GUNNAR FEHLAU

THE recumbent bicycle

REVISED & UPDATED!

The only complete overview of this style of bicycle!

- history
- sports
- touring
- commuting
- physics
- features
- plus more!

OUT YOUR BACKDOOR PRESS

GUNNAR FEHLAU

the recumbent bicycle

Out Your Backdoor Press
THIRD EDITION

ISBN 1-892590-59-X

Third Edition Copyright 2006; 2nd Ed. 2003; 1st Ed. 2000; Out Your Backdoor Press. Jeff Potter—Editor and Publisher. Printed by Color House Graphics, Grand Rapids, MI.

Library of Congress Control Number: 2006929590

The original version of this book was published under the title "Das Liegerad."

A copy may be ordered by sending $25 postpaid to:

Out Your Backdoor, 4686 Meridian Rd., Williamston MI 48895; ph. 800-763-OYBD (6923)

For information on other OYB titles, see catalog at back of this book and the full service website at... **OutYourBackdoor.com**, which hosts:
• OYB Press title details and ordering info • 500+ free homegrown adventure articles
• OYB magazine ordering info and back-issues • textfiles of OYB books
• OYB bookstore (for 100's of related titles) • OYB & Local Spirit Travel Forums
• links to other do-it-yourself culture websites.

Gunnar Fehlau is president of the Bicycle Press Service in Germany, available at www.pressedienst-fahrrad.de.

Jasmin Fischer was the English translator for this book. She is available at www.jasminfischer.de.

OYB Acknowledgments: Huge credit goes to Jasmin Fischer for her translation. She pulled through wonderfully where others failed. And I thank Martha, my wife, for letting me do this project and for encouraging me. Thanks, also, to Joey Harrison for the copyediting on this latest edition and to Owen Neils for his super cover design. —*Jeff Potter, editor*

Front cover photo:

Laurie Smith, editor of the *Easy Riders Recumbent Club* magazine, rides her "Tour Easy," the classic by Easy Racers (www.easyracers.com; www.geocities.com/e_r_r_c/; Michael Berry photo).

On the back cover:

Racer/designer Bram Moens rides a sleek M5 lowracer that his company produces (www.m5-ligfietsen.com; F. Lemmens photo).

Contents

Dedicated to my father,
without whom this book would not have been written.

Preface

Although the recumbent bicycle was invented before the turn of the last century, it has, like many other alternative bike concepts, spent its existence in the shadow of the "normal bike," which is based on the Rover Safety Bike of 1885.

As early as 1869 there was a model that resembled a modern recumbent, but continuous development didn't start until the early 1890s. Recumbents were actively developed up to the late 1930s, and they often beat the upright racing bike in competitions.

In 1934 the recumbent was banned from competition by the UCI (the international bike sport association). Because sporting success very often translates to widespread use by nonprofessionals, the ban devastated the recumbent's commercial market, and it all but disappeared from the world of cycling.

Today, the situation is changed. Apart from a small number of racing enthusiasts, it is mainly everyday cyclists and tourists who enjoy the advantages of recumbents. The beneficial aerodynamics, design diversity, safety, and comfort make the recumbent an ideal vehicle for a wide variety of distances, uses, speeds, and rider types. Its ease-of-use could even help it be a factor in resolving traffic congestion.

The lull in recumbent use following the UCI ban ended in the middle of the 1970s when the IHPVA (International Human Powered Vehicle Association) was founded. It was the IHPVA's goal to develop the full potential of cycling without heed to UCI limitations.

Two parallel developments converged within the IHPVA: Engineers from the West Coast were striving to reach the highest possible speed, and activists from the East Coast were developing safe, human-powered bikes to help solve the energy crisis.

In the more than 30 years of continuous development since then, there has been significant progress. Cyclists can now buy a recumbent that meets any of dozens of needs. With hundreds of market choices, homebuilding is no longer necessary, though some dedicated hobbyists still choose to do so. Some enjoy the craftsmanship, others want to test novel designs, and some have a wish list so refined that homebuilding is the only option. High-level how-to advice is freely shared—especially online—and they're easier to build than uprights.

Recumbents are sometimes accused of poor maneuverability, that they cause your legs to fall asleep, that they can't climb hills, that they're dangerous in traffic. Such accusations spring from ignorance, and have more to do with fear of the unknown than with reality.

This book delivers the information you need to make educated decisions about purchasing or designing a recumbent, as well as offering a lively historical overview. It also introduces you to important builders and racers, and the bikes associated with their names.

The book covers physics, racing, touring, city use, design, homebuilding, fairings, and offers useful appendix of shopping and riding resources. (Note that the "bicycle" in the title precludes me from getting into the world of trikes. There's enough to cover as it is!)

— Gunnar Fehlau

What is a Recumbent, Anyway?

Compared to popular bike types such as the racing bike, the touring bike, the mountain bike, the folding bike, and the tandem, the recumbent is exotic, indeed!

It differs from the others not only in widely varying frame design, but also in the way you are seated. The rider's position on other bikes is vertical or leaning forward, and the legs push downward to pedal.

On a recumbent body position varies widely and the legs are horizontal and closer to the ground.

Efforts to create a faster, safer, more comfortable bike with a greater range of function resulted in the recumbent. And the tremendous diversity of design within the recumbent category is the consequence of builders shuffling the emphasis of those different goals.

The recumbent design makes use of a rider's back, hips, and rump as contact surface, eliminating most standard pressure points and creating better aerodynamic potential. The crank is positioned in the front, and the body is tilted back between 15 and 75 degrees from vertical.

There is a rare variant that should be mentioned: the prone recumbent, or "belly bike." With this bike, the chest and belly serve as the contact surface and the crank is behind. (They can be exciting to ride and have done well in some events.)

We can also differentiate between two basic forms of construction: the long and the short wheelbase recumbent. The common abbreviations for these are LWB for "long wheelbase" and SWB for "short wheelbase."

The position of the front wheel and the bottom bracket define the category. If the front wheel is positioned in front of the crank, we are talking about a LWB; if the two are reversed, we are talking about a SWB. To summarize, we differentiate between four main types:

- back recumbents
- belly recumbents
- long wheelbase recumbents
- short wheelbase recumbents

The variations on these themes are endless. Compact long-wheelbase models (CLWB), sometimes called medium-wheelbase (MWB) are an effective, popular hybrid. Low recumbents, called lowracers, are a variant with extremely low seats with the crank in front of the front wheel. These are currently dominating unfaired HPV racing. Highracers have a seat at about the height of the rear wheel, often using two large-size wheels. They find favor on sporty open-road rides among upright bikes.

The many different construction and design variants—mainly distinguished by frame format and steering position—are the result of the separation of steering, power, and support functions, which in upright bikes are tied together.

You might think the resulting constructions look unusual, but regular bike shapes are diverse as well—and growing more so every year. Just think of the differences between a classic touring bike, a full-suspension mountain bike, a foldable bike and a carbon-fiber monocoque aerobar triathlon bike.

We are only starting to realize how much variety cycling has to offer!

Ch. 1 History and Stories

Francis Faure on the Mochet track recumbent with small rear fairing. (photo: Mochet)

The Long Journey of the Recumbent Bicycle

Recumbent means "layed back." Layed-back travel has been the ideal since the beginning of mechanical transport. As the bicycle was modernized, recumbent versions developed along with it—with a few more twists and turns. Here's the story of how it all came to pass.

Until the end of the 1700s, people had only their feet, the horse and cart, and the ship for transportation. The locomotive of 1789 ushered in the new transportation of the Industrial Revolution.

The "running wheel," made in 1817 by the Baron of Drais, served as the initial pattern for all other bicycles. The Baron had been looking for some kind of transportation that would enable him in his job as a forester to maneuver between closely standing trees. Because neither a horse nor wagon with its side-by-side wheels was narrow enough, and because there was no appropriate vehicle available, he built something himself. Kicking or scootering along on two wheels created plenty of gyroscopic force to keep his craft from falling over.

With the innovation of the crank drive in the 1860s, the real bike was born, because the rider no longer had to have contact with the ground. A treadle was mounted on the front wheel, allowing much higher speeds. To increase speed even more, the front wheel was enlarged. The rear wheel was made proportionally smaller so that the machine would not be too long.

These riders sat at dizzying heights atop their bicycles, which were aptly called high-wheelers (also penny-farthings and ordinaries). The high-wheeler was suitable only for the small population of people who had enough balance and skill to keep the unstable bicycles on the road.

In 1884, Englishmen James Starley and William Sutton made the next decisive push in the development of the bicycle, the technical possibilities of the high-wheeler having been exhausted.

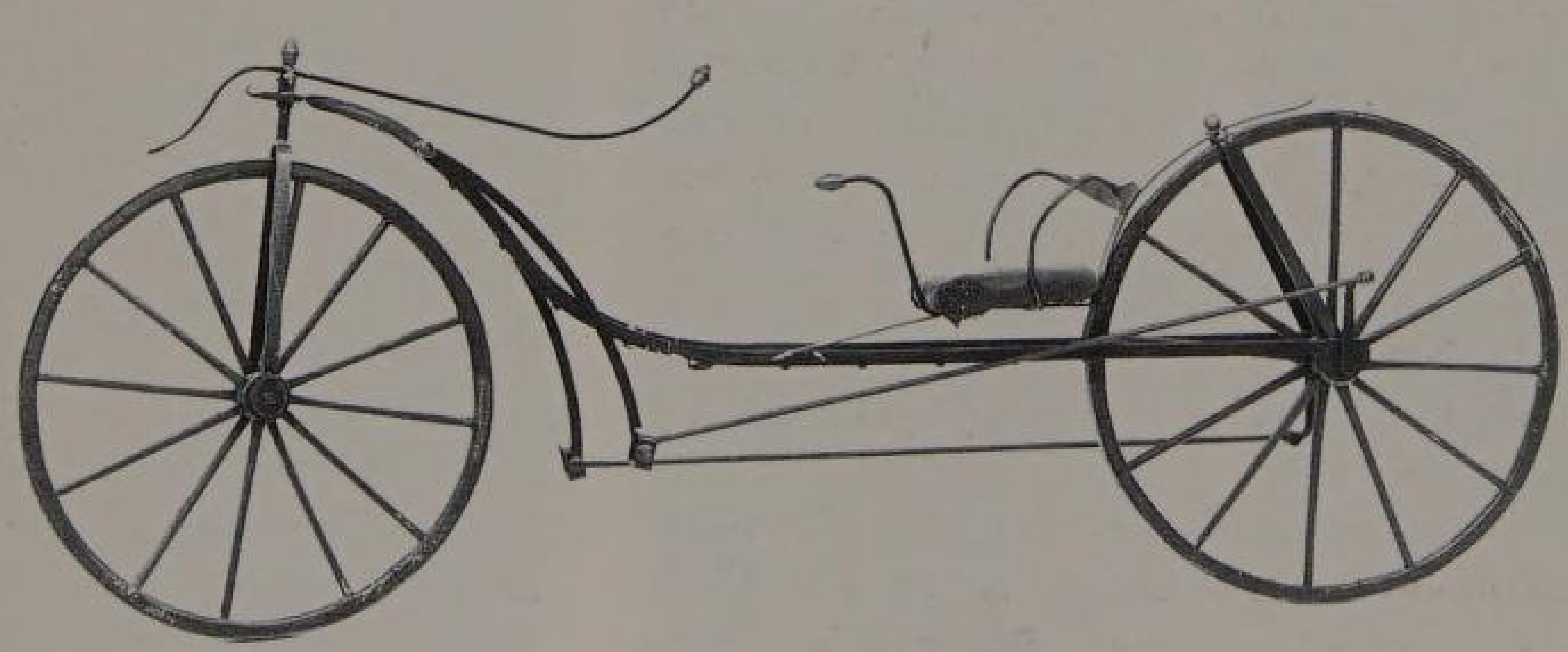
They invented the chain drive, which allowed the creation of a bike that was easy to ride, and faster still. The crank was moved from the front wheel to the middle of the bike and attached to a sprocket, which transferred power to a cog at the rear wheel through a chain. Both wheels were also now the same size.

The new center of gravity was no higher than that of someone walking, which made riding easy. Learning to ride the new safety bicycle was now possible for everybody. The high-wheeler, suitable for only daredevils, had evolved into a mode of transportation for the masses.

The magic word for speed was "translation." Translation—the result of stepped-up gear ratios—created the necessary increase in rotation speed despite the smaller wheels. This technical improvement was also beneficial to sports. Competition with the new bike was faster and more thrilling.

For strength and simplicity, frames were typically built in a pattern that has come to be known as a "diamond" frame.

In addition to numerous design modifi-



This crank-arm bike from 1869 could be viewed as an ancestor to the modern recumbent. At that time there was tinkering in many directions, but most of the ideas were cast aside. (photo: Museum of Engineering and Traffic, Berlin) cations meant for sport, the bicycle was also developed as a utility vehicle, used by mail carriers, bakers, and other workers. Manufacturers offered a broad range of accessories for the diverse needs of cycling tradesmen. The sporting aspect, however, provided the most fruitful ground for technical development.

Due to the continuing efforts of sports innovators, the importance of air resistance became apparent. This insight was responsible for the creation of fairings and several new riding positions in the early period.

The first illustration of a recumbent bicycle was printed in 1893 in the *Fliegende Blätter* ("Flying Pages"), a humor magazine from Munich. We see a rider sitting in a kind of lounge chair between front and rear wheels, smoking a cigar. A crank attached directly to the front wheel propels him, but there is no form of steering apparent. In the background, you can see two safety riders whose faces show more strain than the rider of the recumbent bike.

That same year, the "Fautenil Velociped," which is considered to be the first recumbent bicycle in the world, was built, using balloon tires.

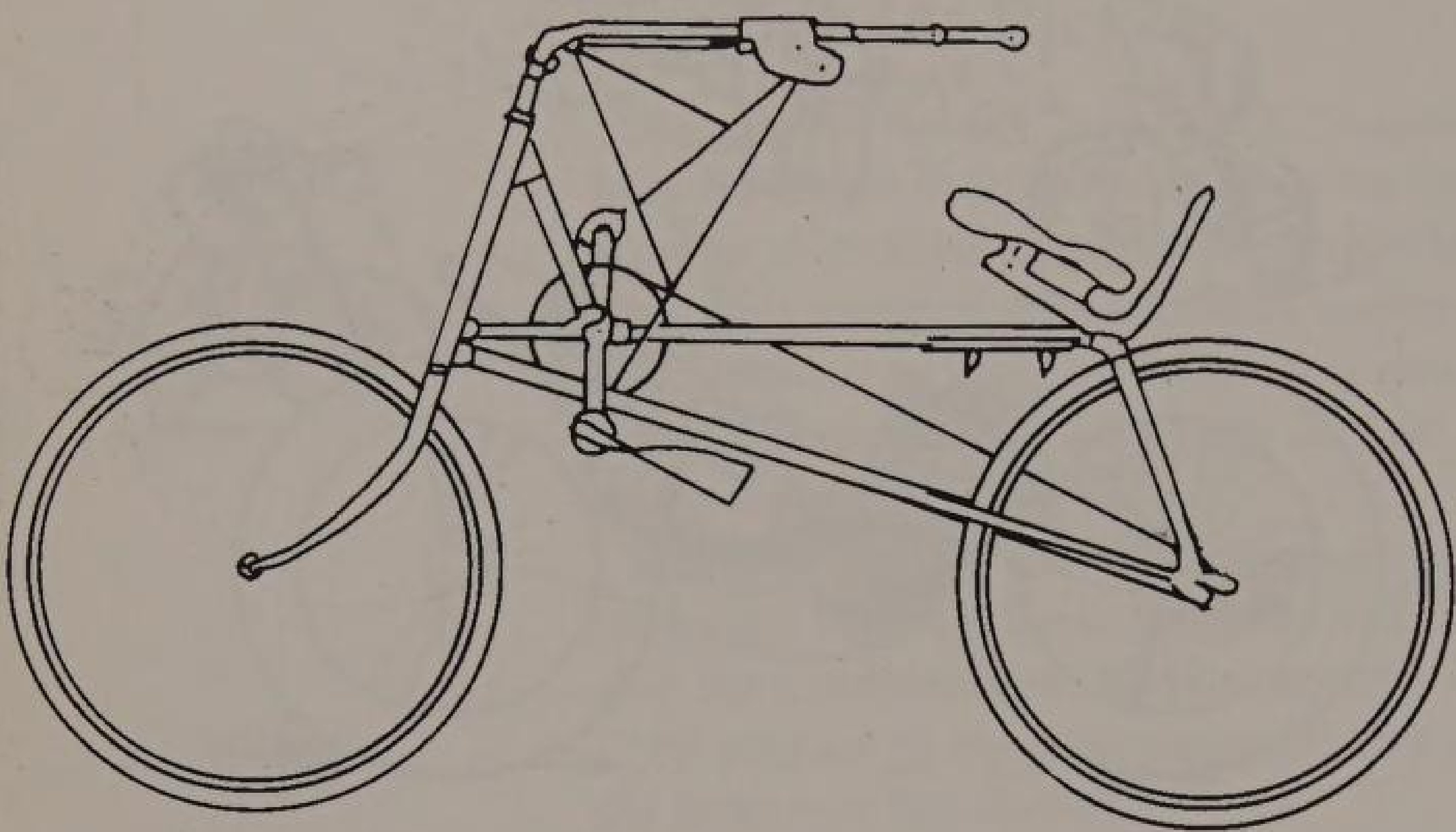
Following soon after, a large number of developments were made in the recumbent bicycle. In 1894, Joseph Turncock, an Englishman, applied for a patent for a recumbent bike. This bike had a rocker-arm drive, it was steered directly from a lying position, and it had a reclining seat above the rear wheel. Its appearance was very similar to the "Jaray bike," which was popular in the 1920s.

In 1893, an armchair-bicycle from the Swiss producer Challand was much admired at the bike salon in Geneva. It had two equally sized wheels, and an arm-and-leg drive. The seat was above the rear wheel, a little in front of the axle. I. F. Wales secured the U.S. patent for this bike in 1896.

At a time when there was no single dominating type of bike, experts discussed all these ideas with interest and an unbiased perspective. One of these was Paul von Salvisberg, who wrote the following in the newspaper *Radsport in Bild und Wort* ("Bicycling in Pictures and Words") in 1897:

This caricature from the Munich magazine Fliegende Blätter *("Flying Pages") of September 10, 1893, marks the debut media depiction of a recumbent, showing two straining upright cyclists while a recumbent rider strikes a relaxed pose. From this year on, horizontal pedaling was pursued with different models coming out worldwide.*

> An engineer from Geneva named Challand recently invented a new bike, which he has modestly named the "Normal Bicyclette," as in his opinion the rider is sitting in a normal position. The attached sketch, however, does not evoke an impression of normalcy, but rather creates feelings in the viewer similar to those evoked when people lean back in their chair as an aid for digestion while eating. If it continues like this, footstools and loveseats will soon also be furnished with foot-driven sprocket and chain drive.
>
> But let's listen to what the inventor himself has to say about the advantages of his new machine:
>
> *"The main power comes from the above-mentioned basis at the back of the seat, which the rider presses against less with his weight than with the strength of his legs. This is done with horizontal rather than vertical leg action.*
>
> *"In an upright, even reclining, upper body position, with a stable seat and completely uncramped organs, the rider can produce a*



In 1895, M. Challand introduced his first recumbent, which apart from a novel riding position, also had a revolutionary full body drive.

Challand's 1897 model appears to be more practical. It foregoes the full body drive in favor of a pedal crank. This machine fascinated the press. (Drawings based on article in Olms Press.)

force with his thighs which is approximately—and this is the inventor's conviction—three times his body weight with each leg. So for instance 2x3x150 kg [?], thus 900 kg. Simply amazing! (...)

"Moreover, the rider does not sit very high. A fall is less risky and less likely to happen than before. He easily steers with one hand, with the other one he can just as easily catch flies or eat apples. The brakes are not less unique, e.g. they have been replaced by a brake shoe which is sensibly mounted to the rear wheel. The powerful backpedaling option, by the way, makes braking seem to be an extreme stopgap action."

At the last exhibition in Geneva [1896], convincing tests were supposed to be conducted with this flying sofa. In spite of the enormous [?] translation of 4.52 meters [56.5 gear-inch], the machine, which was at the time constructed only with wood, ran very swiftly. The latest 1897 model is made of steel and weighs 12 kg [26.5 lbs]. The seat is adjustable, with the positioning of the legs at an angle of about 45 degrees from the horizontal being considered optimal.

Coming to the women's bikes, the matter is a little more tricky, and thus the beautiful sex is brought from the horizontal position to a more vertical one by a seat that is tilted forward more. This is supposed to be better against strong winds. (...)

Now there is nothing more left than to watch the happy inventor recline through the world for a few thousand kilometers on his Normal Chaiselongue.

Hail! v.S.

Soon after its first salon appearance, the experts recognized the advantages of the recumbent construction method. Even if there were some errors in their judgments (for instance the supposed advantages of shorter stroke lengths and improved aerodynamics of the vertical position on the women's bike—women being able to ride with skirts was probably the actual motive) you can find an overall view in favor of the recumbent bike, or at least a neutral opinion. These reviewers do not only give theoretical evaluations, they try to swing a test ride as well.

At the turn of the century, inventors like Challand and Brown laid the groundwork for recumbent bike successes in the 1930s.

Even in the 1800s there was a clear connection between the discoveries of aerodynamics and the development of drive mechanisms. Often the vehicles on display at shows would have some surprising new lying position or a totally novel drive.

Furthermore, from before the turn of the century up to the 1920s, there were attempts to develop a more comfortable bicycle based on the regular diamond-frame bike with 27- or 28-inch wheels.

In 1897 a "Mr. Darling" entered the scene with such a model. His belly-recumbent bike was based on an already existing diamond-frame bicycle that he modified. Extensions were brazed to the chainstays, and the bottom bracket was positioned between them, behind the rear wheel. From there a tube curved upwards around the rear wheel to the seat tube; halfway there it was supported by two stays leading to the rear dropouts. Instead of a saddle, a belly rest was mounted to the top tube.

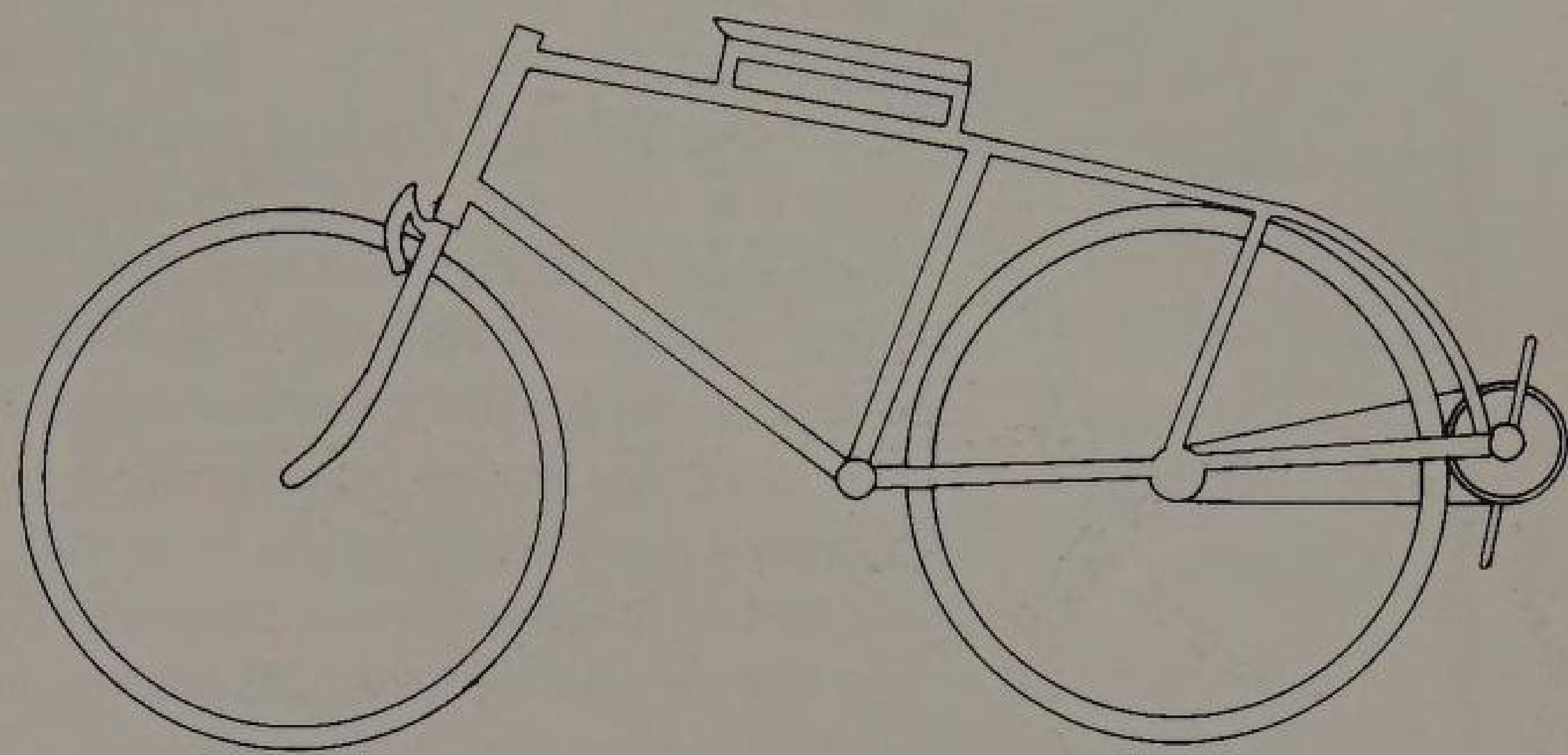
The handlebar was moved down to the fork crown and the stem removed. This design made cheap production possible, as it was based on a regular bike frame, and few special parts were needed.

Belly bikes (or prone recumbents) played a significant role in the development of aerodynamics in land vehicles, but although thrilling to ride (for awhile) they have never been popular. One reason for that might be their biomechanics. Neither the rib cage (and thus lungs) nor bowel or stomach function well under the burden of body weight.

Prior to the 1990s, the last production of a prone recumbent took place in 1955. Italian world-champion Enzo Sacci tested a model of Italian origin, without particular success. There have been admirable recent prototypes and race results (including a hill-climb win) but no production models.

Designs using the rider's buttocks and back as pressure points have been the key to recumbent success. These bikes are comfortable and quick. They can compete very well against safety bikes.

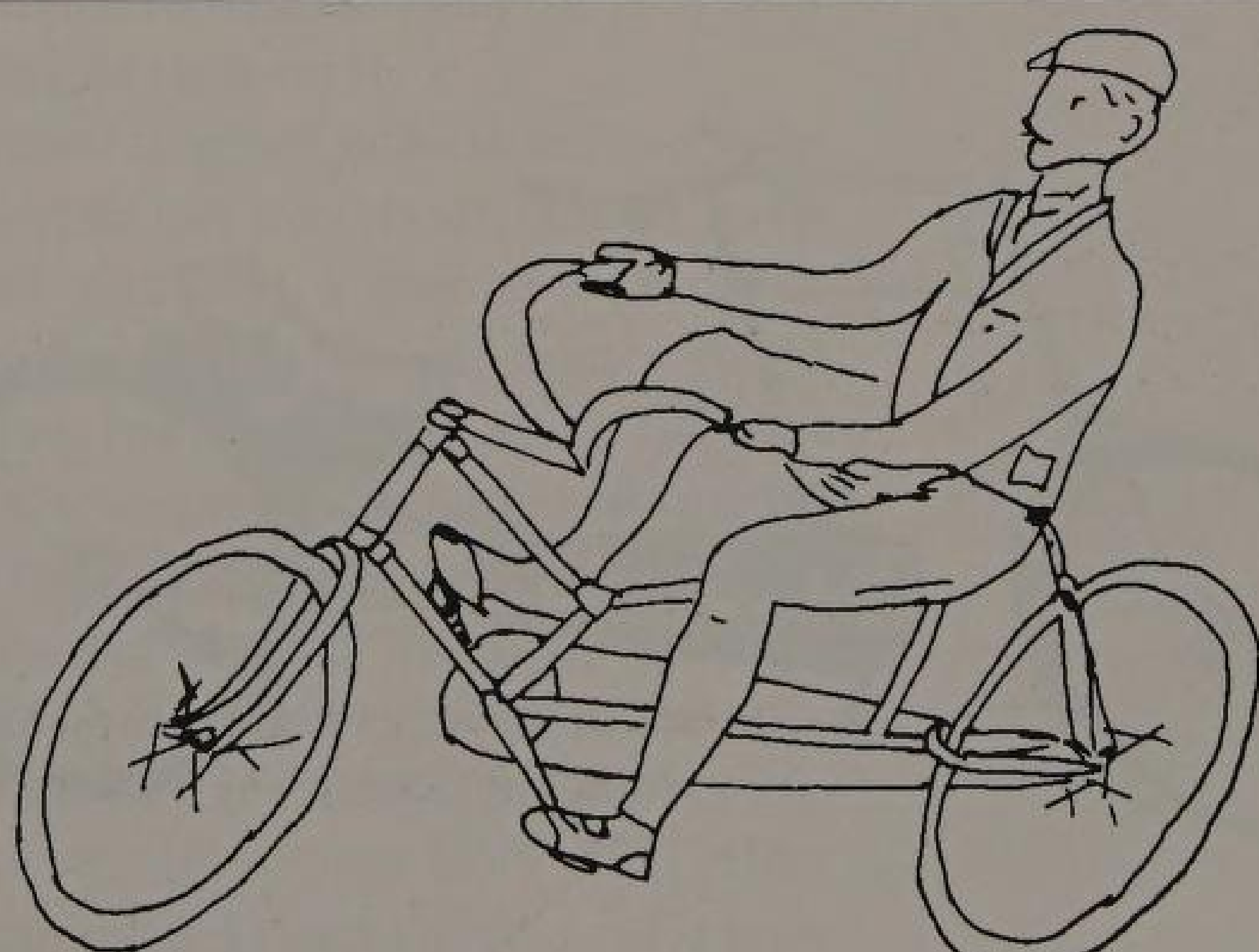
Like the "Darling Bike," the American "Brown Recumbent" was based on a modified diamond frame. It consisted of the front part of a women's bicycle connected to the rear part of a men's by means of a few extra frame-tubes. The handlebar was oddly shaped and mounted for normal direct steering to a reversed stem through a headset to the fork.



"Darling" belly recumbent, 1897.

Riders sat relatively upright on the Brown, allowing a relaxed view of traffic and scenery, and the center of gravity was at a normal height and position. The Brown was exported from the United States in 1901, some models being shipped to England.

The recumbent of Englishman P. W. Bartlett was presented in the September



This sketch is the only thing known about the American "Brown" recumbent, 1901.

1905 edition of Scientific American. Bartlett announced the bike to be as "comfortable as a rocking chair." The bike was very compact: The rider sat on a leather seat above the rear wheel and pedaled the cranks, which were 18 inches lower and between the two wheels at the height of the rear wheel hub. The handlebar was mounted under the seat. Stopping the bike must have been tricky as the seat, at 30 inches above the ground, was beyond toe-touching. On the other hand, a short wheelbase in connection with a lack of steering lock-up allowed for a very tight turning radius.

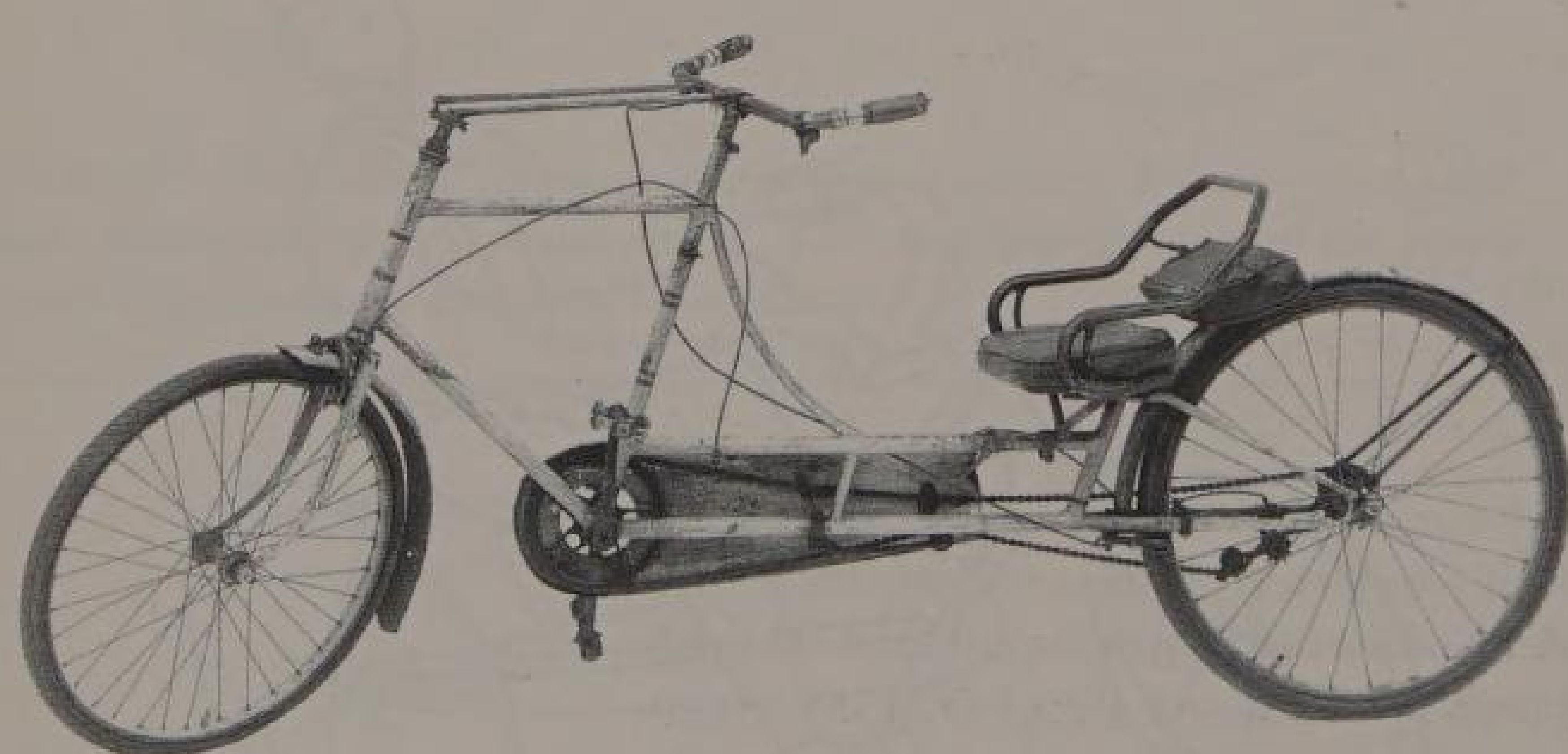
Attempts to mass-produce a recumbent in Europe Prior to WWI, came to nothing. The interest of the media and sports fans was more focused on faired diamond-frame racing bikes.

The first European production recumbent was built in France in 1914. In frame shape and construction it very much resembled the Brown. Interestingly, it had one of the first shifting mechanisms. The wheel sizes were very unusual for this period: 22-inch in front and 26-inch at the rear. This unpedigreed bike is attributed to Peugeot, but there is no evidence for it.

In the 1920s the Jaray recumbent bike from the Hesperus factories in Stuttgart was sold successfully without being intended for sports. It was also distributed in Holland and Switzerland. The unusual rocker-arm drive of the bike should be noted. Paul Jaray (1889-1974), the German zeppelin builder and inventor of streamlining, oriented his frame design toward the contemporary normal bike frame. The rider sat on an extra-cushioned seat high above the rear wheel. The rocker arm drive was run by a kind of "triple gearshift": three pairs of foot rests mounted to rocker arm levers could be chosen to produce the desired speed. Additionally, it had either a 2- or 3-speed Torpedo multi-shift hub at the rear wheel. In this way, six or nine different gears could be selected. The variety of gears made the J-Bike special, and can be seen as a reason for its (relative) success. The restricted recumbent position creates a desire for more gears and wider ratios, and many producers of the time could not do justice to this requirement.

"Brown" Recumbent

Front wheel:	25 inches
Rear wheel:	28 inches
Gearing:	2.134 meter
Weight:	30 lbs.
Steering:	direct
Wheelbase:	67 inches



The first mass-produced recumbent: France 1914. (photo: Museum für Technik and Verkehr Berlin)

In the 1920s Weiss & Co. Reform Fahrradwerke of Stuttgart produced a recumbent that was very similar to the J-Bike. They opted for the proven chain drive. By ovalizing the front chainring, the engineers created an energy-saving way of powering the bike.

Symptomatic of all recumbent bike development until the 1970s is the absence of commonality. Cooperation among engineers was unheard of throughout the long decades. New designs were rarely developed from already existing ones. As a result, the development of the recumbent bicycle proceeded slowly and commercialization attempts went up in smoke time and again.

Georges and Charles Mochet

A milestone in HPV (human powered vehicle) history is found in the inventions of Frenchman Charles Mochet. Before WWII he built light vehicles driven by engine. One day he made a cart with a pedal drive for his son. His wife encouraged him because she thought that ordinary bicycling was too dangerous for little Georges. Papa Charles tested his construction and fell in love with motorless speed. He soon realized that there was a market for vehicles like this since automobiles were too costly for most people.

Realizing that some of the comforts of a car could be met in a pedal-drive vehicle, he designed a four-wheel bike with a lightweight sheet metal body in which its two occupants would sit next to each other. His invention was much cheaper than an automobile, and the maintenance would only be that of two bikes.

Demand for his vehicles rose at the beginning of the 1930s, and development proceeded apace. Charles Mochet's plans were always very complex, but carefully conceived.

Georges eventually joined the family business. Discussions with the public caused him to produce a vehicle with three wheels, and later with just one seat. That recumbent tricycle had a wheelbase of 57 inches and 19.5-inch wheels. The crank bearing was behind and above the front wheel, and power was transferred from the crank to an intermediate drive under the seat, then to the rear wheel.

A two-wheeled model called the "Velocar" was also built. It had a seat 22 inches above the ground and right in front of the rear wheel that was tiltable and horizontally adjustable. The crank was located 3 inches higher. A shaft connected the 15-inch-wide handlebar with a universal-joint at the top of the headset of the fork.

At first, French bike racer Henri Lemoine tested this bicycle. Whether it was because of the ridicule of his sports comrades or the bike itself, Lemoine lost his interest after a few rides and turned back to his racing bike.

Then Francis Faure tested the bike. He is said to be the first pro racer who was really interested in a recumbent, and the first who was willing to train on it.

His friends laughed at him, but when he accelerated he left everybody behind, even though he was only a second-class track racing professional. His colleagues could only follow him with their eyes, flabbergasted. Its low construction made it impossible for his friends to draft him.

After further testing, Mochet wondered whether his bike might conform to the official rules of bicycle racing. On October 26, 1932, he wrote to the UVF (L'Union Velocipedique de France) to find out which conditions his machine must meet in order to be admitted to the record races and rac-

The "Jaray" bike was the first recumbent that had commercial success in German-speaking areas. Ladies versions were available with a child's seat.

Manuel Morand easily leading a French road race paceline at 30 mph, according to the photo caption in "Le Miroir des Sports," June 19, 1934. (Courtesy of Aldo Ross at Wooljersey.com/gallery/aldoross.)

Mochet: Touring model of 1936

Wheelbase:	57"
Seatheight:	22"
Wheel diameter:	20"
Handlebar height:	40"
Seat width:	14"
Crankarm length:	170 mm
Chainring:	46 tooth
Intermediate gears:	18/22 tooth

ing in general. The officials of the UVF eased his doubts in a reply on December 27, 1932, and approved the bike. It was allowed because it did not have any device for reducing air resistance, which was forbidden according to the rules.

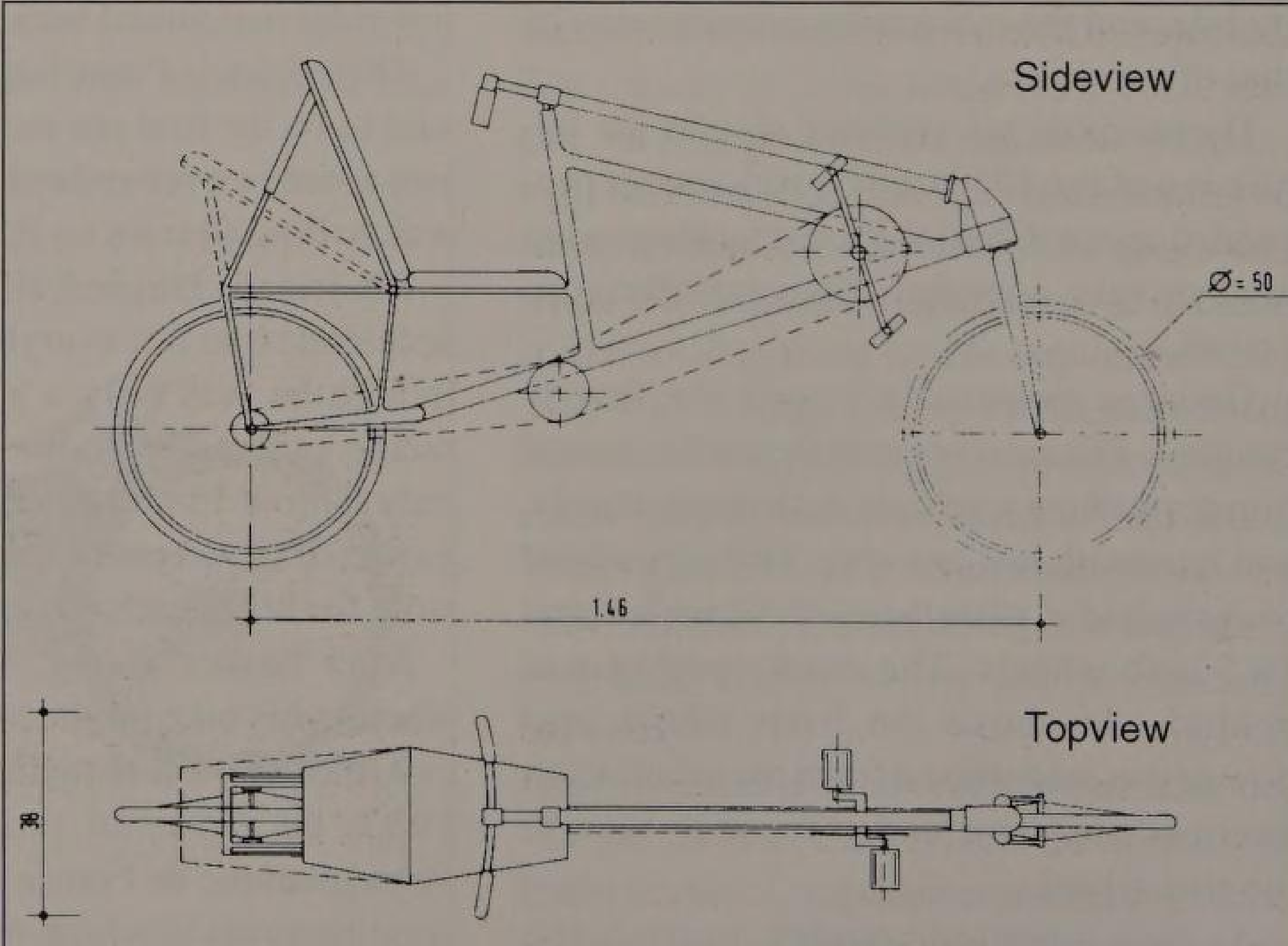
Georges Mochet now set out to beat the one-hour record held by Oscar Egg. Faure, his rider, accomplished this on July 15, 1933, at the Parc des Princes Velodrome in Paris. On that day, Faure rode 27.9 miles in an hour (45.1 kilometers)—a new world record. Five years would pass before a racer on an "ordinary" racing bike was able to reach an average of 28 mph.

The record is even more amazing when you consider that Francis Faure did not belong to the cycling elite. *Cycling* magazine described him as "having no pretensions as a star speedman."

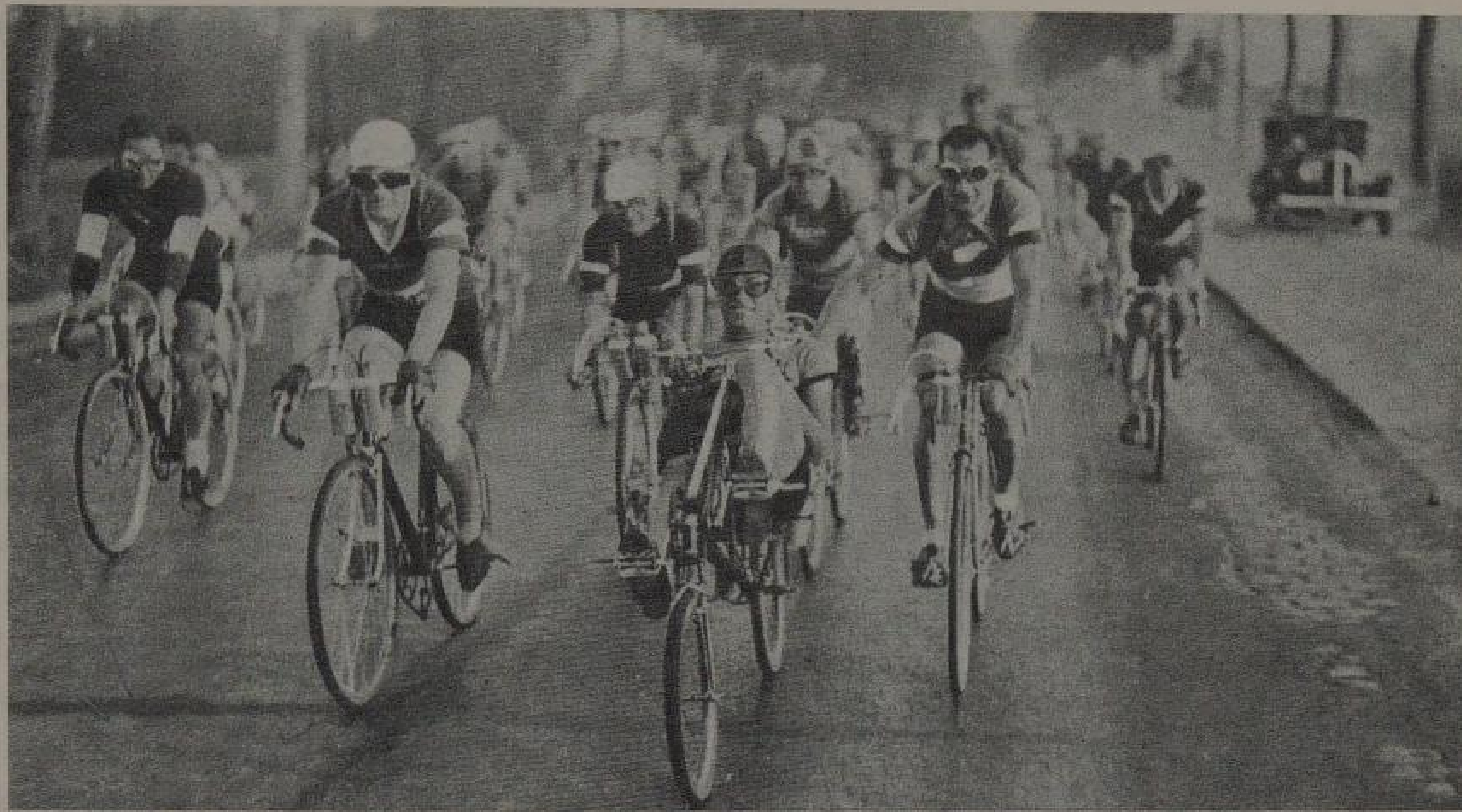
The record lasted barely two months. On September 9, 1933, Marcel Berthet, who was the advanced age of 47 years old, managed to go 48.604 kilometers on a faired upright racing bike. This record caused some people to question whether faired bicycles complied with UCI (Union Cycliste Internationale) rules for admission.

At this time, Charles Mochet wrote a letter to the UCI in which he stated his position about their impending decision about fairings. He thought it would be unjust if any new rule on fairings would also result in a ban on recumbents.

"What is the recumbent bicycle being reproached for? That its rider lays on his back? Advancements are characteristic for technical sports, that is but natural, and everybody benefits! Everybody can pick his bike, buy a recumbent model, build one or have one built. The idea of special races for re-



Construction sketch of the Velocar (drawing: Bernd Kessler) cumbent vehicles is unjust, because races exist to find out who and what is better. If the races are separated, it will be impossible to show that the recumbent bike is better! Therefore it should be allowed to participate. A prohibition violates the rule of fair play and simple logic. How can any titles be distributed in the future if one knows that there are new and better things? If the recumbent bicycle is a mistake, it will disappear just as it has arrived, and it will be soon forgotten. But if Chance decides that it represents progress from which riders benefit, then I am sure that the UCI does not want to take responsibility for preventing the recumbent bicycle from proving itself! In this hope he [the delegate to whom this letter is addressed] should act accordingly!"



Manuel Morand in the early part of a race, with future Tour de France winner Roger Lapebie playfully holding him back. (From "Le Miroir des Sports" June 19, 1934. Courtesy of Aldo Ross at Wooljersey.com/gallery/aldoross.)

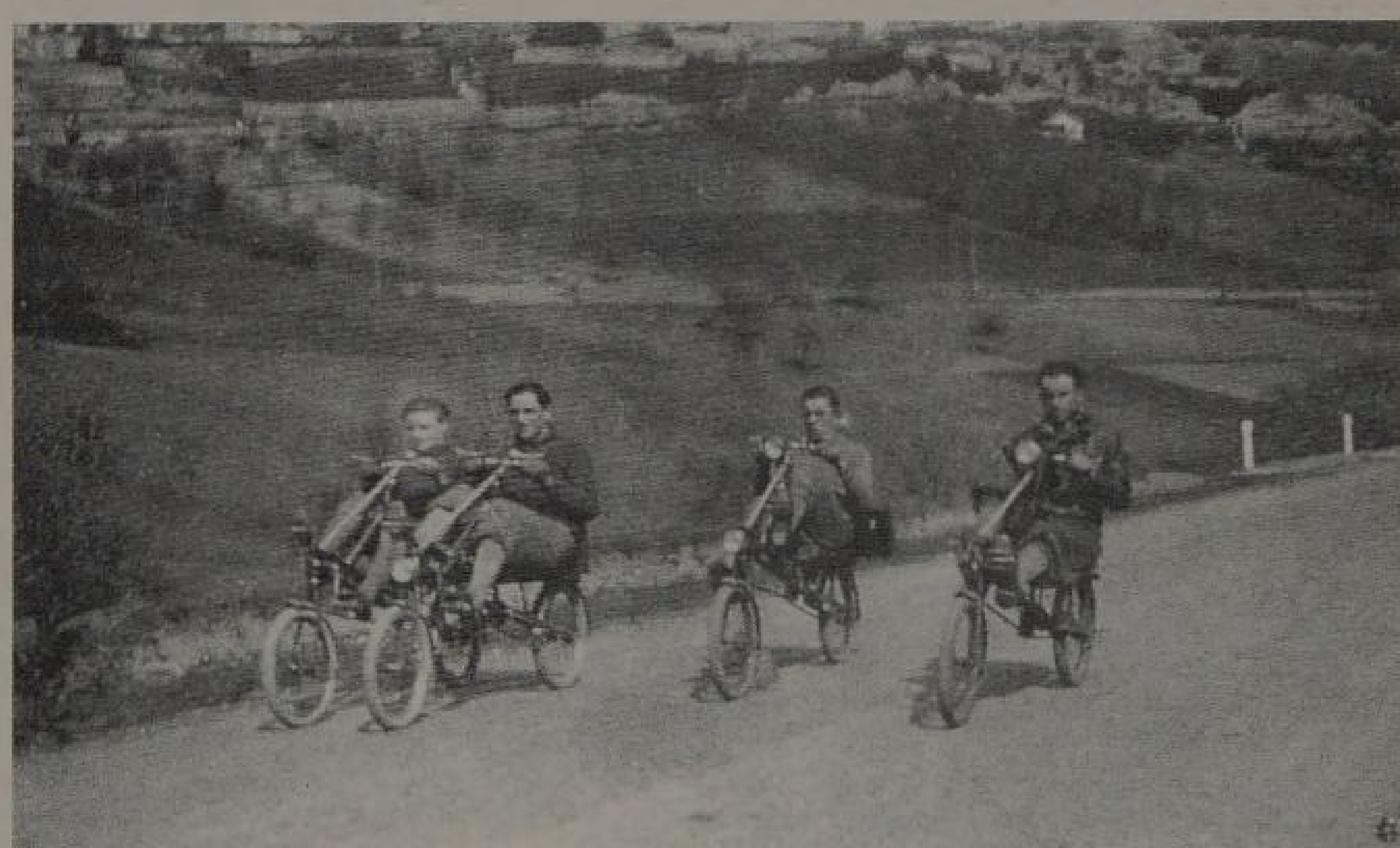
On February 3, 1934, a questionable discussion took place at the 58th UCI Congress, followed by a vote. The debate was about the rules that were to define the form and character of racing bikes.

Henri Martin, an amateur racer and Mochet factory worker, rode a recumbent bicycle around the conference table to demonstrate that such bikes were comfortable, safe, and usable. A representative from England predicted a great future for this design.

But the Italian Bertolini held a different opinion. "This is not a bike," he said, but he could not give a reason for his opinion when the others pressed him. The Frenchman Rousseau supported the Italian. He also thought that a recumbent bicycle did not conform to the definition of a bicycle.

The recumbent bicycle was thus excluded from the main official races by a new definition of the racing bicycle. A separate category was created for bikes that didn't comply with the usual bicycle regulations. The league was thus divided into two classes, one limited to diamond-frame ordinaries with no adaptations, the other for vehicles with aerodynamic adaptations. These changes were ratified and put into effect later that year by a vote of 58 to 46.

There were nagging rumors that the vote might have ended differently if Mochet and Faure had united a bigger lobby behind them



Four recumbent cyclists enjoy a rural Velocar excursion in this photo from the 1930s. (photo: Mochet)

Plassat, Lemoine, and Francis Faure, held by his brother Benoit Faure, at a velodrome, Feb. 20, 1934. This was one of the last races of recumbents against racing bikes, because six weeks later the UCI prohibited mixed events. (Note that Faure's 28-mile unfaired recumbent hour record still stood as of May 2005!) World-champion boxer Al Brown fired the starting pistol here. (Photo: Mochet)

or if more famous riders had achieved the records and wins.

For that last summer the unfaired "Velocar" kept up its good results. The professional Spanish racing cyclist Manuel Morand was hired by Mochet and got several top placings, including an 8th, on his own in pro races against upright racing teams.

"Live happy, live horizontal!"

Francis Faure, winner of the Vel d'Hiv' race, accepts his fate.

(from Auto, *February 20. 1934.)*

To assess the situation at that time one has to remember that the recumbent bicycle was admitted in 1932 by the UVF with the remark that it did not have any added aerodynamic parts. In 1932 the bike had been in the spotlight only briefly and insignificantly, and officials did not see a reason for a prohibition. In 1933, when the bike achieved a sensational record, things suddenly looked different, and this "weird" bike condemned all subsequent models to live in its shadow. Admitting the "velo horizontale" might have meant the end of the diamond-frame era.

In the press, especially in the biweekly French bike magazines of high circulation, the decision by the 58th Congress of the UCI was thought to be important, even before the vote. Caricatures and sarcastic articles questioned the appropriateness of the recumbent bicycle, or gossiped about the hunchbacked bikers on "old-fashioned" racing bikes, or they depicted Faure sleeping on his Velocar at a record-setting pace.

While the majority of the UCI voted against the recumbent bicycle, the print media offered a different picture. Advocates and enemies used the weapons of reporting and commentary. Thus the interested reading public of cyclists, whose sporting future depended on the decision, developed a multilayered and wide field of opinions.

In the December 20, 1934, issue of the German magazine *Der Radfahrer* ("The Cyclist") the "Peter Pedal" column from an English magazine was discussed. It told of a "revolutionary deed that will not be without consequences in the field of biking." It went to say: "In any case, one is convinced that the Velocar is, in France and Paris, the bike of the future, and that it will replace today's bike types. Maybe the French are correct in these assumptions, especially when we think back to all the difficulties the high bike had to fight against when it was introduced."

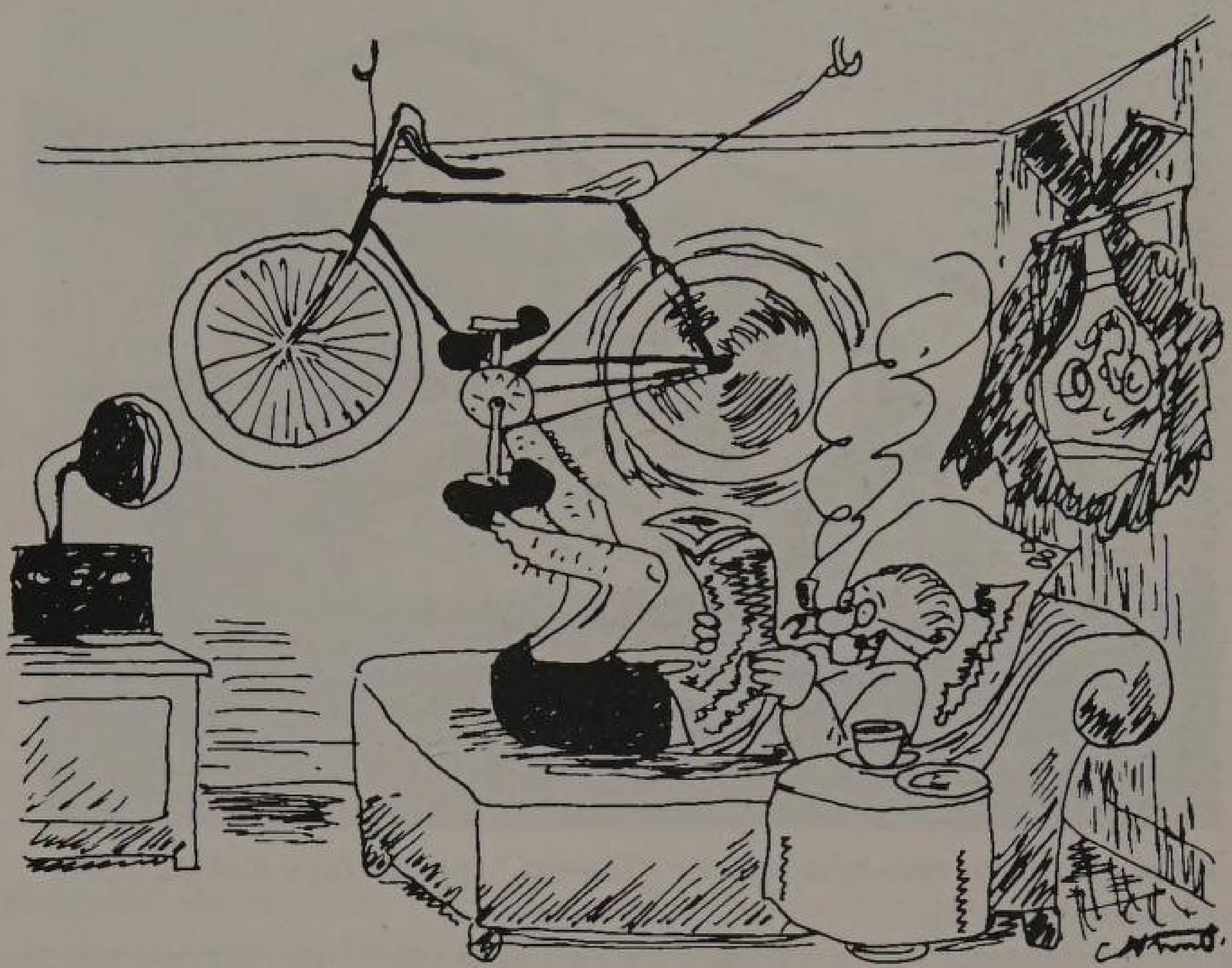
Some papers made sensational discoveries. A newspaper article from December 1933 mentions a recumbent bicycle that was seen, according to the text, in Paris in 1914: "The origins of the horizontally ridden bike, even today, have not been traced. It is known for certain that this machine dates back to a much earlier period than two years ago, when professional racing on it became more common. The photo, which we have reproduced here, should assuage all doubts. In 1914, a young Italian named Guglielmo went to Paris to show an awkward device that clearly reminds us of our Velocar. As he could not make his invention flourish in Italy, he tried to market it in Paris. He met a Monsieur Benaben, who laid the foundation. But then the war came. Monsieur Benaben, a captain of infantry, was killed right at the beginning, and the invention lay fallow."

Despite the UCI's final decision on April 1, 1934, Charles Mochet continued to experiment and construct. He died on June 3, 1934. From then on Georges Mochet continued the work. He built a special recumbent to be used with a fairing. The front wheel was made smaller and the seat was lowered to only 12 inches above the ground. And again it was Francis Faure who tested the bike on the racetrack at the Vel d'Hiver in Paris.

On this 4-kilometer-long track he made his first run without the fairing. It took him 5 minutes and 20 seconds, which put him at the pace of a racing cyclist.

For the next attempt Faure used the fairing. With this change, he gained 2 mph, and he managed to average a speed of 30.8 mph despite of the weight of the 22-pound fairing.

Francis Faure was surprised by the good handling of the horizontal bike even though it was so heavy and, due to the fairing, so big.



"A bicycle, as ridden by Francis Faure, enables you to practice in the horizontal, half asleep." (from a badly-preserved excerpt of a Danish paper)

"I like this position a lot, but isn't it possible to put a small engine underneath?" (from a French newspaper)

Three-quarter profile of a Velocar "Tourist." (photo: Ingo Kollibay/Bike Museum Einbeck)

For the next attempt the fairing was altered: The openings toward the ground were minimized. Now, the 4-kilometer test track was ridden in 4.32 minutes: 33 mph.

Mochet realized the significance of the fairing and tried to shave more time by continued optimization. The lacquered fairing surface was smoothed and polished. Thanks to such slipperiness, the 55-kmh barrier (34 mph) was surpassed by 0.4 kmh. An official record attempt was supposed to follow, but it failed. The air stream caused problems with the rider's eyes because his head was exposed outside the fairing. To shield his eyes—and to gain even more speed—it was decided that he should ride with a fairing that covered his head.

With the new fairing Francis Faure was able to achieve a time of 4 minutes and 20 seconds—56.5 kmh / 35.1 mph—on the Mochet recumbent.

Before WWII there was a duel for The Hour called the King's Competition. Berthet, the former professional cyclist had set the world record at 49.994 kmh (31.1 mph) with a fully faired upright racing bike (Velodyne No.1) in 1933. Who would be the first to exceed 50 kilometers (31 miles) in an hour? Mochet and his rider and Berthet each wanted victory for their side.

On March 5, 1939, Faure and Mochet went to the official racetrack of Vincennes, close to Paris. Francis Faure was victorious with the faired recumbent, finishing a distance of 50.337 kilometers in 60 minutes. By the end of the 1930s, an ordinary unfaired racing bike had only reached an average hour speed of 45.84 kmh (28.48 mph).

This overall HPV record remained unbroken until 1971. Georges Mochet was satisfied with the success and decided to produce the Velocar for sale.

Demand rose during the war years, when people had even less money for a car but were still looking for a vehicle that was more advanced than a normal bike. A handful of other recumbent bicycle producers then on the scene—Triumph Moller, Cyclo Ratio, and Sofacykel—also took advantage of this demand.

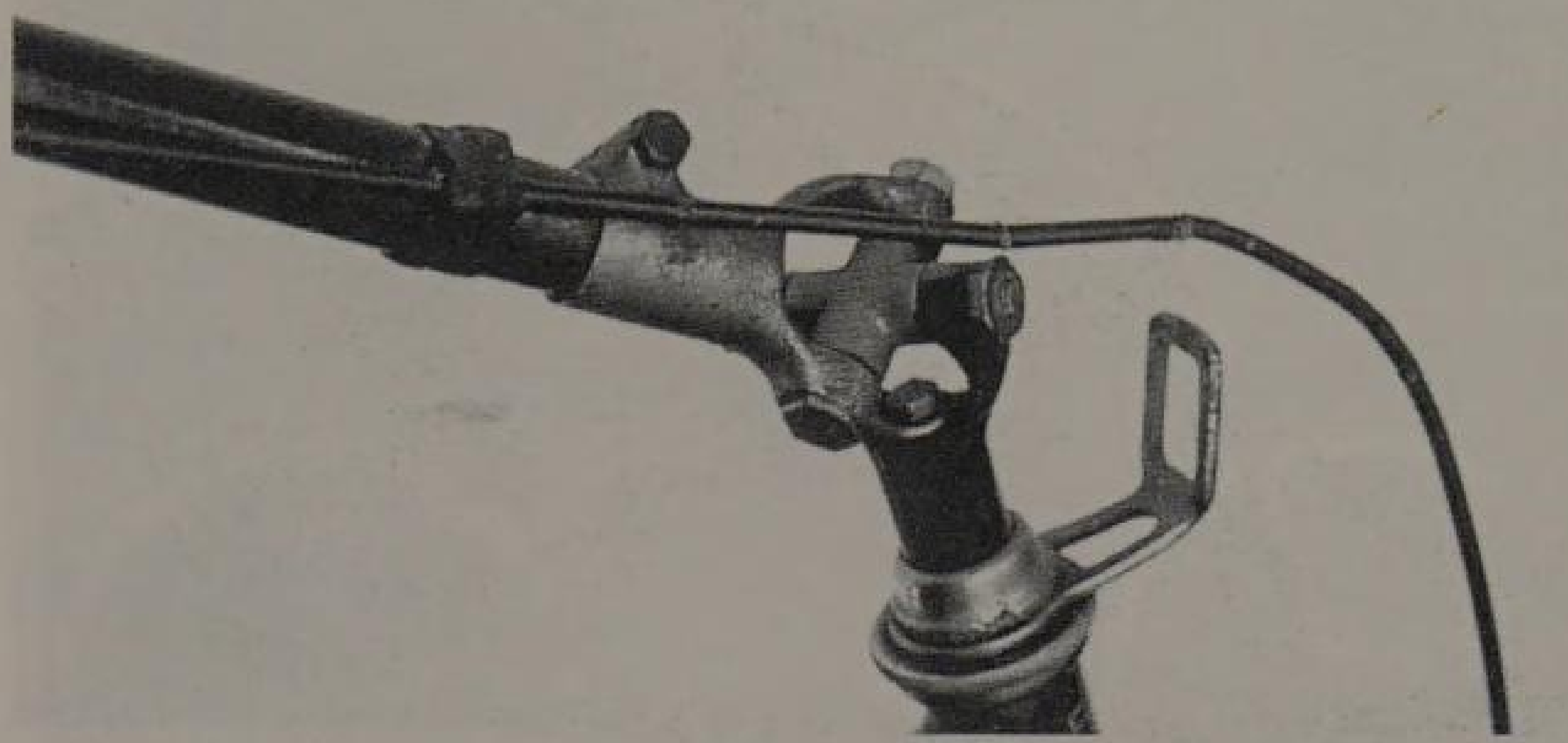
The Danish "Sofacykel" from 1935 has a "crank forward" design. Back to the future! Not a real recumbent, it nonetheless had a special position in the bike market and can, historically speaking, be categorized as a semi-recumbent. The handling is extremely slow due to the shallow head-tube angle. A spring dampens fork-flop when turning.

Other European Producers of the 1930s

The activities of Charles and Georges Mochet dominated the 1930s, but there were numerous other recumbent bicycles in France and the rest of Europe. From the Velocar's homeland came the "Sport-Plex" long-wheelbase recumbent (*LWB*: so termed because the front wheel is placed beyond the cranks). Also, a Frenchman named M. Villard made a recumbent that was specially tailored for transporting and delivering newspapers. The basic construction resembles the Triumph Moller, with the addition of a box for papers. The low position of the paper carrier puts the center of gravity close to the ground, for easy on-the-job handling.

Companies in England also experimented with the idea of bicycles ridden in a lying or sitting position.

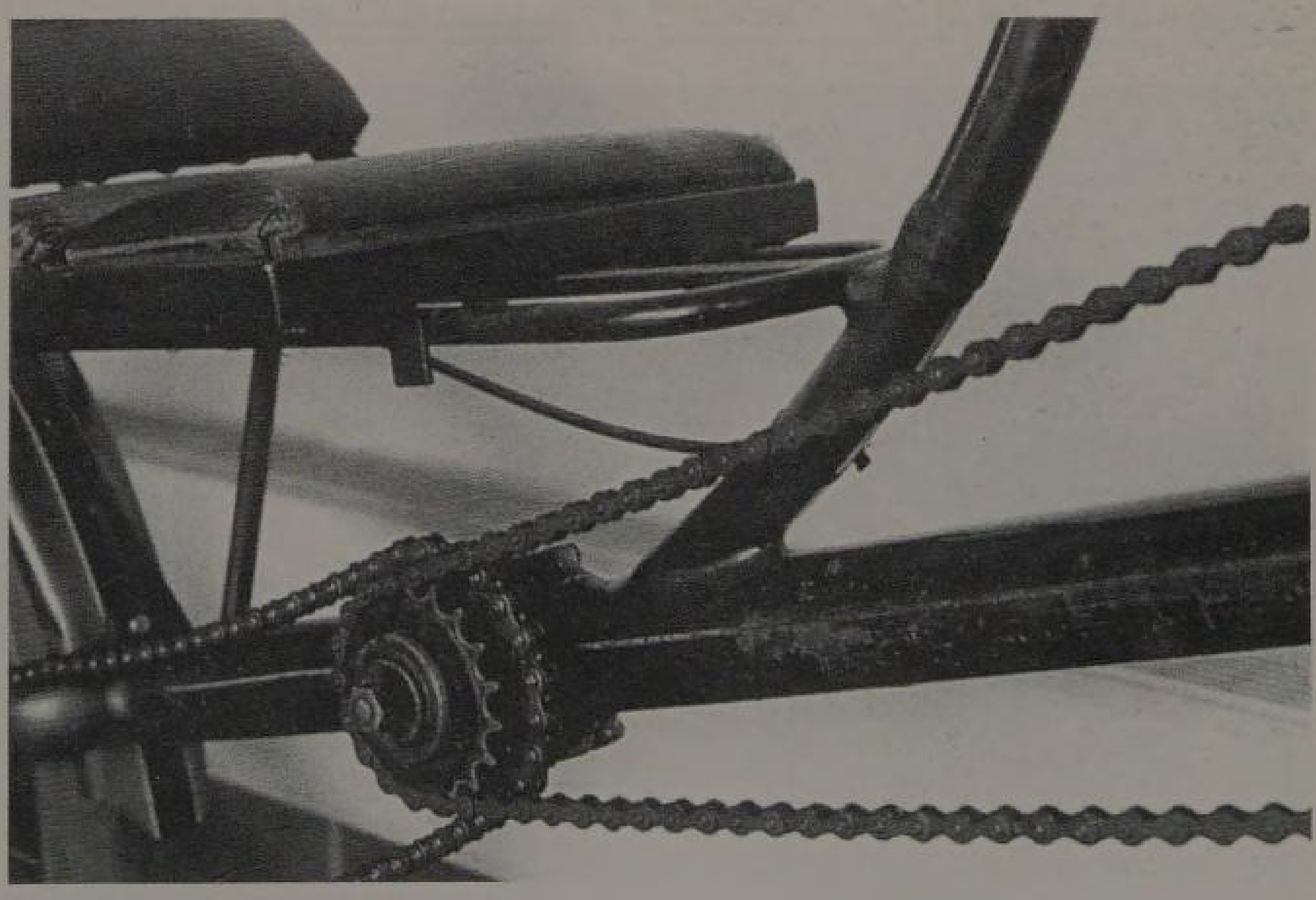
The British have always been innovative bike developers: they developed the pedal drive, the first butted steel frame tubes, and the crossed spoke. In August 1934 the technical expert of the English bike magazine *Cycling*, A. C. Davidson, presented a home-made recumbent bicycle that consisted of mostly standard bicycle components. Only two weeks later F. H. Grubb went public with what he claimed to be the "first English recumbent cycle." He was a well-known British frame-builder. His bike weighed approximately 30 pounds, had two 20-inch wheels, and a wheelbase of 60 inches. At 75 degrees, the head tube angle was relatively steep. The fork trail was 2.5 inches for solid handling. The bike was a long-wheelbase recumbent with indirect steering and an upright seat only 16 inches above the ground. Since the crank was even lower than the seat, the pedals could hit the pavement during turns. Leg-length adjustment was accomplished with an adjustable seat. The bike was sold under the name "Kingston Recumbent."



