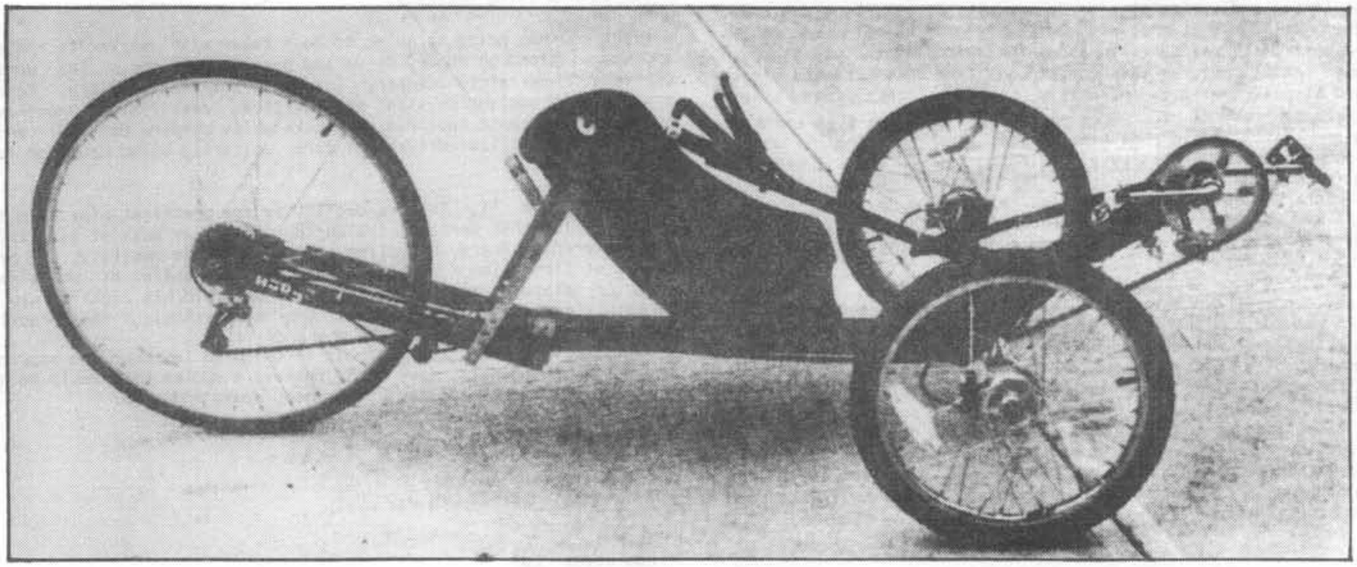
"The financial commitment to do this project is a major one but after considering how many builders, riders and racers need this type of tire we decided to try."

"We have had some very positive response from several major builders so far so we are really looking forward to making these tires available in August."

"We hope the H.P.V. people will support this new tire. If so, we will be bringing out more new sizes."

Thomas McGriff
HuDyN Vehicles
P.O.Box 22444
Indianapolis, Ind.
46222

Thomas McGriff



Theo Schmidt to pedal from London to Paris

The inflatable-pontoon catamaran that Theo Schmidt plans to use for his audacious journey between the British and French capitals is shown in an early form in an illustration to Theo's article in the Spring 1985 issue of HUMAN POWER (page 7). There it is married to a regular "ten-speed" bicycle. For his attempt in May, Theo hopes to attach it to his recumbent tricycle, used in the Swiss Tour de Sol rally (described by Peter Ernst in the last issue of HP). He will ride this from London to Dover, inflate the pontoons, and then pedal across the Channel with a propeller driven by the trike transmission. Then on to Paris and, we hope, the Arc de Triomphe.

Theo Schmidt was born in Basel, Switzerland, 27 years ago, and splits his time between Switzerland and Dorset, UK. He is raising money for the Intermediate Technology Development Group, a British volunteer organization offering help to developing countries and groups anywhere wanting to use appropriate rather than high technology.

We hope to have a full report of Theo's journey in the next issue of HUMAN POWER.

THE TRAYLING INDEX

Greg Trayling, of Vancouver, BC, has produced a useful index of HPV articles in periodicals. He has advertised it in HPV News, and I bought a copy recently. It has 28 pages of computer printout, with about 15 entries per page on average. The categories start with "Early history" (not too early!) and go on to events, speed vehicles, commuting vehicles, recumbent plans, do-it-yourself articles, interviews and profiles, aircraft, watercraft, materials, aerodynamics, stability and steering and so forth. I believe that the cost was $9.00; his address is 3381 E 29th Ave., Vancouver, BC V5R 1W7.

DAEDALUS IS ON THE NEXT STAGE

The Daedalus project made the national TV news recently, being reported at least on CBS by Dan Rather on April 9 after a news conference in Washington to announce that funding had been received by a major commercial sponsor - Anheuser-Busch - to enable the second phase to be undertaken. A prototype aircraft - the Michelob Light Eagle - will be built at MIT this summer, and will attempt to break the world distance record for HPAs early in the fall. A team has just returned from Greece where it placed weather stations and made other preparations, reporting great hospitality and cooperation by the Greek government and other authorities.