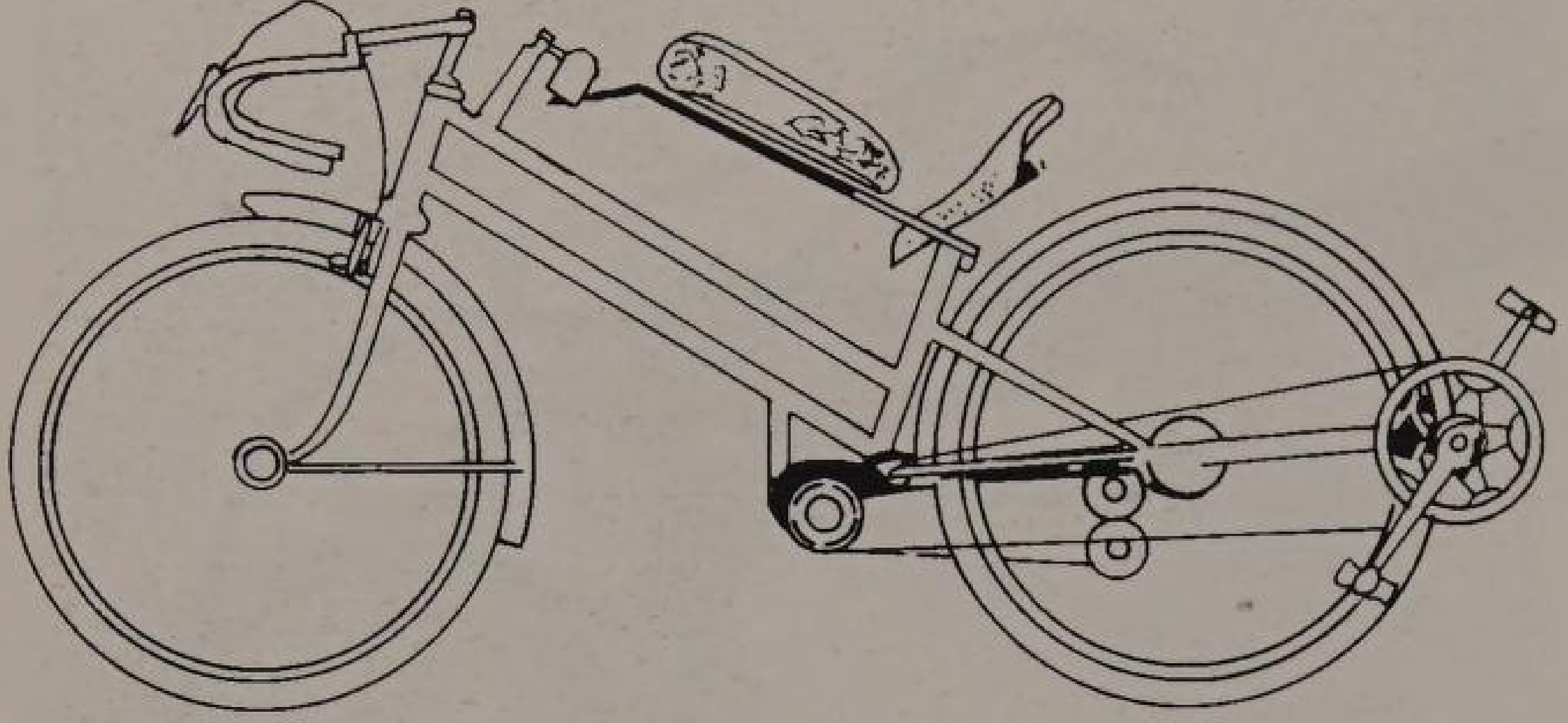
The delicate steering joint of the Velocar "Tourist" wore out easily, resulting in a lot of play. (photo: Ingo Kollibay/Bike Museum Einbeck)

In the summer of 1935, Jack Sibbitt built a recumbent prototype. In October of the same year, *Cycling* reports the following about the Paris bike salons: "On display were a multiplicity of horizontals as well as the Alcyon horizontal tandem."

In Denmark, Holger Moller, who had worked in the automobile industry for 20



A close-up view of the "Tourist" intermediate drive with adjustable tension. To adjust chain tension, you could slide the cogs on the main frame-tube. (photo: Ingo Kollibay/Bike Museum Einbeck)



The Dynacycle belly recumbent was supposed to be an improvement of the famous "Velocar." In practice it didn't succeed

years as a steering expert, developed a long-wheelbase recumbent with a steering wheel. A steering dampener gave a quiet ride on the rough roads of the time. Clever construction enabled riders to adjust the bike to their size. The inventor called his bike a "family bike," and it was built by the Grant Company. The bike museum at Oldenburg displays a model with wheel suspension. In cooperation with an English company this bicycle was also distributed in Britain under the name "Triumph Moller."

The 1934 "Cyclo" recumbent had 20-inch wheels and two gears. (photo: Mark Hall Cycle Museum)

In 1934 one could also buy the "Cyclo" in England, which was a long-wheelbase recumbent bicycle with over-seat steering and 20-inch wheels. The technical innovation of that model was that it had the first Cyclo two-speed chain shifter.

In the same year in which the Triumph recumbent entered the market, the Cyclo Gear Company itself presented a short-wheelbase recumbent bicycle (*SWB*: so termed because the front wheel is behind the cranks and closer to the rear wheel). This model was sold under the name "Cyclo Ratio." It was based on the "Ravat Horizontale" from France, which had already been successfully marketed there.

In 1936 Frenchman F. Albert Raymont registered a patent for the Ravat in England. He exhibited it at the Bicycle Salon in London. However, the Cyclo Gear Company drove it from the market.

The Cyclo Ratio riders were very good at track events and, with assistance from the bike's high-tech equipment, could also climb the hills of Great Britain. These bikes were equipped with the excellent Cyclo four-speed shift. An eccentric, adjustable crank bearing (used nowadays on tandems to adjust chain tension for the synchronization chain) sufficed for the fine-tuning between rider and bike.

Ravat: Cyclo Ratio

Rear wheel:	27.75"
Front wheel:	18.4"
Seat height:	27"
Crank height:	28"
Handlebar height:	47"
Wheelbase:	32"
Tube diameter	.75" x .4" (oval)
Frame length:	66"
Weight:	32-35 lbs

The rear brake was also very interesting and resembles Shimano's aero-brake of the 1980s.

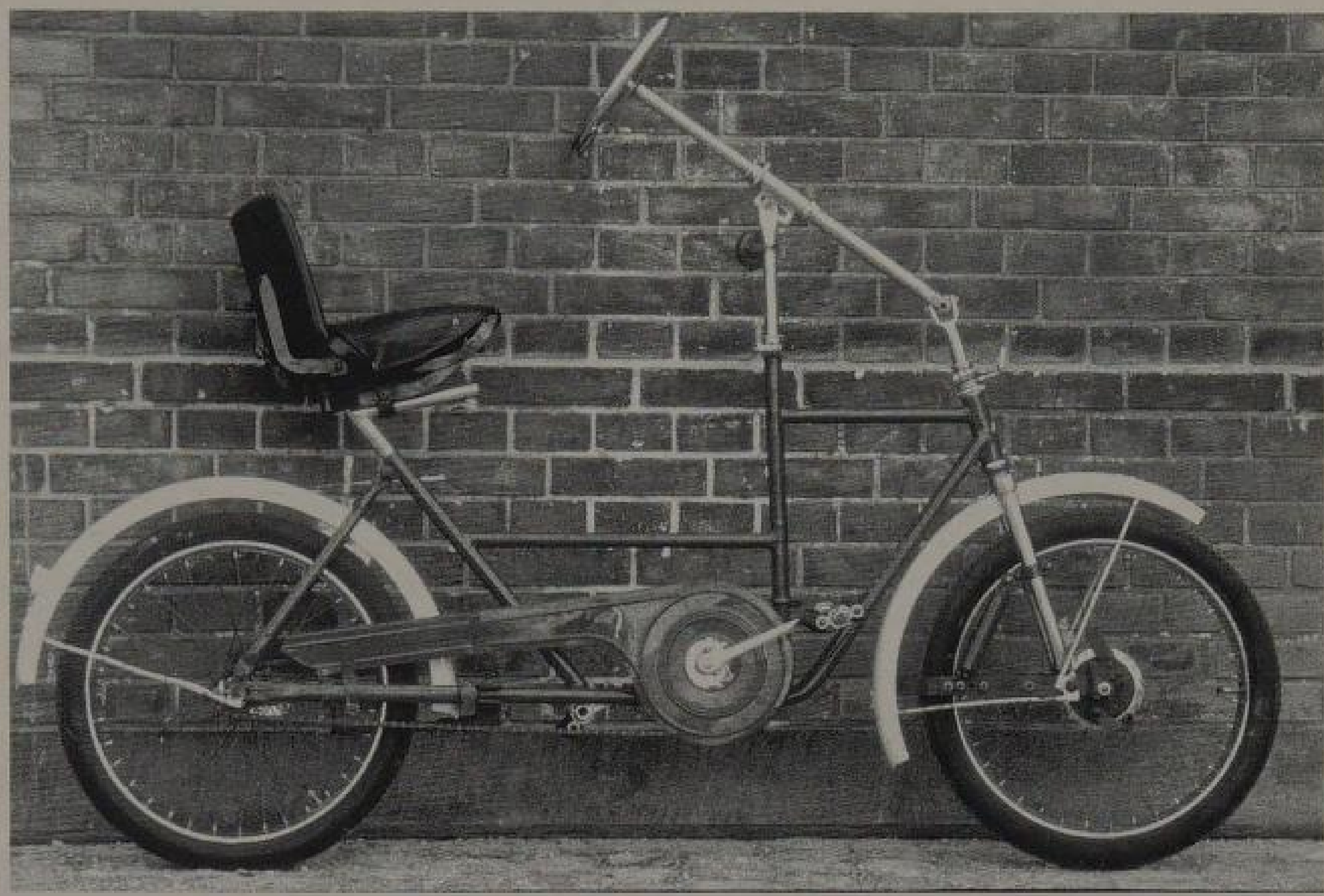
Taking into account the necessarily longer chain, builders of this era found it difficult to provide enough chain tension. This problem caused builders to add an intermediate gear-shaft, turning one long chain system into two short, manageable ones. In general, the front wheel was smaller than the rear and frame dimensions evolved in the direction of greater stability.

Both British models had a seat that combined a regular saddle and a simple backrest. All models sold poorly in England. The 1936 "Kingston" was not an exception, as the tall wheels, low seat, and intermediate shaft created a look that racing cyclists loathed.

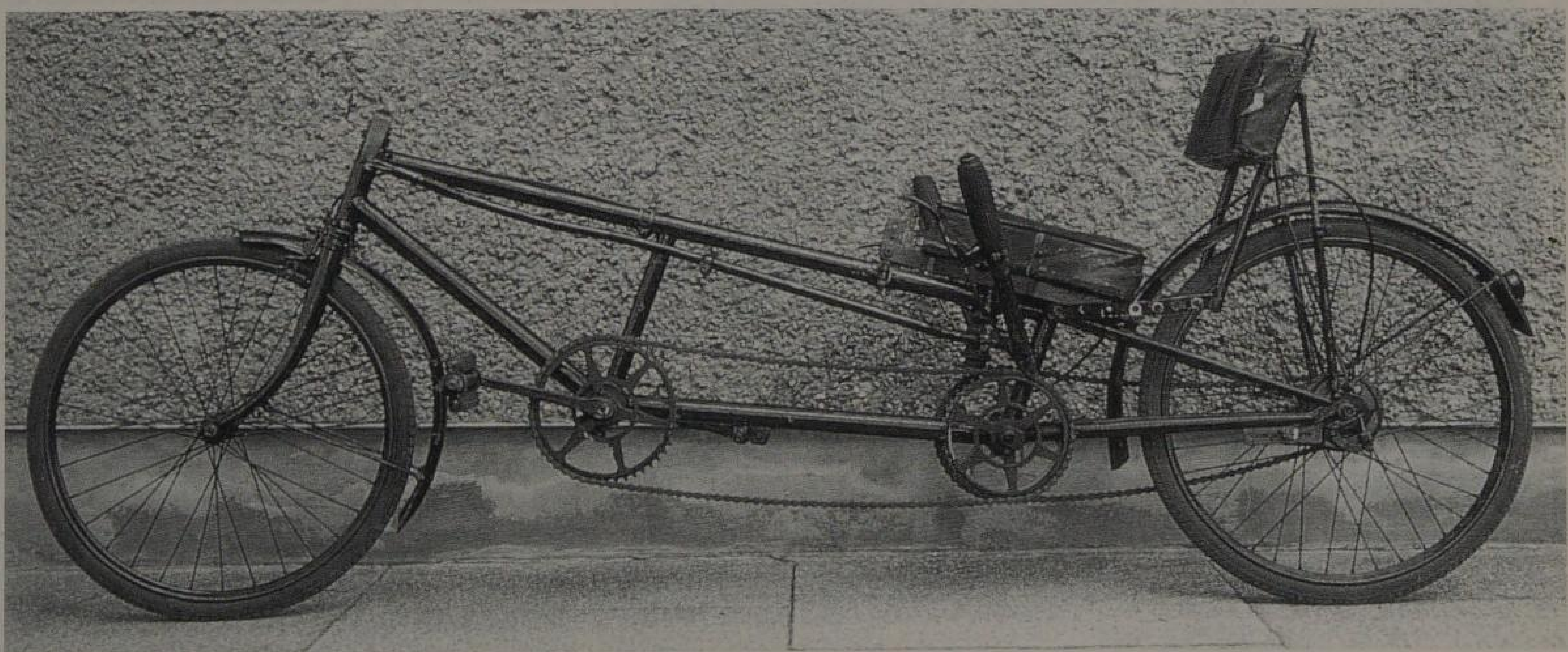
Apart from commercial attempts, there were private initiatives. Arthur Baxter, of Great Britain, for instance, hand-produced some recumbents. He drafted plans for the rocker-arm drive, creating three different models ("Town," "Country," and "Racing").

When it comes to racing, one should mention Oscar Egg. After being beaten by Faure, his legend of bike racing developed his own one-off recumbents for record-attempts at about this time.

Throughout the 1930s the "Sofacykle," created by Hænsler, was available in Denmark. The position while riding on this bike is basically an evolutionary midpoint between the regular bike and the recumbent. The chainstays are 25 inches long, the seat-



The semi-recumbent position of the Triumph "Moller" of 1936 enjoyed popularity in its time, especially in Scandinavia. Now this style is coming into vogue again.



Advertised by the frame builder F. H. Grubb as the first British recumbent, the "Kingston" was sold in 1934-35. The main traits of the modern recumbent are recognizable.

The Cyclo Gear Co. introduced the "Cyclo Ratio" in 1935, a short wheelbase recumbent with an improved four-gear shifter.

To handle the play in the chain, an intermediate cogwheel was added in 1936. (photos: Mark Hall Cycle Museum)

tube angle is a very relaxed 40 degrees, and the handlebar is extremely high, reaching far back. It is reminiscent of the stretched-out beach cruiser popular today and hints as well to today's "semi-recumbent" bikes.

Why Did the Recumbent Disappear?

One of the most interesting questions for recumbent bike historians is why it disappeared so completely from the end of the 1930s to the 1970s, despite its commercial production and the great interest of the media. It is difficult to come up with conclusive answers. It seems as if various circumstances coincided. One of them is certainly that road quality was seldom ideal for a recumbent without suspension. Cobblestone, dirt, and gravel roads did not lend themselves to smooth, controlled pleasure riding. Recumbents also need multi-gear shifting, which only existed with, at most, four or five gears in the years before and after World War II. A gearshift in those days made a bike expensive and required high maintenance—characteristics anathema to an everyday vehicle, then and now.

Today the problems faced by builders of recumbent bicycles in the 1930s are solved. Gearshifts cover a wide range, tires are reliable, few streets are unpaved, and recumbent suspension options are equal to the best offered among all bike types.

The breakthroughs are here, but recumbents still play a distant second fiddle to upright bikes. Why? The prohibitions of the UCI and the triathlon federation are a factor—they prevent direct comparisons and deny the chance for sporting success in events better covered by the media.

Additionally, the pervasive diamond-frame bike shaped perceptions for a hundred years, causing skepticism about designs that deviate from that model. Riders, builders, clubs, shops, and website operators know about this problem only too well and struggle to overcome prejudices.

But recent trends are working in favor of recumbents. Wild frame designs are popping up and becoming popular in the road, triathlon, and mountain-bike scenes. And bikes for specialized use, featuring novel designs and new materials, are acclimating the public to a broadening bike menu. So much so that diamond frames are losing market share to monocoque, composite, beam, and Y-shaped frames. The establishment is finally becoming more open-minded.

Lastly, the physical stress of riding an upright is becoming more widely recognized and riders are looking for ways to relieve painful backs, buttocks, hands, feet, or neck. All these factors open the door further to recumbents.

Paul Rinkowski

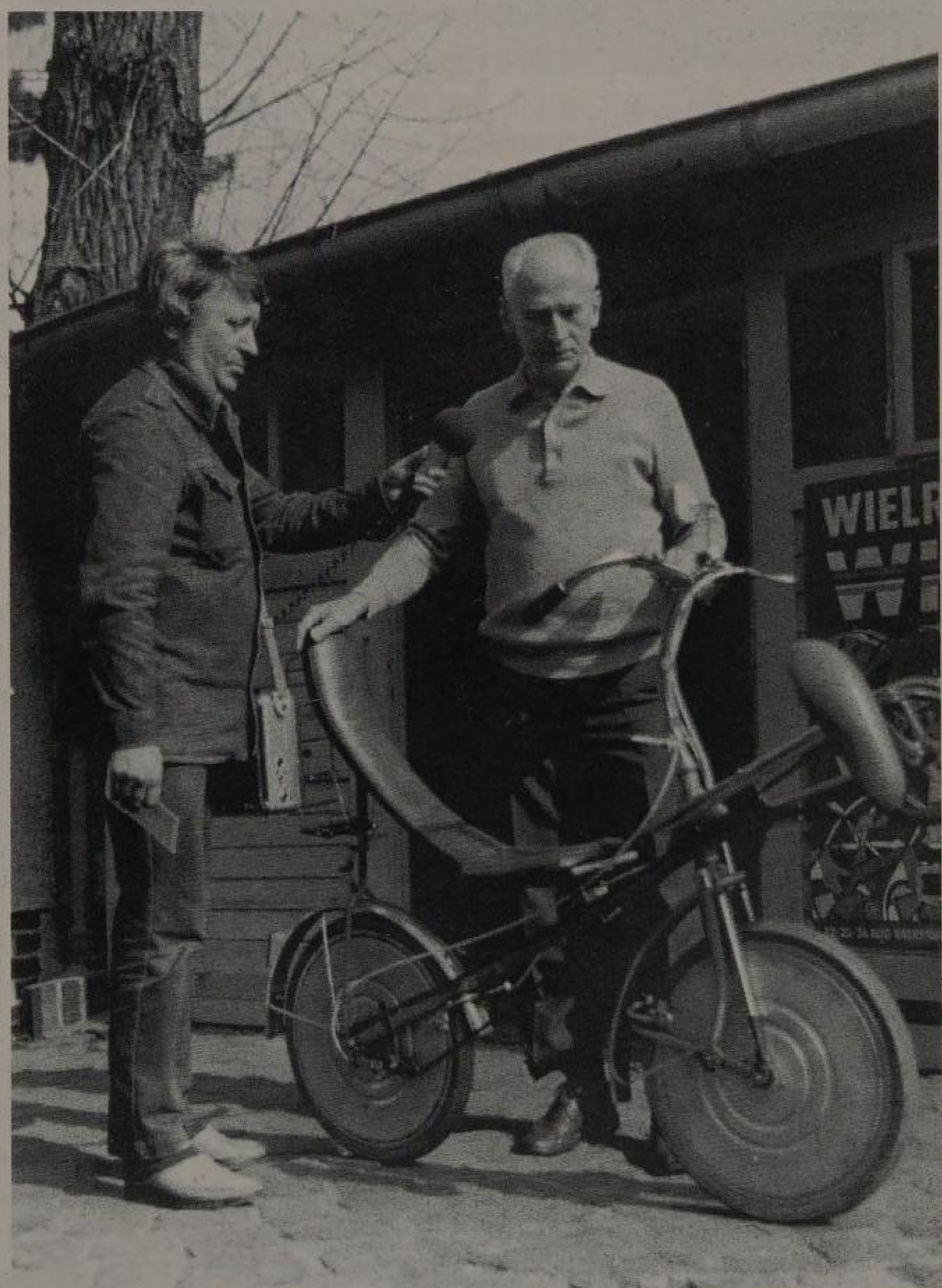
While the activities of builders and tinkerers in Europe sharply decreased after the war and recumbent bicycles were only available intermittently, American activities were much more constant. Even after the war Americans had recumbent bikes. The upright bicycle has at times been as popular in the States as in Europe. But the role of armchair-bikes stayed small. Still, recumbents survived in the United States, in a marginal way, through various major bike fashions (e.g. the Cruiser in the 1950s) for decades until the American recumbent renaissance of the mid-1970s.

During this period in postwar Europe, Paul Rinkowski of Leipzig, in the former East Germany (GDR), played a surprising and singular role in the fields of recumbent research, development, and production—with results that had great impact on bicycles in general.

Rinkowski, born in 1915, put all his efforts into increasing bicycle efficiency and making it a viable alternative to the automobile. Although his designs achieved his goals, and would've been appropriate for mass production, the socialist officials of East Germany did not see any need for such a vehicle and rejected the idea. Nonetheless, the design qualities of existing prototypes are testimony to the innovative talent of their inventor.

Rinkowski can be seen as the most important developer of HPVs during the postwar era because of his untiring work, for which he sacrificed all his spare time and money. It is without doubt that his family, in particular his wife, deserves praise for enabling Rinkowski's successes.

Rinkowski's engineering studies (1931-



Paul Rinkowski (photo: Rinkowski)

34) built the basis for his work on the recumbent. Rinkowski started to develop his bikes before the foundation of East Germany in 1947.

He experimented with full-body drives, because 15 percent more power could be generated. During a day of bike racing in the Bruno-Plache Stadium he demonstrated such a bike. During the first lap laughter echoed from the stands. With a sprint in front of the stands he completed the second round to bravos and applause. Eventually he dropped the idea of a full-body drive, because only few riders could handle it. Wrist-controlled steering contributed to the difficulty, and the second, improved model was a tandem because two riders were needed to control it.

For almost four decades he contributed to recumbent bicycle development and created his own concepts, disregarding existing recumbent approaches. Actually, he worked on his bicycles without knowing that the rest of the world was researching the same subject. He was completely alone and unsupported in his field and in technical production. The supply situation in the GDR was horrible, especially for unaffiliated independent tinkerers. This forced Rinkowski to rely on his creativity and improvisational skills to produce or find the necessary parts.

For uniform stability he chose 20-inch wheels for front and back. The greater rolling resistance of the 20-inchers compared to the usual 27/28-inch wheels did not discourage him. On the contrary, he tried to minimize this resistance.

To improve the everyday performance of the bikes he decided to forgo the use of tires with inner tubes. To reduce rolling resistance and improve reliability, there was only one option: build the tires himself. The result of this project would revolutionize wire-rimmed bike tires.

Rinkowski's tiny bicycle garage soon resembled a giant spider web as he worked on creating his tires—the world's first radials. A hundred meters of thread crisscrossed the workshop. First the thread was dipped in rubber solution then led through innumerable guideways. In this way the solution had sufficient time to dry and to acquire the required degree of hardness. He also built beaded clincher rims turned from wood.

He secured his research with a GDR economic patent in 1954. Rinkowski's radial tire for bicycles was superior to the diagonal tire. He developed the radial tire long before it entered the automobile industry. Tests showed that two-tube tires of ordinary construction and size had a rolling resistance of 6 Newtons. Rinkowski's tires required only 3 Newtons. He himself stated the following figures: "The patented recumbent bicycle tires under burden have a resistance of about 240 grams, while a pair of tube tires has a resistance of at least 420 grams. I know this so accurately because I have developed a rolling-resistance measuring device that is now the property of the DHFK-Academic Sports Club in Leipzig."

photo: Rinkowski

Rinkowski's design resulted in 1.5 miles more per hour in practice compared with a racing upright, if the bikes were powered with 60 watts (which equals riding 12-14 mph on an upright). This includes the general advantage of the improved aerodynamics of the recumbent position.

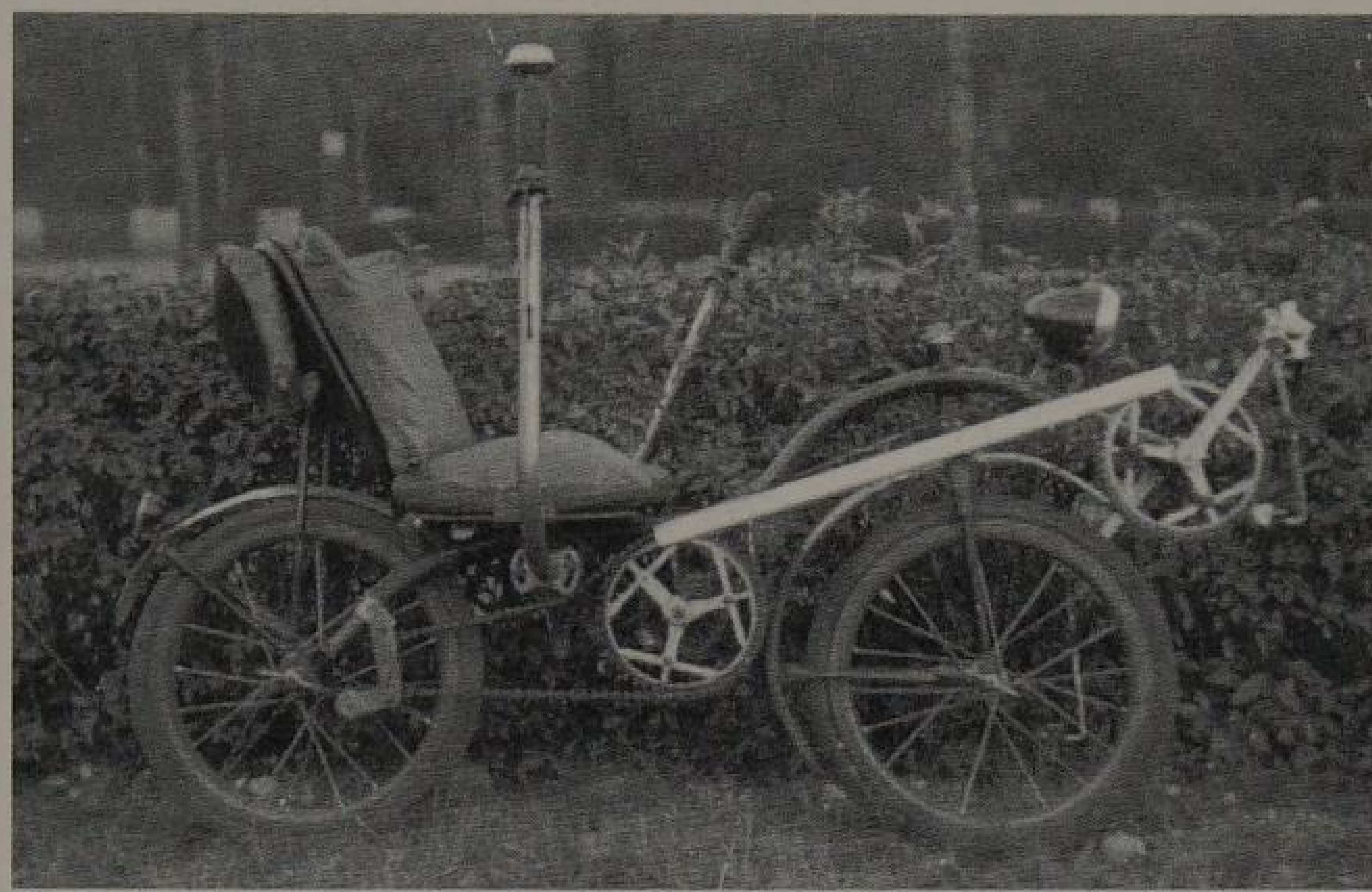
He stayed with and perfected one basic design of recumbent until the end of his life in 1986. The design has been protected by patent since 1953. "After the basic configuration was determined, development did not stop. Test rides were conducted for many years to collect data on frame, fork, and nodal-point stability," as details were ever more fine-tuned. "We did long treks with traveling days of over 200 kilometers. It goes without saying that the street quality greatly differed from today."

But Rinkowski was not solely occupied with bicycles. He also built three- and four-wheelers, children's bikes, and a telescoping camping bike that would fit into the trunk of a Trabant (very small, locally built GDR-era cars). Created in 1963, it had a telescoping fork and the legendary tires.

Around 1958 he motorized some of his recumbents with Mokick engines; they whizzed at 35 mph through the countryside.

On the "Day of the Republic" in 1956, a Rinkowski recumbent was allowed to participate in a local county bike race. Dieter Schipke started and, free from any serious competitors, crossed the finish line after a solo ride with a margin of seven minutes. Such a showing of new technology, speed, and sports potential only resulted in recumbents being banned from racing with upright bikes.

The foreign press interpreted his innovation a little differently. The West-German magazine *Radmarkt* ("Bike Market") reported about the Rinkowski recumbent after the IFMA bike show in 1962 that "...regarding all the novelties and further developments which were presented, there was nothing that could compare to the recumbent bicycle that the Leipzig engineer [Rinkowski] has been working on since 1948."



A Rinkowski bike with full body drive. (photo: Rinkowski)

Unfortunately the Western appreciation did not help him very much as his field of activity was limited to the GDR, due to political reasons.

Only a circle of personal friends, relatives, and people of like mind appreciated his achievements. From time to time the press mentioned this "crazy" engineer and made use of his small sensations and curiosities. He even made TV appearances in 1981 and 1984. But overall, Paul Rinkowski remained misunderstood by officials and the media.

Rinkowski's four-wheeled vehicle was loaded with technical finesse. Indexed shifting, reverse gear, independent four-wheel suspension, and a differential drive for the rear wheels were standard equipment. This HPV, which he called the "Sesselvelo," had a complete fairing made from frame tubing and sheet tin. It was a high speed fairing like that on Mochet's racing Velocars, but the aim was different: a bike for everyday use.

He did extensive aerodynamic research, as well, and soon achieved good results—which were put into regular practice only years later.

For instance, he equipped his Sesselvelos with disc wheels in 1955 to make cleaning easier and to perfect the aerodynamics. It was another twenty years before disc wheels were first used in international bike races.

The GDR bicycle sport federation finally became interested in his talents, and he did research for their racing bikes. One of his ideas was flat-bladed spokes, which have become common in the meantime, and which can provide the difference necessary for victory.

Using meticulous handwork, Paul Rinkowski built super-light and fast tubular sew-up tires to the great delight of the biking elite of the GDR; and with these too he contributed to their international successes. His tires had an excellent reputation and were lovingly called "Rinkis."

In this way Rinkowski finally became a sought-after man in GDR bike sports. However, there was still neither support nor understanding for the genius of his recumbent designs.

In 1962 a Rinkowski recumbent was used to ride the 50 miles between Leipzig and Chemnitz in 2 hours 45 minutes. That might not sound very fast today, but the roads back then were in very bad condition, with all the smoothness of mountain-bike trails.

The following year a comparison race between a Rinkowski recumbent and a racing bike was supposed to take place. Rinkowski was confident. But the race was canceled by bike sport officials. Clearly they were thinking of the recumbent victory in the amateur race of 1956.

GDR race organizations continued to refuse to authorize a strong racing cyclist for recumbent test rides on the track. So Paul Rinkowski met them on their own turf. He built a track version in 1955 with suspension, a handlebar mounted under the seat, and an extremely small, handmade cogwheel. He calculated that his bike would be 4 mph faster than a normal track bike.

Rinkowski decided to equip his bikes with suspension since bumps are transmitted more directly to one's body on a reclining bike, and because the body's natural biomechanical springs in the form of spine, knee, and arm joints cannot work due to such a position. Small telescoping springs inside the fork and rear supports, meticulously built by hand, reduced road shock. The easily adjustable, thin plywood seat was air-cushioned with old inner tubes until the builder managed to get hold of some foam rubber.

Rinkowski's achievements are all the more remarkable when you consider his constrained circumstances. Material was scarce, financial backing was absent, and official support was nonexistent.

In dire straits he petitioned the office of Walter Ulbricht for support of his work, asking for 830 East German marks. He also attached a request for financing for the production of more of his recumbents. Both pleas were rejected.

David Gordon Wilson, Chester Kyle, and the IHPVA

While the tinkerers and bicycle freaks in Western Europe were each working on their own, a group of enthusiasts in America got together under Prof. Chester Kyle with the goal of breathing life back into the pre-war idea of finding extra speed and function in alternative bike designs.

They founded the IHPVA (International Human Powered Vehicle Association) on March 28, 1976, and they're still active. The association's aim is to promote and develop human-powered ground, water, and air vehicles without any kind of limiting regulation.

Kyle offered a seminar on bicycle engineering at the California State University of Long Beach in the summer of 1973. Despite the great number of students enrolled (two!), the seminar started. Kyle focused on rolling and air resistance. The goal was to determine the resistance of the various bike types.

The researchers proved their zeal by setting up a test track within the university building. They equipped a long corridor with electronic ground sensors to measure elapsed time.

They soon demonstrated that a faired bike was faster and rolled farther. In 1974 the students and Prof. Kyle finished building a full fairing that they mounted to an ordinary racing bike, completely enclosing it (but for wheel-holes) and smoothing it into an aerodynamic shape.

In November 1974 the American Olympic athlete Ron Skarin reached a speed of 43 mph in a 200-meter sprint on what they called the "Faired Bike." That year, Kyle met Jack Lambie, who was working on aerodynamic bikes at the same time, and who had calculated that it was possible to reach 50 mph in the 200-meter sprint. The two agreed to further test various bikes—and the International Human Power Speed Championship was born (April 5, 1974).

David Gordon Wilson on the Avatar 2000. He is the pioneer of the safest bike. His research led to the long wheelbase recumbent. (photo: D. G. Wilson)

To reduce air resistance further, it was necessary to reduce the frontal area of the bike to a minimum. Since a fairing attached to a traditional racing bike would result in an extensive frontal area, the group turned to the recumbent bicycle. Here they found no preconceived frame designs or construction principles—just an empty field for research and experimentation.

At this time the tinkerers and do-it-yourself-builders were focused on the high-speed sprint. These engineers worked to attain the ultimate speed possible with human power.

By 1977 a fully faired recumbent bicycle built by Bill Watson reached 46.1 mph. Shortly afterward the sports doctor Allan Abbott reached 49.1 mph in his "cigar" bike. With this self-built high-speed vehicle he demonstrated that he had mastered the art of aerodynamics. Four years earlier he had satisfied his desire for sheer speed. On August 15, 1973, he rode a bike for one mile at 139 mph in the sheltered zone behind a racecar at the Bonneville Flats.

Years later he surprised experts with the construction of his Flying Fish. He developed this hydrofoil water-HPV with a friend and reached speeds exceeding those of a world-class sculler.

Builders were flush with creativity as they put their vehicles on three or four wheels. This allowed vehicles to be much lower. Seats dropped down between the wheels almost to the ground (a seat-height of one inch wasn't uncommon). The pedal radius was also lowered almost to ground level. Additionally, builders experimented with arm drives and tandems or triplets. Riders were positioned every which way in an effort to create the most aerodynamic shape with the most power.

Reports from the IHPVA during this pioneering time give the impression that this era was all about speed. That is not exactly the case. One has only to consider the work of David Gordon Wilson. In 1968 he announced the "Man powered land transportation competition." Bikes were supposed to be improved in every sense, and speed was not the primary criterion. Safety and usability were top priorities. Two participants from Poland brought creations to the competition. Stanislaw Garbien presented a fully suspended recumbent bicycle with a medium-long wheelbase and two equal-sized wheels.

Kazimierz Borkowski demonstrated a recumbent bicycle equipped with a rowing drive. Borkowski was an employee of the National Bike Factory of Poland.

The competition was won by a recumbent bicycle called the "Bicar Mark III" built by W. G. Lychard. The bike had two 16-inch wheels and a shaft drive with an elliptical crank chainring. It was furnished with a pneumatic seat and direct over-seat steering. The relatively low seat height of 16 inches was remarkable. David Gordon Wilson then modified its plan and sent a drawing to Fred Willkie in Berkley, California, with whom he had exchanged letters earlier, asking for more ideas.

Wilson enclosed some money provided by a fund set up by the late Paul Dudly White for the support of muscle force development.

Willkie built a short-wheelbase recumbent, resembling the Cyclo Ratio or the Ravat. He called it the "Green Planet Special I." Historically, one can see this bike as a link between today's short-wheelbase bikes and those of the 1930s. Wilkie tested it and got pains in his upper thighs. He didn't like it.

Wilson revised the plan a second time and got a second report: Willkie greatly enjoyed riding the new vehicle. However, a move prevented him from riding it much, and he sold it to Wilson, who then forgot about it, taking it out years later to show to his students as a design example. That evening he rode it home from campus and was pleasantly surprised.

After some modifications the "Green Planet Special II" turned into the "Wilson-Willkie." It was still not perfect and was prone to nosedive while breaking hard.

In 1978 frame-builders Richard Forrestall and Harold Maciejewski constructed the "Avatar 1000," an improved Wilson-Willkie short-wheelbase recumbent. Despite a 10-inch longer wheelbase, the bike was still front-heavy. Sixty-two percent of rider weight rested on the front wheel. The design was reconsidered once again and the result was the "Avatar 2000," a long-wheelbase recumbent born of the attempt to create a safe, everyday bike.

These two criteria, "safe" and "everyday," describe the aims of a small number of developers and researchers who have merged with the IHPVA and its racing majority.

Vector '80	Singletrack	/ Tandem
Length:	116"	151"
Width:	25"	25"
Height:	32"	33"
Weight:	51 lbs	75 lbs
Frontal area:	0.424	0.437
Aero ratio (*Cd*):	0.11	0.13

They work for the development of the bike as an alternative to or replacement for the automobile. This is an orientation with many historic precedents and a great future.

The idea of a practical long-wheelbase recumbent bike was received enthusiastically. The Avatar 2000 was launched in 1979 with no advertising but lots of media interest. Hundreds were soon sold. Copies and further innovations quickly followed—like the Swiss "Wiglet" from Fateba in 1982 and the bikes from Radius in Germany, among others.

The Wilson-Willkie animated a lot of bicycle "freaks." Milt Turner's "Hypercycle" entered the market at about the same time with a frameset for the sensational price of $200, and sold about 1000 units by the beginning of the 1980s. Turner still builds recumbents today.

The Hypercycle and Avatar 2000 were sold by Sports Warehouse in Ohio (which later became Bike Warehouse, then Bike Nashbar). Production of the Hypercycle ceased in 1983.

In this early period three companies were launched, and their first bikes, despite all the amazing changes since then, are still popular: Easy Racers' "Tour Easy," Lightning's "P-38," and the RANS "Stratus."

In 1982 Wolfgang Gronen's team dominated the European HPV sprinting competitions (with the help of World-medalist rider Gerhard Scheller) using a "Vector" trike like the one pictured here. (photo: Mochet)

Faster, Faster—The History of HPV Races and Records

The racing cohort of the American IHPVA was greatly inspired by the Abbott Prize in 1978. Allan Abbott promised to award $2,500 to the first HPV to exceed the national speed limit of 55 mph (88.5 kmh) in the 200-meter sprint. The prize could also be won if a single rider beat 54 mph.

It's worth noting that for unfaired/upright bikes the records have remained fairly stable at 46 mph for the 200-meter sprint, 35 miles for The Hour, and 533 miles for the 24-Hour (22.2 mph). (The UCI Hour record was relegated back to 30.7 miles in 2000, as set by Eddy Merckx in 1972, now slightly improved by the Czech Sosenka. A "Best Performance" record was added to acknowledge Boardman's 35-mile Hour. Confusing indeed.)

The victorious "White Lightning," built by students from Northrup University, who made use of the aeronautic engineering department's know-how and in-house wind tunnel, far surpassed the speed needed to claim the Abbott Prize cash in 1978. More than 2,500 man-hours went into the creation of the White Lightning, which cost about $3,000. The bike was 18.5 feet long, 36 inches high and 23 inches wide. The three student designers—Chris Dreke, Don Guichard, and Tim Brummer—used a symmetric NASA wing profile to give the vehicle its form. Brummer is the inventor and producer of today's popular Lightning line of recumbents. Butch Stinton and Jan Russell rode this tandem vehicle on its record run. It was the first HPV to exceed the 50-, 55-, and 60-mph barriers, reaching 61.04 mph (94.34 kmh).

A year later the first single-rider vehicle, ridden by American Fred Markham, beat the 50-mph barrier.

In 1980 the "Vector," a child of the team coordinated by Al Voigt, a major designer in the airplane industry, approached the 65-mph mark. The Vector tandem (Grylls/Barszewski) sprinted up to 62.889 mph—only 2.111 mph under the target.

The two "pilots" sat back to back. While the front pilot pedaled and steered, the rear pilot pedaled with both feet and hands. This theoretically produced 17 percent more energy.

In HPV sport, you'll notice a tendency to mix terms coming from different sports. Handling superfast HPVs can seem to be more like piloting an airplane than riding a bike—with taxiing, take-off, and use of landing gear. Many riders and builders have an aviation background. (The popular RANS company builds recumbents *and* small airplane kits.) Three-wheeled, fully faired, fully suspended HPVs can also feel a lot like racecars! Airplanes, cars, motorcycles relate not only to the feel, but also to the science, especially in terms of fairings and handling. Even language translation can add to the mix. The German "fahren" can either mean riding or driving. With fully-faired HPVs perhaps "driving" is a helpful term. It's all cycling, but many fields add expertise—and terminology—to the HPV scene.

Specifications of *Blue Bell:*	
Length:	115"
Width:	23"
Height:	56.5"
Weight:	42 lbs
Frontal area:	0.424 sq meter
Surface area:	6.67 sq meter

Markham and Chris Springer gave an impressive demonstration in the Vector tandem when they "drove" Interstate 5 from Stockton to Sacramento, California, in 49.40 minutes for an average speed of 50.5 mph over the 41.8 miles. This ride took place in highway traffic!

The media attention caught the eye of big business, which saw in HPVs a possible new advertising medium. The British bike shop chain Halfords, the auto accessory producer Brimax, Shimano, and DuPont have all sponsored teams.

In the meantime the speed wave spilled over to Europe. In 1981 the Aspro Speed Challenge took place in Brighton, and European racers came on strong. For example, the 200-pound "Poppy Flyer," an English delta trike (two wheels in rear, one in front) reached a speed of 46.442 mph. The impressive British tandem trike "Dark Horse" gave a convincing ride reaching 45.129 mph.

In response to viewer requests, the German TV show Hobbythek mailed nearly 70,000 construction plans in 1985 for this long wheelbase recumbent. —a boon for recumbents that has never been repeated.

Despite these achievements the prize money of 5,000 British pounds at this event was won by the dominating U.S. Vector team.

"A fine race. It just had the wrong winner," remarked Kyle. "I would have liked a British winner, because competition improves technology. And we want progress!"

A production vehicle attracted attention at this event: the British "Windcheetah." This tadpole trike (two front wheels, one rear) invented by Mike Burrows and piloted by Andy Pegg—who uses the bike on a daily basis—won third place in the sprints.

At the beginning of the 1980s, the "Poppy Flyer III" was a main competitor of the American Vectors in European races. (photo: Mochet)

In 1982 Kyle's wish finally came true: The British "Blue Bell" was the fastest one-man HPV in the world at the 8th IHPSC in Irvine, California. In a 200-meter sprint it narrowly beat "Easy Rider" and the then-current world champion Vector three-wheeler with a first-place speed of 61.91 mph.

A prototype of the Blue Bell fairing had earlier proven that the developer team was on the right track at the IHPVA Speed Trials in Brighton, England. At an average speed of 46 mph in a longer event it ranked third after Vector and Poppy Flyer.

To come full circle, hiding under the Blue Bell fairing was an Avatar 2000. This made the victory a sensation among experts. How was it possible that a recumbent bicycle made for everyday use could be faired and beat the Vector, which was designed from ground up for maximum human speed?

The secret was that the fairing had amazing aerodynamics. Derek Henden and the Nosey Ferret Racing Team had no access to computers or wind tunnels, but nevertheless they built a fairing that was superior to all others.

It all started in the summer of '82 when cycling journalist Richard Ballantine purchased the underlying bike. A former Australian judge, Tim Gartside, was to be the pilot. He was unknown in the HPV circle. Up to then he had only participated in two regular bike races.

The gear ratio of the Avatar—designed for everyday use—was modified by installing a stepped-up intermediate drive, so that it better fit the needs of racing. The gearing and cadence jumps resembled each other in both faired and unfaired versions. Thus a rider who trained on the streets could quickly adapt to high-speed racing.

The Blue Bell fairing was also very light compared to the others—only 15 pounds—and thus the whole vehicle was lighter. This reduced the necessary acceleration power immensely.

The Blue Bell fairing was built precisely to the size of the wheels and of the rider. The bike was equipped with a 17-inch high-performance Moulton front wheel instead of a wider mass-produced 16-inch model. They used a lightweight 700c rear wheel and high pressure tire. The seat was very narrow to reduce overall width. For the same reason the thumb gear lever was replaced by a bar-end shifter. A 1:8 gear ratio (thanks

Professor Ronald Schöndorf teaches vehicle construction at the engineering college in Cologne. Together with his students he built four-wheelers at first, then three-wheelers, and finally he focused on two-wheelers. His "Muscooter" models with suspension ended up being the basis for a serial production recumbent. He says about his own developmental work: "Had I known about the work of Paul Jaray and Charles and Georges Mochet, I could have saved ten years."

to the intermediate drive), wheel covers, and an early-era computer-speedometer finished the bike.

After the competition, the Blue Bell fell twice during training and was repaired. On the following weekend the Nosey Ferret Racing Team's baby won first prize in the San Diego Velodrome Pursuit Race. In the victory lap after the race the rider crashed and the machine was almost totaled.

The reasons for these wrecks were obvious. The fairing had a large side surface area, and the tail was not rounded. Sidewinds had an easy target. Additionally, modifications for the race changed the distribution of the weight on the wheels from 31/69 percent to 25/75 percent (front/back). The front wheel tended to lose traction. In cornering, during braking, or on sandy or wet pavement the problem only got worse.

But with the success of Blue Bell a new era of HPVs began: Two-wheelers took over from three-wheelers.

Giving up a wheel had the advantage of less rolling resistance. Moreover, a trike has aerodynamic disadvantages: Air gets compressed and whirled around in the flat zone between vehicle and ground, and valuable seconds are lost.

Two-wheelers are slim—19 inches wide is usually sufficient for a rider, 8 inches less than a three-wheeler.

At the 1983 Thamesmead Festival of Human Power near London, another English construction showed the optimization of the single-track idea. "The Bean" by John Kingsbury caught attention but created even more of a stir in 1990 (as we will see).

At the 1983 championships in Indianapolis, Blue Bell lost its position as fastest HPV of the world. "Lightning II" by Tim Brummer won the competition at 54.78 mph.

In 1984 the chemical giant DuPont put up a prize of $18,000 for the first human-powered vehicle to exceed 65 mph. (The rules were the standard IHPVA rules, which limited tailwinds and downgrades.) What happened is coming up...

1980s Street-savvy R&D

As an aside we should state again that HPV development in this early period wasn't just about racing. There was global innovation in the 80s in everyday practical bikes. Three excellent European models were also available in addition to the American powerhouses of Easy Racers, Lightning, and RANS. These three represent the amazing diversity of the scene.

The Danish "Leitra," a three-wheeled fully faired recumbent developed by Carl Georg Rasmussen, is remarkable for its orientation toward practical use, for a clever aluminum body that tips forward to allow entry, and for its great safety. Over 250 Leitras are in use around the world today.

The Leitra is still one of only a very few practical multi-track velomobiles on the market. ("Velomobile" meaning an HPV designed to do the work of a car.)

Secondly, there was the "Roulandt" from the Netherlands, a long-wheelbase recumbent bicycle with indirect steering under the seat. Despite good sales, acceptable ride quality, moderate weight, and low price, the maker had to stop production. A quality error in a supplier's frame tubing had caused a wave of frame failures.

The third important model of the early '80s came from Belgium. Under the name "Veleric," Eric Anbergen distributed an extremely well-calculated everyday HPV. The design is nowadays called a "lowracer"—a style that is now dominating races. The seat was located between the wheels only 8 inches above the ground. The chain was led around the 16-inch front wheel by the 20-inch high crank, which drove a 20-inch rear wheel. This bike was offered with an optional full fairing made of unbreakable Macrolon. The drag-coefficient *Cd* value was, according to the manufacturer, a superb 0.18. Unfortunately, this bike was also unsuccessful, so production facilities were sold to the German Michael Kügelen. He had the frame produced in Germany and exhibited at the IFMA (1982). Here, the Veleric appeared absolutely exotic. Kügelen remembers: "It took such an effort to explain, that we just could not cope with it. You'd explicitly explain the advantages of a recumbent to one visitor, and you were hardly finished when ten other people asked the same questions over again." But he sold about 250 units right after the show, half of them with fairings—amazing for that era.

Yet another recumbent was way ahead of its time. In the March 1984 issue of *Tour* a fully faired recumbent prototype from Gazelle was presented. The "SST," as it was called, strongly resembled the Veleric—low seat, high crank. Only a rocker-arm drive differentiated the two bikes.

Gazelle was not the only large company with activities in the HPV sector. The producer Union Fröndenberg contracted with the Italian designer Colani. He developed tandems and single-cab vehicles with three and four wheels. But none of these got further than a prototype.

In a surprising turn of events the German TV show "Hobbythek" caused a recumbent sensation in 1984 that has never been surpassed. A recumbent bicycle was demonstrated on the show, and a simple do-it-yourself plan was offered. The TV station sent out 70,000 plans. In the aftermath there was a lively exchange of letters between viewers and the TV station as tinkerers described their improvements, ideas, and modifications.

The show's producers (today the publishers of the German magazine *ProVelo*) then presented five examples from all the letters with special ideas and modifications. After a second show 70,000 people again requested the extra information offered.

In 1985 a circle of friends dedicated to

Karl Georg Rasmussen and his Leitra. Hundreds of them are now plying the roads worldwide.

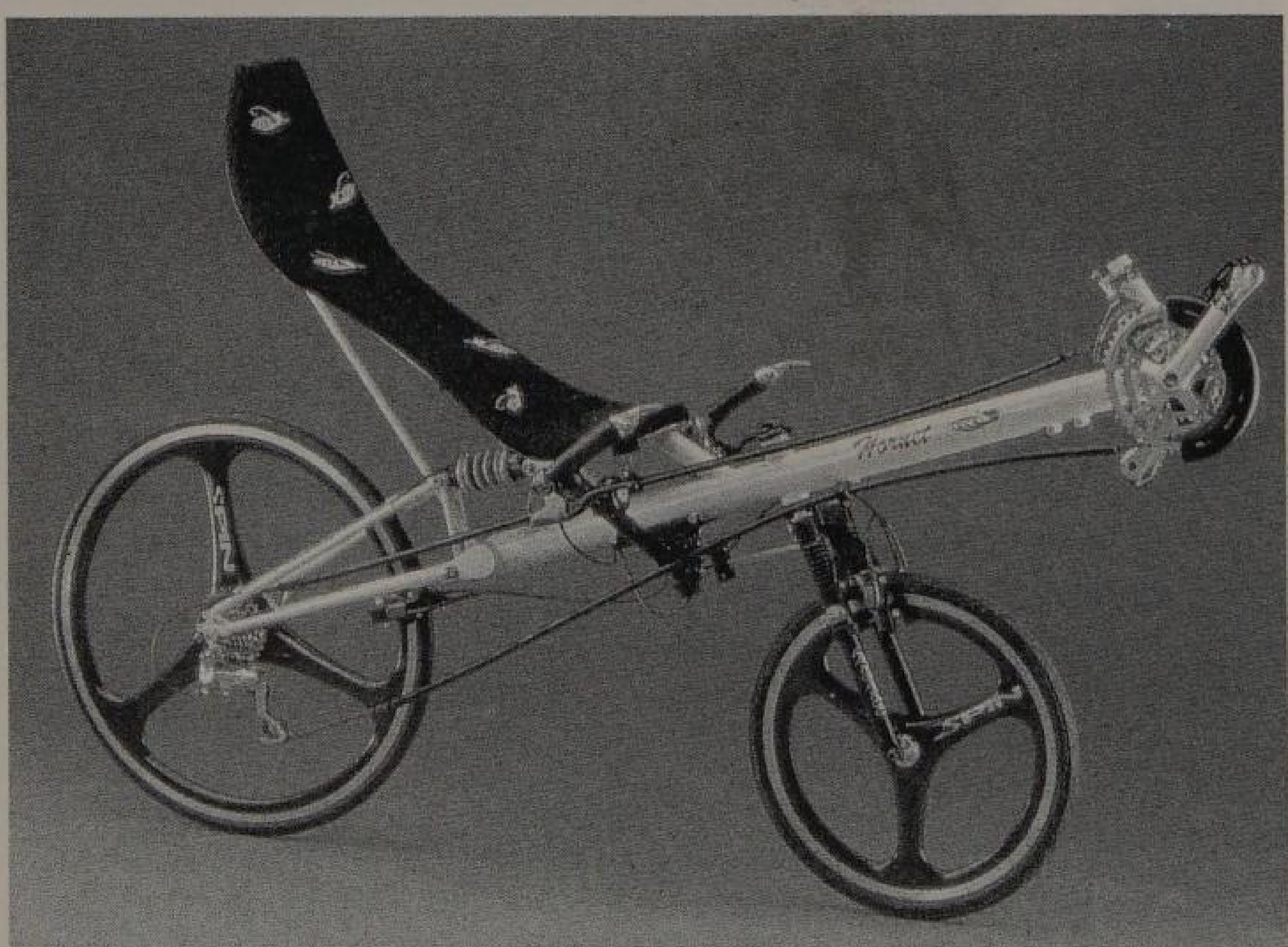
the special mix of sport and innovation that drives the HPV spirit formed the association HPV Germany.

By 1983 Germans Andreas Fortmeier and Peter Ronge were already occupied with recumbent bicycles. They started with short-wheelbase recumbents and arrived—similar to David Gordon Wilson—at the production of a long-wheelbase recumbent. Their customers wanted a bike that was suitable for the city as well as for touring. They fulfilled their goals in 1985 with the "Peer Gynt." Since then, these bikes have attained cult status.

In 1992 their company, Radius, reacted to the demand for sporty recumbent bicycles and presented a short-wheelbase model. In 1995 they replaced the Peer Gynt with the "Viper." The Viper has adjustable rear wheel suspension and 20-inch wheels. Radius was sold at the end of the 1990s.

Also, in the mid-1980s, Kurt Pichler of Karlsruhe, founder of Pichlerrad custom bicycles, sold the first of his recumbents.

"Hornet"—a fully-suspended short recumbent by the Radius company.



More Speed!

In the early summer of 1986 news broke about the winning of the DuPont prize. The dashing American Fred Markham (called "Fast Freddy" ever since) scorched for 200 meters in 6.832 seconds along California Highway 120 for a speed of 65.486 mph. The victorious "Gold Rush," built by Gardner Martin, followed the trends of the time in being two-wheeled. The rider could only mount the bike with the assistance of two other people and even so had to contort himself to enter, as the opening was too small for his shoulders.

An immense amount of work was hidden behind this record. Gardner Martin used his famous Tour Easy touring recumbent model as the basis for the Gold Rush, although he modified it greatly.

Front end and handlebars were reduced to a minimum so that the rider pedaled while bending far forward. This made for a lower vehicle height, and let the arms pull to increase power as in a regular bike sprint. An aluminum frame, ultra-light Kevlar fairing, and other special equipment made for a total weight of only 30.8 pounds! Markham, who had raced in two Olympics on upright bikes, lived close to Martin and had already been a team rider for years. At the end of the '70s, he was the first solo rider to exceed 50 mph—on a belly bike built by Martin. His biggest rival in the race to achieve 65 mph was thought to be the Allegro delta trike team from Don Witte, which held the 200-meter record with 62.98 mph.

After the Gold Rush was finished, there was a first attempt on Columbus Day 1985, which failed. The second weekend in April 1986 revealed a stubborn barrier to breaking the record: The wind exceeded the 5.5 fps limit. That breeziness prevented qualifying under IHPVA-regulation conditions.

Another attempt was made the weekend of May 9-11, 1986. Until Saturday night a strong breeze dashed all hopes. By Sunday participants were ready to take even the smallest chance. At 6 a.m. everybody was on the track, but rough winds swept through the valley until 7 p.m. Then the wind calmed. Only a tiny breeze accompanied Markham when he made a test ride. Finally the wind died completely, and nothing stood in the way of a record. Fast Freddy dashed at 65.486 miles per hour along the highway, and he knew during his ride that he had won the DuPont prize: The drumming inside the fairing had never been so loud.

With the conquering of this barrier, corporate interest in HPV development withered. The hand-craftsmen and engineers again had to rely on their own finances for materials and labor.

In 1987 Gerhard Scheller launched an impressive demonstration in Germany's Mosel valley. He had placed second in the upright UCI World Time Trial championship of 1981. He wanted to single-handedly beat the world 100-kilometer speed record held by a Russian four-man Olympic squad.

On his dramatic ride, set up in a Vector trike, Scheller managed the distance in 1:31:24. This is 28 minutes less than the four-man team time trial. One has to add that our pilot had to handle rain, valley winds, and twisty village streets.

This new Vector team continued the hunt for records, and at the highest bike track of the world, in Bolivia, they started to set new top marks.

The two-wheel take-over continued at the annual European championships in 1988 in Nümbrecht/Cologne. The English Blue Bell (which should have been called Black Bell because of its new color) finished the first of three 200-meter sprints only 0.04 seconds slower than Vector's top time of 8.04 seconds. The second ride was more thrilling: After Glen Thompson brought Blue Bell through the sensors the stopwatch showed 7.92 seconds.

The "Veleric" was the first low-racer. 250 models were sold in 1982, mostly without fairings.

The face of Vector team leader Wolfgang Gronen changed drastically: Nobody had expected an outcome like this. The throne of the Vector hadn't been shaken since it was first brought to Germany in 1982 and since the unbelievable *Cd* value of 0.07 (as listed by its builder) had been pared down even further.

Another single-track model contributed to this disturbance—not by its speed of 52.51 mph, but rather by the circumstances of its creation.

"Sweet Surprise" was not only prominent because of its beautiful fairing, but also because of its prehistoric technical components (steel cottered cranks). It was the product of Maciek Kaczmarek of Poland, who built his cowling with extreme accuracy and to a high aerodynamic level.

Bad Polish components spoiled the first ride; the gearshift went on strike at the start. At the end of the event the planned emergency backup, an architecture student named Kosinski, replaced the real rider after a fall. He took an unofficial sprint around the track. He himself fell and slid through the electric eyes. But an unofficial manual timer showed 58 mph! Those on hand couldn't help wonder how Sweet Surprise would have done with its original rider and better components.

W. Gronen engaged Kaczmarek then and

there to build a similar vehicle for Vector and his sponsor Union Fröndenberg.

Only a year later Scheller rode the new single-track Vector at the 1989 European championships in Münster. But again there was a bike that could easily compete with him. The Dutchman Joost Conijn set the top pace in the 30-kilometer criterium with his early-era homemade carbon-fiber recumbent frame and a fairing made of windsurfer-sail fabric. Only years of racing experience brought Scheller to victory. He let the Dutchman ride ahead, stayed in the pack himself, and only took the lead two laps before the finish. Trailing by a few meters and with an impressive final average of 29 mph, the young Dutchman rolled exhausted across the line.

Easy Racers: "Gold Rush"

Bicycle weight: 19 lbs—6 speeds, titanium parts, spokes and crankset, aluminum frame, Cro-Mo fork, ultra-high pressure sew-up tires (8 bar front, 10.3 bar rear), polyester plastic shell fairing.
Fairing weight: 10 lbs
Fairing fasteners weight: 2 lbs
Gears: 92 x 11-19 (700c rear wheel)
Height: 51"
Width: 19"
Length: 96"

Everyday Bikes Keep Pace

Not only were the racers remarkable in the late-'80s period of HPV development, amazing things were taking place once again in the development and refinement of the everyday bike.

In Germany the main recumbent maker Radius had so far only competed with imports from England and America, as well as Pichler and the Swiss Fateba. But now there were numerous small producers offering short-wheelbase recumbents that were fun and fast, even without a fairing.

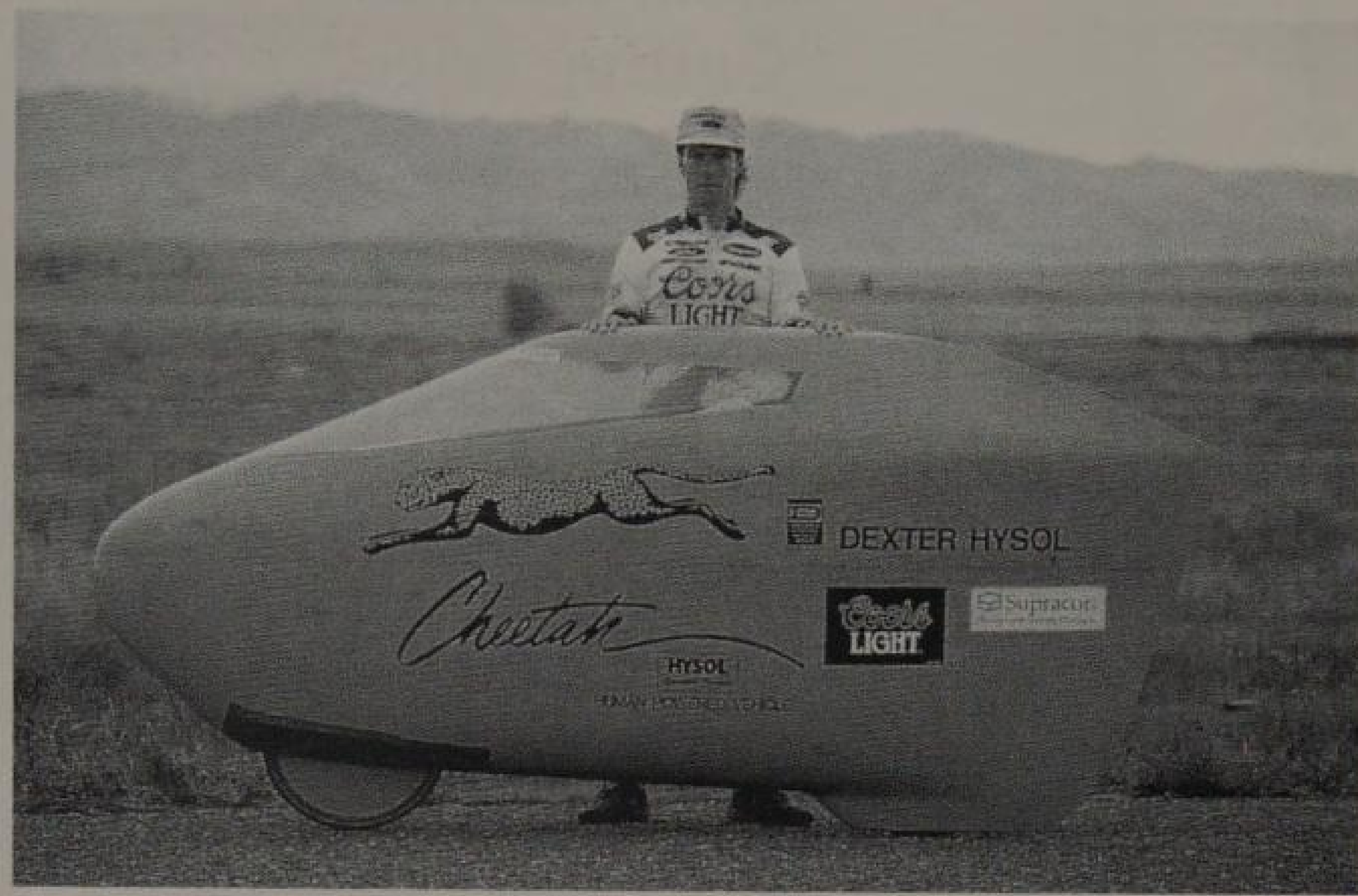
There were the Mertens brothers, who accessorized their short-wheelbase racing recumbent and produced a run of 10. There was also the "Kingcycle" by Miles Kingsbury, an SWB recumbent with 17-inch and 24-inch wheels, linen seat, and triangulated split-frame design.

In the Netherlands, Bram Moens (M5) and Derk Thijs (Thijs Design) both launched models that are successful to this day. Moens' mainstay is a low-racer. But Thijs takes the prize for most distinctive design with his highly refined Rowingbike frame, a clean mono-tube beam along which the feet slide together, back and forth. The steering looks like a conventional pivoting stem model, until you real-

Three-time RAAM champ Bob Fourney finished the 1999 Paris-Brest-Paris in 14th overall place, riding solo in a Lightning F90 (carbon F40) while the rest of the leaders rode in packs. His time of 47 hours for the 750-mile classic brevet was just a couple hours off the winning pace.

ize that a cable attached to the bars lets you apply power with your arms as well, while still enabling steering. With a faired version of his impressive bike, Thijs has won open marathon events against team upright racers.

This producers' push was completed by Christian Uwe Mischner from Munich, who introduced his Flux short-wheelbase recumbent in 1989. Only a year later it was put into production. From the start he impressed experts with its ride quality, smart detail solutions, and quality control. This bike was even equipped with a front brake in the style of a modern V-brake that Mischner made himself.



Chris Huber behind the then-world-record-holding "Cheetah" (68mph; 1992). (photo: Chet Rideout)

Back to Racing!

1989 was not only an exciting year for European everyday bikes, the American HPV racing scene achieved two very big successes.

In August a relay team of four cyclists participated in the Race Across America. RAAM is the longest bike race in the world. Often more than 3,000 miles long, its routes run nonstop from the West to the East Coast. Not only is the distance tougher than any other race, but drafting is forbidden.

Since all bike types are admitted, Michael Coles, Bob Fourney, Jim Penseyres, and his brother Pete—two former RAAM winners—chose to race in HPVs as a team. They used the faired Lightning F-40.

The Lightning excels with high practicality, fine climbing capability, high speeds, and low weight (about 25 pounds). In 1985 this same basic model, with the high-speed X-2 fairing, attained 57.8 mph in the 200-meter sprint.

The Gold Rush team was also at the start. They led the race until about 130 miles before the finish. The four Lightning pilots pulled ahead and arrived after 5 days, 1 hour, and 8 minutes. These HPVers averaged 24.02 mph for the entire distance and still hold the team record. (Since then HPVs and recumbents have been frequent entrants at RAAM.)

In September of the same year "Fast Freddy" set a new Hour record of 45.338 miles aboard the Gold Rush.

The next year, 1990, on a brisk, windless evening in September, Freddy's record was broken on the Millbrook Proving Ground in Bedford, England. The British "Bean" dashed for an hour over a 2-kilometer course and achieved a proud 46.96 miles with Pat Kinch at the helm.

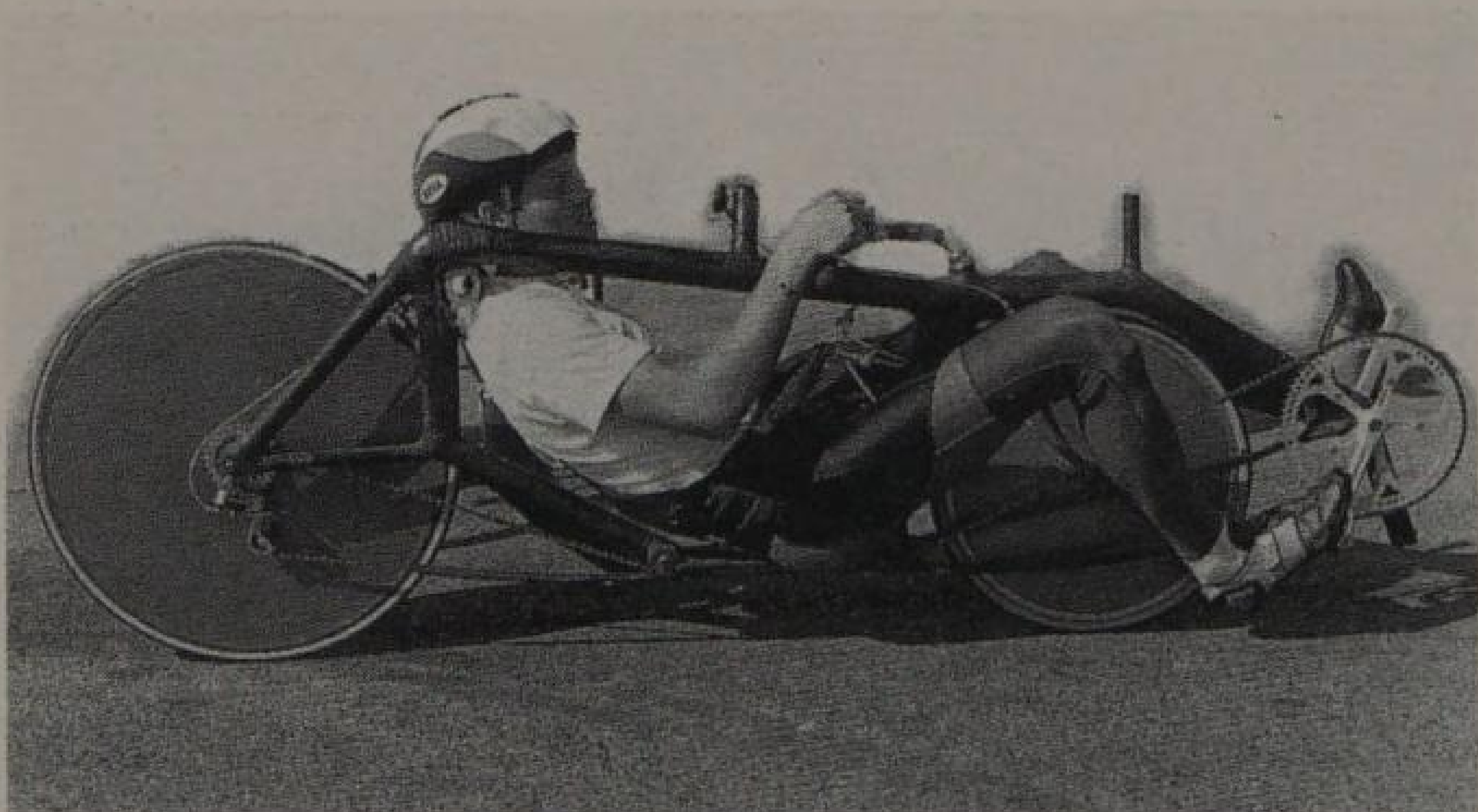
The high-speed two-wheel Bean, developed by Miles Kingsbury after years of intensive work, appeared previously at the Thamesmead Festival and won many victories in the following years.

Then in 1994 the Dutchman Bram Moens rode to a new world Hour record with a distance of 47.92 miles. It remained unofficial, however, because he did not wear a helmet that conformed to the rules. He used an M5 bike from his own company. He is the only HPV champion who developed and built the bicycle that he piloted to a record.

"Gold Rush" versus "Cutting Edge"

Long-wheelbase single-track vehicles replaced three-wheeled craft as record-setters in the middle of the 1980s. The two-wheel Gold Rush won the coveted DuPont prize. Before that Blue Bell and Lightning had already marked out ruling claims. After the success of Gold Rush, Fred Markham remained unbeaten in head-to-head racing. This all changed when 20-year-old Matt Weaver enlivened the American scene with his radical "Cutting Edge." In 1990 at the 16th Human Powered Speed Championships in Portland, Oregon, he dashed away from Fast Freddy and won the 20-mile criterium.

The race was very exciting. Markham and Weaver quickly left the field behind and fought a duel on the tight course. Weaver noticed that Markham lost speed in every corner. He was slowed by washboard ruts in the raceway pavement made by the cars that usually raced there. But the unevenness did not disturb Weaver. He felt that braking put him in more danger. His only chance was passing Markham in a turn and taking the lead. Markham always started wide then swung tight to the inside of the curve, leaving only a small chance to pass on the outside. Weaver finally jumped around and finished the race with a 47-second lead.



Matt Weaver's "Cutting Edge," built in 1988, was the most radical design of its time. The driver is positioned nearly supine just inches off the ground. In tight corners, its pedals could strike the ground, a problem that usually only occurs with upright bikes. (photo: Jon Schwartz)

Young Matt developed and built his soon-to-be-influential vehicle by himself in a small shack behind his parents' house while being sponsored, like Markham, by Gardner Martin's Easy Racers company.

Fast Freddy commented on this engineering achievement: "He did what a lot of people with a lot more engineering background could not do."

But Weaver's success did not come out of nowhere. His father had been involved with building soapbox derby racers, which were highly technical projects, then and now.

Before Weaver started construction he calculated with his computer the ideal frame and, as far as possible, the ideal fairing.

This lengthy research by the former UCLA-Berkeley student resulted in an HPV plan from which the frame and fairing was minted—the first of the truly low lowracers. The low height brings the legs down around the front wheel and fork. The carbon-fiber frame has an outrigger boom from head-tube to crank, located directly in front of the front wheel. Turning is restricted to about 8 degrees each way. In round-track races, the low center of gravity makes up

Specifications for Cutting Edge:

Length:	114"
Width:	16"
Height:	35"
Wheelbase:	52"
Bike Weight:	24 lbs
Fairing Weight:	12 lbs
Total Weight:	36 lbs
Frontal area:	0.26 sq meter
CdA:	0.02 sq meter

Fully-suspended wheels are not just a trend in the mountain bike sector. Suspension has been used on recumbents since the beginning, and it improves a wide variety of uses.

for that, and maintains enough turning capacity.

One of the most unique twists of this design was that of the two main frame tubes, one went *over the right shoulder*, allowing the rider to be positioned lower than with any other design. The over-shoulder tube supports two fasteners for the fairing. The steering is a directly operating handlebar. The necessarily huge gear development results from a 70-tooth chainring leading the single chain to a tiny package of cogs on a 28-inch rear wheel.

Weaver's winning first frame inspired the Europeans. Bram Moens, Walter Ising, and Peter Ross rode similar bikes at the 7th European Championship in Munich in 1992. However, they did not take Weaver's philosophy of "sitting low and in between" quite as far.

As for Weaver, he has continued to push to the furthest limits. He made an assault on the recent prizes with his new bike, the "Virtual Edge." Weaver designed this new "camera bike" from start to finish, using the latest CAD software. He views the road by way of video—previously said to be an impossible way to navigate. He vehicle is also very well sealed, so he needs to be careful that he gets enough oxygen. He says he also gets significant gains from close-fitting wheel-shrouds, which reduce energy-robbing air-pumping by the wheels. However, Easy Racers now oversees this bike, renamed "Virtual Rush," while Weaver keeps building newer ones!

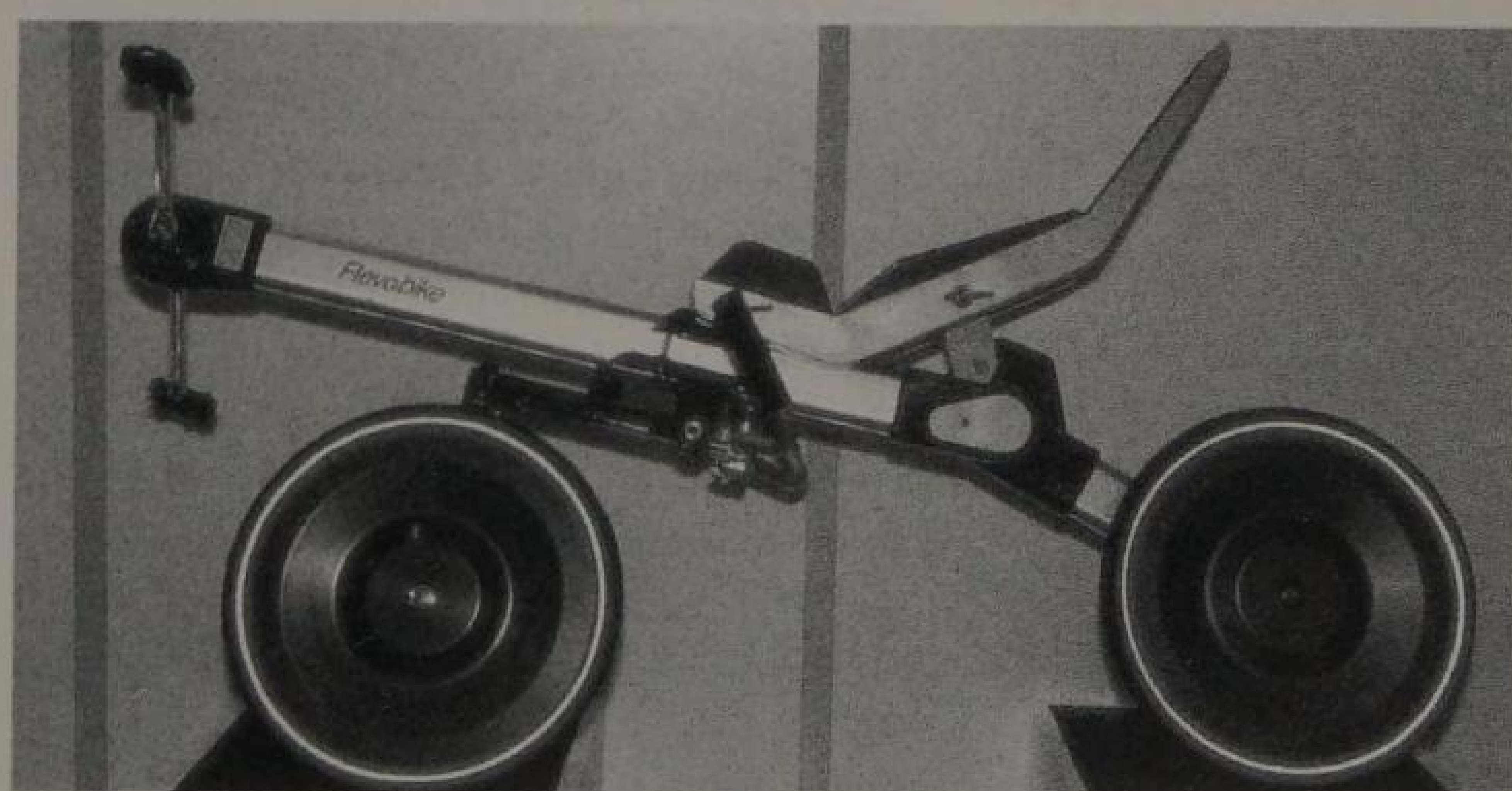
Innovation & Integration

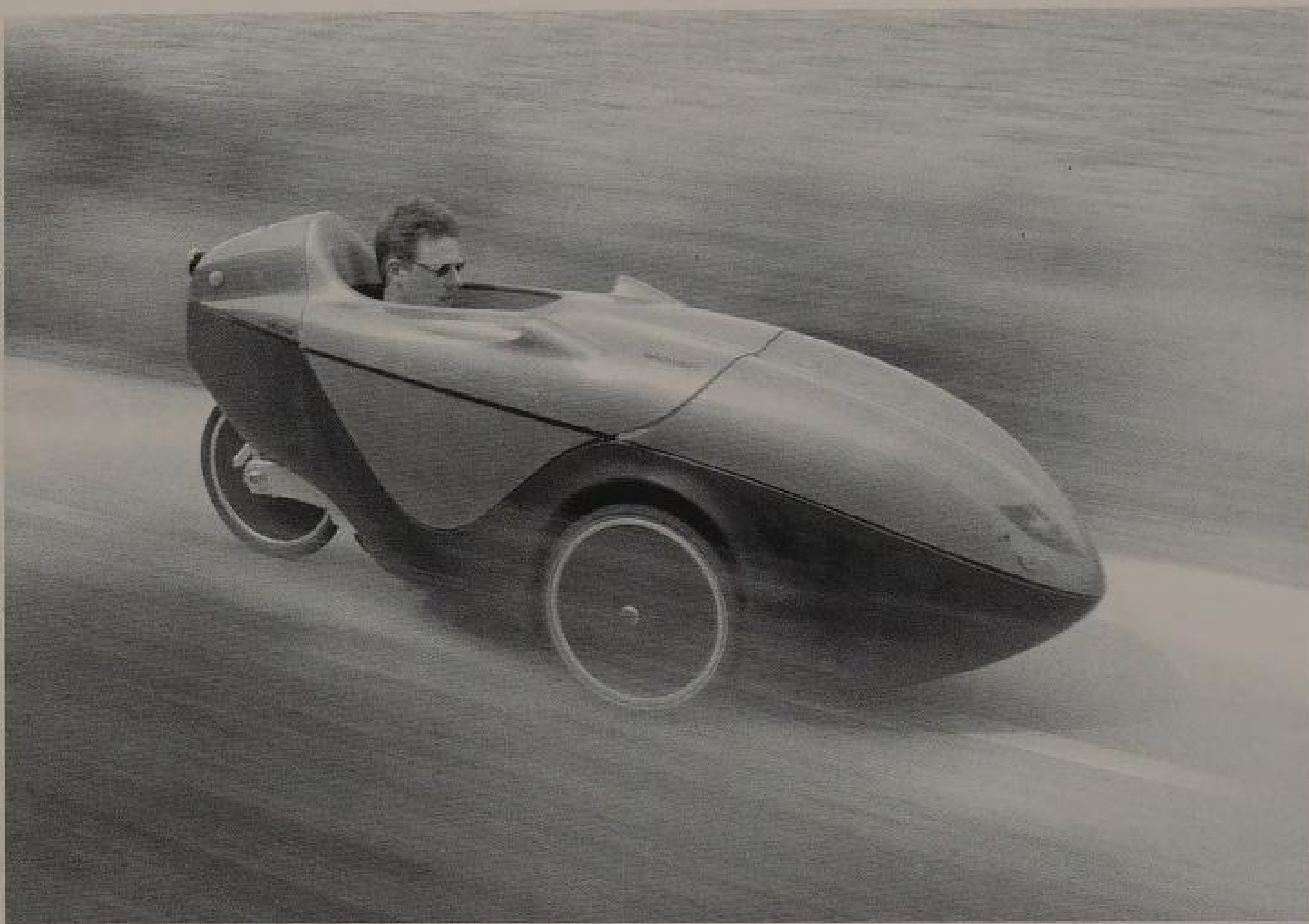
The push for high speed, all-weather capability, and everyday usefulness—and all three together—continues even now. As always, the result depends on one's interpretation of "everyday," "weather" and "speed."

The Dutch "Flevo Bike" should be viewed in this context. In spite of the enormous effort needed to learn to ride one, it sold a few hundred bikes a year while it was available. Buyers decided that its advantages were worth it to them. It has unique leg steering by way of a hinging frame that allows a very simple front-wheel drive, and a very natural riding style—once one gets used to it. It is a robust, comfortable, and simple design fulfilling the demands of a certain constituency.

The new short-wheelbase Bacchetta line and the classic long-wheelbase recumbents from Easy Racers and RANS each show a good approach to achieving all-around popularity. They offer everyday usability

Bikes like the Flevo "Green Machine" show a radical approach to the velocipede future. A modified version went on the market. It offered full-suspension, an encapsulated drive, and one-sided wheel-mounting.





Velomobiles are a big part of the HPV scene. Trikes are a common platform due to their stability. The Flevo design team does a lot of work in this area. Their "Versatile" (pictured) offers deluxe features. Related models are the racing "Quest" and the simpler "Mango." (photo: A. Vrielink)

and are built to the highest standards of the bicycle craft. There are many other unique designs representing individual interpretations of the quest for the ideal compromise between speed and utility. If one test rode the wide variety of recumbents offered today, one would find an amazing range of ride experiences.

Although there are broad general streams in the development of recumbent bicycles, individuality is more characteristic of recumbents than similarity—far more so than among mountain bikes and upright racers.

Today's dominating trends are low seat height and higher bottom-bracket; suspension; and the city-bike. New producers seem focused on low- and high-racers or compact recumbents. This is not because the long-wheelbase recumbent is outdated or that its potential is exhausted. (Short, medium, long, and high and low models were all explored from the beginning.) Simply stated, short-wheelbase bikes are thought to be more sporty and are enjoying fashion's spotlight. Lowracers are winning races, especially in the stock divisions, and are very fast "out of the box" for skilled riders. Highracers thrive in open-road events.

The sporting aspect of recumbent riding seems to be catching on. But in city traffic, certainly the standard SWB construction has advantages that the lowracer variant does not. Highracers offer a fast yet safe option—these are very reclined bikes but with higher seats and larger. wheels. Long-wheelbase bikes offer great comfort and stability. Long-wheelbase models are still popular, and with improved designs could one day surpass SWBs.

Compact or medium-wheelbase models are coming on strong with bikes from Cannondale, Giant and several others. It's a fluid market with shake-ups and shake-outs almost yearly.

In the field of accessories, producers are doing a lot with partial fairings—both front and rear—and tailboxes, which find application in everyday use as well as in races. Recumbent-specific packs, panniers and apparel are finally available.

In the world of bicycle-inspired fitness machines, an interesting tendency is noticeable: Producers like Schwinn, Cat Eye, and Life Fitness offer very popular home trainers in recumbent design. Brochures emphasize their comfort and freedom from back strain. The big question remains: When will these companies realize that you can also exercise outside, on the street?!

Results we saw at a recent weekend event...

5000 m in 5:25:40 min.	= 34.38 mph
1 mile in 1:17:04 min.	= 46.10 mph
1000 m in 42:37 sec.	= 52.80 mph (flying)
500 m 19:88 sec.	= 56.27 mph (flying)

The ideal frame and aerodynamic shape has not yet been found, nor do the HPV clubs regulate anything in this sector. A free field for enthusiasts and inventors remains open, with special solutions serving a rainbow of needs and desires.

Based on recent developments we eagerly anticipate what will appear on the HPV scene in the future.

The Internet offers a great arena for HPV cyclists worldwide to share ideas, photos, plans, methods, and race and ride reports as soon as they happen.

Weekend sportsmen and commuters are doing great work with fairings made of cheap corrugated plastic sheeting called Coroplast. Fairing and trunk plans and videotaped instructions are being shared worldwide among cooperating clubmates.

So far, hundreds of complete streamliners have been built and raced.

Cyclists are discovering the advantages of faired HPVs—especially in centuries and open-field ultramarathon events—thanks to their comfort and protection from the sun, wind, and rain (not to mention the privacy they offer at crowded rest areas).

A hard-racing HPV, faired or unfaired, is nowadays often used in everyday training on open roads. This breed is relatively easy to build and maintain, easy to ride in bad weather, and durable enough to withstand bad roads and the occasional fall. Cargo space for groceries and lighting can be added for those with more utilitarian uses in mind. And of course the rig has to be fast enough to race.

Some teams build two bikes with the same geometry. One is for racing, the other is a "mule"—a trainer built quickly out of crude materials, perhaps without a fairing, which allows a racer to train and get used to any design quirks before risking its more costly cousin.

Some developers are adding features such as roll bars, wrap-around cages, and seatbelts to protect riders. Road-rash is already greatly reduced when sliding in bikes that have fairings. And reinforced fairing bodies provide helpful impact protection.

A fascinating concept for home-building is the "tub" format. A rigid, strong fairing is used as the frame, simplifying construction. The vehicle can be very light. Fairings that are stiff enough for the "fairing as frame" tub concept (and strong enough to stand on) can be made with simple materials such as fiberglass laid over both sides of 1-inch foam panels cut and glued to shape.

Recent Racing Action

All categories of HPV racing have seen extensive refinement and rapid improvement—stock, partially faired, utility, fully faired, and unlimited streamliners. An extensive series of races of all types has developed in the United States and Europe.

At the 1996 HPV world championships in Las Vegas, Dean Pederson raced "Coyote," a partially faired street-legal bike, and won the overall long distance road race in very windy conditions with an average

365 days of the year...

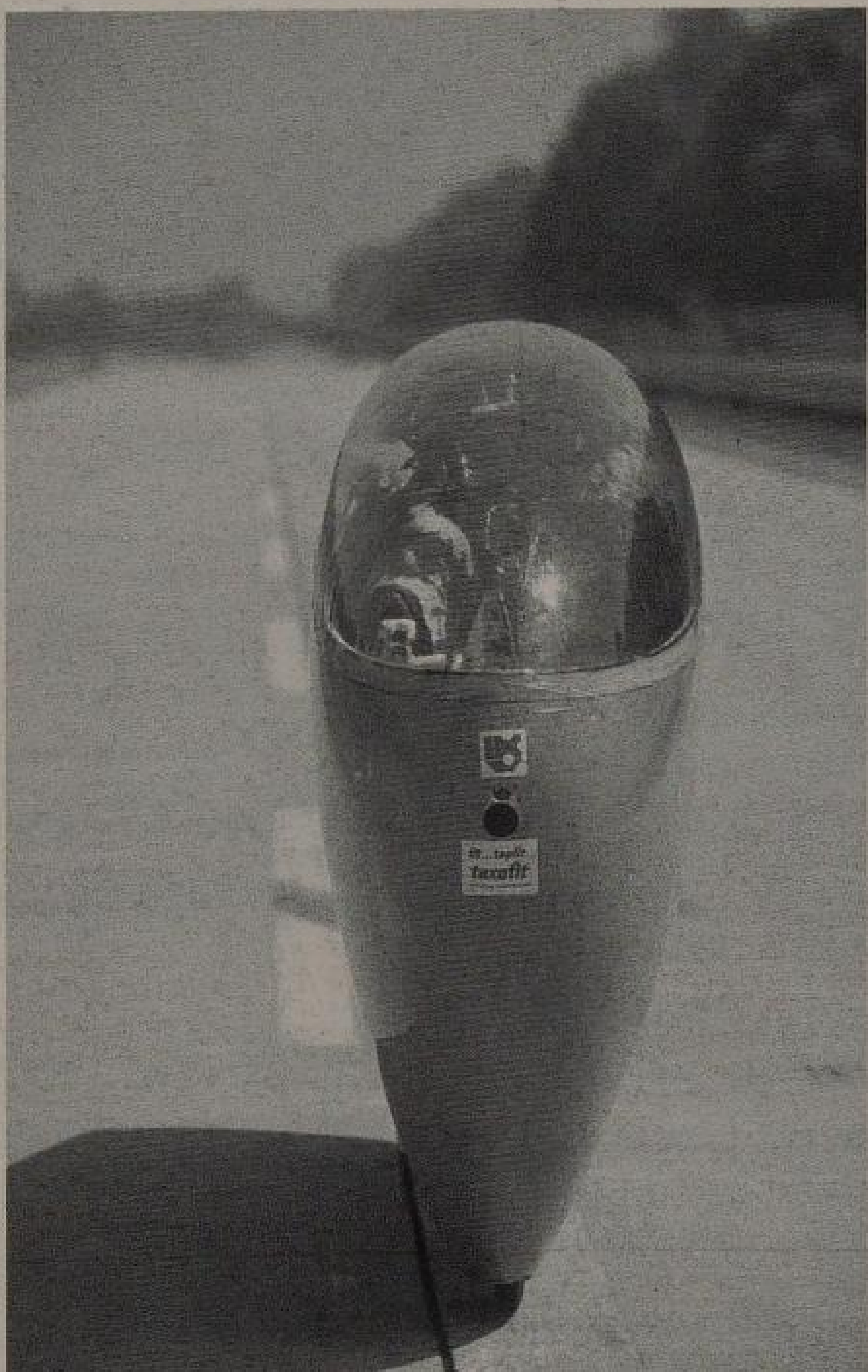
I love the way people react to my recumbent, and those reactions have hardly changed over the years.

In areas with lots of pedestrians, only a flying saucer would attract more attention than a parked recumbent. Whizzing by on one you can watch in amusement as bystanders give you the strangest looks: puzzlement, guffaws, and faces that defy description.

Even greater are the reactions of motorists who catch a glimpse of you in their rear-view mirror as you keep pace with them at 30 mph. They double-check to see if you're on a motorcycle, then check their speedometer, then they speed up.

In general most people enjoy the "performance," and your passing elicits only smiles, as you glide along swiftly, almost as if you were flying...

—Klaus Schroeder
(of Scooterbike and Aeroproject)



A front view of "White Hawk" shows the shape needed for record speeds today. Winning profiles are still being fine-tuned, but the best today are small and very smooth. (photo: G. Fehlau)

speed of 30 mph—while competing against fully faired streamliners. His clever fairing has a portal that allows him to enter without opening any doors. It was built around a stock Rotator bicycle from California builder Steve Delaire.

Production lowracers are becoming very popular. They now dominate unfaired and semi-faired HPV races worldwide. Major brands include M5, Birk, Optima, Velokraft and Challenge. Their speeds are becoming phenomenal, especially with tailboxes. In 2003, M5 lowracers with tailboxes won significant open races against upright bikes, including the Dutch open time-trial championship. Five tail-faired lowracers took the first five places in a very hilly 80-kilometer Swiss amateur race. Frederik van de Walle was allowed to enter the 3.2-kilometer prolog of the 2000 Tour de Seine et Marne. Riding at 32 mph he won by 10 seconds.

More upright events are including recumbent and HPV categories in their schedule, or are admitting them outright. The USCF now allows 'bents to have their own field, admitting them quite readily into time trials as well. This boosts popularity and innovation. Recent race results are encouraging.

In 1997 Andy Wilkinson set a new overall record for the 861-mile End-to-End course in England on a faired Windcheetah trike in 41 hours, 4 minutes, and 22 seconds, besting his previous upright world record by 4 hours—and exceeding 70 mph on some downhills!

At an elite 2003 USCF time-trial, Tim Brummer, owner of Lightning, won his 45-50 age group riding a U-2, a modified, unfaired M5 lowracer he sells. His time of 52:22 for 40 km (28.5 mph average) also gave him fifth overall.

There have been other gains on a smaller scale for recumbent racing within the USCF.

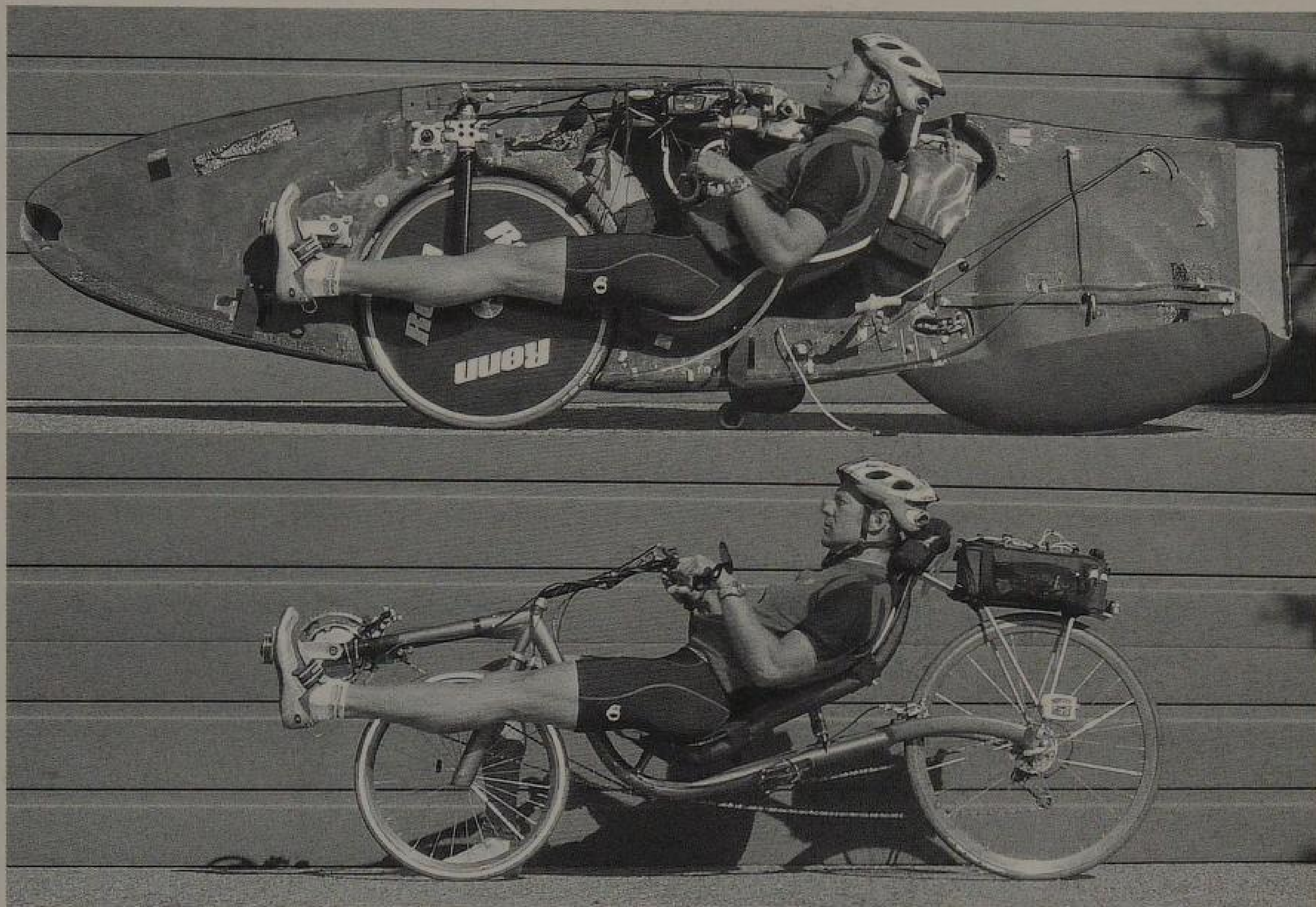
In 1999 Andreas Weigel got second overall (behind pro Shawn Wallace) on an unfaired Lightning R-84 in a USCF time trial in San Diego, with 26:46 for 20 km, for 27.8 mph.

That same year Jeff Potter (publisher of this book) was allowed to race a Michigan USCF criterium on his lowracer on a "noncontender" basis and proceeded to lap the all-classes field.

Highracers are doing well on longer open courses. In 2006 Jim Kern won two major qualifiers on a Bacchetta prior to being the first unfaired recumbent solo racer to start RAAM. John Schlitter, co-owner of Bacchetta, holds the course record for the open-field Race Across Florida, at 6 hours, 34 minutes for 167 miles in 2004.

In 1999, two prizes came on the scene to motivate builders and racers. The $25,000 Dempsey-McCready Prize for the first single cyclist to break 55 miles in one hour, and the .deciMach prize, also at $25,000, for the first rider to surpass 75 mph in the 200-meter flying sprint at sea level.

Sam Whittingham and Georgi Georgiev have so far made the biggest speed news. At the 2002 World Speed Championships, held at the high altitude of Battle Mountain, Nevada, Whittingham in Georgiev's Varna



"Diablo II" topped a multi-year streak of record-breaking with a new official HPV world record of 81 mph! He broke his record of the previous year by 8 mph!

Varnas have been breaking as many records at Battle Mountain as the limited pavement allows—including a new women's record of 64 mph by Andrea Blasecki. She broke her record of two years prior by 10 mph!

It's not only the course, of course. "Fast Freddy" Markham, at age 49, set a new Hour record of 53.43 miles in the venerable Varna "Mephisto" on July 2, 2006. We've seen decades of winning for this rider and his designers!

A key factor for victory seems to be the athletic talent of a rider combined with small size. Reducing the size of the HPV while keeping great sprinting power inside seems to be critical.

The long experience of Georgi Georgiev, Varna team designer, is also critical. He builds the Varna bikes on a very low budget, using no wind tunnels or computers. He says he gets the inspiration for his shapes from nature and animals, and says simply "smaller is faster."

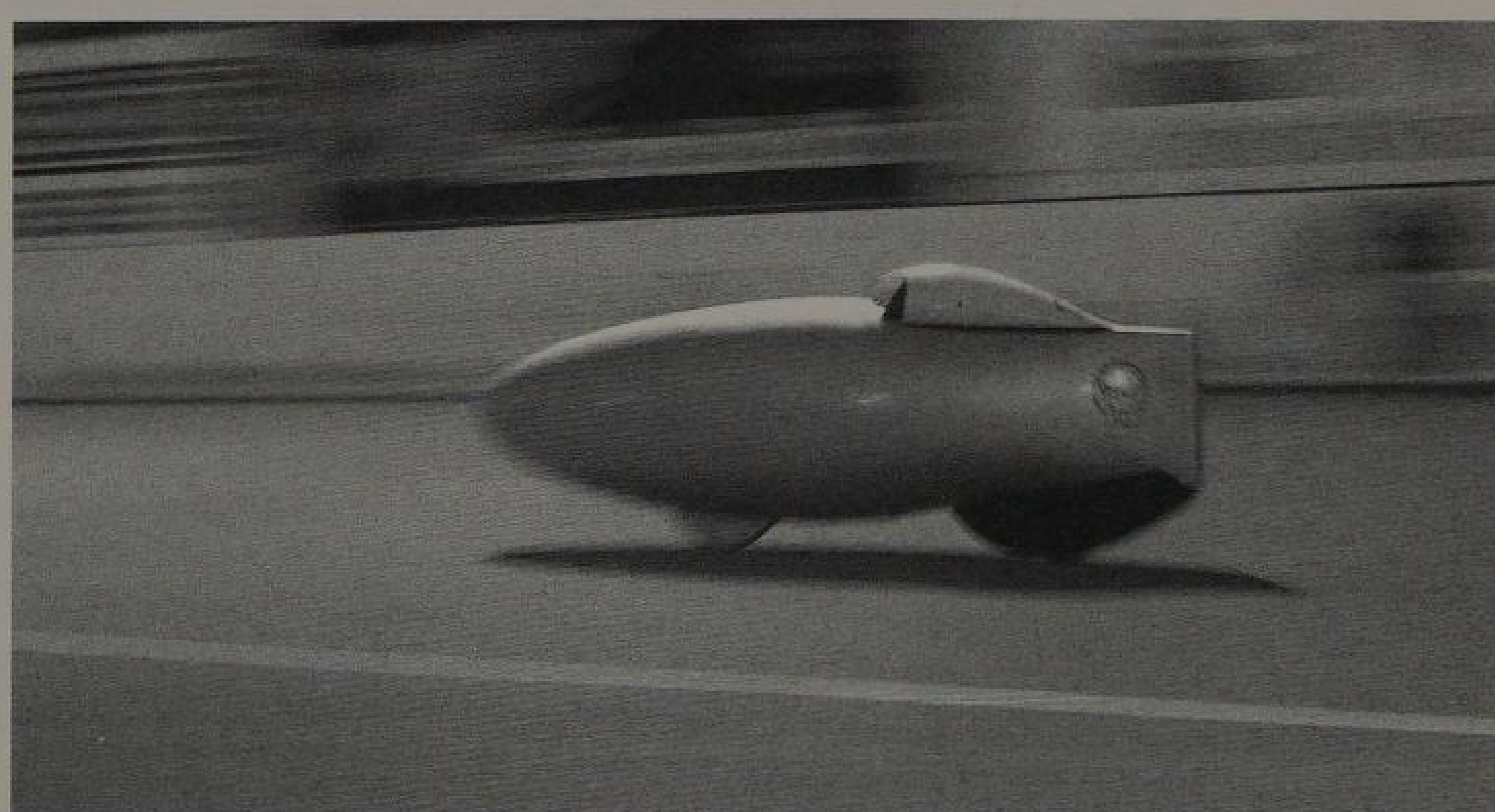
The Battle Mountain event has attracted many top new-breed racers, including Matt Weaver, Sean Costin, and Jason Queally—as well as up-and-coming record-holding teenagers Tanya Markham and Mackie Martin.

Weaver feels his HPVs achieve "attached flow," enabling 80-plus mph—with the potential, he says, of 100 mph!

Costin hosted the inaugural weeklong event at the unusually flat, smooth and quiet roadway located by Weaver. Amazingly, Costin, an Illinois resident, also raced, piloting the only other "camera bike," the "Coslinger Special" to 62 mph. The bike was inspired by Weaver's radical video-piloting concept and built as a WISIL club project with an ultralow "tub" fairing-as-frame design.

UCI track champ Queally came with a heavily funded British racecar project, "Blueyonder," and left cheerfully im-

Training bike shows similar body position as race bike. Greg Kolodziejzyk designed, built and raced "Critical Power" to a 24-hour record of 650 miles in July 2006. Onboard systems included a complex array of watts-cyclometer, iPod, telecom, hydration, nutrition and toiletry. Below: racing to the record, during the night. (photos: G. Kolodziejzyk)



pressed by the friendliness of the micro-budget record-setters.

The event is known for a spirit of cooperation. Racers help each other between runs and share insights while often working overtime in adjusting, modifying, and keeping their vehicles ready for the daily runs of the annual affair. It also has a reputation for cheery relations with the rural community, which goes out of its way to make the event possible. The racers have staged popular presentations for local schoolchildren, putting the HPVs on display and letting kids get into them. Many media people attend the event, including several documentary makers who have made films and presentations for TV.

Thoughts of a Recumbent Commuter

I think it is really pleasant to lie back on my recumbent after breakfast, to chose my riding style depending on personal preference and weather, and to arrive at our bike shop for work all warmed up after the 30-minute ride. On cold days, I arrive warm and energized. Had I driven, I would have saved only 5 minutes. The bus takes me 10 minutes longer. My commute takes up little room on the road, doesn't pollute, conserves the world's dwindling fuel supply, and poses little danger to pedestrians and motorists.

On a personal level, it saves money, keeps me healthy, and offers simple enjoyment.

Over the years I've acquired the sort of clothing and accessories necessary for comfortable bike commuting. Riding in the rain can actually be pleasant when you're adequately protected and your bike is accessorized for safe handling.

In terms of commuting by recumbent versus upright bike, there are impediments shared by both. Steep uphills are one. I can only say that I prefer to tackle them in a comfortable, seated position rather than standing and straining, as I would on an upright. Congested traffic is another. Whether on a recumbent or an upright, when riding on clogged streets you need to be nimble and alert. Inner city traffic is not a place to take anything for granted no matter what bike you're on. And though riding in heavy traffic can be aggravating, it's always more so in a lumbering motor vehicle with no options for escape or rapid route change.

I would like to say something about the fellows who cannot imagine having a quality of life beyond their 16-valve stop-and-go trophies as they blast through inner cities and on highways: Quality does not exist in cities full of polluted air, but in cities which pulsate with life.

Los Angeles, Amsterdam, Luebeck, and other cities have already determined to go in a cleaner direction. Individual vehicles with internal combustion engines are supposedly going to be a thing of the past in these cities. Instead, electric buses and trams as well as human powered vehicles are to replace cars.

—Klaus Schroeder, bike shop owner, bike manufacturer, HPV pilot, true believer

Ch. 2 On Parade with the Recumbent

Everyday Use and City Traffic

As traffic slows and becomes more congested and car parking becomes difficult, more people choose bikes for everyday transit. They share the view that bikes are more practical for short trips in the city than automobiles or public transportation. However, their bikes differ widely. Some riders prefer a simple, durable, and dependable steed, such as the British 3-speed or Dutch citybike—a cult object that can often be found for little money at flea markets. Others prefer to go upscale and might choose a carbon racer with tri-bars and clipless pedals.

Each owner believes they have found the ideal bike for daily use. And indeed they have—ideal for themselves, their expectations, their city, their demands, and their budget.

When considering a bike for city use or everyday errands, a growing number of people are buying recumbents.

A recumbent offers a great increase in range, improved safety, more cargo capacity, and dreamy comfort.

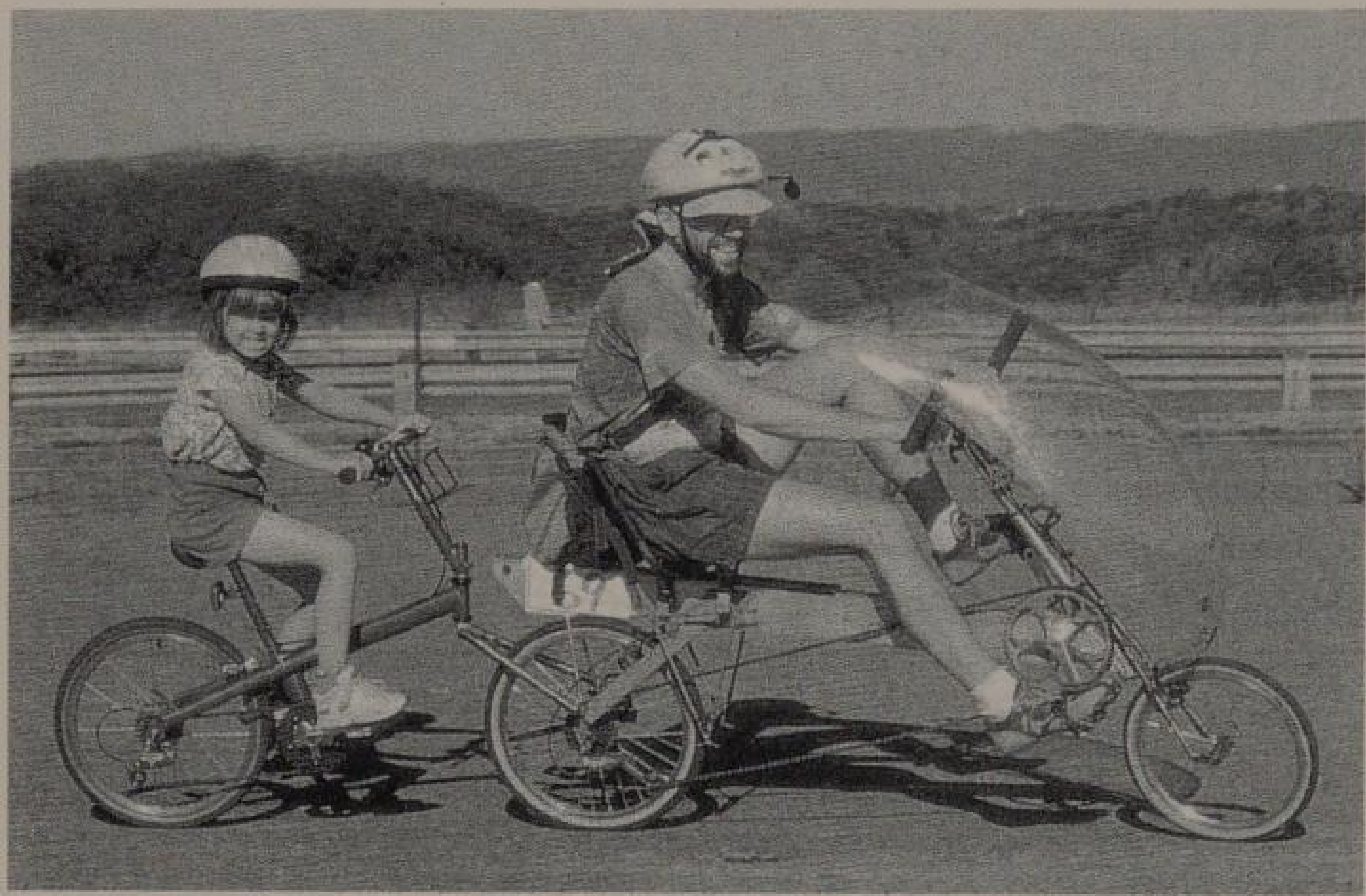
The Recumbent as Everyday Bike Offers These Advantages:

- comfortable position (no pressure points for butt, hands, neck, or back)
- eye-level eye contact with drivers
- low falling height
- faster on flats and downhills
- legs as impact crumple zone rather than head
- ability to keep pace with traffic and synchronized traffic lights (up to 30 mph with strong legs and fairing), boosting safety and convenience
- open, relaxed posture for chest and belly
- unusual appearance and bright-colored fairings increase visibility, safety, and security
- natural "heads up" position improves both close-range and far-ahead field of view
- less effort and extended range
- models with fairings offer protection from cold, sun, rain, and road dirt; fairings also keep bike clean
- wide range of clothing options (no special gloves, shorts, or jersey needed)
- better braking due to low center of gravity
- better crash safety with low, feet-forward position; with fairings, better all-round crash protection

Disadvantages and Limitations

- horizontal position particularly annoying in rain without special gear (side-zip jacket, etc.) or all-weather fairing
- turning head to see behind difficult without mirror
- long-wheelbase or faired recumbent can

This recumbent is outfitted with three fairings to enhance speed, visibility and weather protection, including a large rear "trunk" storage area, creating a system that's perfect for trips to the store.



This specially outfitted children's "tag-along" trailer gives kids a safe and convenient ride.

be heavy and hard to park
- hopping curbs not possible, dropping off them often awkward
- can't stand or lift from seat (very much) for bumps, sprints, or tricky maneuvers
- wobbly start-up with some models
- slower hill-climbing
- heavier in general for lifting/carrying
- can't attach bags to handlebars
- might have lower eye height
- rider can't wear backpack
- fairing windshield can fog or become obscured by rain
- potential for foot entrapment under seat suggests clipless pedals and extra caution
- legs and torso can overexposed to sun

Would-be recumbent buyers should bear in mind that each of the many varieties is best suited for a specific purpose. Before choosing a recumbent, analyze where, how fast, and under what conditions you'll be riding.

Chapter 5 "Basics of Recumbent Design" (page 91) contains information about the design characteristics of different types of recumbents and would be useful for anyone thinking of buying a recumbent. Here, we will look at a rough classification of the two broadest categories.

Type A: Fast on the Road

The term "fast" is open for interpretation, of course. We are mainly addressing here all those who prefer a racer to a Dutch city-bike or English 3-speed, and those who would tend to use a diamond-frame racing bike for daily pedaling. If you're riding in light traffic conditions, then a low, light-weight recumbent with racing wheels and tires, and appropriate high-performance gearing, might be best—possibly with short-travel firm suspension to improve comfort and control at top speeds and in intense cornering. Add a tail-fairing trunk and away you go.

Racer-types mostly forgo lights, rack, and fenders. On the recumbent market, a number of small retailers provide fast models that have been adapted for daily use and are a compromise between racers with a very low center of gravity and those with a more traffic-appropriate eye height. Seat height should be no less than 15 inches. Wheelbase tends to be under 44 inches. Emphasis is directed toward speed rather than comfort and cargo capacity. Prominent in this category are the brands Lightning, Rotator, Bacchetta, Optima, Challenge, M5, and Windcheetah.

Type B: Comfortable on the Bike Path

As opposed to speed bikes, comfort bikes have wide tires, one of which, at least, is suspended. The wheelbase is usually longer and the gearing is widely variable to meet the demands of slow, uphill riding (with cargo). Speed is important (and enhanced with fairings), but a secondary design consideration. The best-known makers of this range of bikes are Easy Racers, RANS and Longbikes.

Somewhat bridging the gap are hybrids, which strive to blend speed and comfort with as little sacrifice of either as possible. The effort is remindful of the industry's recent convergence of the mountain bike and upright bike.

The hybrid/comfort recumbent is a promising development and represents the efforts of the biggest companies involved. These typically use a compact long-wheelbase (CLWB) format, some even reviving the semi-recumbent position. BikeE was the best example of this type so far. Since its demise its place has been taken by from mega-makers Giant, Cannondale, and Sun, as well as Burley, the thrifty Cycle Genius and HP-Velotechnik.

I believe that in this sector one can expect unprecedented developments—especially as suspension is added to so many models, at ever-lower prices.

One versatile model deserving mention is the Lightning F-40, which features a fiberglass nosecone and full cloth fairing. It is fast, light, easy to handle, and comfortable—suitable for racing as well as commuting. The bike can be ridden "naked" as a stock P-38, with nosecone only, or with complete fairing.

More companies are offering add-on fairings that can be purchased separately and used to make a full fairing/cargo system.

The Easy Racer's Gold Rush replica with Zzipper windshield and cloth fairing is another fast, versatile "convertible."

Several European bikes, such as those by M5, Optima, and Challenge, could almost be called low-flying airplanes due to their laid-back positions, with high feet and narrow above-seat steering, especially when combined with optional fairings, the tail fairings of which can often carry cargo. Quite a few people tour with such bikes, even with the lowracer models.

If price is no concern look into the Lightning R-84. This carbon-fiber bike has full suspension, hydraulic brakes, and above-seat steering. It weighs only 20 pounds and costs $5,500; $14,000 will get you the complete fully faired F-90 variant.

The Flevobike from the Netherlands offered several remarkable innovations while it was available in the 1990s. With front-wheel drive (FWD), hip-steering, and full suspension, these two- and three-wheelers were appreciated by many HPV enthusiasts, even though its steering—done through the hips—takes some getting used to. The front fork is fixed, and a pivot in the mid-section of the frame responds to hip action. It takes about a week to master, and then it's second nature. Other FWD formats can include various amounts of leg steering, depending on the location of the steering pivot. But the Flevobike was the height of cleverness: simplicity.

The velomobile is a vehicle designed to replace a car. More people are using trikes (and a very few bikes) designed from the ground up for this purpose. They have thorough weatherproofing, cargo capacity and safety features—and often full fairings which give them plenty of speed. They have robust wheels and suspension to take anything the streets throw at them. They need parking space and can weigh quite a bit, but carbon is showing up in them and they are

The Giant "Revive" semi-recumbent is designed for comfort and ease of use. (Giant studiously avoided the term "recumbent.") The DX model pictured here includes a Shimano Nexus 7-speed internal hub. The enclosed drive system, rear shock, and cargo platform—along with budget pricing—make it a good city bike.

Two intrepid tourists with loaded recumbents travel snowy Scandinavia. Because of their low center of gravity, a mishap is less serious on a recumbent. (photo: F. & B. Magnouloux)

becoming lighter, zippier and more convenient—if still expensive. (Quest, Leitra, Alleweder and Cab-bike are the leaders here.)

There is no single ultimate city-bike. Instead, there are a number of solutions addressing different priorities. Upright enthusiasts who ride primarily in the city seldom use an over-the-counter bicycle. They modify their bikes to meet their needs.

It is exactly the same when it comes to recumbents. The smaller number of producers often results in more customization by the customer, but there are a growing number of models that strive to be complete out-of-the-box city bikes. One can chose from a rainbow of frame styles and materials, wheel sizes, and seat variations. After selecting a bike, the time-intensive and possibly costly modifications begin. Bike shop walls are filled with enticing options, of varying degrees of utility.

On Tour, on a Recumbent

Every mode of transportation has its strengths and weaknesses. The bike allows unmediated enjoyment of nature and direct contact with people; plus it offers thrift, reliability, and an amazing blend of independence and community.

The ideas here apply to most kinds of riding, really. The longer the trip the more robust every aspect should be, but a tour can be of any length. You're on the open road. It doesn't matter whether it's a century ride or weeks away from home, these ideas relate to how to enjoy spending a good deal of time on a recumbent.

To my mind, the recumbent represents the best and most mature variation of the bike. It is fast yet easy on the body, so it increases your range significantly. And the heads-up view makes for a safer, more satisfying experience. The body position is wind-evasive. All other bike types fall short of this. None offer such a beneficial combination of comfort, aerodynamics, and safety. Not even triathlon aero-bars can compete, as their use confines the chest and puts the weight forward.

Additionally, recumbents are well adapted for fairings and luggage trunks.

Traveling by recumbent invites interaction with people you encounter on the road. A loaded recumbent crossing the countryside is quite an attraction. It draws positive response from motorists, kids, and teenagers alike. Sometimes it can be difficult to leave because of all the questions from curious bystanders. Kids eye the weird vehicle, challenge you to race, or simply laugh about "that thing." Two questions later and you end up in a conversation about life, the universe, and more. It may mess up your schedule, but it is part of the charm of journeying by recumbent.

Note: if you've been enticed to stay somewhere, it is nice if you can give a little gift to your host. A stack of pictures of your fully packed bike and family won't take up much room in your kit. ...Perhaps someday the world will be more used to 'bents.

Bodily Comforts...

The stretched-out, open position on a recumbent leaves plenty of space for the inner organs. The lungs work easily and the intestines and stomach are not compressed. In practice, this offers significant advantages. After a power breakfast in the morning you don't have to wait for your stomach to settle. You just get on the bike and go. Stomach and intestines have enough room to do their work despite pedaling. Your unfolded position might not enable you to ride up mountains at "Tour de France" speed, but it prevents stomachaches.

The comfortable seat and the lack of pressure points for hands and neck allows for relaxing, low-stress touring for long distances. Less tension on all body parts is truly beneficial all around.

More adaptation, lighter models, and further innovation may even help us to someday break mountain-climbing records as well!

Bernd Kerke reports about a journey through Australia on his Radius recumbent:

"The roads are often only unpaved gravel, but as we are fully suspended it's no bother. Overall, touring on recumbents is sheer pleasure. After about 300 kilometers our muscles are used to the different kind of strain, and the suspicion of going nowhere leaves after checking your cyclometer. Compared to previous bike tours in Europe, we are about 15 percent faster, but hardly ever exhausted in the evenings. It is a fabulous feeling to have your eyes turned to the scenery, and to ride a bike without any bone twisting. No tense shoulders, no blisters on your hands or boils on your rear, but still we manage to go 170 kilometers a day with 30 kilograms of luggage without falling down dead afterwards. Riding with luggage and on bad roads is easily adapted to."

Two lowracers blazing along at the Horsey Hundred, a major organized century tour in Kentucky. (photo: Larry Varney)

Luggage

Though it isn't possible to wear a backpack while riding a recumbent, there are some alternatives. A small backpack can be worn on the chest. More sensible is a messenger bag, which can be slung to your side or across your chest. Many recumbent-specific, and even model-specific, seat-bags are now available as well, some designed with aerodynamics in mind.

Racks and panniers meant for upright bikes often work fine on recumbents, but special racks and panniers for various models are also offered, many having aerodynamic shapes.

For those traveling or commuting with children or lots of cargo, a trailer might be the most sensible choice.

Loading

A vehicle on tour undergoes heavy strain, and as the load increases, so does the strain. To alleviate the stress, distribute the load. If there is too much luggage on either end, handling gets troublesome. Braking and steering can become treacherous; tires wear unevenly.

A test ride on a loaded bike is absolutely necessary. If the road-contact area of either tire noticeably flattens under the load, you should change the weight distribution. Use a weight scale to verify that you've kept the same wheel-weight ratio. This preserves ride quality; improves safety; and prevents flat tires, rim damage, and broken hubs and spokes.

Light, single-track trailers (such as the B.O.B.) are especially versatile. They do not impair maneuverability, offer plenty of storage space, and bear a lot of weight.

One caution: recumbents with rear suspension may shimmy under the load of a trailer. If you own a recumbent with rear suspension, go for a test run with any trailer you're interested in buying.

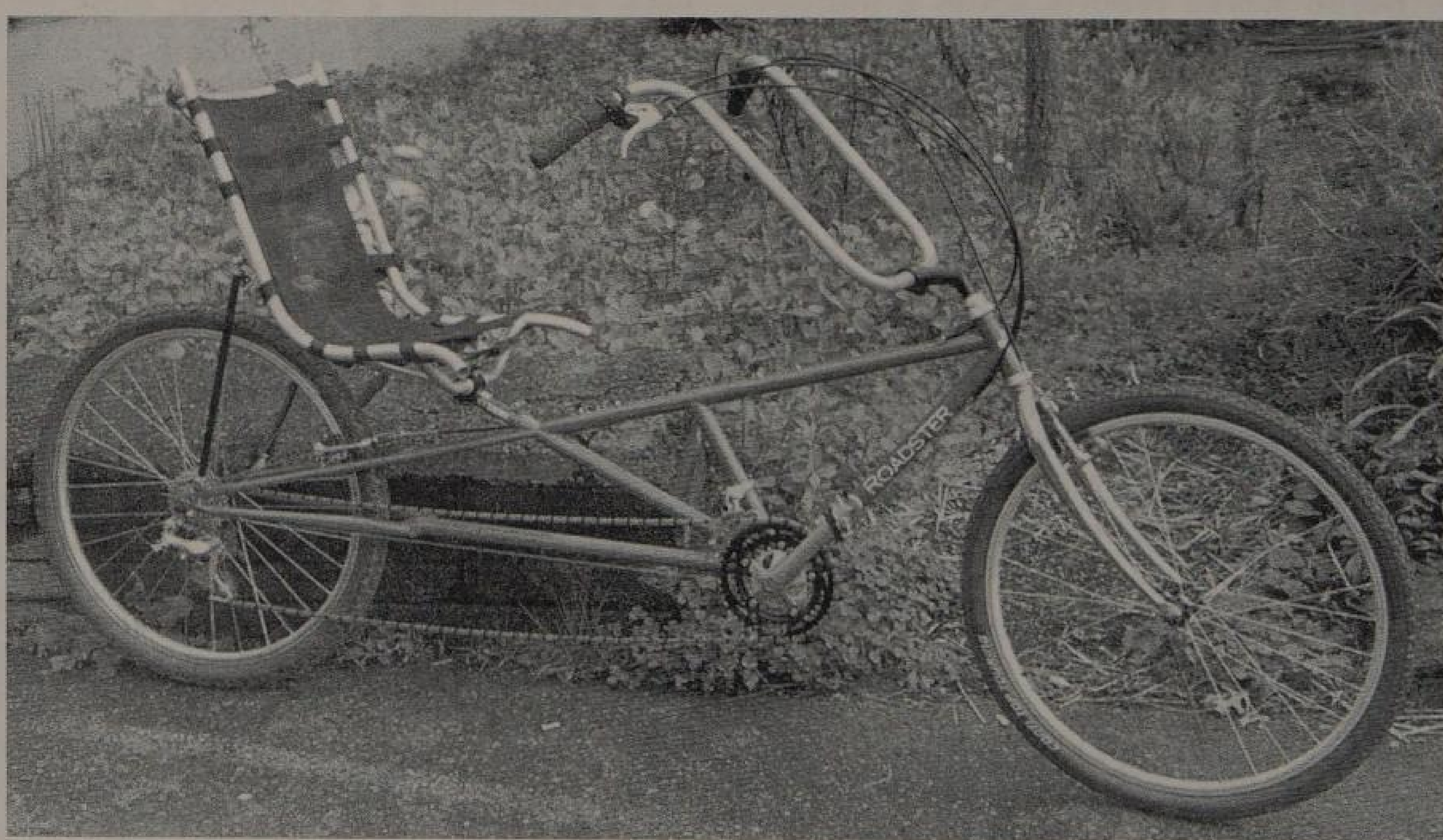
Tire Width

With sufficient air pressure and smooth asphalt, 32 millimeter (1-1/4 inch) tires are sufficient for touring. A wide tire is naturally the simplest, easiest, and cheapest "suspension" for a bike. With any type of fully faired recumbent, especially a high-speed model, you'll want to avoid blow-outs. They're dangerous and repair is time-consuming. Many recumbent riders favor the new breed of wide, slick, low-rolling-resistance tires, which are also offered in the smaller HPV wheel sizes. Thankfully, there's finally a wide variety of quality tires suitable for recumbents, so shop wisely to determine what works best for your needs.

Gear Ratios

Load-weight, desired speed, topography, and riding style all play a role in determining your most suitable gear ratios. Recumbents typically need both a higher high and a lower low than uprights. They require smaller gears than usual for climbing because they're relatively heavier and you can't stand and pedal. Then if you want to take advantage of increased downhill

The "Roadster" by Human Powered Machines of Eugene, Oregon, has relaxed chopper styling with tires and frame geometry suitable for dirt road riding.



speeds, you'll need a big gear to match. Depending on aerodynamics, the desired "translation" (distance traveled per crank rotation) of a recumbent can vary widely.

For the broadest range of gears possible, combine an internal gear-hub with a multi-cog freewheel and derailleur.

Your preferred cadence plays an important role here, and gearing has to be oriented toward that. However, your initial preferences will likely change as you adapt to recumbent riding, so the advice of an expert would be helpful in choosing gears and setting up.

Pedals and Shoes

Efficient energy transfer pays off on long rides. In order to achieve this, a secure connection between pedal and shoe is needed, for the foot hangs vertically from the pedal when riding a recumbent. Every bump tends to bounce it out of regular toe-clips. That is why a clipless pedal is almost essential for performance cycling—and safety, too.

If your foot falls off the pedal and touches the road while under way, you risk injury. The foot can get sucked under the front of the seat, resulting in a twist or even broken bones.

The advent of clipless systems were very fortuitous for recumbent riders and significantly boosted overall recumbent viability.

When traveling on smooth roads, I prefer light, stiff-soled racing shoes, which are comfortable and transmit power the best. On tours with bad roads or tours that include hiking I prefer "in sole" systems like SPD plus rubber soles, to allow easy walking. Many mountain-bike shoes meet this need, along with a few touring-specific models, while still having a stiff sole for vital power transfer. Combo pedals and those with twist straps are best limited to city riding.

Lowracers can be used for touring; however, this practice seems more common in Europe than in the US. (photo: M. Geyer)

Spare Parts

Recumbent bikes should be thoroughly checked before any journey. Prepare for every "impossibility": theft of bike parts, vandalism, accidents, and failures. If the impossible happens, you're faced with finding replacement parts. This situation is riskier in the case of recumbents, many of which include at least a few special parts.

With that in mind it may be best to simply avoid special parts wherever possible. Small recumbent front wheels are at a parts disadvantage. Only the 20x1.75-inch wheel common to the folding bike and BMX bike can be reliably found afield and in faraway countries. Note that the 406 mm BMX rim is not to be confused with the uncommon 451 mm version called a "road 20."

Some of the new breed of highracers and some long-wheelbase models are offered in dual 26-inch or even dual 700C wheels, making tire/wheel replacements a breeze.

Because of the mountain bike's market dominance, the choice of a 26-inch wheel for at least the rear is very convenient. The variety of tires that fit on a 26-inch rim (599 mm, actually) range from a narrow 25-mm slick to a 2.5-inch knobby. With so many choices, tires can be matched to terrain. Many are available as light, space-saving fold-ups with Kevlar beads, making them ideal for carrying along. If you're in a pinch you can always use widely available knobby tires. This is certainly better than waiting days for new tires that are exactly to your liking. Farther down the road you may find a shop with a better tire selection.

The first set of tires you choose may well be specially designed for touring, durability, and puncture resistance. You may also find (by testing and trials!) that a system including tire liner and special tube is most reliable.

If smoothness is preferred over top speed, then wider rims are a good pick.

If you want a wheel larger than 26 inches, check availability in any country you think you might visit. The 27-inch wheel, for instance, is rare in Germany. I was stuck in Ireland for a week once because I needed 28-inch tires.

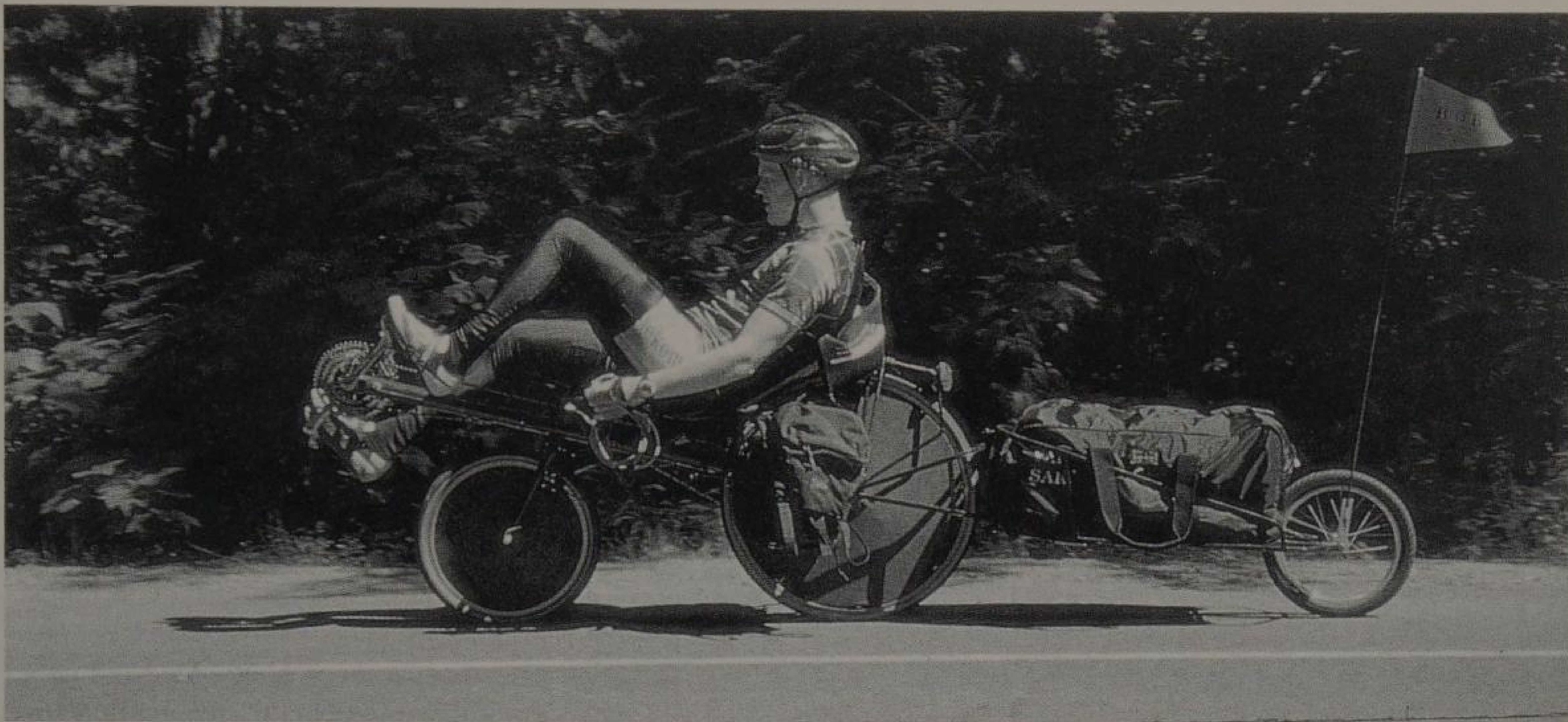
A recumbent facing the rigors of touring needs to be set up with care, with every adjustment "just so." Component choice is crucial. Avoid cheaply built parts that might wear out prematurely. Robust parts improve safety and minimize the chances of breakdown. Sealed-bearing hubs, pedals, and bottom bracket free you from maintenance and are known for their reliability. V-brakes offer powerful braking with little effort, but set-up and maintenance can be tricky. Disk brakes are easy to set up, they're powerful, weatherproof, and tolerant of wheel-rim mishaps, but repairs won't be available in every town, and they're expensive.

A LWB recumbent is often used as a travel bike, due to superior comfort and stability. This Ryan is a real "Cadillac." (photo: Vanguard)

Components, to the highest degree possible, should be compatible with a wide variety of domestic makes. Some form of indexed gear-shift lever or twist-knob, like STI or Gripshift, should be available in developed areas (check first!). High-tech components like these—including the amazing Schlumpf crank-gear and new-era hub gears—are marvelous things, but touring with them in remote areas is asking for trouble. Their repair requires dozens of manufacturer-specific parts, cogs, chainrings, chain, hub, cable knobs. This is especially true for 8-, 9-, and 10-speed groupos. Bar-end or thumb-shifters are better because their indexing function can be switched off. They do their work independently from the choice of cog, chain, and shifter. If you get entangled in an accident on a remote part of your journey, you simply shift into the first cog that fits, switch off the indexing function and continue riding.

Tools

A wise cyclist always carries tools on tour. Obviously you only want to take those needed for your particular bike. The more you bring the less dependent you'll be on others—who may or may not have what you need. A careful weight-versus-utility evaluation is in order. The truing stand will have to be left behind, but how about a bottom bracket tool? Inevitably, one of the tools you



A trailer is a sensible addition to panniers on tours with a lot of luggage.

leave behind will be the one you need. Short of being followed by a fully equipped sag wagon, you'll have to make some difficult choices.

Your choice of components can reduce the number of tools you need to bring. Using Mavic hubs, a Mavic headset, Edco internal bearings, the Sugino "Out-tex" crank arm replacement screw, as well as Dia Compe 986 cantilever brakes, all greatly minimize the number of necessary tools. You can further lighten your tool bag by using a multi-tool, such as the Topeak McGyver, with its 30-plus bike tools in one small unit. You might want to add one or two commonly used full-size tools, a Swiss Army knife, a Leatherman tool, some cord, wire, duct tape, patch kit and spare tubes, and, if it's a long tour in remote areas, a spare tire.

Lastly, a pump. They've gotten smaller and lighter in recent years. Just make sure you choose a reliable one. Test before you tour! The emergency micro-pump that's handy in town is not the one to rely on for touring.

Daily Range and Day-trips

You can cover more territory in a given day on a recumbent than you would on an upright bike. Why? Three reasons: greater comfort, freer breathing, and improved digestion (from the stretched-out position). Covering 60 to 100 miles in a day requires no great exertion, and seasoned riders can double or triple that.

Ferries, Planes, Buses, and Trains

Since the World Trade Center attacks, taking a bicycle with you when traveling by plane is becoming more difficult and expensive. Airlines have different rules and restrictions, so be sure to check ahead before showing up at the airport. Some may require you to declare in advance your intention of carrying a bicycle on board. Likely you'll be charged a fee approaching the cost of your airline ticket. You'll need a bike box or suitcase large enough for your folded or disassembled bike, of course, and its weight, combined with your normal luggage, mustn't exceed your allowed maximum.

Waiting for the start... Organized tours and century events are seeing more and more recumbents. (photo: Mark Sloan)

It may be more convenient, and cheaper, to mail your bike to your destination ahead of time.

If traveling by train, be sure to inquire ahead about restrictions and requirements. Not all trains allow bikes on board. Your suitcased bike will probably be loaded by a baggage handler, so make sure your suitcase is sturdy enough to endure rough treatment.

Many city buses are equipped with exterior bike racks, making a suitcase unnecessary. But don't assume your recumbent will fit. They're designed for upright bikes.

On boats and ferries you'll find travel with a bike much easier—you may not even need a bike suitcase. Just be sure to alert the ticketing agent of your intention of bringing a bike with you; there may be a surcharge. A friendly heads-up to the staff loading the boat might secure your bike a favorable spot, protected from the elements and shifting cargo.

Generally speaking, the novelty of the recumbent can work in your favor. Coupled with a little charm, the bike opens doors. Use this good will to negotiate situations to your liking.

Theft

A bike trip without a bike—that does not compute. Without turning yourself into a raving paranoid, you need to be ever vigilant. Bike thieves are everywhere. That said, a recumbent is a little less vulnerable to theft than an upright bike, which can be thrown into the back of a truck during the few seconds your back might be turned to drink from a fountain or dash inside a store for a snack. Further, just by virtue of its oddity, more eyes will be on a parked recumbent. A thief may think twice before stealing something getting so much attention.

Obviously, it's best if you lock your bike during every unattended moment. For short absences in areas with a low crime rate, a cable lock may be sufficient. In an urban setting or for longer absences, I advise a U-lock with a cable threaded through the wheels.

Things get tricky with cargo. Panniers are easily removable, so secure (or lock) them to the bike to discourage theft. Especially valuable cargo (camera, GPS, etc.) should go where you go.

If your bike is actually stolen, you have an edge over the rider of an upright bike. The recumbent's uniqueness may help you recover it. Alert police of the theft and describe the bike. You may want to carry a photo of it for just such a purpose. You're battling an attitude of "bikes all look alike." But in your case, that isn't true. If you're in a small town, it might be worth your while to enlist the local newspaper or television station in your search. In this instance, a photo of the bike will make all the difference in gaining their interest.

Test Tours, Rallies, Expos, and Pro Shops—HPV is a Growing Scene

Interested in trying a recumbent before buying or building one? Seek an organized recumbent bike tour. Call a local bike shop or a regional recumbent specialist, search the Web or check the back pages of bike publications such as *Recumbent Cyclist News*, *Tandem & Recumbent Rider* and *VeloVision*. On a group ride, you'll be led by experts and join with folks with a shared interest in recumbents. Larger events will have bikes to test, expo booths and company reps. Specialty shops are well worth hours of driving to visit for a serious test session. These are all valuable resources for you, offering hands-on answers to your most urgent questions.

Some shops will rent or loan you a bike overnight.

Be sure to have any test bike adjusted to fit you first. If there's a fee for extensive testing, it's likely a bargain. Let the knowledge of what you need and your recumbent education lead you. Temper the excitement of first impressions with the awareness that your appreciation (and skill) will change greatly after months of riding, but test riding is invaluable...and thrilling!

These Dutch recumbent club cyclists go on several multi-day tours each year. (photo: ligfiets.net)

13 Years of Building Recumbents

I called it my "Ultramobile." I could not think of a better name for the conveyance I created at age 12 by bolting my broken, chain-driven toy vehicle to the front end of a broken foldable bike. The result was an agile three-wheeler that didn't go forward very well but was lots of fun nonetheless. A couple broken toys, two bolts, and a crazy idea had amounted to quite something.

Six years later I bought an arc welder, and new possibilities opened up. Using parts from spare bikes, steel furniture, and plumbing pipes, I created a usable three-wheeler.

My next project was a long-wheelbase recumbent with indirect steering. Unfortunately it was severely vulnerable to wind, and after hitting my first bump the steering broke.

After fixing it, I used it in Germany's first HPV competition, in 1986. The abundance of ideas and apparent perfection I encountered there was impressive—and frustrating. Everything had been done, it seemed. Upon closer examination I began to find flaws. There was room for improvement and innovation after all.

I went back to work, alternating between two- and three-wheelers.

In the meantime I had discovered thin-walled tubing and set about building my first good recumbent, a short-wheelbase model with rear-wheel suspension. I also built a fiberglass nosecone and cloth fairing. With this bike I competed in the 1989 Tour de Sol, and, surprising to me, I won.

I perfected my concepts on the next bike and became the European Vice-Champion in Muenster that same year.

Berhard Klar, whom I met during this time, sparked some great ideas. During long afternoons, when I was supposed to be attending lectures, we rid each other of preconceptions and developed a simple, light, and beautiful frame. The "fastest bike in town" concept was born. We built 10 of these bikes before we realized the concept was not suitable for serial production. Nonetheless we benefited from the experience.

In 1990 five colleagues and I conceived of a high-speed vehicle. Frustrated by the cost of the project, we turned our energies into developing an everyday fairing instead. Each of us contributed experience, skill, and materials, and the "Z-2" fairing was born. With assistance from some experts in plastics, we developed an improved second model. It was fast and safe, and it fit a wide range of bikes and riders.

The Z-2 became very successful, helping the talented Walter Zorn win many races.

—Martin Staubach

Ch. 3 Recumbent Bicycle Sport

The recumbent is the product of the desire to make cycling safer, more comfortable, more enjoyable—and faster.

After recumbents were banned from "normal" bike races in 1934 by the UCI, no separate sporting division for recumbents was formed. As a result, recumbents disappeared from sports for a long time.

Even today the statutes of most bike associations are worded to make it difficult to construct a recumbent that meets the requirements while still possessing the advantage of a safe, aerodynamic body position.

But times are changing. Triathlon handlebars are now accepted in some parts of the racing scene, even though they offer only the advantage of aerodynamics and some shock absorption. Moreover, they impair safe handling.