FOIL PROPULSION - A natural for HPBS?.

A new form of an old system of boat propulsion - sculling, in the old style of oscillating a single oar at the rear of a boat simulating a fish's tale - has been developed in Norway. The principal purpose was to harness wave power to drive a boat through the water. A horizontal high-aspect-ratio foil is rigged under the water surface just ahead of the boat's prow, and another just aft of the stern. Each foil is pivoted somewhere near the leading edge and allowed a few degrees of pitch change as the boat rocks from wave motion. As the foils are pulled upwards and driven downwards, they develop forward thrust to propel the boat forward. The inventor and developer, Einar Jakobsen, of Wave Control Co., Roven, N-1920 Sorumsand, sent a videotape of models in a wave tank and a launch in a harbor making good headway against a choppy head sea with no external power other than that coming from the waves.

Mr. Jakobsen also built a small catamaran with hand linkage to the foils, and in the videotape is shown moving at an estimated two m/s with very little energy apparently going into the linkage. He claims very high propulsive efficiencies, of the same order as Larrabee propellers. The craft pitches considerably as the foils are raised and lowered: it may be possible to arrange for pairs of foils to move to cancel any overall vertical forces. Foils should offer the prospect of simpler linkage for foot operation than the cranks and right-angle drive required for propellers; and the draft needed could be less. On the other hand foils and the supporting and operating structures seem likely to be heavier than equivalent propellers.

We will try to give more information in a future issue of HP.

Builder's Guide Update

As reported in the last HPV NEWS, Mike Eliasohn is preparing an update of the HPV-builder's source directory which we published in the fall, 1985, issue of HUMAN POWER. We hope to run this list of corrections, additions and deletions in the next issue of HUMAN POWER. (A full revised edition will come later). If you have revisions, please send them to:

Mike Elasohn
2708 Lake Short Drive, apt 307
ST. JOSEPH, MI 49085
Phone 616 982-4058

THE IGOR I. SIKORSKY
Human Powered Helicopter Competition

A prize of $15,000 has been offered by the American Helicopter Society for a successful controlled flight of a human-powered helicopter. The prize was announced in 1980, but so far no successful flights have been made. The rules are detailed, and they will be given out with the entry forms when a fee of $15.00 is paid to the Society at:

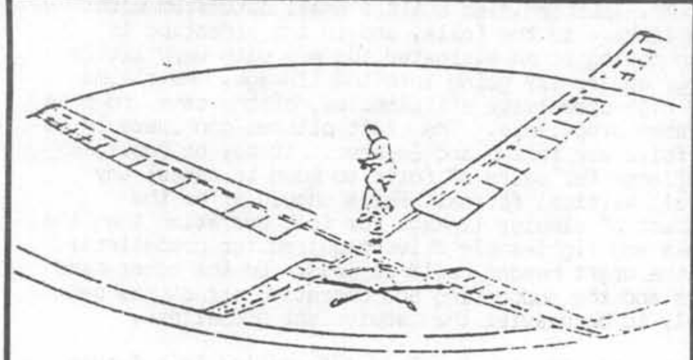
American Helicopter Society
217 N. Washington Street
ALEXANDRIA, VA 22314
(phone 703 684 6777)

Briefly, anyone from any country may enter; the crew may be as large as desired; energy storage and lighter-than-air gases are prohibited; nothing may be jettisoned or left behind; a successful flight is defined as hovering in still air for one minute within a ten-metre square, and exceeding, at least momentarily, three metres height of the lowest part of the helicopter.

I asked the AHS if there were accounts of nearly successful attempts that we could publish. Michael Debraggio, director of communications, told me that people were quite secretive about what they were up to. He sent me a report of a paper study of HP-helicopter designs, published in the November-December 1985 issue of VERTIFLITE (p. 65) but there is little available, apparently, on any practical developments.

However, I have just (April 14) received a note from Ernst Schoberl, author of our lead article on the MUSCULAIR, who visited Prof. Ahiro Naito at Nihon University, Tokyo in March. His team did in fact succeed in getting an HP helicopter a few centimetres off the ground for a few seconds in December 1985. Prof. Naito reached 65 and retired in March, but we hope that the efforts will continue.

Dave Wilson



パイロットの足がペダルにかかり、いよいよ浮上…（下は全体図）

Nihon University, Tokyo -- Man-Powered Helicopter

Newspaper photos sent by
TOSHIO KAKAOKA, Yokohama, Japan

IHPVA Membership Information: Dues are $15 per year for US mailing addresses. Addresses outside the USA, please remit: US$17 for Canada and Mexico; all other countries US$20. Please make check or money order payable in US funds to: IHPVA, PO Box 2068, Seal Beach, CA 90740, USA. Membership includes a subscription to Human Power and to the HPVNews.