Many race organizations also accept innovative frame designs such as the Softride beam and Trek's Y-Frame. (The UCI, however, does not allow them. Tri-bars in mass start events and sub-15-pound bikes are also disqualified by the UCI.)

From 1995 to 2004, the American USCF gave its officials the discretion to include recumbents, though their 2-meter overall length limit effectively barred many. Recumbent racers got their best access via USCF time trials and smaller races. The success of recumbents, as well as the complexities of the discretion approach, resulted in a reining-in in 2004. Recumbents must now race in their own category, which organizers are not obliged to provide.

Prior to the new rule, a recumbent achieved an age-group win at the 2003 USCF Record Challenge Time Trial. They also won four other races before the new rule. Since then one won the 2005 ABR National Time Trial. Combined racing continues in open non-USCF events. These are

Unfaired racing performance has risen dramatically over the last several years, with production lowracers dominating. Among top racers, average speeds of 30 mph are typical. (photo: www.tim.be)

increasing. New race groups are forming apart from the USCF, and they are often friendly to recumbents.

The USCF situation still offers opportunity, but the question remains as to why the biggest organization, the UCI, totally excludes a design variant that allows so much diversity of position and fit and so many advantages.

In events outside the major associations, some races will bar recumbents simply for being recumbents—not because they fail to meet prescribed specifications. Rules can be arbitrary. In events where they are given their own class, fairings might not be allowed. Some organizers question the safety of recumbents. A race organizer exposed to an awkward recumbent novice may judge the type as a whole on that first impression. In general, organizers seem to be taking a wait-and-see attitude, and even the associations might change their rulings. Certainly the recumbent faces bias on the racing circuit, but keep in mind that every new class adds more work to a race organizer's already overloaded schedule. They'll only be happy to do it if it's worth their while—if plenty of paying recumbent riders commit well in advance. (Also, it can only help if recumbent racers volunteer at races and work within race clubs.)

Organized 100-mile "century" rides are a popular venue for informal recumbent racing and mixing with uprights. There are typically no rules restricting bike type or fairings—just an expectation that traffic laws will be obeyed. These rides are basically the only occasions where recumbent riders can freely compete against upright riders. When riding for most of a day, comfort becomes an issue, so we're seeing an explosion of 'bent riders at these events—no matter what pace they ride. And uprighters there seem to get along with them fine and give them respect. The Holy Grail for century riders—the sub-4-hour finish—is unattained by upright riders, but it has now been achieved quite a few times on very aerodynamic recumbents. Recumbents have "won" quite a few of these popular events recently, greatly raising awareness of the merits of this bike type.

Young people, too, participate in HPV sports. Tanya Markham, age 16, gets ready for a run in "Gold Rush LeTour" by Easy Racers. She set the record for junior women with a blistering 52 mph sprint. Mackie Martin holds the junior men's record at 60 mph in the "Virtual Rush." (photo: F. Markham)

HPV clubs and associations have sponsored recumbent races in the United States since the middle of the 1970s. Several seasonal series, some of which have annual points rankings, have developed, such as today's HPRA (Human Powered Race America), but the main races are organized by the IHPVA, which was founded in 1974. This organization puts only two restrictions on design: competing bicycles must not store any power, and they must not pose a danger to rider or participants. Any additional restrictions result only from "sports Darwinism." Unfit or unusable innovations disappear from the scene pretty quickly. Experience, imagination, and smart engineering continually push the "limits" of what is possible.

Types of HPV Races

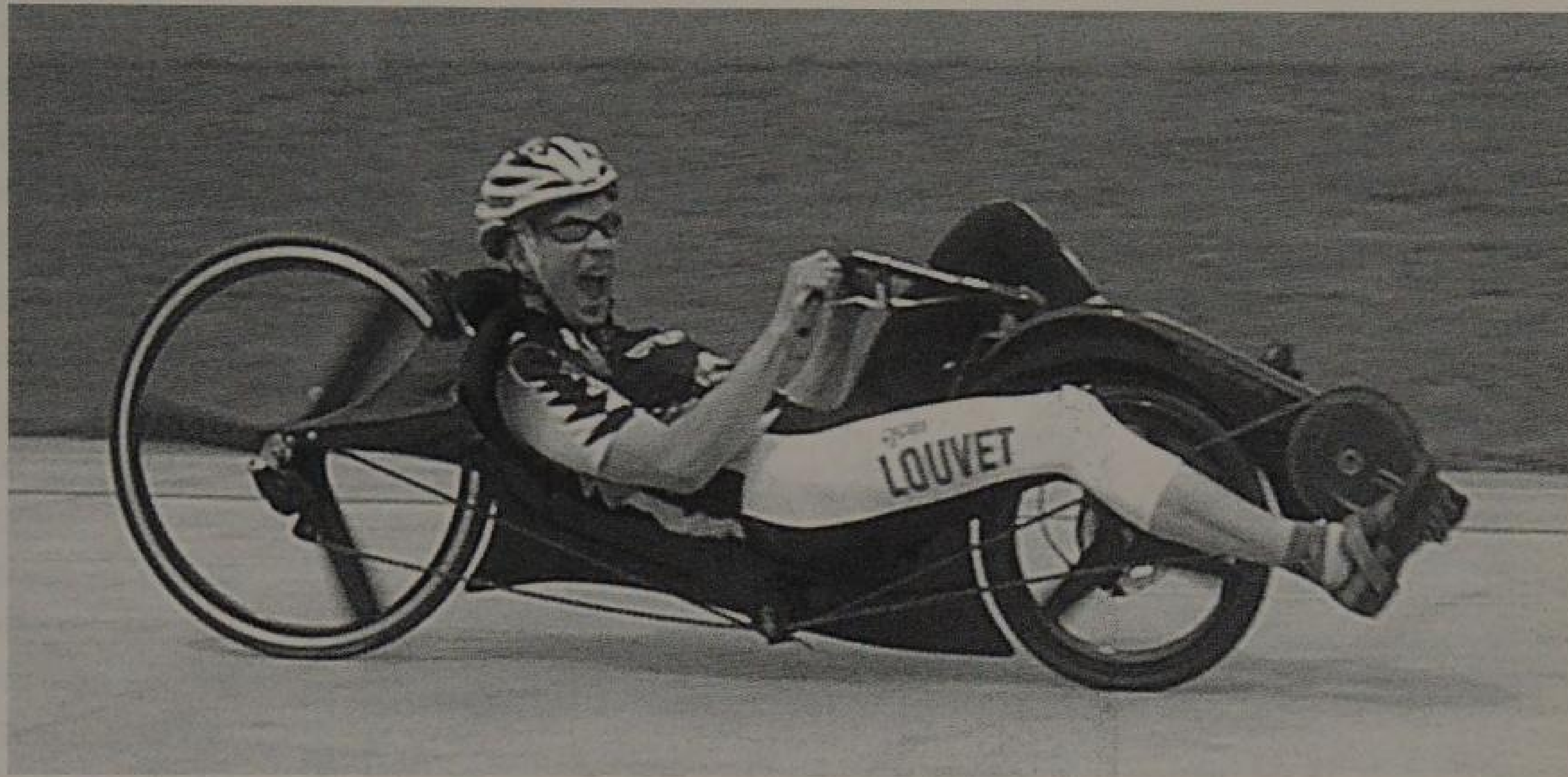
The striking thing about HPV events is how many different design types there are and the camaraderie among the participants. A convivial air prevails both on and off the course.

Nonetheless, HPV racers are still racers. They are keenly interested in winning and eager to demonstrate the superiority of recumbents.

Among the races they might encounter at a weekend HPV event or during a season of racing:

- Centuries, brevets, and ultramarathons
- Circuit races, criteriums, road races
- Time trials (on road and track)
- Hour races
- 200-meter sprint
- Hill-climbs
- Drag races
- Stage races
- Season-long point series
- Utility tests

200-Meter Sprint



The 200-meter sprint begins with a flying start. The cyclist gets either an unlimited run-up or 600 meters (depending on which record they are after), then flashes past an electronic beam to start the timing. A finish-line beam is passed after 200 meters, followed by a length for cooling down.

The short time frame and high speeds make selection of building materials extremely important. Unfortunately the cost of building a competitive bike has risen to a level that few individuals can afford. A successful racer nowadays can hardly hope for records in this event without an affluent sponsor. (A weekend racer competing against regional friends finds access to wins much easier.)

The Varna Team's 81mph record is standing strong, but high-speed buffs are investing all their ambition into toppling it in an effort to claim the $25,000 .deciMach Prize, which will go to the first rider to officially break 75 mph (or 82 mph at altitude—or to the current champ when the prize goes on hiatus due to road repairs at the elite venue). To win, you need a vehicle with very low air resistance and great power transfer efficiency—with power-weight ratio being a critical factor. Without a doubt a top athlete must be at the pedals. Record-holders like Varna's Sam Whittingham (current champ), Chris Huber, Fred Markham, and Lars Teutenberg are all top UCI racers.

Almost without exception, sprint racers prefer two-wheeled bikes, called "inline" or "single-track," to three- or four-wheel bikes. Inline bikes offer the smallest possible frontal surface and less rolling resistance. The smaller undercarriage also translates into less turbulence than what would be created under a multi-track bike with fairing.

Streamliners like the Varnas of Canada, the Bean of England, and Vector's German White Hawk teach three-wheelers to be afraid of the single-tracker in this event. (Trikes come on strong today mainly in distance events.)

To shave even thousandths of a second, sprint-bike builders test their designs in wind tunnels to find the optimum profile. Frames and fairings are tailored to each rider. Every millimeter of frontal surface area is considered in the struggle for optimum aerodynamics. Drivers twist and turn, helped by assistants, to insert themselves into their vehicles. Door cracks are sealed with the thinnest possible tape to avoid any additional turbulence. And, of course, only the finest components are used. The bike/rider package is then rolled to the start and held upright for the launch.

Basically, shell and frame are made as light and stiff as possible. Thus the choice is often made in favor of unconventional, experimental, and expensive components and accessories. Frames made from aluminum honeycomb, covered with carbon fiber, for instance, make it possible to build a fully faired sprinting machine that weighs only 28 pounds. The Nilgo III, designed by R. Brichet of France, is a fine example.

Exotic lowracers using "splitter" designs that incorporate faired shapes into their frame design, such as the NoCom by Velokraft, are being used to win top HPV events, giving speeds on par with faired bikes and UCI pro cyclists. (photo: Velokraft)

The Kilo

The kilometer sprint is the big brother of the 200-meter. It's only offered at major HPV events. If a velodrome isn't available, organizers must obtain clearance from local officials to occupy a stretch of smooth road—usually about twice the length of the event in question. It's easier to get permission to use roads for shorter closed events or for open events where traffic is allowed and all laws must be obeyed.

Today's top speeds require such long build-up distances (several miles) that several records can be broken at once, as Sam Whittingham did in his Varna on the lengthy Battle Mountain course in Nevada.

Time Trials

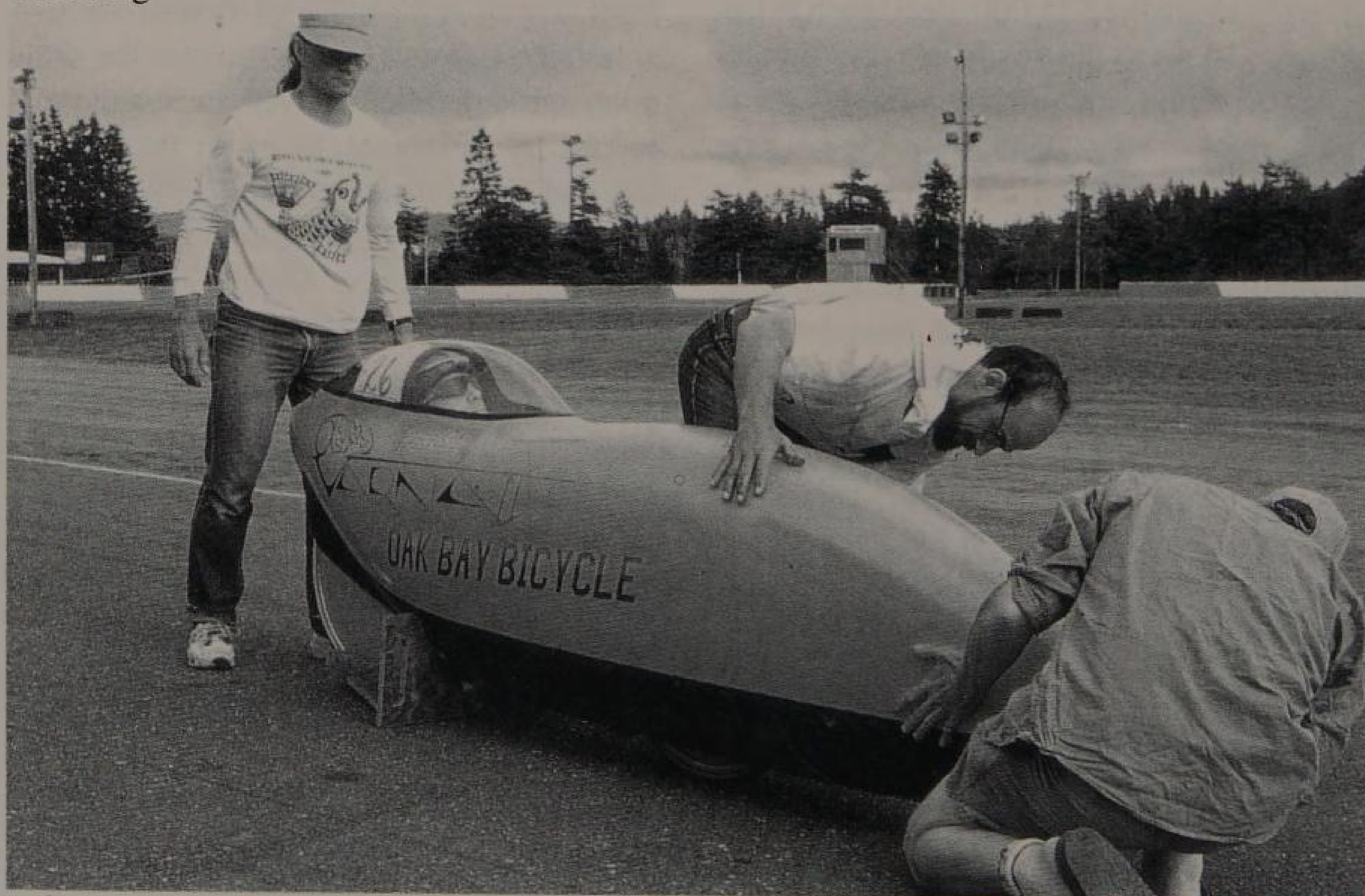
Time trials are a common event for many distances and time limits. In HPV racing, however, time trials aren't always awarded trophies. They are sometimes used to split participants into groups of similar abilities. Seeding racers in heats for subsequent main events prevents the danger of a fast rider colliding with a slower one.

Drafting is permissible at most HPV timed events. (The pure no-drafting time trial is often reserved for record attempts.) There's less drafting benefit for faster faired recumbents or lowracers anyhow, compared to upright bike racing. Moreover, allowing drafting keeps things simple for the race organizers. To forbid drafting would require riders to awkwardly keep their distance on crowded small courses. And many HPV events are held in velodromes, where it would be even harder to avoid groupings.

Time trials are the easiest USCF events for 'bents to gain admission to, but drafting is not allowed.

The Hour

Fans of both upright bike and HPV races alike are fascinated with The Hour. The records of Chris Boardman and Francesco Moser delight the UCI world, but their speeds barely elicit the interest of HPV enthusiasts, accustomed as they are to greater velocity. A faired recumbent broke the current 30.6 mile UCI standard upright record



Georgi Georgiev, center, and two assistants tape the edges and openings of a Varna Diablo to prevent the disruption of airflow—critical in record attempts. Georgiev, whose Diablos hold several current records, also produces everyday bikes and handcycles.

Riders desiring longer events are finding more organizers opening up tour-type races to all types of bikes. The Black Bear is a popular 100-mile road race in Michigan which sees faired HPVs win and unfaired recumbents place highly amid top upright racers. (photo: Mark Sloan)

as long ago as 1939. The latest HPV Hour record was set by "Fast Freddy" Markham, age 49. He blazed 53.43 miles in a trusty Varna on July 2, 2006. In so doing he won $18,000 of the Dempsey-McCready Prize (the 55-mile goal for $25K remained unmet).

You can't help but wonder what speeds might be achieved if professional racers swapped their uprights for recumbents.

Hour races with lots of bikes on the track are especially thrilling (these are not for records). If drafting is allowed, exciting pacelines can develop among the major vehicle types.

Stock Racing

Unfaired and partially faired classes allow for popular racing that's a lot like upright bike racing.

HPV classes, however, vary in definition between the United States and Europe. The HPRA has four classes: unfaired Stock, partially-faired Super Stock, a "no moving panels" Super Street, and the fully-faired unlimited Streamliners. European races tend to have only two classes—faired and unfaired—but their unfaired bikes are allowed to have a tail fairing. The unfaired and partially faired classes—on both sides of the pond—draw by far the most competitors.

Stock races and championships have been held for years, with results that surpass many UCI efforts.

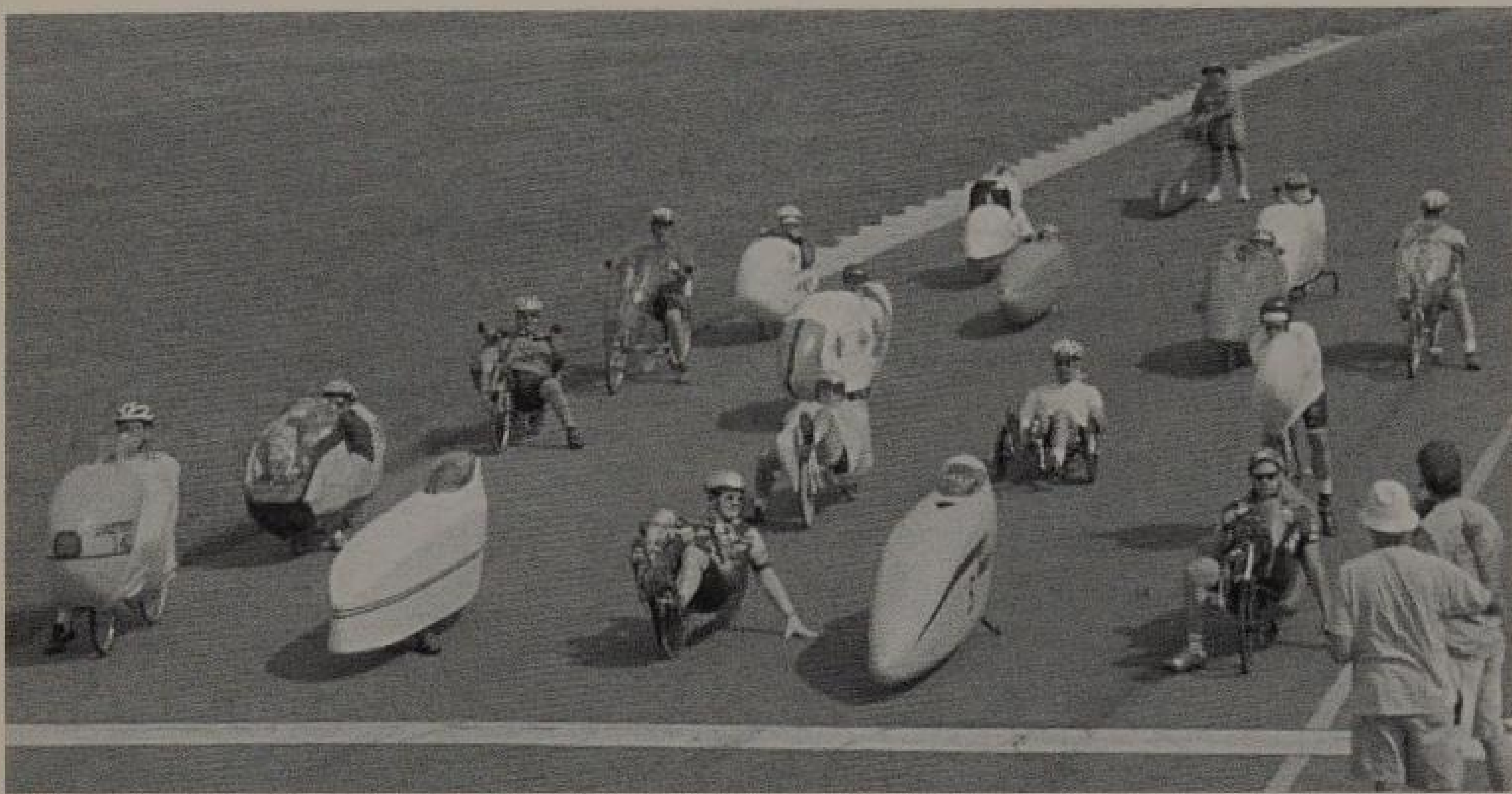
What makes this form of racing so successful is that events can be held anywhere regular bikes are raced. Also, the bikes are readily available. Top stock race bikes bought off the shelf are represented mostly by European imports like M5, Velokraft, Optima, Birk and Challenge—with and without stylish tailboxes, nosecones and other fairings. In the United States, Bacchetta, Lightning, and Barcroft build race options. Bike shops and workshops alike can produce serious contenders. Sometimes streamliners race the unfaired class on the same day simply by removing their fairing.

Recent developments in this scene show great promise. In 2005, the World Recumbent Racing Association formed to promote popular and affordable HPV racing. The WRRA is highlighting unfaired and partially faired racing and records—records that hadn't been focused on or even officiated. The IHPVA announced that it, too, would start keeping Restricted records for non-streamliners for the same reason: to grow racing. So, there should soon be more exciting action!

A note of interest is that the unfaired recumbent Hour record of 27.9 miles set by the original Francis Faure in 1933 still officially stands as of March, 2006. Boardman's "Best Performance" Hour record of 35 miles on a radical upright bike also tantalizes some unfaired HPV enthusiasts.

Points Races & Stage Racing

Points events, where racers win points for results in a variety of events held over a weekend or a season, are a common form of multi-event racing. Versatile bike designs



A typical starting line-up for an HPRA race, showing the diversity of bikes which all cooperate in sharing the course while competing for various class prizes. (photo: J. Hunn)

are required for success due to the various events and varying conditions at different venues.

The HPRA presently offers a seasonal series of points events across the nation, with an emphasis on the Midwest.

The "Tour de Sol" has so far been the only true stage race for recumbents; it was held twice in the mid-90's. Participants rode in stages over Switzerland's famous Alps—a challenge to both humans and materials alike. Racing heavier HPVs for days on end can really take a toll. In stage racing, especially in mountains, areas of weakness are readily apparent.

Criteriums

Short-course criterium races with plenty of turns held in areas suitable for easy viewing are the most popular events at HPV festivals. Speed and skillful bike-handling make fans' hearts beat faster. A common distance is about 20 miles. Depending on topography, the average speed of unfaired packs can reach 30 mph. Riders who want to win in a faired class should work toward a 35-mph average.

Utility Prize

There is a second contingent of velo riders under the HPV event roof: the daily cyclists. Rather than speed (or in addition to it) they are concerned about utility. They loathe being stuck in traffic jams, and they see the bike as an ideal mode of transportation for distances up to 5 miles. But in their view, the upright bike is not comfortable, fast or weatherly enough. Instead, they prefer the recumbent, which they use for shopping, commuting, and visiting friends at any time of day.

Fans of the everyday utility bike get a chance to compare skills at various HPV meets as well as the IHPVA World Championships. Participants can take part in function, cargo, and balance tests that are designed to resemble everyday situations. The winner is the one who has a bike that meets all the specs and who makes the fewest mistakes on the course in the shortest time. Riding without mistakes isn't much of a problem on a daily basis. But winning here requires not a wasted second as one goes through the various challenges. One little slip and victory is lost.

The agility test, especially, requires an exquisitely tuned bike, with breaks and gears operating smoothly and responding instantly. The test occasionally includes a see-saw, which must be ridden over successfully. There is sometimes a "slow bike" portion of the course.

The utility competition checklist covers such usability features as lights, fenders, cargo-carriers, and daytime visibility measures. As with everything in the world of HPVs this checklist varies from event to event and even emphasizes different aspects from year to year in an attempt to reward the whole range of commuter bike strongpoints.

Utility riders on unfaired bikes used to dominate these skill tests. But a new type of cyclist is challenging them: the racer who uses his racing recumbent as a commuter. These riders with their elite machines and high-speed skills bring a second kind of talent to bear: commuter street smarts. They're cranking up the competitive level for the cause of comfortable everyday bikes.

An event designed to reward nimble commuter bikes is the tight-turn parking lot race. Streamliners shed their fairings and, along with the other high-speed bikes, try to make the slow corners without being left behind by the city bikes. It's an event that showcases the friendly "everyone join in" spirit of HPV racing.

Distinctions and Similarities Between HPV and UCI Racing

Unlike racers on upright bikes, recumbent racers can't jump out of their saddle for a burst of speed or draft behind a stronger rider. And explosive, close-quarters sprinting during the last few meters of an HPV event is almost unheard of. Instead, with HPVs the focus is on rider fitness and aerodynamics.

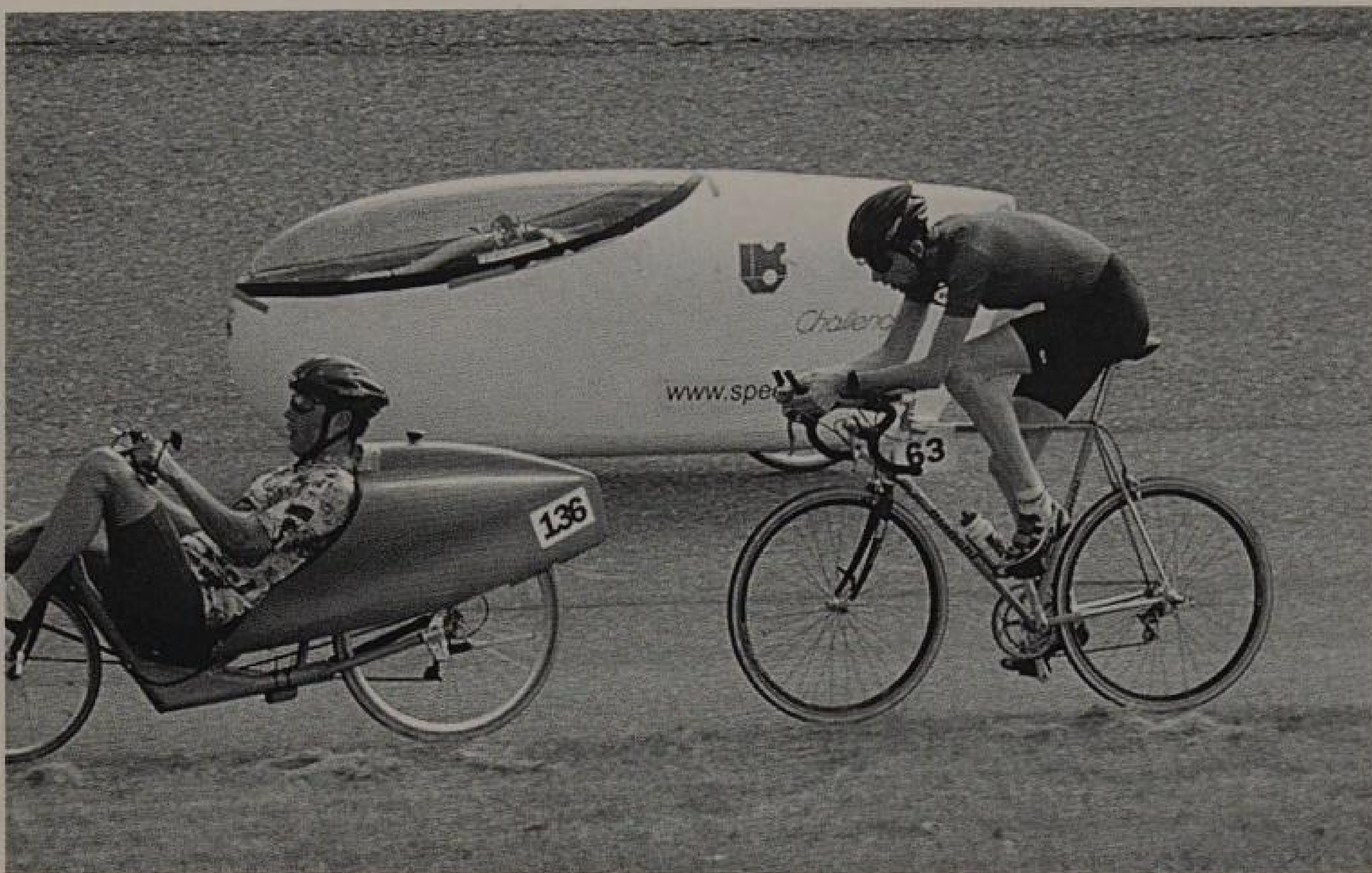
Tactics are important with HPVs, but they aren't nearly so determining as they are in upright pack racing. Upright racing tactics can be thrilling, but they are also often negative, with weaker riders ganging up on stronger ones and preventing a race from displaying the best possible action. The friendly HPV scene, with its clearer reward for talent, could possibly recruit more upright racers for this reason.

Technology plays a different, not to say bigger, role for HPVs—one which is also more straightforward than it is with uprights. It rewards racers who like to build or who make friends with builders. It also rewards those who, as with upright racing, like to buy the fastest new improvement.

Drafting with unfaired recumbents can shave critical seconds, but not without risk. The recumbent position results in large blind spots in the immediate vicinity of the bike, requiring mirrors and caution. (photo: D. Arezki)

The bikes themselves have to be handled differently when being raced. The rider of a faired bike must take its weight into account when trying to pass. Two hundred to 300 meters may be necessary. The heavier the vehicle, the more time required to accelerate.

The parts of an upright bike must endure only the forces of body weight and limb exertion, plus a certain amount of road



All bike types get along together in HPV racing. Various classes are often on a course at the same time, without complication, thanks to road-sharing etiquette and passing manners. (photo: www.tim.be)

abuse. The forces on high-speed HPVs require some parts to be more robust, while other parts become less relevant. Accelerating a recumbent puts a lot of pressure into the seat back. Compared to an upright bike, the seat of a recumbent and parts of the frame near the seat take more abuse because weight is focused there and a rider can't lift for bumps.

A faired vehicle has to handle a wide array of powerful forces, without damage or flex, at speeds far exceeding upright bikes. Riding in a strong sidewind, for instance, can require a rider to lean hard to the side—like "hiking out" on a sailboat—greatly stressing tires, wheels, fork, handlebar, frame, fairing, and mounts. Thus a "light" homebuilt HPV suitable for both racing and everyday riding at 30 to 50 mph will often weigh 40 to 70 pounds.

A standard racing bike's gear range is not very useful on a heavier, faired recumbent. Unable to rise from the saddle for a "jump" and likewise unable to maintain a "honking" standing position, the recumbent racer compensates by equipping his bike with a wide range of gear ratios, with a lower low and higher high than an upright bike. Ten-speed rear cassettes and/or triple cranksets are a good choice—the more gears, the better, especially in hilly terrain. Chainrings with over 65 teeth are common with faired bikes, for instance, while a low gear of 20" can be helpful for steep climbs. (There are examples in Chapter 5 of sensible gear ratios for touring, racing, and everyday city use.)

A course with many tight turns is rough for upright racers when they bunch up, but worse for recumbents, so it's important to avoid bottlenecks. The more riders in a corner, and the further back in the group they are, the more they have to slow down—then re-accelerate coming out of the turn. This phenomenon, known as the accordion effect, is killer on recumbents because of their heavier weight.

On mountainous courses, a heavy recumbent will make a rider miserable. Aerodynamics plays a less important role going up steep hills. Overall weight as well as good seating and pedaling angles are more vital in steep terrain. If the hills are moderate and rolling and a rider can conserve momentum, then aerodynamics become critical again.

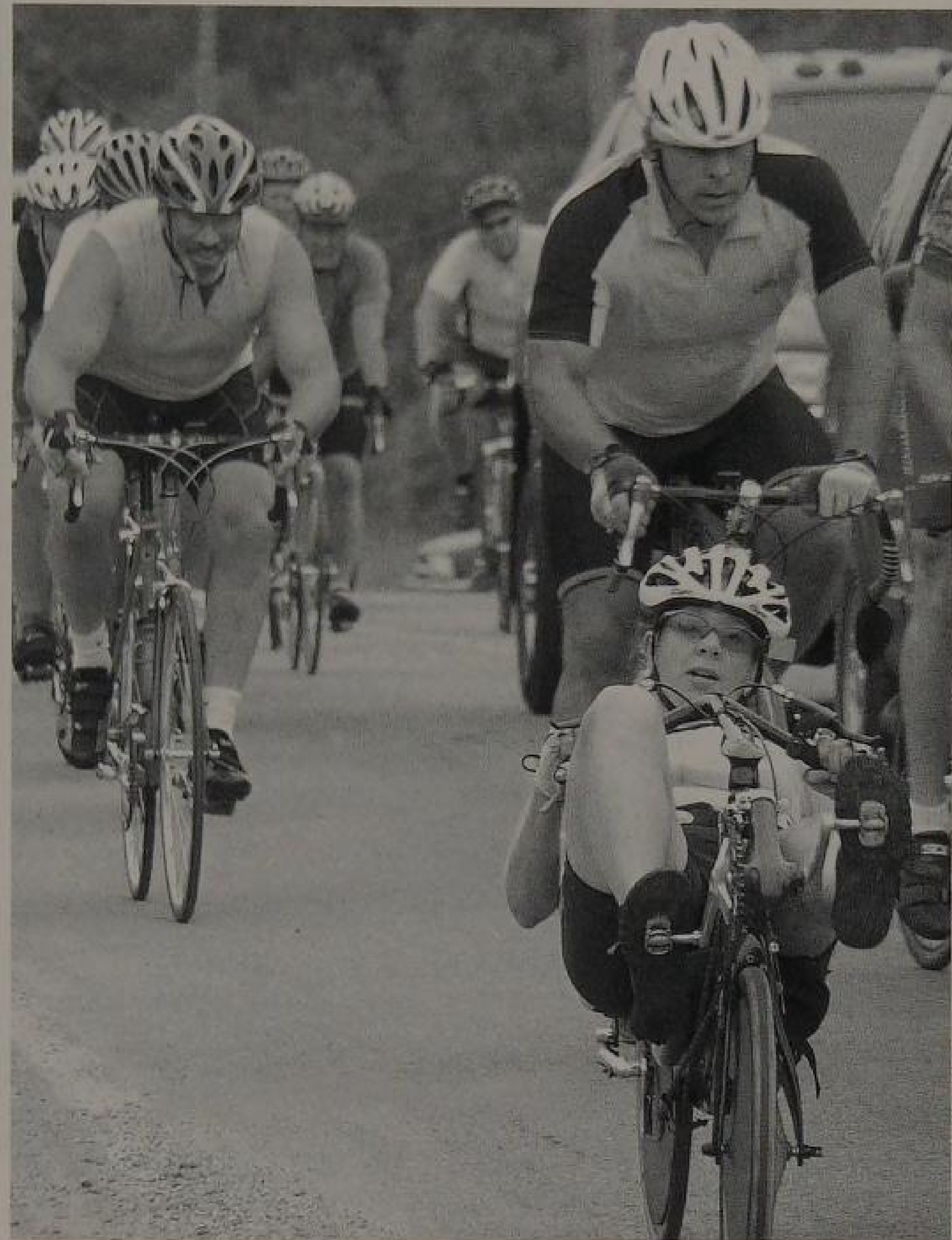
Recumbent riders in flat terrain tend to prefer a steeply reclined seat and a high crank: up to 11 inches higher than the seat. Mountain riders gravitate to a more-upright seat with somewhat lower bottom bracket. They would argue that an ultra-reclined position puts the rider on a steep uphill at too much of a pitch, so that he's pedaling with his head almost lower than his feet. If you start out in a more upright position, as a ride gets steep your angles are still comfortable. A position that allows the rider to pull on the handlebars can also help mountain racers.

The Easy Racers Tour Easy and the Lightning P-38 are good examples of an "upright" California design sensibility which answers to the needs of mountain riders.

Adding suspension and fairings to a recumbent can jack up the weight significantly. For uphills, a bike (and its rider!) need to be light and able to fly up the slopes, otherwise chances for victory evaporate.

It's different on a flat course with easy cornering. In that case, aerodynamics play the biggest role. Once the bike is accelerated the goal is simply to get to the finish line without many speed alterations.

Trike riders are also pleased about an open, gentle course. Their vehicles are often heavier than single-trackers and thus they have more difficulty riding through or accelerating out of sharp corners. Three-wheelers do have it easier at the starts, to be sure.



A woman lowracer rider shows a clear advantage in reduced frontal area at the start of the 100-mile Black Bear open-field road race. (photo: Mark Sloan)

Skills and Strategy

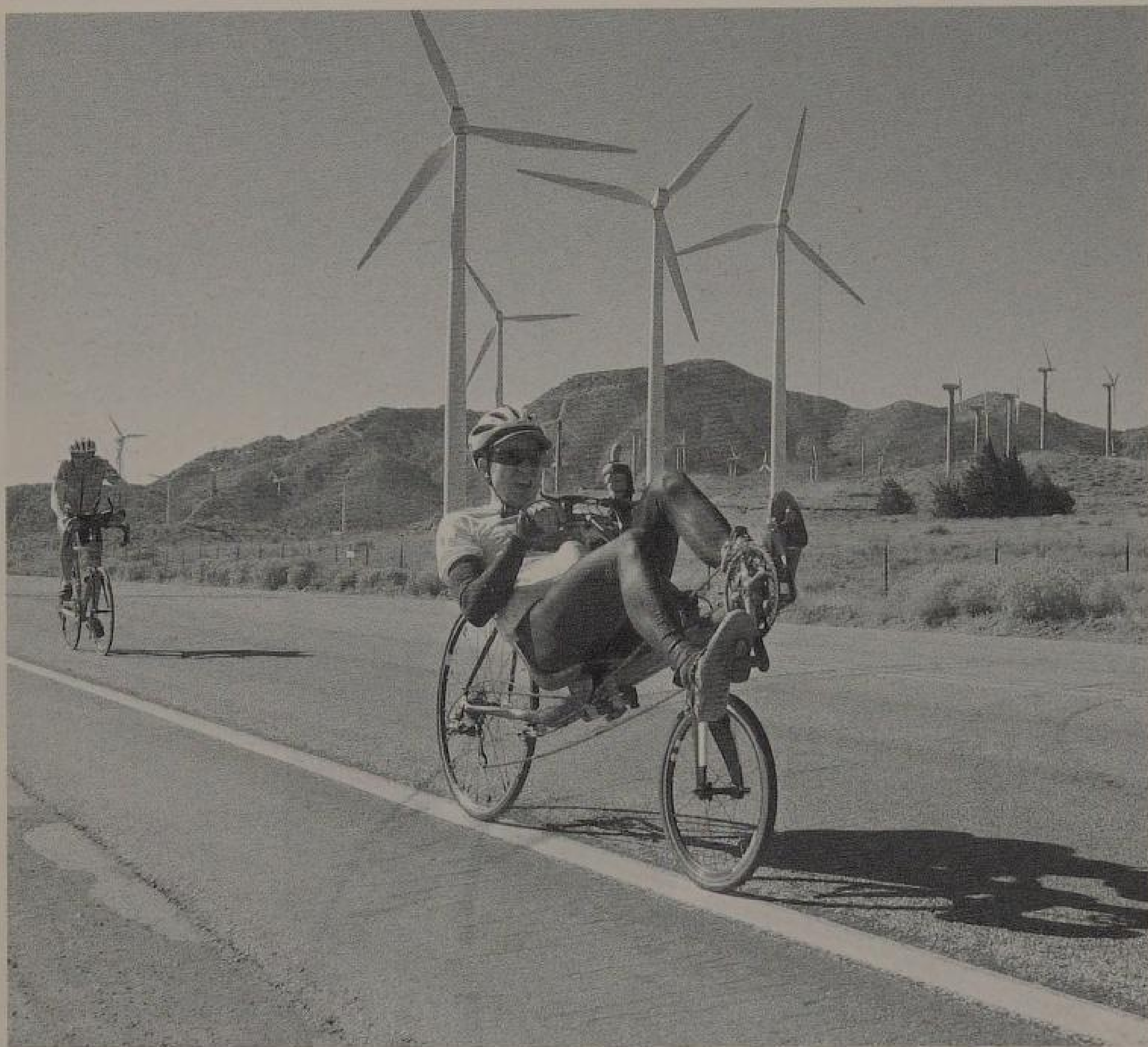
Drafting is common even though it gives less advantage. But even with very little draft, pacing is helpful, even for tactics. HPV drafting requires more skill than with uprights. The riders of very reclined or partly or fully faired recumbents have only a limited view of what is directly in front of them. This blind spot can extend from 2 to 4 yards ahead. If you're riding such a bike and use the tiny slipstream offered by a very aerodynamic rider in front of you, the rear of his HPV will be in your blind area. A skilled rider has a practiced, yet intuitive sense of the outside dimensions of his bike, and he quickly memorizes the shape of the leading bike's rear. With that information he can maintain a safe gap between the two bikes. Failing that, he's likely to collide.

Unfaired and less-reclined recumbents have much less of a blind spot—or none at all if the crank is in a low position. Their risk of bumping, therefore, is much smaller. But riders often use that greater visibility to draft even closer. The crank arm of a following rider on a short-wheelbase bike with high bottom bracket can rotate very close to a leader's rear wheel. A false move can mean disaster. However, in the case of contact it's important not to panic. Minor bumping doesn't have to cause accidents if riders respond calmly.

All recumbents have limited rearward visibility as well, requiring the use of mirrors. Even with mirrors, it's easy for riders of faired bikes to lose track of those behind, or to be surprised by a surging pass from a strong rider. This requires alertness for safety as well as tactics. It's standard etiquette for faster faired bikes to check their mirrors after every pass before pulling back into line.

This brings up another standard practice at HPV races: Slower bikes stay to the outside of turns. However, at velodromes slower bikes stay lower, to the inside.

Even in pre-qualified faster fields the speed differences among riders at HPV races can be startling when you're not used to it, but pleasantly exciting once you adapt.



Jim Kern looks forward to being the first RAAM recumbent soloist in 2006. He and a Team RAAM recumbent hopeful have been winning open qualifiers in the build-up to the main event. (photo: D. Bradley)

When racing at 25 mph on a stock bike it can be fun to have 40 mph fully faired bikes whiz past you, followed by a line of 33 mph lowracers.

After considering the differences between competing on an upright bike and competing on a heavier, faster machine with narrower field of vision, we come to the similarities.

Recumbent racing at its higher levels is similar to upright bike racing in many ways. Drafting is often important, and becomes more so as the race class restricts the degree to which a bike may be faired. Clever pacing can be vital, as riders test each other. Some riders will hang back until the right moment to make their move. Thankfully, negative racing isn't hardly possible, as weaker riders can't really either balk or easily hang onto their betters. However, one doesn't have to show their whole hand right away.

Cornering technique is the same as for uprights, with the shortest, smoothest line being the best. At top speed on narrow roads, use the whole road—start wide, dive to the inside, then carry wide again, as fast as traction will allow. Pedal through, if you can. The faster the bike, the more road you'll use in curves. Experience in a wide range of upright bike racing is a real plus for the recumbent racer.

You'll probably find sidewind drafting more effective, as the side of a recumbent presents the most "wind shadow." And you should always choose to pass on the downwind side of other riders if possible.

Fully faired racing offers the thrills and sensations of auto racing. Being jostled in the interior, white-knuckling it through turns, running in a long line of top-performance bikes, feeling your suspension working at its max to smooth out the washboard and give you traction, hearing the loud thrumming of wind and chattering of parts—you feel like you're in an auto race! With corners coming fast and furious, you might even forget the effort you're making, what with all the other demands on your reflexes and senses.

Mixed Events

Recumbents can compete against upright bikes in only a few races. The main types are century rides, ultra-marathons and "open" races, none of which are subject to USCF or UCI regulations. These include such events as the 3000-mile Race Across America (RAAM), and the quadrennial Paris-Brest-Paris 750-mile event.

When racing in mixed events with upright bikes, it's best to work with small groups, or at the front, back, or to the side of a larger peloton. It's not pleasant, safe, or strategic to ride low in the midst of a large upright pack, where visibility is nil. When working with small groups, though, eye contact is easy, since your eyes are at about the same height as the upright racers in the drops near you. The difference in seating position is then less noticeable, except that you only offer a minimal draft.

Highracers are proving to mix with uprights perhaps better than other types. John Schlitter co-owns the Bacchetta line of highracers and, riding with his own team, fares very well at organized "open" events, centuries and ultramarathons.

Recumbents are making amazing inroads in these grueling competitions.

The Lightning F-40 HPV holds the team record for RAAM, at 5 days 1 hour (1989).

Pete Penseyres led the 1995 PBP overall, again riding a Lightning, a full-suspension carbon-tubed F-90. Unfortunately, a malfunction stopped him at the halfway point. In 1999 Bob Fourney riding a Lightning finished 14th overall in 47 hours at PBP.

Century events are more often seeing recumbents as front-runners.

"Unrestricted" or "open" races, such as the annual Black Bear Challenge in Michigan, are meant to catch the interest of high-end racers and tourists alike. Recumbents are also occasionally welcome at such events—and finish at or near the top. Their admission depends on the good will of the organizer and its relations with area recumbent clubs.

Recumbents technically can participate in USCF races, but in separate fields (as of 2004). Time trials are presently the best bet for admission (call beforehand). Anti-recumbent officials sometimes switch to UCI standards to totally exclude them. Officials always have the final say regarding bikes and riders.

A growing number of organizers are receptive to recumbents, but they need to be assured of enough entrants of sufficient skill before offering a category for them and setting aside time in their already over-full day. Progress will likely arrive in fits and starts, with organized recumbent clubs and skilled riders proving their mettle and offering support, thus earning acceptance. Approaching both officials and organizers well before events, so you can resolve questions, is highly recommended. Each successful entry makes it easier for the next would-be recumbent racer to find a place at the starting line. Volunteering at events also creates goodwill.

John Schlitter, co-owner of Bacchetta, has been showing the competitiveness of highracers by winning or placing high in several open century-type events.

HPV Speed Records & Achievements (current as of July 2006)

Discipline	*Start*	*S/T*	*M/F*	*Mph*	*Time*	*Date*	*Rider*	*Vehicle*	*Designer*
200 meter	f	S	M	81.00	5.523 s	10.02.02	Sam Whittingham	Varna Diablo II	Georgi Georgiev
200 meter	f	S	F	66.59	6.718 s	10.07.05	Lisa Tonnello	Varna II	G. Georgiev & Balfour
200 meter	f/arm	S	M	32.60	13.803 s	05.12.95	Jacob Heilveil	Chairiot	GM/AV/Forsyth
200 meter	f	T	M	68.405	6.540 s	10.03.02	Maynes/Doherty	Bearacuda	UC Berkeley
200 meter	f	T	F	47.59	9.4 s	03.05.80	Bowen/Sandlin		Tom Rightmeyer
1 km	f	S	M	79.79	28.037 s	10.06.01	Sam Whittingham	Varna Diablo	Georgi Georgiev
1 km	f	S	F	47.31	47.558 s	07.27.99	Andrea Blaseckie	Varna II	Georgi Georgiev
1 km	f	T	M	63.73	35.100 s	17.09.93	Markham/Whittingham	Double Gold Rush	Gardner Martin
4 km	s	S	M	42.70	3:29:56 m	07.29.98	Robert Lafleur	Lafleur IV	Robert Lafleur
10 km	s	S	M	47.29	7:53:02 m	07.22.98	Paul Buttemer	Varna	Georgi Georgiev
100 km	s	S	M	50.32	1:13:05 hr	07.27.02	Lars Teutenberg	White Hawk	Vector/IKV
1 Hour	s	S	M	53.43	1.00 hr	07.02.06	Fred Markham	Varna Mephisto	Georgi Georgiev
1 Hour	s	S	F	46.46	1.00 hr	08.20.02	Ellen van der Horst	White Hawk	Vector/IKV
12 Hour	s	S	M	31.46	377.6 mi	04.14.95	Axel Fehlau	M5 faired lowracer	Bram Moens & Derk Thijs
24 Hour	s	S	M	27.11	650.54 mi	07.20.06	Greg Kolodziejzyk	Critical Power	G. Kolodziejzyk & B. Eadie
RAAM / 2910 mi		team	M	24.02	5 days 1 hr	08.04.89	P./J.Penseyres/Fourney/Coles	Lightning F40	Tim Brummer
SF > LA / 400 mi		S	M	22.16	18:05 hr	04.28.91	Pete Penseyres	Lightning F40	Tim Brummer
24 Hour, u-f	s	S	M	20.26	486.3 mi	02.20.05	James Kern	Bacchetta Aero	Rich Pinto
1 Hour, u-f upright		S	M	35.04	1.00 hr	09.06.96	Chris Boardman	Merkcx/Superman	Mike Burrows
1 Hour, u-f tailbox		S	M	33.21	1.00 hr	06.04.00	Leo de Nooier	M5 lowracer tailbox	Bram Moens
1 Hour, u-f (WRRA)		S	M	27.9	1.00 hr	07.14.33	Frances Faure	Velocar	Georges Mochet
1 Hour	s	S	M	33	1.00 hr	10.01.00	Tyger Johnson (age 63)	Lightning F40	Tim Brummer

f = flying start *S = Single* *M = Male* *u-f = unfaired*
s = standing start *T = Tandem* *F = Female* *arm = only arm power*

HPVs first entered RAAM in 1989 in the inaugural team event. Recumbents have been a part of RAAM many times since. Set that first year, Team Lightning's record 5-day crossing in F40's, with a 24 mph average, still stands as of 2006. (left photo: R. Sturdevant) Tyger Johnson, below, also races an F40, and has for years. The 69-year-old often wins overall and set a record in 2004 for a hilly 50-mile course of 1 hr 45 min. The venerable Lightning F40 is suitable for general open road racing as well as for everyday utility riding.

Ch. 4 The Physics & Biomechanics of Recumbents

The overall handling qualities, steering traits, and powering of a recumbent depend on the same physical laws as an upright bike. But there are a few notable differences.

Simply starting to ride a bike is a complex physical process, because the state of standing still gets changed into a state of energy, the state of moving.

The recumbent position prevents standing up and shifting body weight to help get under way. Inertia has to be overcome by seated muscle power alone. Starting is thus more precarious and energy-consuming than on an upright bike. Of course, this is most noticeable when you have to start up often, as in traffic, or in the mountains, or with a heavy load.

So too with acceleration. Short "jump" sprints, as are common in upright racing, are more difficult on a recumbent. Steady, controlled speed is more important on a recumbent than on an upright bike.

When starting up on a bike that has a lower height, the stabilizing gyroscopic effect is diminished, especially with smaller wheels, so the bike is at first more unstable. Thus, for safe starts, or whenever going slowly, one's center of gravity has to be kept directly above any bike's support line—the theoretical straight line between the contact points of the front and rear wheel. Sloppy starts and lazy riding, which are fine on an ordinary bike, are riskier on recumbents—the more so the lower the seat and the smaller the wheels. An over-the-shoulder bike with 2-inch seat-height and dual 16-inch wheels, for instance, is a tippy starter indeed!

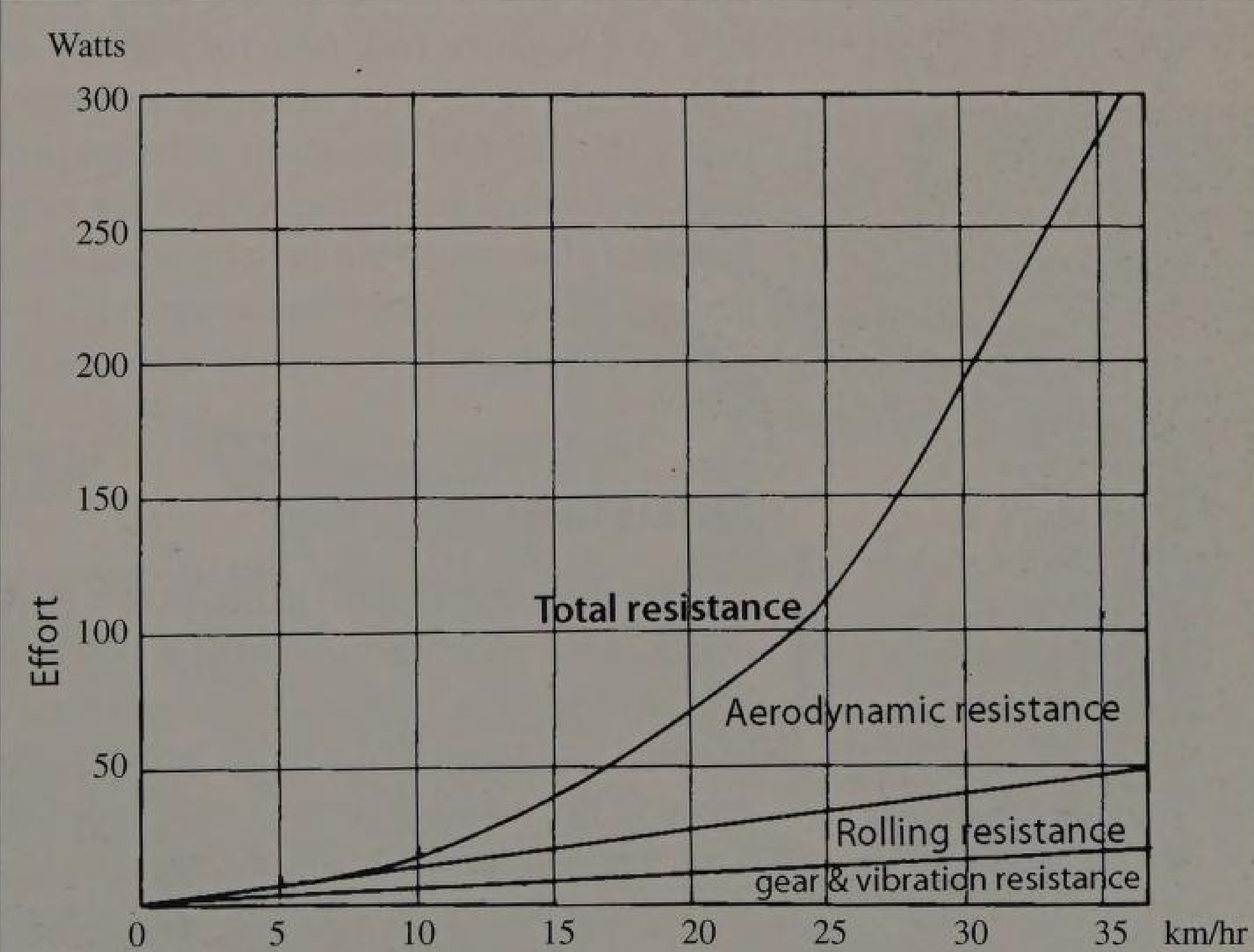
A good analogy for the start-up stability of upright versus recumbent is that it is easier to balance a 3-foot stick on the end of your finger than a 3-inch twig.

A highracer has an easily started seat-height and wheelsize, but because the feet have to do a lot of reaching from ground to cranks it, too, requires practice.

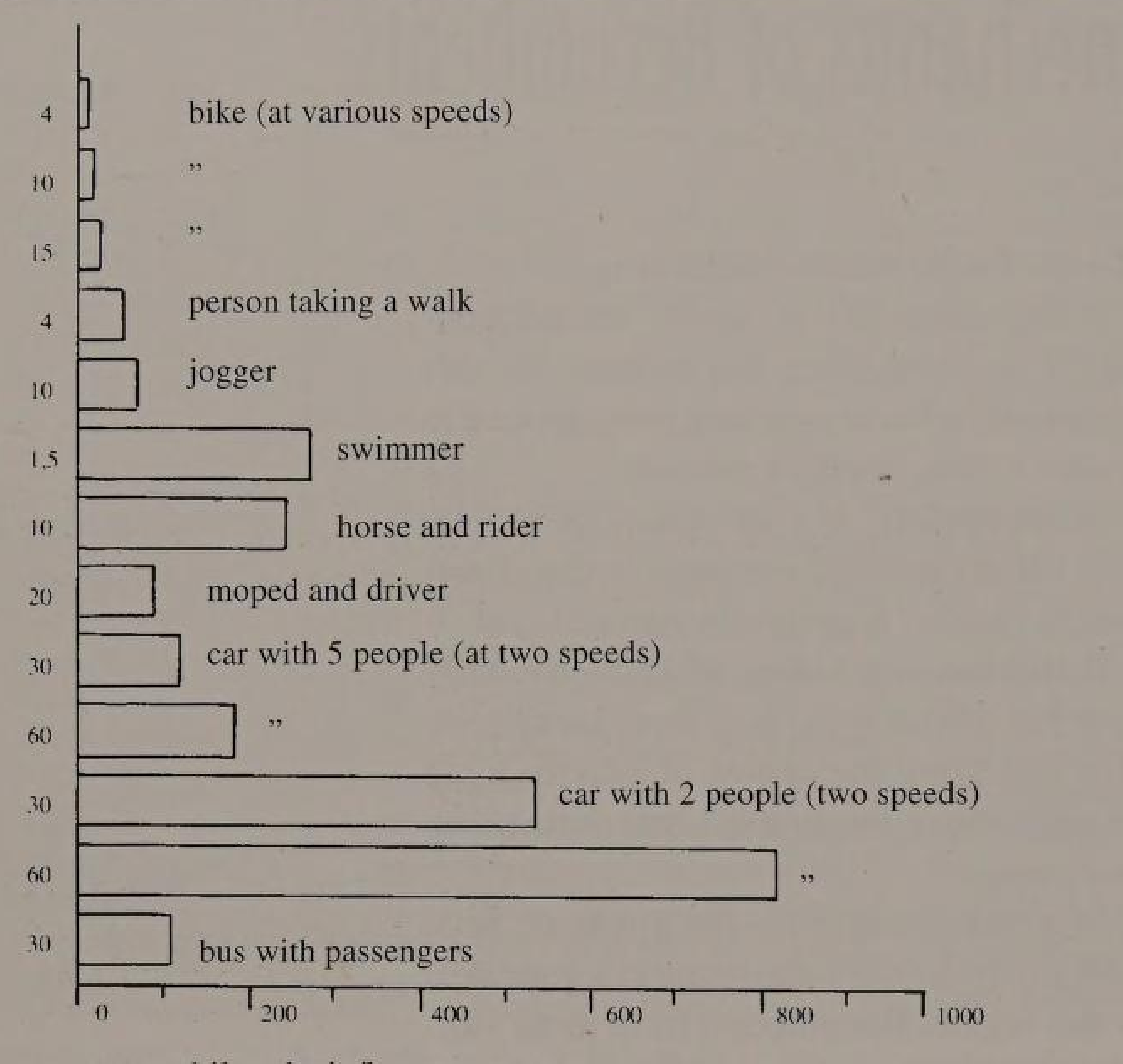
In all cycling, if your center of gravity falls off to one side, you steer in that direction to "catch" it and right yourself.

In this instance a short-wheelbase recumbent has advantages, as a short turning radius can bring the center of gravity more quickly above the support line during maneuvering.

Steering geometry—the angle of head tube and fork rake—also matters a great deal in this regard. Recumbents have more variety in handling qualities than upright bikes. Some have heavy fork flop, others have a



Air offers the most significant resistance. As drag is reduced, less exertion is required. Recumbent bicycles, especially those with fairings, have less frontal surface area than upright bikes and offer the least air resistance.



source: Cycling Science

very light touch. Some have a steep head tube and negative fork rake for stability at high speed—at the price of having a strange, heavy steering feel at start-up: a design perhaps best suited for racing. Others are easy to ride at slow speed but twitchy when fast: perhaps more of a city bike set-up. It all depends on your preferences and your goals.

Resistances

After inertia, air resistance is the next major factor in determining the speed and acceleration of a bike. If air resistance is lowered, the improvement can be felt right away. Other resistances determine speed as well. We will look into all of them.

There are three categories of resistance in cycling:

- air resistance
- rolling resistance
- mechanical friction

Mechanical resistances—such as friction in the drive chain—are relatively small. Rolling resistance is the biggest factor at lower speeds. It is a constant, but the necessary power to overcome it increases proportionally with speed. Air resistance is the most critical factor at higher speeds. The power needed to overcome it rises exponentially in relation to speed—even to the third power. To achieve the highest speeds on windy days, you must reduce air drag.

Drag results from the coefficient of air resistance (*Cd* value) and the frontal surface area of the vehicle, as well as vehicle speed and air density.

It should be emphasized that with the coefficient of air resistance alone, you cannot predict the speed potential of a vehicle. Only multiplication by frontal area makes a value that can be compared to other vehicles. This final value is called the effective frontal surface. The strength of air resistance can then be calculated, in newtons of force, like this:

$$F = \frac{\rho}{2} \cdot v^2 \cdot C_w \cdot A$$

(Rho, ρ, is air density, v the streaming speed: ground-speed plus head wind or minus tail wind, A = frontal surface area.)

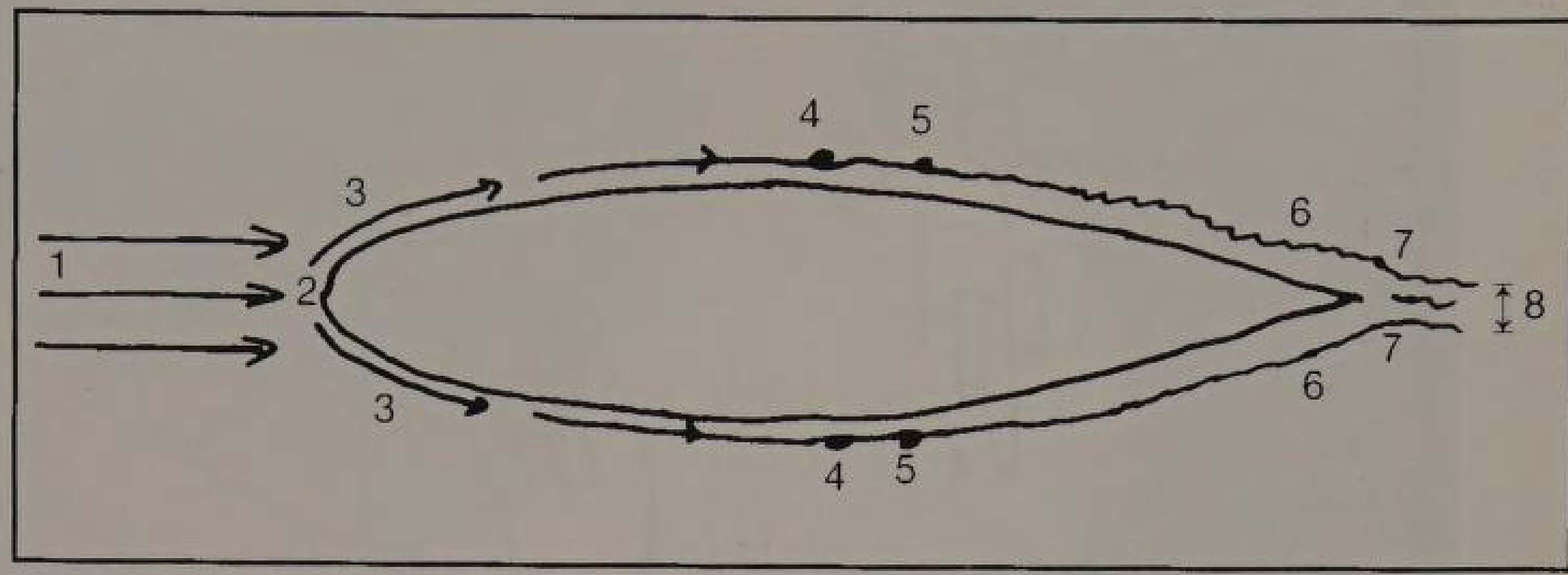
If the required power is to be calculated in watts, the following formula is used:

$$p = \frac{\rho}{2} \cdot v^3 \cdot C_w \cdot A$$

There are several methods of determining the values needed to calculate effective frontal surface (*Cd* x *A*):

- wind tunnel (theoretically precise, but expensive, and of only limited practical application)
- rolling downhill method (cheap and simple, but requires suitable topography; inaccurate due to environmental variances)
- rolling-out method (demands an even, horizontal test track, preferably indoors)

Perhaps the easiest way to calculate your bike's frontal surface area is to cover a large piece of cardboard, say 3 feet by 4 feet, with a 2-inch by 2-inch square grid, and stand it up behind your bike. Then take a photo from the front end looking back using a camera with a long focal-length lens for greater depth of focus. Count the number of squares on the photograph not hidden by the bike and subtract them from the original quantity on the board to determine the approximate frontal area of your bike.



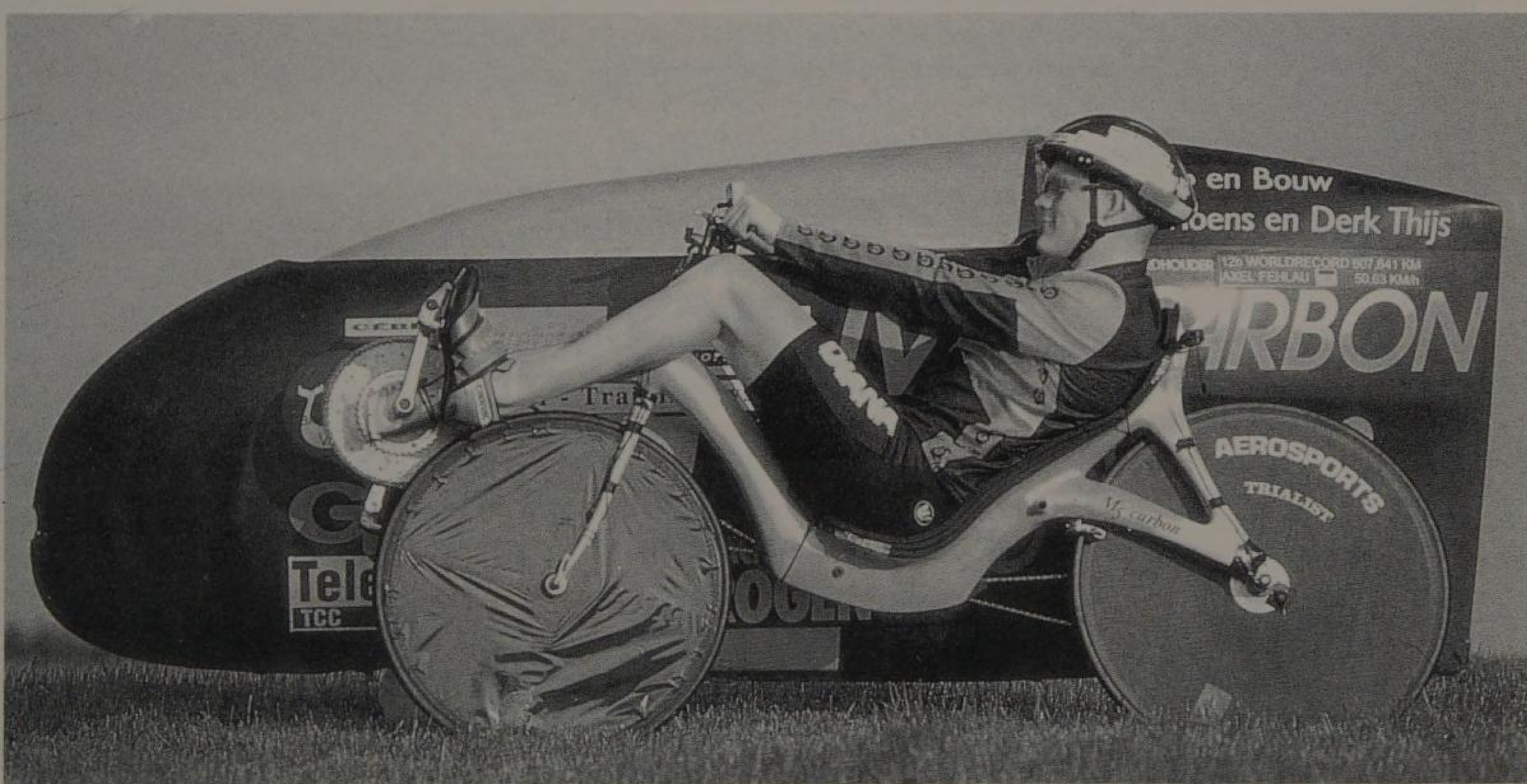
Streamline-optimized body. (See detailed explanation, starting on this page.)

Aerodynamics in Theory

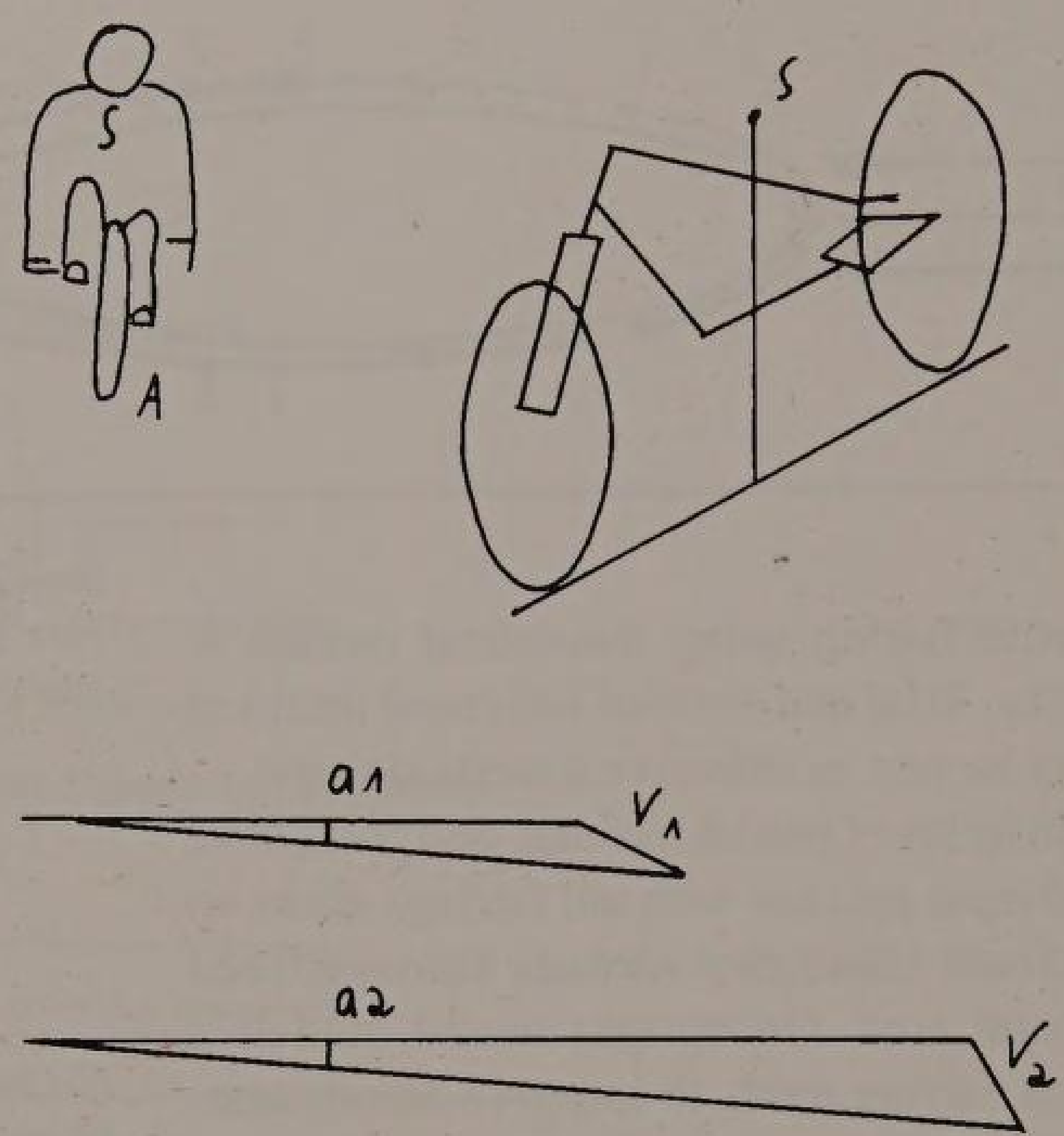
In the following section some aerodynamic principles are described using a theoretical ideal. In the case of a fully faired recumbent the deviation from this is rather small. But when it comes to partly faired models, style and quality of fairing play a major role. Turbulence from the unfaired area of the bike—combined with the added weight of the fairing—can offset the gains of the faired area. Without a seamless shell from nose to tail, airflow "catches" on unfaired areas. Finding a good design for a partial fairing using theoretical models is tricky. Trial and error or informed intuition may be just as effective a methodology.

In terms of partial fairings, designers have had most success with tail fairings alone on reclined bikes that already have reduced frontal area. On upright-seated models a front fairing tends to improve aerodynamics the most.

Lowracers are achieving gains from fairing the bike itself, using "splitter plate" ideas from race cars. Fairing the "humped" frame over the front wheel is part of the splitter approach for Velokraft's NoCom bike, as is using a large rear wheel positioned right



If a fairing is supposed to be really fast, the total surface area and front surface both have to be minimized, closely conforming to rider and bike outline. Axel Fehlau is shown here with the bike and fairing he used to set the current 24-hour record.



The top-left sketch shows the position of the center of gravity (S) as viewed from the front. The top-right sketch shows the center of gravity from a side view. The lower sketches show why steering a short wheelbase recumbent is easier than a long one. If the center of gravity falls to one side, the rider has to "catch" his bike until the center of gravity is back in line. This is easier to do on a short-wheelbase recumbent. (source: Pro Velo/Werner

behind the rider, to help restore airflow. The bottom of the seat and handlebars are also faired to improve airflow around these irregular shapes.

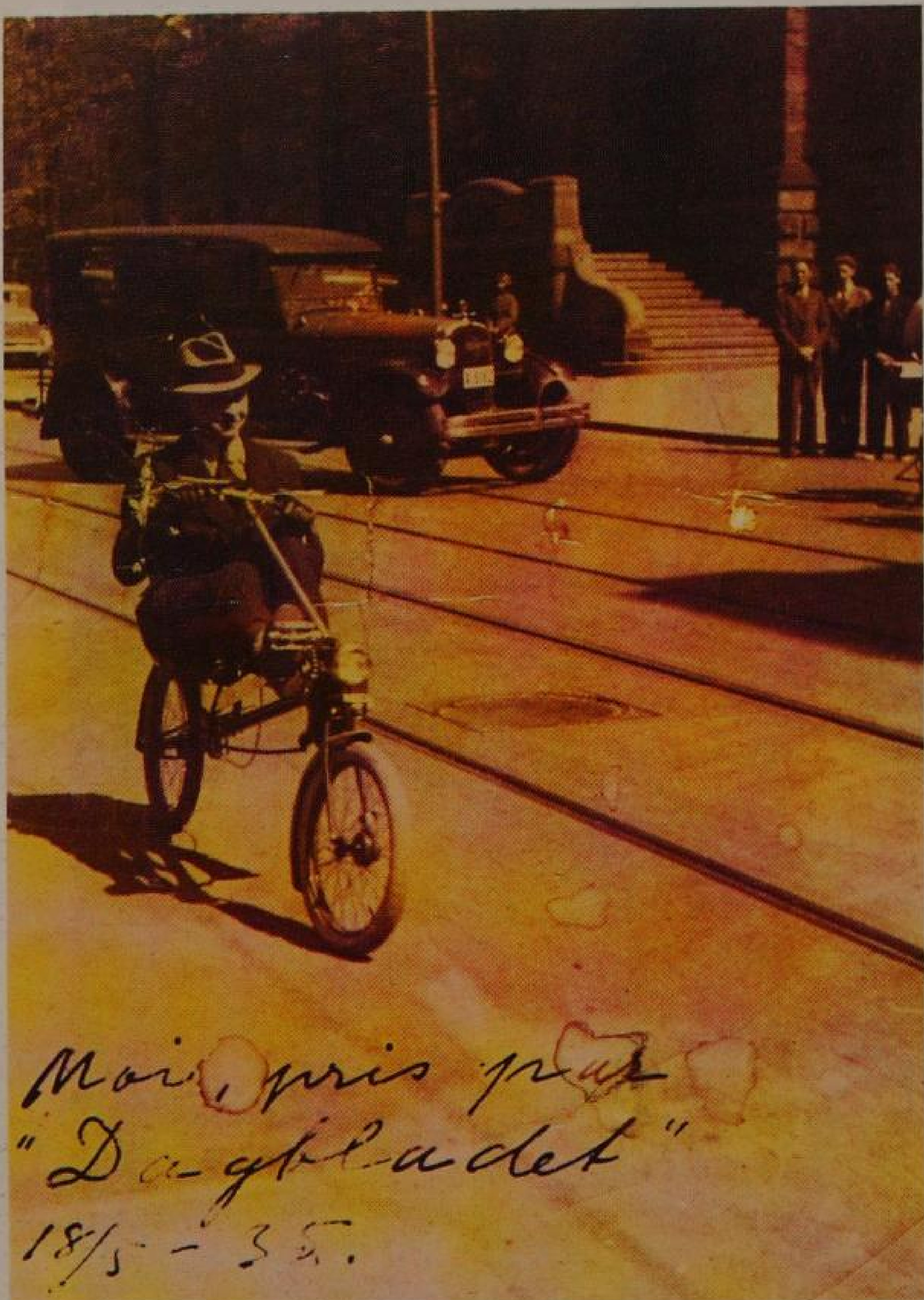
There is widespread belief that a drop of water embodies the ideal aerodynamic form. But some hold that the oil drop is optimal. Neither shape can be used to make an ideal vehicle body. At the most, only the use of a shape called an "ideal airflow body" can be seriously considered. (See diagram, Page 63.)

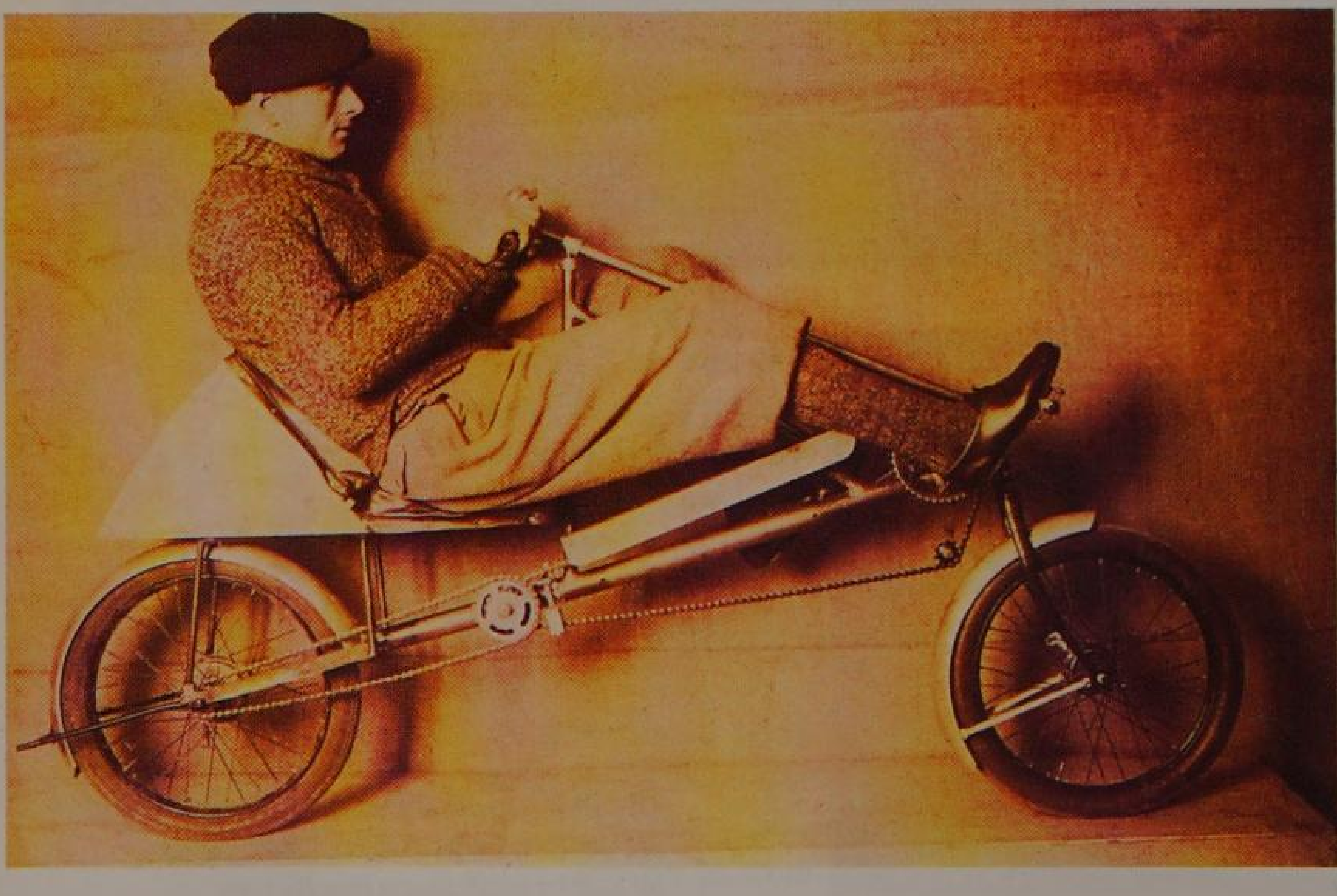
A streamlined body has to part the airstream at its front then reunite it again in the rear. In theory, air flows without disturbance directly in front of the machine (1). Pressure builds up right in front of the body (Pressure = force per unit area). Correlating with build-up of pressure is a decrease in air speed. This accumulated pressure is not form-dependent, rather it depends only on speed of airflow. At the front part of the form, the speed of the flow will be zero at one point (called the "accumulation point"), and here the pressure is at its highest (2). Now the air streams around the front of the body, the accumulated pressure decreases again, and the speed increases (3). The form determines the extent of flow disruption. A square wooden box has the same pressure accumulation as a streamlined body with the same frontal surface, but turbulence forms immediately at the edges of the box, and smoothness of subsequent airflow is disrupted.

From the second quarter of the body on, surface air layer friction gains influence. These are the layers of air that lay directly on the body. The body air on these surface layers rubs against the body surface and speed is lost. However, one must differentiate between laminar and turbulent border layers. With laminar airflow, the flow is parallel to the surface area. With turbulent flow, the flow is disturbed by cross movements. When the speed is 0, the flow peels off and heads back to the front area (4). Turbulence develops (5). This phenomenon is called surface layer flow disruption. From this moment on laminar flow turns into turbulent flow. This process is irreversible, but its development can be delayed. The turbulent airflow now follows the outlines of the body in the direction of the main flow (6).

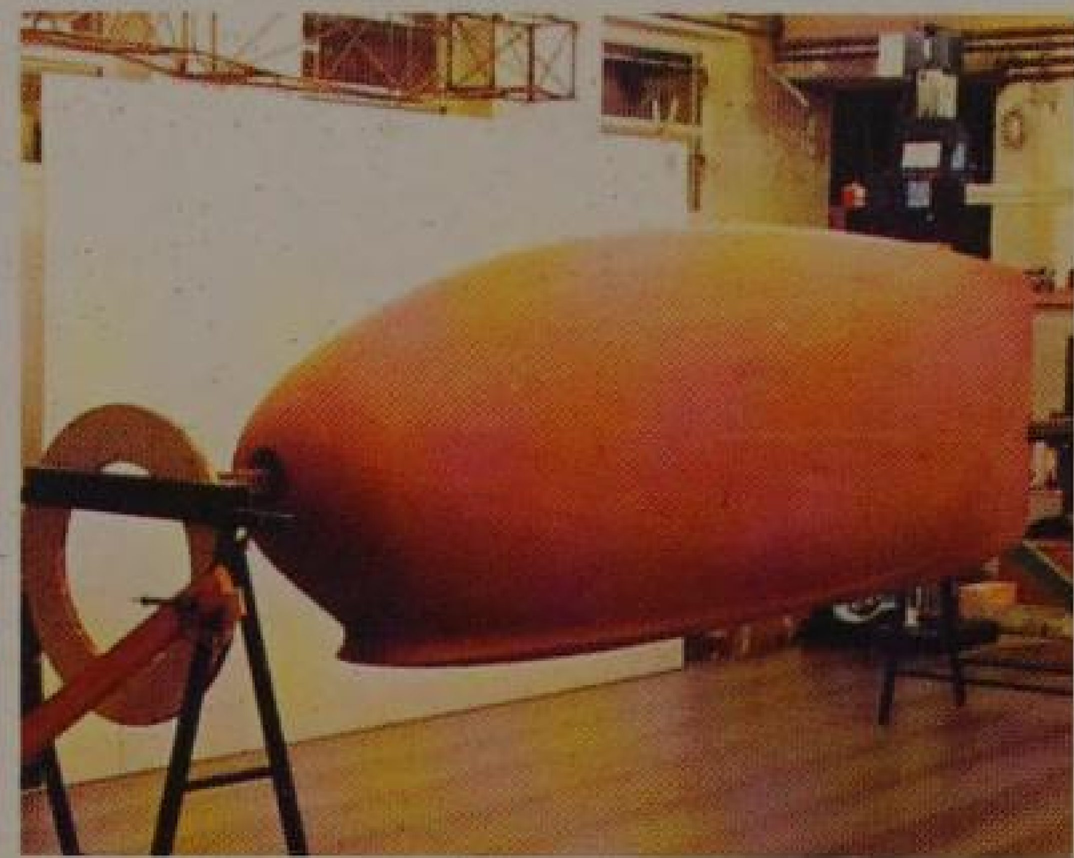
In the rear area of the body, the air streams reunite (7). With decreasing speed, however, the pressure from the rear increases again. The pressure behind the body will never equal the pressure in the front, though, because turbulence consumes part of the energy. Due to this incomplete regeneration, pressure resistance comes into play. If the pressure behind the body corresponded to the accumulated pressure in front, the

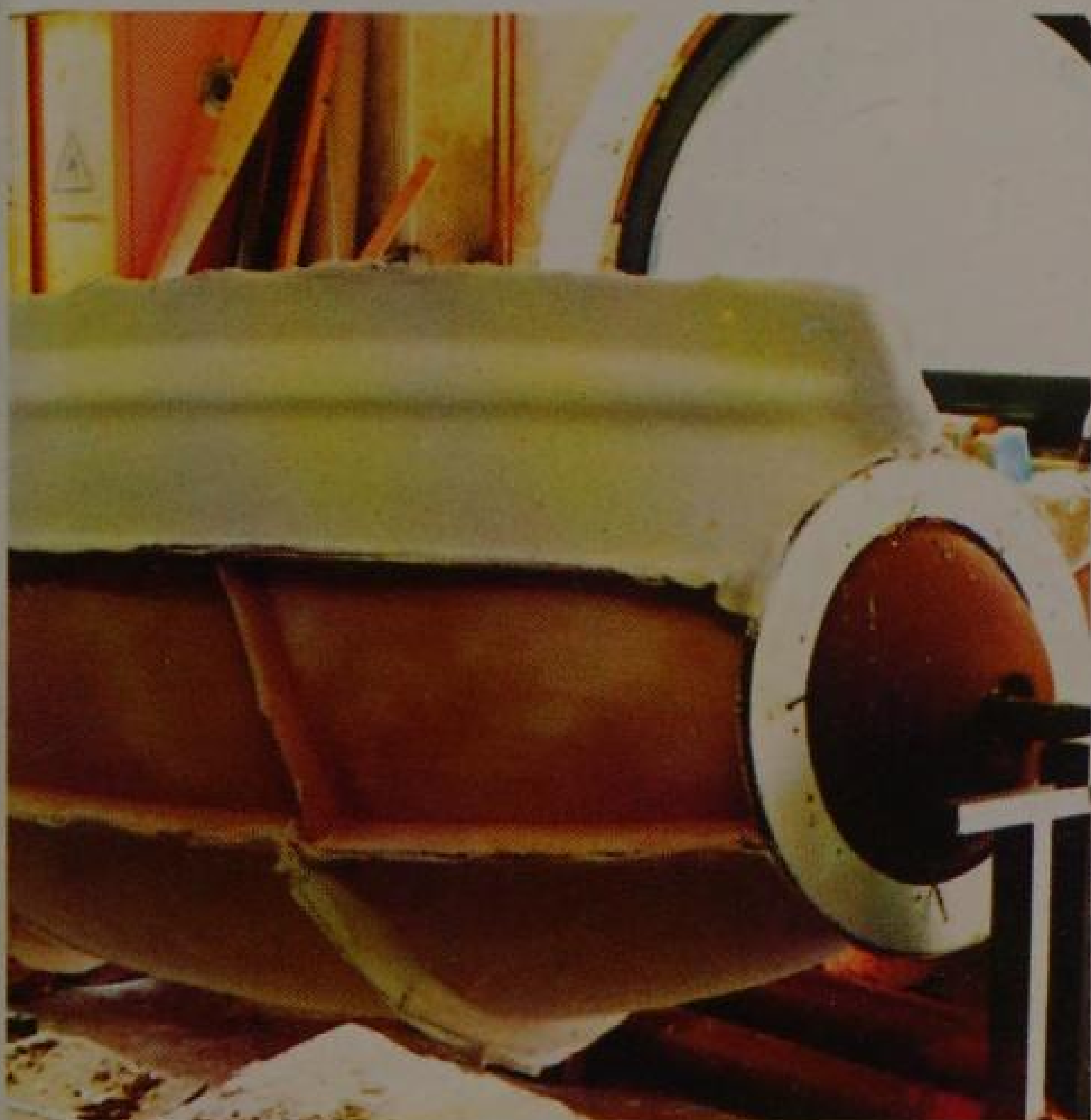
The first modern European production recumbent was the fast, versatile Windcheetah from the British Mike Burrows. (photo: Mochet)





The pre-war cobblestone streets of Europe were trying on cyclists, but the Mochet Velocar served well, with comfortable tires, lights and fenders. Thus its aerodynamic advantages were also put to everyday use. (photos: Mochet)



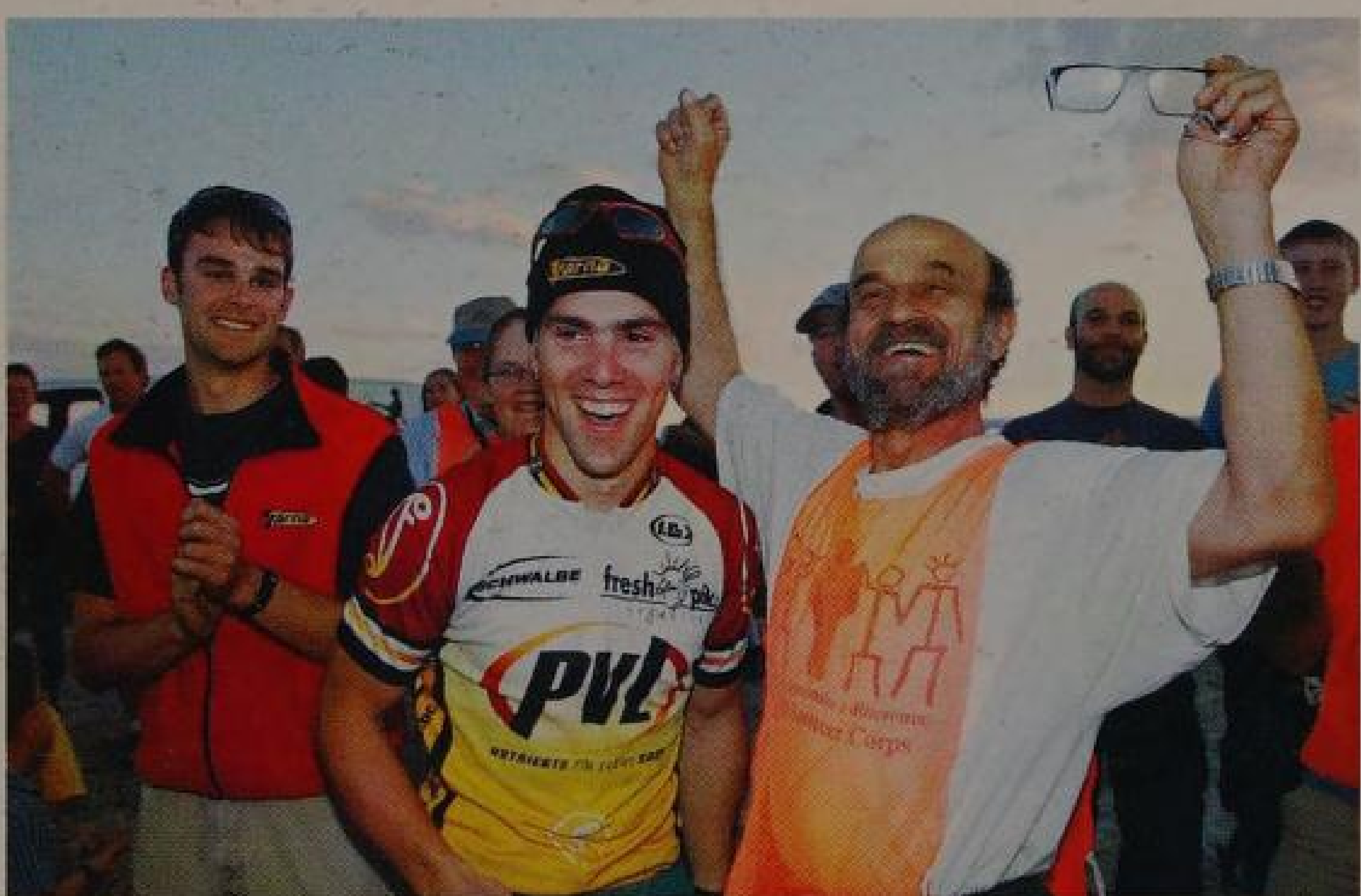


Fairing made by Zillner Design:
– establishing the measurements with a "wooden man's" help
– skeleton
– original form
– female mold
– mounted fairing (photos: Zillner Design)

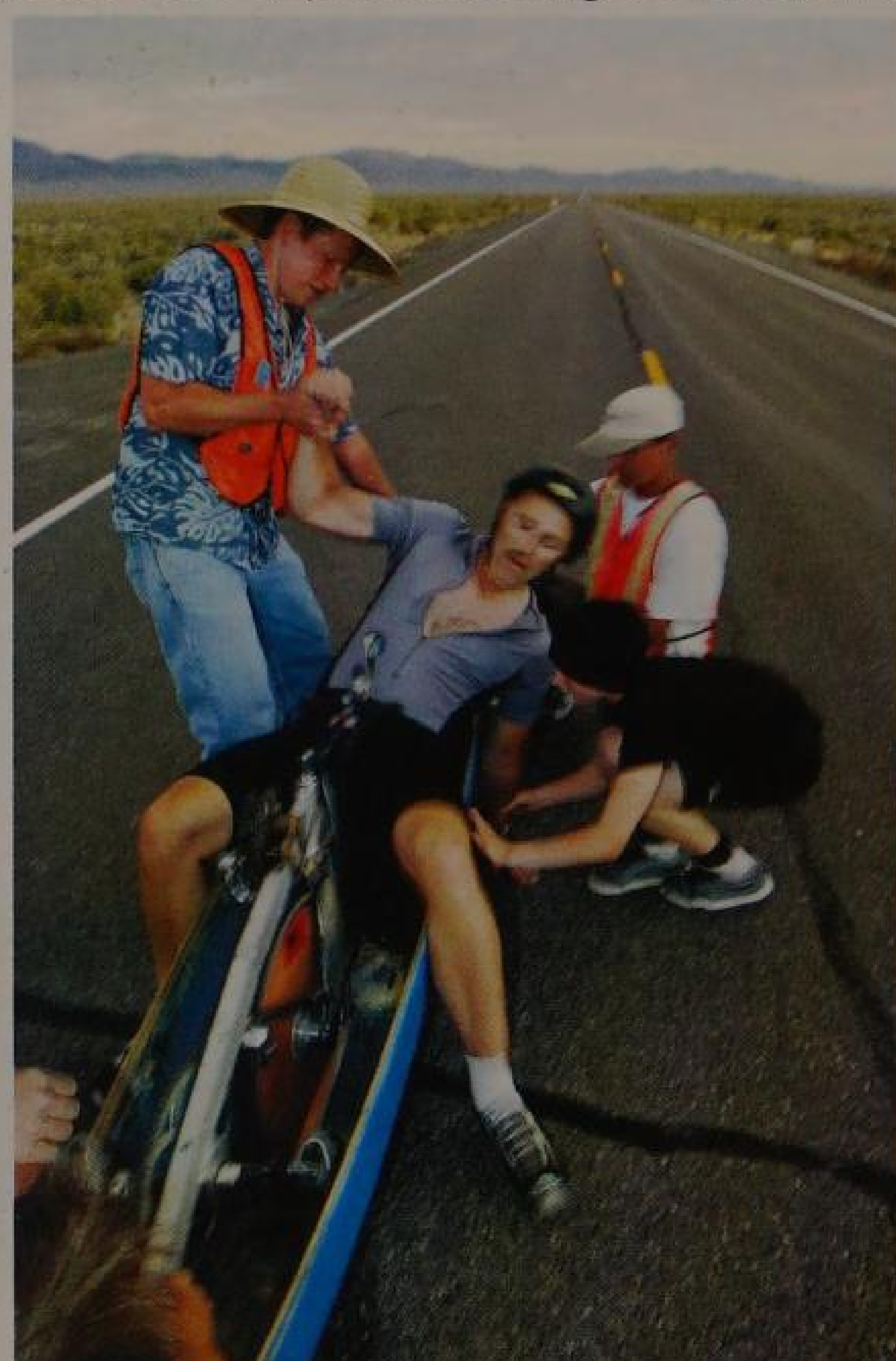
The start of the Trondheim-Oslo long distance race. Recumbents with or without fairing were allowed to participate.

Above, the Varna "Diablo" streaks by at record speeds at the 2004 Battle Mountain Speed Challenge in Nevada.

Below, exhausted racer/builder Thom Ollinger is helped from the "Coslinger Special" after a sprint following a 3-mile run-up.



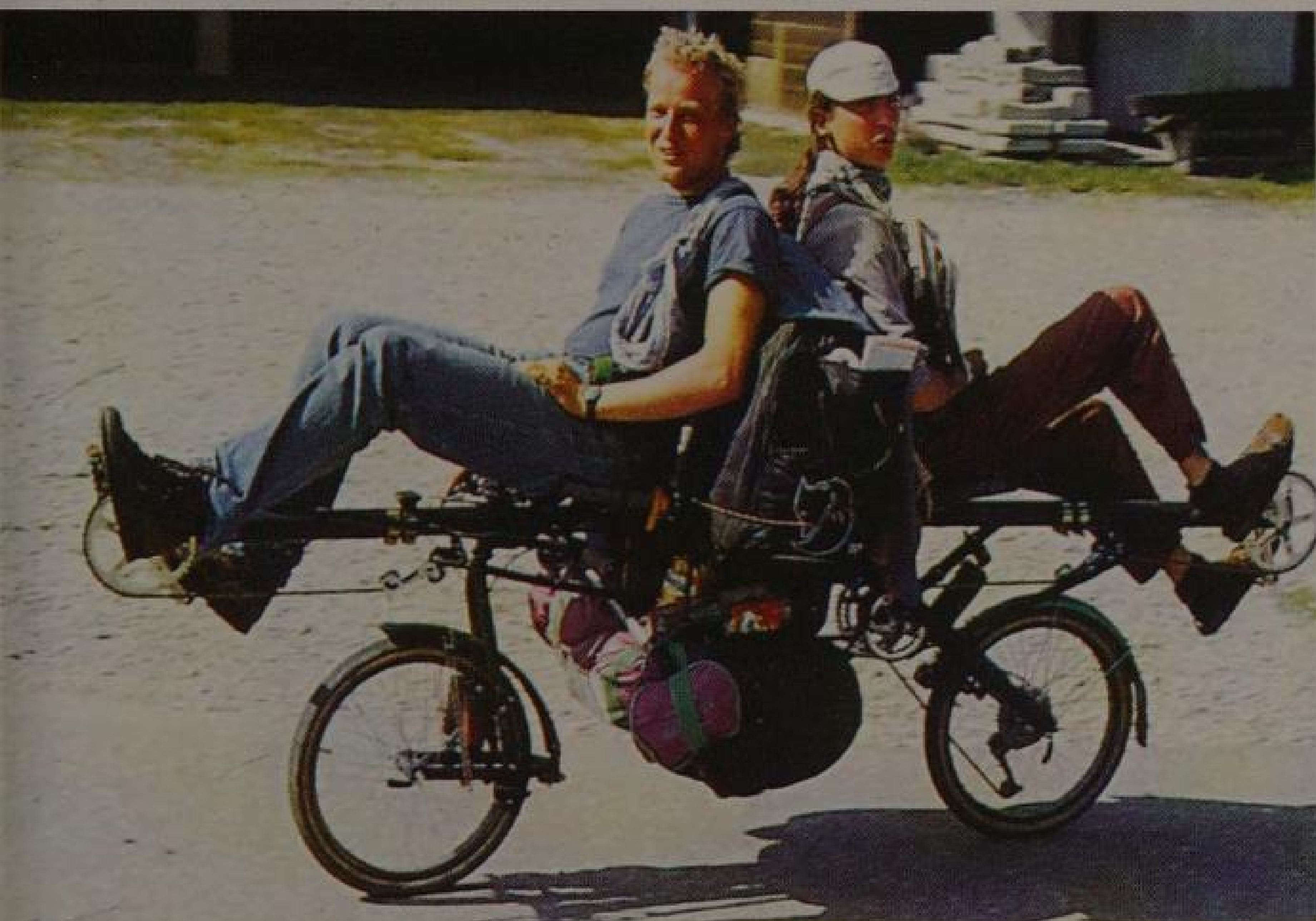
Sam Whittingham celebrates his 81-mph world record with Georgi Georgiev, Varna designer. "Virtual Rush" camera bike, below.



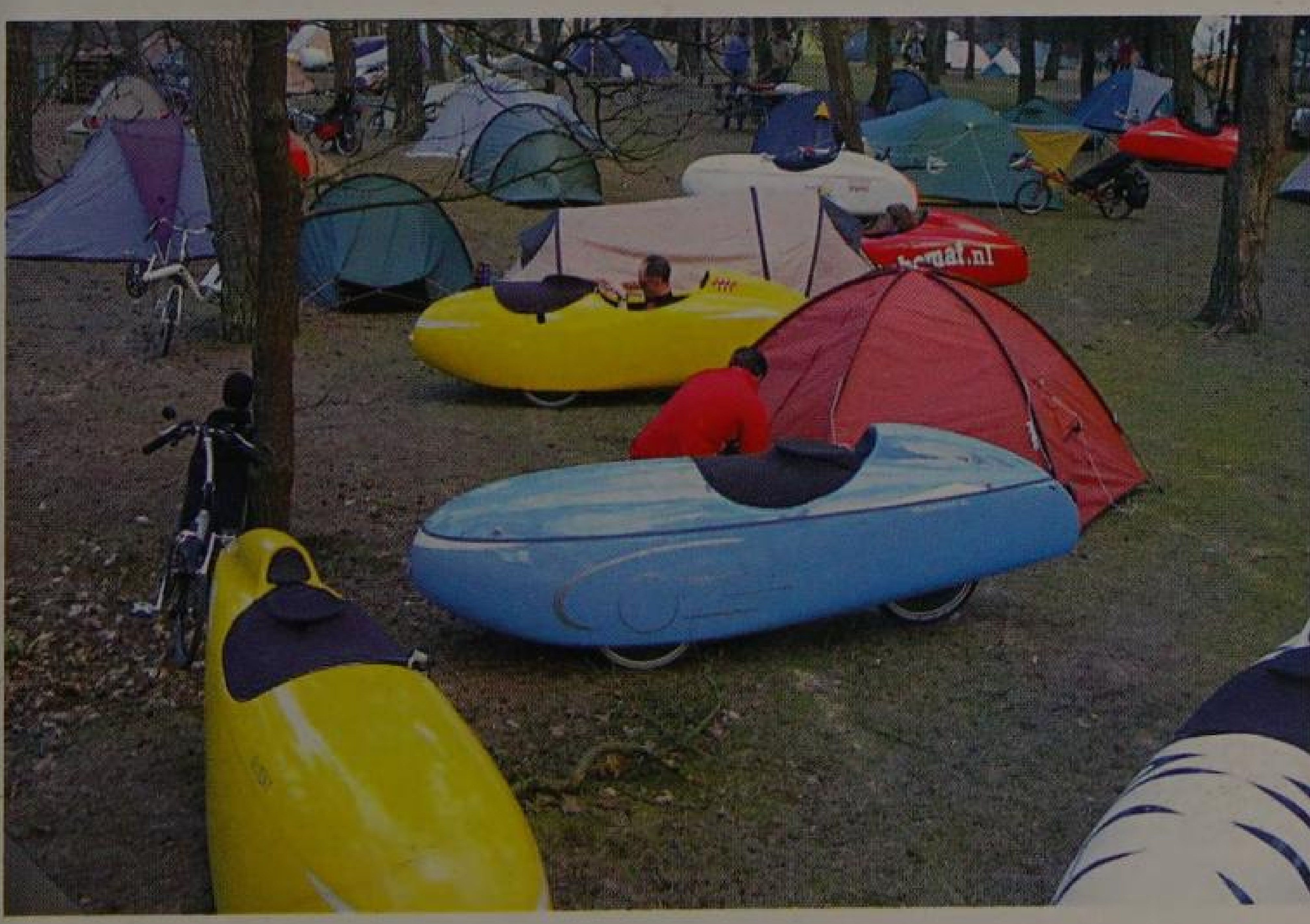
(photos above, left: Arne Hodalic)

Competitor at 2004 Cycle Vision, Holland. (photo: tim.be)

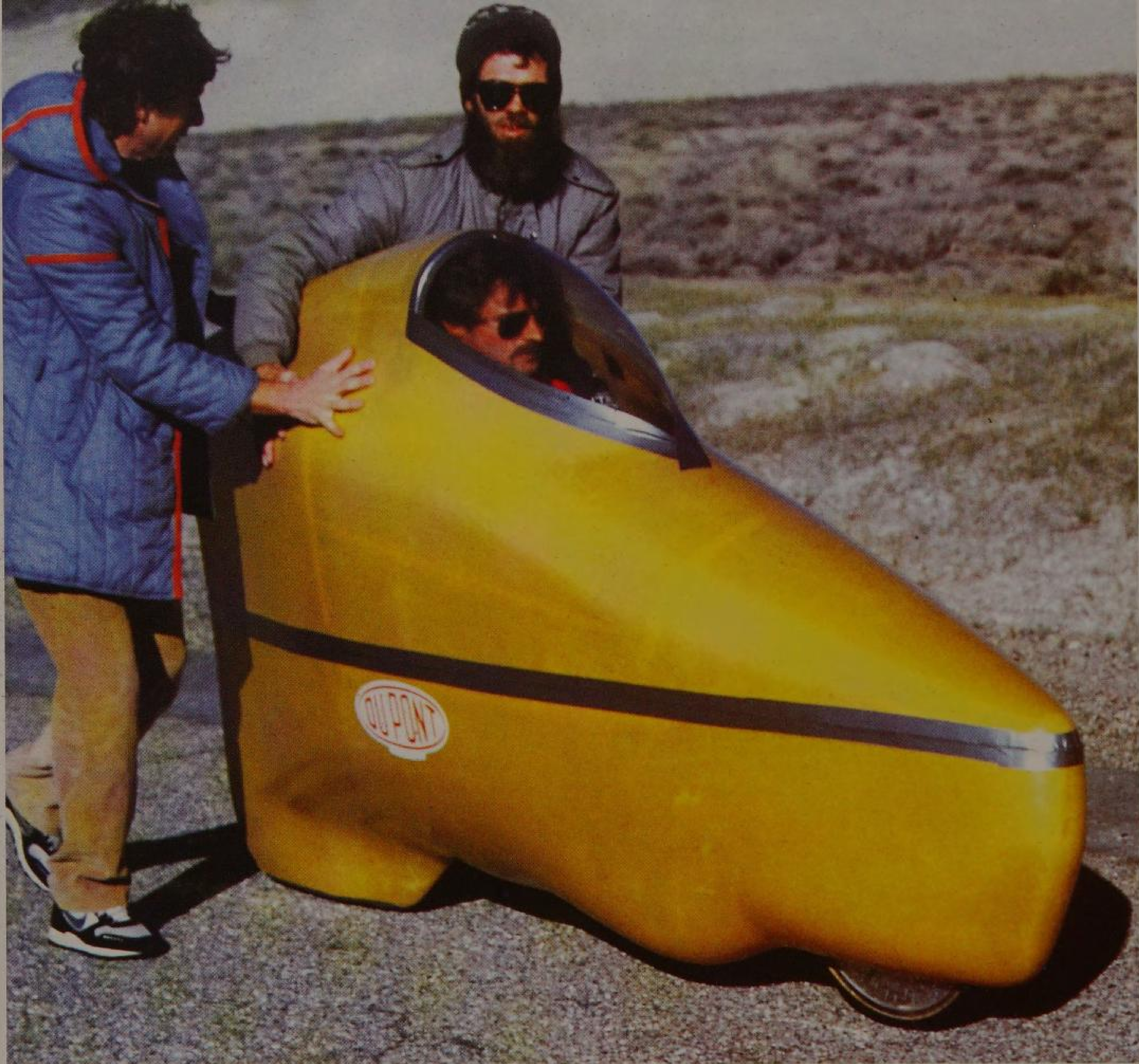
Recumbents give uprights a challenge at open races such as the Black Bear in Grayling, Michigan. (photo: Mark Sloan)



You can admire a huge variety of creative designs at gatherings like Cycle Vision. Upper left, a back-to-back tandem. Above, a rare belly bike —one recently won a hill-climb.



A campground scene on a Dutch HPV club tour. (photo: www.ligfiets.net)

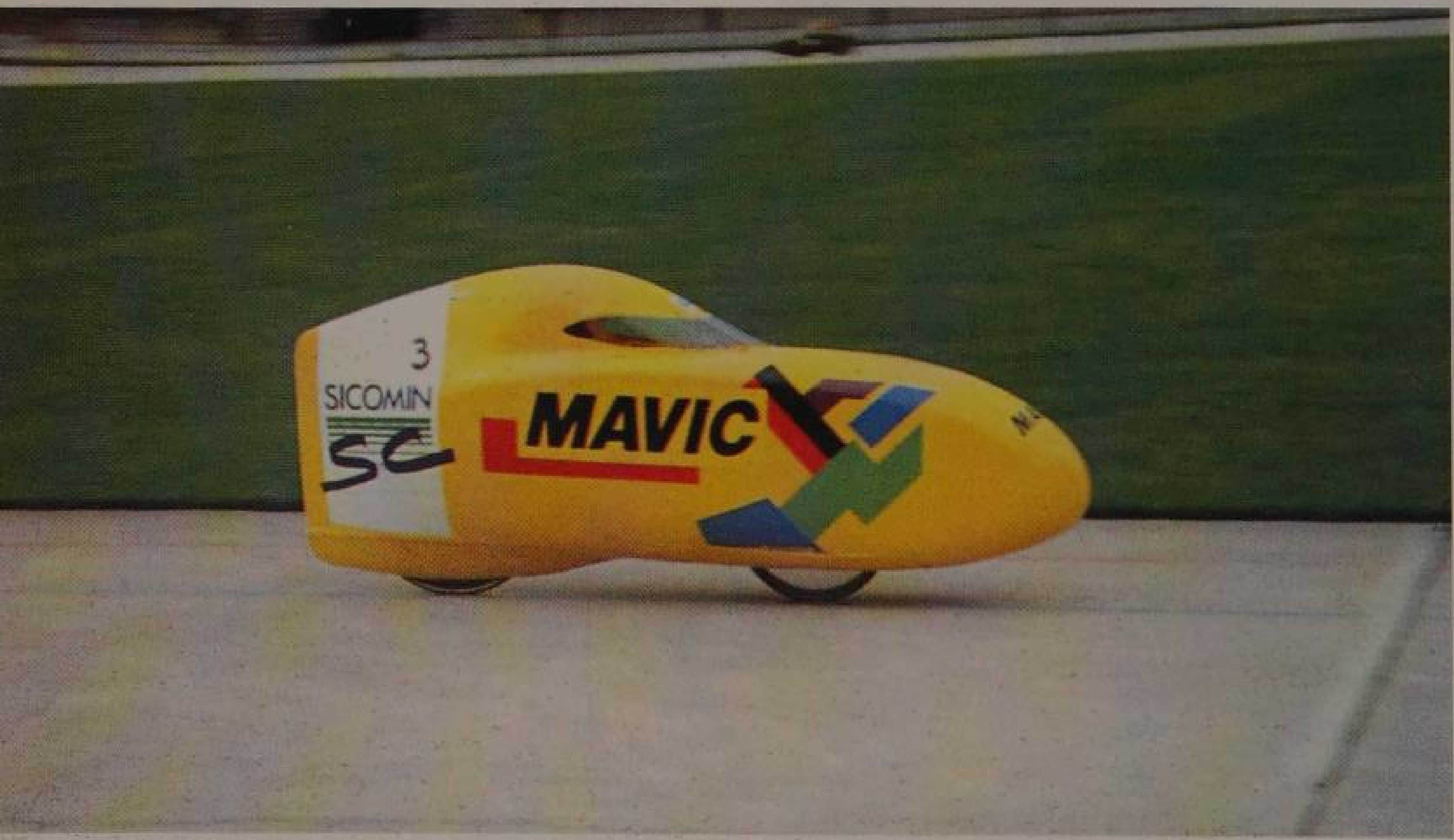


The Easy Racers "Gold Rush" on its way to a record race. Fred Markham was the first person to reach the 65 mph mark in 1986. Gardner Martin (R), builder of the vehicle, and a team member launch "Fast Freddy." (photo: Easy Racers)

...Easy Racers also makes fast touring bikes. Laurie "Wo" Smith is loyal to her Tour Easy, which she often enhances with a "bodysock" stretch fabric fairing.

The colorful splendor of a mixed-field start in 2004 at the Cycle Vision, an HPV festival in the Netherlands. (photo: www.tim.be)

Diversity, versatility reign in recumbent design and function. Moderate trail riding is a breeze, especially with suspension. The compact "WYMS" ("With Your Main Squeeze") tandem —with front and rear drive.



Martin Sörensen in a faired HPV on the road during an open-field race between Trondheim and Oslo.

Fast and beautiful—a faired HPV sponsored by Mavic. Lack of foot holes and a tiny windshield means this is strictly a race vehicle, but some racers build faired bikes which are competitive as well as safe on the road.

The changing of the guard in 1990: the first lowracer on the elite scene, "Cutting Edge" passes the record-holding, previously best "Gold Rush."

A "mixed" HPV racing field is colorful and diverse. Because the speeds vary widely among vehicles which are welcomed into these events, passing has developed an etiquette of friendly courtesy.

A front fairing improves weather protection and makes the vehicle faster. Neither field of vision nor handling of the bike deteriorate.

A meticulous wind tunnel test of the M5 "Tour" reveals the truth: Faired recumbents are the best choice when it comes to aerodynamics. Other ways of testing let you avoid the wind tunnel —which pleases people with small wallets.

The popular children's event at the Cycle Vision festival brings out quite a few young riders. (photo: www.tim.be)

A front fairing pays off especially in bad weather. It helped the French Francoise and Bernard Magnouloux to deal with cold winter winds at the North Cape. (photos: Francoise and Bernard Magnouloux)

HPV sports: distance races...

...200-meter sprints...

...and practical-ability tests...

coefficient of air resistance (*Cd*) would equal 0 (not taking friction into account).

Airflow does not have any chance to follow the outline of a wooden box, nor can it cause a pressure regain at the rear. A big "transfer" area results. The size of the transfer area (surface measures of the rear turbulence) is the measure for the loss of pressure (8).

Therefore beneficial aerodynamics keep pressure at the body's front and rear relatively even. Unfortunately this theoretical ideal cannot be realized in practice. Four factors are responsible for that:

- angled airflow
- design compromise
- surface roughness
- system vibration

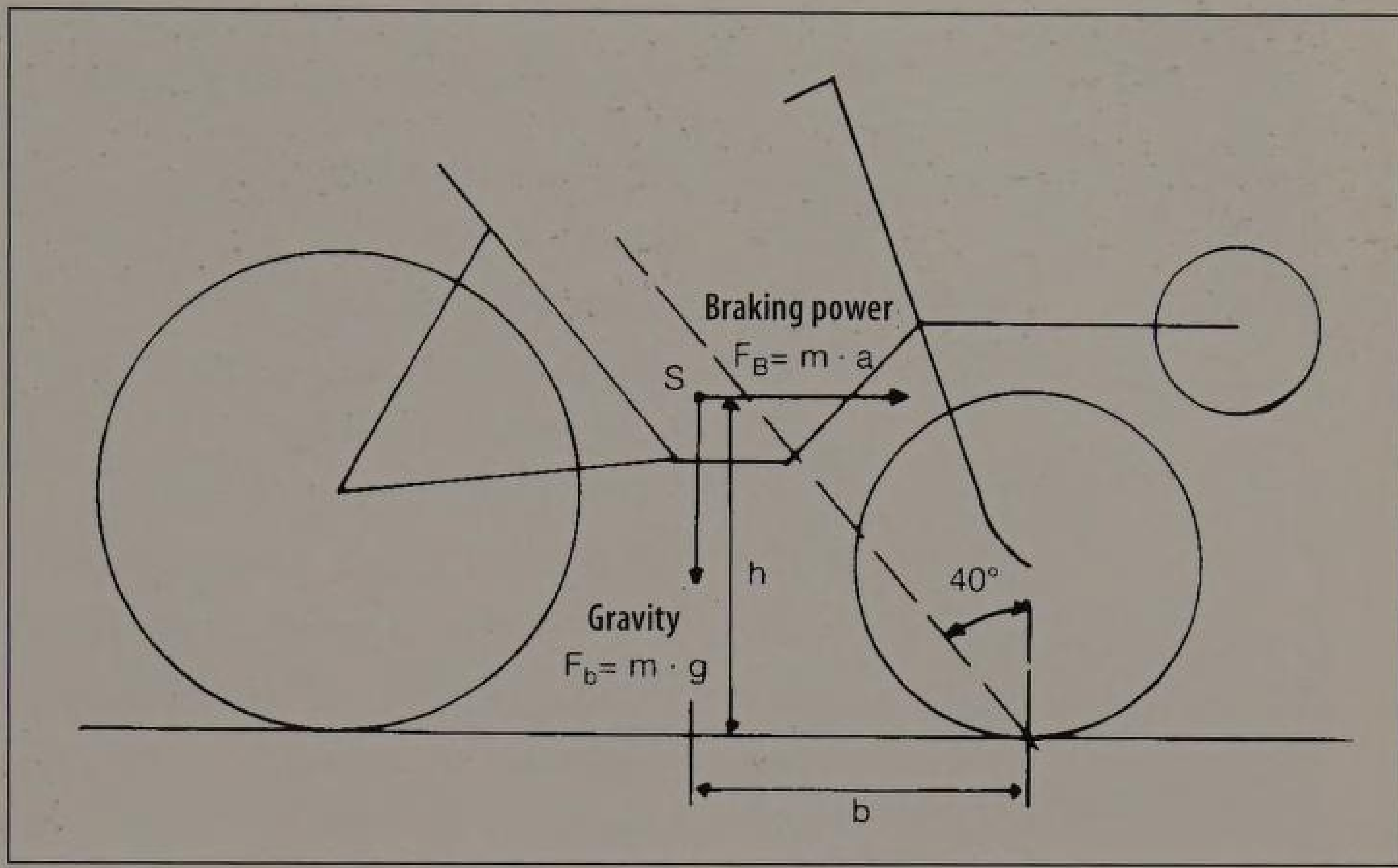
A real-world fairing can't sustain laminar flow, but it can avoid wasteful separated flow and a big energy transfer. A practical optimum, achieved through an artful balance of all four factors, is attached flow which is turbulent but still closely follows the shape of the body.

Angled Airflow

In practice, there are no absolute 0-degree-airflow surfaces. In automobile construction a 5- to 10- degree angled airflow is usually assumed. This makes the construction of aerodynamic parts very difficult. Moreover there are few laminar airflows in nature. Ground unevenness, obstacles (trees, houses, bridges, etc.) and moving bodies (cars, humans, etc.) cause permanent turbulence near the ground even before vehicles pass through it.

Design Compromise

An unfaired recumbent suffers from significant compromises with the demands of aerodynamics. It becomes obvious why even the smallest fairing can reduce drag. (Fairing design and a detailed analysis of side winds can be found in Chapter 5.)



Surface Roughness

Surface roughness of a fully faired vehicle refers to the surface quality of the body paneling. If the bike is not faired at all, the surface roughness is determined by the individual components and the rider. As the rider represents the biggest surface, racers pay close attention to the clothing they wear. Some shave their legs to reduce air friction. Bike frame shape and parts also significantly affect drag.

System Vibrations

System vibrations are highly significant to aerodynamics. While suspension is usually only considered for reasons of comfort and improved traction, it is also beneficial to aerodynamics.

"Micro bumps"—the ever-present surface imperfections found on new and old roads alike—cannot be absorbed even by wide, partially inflated tires. The result is constant vibration of both bike and rider. These vibrations cause the airstream at surface layers to tear off prematurely. The effect, however, is only relevant for fairings. System vibrations also develop as a consequence of asymmetrical pedaling, body movement, or rocking the bike. Good suspension can reduce all these effects. Even a fairing can be

CdA	*Vehicle Type and Rider Position*
.79	average car sedan
.68	standard bike
.51	racing bike, on tops
.47	Honda Insight hybrid car
.38	racing bike, in drops
.31	SWB, USS, unfaired
.27	LWB (Tour Easy), OSS, unfaired
.23	triathlon bike, aerobars, diskwheels
.21	Highracer, SWB, OSS, unfaired
.15	Lowracer, no fairing
.12	Lowracer, tailfairing
.07	Zote foam street-safe streamliner
.06	Quest velomobile
.05	Weekend/club streamliner
.04	Gold Rush streamliner
.02	Varna Diablo streamliner
.01	Virtual Edge streamliner

(*CdA* in meters-squared. From Recumbents.com, Kreuzotter.de, and Wikipedia.org.)

"suspended" with dampers to reduce these losses.

Braking

The combination of longer wheelbase and lower center of gravity for a typical recumbent naturally increases braking capacity. Studies show that a long-wheelbase recumbent's braking ability is 60 percent better than an upright bike of equal weight. However, since recumbents are typically heavier than uprights, the figure drops slightly.

The process of braking involves an interplay of braking power, forward motion, gravity, and surface friction. Gravity and friction assist braking, but inertia keeps a rider and vehicle moving forward.

The forward-pointing "moment of inertia" that arises (from the braking force) creates the "flip-over" inertial moment (power x lever arm) above the height of the center of gravity. To keep a bike from tipping forward this moment has to be smaller than the standing moment of inertia, which is formed by the distance to the front center of gravity and the weight power. In the moment just before a vehicle tips forward, both momentums are equally large and the load on the front wheel is at its maximum. This is also the instant of biggest deceleration is possible, which depends on the coefficient of friction between tire and ground. This variable is never greater than 0.85, which means no more than 0.85 times the weight power of bike and rider can be used as braking strength. It is not a physical limit—it's just that any more means you'll be injured, as if you were to crash into a concrete flower box.

Because of this value a rider can calculate that a bike will never flip forward when braking if the center of gravity lies below a line that goes through the front wheel's center of rotation and which runs in a 50-degree gradient away from the ground toward the rear.

Some helpful braking equations:

- standing inertial moment = m (mass) x g (gravity) x b (distance between front wheel hub and center of gravity)
- turn-over inertial moment = m x a (braking strength) x h (height of center of gravity)
- braking strength $F_B = m \times a$
- momentum $F_G = m \times g$
- a max = 0.85 g
- g = gravity = 9.81 N/kg

Cornering

Riding a recumbent through a curve has a different feeling than what you get on an upright bike. There is one main reason: While leaning the upper body sideways on a diamond frame in curves is possible and common, it is usually unfeasible on a recumbent. The upper body is pressed against the seat and so the body and thus the head follow through every curve and experience every banking motion. You're "in" the action.

Most recumbents have sufficient ground clearance for pedaling at speed through any "rideable" corner. This lets you increase speed in many typical corners, increasing even more the "fighter pilot" feel.

However, in slow or tight turns a caution is in order for models that have a small clearance between pedal and front wheel. Your foot might hit the tire where the wheel has to move a lot to turn the bike, requiring coasting in such cases. After you get used to it, proper pedal positioning to avoid any foot-strike becomes a reflex. In high-speed corners there's no worry for any model, so forget about it and keep the power on!

Recumbent Biomechanics

The recumbent bicycle challenges body and mind differently than an upright bike. (It's interesting how various bike types challenge us differently, including tandems and trikes.) There are also some trade-offs. For example, you can't gain power from out-of-saddle pedal action on a recumbent, but you gain the ability to push against the seatback for additional force.

When you begin training on a recumbent for the first time, your exertions may not result in the performance you expect. You'll also experience new strains on the body. Knee joints, ligaments, feet, and sometimes hands may ache. With your legs more elevated than you're used to, you'll need to acclimate to reduced blood flow. Comfort and performance will come slowly as you gently and gradually build up new muscles.

While upright cyclists have a "secret" power source in out-of-the-saddle pedaling, the real strength of this rocking pedal action may not be what it appears.

The thrill of fast, hard-lean cornering. (photo: tim.be)

Martin Staubach, recumbent rider and builder, looks at it analytically:

"So what is body weight able to do anyway? It only forms the counter power against the power that the standing cyclist conveys into the pedals. Action equals reaction. What happens on a recumbent? The seat takes over the reaction, the counter power to the pedal power. If the seat wasn't there, the rider would slide back and the pedal wouldn't move. On a racing upright bike a different process takes place. The racing cyclist pushes down so much into the pedals that he pushes himself out of the saddle. The reaction is that body weight is now too small. Thus he accelerates his body upward instead of his pedals downward—this he doesn't really want! So he pulls himself down again at the handlebars. Consequently he strains his muscles and metabolism, but not to go forward. However, when standing while pedaling he uses different muscles, which have not yet been overused. That means he's using "fresh" muscles. That is the only real advantage, and not the dubious 'use of body weight.'"

However, gravity does seem to assist the upright cyclist in another small way: It helps the legs drop through the downward phase of the pedal stroke, where the leg is exerting the most force.

For recumbent cyclists, gravity only helps the pedals fall through the "bottom" of their stroke, where the leg is extended and exerting less force. Still, recumbent riders can learn to take advantage of such help by letting the legs "fall" in a relaxed way as they go through that part of the stroke, or by adding downward force there to greatly minimize the infamous dead zone. (Cyclists try to minimize the dead zone in various other ways as well, including by the use of oval chainrings and the new phase-altering Rotor cranks.)

It would nice if recumbent racers could jump from their saddle as upright cyclists do. But don't count on that anytime soon. Such a bike would require a convertible frame that switches from upright to recumbent modes at the flick of a lever while still riding. There are designers exploring this, so stayed tuned!

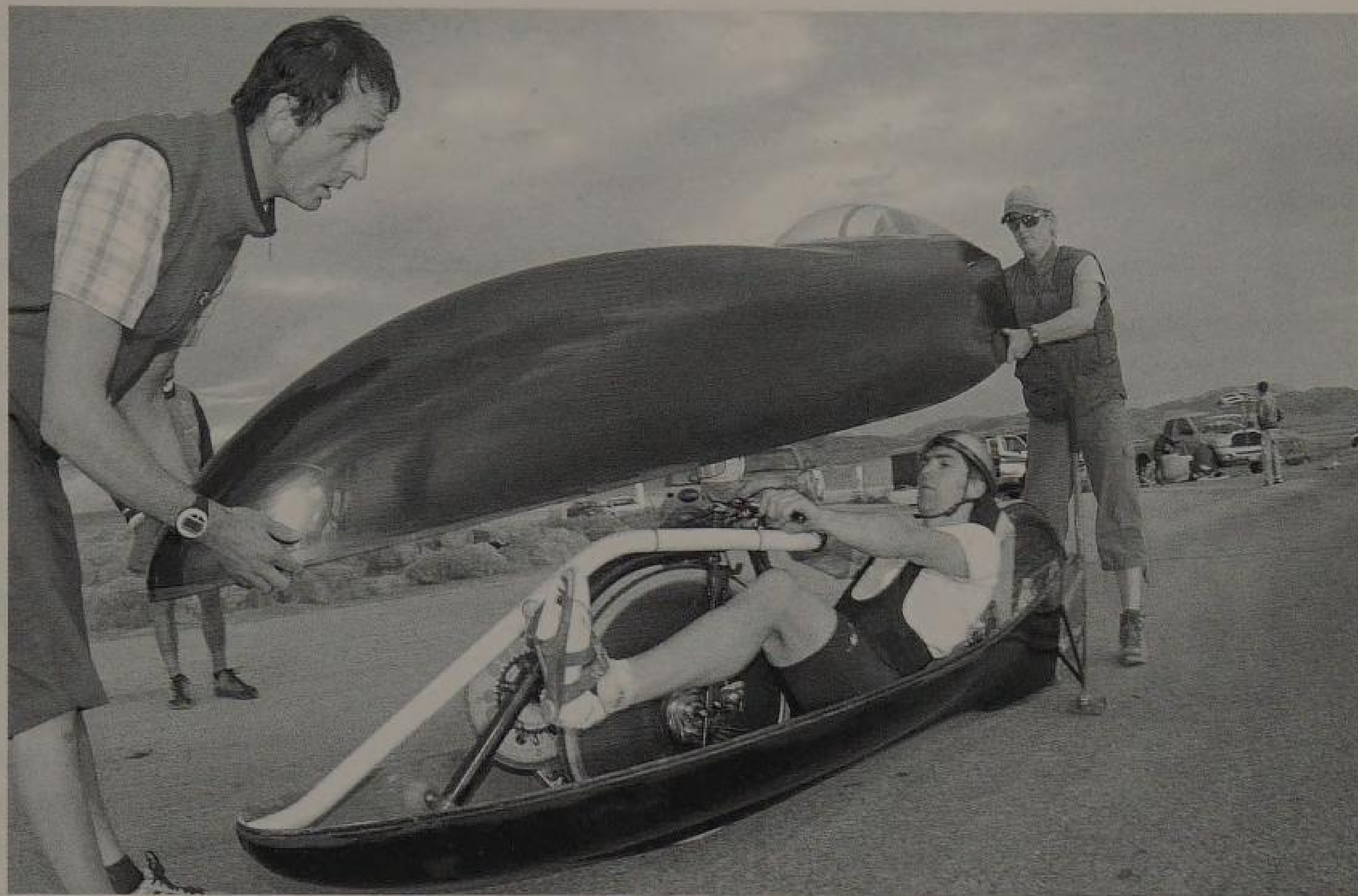
Onetime New Hampshire recumbent producer George Reynolds presented a convertible prototype called the "Redundant." Joe Kochanowski, the ultimate scavenger/designer, also has a two-position recumbent among his stable of home-crafted cycles. A nimble rider can switch from the upright position to a recumbent position quite quickly, judging by a short video clip that can be found online.

Until a workable, high-performance convertible is introduced, recumbent riders must adapt to their format's "limitations," perfecting a smooth spin, especially in mountains. You simply cannot stand up, even if you need a sudden burst of power. Instead, for big climbs you need to determine your sustainable speed at the bottom of a hill and maintain it as best you can all the way to the top. Lower than usual gears help in case of surprises on the way up. If you overestimate yourself and start off too fast, you'll pay the price farther along.

Studies have shown that the significance of "honking"—vigorous pedaling in a standing position—can be overrated, especially at low speeds. T. W. Ryschon determined, after testing at the University of Texas Human Performance Center, that at a low speed of about 13 mph and a gentle uphill of 4 percent, standing pedaling demands more power than seated pedaling.

Another study at the California State University at Long Beach confirmed other suspicions—and the idea Staubach mentioned above. A test took place on a surface 3.5

George Reynold's "Redundant" prototype converts in seconds between upright and recumbent modes. (photo: G. Reynolds) kilometers long with a 150-meter rise. The test riders (a man and woman) reached 2.7 and 2.4 on the USCF's "dynamometer" effort output scale. Their results showed that it is not the rocking pedal action itself that is useful, but switching back and forth between riding seated and standing. The improvement in performance is very small anyway. Riding only out-of-saddle is about 1 percent slower than switching between seated and standing pedaling, while it took 3 percent longer to ride entirely seated. The measurable gain from switching comes from using two different muscle groups. When one fatigues, a switch to the other offers fresh power.



Sam Whittingham prepares for a sprint in his ultra-low, ultra-small Varna Diablo during a series of record-setting runs in 2004. He achieved 81 mph. Designer Georgiev's theory is to build the smallest bike around the smallest rider with a potent sprint. Also, note the white ventilation tube running from a hole in the nose to just above his knees. (photo: Arne Hodalic)

Let's consider a hypothetical situation. Two bikes—one a recumbent, the other an upright—are racing each other on a mountainous course. The bikes weigh the same and the riders are physiologically identical. Who will win? I would suspect the recumbent rider wouldn't be as far behind the upright rider as some might think.

It goes without saying that a recumbent will never measure up on the mountain goat stages of the Tour de France: Recumbents weigh more, and that 3 percent climbing-loss due to being seated adds up!

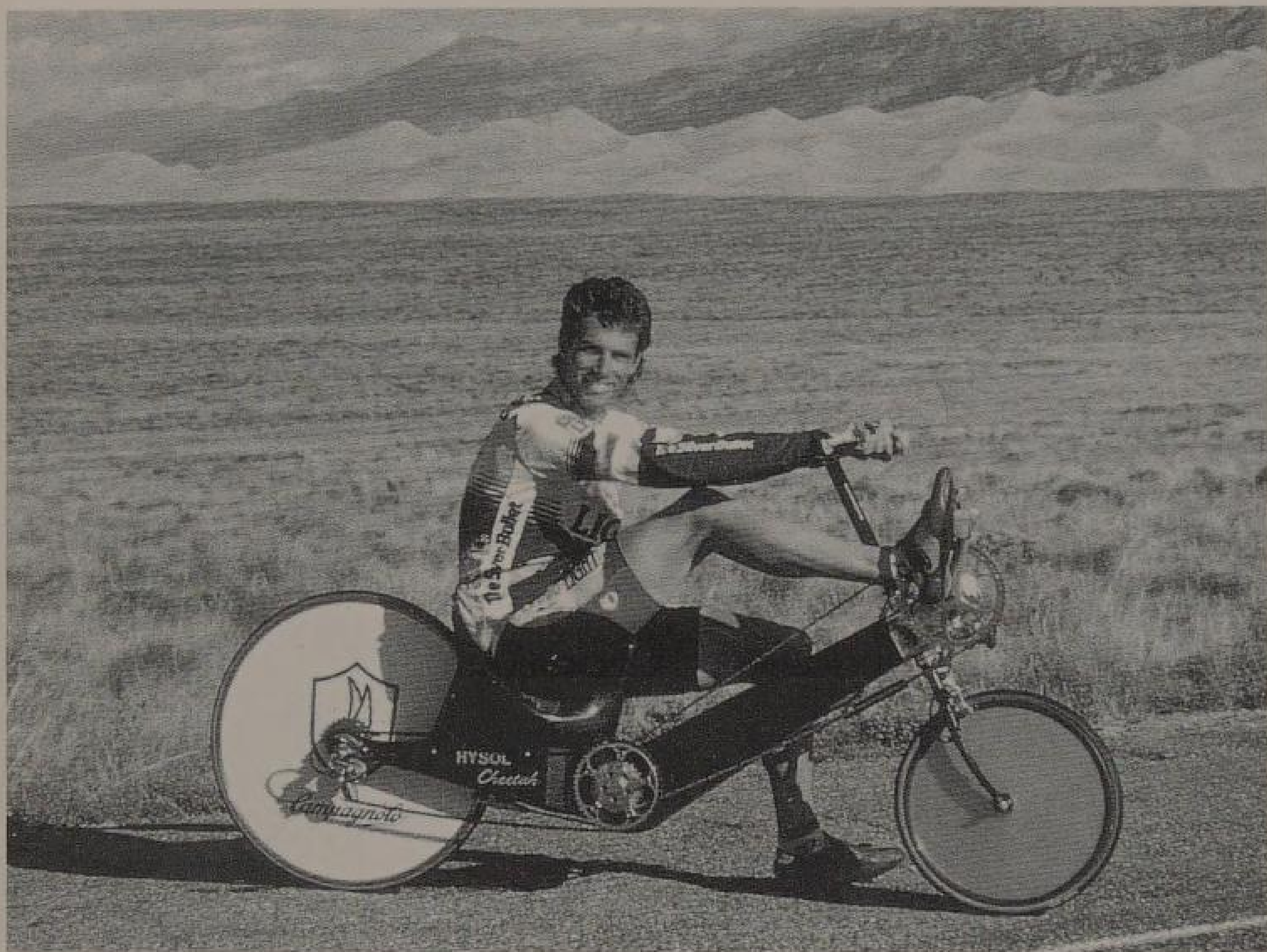
However, I once toured the Scottish Highlands with 45 pounds of luggage, and found that I could master the rises quickly. I could overcome even a 20 percent grade at a speed that I did not have to be ashamed of. Practice greatly improves results! Small, steep hills seem to require sharper effort on a recumbent, but those willing to make such effort will be able to stay at the front of a club pack.

In moderate terrain the story changes. Recumbent riders can make up for time lost in the hills by improved speed on the flats and downhills.

Pedaling in the recumbent position demands a special development of certain muscles, in particular the lower fringes of the *vastus laterales*, the *vastus mediales*, and the *rectus femoris*. The first two are located just above the kneecap, on the right and left sides; the third one runs all the way from the upper leg down to the kneecap.

To understand the significance of the kneecap, take a look at the motion sequence in the knee area. On an upright bike gravity assists the legs push through the downstroke, while the legs of recumbent riders are horizontal (or nearly so, depending on the bike design). Their inherent weight, plus that of pants and shoes, pulls them down, requiring muscle tension and exertion to hold them up (see "Pedals and Shoes," Chapter 2, page 47). The nature and consequences of this specific strain can be compared with those of a construction crane.

A lifting crane has a base pole (femur) with a joint at its end (knee joint), which is connected to the swing arm (lower leg). Wires run across a steel trestle at the joint.



Chris Huber shows what's behind the fairing of the record-setting "Cheetah" —a bike with ergonomics focused on the exploitation of energy. It's sure not suitable for commuting, but it was good for a 68 mph sprint. (photo: Team Cheetah)

Here is the focus of highest strain. The more the swing arm approaches a right angle towards the base pole, the bigger the lever gets and the greater the forces are at the joint. There are exact tables for cranes about how much weight is permitted in which swing-arm position. There is no such table for the knee.

The kneecap's task is similar to that of the main cable at the joint of the lifting crane. The *vastus mediales* and *vastus laterales* hold the kneecap in its groove. The *rectus femoris* pushes the ligaments up and reduces the forces working on the kneecap. If this muscle is underdeveloped, the cartilage under the kneecap gets used up more quickly.

During recumbent pedaling, these three muscles are under heavy strain. Hard pedaling under such tension in a horizontally held leg can have painful consequences for a cyclist if he makes the following mistakes:

- pedaling cadence too low
- start too soon with strenuous rides
- not allowing recovery or build-up phases in muscle training

The consequences of such mistakes are simple: knee injury.

If the pedaling cadence is too low, the need for power rises and so does length of time in each crank position. If frequency is high, strain is reduced enormously. One also needs the already mentioned muscles for the "holding-up" work of the legs. Not even racing cyclists possess the right muscles needed for aggressive recumbent riding from the outset.

Only the long distance runner uses these muscles to a similar degree as the recumbent rider. Few of those who come from running to recumbent riding have problems with their knees.

Here are some rules that can help the novice:

- Start off your training very slowly.
- Use a high pedaling cadence.
- No straining in the first three months.
- Develop and perfect a "round" spinning style of pedaling.
- Do not use long crank arms; they make spinning more difficult. 170 millimeter is suitable. If you are over 6 feet tall, you can go a bit longer. Consider testing short cranks in the 150-to-160-millimeter range (Bikesmithdesign.com is a resource).
- In addition to your bike workout, leave time and energy for running.

Some upright racers, after buying their first recumbent, think they have to achieve a "personal best" on their home course right away. Bad idea! There's no surer way to move that goal even farther away. A premature, vigorous pursuit of top speed—on a bike that uses new muscles in new ways—is a great way to incur strain that may take weeks, or even months, to heal.

To avoid this start with slow, daily workouts of 2 to 3 miles. Over a period of three months, gradually increase your distance to 20 miles, avoiding steep hills and racing. In this way, your muscles will adapt to the new movements, new resistances, and new strains.

Your regimen should include cadence training. Begin with a cadence of about 90 rpm; for hill-climbing it should go down to no less than 75 rpm.

Include "no push" pedaling practice as well, where you work on pedaling in every direction but the most powerful one. This builds important muscles and improves spin.

Riding a recumbent—especially uphill—is mostly a matter of adaptation. With a good start and a smooth crescendo in your training plan, your recumbent will be no more stressful than an upright bike.

Physiological variations may require a more finely calibrated training regimen. Those with undersized kneecaps, for instance, may require individualized workouts.

The new trend among 'bent riders to shorter cranks is worth exploring, especially for those experiencing strain. Many find strain reduced and say their power is enhanced with the reduced foot motion offered by crank-arms in the 150-millimeter size-range. (Upright bike data published by VeloNews magazine verified that power was indeed improved in some cases.) The Bikesmith company can shorten many regular crank models.

By the way, the lower the crank is in comparison to seat height, the quicker it is to feel comfortable for casual riding on a 'bent.

'Round' Pedaling and Spinning

"Round" pedaling is a controversial theme in the world of cyclists. During one rotation of the crank the pedaling leg goes through various positions with different lever forces. The dreaded dead zones in the extended and retracted positions do not produce any lever force. Only when pedal power is applied tangentially is it possible to overcome these weak points.

The more time spent in the dead spots, the more "square" or ragged one's pedaling becomes. Pedaling should be as round as possible for both physical and biomechanical reasons. High pedaling frequency makes it easier to keep the stroke round as the foot spends less time in the weak zones of each rotation.

In contrast to the dead pedaling points on an upright racing bike, the six and twelve o'clock positions, on a recumbent they occur in the three and nine o'clock positions. The advantage here goes to the recumbent. When pedaling down through the nine o'clock position, the weight of the whole leg helps minimize the dead zone. In fact, a bit of power can be added using a chopping action, pulling down with the heel with the leg extended—best applied with the help of a somewhat long leg-length adjustment (or scootching back in your seat).

This gravity-assisted attack on the dead zone at full extension can be effective and exciting to use. It is more powerful than its counterpart in upright riding where you *pull* through the dead zone, much like wiping your foot on a rug.

A cyclist with a smooth spin on an upright may find it necessary to relearn spinning while adapting to a recumbent. The familiar areas where you used to exert to keep your cadence smooth and get through the dead zones are now 90 degrees out of phase. That's a big adjustment. For instance, the fully retracted dead zone at twelve o'clock for an upright cyclist is easy to get through, but for a recumbent rider this occurs at nine o'clock—where gravity is fighting you hardest.

As you might expect, equipment makers are trying to defeat the dead spots. Several new contenders have added their services to that of the oval Shimano Biopace chainring and seem to be gaining favor among

Brad Graham's "Atomic Zombie" book and website offers step-by-step plans for many bikes, including the efficient, thrifty "Marauder," a LWB lowracer with indirect steering. Such a set-up lets you customize handling traits separately from handlebar action, while the long-wheelbase smooths out road roughnesses. (photo: AtomicZombie.com)

recumbent riders and racers. The popular variant is the Rotor Crank, which advances the power-phase on each stroke, and Rotor's adjustable Q-ring chainrings. Also in the running are EasyCranks, which have crank-arms that change length as you pedal, and PowerCranks, a round-pedaling enhancer.

The seat, quite obviously, determines the position of a recumbent rider. Because a recumbent's seat allows less room to shift around, the knee constantly works in the same angle. On an upright bike the angle can be readily changed: by tilting the pelvis, by shifting from fore to aft, or by raising the torso in going from the drops to the tops of the bars.

You can help prevent a focused strain on the knee by occasionally changing the leg-length adjustment, by changing between soft and firm seats, or with a mesh seat with adjustable firmness.

With conventional pedals or toe-clips it takes some effort to keep the feet on the pedals, especially on long rides. On bumpy roads your feet can easily get jostled from the pedals and out of the clips, and an injury could result if your foot hits the moving pavement and is wrenched. Working to keep your feet on pedals increases strain on knees. The solution is easy: Use a clipless "click in" pedal system. It's almost a must for recumbent riders. They're one of the great boons to recumbent riding. Shimano, Speedplay, Crank Brothers, Time, and many other manufacturers offer them.

Only when the shoe can take over the effort of holding up the foot can the knee be eased from this work duty.

Cleat position is a matter of consideration for upright and recumbent riders alike. In recumbent riding a cleat position closer to the heel can reduce knee strain.

To further ease knee strain, many recumbent riders find that moving their seats back farther than usual—extending the legs—can help.

After you've passed through the training and adaptation phase and become a fit recumbent cyclist, you'll develop pedaling tricks to suit your needs (such as the "chopping" pedal stroke described earlier). Be patient. Complete adaptation to high performance riding may take several years of steady riding. Don't rush it.

Although the seatback restricts your movement somewhat, there are ways to alter your position and change your pedaling style enough to recruit fresh muscles. Recumbent racers sometimes pull on the bars (if the steering isn't overly sensitive) to add power to their stroke, since many seats flex a bit or let the body slide somewhat when pedaling at full force. (Elite riders report best all-round results from a light touch on the bars.)

You can also close up leg angles and change muscle groups slightly to get a break from pedaling at the usual angle by pulling on the bars and leaning forward in your seat as you pedal. You can then sometimes shove yourself back a bit further and roll the hips forward to find new muscles, or you can slouch in your seat by sliding forward. Slouching also helps you hide from the wind and shortens your stroke, raising your knee height. Now push through and flex your ankle more deeply, then pull down with your heels, using the traditional "ankling" technique.

Tim Brummer, of Lightning fame, describes riding one-handed and pushing on his knee with the free hand to add surprising force on hard uphills (alternating sides).

Occasionally changing your seat angle also allows new muscles to be used. It also changes your exposed frontal area—when further reclined one can often ride faster into a headwind. This also changes how your weight is supported—whether by your back or your butt. It changes how open or closed your pedaling angle is—a more closed angle can help with hill-climbing. Changing seat angle has the effect of changing leg length, so you might have to adjust for that too. Seat angle is just another factor to vary in the effort to find the most efficacious and comfortable position.

Don't get locked into thinking that only one angle is correct. Muscle groups will tire, and changing positions—even on the same ride—gives you a lift. Spring-tensioned quick-releases on some bike seats make "on the fly" changes easy.

Recumbent pedaling is limited in some ways (as is any kind of pedaling), but it opens up other options for creatively getting the most from your arsenal of strokes.

Bike Fit: Handlebars

Like any bike, the recumbent must be custom tailored to fit the rider.

Handlebar height, width, and orientation is almost as critical to the recumbent rider as it is for the upright rider. Bar position for best power leverage, for best handling and cornering, for easy entering and exiting, for ideal breathing, for least strain in holding, and for best aerodynamics will vary from person to person. Many racers prefer a "tweener" bar positioned quite far from the chest, so that the arms are nearly straight, with the legs cycling between the arms. Some prefer a relaxed "begging hamster" position, with arms bent and close to the chest, usually mounted with a pivoting stem to let you get in and out of the seat easily. Some prefer underseat steering, which can range from a narrow, aerodynamic bar under the legs to wide and close to hand. Bar shape—including levers, shifters and cables—also has an effect on aerodynamics, with flat bars being explored.

Test them for yourself. None is better than another in terms of health, but your enjoyment of the ride or your results in a race might possibly hinge on handlebar style.

Bike Fit: Leg Length

Studies of diamond frames suggest there is an ideal distance between the saddle top and the crank. Renowned cycling coach Eddie Borysewicz developed perhaps the best method for determining that distance. And his method is the only one transferable to the recumbent.

The saddle, or other leg-length adjustment such as a sliding boom, is first set at a distance that is likely to be too short—as when your heel touches the pedal with outstretched leg. Then, gradually, the length is increased until the pelvis starts moving during easy pedaling. Now it is cautiously shortened again until pelvis movement stops. This is the spot.

Bernhard Klar found an interesting way to determine ideal bottom bracket distance from seat during research of recumbent ergonomics.

Matt Weaver races an elegant front-wheel drive LWB highracer with indirect steering custom made by Rotator. He took first place in an unfaired road race at Battle Mountain, Nevada. (photo: Arne Hodalic)

The Klar method involves first removing one crank arm and reinstalling it in the same clock position as the other crank arm, so that both arms point the same way.

While sitting on the bike, insert stout 15-millimeter-thick disks between pedals and heels, then apply pressure to both pedals. Adjust seat position so that you're just able to straighten out your legs and still clamp the disks with your heels. Once you've removed the discs (and reinstalled the crank arm), the resulting leg-length setting should be optimum for riding.

From an ergonomic perspective it is perhaps better to choose a distance somewhat long rather than too short, because a long setting allows for changing strain-angles for ligaments and muscles, while a too-short distance concentrates the load. Pain (mostly in the knees) can be the consequence of an overly short length. Some knee problems can be helped with an extension of this distance. Sometimes early-season weakness can be worked away by riding with a shorter leg-length on brief, easy rides, until the initial adaptation to holding one's legs up is made.

Regardless of the merits of scientific research, there's always room for individual adjustment. In a nutshell, you should find a length adjustment that does not cause pain. I ride my upright bike with the saddle 10 millimeters higher than studies recommend. On the recumbent my seat is 20 millimeter farther from the pedal axle than it "should" be.

Ergonomic Efficiency

Research on aerodynamics and ergonomics as they relate to recumbent cycling is still in its infancy. Recumbent designer Chester Kyle conducted some research recently that suggests a few coarse generalizations.

Assigning an index number of 100 percent to the upright racing bike, Kyle found that the recumbent position's degree of efficiency is 97 percent, and the prone position (belly down) is 96 percent. The study doesn't mention the ergometers and bikes he tested, and the riders are not described, so the conclusions are subject to skepticism.

Still, this hints at what a lot of recumbent partisans do not want to admit: The recumbent may not measure up to the upright bike when it comes to basic ergonomics.

Superior aerodynamics and the admittedly subjective gains in comfort and pleasure, however, can compensate for such measurable losses.

Ch. 5 Basics of Recumbent Design

A Showcase of Philosophy in Design

On a formal level, bike design is about measurements, weights, angles, and materials. We'll look into all that soon enough, but for now let's look at the stories of some actual bike designs, and find out why they were built as they were.

After that we'll present a side-by-side presentation of eight basic bike types.

Then we offer explanations and comparisons of all the major features offered by recumbent bikes.

Taken together, these three levels of design comparison should help readers better understand what they want in a bike and how to get it—either from a manufacturer or when home-building.

But the greatest favor you can do for yourself is to test ride as many bikes as you can: short and long wheelbase, lowracers and highracers. You'll then be in a much better position to know how the analysis you've learned works best for *you*.

The Recumbent Cyclist News, a bimonthly magazine published in the United States, offers a yearly buyer's guide. RCN reviews, as well as those of BentRiderOnline.com, are great resources in addition to this book. Also explore the many websites in the appendix of this book.

The examples I've chosen illustrate conspicuous differences in overall design theory. The selection does not imply endorsement. Some profiled bikes aren't produced today, but they highlight important distinctions in design theory.

Now, on to the bikes.

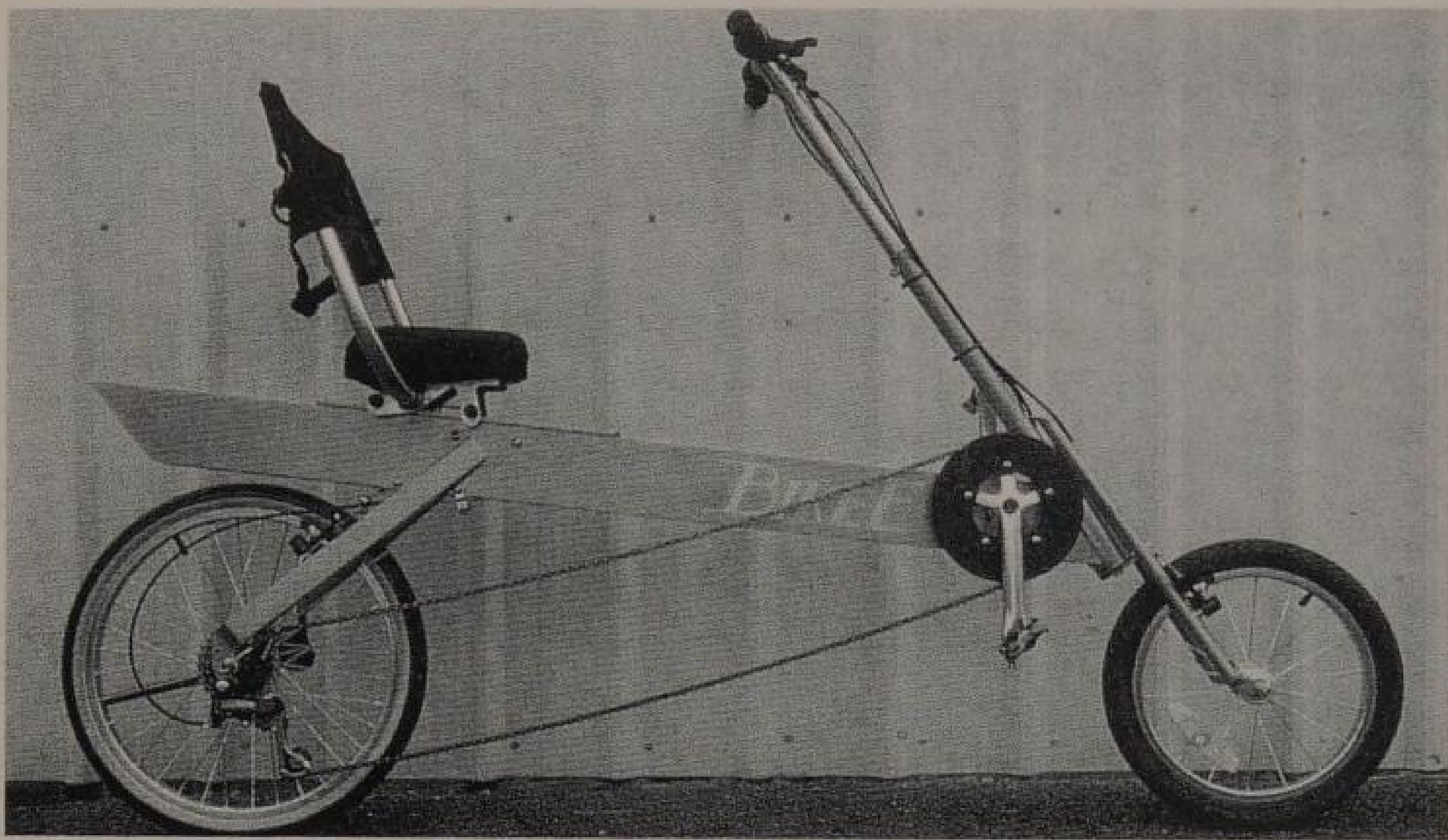
Bevo Bike: versatile innovation

Klaus Beck ("Be-") and Hans H. Voss ("-vo") possess years of experience with recumbents. Their goal in making a new bike was to create an everyday model that is safe, comfortable, fully adjustable, with room for luggage, and which itself can be easily carried—all for an inexpensive price.

For visibility in traffic, the seat is positioned at a 30-inch height. Even with the seat steeply reclined the rider can still see and be seen.

To keep frame construction simple, to reduce the chances of pants being splashed with dirt, to avoid a long chain, and to guarantee the smooth working of the rear suspension, Beck and Voss decided on front wheel drive. FWD is still an uncommon drive solution, but it offers all the virtues mentioned above, plus enough maneuverability for defensive riding. If combined with a hub shifter, FWD is suitable for everyday use. Beck and Voss decided that the best "footprint" was medium wheelbase

The luggage rack of the BeVo is ideally positioned. When loaded the bike's handling changes only slightly. (photo: Voss)

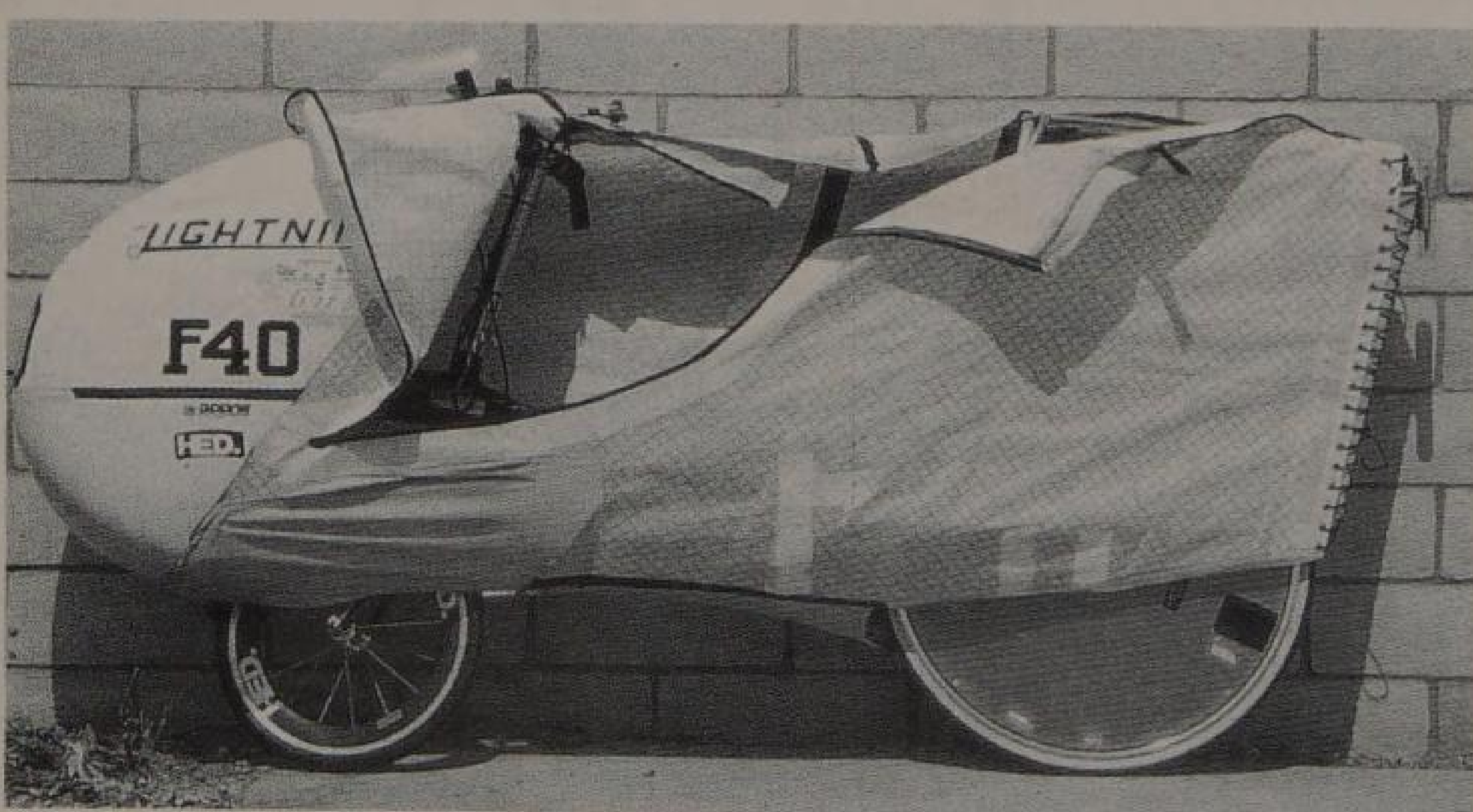


The BikeE combined functional design with low weight and a good price.

(MWB), also called compact long-wheelbase (CLWB)—a length between short and long wheelbase. They were able to combine advantages of short and long wheelbases in a bike not much longer than an upright city bike. CLWB is popular for an increasing number of city recumbents. The over-seat steering reduces the time a novice might need getting used to a recumbent, and it contributes to better aerodynamics.

It's quite a creative challenge to build a bike suitable for both town and country, so the Bevo is astonishing: This bike could meet the needs of a variety of riders. It could even catch the eye of someone with no previous interest in recumbents.

Following the motto "Cost what it must," the Lightning R-84 (shown with revised F-40 fairing) stands out: The frame costs over $1000 per pound!



Lightning R-84: $$ doesn't matter!

Tim Brummer, owner, developer (and often racer) at Lightning, discovered recumbents via the HPV record sprints, and his bikes bear evidence of this original inspiration. He strives to combine the intoxicating ride of an Italian racer with comfort.

The profile of the R-84 features a fairly low seat (16 inches) and a high crank (8 inches above the seat). Its upright seat angle gives it superior climbing and sprint capabilities. This bike is fast! The brash geometry meets the demands of speedy criterium races. Complete suspension keeps tires on the ground, giving cornering confidence even on rough surfaces.

Of course an Italian racing bike pleases the eye, and your eyebrows rise admiringly when you lift one. This bike is similarly pleasing. With suspension, hydraulic brakes, fabric seat, and top steering, the bike still weighs only 19 pounds because of its light carbon frame (3 pounds).

Like an Italian racer, the Lightning is pricey. The frame alone is $4,000, and a complete Campy/Ti bike is $6,500. Add a full-fairing package and other special mods to create an F-90 for $14,000. Brummer isn't concerned about meeting a price-point; his only thought is creating a fast bike with great handling.

BikeE: change comes if you can reach the masses

This small company from Corvallis, Oregon, pursued an entirely different goal during its ten years of large-scale production. For this co-op, being different meant offering improved transportation for people of modest means. Their goal was to create an affordable bike that's easy to make, easy to ride, easy to adjust, easy to look at, and made of widely available parts.

Their final product met these goals. Only three (!) welds were used in the main aluminum frame (for bottom bracket and headset area); the rear end is bolted on. The goal of really simple handling suggested an upright seat, low bottom bracket position, and adjustable over-seat steering. A well-organized production system, close tolerances, and spiffy details such as a 3x7 Sachs hub, a quick-release seat, a stylish look, and clean welds resulted in a city bike that sold for under $1,000. Plus it weighed under 30 pounds. Other models came with suspension.

This medium-wheelbase (MWB) bike wasn't suited for racing or long tours, but with easy on and off, nimble maneuverability, and good visibility in traffic it was perfect for errands and commuting.

However, BikeE's attempt to find a larger market foundered and the company declared bankruptcy in 2002 after years of leadership and popular success.

The website BikeE.Org now assists BikeE enthusiasts with links to lists and forums where parts are swapped and sold, and technical issues and recumbent-related matters are discussed.

Huge companies like Sun and CCM, and small ones like Cycle Genius, have since taken up the cause of quality, affordable recumbents and, like the pioneer BikeE, are finding the compact/medium wheelbase to be a popular, market-friendly format.

Aeroproject Ultratief: flying low to take off

Aeroproject Ultratief began with a goal: to win the European HPV Championship. Then the Aeroproject team formed: Guido Mertens and friends. Then the fairing came into existence using a copy of the proven Mavic fairing. Only the bike was missing.

Actualization of the Aeroproject Ultratief (Ultratief = "ultra-low" in German) flowed step by step from the givens and limits. First, measure fairing and rider. The room within the fairing and the size of the rider determined the size of the bike. Seat and crank height, the seat angle—all were set by the limiting factors of volume and rider size. Suspension was set aside because of the low design, so the choice was made for a large, smooth-riding 28-inch rear wheel. The bike would be stiff and be easy to accelerate for passing. Because the frame was stretched out and quite long, and due to the bends in the frame, the ride was actually quite soft while still offering good pedaling performance because of extreme side-to-side stiffness.

The "Ultratief" early-era lowracer was originally designed for a fairing, but it looks and rides good "naked" as well.

A comfortable racing sedan thus came into existence. A fork with extra curving in it increased smoothness even more. During testing, the bike turned out to ride very nicely without a fairing. As a result, teammate Manfred Harig decided to offer a series of 10 to the public in the mid-1990s.

By the way, the team reached their goal and won the European title.

Profiles of 8 Basic Types of Recumbent

There are about 250 models of recumbents manufactured today. The following eight models are a sampling from the main types available, based on wheelbase length, handlebar location and purpose. These profiles let you compare common styles, and see how builders combine components to achieve different goals. (Info from 2006.)

Long-wheelbase (LWB) / Touring

"Tour Easy" / Easy Racer

The "Tour Easy" has been produced longer than almost any recumbent yet it's still popular. Known for classic LWB traits: stability and comfort, which translate into efficiency (add-on fairing helps). Upright seat, low BB, are user-friendly, and are good for long climbs, like the mountains where the bike was designed. Requires adaptation for best power and butt endurance.

Price	*$2295*
Weight	*30.5 lbs. (Med.-Lg.)*
Frame	*4130 Cro-Moly TIG, made in USA*
Fork	*Custom Chromo*
Wheelbase	*67.5" (Med.-Lg.)*
Overall length	*90.5" (Med.-Lg.)*
Seat height	*22"*
Head tube angle	*59°*
BB height	*13"*
Crank	*Shimano ER/Sugino 26-42-52t*
Bottom bracket	*Shimano LX Sealed*
Stem	*Kalloy Hi Rise*
Derailers	*F: Shimano 105 trpl, R: Shimano XT*
Shifters	*SRAM Rocket 9 speed*
Gears and Freewheel	*27 sp, 11-34t*
Gear inches	*21"-128"*
Brakes	*SRAM 7.0 V-brake*
Wheels	*F: 20"x1-1/8" (451), R: 700c x 28c*
Hubs	*Shimano LX 32/36 spoke F/R*
Spokes	*Wheelsmith Stainless*
Rims	*Sun Alloy*
Chain	*SRAM-Sachs PC 58/59*
Colors	*red or black*

Long-wheelbase (LWB) / Sport

"Velocity Squared - V2" / RANS

Most LWB bikes avoid low, reclined seats and high bottom brackets. The V2 steps out of type to give a comfortable, stable, yet high performance ride. (Aluminum frame option is stiffer but harsher.) RANS spec'ed this bike at a mid-range price-point. RANS also makes small airplanes, so they have a serious background for quality.

Price	*$1395*
Weight	*31 lbs.*
Frame	*4130 Cro-Moly, TIG, Taiwan*
Fork	*Cro-Moly Steel, Unicrown*
Main tube size	*2"*
Wheelbase	*65" (Lg)*
Overall length	*87" (Lg)*
Seat height	*19.5"*
Headset	*1-1/8" FSA TH-860N*
Crank	*Truvativ Elita 30-39-52t*
Bottom bracket	*Truvativ Isis Drive*
Deraillers	*F: Microshift, R: SRAM X7*
Shifters	*SRAM X7*
Cassette	*SRAM 7.0 9-Speed 11/32t*
Gear inches	*24.4"-122.9"*
Brakes	*Avid Single Digit 7, Avid levers*
Wheels	*F: 20"(406mm), R: 26"(559mm)*
Hubs	*Shimano Deore 36 Hole,*
Rims	*Alex DA16 Satin Anodized*
Tires	*F: 20"x1.5", R: 26"x1.5", 100psi Primo Comet*
Pedals	*Wellgo LU-897*
Chain	*KMC Z9000*
Color	*Galaxy Red*

Short-wheelbase (SWB) / Sport

“Jetstream” / ActionBent

Price	$625
Weight	32 lbs.
Frame	Cro-Mo main tube & hi-tensile
Steering	converts from USS to OSS
Seat	alloy, foam-padded, vented
Wheelbase	41”
Overall	73” (varies w/ boom setting)
Seat height	22”
BB height	24”
Crank	30-42-52t Durabi 400 alloy
Deraillers	F: Shim. Tiagra, R: SRAM X7
Shifters	SRAM X7 twist-grip shifter
Gears	24 sp
Brakes	Tektro 832 V-brakes
Tires	F: 20”x1.5”, R: 26”x1.5”; 100psi
Hubs	alloy
Spokes	14# stainless
Rims	alloy; double wall
Pedals	alloy
Chain	KMC Z9000
Colors	black, blue, silver, green

Underseat-steering isn’t so popular in the US, but could make a comeback. It’s easy-to-learn, relaxing, enjoyable, and adds to the liberated feeling of a recumbent. This model can be converted to OSS, if desired. ActionBent imports bikes from China and only sells direct from its website. This lets them offer low price-points on a wide range of models.

Short-wheelbase (SWB) / Sport

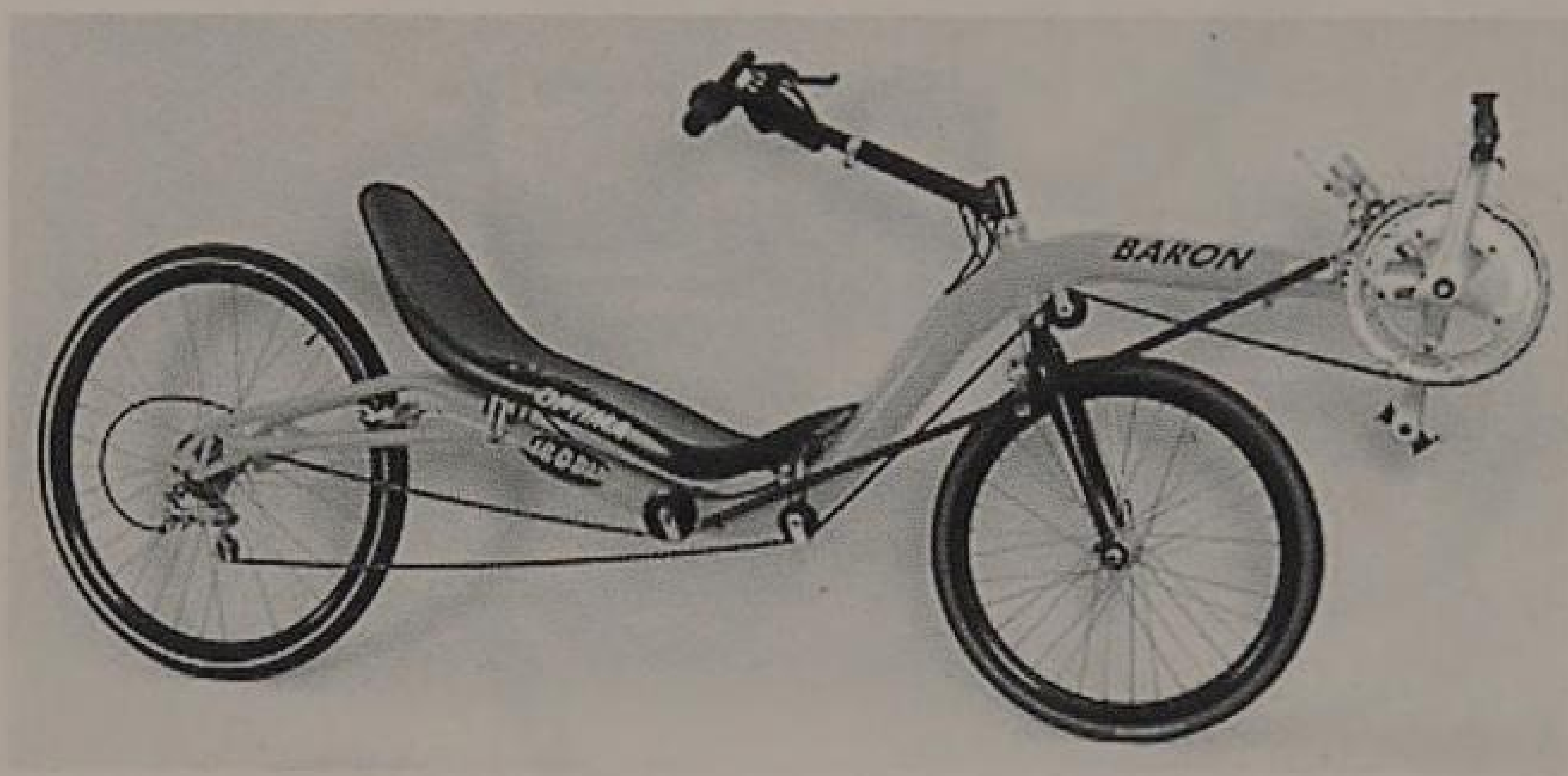
“V-Rex” / RANS

Price	$1725
Weight	30 lbs.
Frame	4130 Cro-Moly, TIG, Taiwan
Fork	Threadless Cro-Mo, Unicrown
Handlebar	“close to chest” style, pivoting stem
Wheelbase	42.75”
Overall length	69” (Lg)
Seat height	23.5”
BB height	23”
Headset	1” Threadless Ritchey Logic
Crank	Truvativ Rouleur 30-42-50t
Bottom bracket	Truvativ Rouleur
Deraillers	F: MicroShift, R: SRAM X9
Shifters	SRAM X9
Cassette	SRAM 7.0 9-speed, 11/32t
Gear inches	24”-123”
Brakes	Avid Arch Rival, Avid levers
Wheels	F: 20”(406), R: 26”(559mm)
Hubs	Shimano Deore LX, 36 Hole
Rims	Alex DA 16 Black Anodized
Tires	F: 20”x1.75”, R: 26”x15”, 100psi Primo Comet
Pedals	Wellgo LU-897
Chain	KMC Z9000
Color	Emerald Black (dark green)

The V-Rex is a classic overseat-steering (OSS) SWB that remains a significant player. Compact, sporty and nimble—an optimized design of the type. It has dozens of available options and accessories. SWBs with wheelbase under 39” can be harsh, but at almost 43” the V-Rex offers comfort and stability. Known for light handling and sensitivity to pedaling smoothness. A small front wheel lets this style of SWB start up and makes it compact for transport.

Lowracer / Racing

"Baron Pro" / Optima



Price	*$3010*
Weight	*22 lbs.*
Frame material	*aluminum*
Front fork material	*Cro-Moly, with pivoting stem*
Seat material	*carbon fiber*
Wheelbase	*50.8"*
Seat height	*12.6"*
Bottom bracket ht.	*20.9"*
Seat angle	*20-25 deg.*
Crank	*Shimano Ultegra Hollowtech*
Bottom Bracket	*Shimano Ultegra Hollowtech*
Deraillers	*Shimano Ultegra*
Shifters	*Shimano Rapidfire*
Brakes	*Magura Julie hydraulic disc*
Hubs	*Shimano Deore Disc*
Rims	*aero rims*
Spokes	*SS double butted*
Tires	*Conti Grand Prix 28 mm race*
Pedals	*Tecora SPD*

Lowracers are popular in recumbent racing these days. Some models are also used on open roads and for touring, but extreme models offer restricted forward views and less traffic safety. Racing models often have chainlines that interfere with tight or slow turns—the Baron solves this with idlers. This model is used more than any other in racing, yet it's versatile enough for training on the open road. Imported from Europe.

Highracer / Sport

"Sport" / Volae

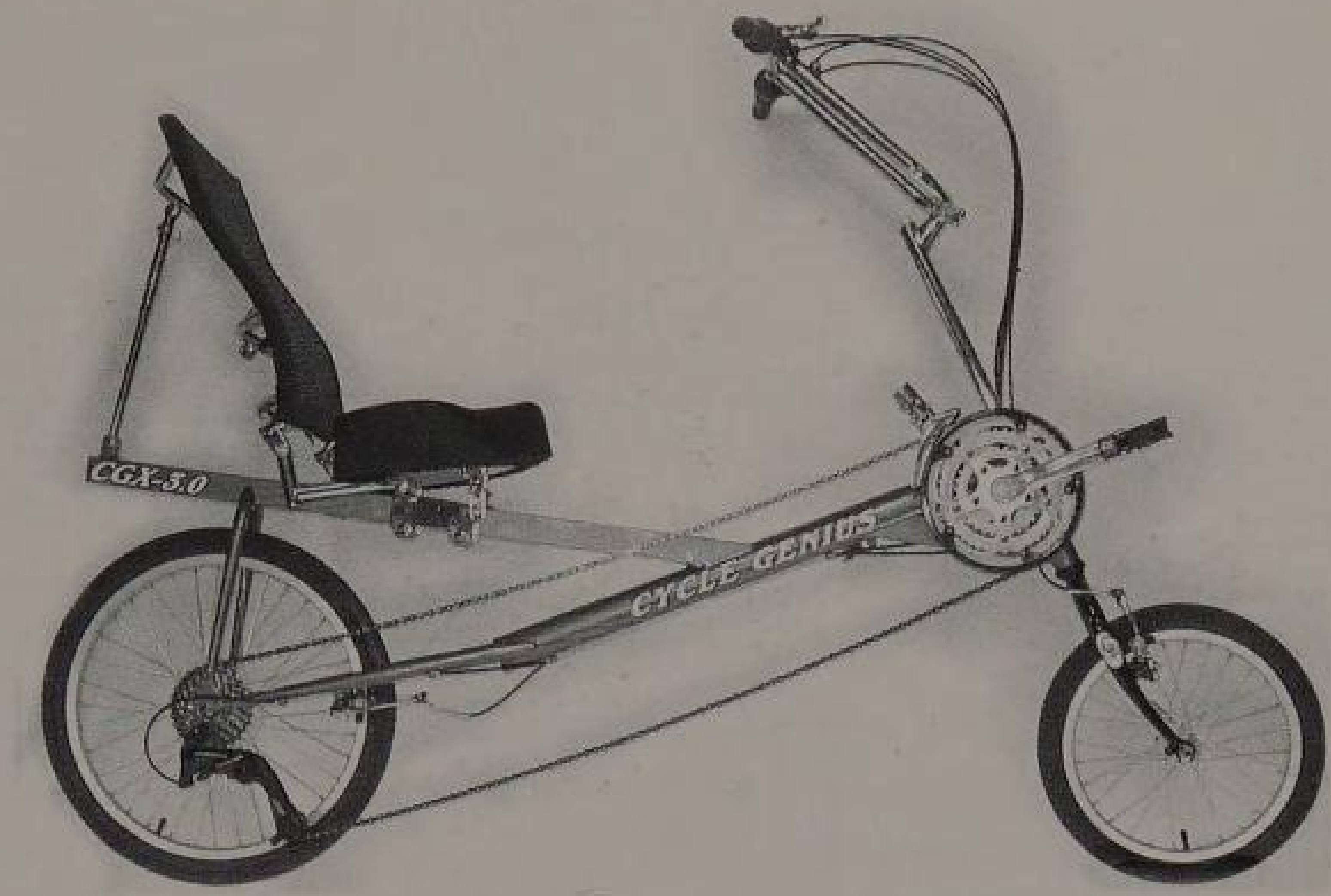
Price	*$1700*
Weight	*27.5 lbs.*
Frame	*4130 CroMoly, made in USA*
Fork	*Volae Ultralight Alloy*
Handlebar	*"tweener" style, wrap outside of legs*
Seat	*Volae Fiberglass, adjustable*
Wheelbase	*46" (Med.)*
Overall length	*71"*
Seat height	*26"*
Bottom bracket ht.	*33"*
Headset	*Token cartridge*
Crankset	*Truvativ Elita ISIS 30-42-52t*
Bottom bracket	*Truvativ ISIS*
Deraillers	*F: Microshift R439 SS, R: SRAM X7*
Shifters	*SRAM X.7*
Cassette	*SRAM PG950, 9-speed, 11-32t*
Gear inches	*23"-117"*
Brakes	*Volae RC452 Dual-Pivot*
Wheels	*650C (26"), Shim. 105, Alex DA22*
Tires	*Conti Ultra Gatorskin 650Cx23C*
Pedals	*Wellgo LU-897*
Chain	*SRAM PC950*
Color	*Bengal Red*

Highracers are a recent trend in open road sport riding, particularly for group rides with upright bikes. A highracer puts a rider at a compatible height for joining in with upright riders and increases traffic visibility. Their large wheels and longer wheelbase are said to boost comfort and stability and give road-bike-like handling. Starting up from a high seat (with a high BB) takes practice. Dual big-wheel designs are spreading to other formats as well. Volae is a direct-order company offering a full line and owned by the Hostel Shoppe store/catalog, which also offers many other brands of bikes.

Compact long-wheelbase (CLWB) / General use

"CGX - Starling" / Cycle Genius

Price	*$499*
Weight	*39 lbs.*
Frame/Fork	*High tensile steel; Taiwan*
Seat	*Molded foam pad base, adjustable*
Wheelbase	*52"*
Overall length	*70"*
Seat height	*25"*
Bottom bracket ht.	*21.5"*
Crank	*30-42-52t*
Headset	*1-1/8" threaded*
Deraillers	*R: SRAM Wide Range 8sp, F: SRAM 3.0 Triple*
Cassette	*8spd, 11-28t*
Shifters	*SRAM 3.0 24sp*
Brakes	*V-Brake with linear springs*
Brake Levers	*Alloy, linear pull specific*
Rims	*Alloy, 16" Front, 20" Rear*
Hubs	*Alloy, F: 28H, R: 36H with QR*
Spokes	*14ga. with brass nipples*
Tires	*Kenda Kontact, street tread*
Pedals	*Composite, w/ 9/16" axle*
Chain	*KMC 8 speed*



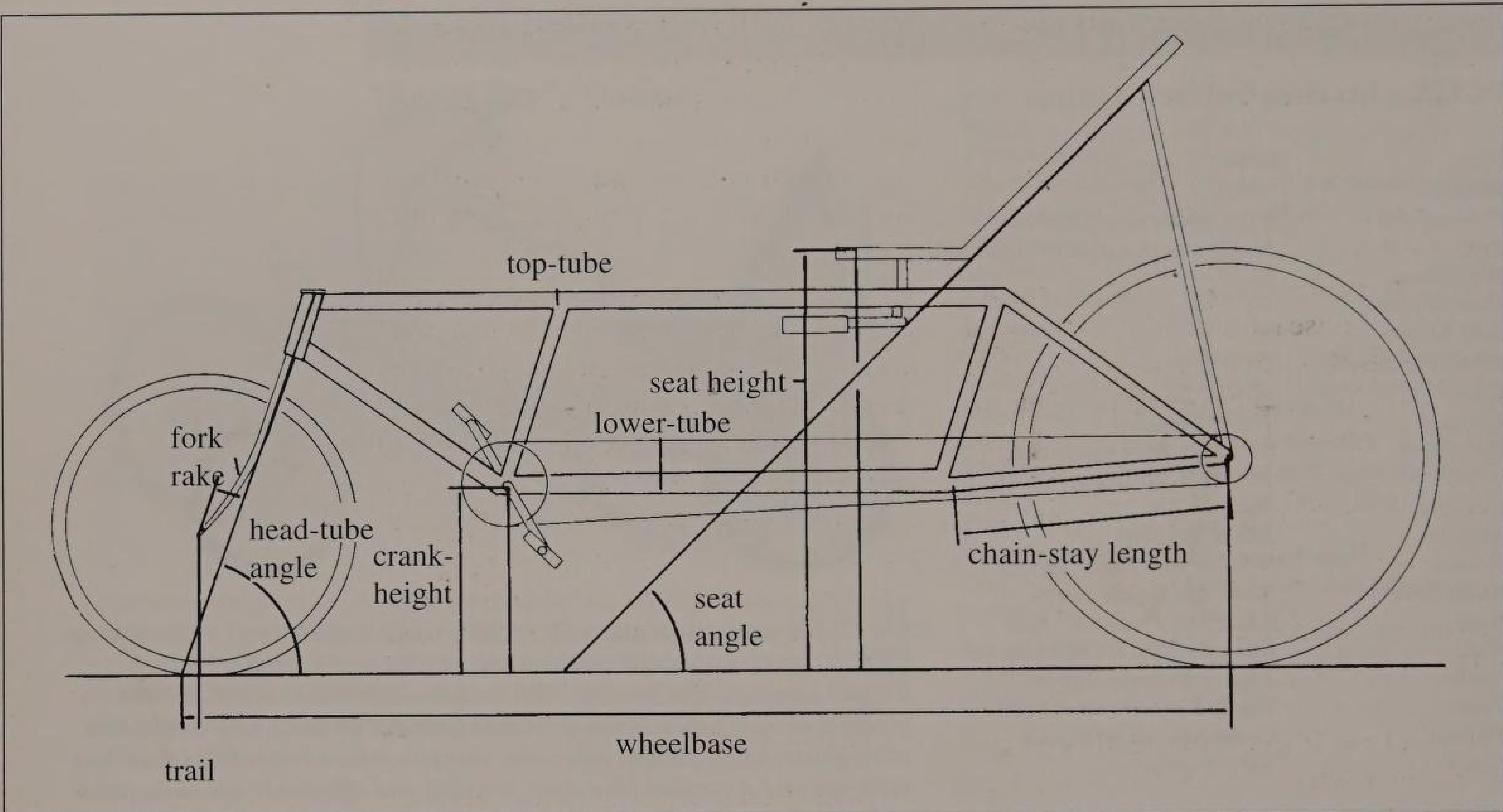
The CLWB format is popular for citybike and bikepath use. Longer than an SWB, it's more stable and comfortable, yet due to the small wheels it's still compact. The Starling's BB is high compared to other CLWB's, giving it more zip than is usual for this format. For those who only desire ease-of-use, Cycle Genius offers the Sparrow, with a lower BB, for easiest start-ups and a comfort bike style. Sensible and affordable are main traits of Cycle Genius products.

Semi-recumbent / City & Bikepath

"Revive DX" / Giant

Price	*Cn$1359 (US$1178)*
Frame	*6061 T-6 aluminum*
Fork	*Steel unicrown*
Saddle	*Comfort w/ adjustable lumbar support*
Rearshock	*Giant coilspring, adjustable, 3" travel*
Crank	*Giant alloy 48t*
BB	*Cartridge*
Headset	*1 1/8" Ahead*
Seatpost	*Monorail One-Touch micro-adjust*
Shifter	*Shimano Nexus 7-spd Twist*
Brakes	*Shimano Nexus Roller Brake*
Levers	*Alloy comfort*
Cassette	*16t Cog*
Rims	*Alloy 28H*
Hubs	*R: Shimano Inter-7, F: 28H; non-QR*
Spokes	*Stainless Steel, 14G*
Tires	*20"x1.75" Multi-Surface, w/ Slime sealant-filled tubes*
Pedals	*Platform comfort*
Chain	*KMC Z51 7-spd*
Extras	*Internal cable/chain routing, rear alloy rack, kickstand, shock cover*
Colors	*Blue/gray metallic or silver/black*

The semi-recumbent or feet-forward bike is a strong new format of comfort bike. It's proving popular around town. The Revive is a stylish, easy bike to use, and has good traffic visibility (its upright rider position makes it easier to look behind while riding). Comfortable, simple and feature-packed—too bad Giant pulled it out of the U.S.; it's available in other countries, though. An electric-assist "Spirit" version is also offered.



Basic Design Principles

The foundation of any bike is the wheels—usually two, but not always. Three-wheeled recumbents are increasing rapidly in popularity. Trikes offer advantages in stability, especially at low seat heights and low speeds, and improved handling in slippery conditions. But because of the added complexity and the variety of frame designs and steering arrangements, we are limiting our in-depth discussion in this book to two-wheeled (single-track) vehicles.

The most common comparative factors for recumbent bicycles are wheelbase length and crank position.

Variation between models within a category mostly accommodates different rider heights rather than changing the general handling qualities.

Wheelbase

A low seat and large rear wheel, with the rider positioned between the wheels, result in a long wheelbase recumbent (LWB). The wheelbase is consequently stretched out. Conversely, small wheels and a high seat result in a short wheelbase recumbent (SWB). This is because a high seat can be placed further above the hubs, allowing the wheels to be positioned closer together. Crank position is also a factor. A low crank lengthens the wheelbase when the front wheel is placed beyond it, while a higher crank lets a front wheel be placed under it, shortening wheelbase.

The distance between crank and seat is equivalent to the frame height plus seat post of an upright bike, with wiggle room for adjustment. The rider's choice of a thicker seat pad or even different shoes can make the frame-size vary a few centimeters, which should not be neglected when sizing. However, most makers design frames to be adjustable—with a sliding seat and/or an extendible crank area—to accommodate a wide range of rider heights.

Give special consideration to the distance from the crank arm at its farthest extension to the wheel at its perimeter. Make sure your toes or heels don't hit the wheel on turns. If this can happen there better be a good design-compromise reason for it. Allow extra room for fenders, if you might want to add them later. These considerations often result in a stretched-out frame—65 to 70 inches is an average wheelbase for a LWB—which can result in great comfort and stability. (LWB examples include Easy Racers' "Tour Easy," the RANS "Stratus," and the Burley "Adirondack.")

The overall length of a short wheelbase recumbent is determined by the size of the rear wheel, the length of the rider's legs, and the position of the seat. The final wheelbase then results from the intended weight distribution—determined by the position of the seat between the two wheels—and from the size of the front wheel. (SWB includes RANS "V-Rex," Lightning "P-38," Barcroft "Virginia.")

The compact or medium wheelbase bike is a variation of long-wheelbase recumbent (CLWB or MWB). This design puts the crank very close to the head tube, creating some overlap between foot and front wheel, but it gives more stability than a SWB, with easier maneuvering than a LWB. CLWBs tend to be neighborhood or commuter bikes, but they're readily designed for other uses. US consumer opinion, however, seems to have "typecast" what can be readily sold in this format. (Sun, Cycle Genius, HP Velotechnik, Giant, and Cannondale produce good examples.)

Lowracers are a high performance breed of SWB recumbent. They have an extremely low, reclined seat (4 to 10 inches above ground) and high crank (between 5 to 10 inches above the seat). If you can stop and prop yourself up with your hands alone, you have a lowracer. They have a short wheelbase because the front wheel is situated under the rider's legs, with the crank extending forward and beyond. (The European builders Optima, Challenge, and M5 offer good examples.)

Highracers are another sporty variant. They are as high or higher off the ground than a SWB, but their seats are greatly reclined and the wheels are often large, sometimes equal in size—these features add up to speed, comfort, and traffic visibility, but can hinder easy starts and stops. One usually has to sit up off the seat-back to put the feet down, not difficult but requiring practice. (Bacchetta and Volae offer many models.)

Advantages of LWB:

- relaxed upright posture with great view of road
- feet are on the ground quickly
- easy starts and stops
- clear chain line makes all gears usable
- luggage transport very good
- partial fairing easy to mount
- extremely good braking power
- smooth straight-ahead riding and superior comfort even without suspension
- front and rear wheels create crumple-zone in case of collision

Disadvantages of LWB:

- heavier than short model
- longer turning radius, less responsive
- weight distribution favors rear so front wheel is prone to sliding out
- often mediocre aerodynamics
- bulky

Advantages of SWB:

- wider variety of seating positions
- sporty handling
- lightweight

- same length as upright bike
- improved aerodynamics

Disadvantages of SWB:

- slow-speed handling can feel twitchy and unstable at first
- harsher ride; needs more suspension
- less high-speed stability
- steeply reclined seat makes it uncomfortable to glance behind without mirror
- extreme braking can result in tip-over
- difficult to balance all rider needs within space available (other formats more tolerant)

Advantages of Compact LWB:

- stability and safe braking in a shorter package
- maneuverable
- easy to handle when not being ridden
- compromise: handier than LWB, more stable than SWB

Disadvantages of Compact LWB:

- occasional foot-wheel overlap
- compromise: not as stable as LWB or as light and nimble as SWB

Advantages of Lowracers:

- small frontal area
- low air resistance
- feet can remain clipped to pedals at stoplights because hands can reach pavement
- best for high-speed cornering

Disadvantages of Lowracers:

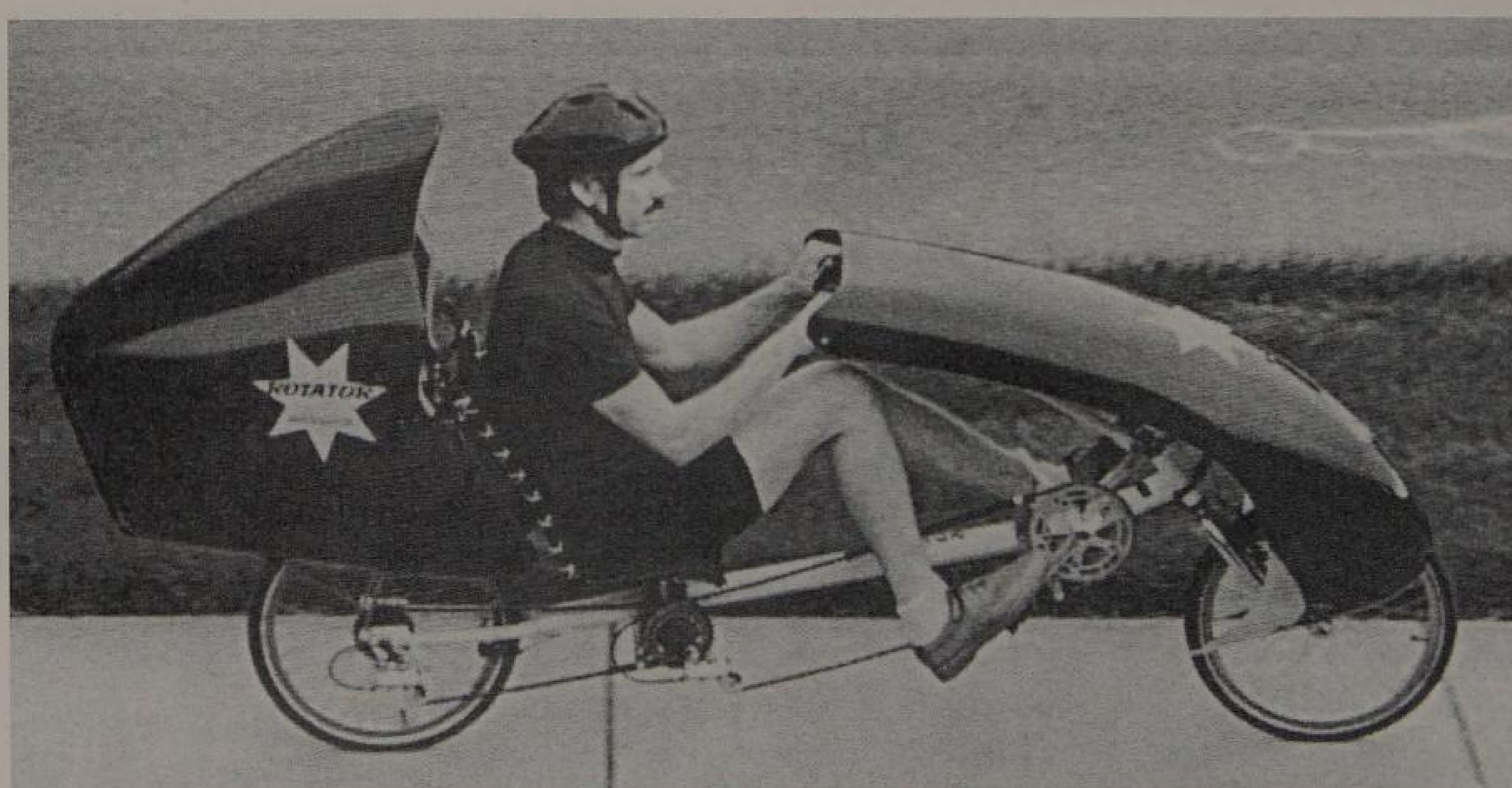
- limited steering angle
- low height demands great care when riding in traffic
- slow-speed riding requires practice
- mounting and dismounting can be awkward
- harsh ride without suspension

Advantages of Highracers:

- good aerodynamics
- interacts better with upright riders
- safe in traffic
- easy maintenance with equal, common wheel sizes
- smooth ride, "road bike" handling

Disadvantages of Highracers:

- awkward starts and stops for many
- otherwise, same problems as SWBs.



Steve Delaire's Rotator line includes the classic high performance "Pursuit" —rare among long wheelbase production models in that it's made for speed as well as comfort —with low seat, high crank, and light weight. It is available with front and rear fairings.

Wheelbase is not just a way to describe recumbent categories, it also plays a major role in bicycle riding behavior.

A short wheelbase in general is 42 inches or less (but less than 36 inches is uncommon). This gives us clues as to likely riding behavior.

In general a wheelbase less than 42 inches provides:

- maneuverability at slow speeds
- agile handling in fast turns
- sensitivity to steering input

A longer wheelbase provides:

- rock-steady straight-ahead handling
- safer handling, including over rough surfaces
- stability at high speeds

Handling Quality: Trail

Whatever handling quality you're looking for can be created by a combination of steering-head angle, fork rake, trail, and front-wheel flop.

These four factors would seem to make wheelbase less definite in determining ride quality—and rightly so. But in all cases, only the right mix of all variables creates good handling. They're like the ingredients in a soup: Only good proportions result in good flavor, with each factor affecting the others.

To trace the ingredients of ride quality, start by distinguishing between steering behavior and suspension behavior (we'll cover suspension in Ch. 5).

Steering behavior is determined by head angle, fork rake, bike height, and trail. The head angle is the angle between the horizontal line of the ground and the head tube. Trail, or caster, is the distance between the point where the imaginary line formed by the projection of the steering axis hits the ground, and where the tire hits the ground.

It is interesting that among riders of upright bikes these matters aren't given the attention they once were. Upright enthusiasts tend to gravitate toward sporty models that vary very little. Riders of relaxed-handling upright cruiser bikes, for the most part, also aren't very concerned about technicalities.

Wise recumbent designers and riders pay careful attention to these matters and greatly benefit as a result.

Generally, the following holds true for the trail of a 20-inch front wheel:

Trail longer than 2 inches means...

- stable handling at high speed
- slow response to steering
- steering mistakes are more tolerated
- comfortable, solid handling in curves
- great for touring

Trail shorter than 2 inches means...

- steering reacts quickly
- lively handling in curves; good for sporty use

The handling and steerability of a bike depends on the trail of the front wheel. If you have chosen a steep head-tube angle and you want to change the handling, simply change the trail. The practical effect of this is that the longer the trail gets, the more solid is the tracking. The longer the trail, the safer the bike can be steered at high speed, although it is the other way around when riding slowly, due to the slow response. For a given wheel size, the head-tube angle creates the initial trail; the fork rake (bend) or angle modifies it. Changing wheels or even tires for a given set-up changes trail: the larger the diameter, the longer the trail.

The slow handling of a shallow head-tube angle can be enlivened by a longer fork bend. A vertical fork without a bend would have zero trail and would have absolutely direct steering. In unicycling or acrobatic cycling such forks are used, because ultrafast handling at slow speeds is a necessity. Children's tricycles have steep steering angles as well.

How would the combination of a steep head tube and a fork with no trail effect a recumbent bike? On a fast downhill, a small pebble would almost assuredly put the front wheel out of track, resulting in an accident. But with proper trail a bike glides over uneven pavement and road debris.

Why? A rotating wheel stabilizes itself around its longitudinal axis. In physics this quality is called gyroscopic force. A pebble in the road jostles the front wheel, which, in turn, moves the fork and with it the headset bearing. The phenomenon is accentuated as the bike is leaned and its height drops. A bike moving straight ahead is in its highest position. When handlebars are turned to the left or right, the front end of a bike is lowered slightly because of the head tube angle and fork rake. The weight on the front end causes a bike that is slightly tilted to turn even further in the direction it is already going.

Fortunately, reality doesn't always precisely jive with theory. From the first day you learn to ride a bike you learn to counter the disruptive forces of road bumps. You learn to steer the bike quickly back under itself to prevent the falling action. With increasing speed the influence of these forces on handling and ride quality actually get less important, because gyroscopic force and rolling resistance increases.

Smart fork and wheel design help counteract the "falling front end" phenomenon. A lever is added to the stabilizing gyroscopic force of the front wheel. This is done by way of the trail. The power of gyroscopic force also depends on wheel size and weight. A bigger wheel has greater inertia, which strengthens gyroscopic force. A heavy wheel has a similar effect. Here we can see how small ultralight wheels could have a surprising influence on bike handling.

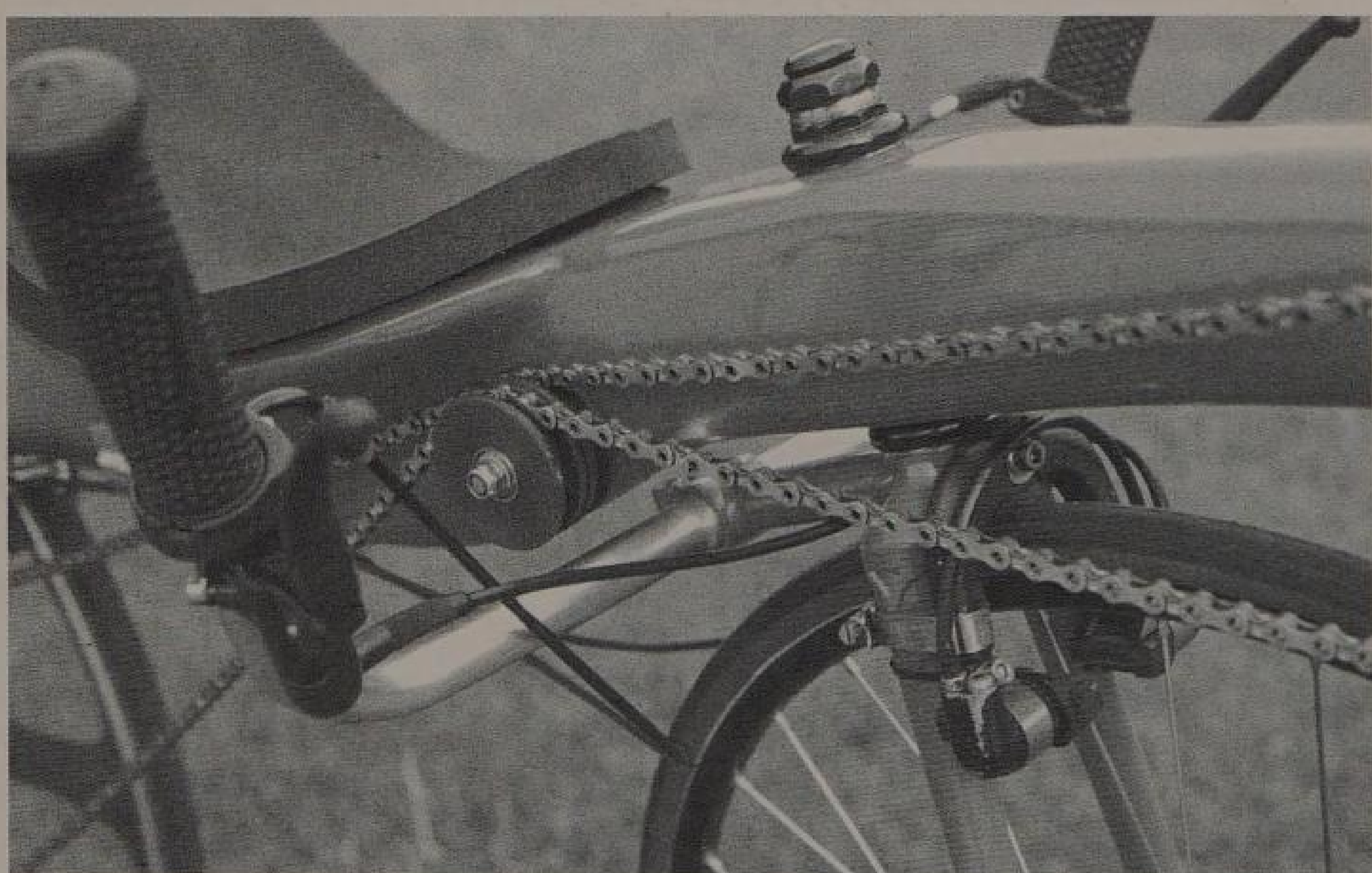
Handling and ride quality are also affected by the weight on the front axle, since rolling resistance rises as weight increases. Trail is also increased as pressure is lowered in a tire, creating a longer contact area on the road with its own lever component. Additionally, as front axle load increases, leaning the steering assembly becomes more difficult. Thus riding slowly (making quick changes) becomes harder.

Yet another factor comes into play: "fork flop." This is the distance that the front end falls when the handlebar is turned. A bike with a lot of fork flop can have high-speed stability but, like a heavy front end, makes slow-speed handling difficult.

To sum this up, the following general rules can be deduced:

- if you have a heavy front axle load, make trail smaller
- if you have a long wheelbase, make trail smaller
- if you have a large wheel, make trail bigger
- if you want to improve tracking steadiness, increase trail
- for quicker steering, shorten trail

Extreme angles, rake, and trail are not advisable, as it requires other unconven-



Detail photo of a chain idler pulley. Power side is inboard, return side outboard.

tional measures to counterbalance them. You're looking for a frame geometry that provides a smooth, efficient ride.

If high speed is your thing and you have a small front wheel, a steep head-tube angle with a straight or even negative-rake fork provides secure handling and a steady ride. This set-up creates lots of trail—the front wheel tends to follow the direction of effort very reliably, like a shopping cart caster. This is like the set-up used in motor-paced velodrome racing at very high speeds behind motorcycle dernies. (In contrast a steep head tube plus strong forward-raking fork can create negative trail and an unrideable bike!)

Note again that the head-tube angles and trail that work best for small wheels is different than for large wheels.

Fork and Frame Flex and Ride Comfort

Fork rake plays a double role in handling and ride quality. On the one hand it has the above-mentioned role in steering. It also dampens vibration, reduces shimmying, and absorbs shock.

The weight of a rider flexes not only the bike frame, but also the tires and saddle. A significant amount of flex also occurs in the fork. Even a centimeter of flex is significant. During rides the fork responds to road unevenness, functioning much like a spring. The radius of curvature plays a role here. With enlargement of radius the spring-capability decreases. A small radius, bent directly at the end, produces the most comfortable forks. Fork material stiffness is also an important factor.

A recumbent with a small front wheel has a short fork that flexes less than the long fork on an upright bike with a much larger wheel. This makes for correspondingly more road shock. A long wheelbase, a vertically complaint frame, or suspension can all help create comfort with small wheels.

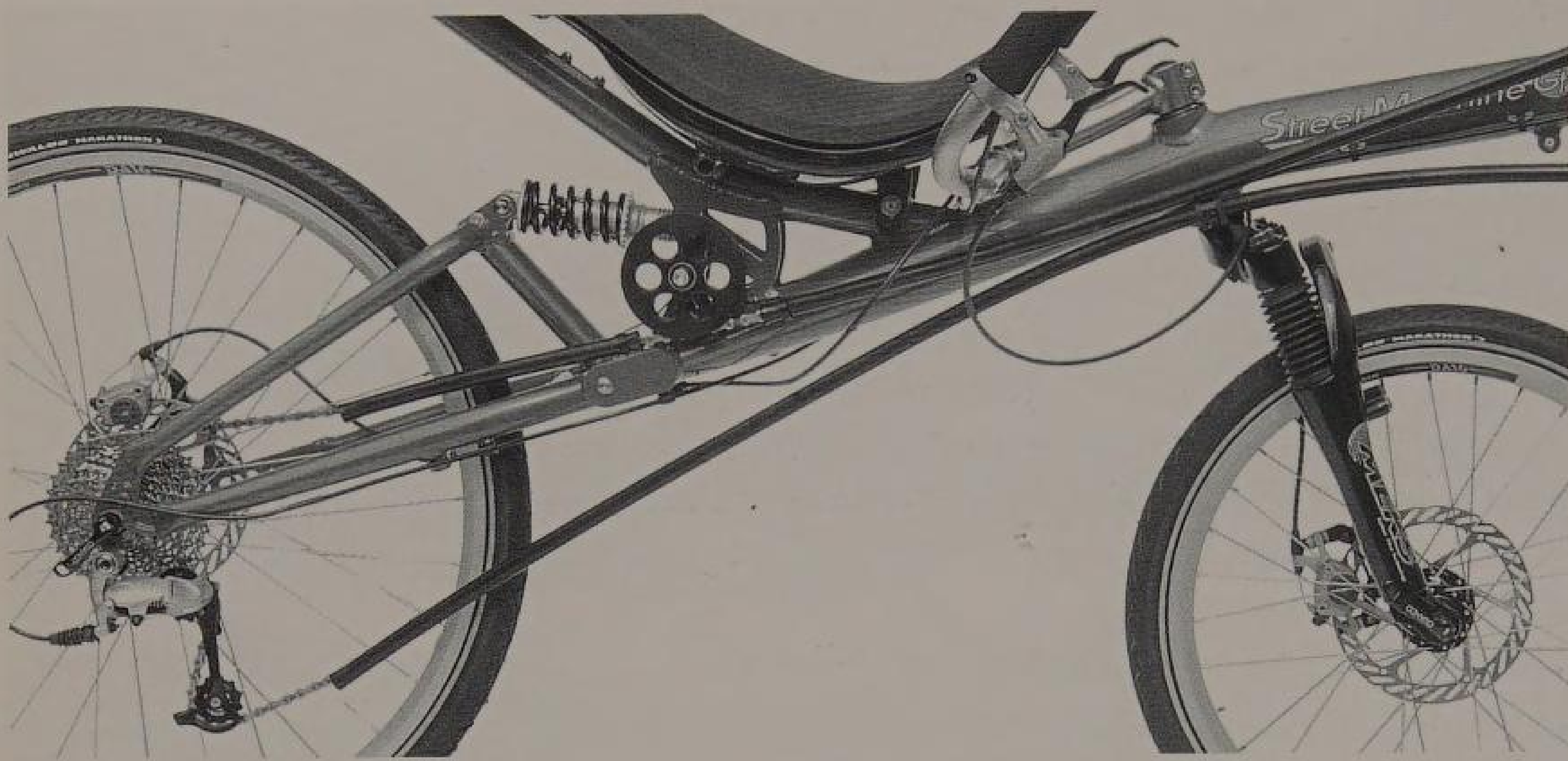
Thus fork rake is important for steering, as a lever to control against an uneven road, helps handle the overall vehicle weight, and improves ride comfort, all at the same time.

Finding a compromise between the competing demands of steerability, tracking steadiness, lateral forces, and suspension can be time-consuming and frustrating. For the builder, it requires costly experimentation. Reliable bike geometry developed exclusively on paper is almost unheard of.

What holds true for the length and diameter of the fork is true for all tubes. The longer and thinner a tube is, the more flexible it becomes.

To further reduce sideways flex—which occurs when pedaling, and consumes energy—seatstays and chainstays are used. Based on their diameters, tapers, and trian-

The Python is a concept being cooperatively developed on the Internet. It's a negative-trail, hands-free, lean-steer (center-pivot), FWD bike that offers a "metaphysical" ride quality to enthusiasts who happily spend weeks learning to ride it well. Dozens of variants have been constructed. More at www.python-lowracer.de.



A detail view of the full suspension system of the 2006 HP-Velotechnik Street Machine Gte. The adjustable front and rear suspension completely smooth out the ride of this deluxe SWB from Europe. (photo: HP-Velo)

gulation (some stays are even curved), they can produce a stiff ride for pedaling yet be comfortable for the rider. This is done without adding much weight and without needing much calculation. Stiffening stays are also sometimes employed in the front area of a recumbent near the crank, or anywhere else where extra rigidity is desired.

The length of the chainstays is also significant. On an upright bike they must be at least as long as the radius of the rear wheel, with a little extra for tire clearance. Longer chainstays are preferred for touring models. Since the bottom bracket of a recumbent is rarely located at the front end of the chainstays, it's not used for measuring stays, as it is with upright bikes. Instead chainstay length is typically the distance between the axle of the rear wheel to the beginning of the main frame. Long chainstays often benefit ride quality more than another sort of wheelbase extension because they provide internal suspension with little change to recumbent geometry.

Frame dynamics work differently with recumbents than with uprights. With uprights, pedaling, support, and steering all depend on the same structure—the frame diamond—so that stiff energy transmission often results in a harsh ride, and every weld has to be perfectly aligned for reliable handling. With a recumbent the support plane is separate from the power plane, which in turn is separate from the steering. The pedaling forces from side to side can be easily resisted with stiffness in that direction while allowing plenty of comfortable flex in the vertical supporting plane.

Wheel Size

Wheel size affects handling, weight, price, speed, aerodynamics, bike purpose, and the shape of the frame.

As wheels roll over the ground they transmit bumps to the frame. How sensitively the wheel reacts determines how severely a bump jars the rider.

A bigger wheel rolls over stones and surface irregularities easier and more smoothly than a small one. The shallower angle between the obstacle and the tire is the reason. As the angle gets shallower, the severity of the bump decreases. The wheel absorbs or weakens the bump and deviates less from its path.

Wider, high-volume tires increase the absorption zone between rim and ground, softening jolts, and enhancing the effect of shallower approach angles to obstacles.

Wheels also affect bike weight. Small wheels weigh less. Small wheels are also stronger. And they can be built with fewer spokes—cutting weight even more—without losing strength. Their tubes and tires are lighter as well.

But small wheels are harsher, have higher rolling resistance, higher tire wear and tear, and finding spare parts can be difficult.

Note that there are two sizes of "20-inch" wheel used by recumbents, creating confusion. A "BMX-size" 20-inch wheel (its rim is 406 mm) is common, so finding tires and parts is easy. "Road-size" 20-inch tires (451 mm rim) are much scarcer—but the tires made for this size are high quality and well suited to pavement. Thankfully, more road-quality tires are being made in the BMX size these days. Note that the BMX size is marked in decimals—"1.75," for example—while road-size 20" tires are marked fractionally, like "1 1/8."

Components for 16-, 17- and 24-inch wheels are difficult to obtain. But the situation is improving. Mail-order supply houses, Internet dealers, and specialty shops are increasingly catering to the needs of recumbent bike riders.

For comfort and everyday practical value, consider small wheels with wide tires. Just make sure they're built with strong parts since they take harder hits and have to soak up more shock. Certain brands of wider, heavier tires roll faster than thin ones on small wheels in typical riding conditions, perhaps due to improved shock absorption and casing quality.

High-speed fully faired commuters and road-racers should use stout tires to avoid dangerous blowouts and to smooth out roadway surprises that even suspension can't always deal with. Small wheels endure greater stress during high-speed than a larger wheel. The broad traction patch of a wide tire can improve recumbent racing speeds in twisty conditions.

For racing on smooth racetracks and roads, you're better off with the reduced frontal area of small wheels and tires. And of course you save weight as well.

Select gearing to fit your rear wheel size. Small wheels don't travel as far as larger wheels per crank rotation. To make up for this, you might use a larger chainring on the front, or smaller cogs on the rear (but bear in mind that small cogs wear out more quickly). Or go with a second set of cogs (called an intermediate drive), which offers a chance for stepped-up gearing between chainring and rear cogs. The better aerodynamics and smaller moment of inertia are sometimes beneficial enough to compensate for the higher friction of an elaborate transmission system.

Advantages of Small Wheels:

- lighter
- stronger
- more aerodynamic
- frame can be somewhat lighter
- easier to build suspension around
- if using aero disk wheels, a small size is less sensitive to wind

Disadvantages of Small Wheels:

- don't run as smoothly
- tires wear faster
- bumpier ride
- more speed loss due to wheel vibration on rough pavement
- higher rolling resistance
- gearing alteration necessary
- parts, tires, and rims harder to find
- parts get dirtier because of lower height
- if intermediate drive is used, then more weight and maintenance

This fully suspended dual 20-inch lowracer is fast, compact, light, versatile, comfortable, and efficient. It has a smaller high gear, but good low gears for hill-climbing, and a low-loss chainline. It's designed so that it and its full Zotefoam fairing fits into a small car. (photo: J. Tetz)

Advantages of Big Wheels:

- absorb bumps better
- less rolling resistance on rough surfaces
- strong, light construction
- spare parts readily available
- huge tire selection
- for unfaired lowracers, a big rear wheel right behind rider can boost aerodynamics

Disadvantages of Big Wheels:

- heavier
- less aerodynamic in general
- frame construction is more crowded

All things considered, big wheels (26 to 28 inches; 700C) may have the net advantage. But wheels don't exist in a vacuum. Big wheels require a different frame than small wheels. And frame construction argues against large wheels.

Experts have time and again examined the rolling resistance of small wheels. The British bike designer Sir Alex Moulton demonstrated that his 17-inch high-pressure tires had a smaller rolling resistance than a 28-inch wheel on smooth surfaces. The suspension of his bikes plays an important role in his results in real world riding conditions, however.

Bike Friday's "Sat R Day" folding recumbent with 20-inch (451mm) wheels fits in a suitcase. Bike Friday is a highly regarded maker of high-end folders. (photo: Bike Friday)

Clever tire selection is critical for the fastest, smoothest ride in a given set of conditions and handling needs. There are many factors involved in making a fast tire. Equal-sized tires at the same inflation can vary widely in rolling resistance. Sometimes wider tires roll better, but at higher speeds their bigger frontal area decreases aerodynamics.

Many recumbents are designed for two wheel sizes: large in rear, small in front. This allows for optimal rider positioning and improved foot-wheel clearances. But the obvious disadvantage is that you need to carry two sizes of spares.

Steering

Recumbent bikes are typically steered from one of two locations:

1. Over-seat steering (OSS; top)
2. Under-seat steering (USS; beneath legs)

And there are two modes of steering:

1. Direct steering—which controls the front wheel via a conventional assembly of handlebar, stem, headset, and fork.
2. Indirect steering—in which the handlebars have their own set of pivots, and control the fork via push rod, cable, or chain.

These variables allow for four combinations, any of which can create comfortable, reliable steering to suit the needs of an assortment of recumbent designs.

Advantages of Top Steering:

- very aerodynamic if combined with narrow handlebar and/or outstretched arm position
- easy, familiar handling similar to upright bike or motorcycle
- can be built with ordinary bar and stem components

- pushing bike by bars when dismounted is easy
- bar-mounted accessories can be easily seen and accessed

Disadvantages of Top Steering:

- collision of legs and knees possible
- mounting bike can be more difficult (might require pivoting stem)
- during accidents the handlebars might prevent quick, safe dismounting
- longer shifter and brake cables

Advantages of Under-seat Steering:

- arms hang at ease
- can be aerodynamic with narrow bars mounted a bit up and forward
- nothing obscures forward view
- hands are in supporting position for bumps and during a fall
- possible increased security from theft due to unusual appearance

Disadvantage of Under-seat Steering:

- gear and brake levers can be damaged in a fall
- requires brief initial period of adaptation
- usually less aerodynamic

Advantages of Direct Steering:

- lighter weight
- saves time in design and fabrication
- uses standard, available parts
- easy mounting of brake and gear shift levers
- no play in steering
- no getting used to it necessary
- low risk of mechanical trouble

Disadvantages of Direct Steering:

- steering mechanism position restricted by frame design
- limited steering range
- arm-reach less adjustable (often requires frame front-end adjustment or buying new bars/stem)
- results in "tiller" action in LWBs, where the handlebar swings far to the sides

Lowracers have influenced the design of everyday recumbents, both production models and those made by do-it-yourselfers. Here's an American-made home-built model with fenders, a detachable seat (detached in this photo), and a diverted and guarded chain.

Advantages of Indirect Steering:

- easy to adjust for perfect ergonomics
- low risk of injury
- offers greater latitude for frame design
- turning angle can be widened via stepped-up steering linkage gear
- allows for better weight distribution on the wheels

Disadvantages of Indirect Steering:

- heavier
- time-consuming and costly in planning and installation
- greater risk of malfunction
- inevitable slop and play
- requires special parts
- more finicky in terms of adjustment, maintenance

In general a limited range of steering is only a problem on slow rides. At higher speeds you turn a bike by leaning rather than turning the bars. For that reason racing bikes can tolerate a limited steering range. City

Recumbent designs pictured side by side offer a handy visual comparison. The lowracer (left) presents the smallest frontal surface, making it the fastest, but less practical for city riding. A higher bike (middle) with relatively lower crank allows better visibility. Underseat steering (right) offers a relaxed arm position but gives a wider profile and exposes more bike-parts to the wind—here a higher crank offsets some of this. (The influence of clothing on drag is also evident.)

and touring recumbents, however, need a wide range of steering motion.

Under-seat steering in general has advantages that are hard to argue with. Shoulder and back muscles experience less fatigue since your arms just hang comfortably. When you mount the bike the steering mechanism is out of your way. And when riding you have a uniquely unobstructed pleasing view ahead.

With short-wheelbase recumbents, direct steering is generally preferred. A short wheelbase puts the rider close to the front wheel, allowing a steering setup that can be built with conventional parts. Depending on frame design and seat position, the steering can be easily located either under or above the frame. A recumbent built with standard parts means that spares will be readily available.

Many LWBs have indirect steering because the front wheel is so far from the seat.

Because of the complexity and vulnerability of indirect steering, the disadvantages tend to outweigh the benefits. Stick with direct steering unless the frame demands it or an ergonomically sensible assembly is not feasible otherwise.

In the event you decide that a bike with indirect steering is necessary, consider that there are four types:

- shaft or push-rod steering
- cable steering
- universal-joint steering
- stub axle steering

Shaft Steering

Shaft or push-rod steering is the most common manner of indirect steering and is the simplest. A bearing pivot (usually a headset) is set into the frame under the seat area, as well as a tube (same diameter as the fork-steerer tube) to which a stem is mounted. This holds the handlebars, which have a pivot point attached to them some distance from the center pivot from which a shaft leads to the fork. A ball joint at the other end of the shaft fits into a socket in a bracket on the fork. This transmits steering movements from the handlebars to the front wheel. For alignment, the shaft often has an adjustable length.

By changing the mounting position of the shaft on the handlebars or fork (changing the distances from center axis to outer pivot) you can alter the affect the handlebars have on the front wheel and vary the handling anywhere from slow to twitchy.

The cyclist counters forces exerting on the front wheel by holding the handlebars, but the ball joint also has to absorb all influences. Such joints wear out relatively quickly and slop in steering increases with use.

Cable Steering

Cable steering is achieved by way of pulleys. Cable steering avoids the wear-prone ball joint. But for perfectly tight steering without slop, the cable has to be absolutely stretch-free. Neither heat, cold, wetness, nor constant tension can have any influence. Steel is your cable material of choice. Experiments with carbon fiber and similar materials have not been successful.

Cable steering requires exact installation. The axis of the pulleys has to run exactly like the radius of the fork steerer tube and handlebar bearing. The cable has to wind around each pulley before it is led to the next to prevent the cable from slipping. To doubly prevent slippage, the cable should be clamped with a washer and screw on the pulley.

To change the tension of the cable or the distance between steering mechanism and front wheel, the cable ends have to be connected to a component that is length-adjustable so that the total length of cable can be altered.

Note that cable tension stresses the headset bearings and contributes to early wear.

Universal-joint Steering

U-joint steering is more robust and demands fewer securing mechanisms. This type of steering can be found on some old recumbents with chopper-style handlebars and on the Velocar from the 1930s. It is only usable for top steering mechanisms that are set up to stay close to the body when moved (a steering wheel is even an option). They eliminate "tiller" action in steering. A three-way turnable joint is mounted to the top of the headtube and sends handlebar input through a sharp change in direction, without alteration, to the front wheel. The handlebar is located in an ergonomic position, and the shaft that connects it to the U-joint is supported by framing. A common solution is a tube at the main frame that leads to the steering tube and is attached to it with a hose clamp or other adjustable guide. Neither clamp nor joint is free from mechanical play, so this steering mode tends to be wobbly.

Stub-axle Steering

Stub-axle steering behaves in a way like no other. This high-tech approach allows precise steering, but is also expensive. Count on special engineering, special parts, and meticulous work to enjoy the advantage of a mode of steering that is absolutely free from play.

Calfee makes some of the world's best upright carbon-fiber bikes. Now they offer the "Stiletto," a carbon-fiber long-wheelbase recumbent. Weighing 24 pounds, it features indirect steering —for optimal handling—and an eye-catching selection of translucent finishes. Pictured here with the optional carbon fairing.

With all steering variants adjustments should be made very carefully. To determine the distance from handlebar to body it is advisable to subtract five percent from your arm length. While this setting is not as important as the leg adjustment, you may experience backaches if the bars are too far away—your shoulder joints will be forced to bend forward to make up the missing inches. On long distances or multiple rides your steering muscles can get tense (often including adjacent muscles) and ligaments can be stressed. The pain of too much reach is similar to what triathletes suffer when their streamlined handlebars are too narrow.

To prevent that, adjust the steering so that your shoulder joints are aligned with your spine. Your arms should form a slight bend, just as the legs do when pedal distance is adjusted properly.

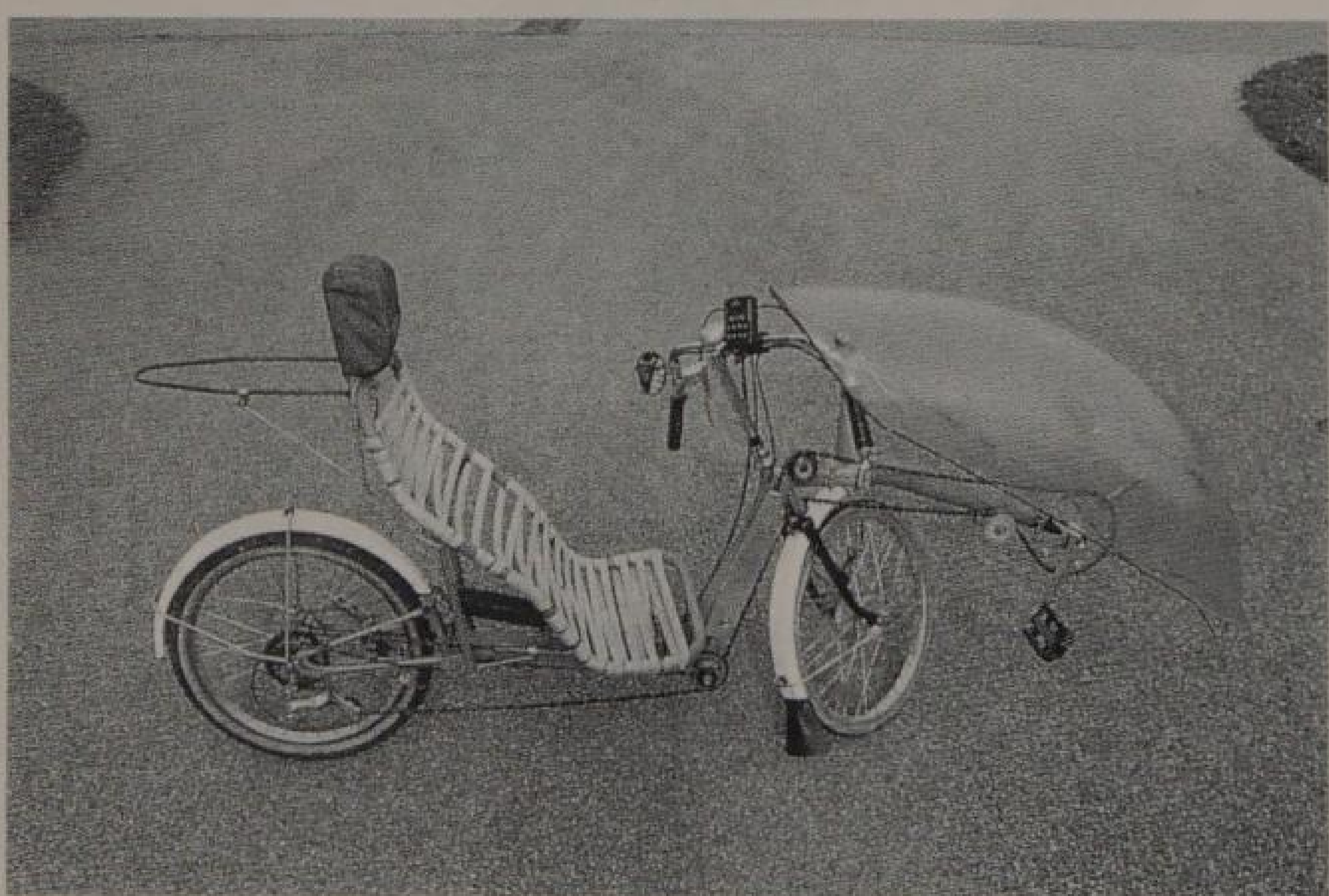
Handlebar Aerodynamics

The form and position of the handlebar is mostly derived from the ergonomic demands of the bike frame. The position and type of handlebar also influences the exposed frontal area, the bike's air turbulence, and thus, the aerodynamics.

The aerodynamically ideal form of handlebar for an unfaired recumbent would be no handlebar at all. That would be impractical, so we'll just say that the smaller and flatter the handlebar, the better the aerodynamics. (Clean cable management and lever design is also important.)

Handlebars that position the arms next to the body create up to 10 percent more air resistance than handlebars that hold the arms in front of the body in a straightish position and which locate the hands at no wider than the width of the shoulders. With a forward bar the frontal area of handlebars and arms is subsumed by the exposed surface of chest and shoulders.

The issue is irrelevant if your handlebars are within or behind a fairing. In that case you only need to watch that they don't increase the frontal dimensions of the fairing while still allowing enough range of steering.



A compact low-racer commuter. Low-racers are usually designed for sportiness but it's possible

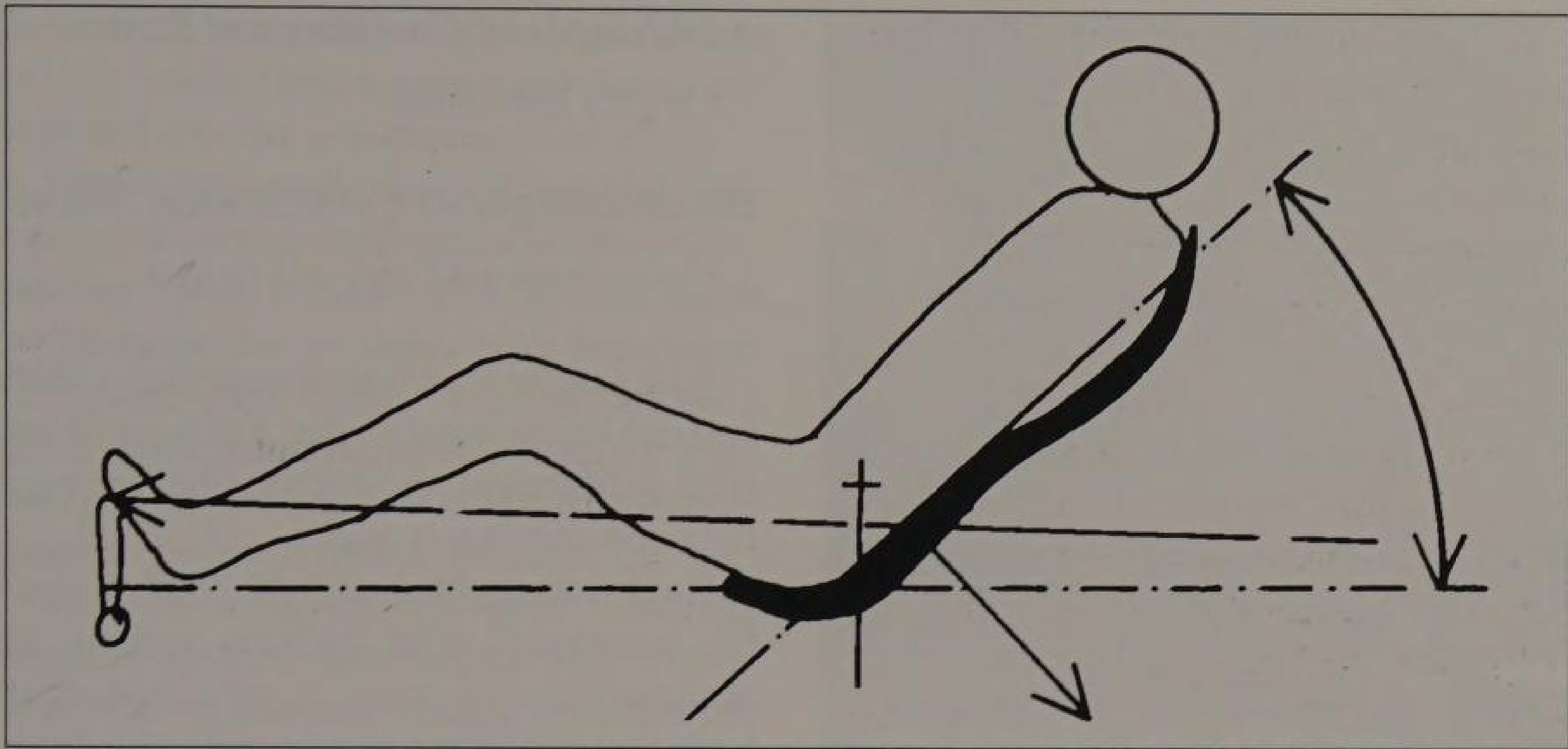
Ergonomics of Handlebars

If you're considering comfort alone, an under-seat steering mechanism is your only choice. The arms are not required to support anything, and the hands fall into position without effort. For long-distance travel, under-seat handlebars are a great choice.

For over-seat steering, a relaxing position can still be achieved with a folding stem that settles the handlebars close to the chest, putting the hands in a "praying chipmunk" posture.

Racers tend to like an over-seat handlebar position with their arms in an outstretched position. This lets them pull on the bars in certain conditions to increase power. Some position their bars so far forward and low (for maximum sprinting power) that their torso is no longer reclined back.

Handlebars are typically shaped for a specific type of riding. Bars intended for rac-



Ideal angle between seat-back and legs is generally 120 degrees.

ing are poorly suited for casual riding. Bars intended for city biking are poorly suited for sprinting. Handlebar shapes vary greatly, so be sure you're comfortable with what you pick. Don't despair if you choose wrong. Manufacturers often sell bars separately and they often fit into each other's stem assemblies.

Recumbent Seats

If there is one factor most responsible for a pleasurable ride, it is the seat. The most common complaint voiced by novice cyclists is butt pain. Such complaints are rarely heard from recumbent riders. The recumbent's large seat distributes weight better and reduces chafing. Moreover, circulation is improved and bruising is almost nonexistent.

But seat quality is still important. An uncomfortable recumbent seat—and they do exist—has the same effect on your behind and well-being as a bad upright saddle.

There are three basic types of recumbent seats: shell seats (also called rigid seats), mesh seats, and combination seats.

Shell seats are made of fiberglass, metal, carbon, wood, or plastic and are fitted with closed- or open-cell foam padding.

Mesh seats are made of a tubing framework covered with a tight hammock of mesh nylon fabric or other strong material or webbing.

Combination seats have a carefully padded base integrated to a mesh or padded seat-back. The base is often independently tiltable.

There's a wide variety of seats available in each style, so if the bike you buy doesn't come with a seat to your liking, get yourself a replacement. Seat manufacturers compete aggressively, offering many different ergonomic shapes and padding configurations.

The right seat is critical to your enjoyment, first of all, but also to performance (if you plan to race), and for all-day comfort (if you plan to tour).

Advantages of Shell Seats:

- lighter
- replacement and installation is easier
- more compact
- seat can merge into frame
- firmness can be adjusted by changing padding
- almost no flex
- excellent power transmission

The "Spirit" compact from HP Velotechnik is a well-conceived urban recumbent with rear suspension and sporty crank height. (photo: HP Velotechnik)

Disadvantages of Shell Seats:

- sweat-enhancing since they don't breathe
- adjustable only by pads

Advantages of Mesh Seats:

- built in air-conditioning
- material can be replaced
- cover firmness can be altered
- seat-tubes can be part of bike frame
- more comfortable
- adjusts to any rider

Disadvantages of Mesh Seats:

- heavier
- prone to malfunction
- larger, wider (less aero)
- mounting can be complicated
- bad power transmission—push absorbed by flexible mesh
- rider's back is more exposed to weather

Advantages of Combination Seats:

- highly ergonomic

Disadvantages of Combination Seats:

- base shape/pad may not fit you

With careful selection of materials, a shell seat can be extremely light. Artificial fibers such as fiberglass and carbon fiber are very light and commonly used.

Shell seats molded with the "hollow profile technique" offer stiffness without an accumulation of mass. If your budget is high, you can have a plastic seat made from a mold of your body impression.

The shell seat can be a single unit, compact and without extra supports. Fastenings are reduced to a few bolts and thicker support points where power comes to bear. Mounting or changing such a seat can be quite simple. Tilt and position can be adjusted with telescoping seatstays and/or sliding bottom attachments.

Power flow with a shell seat is very efficient—better than what you'd get with a webbed seat or regular bike saddle. Shell seats can be comfortable, but they're not very flexible—meaning that you feel great until you hit bumps. You can alleviate this with padding, using whatever thickness you like. Closed-cell camping pads work fine. Just cut to fit and fasten or glue in place. Some open-cell pads absorb water and sweat, making them less suitable.

Make sure the forward edge of the seat doesn't cut into your legs and that you have room enough for your legs to work at a variety of seat angles.

Mesh seats are another breed entirely. The seating area consists of fabric stretched over a frame. On most recumbents the seat frame is mounted separately to the bike frame, and its angle and position are usually adjustable. You can thus adjust for leg length just by sliding the seat.

There are two subgroups of mesh seats.

Some have lacing that wraps behind the seat tubing, others have a tensioning device integrated into the seat frame.

Depending on the type of material, you can count on varying degrees of "air-conditioning" with a mesh seat. Plastic mesh webbing is, for instance, very breathable compared with leather. Leather can be a good supplemental covering for heavy wear areas, if limited to a few straps where there is apt to be less moisture buildup.

Some mesh seats have a "horn" under the mesh at the front between the legs to prevent sliding forward. (Some combination seats even use a wide bicycle seat for a base!)

A mesh seat can be nearly as light as a good shell seat.

These types of mesh cloth are appropriate:

- leather (warm, natural, heavy, expensive)
- plastic (airy, expensive, light)
- nylon webbing (cheaper than cloth by the yard)
- seat belt strapping (cheap)

Cotton and other natural fibers are not appropriate because they stretch when they come into contact with water or sweat.

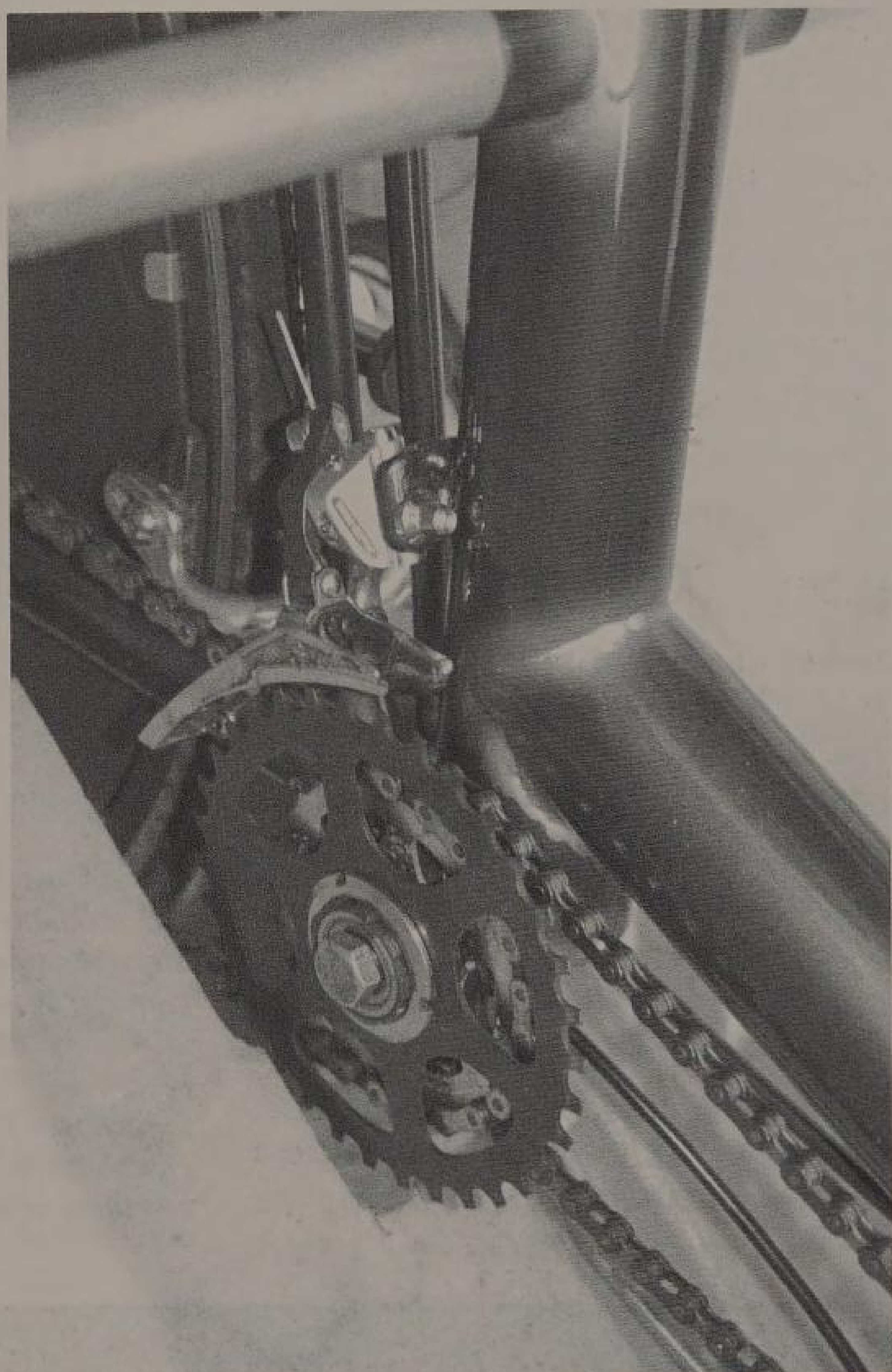
Combination seats come on some of the most popular production bikes. They offer bases with ergonomic padding and cut-outs, along with ergonomically curved seat-backs. The growing popularity of recumbents on all-day century rides has inspired the larger brands to put ever more attention into seat design. Each company takes a different approach, so test a variety if possible. Be aware that the real test of a seat is using it for a few weeks under conditions that are typical for you.

The form of the seat-back should correlate to the double-S form of the spine, with attention paid to lumbar support. A good shape is the only way to have a relaxed back and spine. A slight convexity in the seatback may provide the necessary degree of lumbar support. The tension of the mesh should be significantly harder in this area too. Lumbar support also helps support the pelvis. With sufficient support you have a better base to push against. If the pelvis cannot be supported in the seat, the spine becomes fatigued, and disk compression can result.

The lumbar support also determines the position of the pelvis. If the pelvis is rolled too far back, the burden on the spine increases. If it is rolled too far forward, the spine has less contact with the seat and extending the legs will be hard. Too much lumbar support also tends to cause a hollow back, rolling the pelvis too far under. An inappropriately tilted (overly flat) seat-base can also be responsible for that. Tilting this portion backward can help.

Avoid concavity in a seat-back. Such a bend rounds out the spine, positioning the

The Modular Bike from Steve Nurse of Australia converts between recumbent, upright, load-hauler and tandem...in any combination. Available complete or as plans.



Close-up view of a rear cassette hub and front derailleur set up as an intermediate drive inside a faired HPV.

pelvis flat and compressing the heart and other organs.

Bottom Bracket Height and Seat Angle

The interplay between bottom bracket height and seat angle is one of the most important factors for power transmission. Here is the simplified relation: The higher the bottom bracket (in relation to the seat), the more reclined the seat should be. And the lower the bottom bracket, the more upright the seat should be. (It is interesting that with recumbents, a bottom bracket is often nowhere near the bottom of anything.)

A high bottom bracket improves aerodynamics, but it demands a well-shaped seat since you ride with far more weight on your back than if you were sitting upright. And the lumbar support of a reclined seat must be more pronounced as the back tends to slide around when pedaling. A more upright seat, conversely, needs a more carefully designed base, as that is where the weight is.

The weight of the body is usually sufficient to keep skin and clothing firmly in contact with the seat. The sliding takes place under the skin, so to speak. The back's connective tissue between skin and bone acts like a spring, and this can become fatigued. This phenomenon occurs during hard riding and on bikes with a very reclined seat (less than 33 degrees up from the horizontal). Again, this can be helped by a lumbar support and/or a concavity high in the shoulder area, which also reduces the work of the neck muscles in holding up the head.

The line of the back should have an angle of about 120 degrees to the line of the legs. Angles that are much smaller fold the body together, limiting breathing and leg movement. Bigger angles cause sliding and power loss—even with lumbar support—because the big quadriceps muscles can't apply full power (or require more adapting than usual to do so). For racing purposes, the bottom bracket should be high enough that the quad muscles do the lion's share of the work but low enough that the gluteal and hamstring muscles get a full range of play as well.

A seat that is too reclined can strain the neck, since you have to hold it up to see down the road. (Riders of upright bikes with dropped handlebars experience a similar strain but from the opposite direction.) A bike with too much recline can also impede vision, and is really suitable for only limited racing application, such as on a velodrome in solo events. Headrests can be helpful on longer rides with very reclined seats.

Conversely, a position that is too upright results in too much weight being put on the seat bottom—and your bottom—and not enough spread along the length of the back. Too much weight on your rear can cause the dreaded "recumbent butt." With most recumbent seats, some weight is on the very muscles you have to use—unlike regular bike saddles where the weight is supported by pelvic bones, leaving the butt muscles free to work. Too much weight on the butt can result in a compaction of these well-used muscles and early fatigue, pain, or cramping. The best seats designed for upright angles (common on popular touring recumbents) feature carefully shaped and padded bases with relieved areas, similar to today's upright-bike saddles.

Ideally the load of your body weight should be distributed about equally between butt and back, though a carefully designed bike can deviate from this ratio and still yield good results.

Distance of Bottom Bracket to Front Wheel Hub

There has been little research studying the distance of the bottom bracket to the front wheel hub. Nevertheless there is anecdotal evidence of some broad conclusions.

Advantages of a Small Distance:

- good braking behavior
- long wheelbase and compact-length designs are possible

Disadvantages:

- feet, crank-arms, or even thighs could touch front wheel
- needs getting use to for slow riding, to avoid foot-strike

Advantages of Big Distance:

- freedom of the feet
- no slow-speed riding change necessary

Disadvantages:

- braking behavior suffers
- bottom bracket outrigger boom is longer (more flex)
- design usually limited to short wheelbase

Center of Gravity

The position of a recumbent rider's center of gravity is very important. And locating it is as simple as locating your navel.

The recumbent rider has a lower center of gravity than the rider of an upright, and with that comes the advantage of lower air resistance because of the smaller frontal area.

Riders of 19th-century high wheelers often went head-over-teakettle. Two things were responsible for this: First, the center of gravity was very high, and second, the

This homebuilt lowracer is shown without its fairing. It has flex-chain front-wheel drive with an intermediate gear located at the head tube. This is strictly a racing bike because as you turn the handlebars the chain twists, making low-speed, sharp turns difficult. Foot-strike is also an issue.

The pivoting front drive of a Flevo Bike connects the entire drive unit with the front fork. The frame and mechanism swing together to steer —a feeling that takes a lot of getting used to. (photo: Pichler)

center of gravity lever arm was short, because the center of gravity was so close to the effective brake center (the rider sat close to the braking pivot point). This design all but begged for a flip-over. The rider of a low recumbent with a low center of gravity would never suffer this indignity. The lower you are and the farther away from the braking pivot, the less likely is a flip-over.

Advantages of a High Center of Gravity:

- good field of view in traffic
- handling is similar to an upright bike
- bike wobbles only a little during startup

Disadvantages:

- danger of tipping over forward when emergency braking or hitting something
- poorer aerodynamics (even for highracers)
- greater chance of a bad outcome in case of accident

Advantages of a Low Center of Gravity:

- small risk of flip-over
- good aerodynamics
- mild consequences in case of an accident
- extreme cornering possible

Disadvantages:

- poor visibility in traffic
- relatively long period of adjustment to attain comfort and handling skills
- bike tends to wobble at slow speed; more difficult startups

Advantages of Short Center of Gravity Lever Arm (Rider Close to Braking Pivot):

- front wheel has good weight on it for traction

Disadvantages:

- higher risk of turn-over
- rear wheel often under-weighted
- vehicle will be longer
- heavier

Advantages of Further-removed Centers of Gravity Lever Arm (Rider farther from front brake):

- no risk of turning over
- lighter
- rear wheel well-weighted

Disadvantage:

- not enough weight on front wheel

In relation to the distribution of weight, the center of gravity is decisive. On an upright bike a distribution of about 40 percent in the front and 60 percent in the rear is considered a good balance. This guarantees that the drive wheel has enough traction that it won't slip under strong pedaling, while still leaving enough weight over the front wheel to prevent it from slipping during cornering or braking.

Recumbent designers strive for a distribution of weight that achieves the same goals.

Racing models have to be more sensitive to these issues due to the greater forces involved. A city bike can have a higher center of gravity and shorter lever without harm.

Determining Front/Rear Weight Distribution

A simple method to establish the division of weight between the axles requires only an assistant, two bathroom scales and a carpenter's level.

First position the scales at a distance equal to the distance between your bike's wheel hubs. Place the level across them (resting it on a straight 2 x 4 if it's not long enough) to insure that the floor is level. If not, raise one scale until it reaches the level of the other. Then position the wheels on the scales and sit on the bike (place a chair on either side that you can grip to remain balanced). Have your helper read the scales and transform the figures to percentages of overall weight on each axle.

Bike designers can shift the axle weight ratio by shifting the center of gravity of the design. Calculating and optimizing this ratio is vital when it comes to the construction and fine-tuning of any suspension. A highly adjustable seat and/or crank "boom" (frame extension on SWBs) can also help in this regard.

Chain Routing and Power Transmission

The chain transfers the power you generate from the crankset to the drive wheel. During pedaling the upper chain is pulled under tension, while the lower chain is returned passively back to the cogs.

A recumbent with a longer wheelbase and elevated crankset can sometimes require a convoluted system for guiding the chain from the crank to a distant cogwheel. But every intermediate cog or pulley costs power. For that reason the chain's travel should be as short and straight as possible.

Like any bike, a recumbent's overall design is a compromise between competing needs. So even though a short, straight path of chain travel is best in theory, there are a host of design considerations that may necessitate a deviation from that ideal—deviations that may offer their own rewards.

Here are some things to consider when judging chain routing.

For chain lines that can't be straight and direct there are two feasible options:

- change direction via a pulley
- use a dual set of gears or an intermediate cog.

For extra-long chains it's best to have an idler wheel pulley on either the part of the chain under tension or the passive part (the part of the chain that returns from the crank back to the hub). An unguided, freely swing-

Seat adjustment on this bike is made via a modified seatpost and road-bike style seat tube lug, creating an unusual but effective support.

ing passive chain presents trouble. It can interfere with steering, it can be noisy, it can scratch the frame, and it can get grease on clothing and luggage.

It's different with the chain's drive side. Since it's under tension when pedaling, it takes the most direct path from cog to crank. Any re-direction of the power-side chain means increased friction. Estimates assume a 3 percent loss per pulley in the power-side drive chain.

For lower chain management, many builders use a pulley off of a rear derailleur and put a little cage around it to keep the chain from jumping off. Using a pulley with a center ridge like those on a rear derailleur prevents the chain from running on the link-plates, reducing resistance. Using a bigger pulley is another way to reduce friction—such as one made from a skateboard wheel—also reduces noise considerably.

These 2- to 3-inch pulleys are mounted to an axle stud so they can both roll and slide a bit and follow the angled line of the chain according to the gear. The profile of a power-side chain mills itself into these pulleys after only a few hundred meters, demonstrating the enormous forces that are generated. This argues for a strong axle—at least three-eighths of an inch, radius M8 or M10.

There is an alternative to low-side pulleys. A chain tube is a tough, flexible plastic hose that the chain is routed through, and it can control the direction, noise, and cleanliness of your low-side chain. Some bikes use tubing that runs the entire length of the low-side chain, while others use shorter lengths pinned in strategic locations.

An elegant solution involves an intermediate drive such those used on tandems. A tandem crank powers a chain on the left that goes to a chainring under the seat, which in turn drives another chainring on the right back to the rear cogset.

Unfortunately, this "solution" presents its own handicap (which is shared by upright bikes). Because of the proximity of the intermediate drive and the rear cogset, not all gears can be used—the chainline would be deflected too much. "Dead gears" are the result. If the intermediate bearing or power-side pulley is 20 inches or more from the cogwheel, then all gears can be used.

This form of drive can be made from a conventional tandem set. The unused crankarm forged to the "spider" of the rear crankset has to be sawed off.

A left-side synchronization chain on a tandem is not tensioned with a derailleur like the right-side chain on an upright bike. Thus it has to be tensioned artificially. An eccentric camming bottom bracket is useful, but costs more. On a recumbent, however, the eccentric bearing is installed in the intermediate drive. If it's used at the actual bottom bracket, the adjustable position of the camming bearing can change the distance to the seat, and that creates a change in leg length.

At the intermediate bearing the two chainwheels cover the access to the bearing. You need to remove one of them in order to adjust the chain tension of the synchronization chain via the eccentric bearing. One primitive but effective solution is to have a

The Mikado "Quetzal SE" is a stylish, affordable, semi-recumbent city bike with 21 speeds.

small pulley mounted to the left side of the bike that is height-adjustable and located in a metal holder. This small pulley pushes the chain up, giving it tension.

The only disadvantage of this easy, cheap, and uncomplicated approach is a slight power loss. When the drive chain is under power, it causes a slight hanging of the return portion of the chain.

Exactly how much energy is wasted by an intermediate bearing set-up is in dispute. There are no unequivocal statistics. But supporters as well as detractors agree that increased friction is only acceptable if it offers advantages elsewhere.

An intermediate drive allows for a secondary shifter and cogset. With such a set-up you can get a good gear-range without a front shifter and you can even use a front chainring of small size, avoiding an expensive extra-large chainring. If you select components cleverly you can even reduce weight.

Inexpensive tandems have a right-sided chain leading from the front crank to the inner chainring of the rear crank. If the rear is a triple, its two outer rings are thus available to the secondary drive for transmission changes. This reduces the number of gears, but it is cheaper than a right-left combination.

The Z-2 recumbent by Martin Staubach is worth mentioning in this context. He mounts a Shimano cassette as his intermediate drive. Four cogs with spacers are mounted on the cassette body. One holds the chain, which drives the rear wheel, and the remaining three are driven by the crank in front. A standard derailleur shifts the front chain among them. In this way he creates a fully functioning 21-gear shifter.

The cassette body is mounted to the hub, heated (to reduce hardness), and turned from the inside to mount to a stub on the frame. Then Staubach presses in industrial strength bearings and screws the cassette to the frame.

The CruzBike is an online-order kit that quickly converts a Y-frame mt-bike into a FWD recumbent. (photo: Cruzbike.com)

If both chain lines were equipped with freewheel and shifter, more than 50 gears could be realized.

Intermediate drives are helpful for designs using rear suspension. They help minimize loss of power because the chain line moves less when different gears are selected, so the position to the suspension-pivot differs less. They also simplify the accompanying needs of chain management.

Advantages of...

... direct chain routing:

- lightweight
- no loss of energy
- inexpensive
- standard parts
- no problems with chain tension, because the rear derailleur provides it
- all gears useable

...controlled return chainline:

- light
- inexpensive
- standard parts
- all gears useable

Derk Thys gets an all-body workout on his successful, innovative and smooth-operating "Rowingbike." This is the sport model; he also offers a lowracer.

...tandem left intermediate:
- elegant
- flutter free; the chain won't move or "boogie" while you ride

...tandem right intermediate:
- lighter than left
- standard parts

...cassette drive:
- the lightest tandem version
- 21 gears and more possible
- cheaper than left
- standard parts
- fast shifting in the front, since Hyperglide equipment can be used

Disadvantages of...

...a direct chainline:
- lower chain vibrates
- limited transmission modifications

...diverted chain:
- loss of energy (small)
- pulley is source of potential malfunction

...tandem left:
- energy loss
- tandem-specific parts are more expensive
- crank arm has to be removed
- heaviest tandem variant
- difficult to get spare parts
- problems with chain tension
- cannot use all gears

...tandem right:
- energy loss
- crank arm has to be removed
- hard to implement
- expensive; as additional parts are needed
- problems with chain tension
- cannot use all gears

...cassette:
- special brazing necessary
- energy losses
- heavy
- cannot use all gears
- not all gears can be shifted with just a front derailleur

Front Wheel Drive

Though uncommon, front drive is a viable alternative to rear drive. In practice, front drive is typically found on recumbents with a short or medium wheelbase. There are two basic designs:

- pivoting drive
- flex-chain drive

A pivoting (or swinging) drive is built into the fork, with the crankset boom mounted to the fork as well. When you steer, your legs turn too. Thus the legs can contribute to the steering work and riding no-handed becomes simpler, depending on how well you adapt to it. (An example of this drive is the mountain-bike conversion kit from CruzBike.com.)

The biggest advantage of such a configuration is a compact and efficient drive. The second benefit is a greatly simplified back half of the bike (no chain, shifter, gears or idlers). At the front, the chain is short and directly routed, with no diversions. The power vectors can be easily triangulated with short, light frame-tubing. This set-up usually uses a normal headset.

The pivot can also be located between fork and seat, or even at the seat, so that "lean-steer" qualities requiring body English can be built in, even to the point of having passive handlebars (mounted behind the pivot) so that all steering is done with the legs. An example of lean-steer was the Dutch Flevo-Bike. Homebuilders today are exploring variants such as the bike at the Python-Lowracer.de website.

The flex-chain (or rigid) FWD presents a mechanically "unclean" solution. The bike has a normal steering arrangement. The chain is re-directed in the area of the head tube and is led by pulleys or an intermediate drive to the cogset at the front wheel hub. All examples of this mode create chain twist or flex when turning, which, in turn, creates considerable friction losses.

Is that a big problem? Not necessarily. When you're turning the handlebars, you're usually not exerting much power or in need of great speed—except on steep uphill corners and switchbacks. Then you need all the help you can get! Flex-chain FWD is often the choice of racers, since they don't turn their bars much.

An exception here is the StitesHub, which uses a universal-joint in a normally steered configuration to totally separate the steering and powering functions. It's basically a flex-chain system without the flex—albeit with the added complexity of a U-joint.

In all types of FWD, the front wheel should carry more than usual (55 to 60 percent) body weight, otherwise the front wheel is likely to spin-out on an upgrade.

Advantages Front Drive:

- light
- short chain
- rear suspension can be easily constructed
- opens up space below the seat for luggage

Disadvantages:

- cannot use all gears
- traction problems when starting

...rigid drive:

- chain might kink or lock when steering
- limited steering angle range
- mechanically "unclean" losses due to chain-twist

...swinging drive:

- needs careful design
- aany leg-steer involved has a learning curve

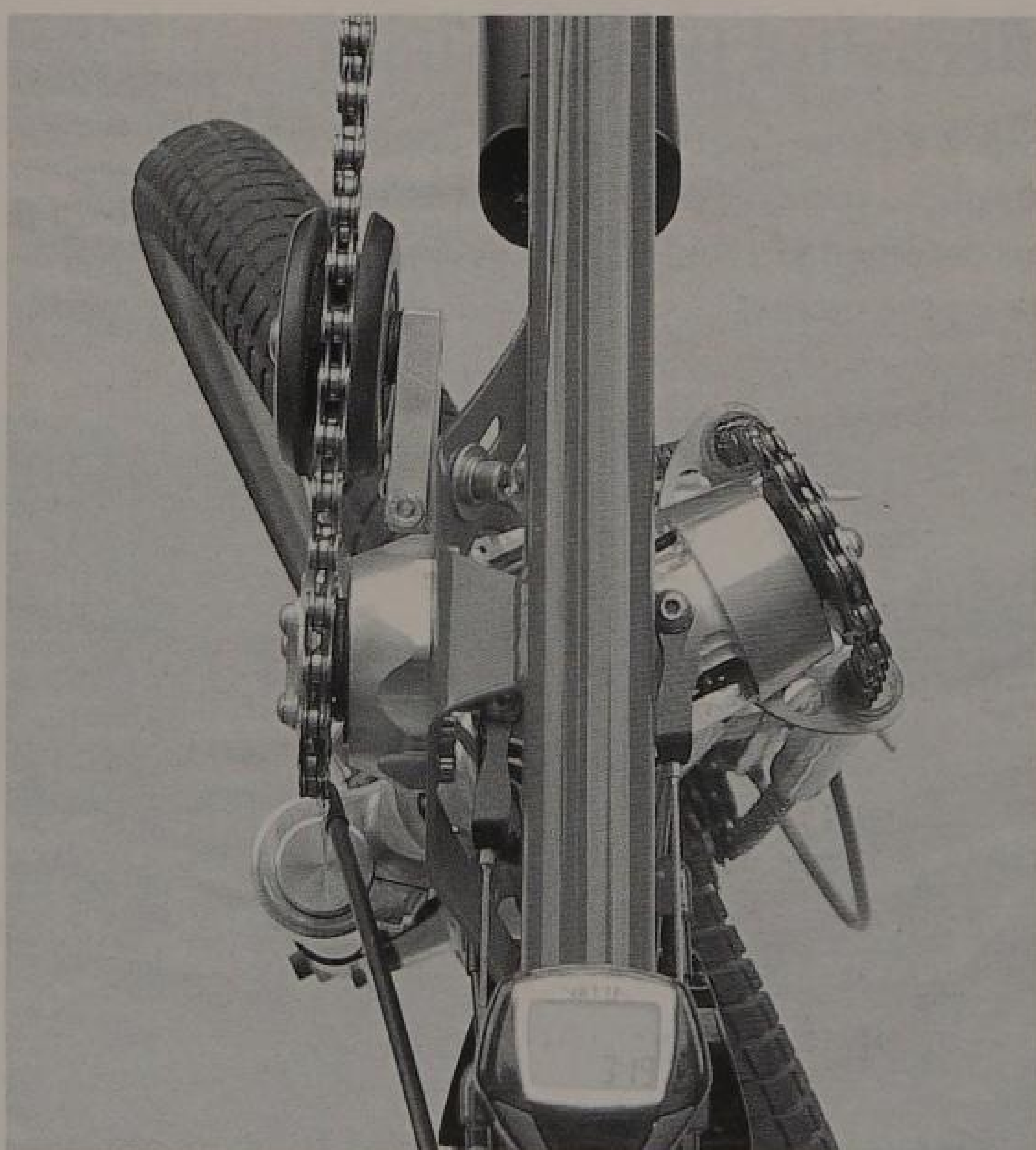
Alternative Drive Options

Since a recumbent has a long, complex, and rather expensive drive train, novel variations designed to avoid all this regularly appear on the market.

A pack of Thys Rowingbikes (right) alongside a pack of lowracers in a Cycle Vision race. Notice that the lead Rowingbike is a lowracer model. (photo: www.tim.be)

The belt drive is usually ruled out for two reasons: It only allows for a hub gear, which is only offered in 3-speeds up to 9-speeds, which limits use to the city. Furthermore, it is relatively expensive because no company produces such a bike and there are few usable belt materials on the market for homebuilders. You'd need to be highly dedicated to build your own bike with a belt drive, and creating your own bike takes a lot of time as it is! That said, belt drives have their virtues. They are maintenance-free, light, and very clean (no oil).

Some builders have tried smaller chain sizes to lower the size and weight of the drive unit. But you lose reliability as you reduce the overall mass of the chain. Smaller parts just aren't strong enough to endure the stresses of vigorous riding, and they wind up either broken or bent. There are also compatibility problems: Shifter, crank, and gears would all require modification.


A top-down view of the unique StitesHub front-wheel-drive unit. A U-joint separates pedaling from steering forces in a regularly steered, rigid FWD set-up. (photo: B. Stites)

The only significant alternative at this point seems to be the "Rowingbike" system developed by Derk Thijs, a Dutchman. His bike is powered by—you guessed it—an arm-and-leg rowing drive, whose motion sequence resembles that of a sliding-seat rowing shell. Not coincidentally, Thijs is an elite rower.

The legs slide next to each other in parallel, and the arms pull a lever at the same time. The lever for the arms is the steering handlebar and pivots at the headset. This enables the rowing lever to be used for turning as well.

Clipless pedals for the leg drive are located on a slider, which glides on metal rails on the main tube of the bike frame. The combined pulling power straightens a steel cable connected to an amazing patented "Snek" mechanism that creates an efficient, wide-ratio, stepless gear range. Thijs has won significant marathon races with this drive, competing with upright racers and other HPVs. Rowingbikes even have their own race series in addition to participating in usual HPV events.

Hand cycling is a growing aspect of the HPV scene, with several high-end models available and world records established in various classes.

In the field of motorcycles, the Cardan shaft drive is highly praised. It's tempting to try to adapt it to a bike. However, it's heavy and complicated, and though often proposed, it's rarely seen. With a shaft you also lose 7 to 17 percent efficiency.

As Whitt and Wilson point out in "Bicycling Science," the standard chain has a maximum efficiency of 98.5 percent. Even after a half-year of use the degree of efficiency is still at 95 percent. That's hard to beat!

Chain Protection

Chain protection can be looked at in two ways:

- protection of the chain from dirt
- protection of the rider from the chain

It makes sense to protect the chain from dirt, especially with everyday bikes, which ride through puddles, slush piles, and perhaps the occasional dirt road.

A clean chain needs less oil, which, in turn, slows the accumulation of dirt, thus extending the effectiveness and lifespan of the chain. Clothing, legs, and passersby have to be protected from the chain as well. A dirty chain leaves ugly stains on clothes and body. A sealed chain enclosure is, of course, the ideal solution, but tricky to install. The Revive DX from Giant has done good work here. This deluxe version of their compact semi-recumbent bike has an enclosed drive train and rear suspension and is still quite affordable.

It is simpler to enclose as much chain as you can in plastic tubing. Such tubing has to be interrupted at any pulleys and must allow the chain to run freely.

It is worth guarding the chainrings of SWBs and lowracers. Prominent chainrings pose a risk for injury during collisions. Chain guards are quite easy to install.

Frame Adjustment

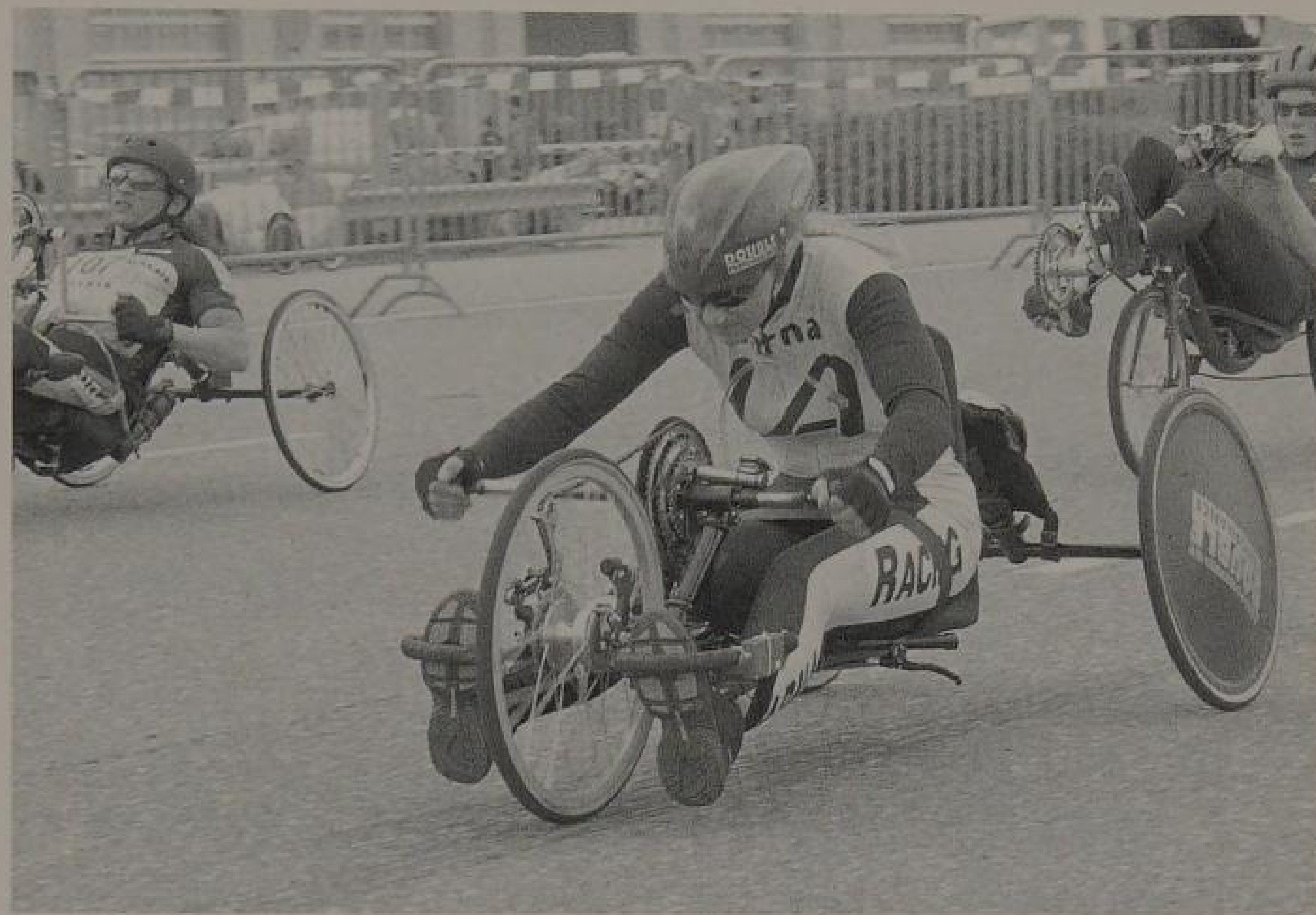
An adjustable frame lets you match your bike exactly to your leg length and body size. Most recumbents have two areas of adjustment: frame and seat (often both). An adjustable boom-type frame extension for the crank area can be found on most SWB recumbents that use a single large-diameter frame tube as their basis (a "mono-tube" frame). This option allows for easy adjustment.

The main tube of the frame of this type does not end with a bottom bracket, but as a hollow tube with a slot. The bottom bracket itself is built onto a tube that slides into the main frame tube. Two clamps fix the crank boom in place. A more elegant solution is an integral (brazed-on) bolt-clamp or two at the slot, like a seatpost clamp on an upright bike.

To ensure strength, the length of the section sliding into the boom has to exceed its radius by at least 50 percent, otherwise you risk the possibility of torquing the crank assembly out of the frame under vigorous pedaling.

Seat adjustment is more complicated. Let's take a look at two approaches. First, there is the option of sliding the seat in a slotted bracket on the frame. Alternatively, seat position can be altered with position holes drilled through the frame. The seat gets a second adjustable support at shoulder height to resist pushing strain. Seats made of steel tubing provide adequate stability for systems supported only at two points.

Molded fiberglass and carbon seats are becoming quite common and can be fitted with pivot points, holes, and slots for various approaches to adjustability.



Handcycles are a growing part of the HPV scene, with riders reaching speeds of 30 mph in sprints. (photo: www.tim.be)

The EZ Tandem made by Sun and designed by Easy Racers is solid, easy-to-use, and affordable. (photo: Easy Racers)

One clever homebuilder used a conventional seatpost lug. An adjustable L-assembly of tubes works like a regular seatpost, but slides horizontally instead of vertically. A regular seatpost clamp holds everything in place (see photo, page 117).

More complicated and heavier are seat-adjusters that use clamps. The clamps circle an assembly on the main tube at the lower part of the seat. In the back area two stays support the seat. They are length-adjustable and pivot to work with the position of the lower seat fastening. These stays and the clamping block on the main frame add weight and necessitate a lot of production work, but they let you mount a comfortable mesh seat.

Advantages of…

…sliding boom:
- light
- stable and firm mounting
- easily made
- adjustment is millimeter exact
- distance between handlebars and seat remains constant
- seat can be integrated into frame

…seat adjustment at the frame:
- light
- stable
- easy construction
- chain length does not change
- combines easily with adjustable seat back

…seat adjustment with clamps:
- seat angle adjustable
- installment of a mesh seat is easier
- chain length does not change

Disadvantages of…

…sliding boom:
- chain length changes
- exact vertical alignment of the crank can be difficult (many bikes have guide stud on boom that rides in slot in main tube)
- tubes tend to rust together
- bolts and clamp can fail, allowing slip

…seat adjustment at the frame:
- heavier
- higher production cost/effort
- seat can be stressed (less frame support)
- alters angle between seat and handlebar

…seat adjustment with clamps:
- heaviest variant
- high production effort
- seat can be stressed
- alters angle between seat and handlebar
- center of gravity can change

Storing Luggage and Cargo

The recumbent is especially popular and appreciated as a travel bike. They're more comfortable than an upright bike, you'll cover more ground in a day, and the relaxed seating position affords a better view. On top of that, you have superior aerodynamics and greater luggage capacity. These factors make recumbents attractive to tourists.

The variety of designs opens up a multitude of stowage possibilities.

A growing number of recumbent companies are offering racks and panniers to fit their bikes—which may fit similar models from other manufacturers. Accessory makers are getting on the bandwagon too, with luggage specifically tailored to recumbents.

If you're willing to modify conventional parts or to build a carrier system yourself, then the storage space on most any recumbent can be greatly enlarged. If you're a bit handy and willing to tinker, you can probably fashion a bag holder behind the seat. It may be no more difficult than fastening a standard handlebar bag to the seat back.

Lowrider bags can often be fastened under the seat at the main frame. Just take care with the spacing to avoid having the right-side bag collide with the chain.

Aerodynamic rear tailboxes with a lot of space are very useful. Form, carrying capacity, and price vary. And not every tailbox fits every bike.

Some fairings can also be fitted with interior cargo bays.

Lastly, consider a trailer. For someone with a lot of gear, trailers offer the greatest carrying capacity, and they roll easily right in your draft.

Tandems

It is often more fun to ride with two on one bike than two on two! And while conventional tandems are pretty much alike, recumbent tandems differ wildly.

In principle, the type and position of the seats has to be determined before moving to other steps of planning. The following are typical options:

- recumbent position in front; upright bike position in back
- upright-angled recumbent in both front and back, usually with low cranks and rear crank under front seat
- reclined-angle recumbent position in both front and back (resulting in a very long bike)
- back to back: regular recumbent in front; reversed recumbent in back
- side by side (called a "sociable")

Combining recumbent and upright-bike seating allows a number of interesting features. Bilenky Cycle Works of Philadelphia offers the clever "Viewpoint." Stoker and captain have switched seats, so that the rear steers and front provides only power. The upright-bike "captain," seated in the rear, has a good overview of traffic above the front rider, who is seated lower with legs extended. Their two heads are close together, making it easy to talk. A wide array of accessories are offered, including a front pannier rack. There's also space for conventional rear panniers. A front fairing is easily fitted. As you might expect, the aerodynamics of the Viewpoint, with its low front end, can be superior to an upright tandem.

A tandem recumbent's chainline can become complicated. I recommend using a conventional tandem drive train at the rear

The Dutch M5 tandem: elegant, fast, and very expensive. (photo: M5)

The Bilenky "Viewpoint," a mixed-position tandem, puts the stoker in the front in a reclining position, while the captain sits upright in the rear and steers. A fairing can be fitted to boost speed. Bilenky also offers handcycling and child stoker-seat options. (photo: Counterpoint)

as a starting point. It carries the chain to the cogset on the right side and takes in chain on the left. Bottom bracket locations are then determined according to seat positions and angles.

Different manufacturers have different approaches. Some tandems offer completely separate drives, with the front rider using FWD. On some bikes, the front rider has his own shifter and can choose his own gearing, though they are still somewhat limited to a gear that works with the stoker's choice. Others offer only independent coasting. The end result is no synchronization problems and little need for practice rides and long periods of adaptation. Recumbent tandem makers were the first to offer independent gearing, an innovation that then spread to the upright scene. However, advanced riders often prefer the "communication" between riders that connected systems offer via the chain. (Tandeming offers more than one might expect in many ways.)

Suspension for a recumbent tandem is doubly important because the carrying mass is doubled.

Recumbents and the Auxiliary Engine

Human-power buffs and motor-phobes loathe the idea of equipping a recumbent with an auxiliary engine, but the aversion must not be universal because the idea keeps resurfacing.

Paul Rinkowski equipped some of his recumbents with Mokick moped engines as early as 1958. The bikes had a 50cc engine and zipped along at 35 mph across the hills of old East Germany. Excellent recumbent aerodynamics, assisted by stationary legs, resulted in breathtaking fuel efficiency: 250 mpg!

Options today include the ZAP Power System and Chronos Hammer—add-on electric motors that assist pedaling, each for about $500.

The concept is appealing for those who use the recumbent as an everyday vehicle and who want to improve their use, speed, range, and options, combined with an occasional (or full-time) relief from pedaling.

Cyclists who foreswear bikes powered by combustion engines and electric motors, whether out of concern for the environment, noise, weight, or other reasons, limit the practical range of their bikes. Recumbents outfitted with auxiliary engines and fairings present a low-cost, fuel-efficient alternative to automobiles.

Braze-ons: Finishing Touches for a Fine Frame

A nicely built frame encircled by hose clamp fittings is like a table in a four-star restaurant set with plastic utensils and paper napkins.

A carefully crafted frame deserves fittings to match: braze-on attachment points. Hoseclamps are ugly, and they rust. The only thing that can be said for them is that they're cheap and easily replaced. Brazed attachments are the aesthetic choice for discerning cyclists.

Advantages of…

…hoseclamps:

- can be used exactly where needed
- cheap, available, easily exchangeable

…brazed attachments:

- elegant
- simple
- light
- can be installed almost anywhere

Disadvantages of…

…hoseclamps:

- ugly
- limited use
- fiddling required to position just right

…brazed attachments:

- not quickly exchangeable
- difficult to repair if defective
- initial mounting laborious

When sensibly arranged, braze-ons, bosses, and other attachment points built onto a bike (or glued or molded in with a carbon frame) do not detract from a clean and stylish frame.

Braze-ons are good fastenings for:

- brake bosses on seatstays
- mounts for chain-pulley axles
- brake bosses for cantilever brakes
- cable guides
- cable stopper
- bottle holders
- levers
- m6-nuts for fairings or luggage racks
- outer cable and chain guides
- pump holders
- chain hooks
- fenders
- luggage racks
- front derailleur
- chain holder for removing rear wheel
- brake bridge fastening
- stiffening struts
- pulley guides
- front lamp
- back light
- dynamo
- computer
- kickstand
- reflectors
- race number
- fairings
- bags
- chain protector
- derailleur protector

If homebuilding, evaluate the exact position of braze-ons and check the mounting several times before setting to work. Nothing is more frustrating than discovering, after you've finished painting, that a cable-stop was soldered the wrong way.

Mounting braze-ons for shifters and brake cables demands great care and planning.

The RANS "Screamer" allows riders to pedal at independent cadences.

Burley's affordable "Jett Creek" features a pivoting handlebar for easy step-over and a long wheelbase for comfort.

Modern, super-precise shifters are unforgiving. Every bend causes tension in the outer case and friction for the inner surface. So smooth shifter functioning depends on the positioning of the guides. Guides must not force cable into extremely small radii. It is advisable to let the cable run along the frame as much as possible without outer guides. The same is valid for brake cables. Bends and unnecessary cable length eat up braking power.

Test the furthest range of steering on both sides while measuring cable. This will save you unpleasant surprises, such as what you'd experience while braking in a steep corner if your cable were too short. If the handlebar is supposed to be adjustable, cables should run in all positions in an ideal line. Mountain bike cable guides are good examples to study.

Similar guidelines hold true for lighting and computer cables. A lighting wire shouldn't cost more than a dollar to replace, whereas a torn computer cable could eat a 20-dollar hole in your wallet.

When the frame is equipped with the necessary brazed attachment points and painted, it is time to consider and put together the rest of the bike. Basics like wheel size, bottom bracket threading, fork steerer tube size, and brakes are determined by the frame construction. Their final selection and detailing, however, demands attention, and is not as easy as it looks. Whether you leave it up to the manufacturer or assemble it all yourself, it pays to know the pros and cons of these components.

Wheels

Front Wheel...

The front wheel of a recumbent undergoes more and heavier strains than that of an upright because you do not leave your saddle, or lift up with the handlebars to ease the impact of obstacles. To lower the risk of failure, high-pressure or large volume tires are essential. There are many high-pressure 20-inch tires to choose from: 20 by 1-1/8 inch 100 psi high-pressure tires with racing profile, 20 by 1.75 inch large-volume tires for all conditions, and others. As mentioned earlier, watch out, because there are several different, noninterchangeable 20-inch tires.

20 by 1-1/8 inch = 451 mm dia ("Road")

20 by 1-3/8 inch = 440 mm dia (rare)

20 by 1.75 inch = 406 mm dia ("BMX")

Overall, the best selection of tires can be found in the 406 mm BMX size.

Hubs for small wheels should be of high quality because of the high rpm's. You may want to consider a hub with sealed bearings; they run smoothly and maintenance-free.

Another thing to consider are spokes. The sort of riding you do will determine the number, kind and crossings of spokes. Everyday bikes are well-equipped with 32 spokes and 3-cross. For touring, 36 or even 40 spokes with 4-cross are more typical. Race bikes today often use aerodynamic bladed spokes and wheels of a wide variety. They are indeed fast but consider ease of repair if buying them for anything but racing—some of the new high-tech wheels are much easier to work on than others.

I prefer a 3-cross, 36-spoke set-up for loaded touring. For racing and light everyday riding, I like 28 radial spokes. They should be of high quality. Stainless steel spokes—DT Swiss and Prym are two to consider—last the longest, do not rust, and do not stretch significantly.

Rims too should be of the highest quality. Sun Mistral, Alesa, and Araya, are all very fine rims.

Rear Wheel

The strains on a recumbent rear wheel are also of a different order than those on an upright bike. Recumbent wheels are not subject to the stresses and strains that come from sprinting out of the saddle and extreme acceleration. On the other hand, shocks from bumps are much harsher, because the rider's legs are not acting as shock absorbers, as they do on an upright bike. The body's natural suspension is blunted by the recumbent rider's reclined riding position.

Hub choice, unfortunately, is tied to your choice of cogset. Get the best that works with the cogs you desire. For rims, what works on the front will work for the rear. Tire choice depends on what sort of riding you have in mind and what your frame-width clearances are. But most any bicycle tire can be used for recumbents.

In general, high-speed commuting and open-road riding on fast, fully faired recumbents require the protection of wider, stronger tires to avoid dangerous blow-outs and time-consuming repairs, and to better absorb shock.

Lighter wheels can sometimes be used on bikes with suspension as impact stresses on them are much less.

Cockpit and Handlebar Set-up

Grip-shift, thumb, or bar-end shift levers all work fine on recumbents. Design your set-up so that, together with brake levers, the handlebars form one steering unit, allowing quick reactions to traffic or race conditions. Individual anatomy, steering mechanism radius, and weight are all things to consider when choosing shifters and brake levers.

Integrated brake-lever shifters ("brifters") that work by pivoting inwards are designed for curved drop bars on upright road bikes. Only a few recumbents are set up to use them. (Above-seat steering doesn't usually allow for easy pivoting wrist action, and under-seat steering isn't usually conducive to a strongly curved bar.)

Brakes and shifters designed for mountain bikes tend to work best for recumbents due to the similarity of handlebars.

A bicycle computer can be placed anywhere on the bike as long as you can see it and push its buttons. The main frame, handlebar, and front derailleur "sprout" are

In addition to recumbents, handcycles, and record-setting streamliners, Varna of Canada makes the "U-Bike," a semi-recumbent utility cycle. The rider sits low enough that both feet can rest on the ground at a stop, and the seat back allows the rider to apply extra pedal power.

The BigHA (Apache for "because"), is a feature-packed, luxury CLWB-type recumbent whose seat, back support, and handlebars are easily adjustable. An optional handlebar console includes lights, turn signals, speedo, heart rate monitor, wind direction sensor, and horn. They emphasize high-tech direct ordering via their website.

all suitable spots for instrument mounting. Computers are especially important for faired vehicles since the rider's sensation of velocity, wind speed, and direction is greatly mediated by the fairing. Headwinds are especially difficult to judge. The numbers can help!

The steering console is complete when you add a bell or horn.

Derailleurs, Gearing, and Brakes

It is advisable to use shift levers made by the same manufacturer as your rear derailleur; today's indexed systems aren't always compatible with one another. High-tech gear systems are exceptionally precise and complicated. Mixing components can lead to undesirable performance. The longer cable housings of the recumbent causes some imprecision anyway, similar to an upright tandem, and should not be made worse with a mix of components. When in doubt, check with your local pro shop. Cables with Gore-Tex or Trac-Pearls lining (as used by today's Tour de France heroes) can make a difference, but beware: They're very expensive.

If you're homebuilding a fully faired bike, as long as you can get the gearing you want and it works as you like, that may be enough! You have bigger problems to worry about than transmission. You can make far greater performance gains in other areas; your main concern with shifting might be to just keep it simple.

We have now reached the problematic question of what transmissions work best for the special needs and the diverse array of recumbents. You'll need a wider gear range than an upright bike to make up for the loss of stand-up pedaling. It might have to cover anything from a slow climb to a 40 mph speeds on a racecourse to a 60 mph mountain descent, and it also has to do justice to the recumbent's distinctive cadence needs (see Chapter 4, Physics).

The long chainline of most recumbents has an obvious advantage: The "dead" gears you expect on an upright bike are fully functional on a recumbent. Thanks to the long distance between bottom bracket and cogwheel, the angle of the chain, even at its most oblique, is really very slight. That means every rear cog can be used with every chainring. The gears that would be useless on an upright bike regain their status on a recumbent. Note, however, that if a recumbent is equipped with an intermediate drive, or FWD, dead gears can reappear.

Triple chainrings are very popular on recumbents. A small chainring helps you on big hills, mountain rides, and slow sections. The middle ring works well for city traffic. Descents and races demand the big ring.

If you opt for a triple crankset you'll wind up with 18 to 30 gears, depending on the cogset in the rear.

I use a 32/42/54 crankset with an eight-cog Dura-Ace cassette of 12/13/14/15/17/19/21/24. The 32- and 42-tooth rings help me to manage everything up to a 10 percent grade. The close cog gradations in the rear enable me to shift smoothly, especially in the mountains, and you can quickly jump up 5 kmh by spinning in contrast to stomping, grinding, or hammering. The newer trend of cassettes of up to 10 cogs might be overkill with most uprights, but it works in favor of recumbents, where spinning is a virtue. You can create a workable gear range for mountain riding with even an older 6-speed cogset using 12/14/16/19/24/30 combined with a triple chainring with a granny gear.

Knowing your cadence preferences, shifting style, speed range, bike type, and typical riding conditions will help you select cog and chainring sizes. Remember that small rear wheels require bigger gears. Companies that make parts for mountain bike downhill-racing, with their computer-aided CAD milling machines, are the best source for big rings of 60 to 70 teeth. Rear cogs of only 10 teeth are also available via special order.

Another source to consider is the French company Spécialité TA. They offer crank lengths from 150 to 185 mm and chainrings from 26 to 68 in one-tooth increments. They can make custom rings with up to 146 teeth! The real attraction, however, is their abundance of combination options. They have a bolt pattern for their outer chainring that all their other chainrings are made to fit. Either one or two inner chainrings can then be mounted to the outer one. The one-, two-, and three-ring mounts are all built on the same crank-arm. You decide the number of chainrings simply by how many mounting bolts you buy. Tinkerers have built quadruple cranks from TA parts.

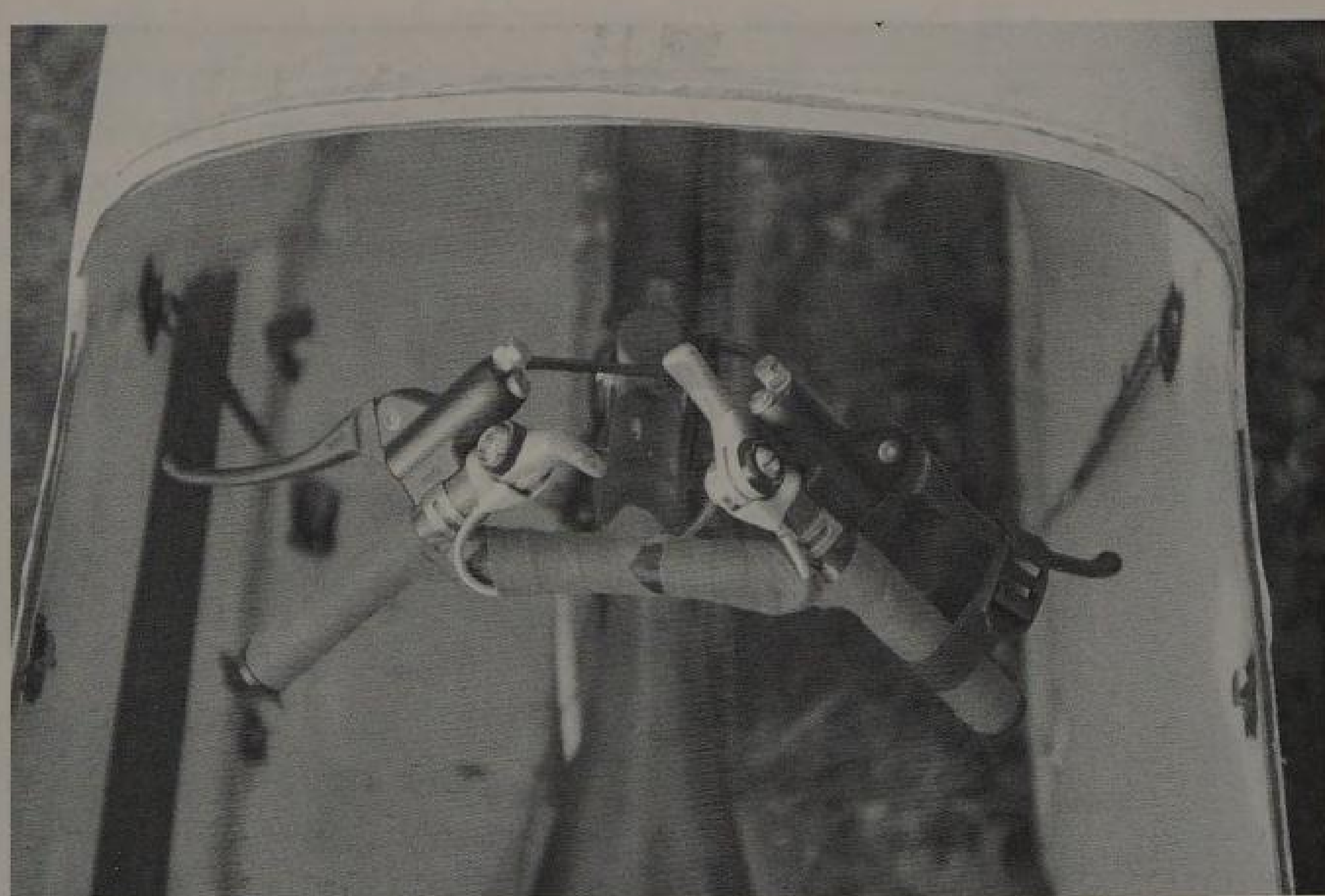
Most recumbents use a long chain—typically made from two bike chains pinned together—which must be kept under tension by a rear shifter pulley tension spring. Because of this extra strain, shifters can die after about 10,000 to 20,000 miles of use. With that in mind, it is advisable to buy a shifter from a manufacturer that sells tension springs individually and whose availability is dependable. In Europe, Mavic, Edco, and Campagnolo are good bets.

There are several recent players in the gearing scene.

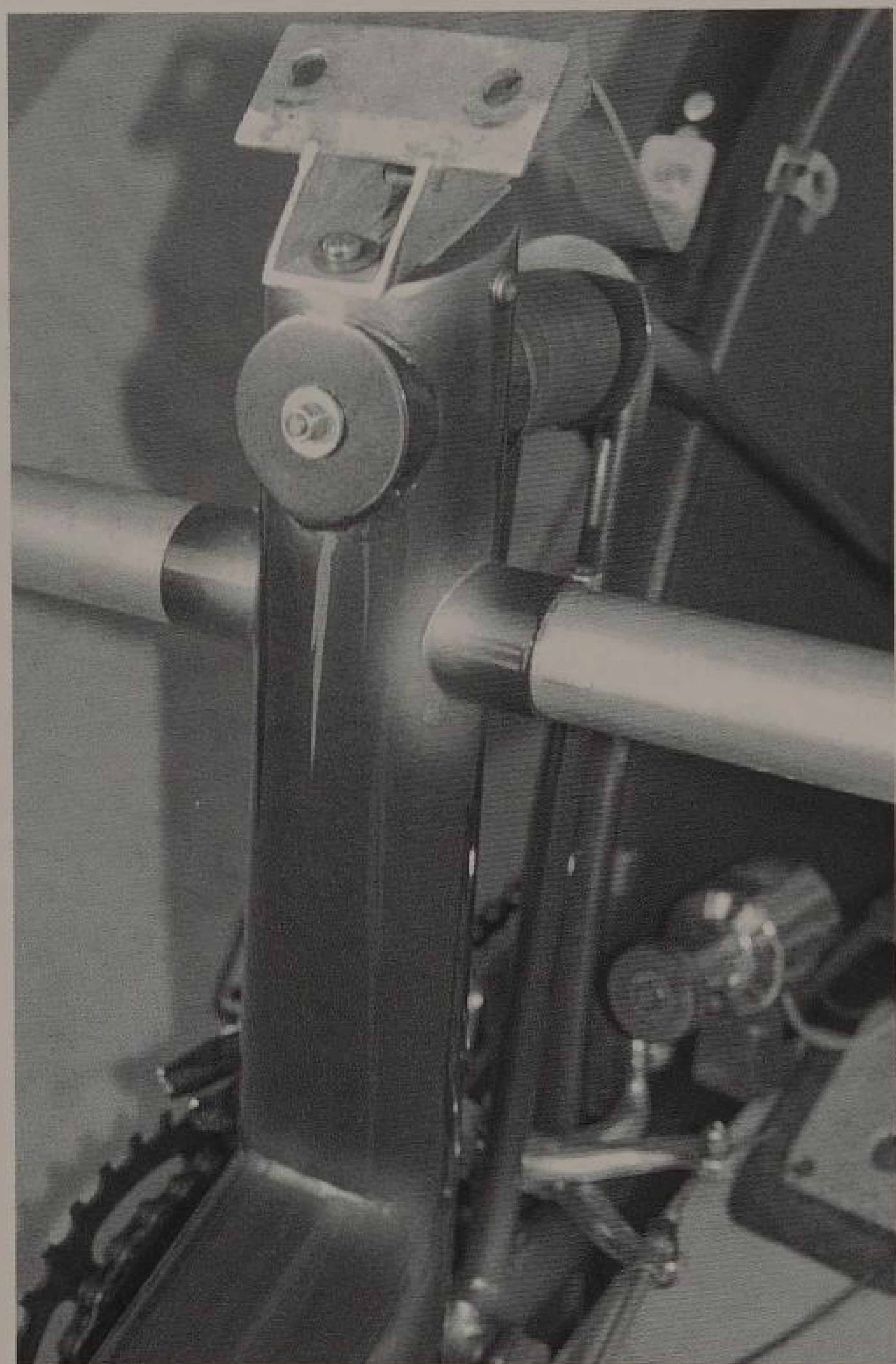
SRAM (formerly Sachs) and Shimano offer interesting alternatives and/or additions to derailleurs. Shimano's 8-speed Nexus is a tidy stand-alone hub gear. While SRAM's Dual Drive 3-speed hub integrates with an 8- or 9-speed cassette.

Rohloff offers its Speedhub with 14 gears, but take care: If you have a rear wheel smaller than 24 inches you will need a big ring on the front for higher speeds.

Another popular multiplier of gears is the amazing Schlumpf Mountain Drive. By pressing a button mounted on the right crank arm with your ankle (easier than it sounds), you can get two gear ranges without altering your shifters or cogset. The gear mechanism is built entirely into the bottom bracket axle. Some record-attempt recumbents are using this device.



A compact "command and control" center inside a fairing.



An elastomer rear suspension, here combined with full-fairing mount. Elastomer is visible at top-rear, attached with through-bolt. Cross-tube attaches to fairing sides.

Manufacturers and homebuilders alike are using these hubs and gears in many configurations, often yielding a huge variety of gears.

All kinds of brakes work with recumbents. Disk brakes are coming on strongest at present, but V-brakes are also a good choice. For moderate terrain, old-style brakes and BMX brakes give the clearance needed for wide tires.

When using high-speed faired bikes and heavier bikes in the mountains, however, you need powerful brakes that are resistant to heat buildup. Some builders have experimented with aluminum heat sinks to reduce brake overheating.

Lighting

One thing shared by all bicyclists—whether they're riders of upright bikes, recumbents, unicycles, or high wheelers—is poor lighting. Both power and reliability are unsatisfactory. And we've become used to it!

There is a world of lighting choices. Some have bright high beams, some have multiple fields, some are powered by generators, and some by rechargeable battery packs. One can now ride in cold or rainy darkness for a few hours before needing a recharge. Dynamos on hub or tire light up quite nicely once under way. The array of options and performance is dizzying. Look for guidance on Internet support groups and at club rides.

High-speed recumbents with full fairings need powerful lights to illuminate farther and wider. You need a lot of light to ride safely at 35 mph in an urban environment; you need to see and be seen. Things happen faster at high speed!

I ride an unfaired recumbent with a Union dynamo, halogen front lights, and Seutec rear lights. I also use the truly perfect Vistalite. Its flickering red LED light grabs the eye even at long distances. LED lights are coming on strong as headlights as well. They're small, bright, affordable, and long-lasting. If a white front LED has a strobe mode, it's even helpful for daytime safety, to alert opposing cars that might turn in front of you.

Overall, bike lighting is improving but there's still a lot of room for advancement.

Pennant

The safety pennant, frequently seen on kids' bikes, is just as useful in protecting low-riding recumbent riders from inattentive motorists. And while a recumbent rider can often make eye contact with drivers of cars, that isn't possible with large SUVs, trucks, and buses. A brightly colored pennant provides an extra measure of safety at little cost.

Rear-view Mirror

It's very difficult on a recumbent to turn around for a look. On some models it's impossible. For that reason, mirrors are key to safe recumbent cycling. One is essential; two provide an added layer of safety. In some HPV competitions, two mirrors are required.

There are many types of bike mirror to choose from. A convex surface broadens the view but shrinks the apparent size of objects in the distance. Glass is the most optically pure and cleans the best, but weighs more than plastic and can pose a danger in a crash. There are models that mount to handlebars, bar ends, and fairings. Some clip to helmets and others affix to your glasses. Riders have even put them on their gloves.

Ultralight Racing Designs

It hardly needs to be said that extra weight will slow you down when climbing hills, sprinting, or accelerating. Serious cyclists spend thousands of dollars to shave ounces from their bikes in an effort to gain critical fractions of seconds.

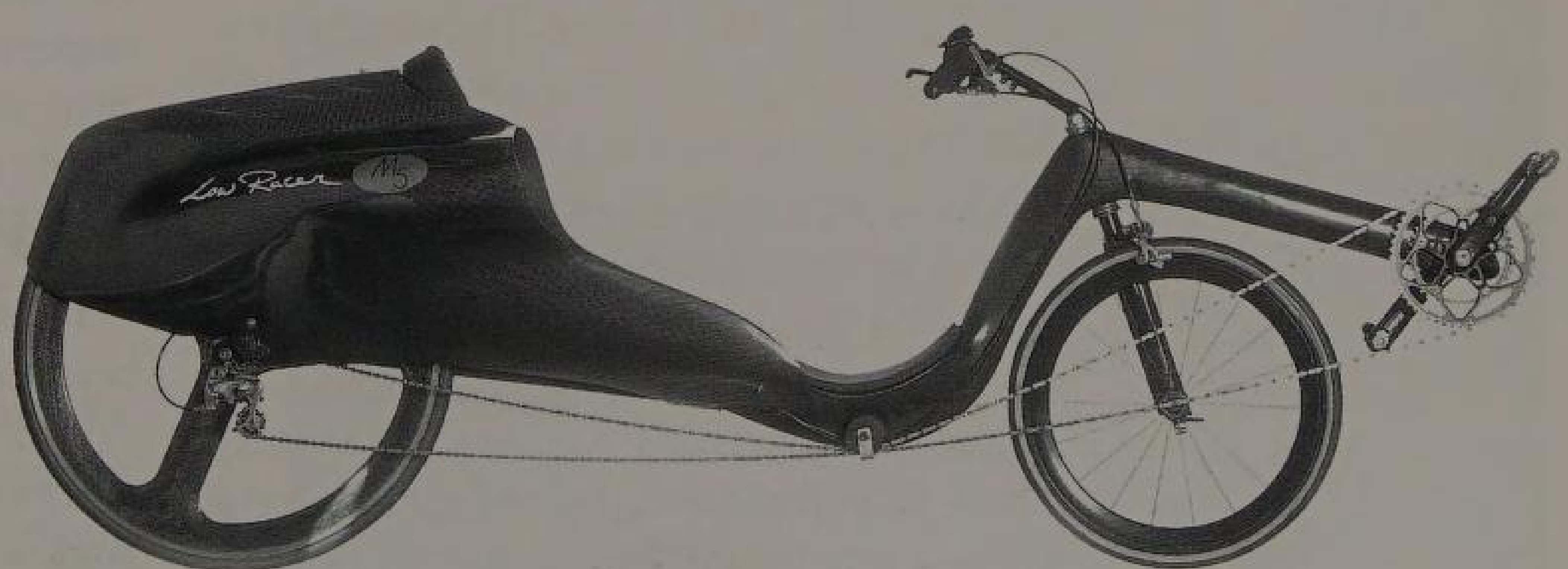
Don't neglect your own weight! Your personal body weight plays a big role in cycling performance. But, since the tuning of a bike requires less self control than the tuning of your own body mass, the first is much more common. It only costs dollars!

It's a given that recumbents, with their larger frames, bigger seats, and longer chains are heavier than upright bikes. Those factors aside, weights are coming down fast as recumbents become more popular—especially among long-distance riders. The market is still small, though, so models in the 20- to 25-pound range cost proportionately much higher. Weights and prices alike will come down when interest finally catches on among bike manufacturers with deep pockets and economy of scale.

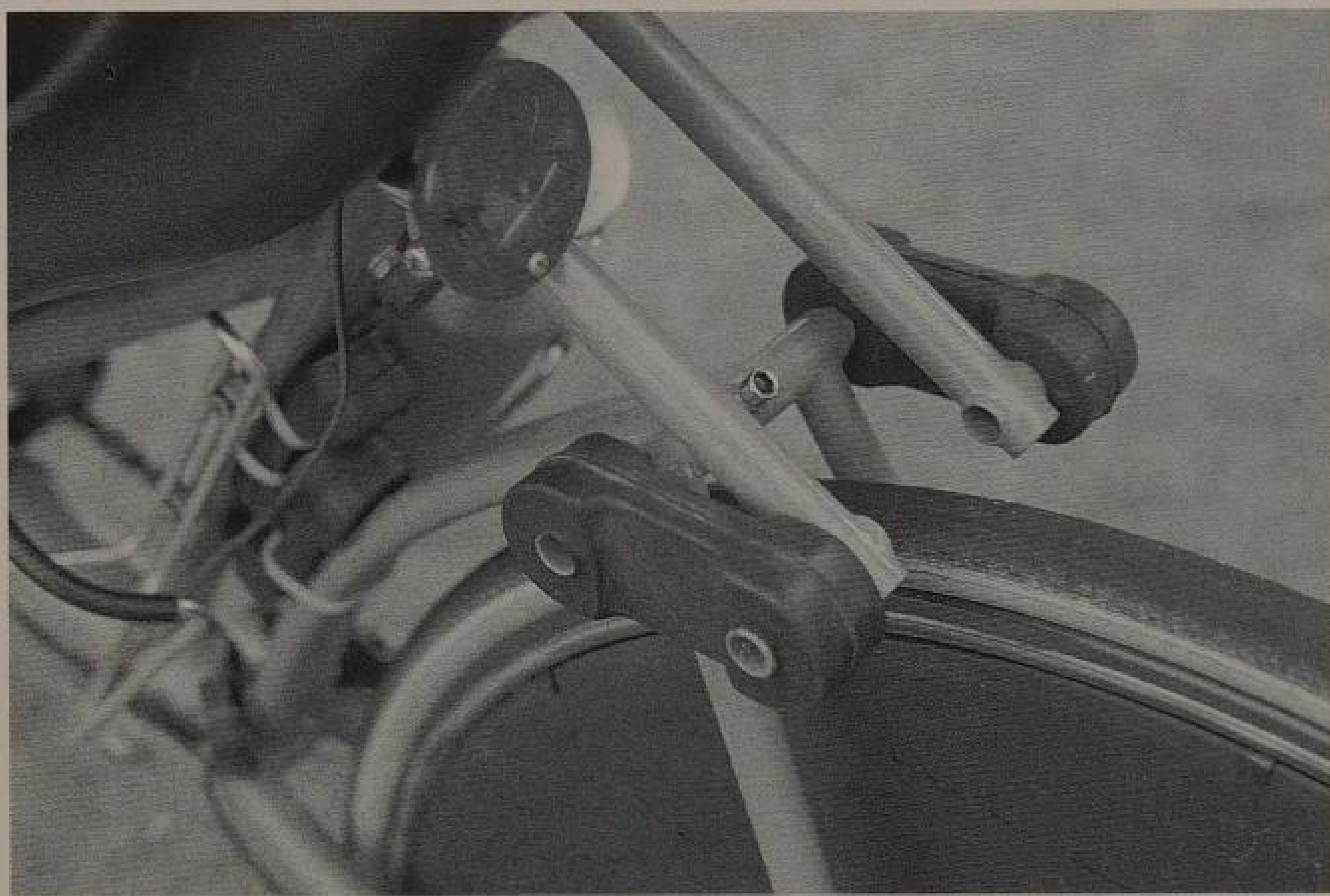
Intense research and development among the large manufacturers has significantly lowered the weight of upright bikes, while little has been done for recumbent bikes. The reason, of course, is the small demand—so far.

At this point, small recumbent builders have made all the significant advances in design, but they are hobbled by cost structuring that favors the large manufacturers. Case in point: The required minimum orders to get good pricing from the renowned ultralight tubing makers are too large for small builders.

Excluded from the cost savings available to bulk purchasers, savvy builders turn their attention to smart construction and clever component selection. This often means they pay a premium in both time and money. In this light, the successes of homebuilt lightweight bikes are nothing less than amazing.



The M5 "Carbon Racer" is one of the lightest and fastest production recumbents, at 9.5 kilograms (21 pounds) with tailfin. M5 holds eight world records. (photo: M5)



An elastomer suspension, where the elastomers are stretched rather than compressed. This is an adjustable design. For a heavy load, just stack or bolt on a couple more elastomers; for a light load, take some away.

"Self-baked" carbon chainrings, light-gauge alloy brakes, and thin-wall fairings on the quality level of a custom body shop or injection-molding plant can be found in many high-end recumbents from boutique shops.

Short of industrial R&D, personal initiative is the catalyst.

The Frenchman Rodolphe Brichet, for example, created a 30-lb fully faired SWB recumbent in 1990. The bike consisted of an aluminum honeycomb frame covered with a carbon-fiber fairing. He saved a few grams with a simple nonindexed 8-speed shifter and by using only a single brake.

It's exciting to behold the constant parade of new designs that emerge from the workshops of dedicated—some might say obsessive—recumbent builders.

Some are feverishly working on the fully faired 22-pound bike. Homebuilders have gotten a bare recumbent down to 15 pounds, while there are three commercially available models weighing less than 20 pounds (from Lightning, Velokraft; M5 has a new 16.5-lb highracer!), with the Lightning R-84 at 28 pounds with full F-40 partial-cloth fairing.

Builders are sharing ideas and plans by way of the Internet and videos for easy-to-build lightweight fairings made of thin-wall corrugated plastic panel and also Zote foam rubber. They are collaborating and sharing information on building vacuum ovens out of bricks and styrofoam, with hair dryers and heat guns designed for "blowing" and molding lightweight plastics. Tricks are shared far and wide for working with high-tech materials, glues, and CAD software. (An easy weight-saving tip for fiberglass: Squeegee out all excess resin!) Folks are learning about carbon fiber, and finding that it holds promise for small shops. Suspension is acquiring some protocols so that each builder is not reinventing the spring, so to speak.

Internet information sharing is helping to solve the mysteries of recumbent design and construction, without any help from the corporate manufacturers.

Materials are available from some high-tech producers eager to create new markets. They sometimes give samples to HPV clubs with the expectation that they will find novel uses and possibly place orders.

To get help with your own project, let other clubs and individuals know what you're doing through the Internet and HPV associations. You might be surprised at the response!

Suspension

Today about half of commercial recumbents offer some form of suspension.

Full-suspension upright bikes are now quite common, thanks to mountain biking. And some of their innovations have been adapted for commuter and even road racing bikes.

Suspension is a godsend for commuters who travel rough roads. Studies from the

University of Oldenburg, Germany, show that long distances on an unsuspended bike can lead to health problems.

Due to your position on a recumbent, the bodily suspension mechanisms of knees, spine, shoulders and elbow joints cannot be used, so external suspension is more important than on an upright bike.

There are four ways to suspend a recumbent: by way of tires, seat, frame, or fork. Adding suspension creates special demands for the framebuilder. The bike's design must leave room for the suspension, and it must account for moving frame parts to prevent collisions between components.

Tire suspension is without doubt the cheapest, easiest, and lightest option. Reducing air pressure raises the level of comfort. However, a general rule for all tire sizes and profiles is that if you decrease pressure, rolling resistance and likelihood of flats increases. On top of that, tire sidewalls can fatigue due to flexing. So keep inflation within the pressure range marked on the tire. However, some tire models are designed with higher volumes and quality casings for good performance at lower pressures.

Another suspension mode should be noted as an effective addition to the list of options. Pantour makes elastomer suspension *hubs* that absorb a half-inch of travel for only a modest increase in weight.

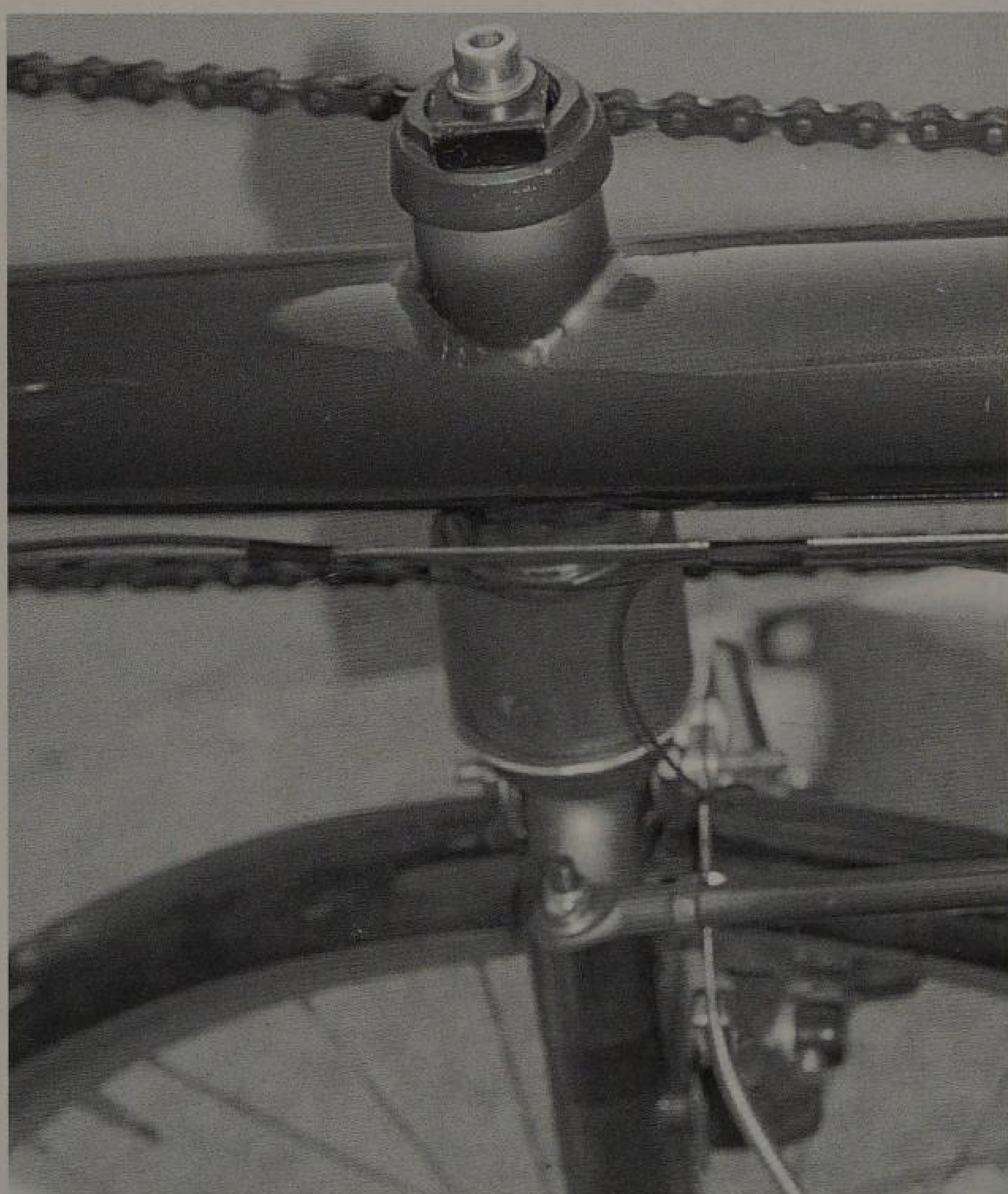
Those buying a manufactured recumbent with suspension don't have to do any planning, of course. Those building their own bike can copy an existing approach. Both groups, however, need to test and evaluate and so are helped by understanding some suspension science basics.

Seat and frame suspension can be achieved via tension or pressure. Pressure options include rubber and polyurethane blocks, coil springs, and fluid or air springs. Spring numbers tell you by how many Newtons the suspension power rises per centimeter of compression.

When two springs are installed next to each other using the same lever, the spring numbers are combined and the needed power doubles. A spring twice as hard is the consequence. Conversely, the powers are divided by half if two springs are mounted in line. Spring travel is twice as long as any given strain on the springs.

Spring forces are usually transmitted with the help of a lever to keep the size of the suspension mechanism small. That means that the spring lies closer to the pivot than the wheel. If the rear axle is 20 inches from the swinging axis and the spring is 10 inches from it, you arrive at a 1:2 ratio.

Selecting the suspension element should be done with regard to the work capacity.



Suspension in the steering head tube requires careful mounting and planning. It is only feasible for those with strong technical abilities.

This term signifies the maximum strain capability of an element, and it should not, for safety reasons, be exceeded. Based on my experience, I recommend a 2-to-2.8-fold statistical burden. If the suspension is fine-tuned according to the lever relationship, then the suspension will never reach its maximum point, and you can expect it to be comfortable. The work capacity can be deduced from the maximum extension and its power, thereby, in this formula:

E (work capacity) = 0.5 P x s
s = maximum extension
P = apparent power

An effective, but complicated front wheel suspension.

For example, imagine mounting a suspension system directly to the rear wheel that is supposed to resist a statistical strain of 720 Newton. You arrive at a maximum impact of 1800 Newtons. If you desire a total suspension travel (which includes the weight of the statistical strain) of 18 centimeters, it demands:

E = 0.5 x 1800 x 18
E = 900 x 18
E = 16.200 Newton/centimeter = 162 Nm

The decision could be made in favor of four rubber blocks with a work capacity of 40 Newton-meters each.

Then there is the question of the positioning of the rubber blocks. The lever relation at the pivot plays an important role. If you position the blocks in parallel, with a lever ratio of 1:2, you will gain the same effect as if you had positioned them in line and made the ratio 1:1. If all four blocks are switched to a lever ratio of 1:1, the statistical strain on each block would be marginal, about 50 percent less than the previous set-up. However, you'd get a suspension as hard as a board because of the doubled spring number. If you use only two rubber blocks and one lever arm of 1:2, the suspension would be all right but the blocks would be overburdened.

Strain on springs can be calculated very well on paper, but it is more complicated when actually building a frame. It is even more complicated to determine the assumptions about the strains that form the calculation basis.

If the individual dampening frequency is about 200 cycles, it causes a noticeable reduction in frame stresses but no comfort. A desirable comfort starts with about 150 cycles. The dream-like feeling of gliding over pavement as if on a sofa kicks in at about 120 cycles a minute or less.

Suspension critics often point to energy loss. They believe that suspension costs energy. Werner Stiffel, an expert in the field of recumbent suspension, holds a different view. He contributed a calculation for the correct position of the pivot point:

"Even a badly constructed suspension that seesaws during pedaling only consumes the energy of the friction in the suspension parts. However, the pedaling suffers and becomes inefficient. This can be avoided by choosing the proper pivot point. The calculation is not so easy though. You must not only consider the rhythmically changing chain pull power, which kicks in at the tire resistance point and which works horizontally. There's also the acceleration power, which includes a pulsation, as well as a residual strain. These three powers have to be summed up with vectors. The optimum pivot point is located on the resulting vector. The conventional LWB recumbent has a turning point at about 12 inches below the power side of the chain. Bikes constructed like this have already proven their suitability in competition."

The overall energy equation tells the final story. Are the power losses and distortions attributable to suspension smaller than the power that would be lost otherwise due to ground unevenness? If a suspended rider can pedal with disregard to ground conditions, he will crank more efficiently than without suspension, and will save energy that would have been lost to bumps and vibration.

Kickback, or pogoing, as mountain bikers call it, plays an important role in the suspension of the drive wheel, and its three individual effects influence pedaling smoothness greatly. Avoiding it is critical for efficiency. If you are aiming for mutual independence of drive and suspension, you have to avoid any kind of pogoing.

Pogoing (or kickback) means:

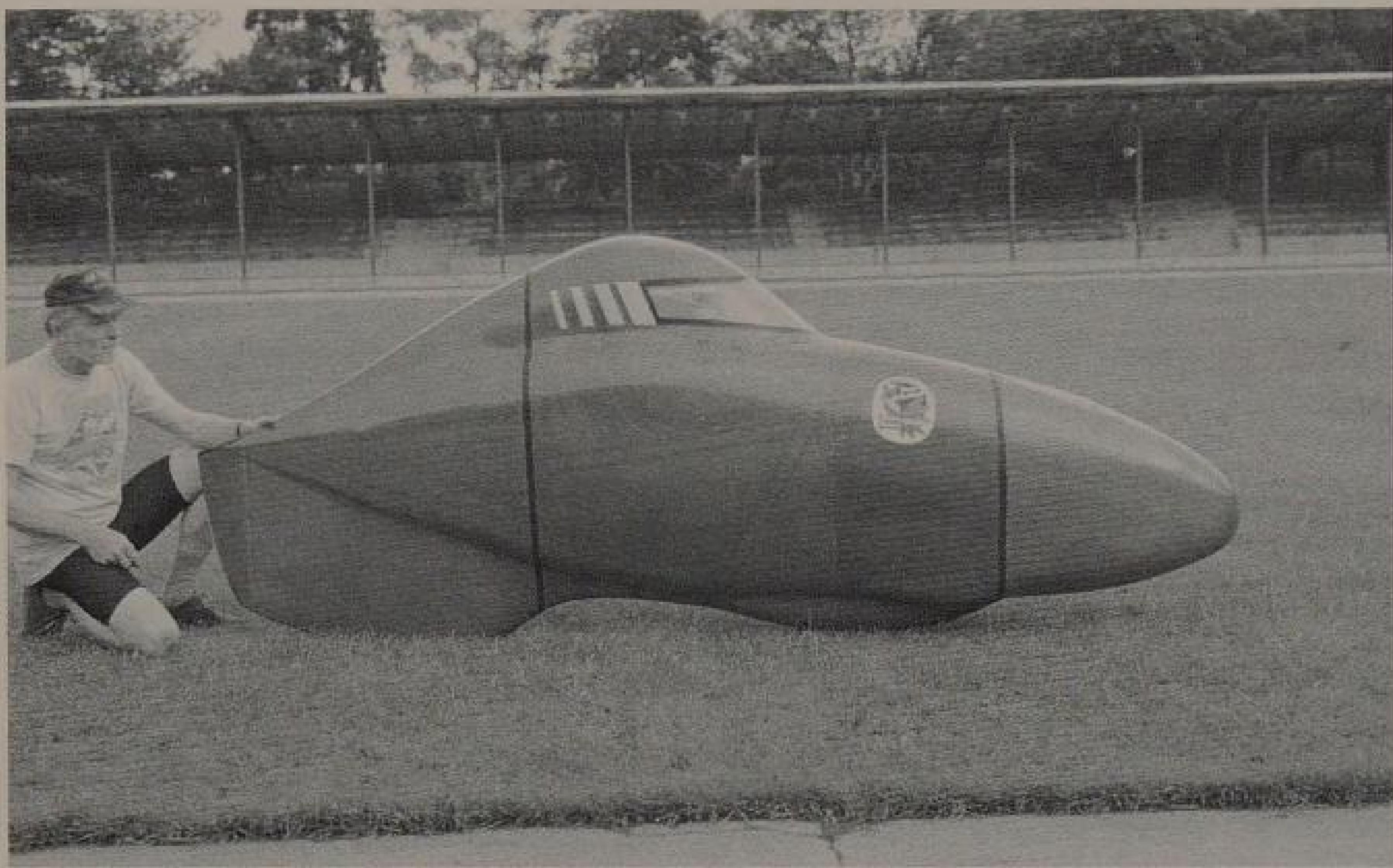
- planetary movement
- shifting movement
- extension/shortening of the part of the chain that is under tension when you are pedaling.

Various items can be used to create suspension. Here, somebody used the pistons from a car trunk lid.

These effects, their significance, and the design possibilities of influencing them are very complex. A detailed description cannot be given here, but look into literature on motorcycle design for more insight. Information about specific suspension problems (and more importantly, their solutions) are summed up in Werner Stiffel's illustrated essay, "Suspension," available online as "Federung" and translatable via Google.

An online program at the Web site Kreuzotter.de graphically displays the effects of position and quality of various suspension elements (this site offers other interactive cycling calculators as well, such as for rider performance for various bikes and conditions).

The terms attenuation, damping, and "stiction" are often used in context with suspension. They refer to kinds of friction in suspension, such as bearing friction, inner material friction in PV-blocks, and fluid



Resembling a spaceship, the "Nilgo III," designed by Raymond Brichet of France, weighs only 30 pounds.

friction in hydraulic absorbers.

A suspension without attenuation would never stop oscillating once set off by a bump in the road. If a second bump followed, an unpleasant vibration would result. Thus it is necessary to attenuate the suspension, i.e., to destroy the vibration energy.

Expert builder Martin Staubach says:

"An attenuation is ideal if it damps during compression lightly and more strongly during expansion, to prevent over-vibration. Hydraulic damping elements show this behavior. Friction attenuation is simpler. A tightly fastened pivot bearing is representative—it's simply hard to move. The general reaction of this system, however, deteriorates; and even when it's working fine, bumps are not absorbed very well. A good compromise between elaborate hydraulics and friction damping are polyurethane suspension elastomers. They possess a large amount of self-attenuation."

A gas and coil suspension with hydraulic dampeners would be ideal. Progressive suspension is preferred. A suspension is called progressive when it reacts to soft nudges without losing the capability to counter harsh bumps. This principle is standard with automobiles. With growing compression, the suspension becomes harder.

A simple suspension is often not enough; it should be adjustable. On weekdays you ride to work with your briefcase, a change of clothes, and a lunch box; on weekends you tour or train. Different riding contexts require different suspensions. Short of having a different bike for every situation, it's helpful to have an adjustable suspension.

And you can.

With rubber block suspension, a set screw can adjust the fasteners. If you have elastomer ring suspension, the number of rings will vary the results. If the suspension is cleverly constructed, you can change the lever ratio with a few turns of the hand, which is very efficient. Leaf spring suspension can be changed by adjusting leaf-length (length relates to the strength-number of a leaf spring raised to the fourth power—so a slightly longer leaf really softens the ride).

Suspension at the Front Wheel

LWB recumbents rarely have suspended front wheels because it carries only 23 to 35 percent of the rider's weight, and the long lever arm makes bumps less noticeable anyway.

But this lighter axle load can make a front suspension helpful for safety reasons, because it greatly improves the tire's contact with the pavement. Without suspension the front wheel can bounce, which can lead to loss of traction, especially in corners, creating a greater risk for an accident.

The situation is different on a short bike. Here the weight distribution is closer to evenly split between front and rear, so that a suspension noticeably improves both comfort and handling.

The growth of the mountain bike market brings many new suspension forks and systems to stores and catalogs. Inexpensive systems from the Far East are probably cheaper than what you could build. Twenty-inch suspension forks are now available for recumbents from Meks and White Brothers, as well as from BMX producers. However, none of the available suspension forks are optimized out of the box for use on a LWB recumbent. They are too firm for the relatively small load, since they are designed for greater weight on the wheel. So you have to go to a manufacturer who offers custom tuning kits.

Rear shock units are also available, but a homebuilder will have to create the pivot and mounts.

Interested in building your own fork? You can modify a Manitou suspension fork so that it is suitable for a 20-inch wheel—but only when using disk brakes or a Magura cantilever brake (whose bosses are mounted the other way around).

Clothing

While it is easy to equip a recumbent with conventional bike parts, it's harder to satisfy a recumbent rider with regular bike clothing. The recumbent position creates clothing needs that are quite different.

Leaning Back Instead of Bending Over

Cycling jerseys with back pockets on the rear aren't any use to a recumbent rider. Luckily, there are several companies now making jerseys with pockets on the front.

In the case of jackets and jerseys, the extended back that is so helpful on an upright bike is just extraneous material for a recumbent rider. Front-fastening raincoats and shorter front lengths can leak due to the puddles that can form in the belly area when riding in the rain. Pullover rain jackets work better for recumbent riders.

From an ergonomic standpoint, the recumbent position demands special attention to everything. For instance, the helmet has to be adjusted to keep it from sliding into the back of your neck and prevent the strap from digging into your throat as you tip your head forward instead of back as it was designed for. The more reclined the angle of the seat is, the stronger is this negative effect. Unfortunately the market doesn't offer helmets with enough adjustment possibilities. Of course you should still wear one anyway.

The Wind Takes a New Approach...

Skintight biker pants with chamois crotch inserts are not necessary on the recumbent. Nonetheless, I advise you to wear them. They prevent abrasion, smooth the airflow, and—depending on the material they're made of—wick perspiration from your body.

Flapping casual shorts can parachute in the wind, creating drag. And I know of one recumbent cyclist who caught a bee in his shorts—certainly not a desirable travel companion.

Bike shoes with holes in the soles can cool your feet very nicely. Very nice for hot-weather riding, though there's a small price to pay in wind drag. For cold-weather riding, perforated soles are not such a good idea.

Volae president Rolf Garthus takes a winter ride on one of his company's highracer recumbents. Garments with double layers on shins and butt, as well as under the thighs and arms are ideal for cold-weather riding.

Typical bike pants for cold-weather use are made for protecting vertically positioned legs. They usually have extra layers in the upper thigh area, shins, and kneecaps. On a recumbent, insulation is needed instead in the *under*-thigh area. I also recommend extra layers for crotch and butt. Pants should have elasticized cuffs or some means of fastening them tightly. Loose pants will inflate, whip, and make your legs cold. Also, because your torso leans back instead of forward, so your waistline also needs to be kept snug and insulated.

Bike clothes that fit the needs of recumbent riders aren't available in many shops. Even specialty catalogs may not have exactly what you want. You may have to modify or make your own.

Different recumbent designs create different clothing needs. Racing machines with a high bottom bracket (10 inches above the seat) expose the underside of the legs even more. Airflow over a low-crank recumbent (most long-wheelbase recumbents) more closely resembles that of an upright bike, making conventional bike pants a viable option in old weather.

This team of Optima lowracers uses carbon rear fairings all pulled from one mold, greatly economizing on time, labor, and costs—and giving the team a stylish, unified look. (photo: www.tim.be)

Hand position varies from one recumbent to another too. Under-seat steering puts your arms in the same position as you would have on a diamond-frame bike—their fronts need to be kept warm. Above-seat steering with straight arms or arms bent upward necessitate tight cuffs, and extra insulation along the undersides of the arms.

Designing a Fairing

Every recumbent rider dreams of a streamlined fairing that allows high-speed travel even in strong winds and bad weather. This dream—seemingly straightforward—often becomes almost unsolvable in practice (Chapter 4 gives some insight why).

The following will help you to compare the available options and to design your own solution. Detailed "how-to" information follows in Chapter 6.

Faired bike performance in high-speed sprinting shows what is possible aerodynamically. Georgi Georgiev's Varna Diablo II, with an effective front area of 0.191 m^2 and a *Cd* value of 0.097, combined with Sam Whittingham's not-inconsiderable personal effort, achieved 81 mph for a 200-meter sprint in 2002.

In the world of everyday riding, we have to put a big emphasis on convenience, access, reliability, cargo-capacity, weatherproofing, and crosswind stability. These are areas that record-setters don't have to worry about.

(Don't you wonder why more upright cyclists, with their aero-bars, aero-frames and aero-wheels, don't add small fairings? Fairings could easily integrate with the aerobar, streamline the saddle and other areas for more speed.)

One has to remember that fairings don't perform miracles. Easy gains of several miles per hour can be made with a commercial front windshield fairing for bikes that start out with poor aerodynamics, such as city bikes have, whether recumbent or upright. Improving beyond this for such bikes is more difficult.

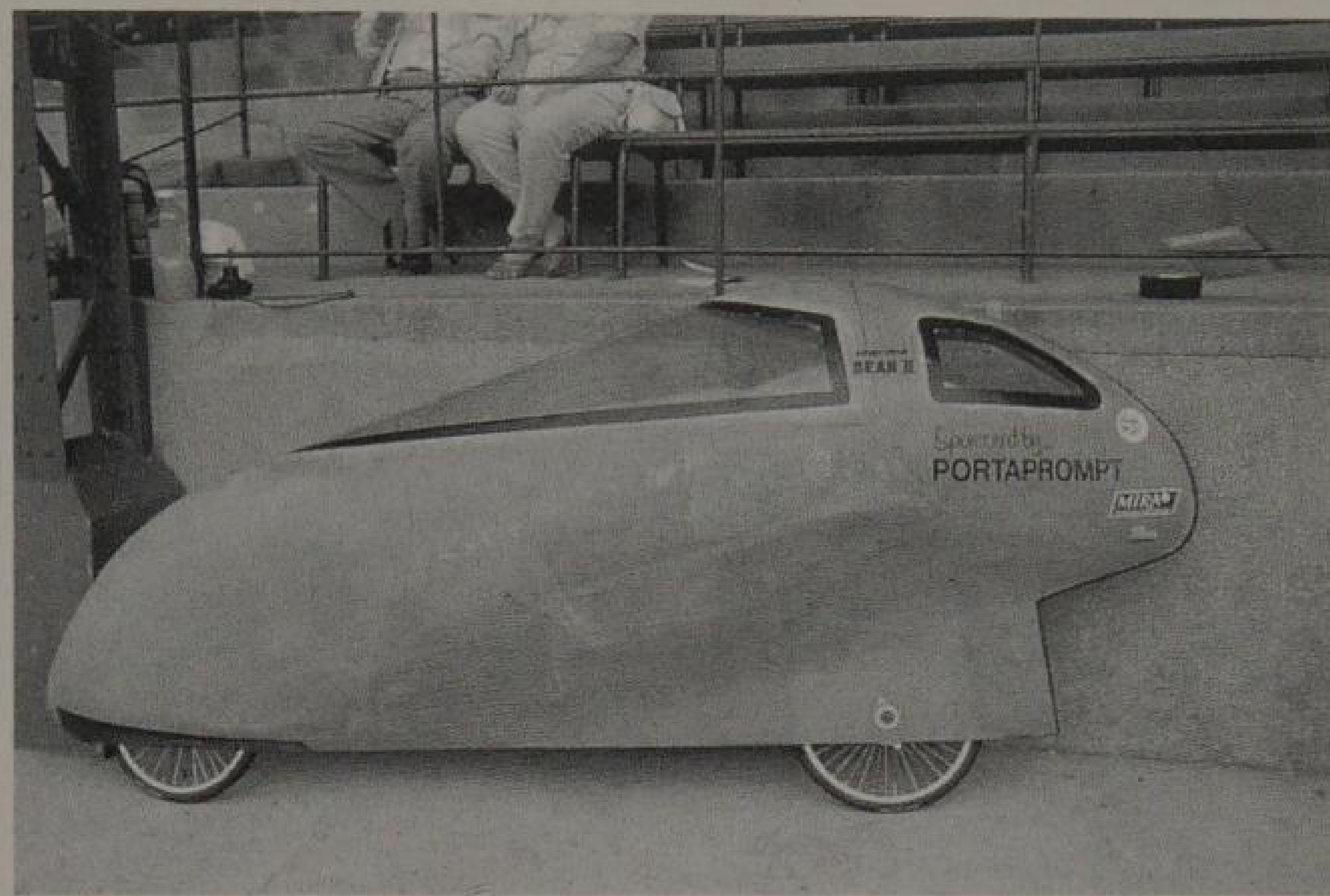
Still, the gains can be a thrill. Say you start with a trusty bike that you usually ride unfaired. Now you add a fairing or two. Suddenly you get a couple free gears. You're spinning out your old top gears. The wind noise is suddenly much reduced. You stop pedaling and coast at high speeds for long seconds more than ever before. What fun! Maybe you eventually create your own full fairing. You pop it onto your faithful steed. Now the cars only slowly pass you and you roll fast far up the hills. Amazing!

The need for speed is addictive. But you do have to be more careful on windy days. There are many new things to learn about faired HPV speed—pro's and con's alike.

Riders of lowracers find that tailboxes are more effective than nosecones due to their already small frontal areas. These bikes, again, get their best speed gains with a fairing in the area of primary drag.

Each fairing element beyond the first seems to give just one or two mph of gain. As with any bike, each mph at the higher end is harder to achieve. Getting more than 5 mph or so of extra speed becomes very difficult, as you are now in the area of full-fairings where surface perfection is essential. Overall weight also becomes a major factor, along with drive-train friction, ease of entry/exit, frame stiffness, and stability in crosswinds. But if all this is achieved, one can do amazing things! Still, the easiest gains come from fairing your primary area of drag.

The simplest fairing starts with a "nose cone" or windshield mounted in front of the bottom bracket, which hides the rotating legs from the air stream. These fairings can be built readily from fiberglass (details in



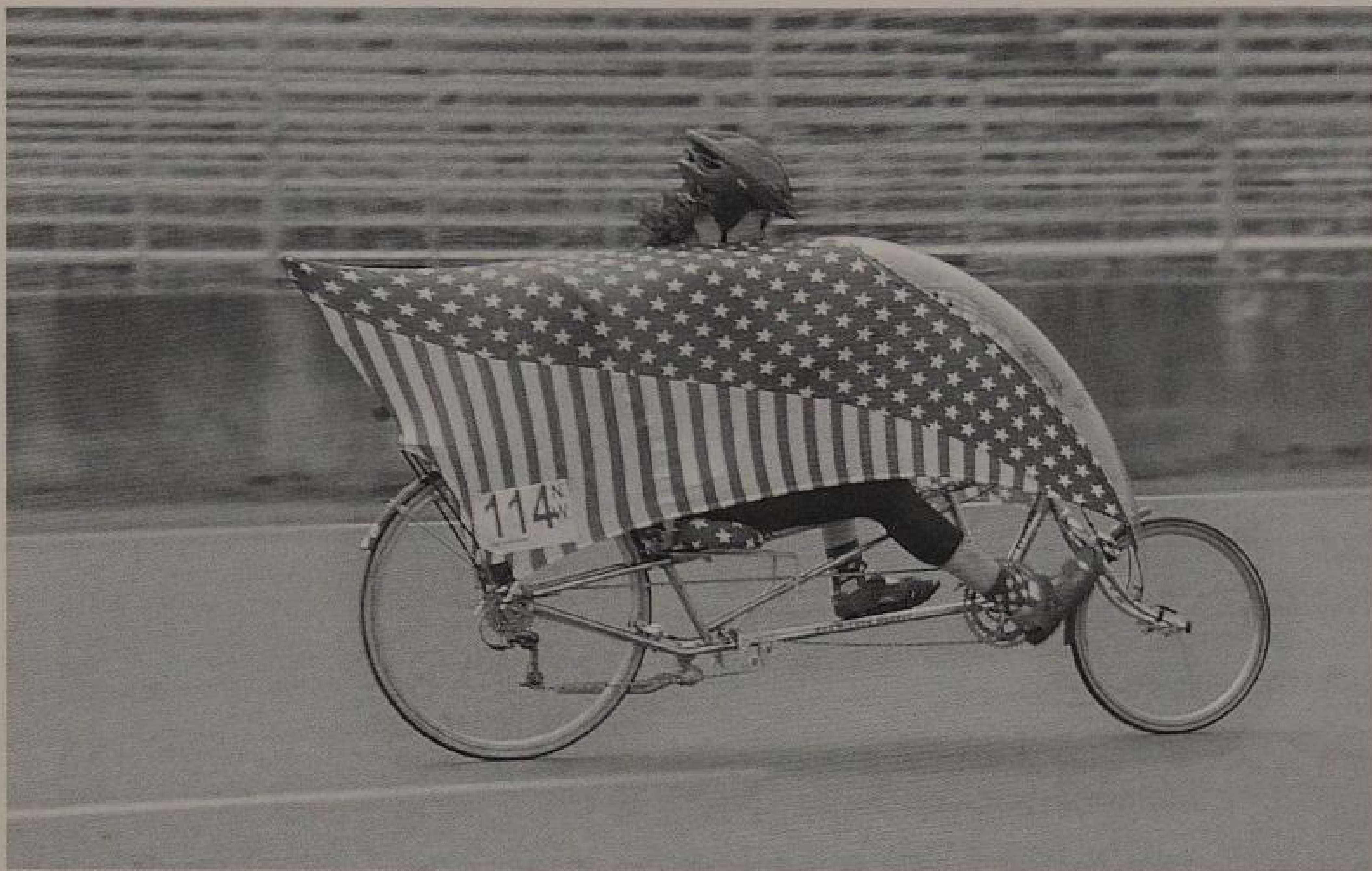
"The Bean II" is the successor model of "The Bean," which held the Hour world record in 1990. Human-powered vehicles have to be slim, light and as aerodynamic as possible to achieve record speeds.

the next chapter). A similar fairing at the rear, called a tailbox or tailfin, helps the off-streaming air reunite in a clean line to prevent rear turbulence. The rear fairing can be readily configured as a trunk and tail-light mount.

Fairings can be made in a variety of shapes, and their large side area allows for creative graphic expression, if you're so inclined. Advertising on fairings is a possibility as well.

Fairings offer significant crash protection. Sam Whittingham crashed at 80 mph in his Varna—without injury. Obviously, everyday riders can also benefit.

When built for speed, a fairing is, above all, characterized by a very small frontal area. Based on the measured height and width at the heels, feet, shoulders, steering mechanism, hands, head, seat, and rear wheel, a plan can be made. To determine the fairing form, you connect the individual points that you have measured so that they surround the rider. You then smooth this edgy outline into a streamlined form similar to a water drop or airplane wing.



Laurie "Wo" Smith uses a variety of affordable colorful bodysock cloth fairings in combination with a standard clear plastic front fairing for racing and day-touring with her Tour Easy.

It may be helpful to look at the aerodynamics studies developed by the auto industry. Designers there put into practice the results of their experiments in wind tunnels.

You can buy manufactured fairings from several suppliers. For simple, clear, effective windshields and partial nosecones that quickly mount to a variety of popular bikes, consider the Zzipper or Mueller Windwrap. Novosport sells carbon tailboxes and nosecones, too. If you want something faster that nearly encloses you, your options narrow and you may be left building your own.

To build your own fairing, the first step is to sketch a plan. Once the basic form is put on paper you need to ensure that the contours of the fairing are large enough to contain the bike and your body in all positions and extensions.

Trace an outline of the fairing with chalk on a wall, and put the bike in front of it and sit on it. Have another person check whether your simulated movements stretch beyond the drawing's borders.

The same holds for the front view, though it is a little more complicated because of the distance of the feet from the rear wall. A camera can help you see what may not be discernible to the human eye. Take photos with a long focal length lens and a tripod. This will yield a photo where both forward feet and rearward wall outline are in focus; then evaluate.

Don't forget to include an exit, and make sure you can get your feet on the ground quickly. Otherwise your fairing may become a riding coffin!

The steering range of the front wheel must be unrestricted, as well as the shifters and chain pulleys. You should also have easy access to water bottles, lights, and shift and brake levers.

The next step is to build a model.

There are three fairing types:

- cloth
- foam rubber
- hard shell plastic

Advantages of a Cloth Fairing:

- light
- foldable
- inexpensive
- easily constructed
- easy on, easy off
- can double as a rain parka, tent, etc.
- easily repaired
- adjusts to bike and cyclist
- quiet

Disadvantages:

- water gets in through attachment points
- more sensitive to crosswinds
- less aerodynamic

Advantages of a Foam Rubber Fairing:

- light
- can be constructed in separate parts
- easy to shape into 3D curves
- can be used as a sleeping mat or tent
- simple to adjust
- quiet

Disadvantages:

- limited shapability (without surgery)

- mediocre look
- rough surface
- cannot always be painted

Advantages of a Hard Plastic Fairing:

- very aerodynamic
- moldable to any shape
- holds shape well in strong winds
- easily waterproof
- less sensitive to crosswinds
- protection in accidents

Disadvantages:

- often uses toxic materials that pollute the environment and are harmful to work with
- time-consuming construction and installation
- easily damaged
- noisy
- expensive

Cloth Fairings & Bodysocks

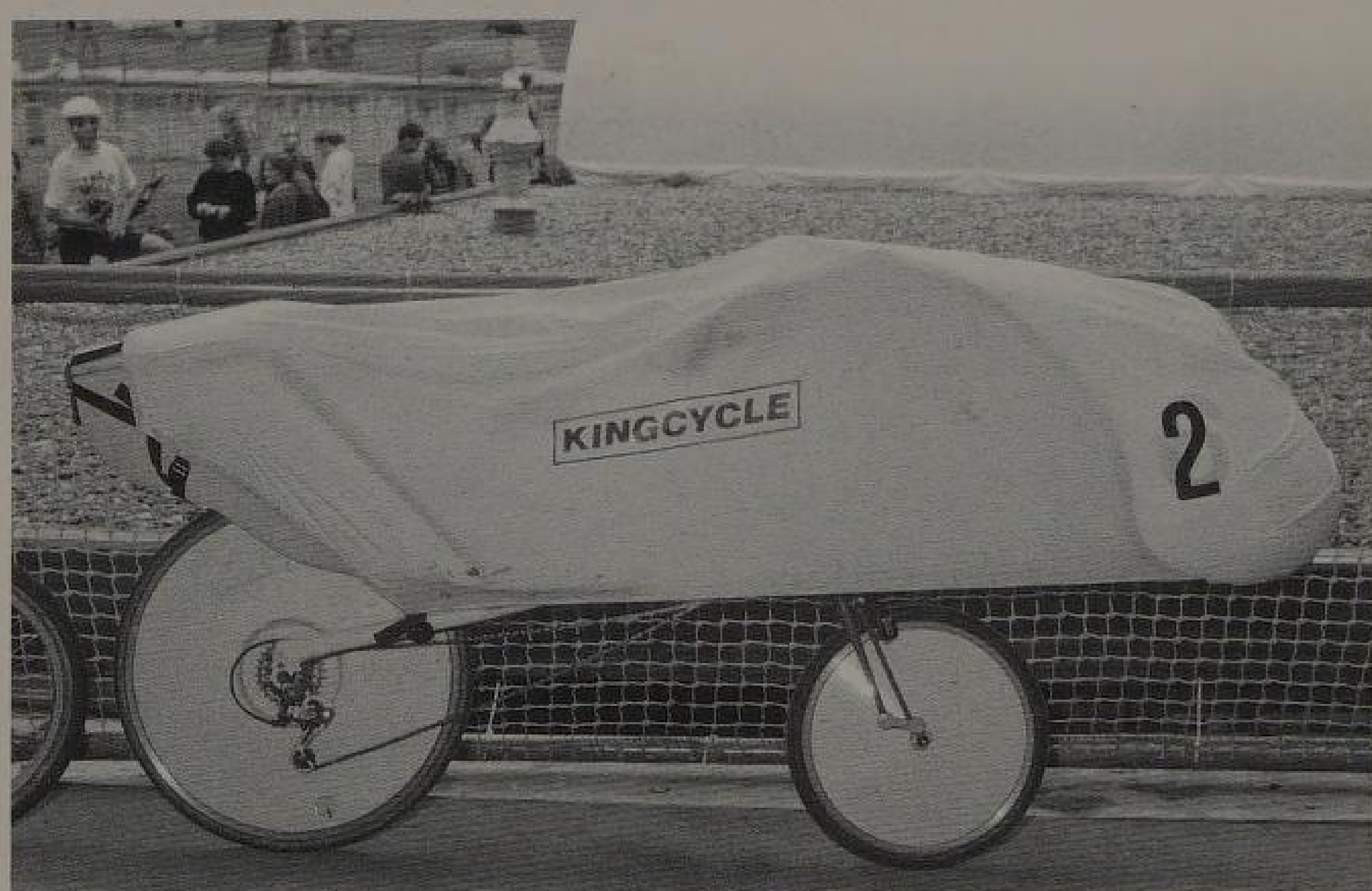
Since cloth does not hold its own shape, a cloth fairing requires a skeleton of some kind. A skeleton made of tubing that starts in front of the bottom bracket and encompasses the rotating radius of the legs, surrounds the rider's body, and ends behind the rear wheel results in a sort-of torpedo shape.

Hollow fiberglass rods can be connected like tent poles with sockets or internal cabling for rigidity. The goal is to create a frame that can be mounted and removed quickly. Tent poles can even be recruited for this purpose. (And then converted back to tent-use for camping at night on tour!) All you need is a cloth covering tailored to fit. Parachute silk and sailcloth are very light, UV-resistant, waterproof, tear-safe, inexpensive, and easy to sew. These materials are usually better than Lycra or Spandex since they don't stretch. Stretchy cloth sags in the wind and should only be used in areas where strategic "give" is needed.

The Easy Racer's Tour Easy is a bike that is often used with a cloth fairing, which, because the rider's body contacts it quite a bit, is called a bodysock. Several businesses offer colorfully patterned bodysocks and pennant-pole kits to fit this bike, as well as other LWBs such as the RANS Stratus. The bodysock stretches over a standard clear plastic front fairing and pulls back to slip over a pole mounted to a rear frame or rack. The simple, lightweight result adds a few miles per hour of speed in mild conditions.

To make your own template from bed sheets fastened with straight pins. In this way you can adjust repeatedly as you determine the fit. To insure good aerodynamics, the front should have as few seams or flat spots as possible.

When the template is finished, you have to determine the position of the zipper, Velcro, or snaps for the exit. A piece of sewn-in stretch cloth brings the necessary tension into the overall fairing. Some place



The compact "Kingcycle" SWB was sold with optional rear fin, front nosecone, and a cloth fairing, making for a fast club racer.

where many seams come together is a good spot. This is often at the nose of the fairing. Although the stretch piece produces somewhat more turbulence than sailcloth, the damage is offset by being in such a small area.

Next, the pattern is cut—in as few pieces as possible. (Don't forget to add a few centimeters for seams.)

You can integrate your head profile into the fairing if you choose. Make the skeleton higher and broader in the head area and sew in a transparent plastic cowl. Transparent plastic such as that used in windsurfing sails is very suitable. Treated with a product like Rain-X, water runs right off and your sight remains unobstructed. For best results, keep the windshield small and close to the face.

Because a cloth fairing can be taken off completely, it can also be used for other purposes. Some HPV buffs in the Netherlands have made a design that can be used as a one-person tent. This is very practical on tours as the same item fulfills two purposes and a large amount of weight can be saved.

Harald Winkler and his "Meufl" foam fairings combine advantages of both cloth and fiberglass fairings.

Apart from the light framework option, where the cloth fairing is stretched over a solid nosecone. When the cloth portion is stowed away—such as during strong sidewinds or when doing urban exploring—the bike is still partly faired.

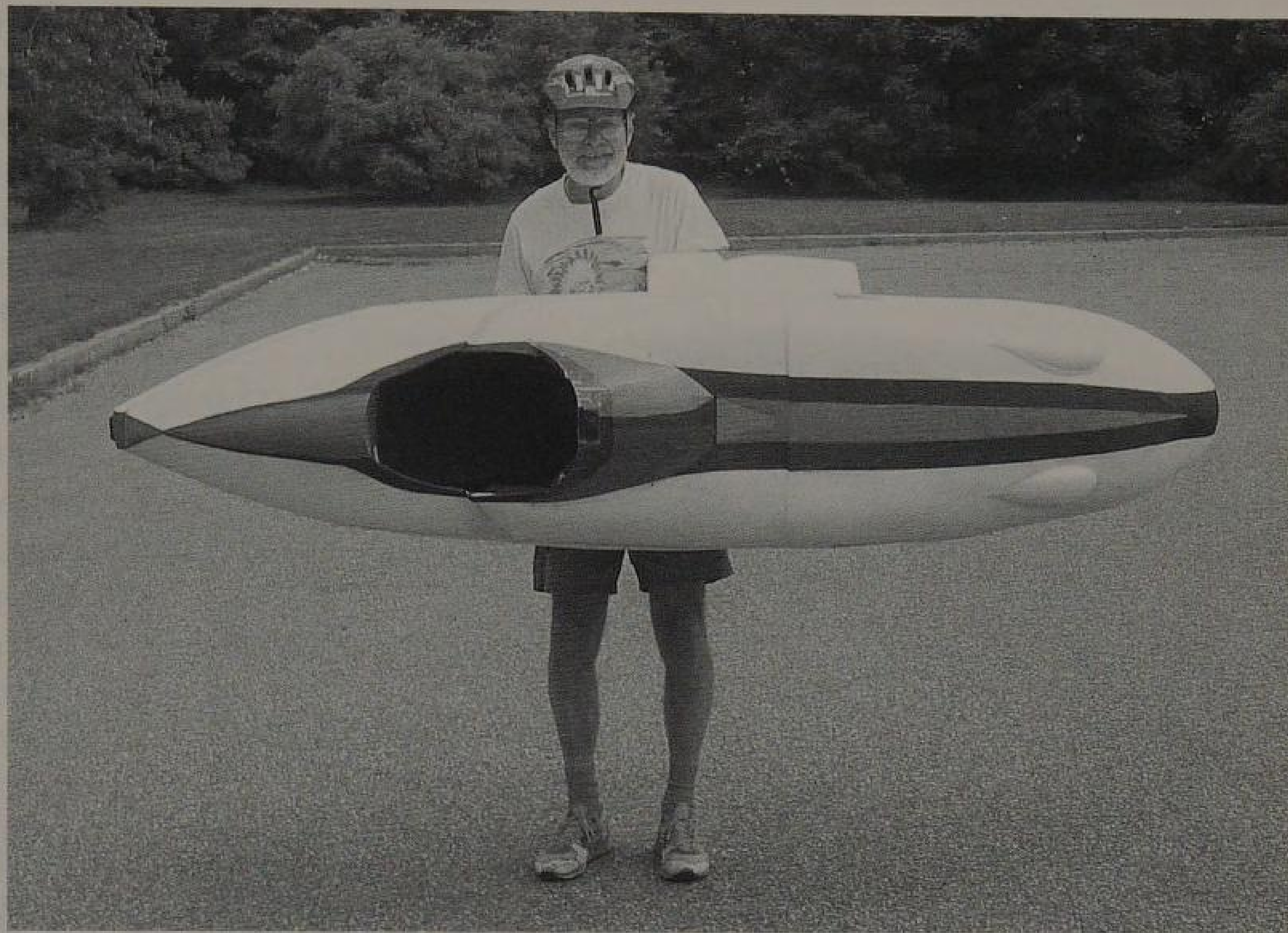
The nosecone, in this case, has to be constructed specially for such dual purpose, as it determines the shape of the cloth fairing. The radius of the rotating knees and heels have to be considered in the height and breadth of a partial fairing. A part of the nosecone usually supports a framework above the shoulders, the cloth then adjusts itself to the rider's size and the luggage in the back.

The end of a cloth fairing is secured by slipping it over a vertical rod at the back of the bike, completing the fairing. Instead of this light and simple solution, you can also use a rear tailbox over which, similar to the front cone, a fairing "sock" is stretched. As cloth always stretches tangentially between points of contact, this fairing type can acquire sharp "edges" and flat spots, reducing aerodynamic qualities.

The variability of the cloth produces concavities in the sides during strong crosswinds and high speeds. These will cause aerodynamic problems and increase handling stresses. Basically, you get blown around more, which is not always safe or relaxing.

Lastly, cloth can be used to create stretchy doors and "bomb-bay" floors to close off openings in hard-shell fairings.

Foam Rubber Fairings



At age 74, John Tetz loves streamliners and innovating with foam rubber. He cruises at 33 mph in his 33-pound streamliner made from vacuum-blown Zote foam (gives a 9-lb full fairing).

The German Harald Winkler was the pioneer in the field of foam rubber fairings for recumbent bikes. At the beginning he laughed at the idea of fairings made of foam rubber, but he discovered it to be a fully acceptable alternative to the two traditional fairing types. More environmentally friendly and less process-sensitive (or intensive) than a hard plastic fairing, more stable and safer than a cloth fairing, it is also very light, and it both absorbs shock and doesn't slide far in crashes.

More recently, in 2003, 74-year-old American John Tetz developed an effective new foam fairing by vacuum-forming Zote foam sheets, to create a 9-pound full fairing, which he fully describes at Recumbents.com. It lets him cruise at 33 mph on flat sections of the open road.

Winkler used closed-cell, elastic PE-foam, which can be bent spherically by shortening the edges—as can Zote foam. Such bending creates an amazingly stable and streamlined form. Working with the material requires no more than glue and a pair of scissors. The mats are simply cut and glued. Zippers can be glued in place along edges, allowing the mats to be connected as well as easily taken apart and transported in a bag.

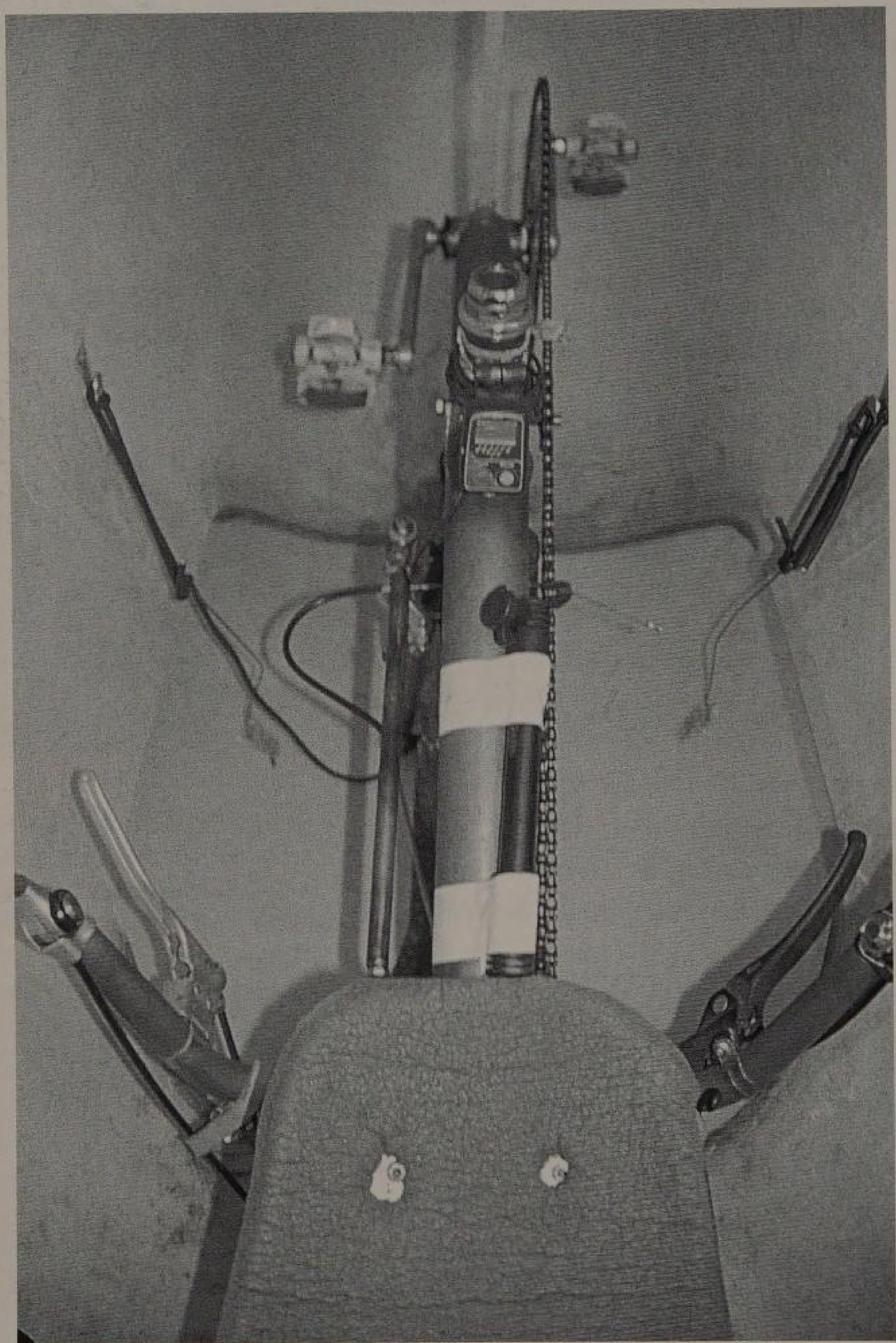
Tetz and friends have developed other techniques for bonding and shaping Zote foam, including welding pieces together using a heat-knife, and vacuum-shaping heated panels in a mold.

The main problem is creating the right piece shapes to begin with. To create a cutting pattern, you can forget about using a computer, or even a pencil. The pattern cannot be calculated; only experimentation will lead you to your goal. A first model is conceived; material is cut and added or cut some more where it is too short or too big. You'll probably use up about 10 to 20 yards before you find the ideal pattern for a removable body.

Hard Plastic Fairings

Hard plastic fairings are the fastest. They also have the advantage of built-in structural stability. They maintain their form if the material used is sufficiently strong and if the stresses aren't too great. Only in strong winds or at high speeds do they flex slightly. A plastic fairing slips through the air with less resistance and is less sensitive to side winds. The sides can be constructed to present a curved and flowing profile to crosswinds, letting wind slip right over without taking hold. Of course, a lower overall profile will also reduce vulnerability to gusts.

Plastic—epoxied fiberglass, carbon fiber, or Kevlar—does not need a skeleton. And its shape can be perfectly molded to purpose, rider, and vehicle.



Cockpit view of "Antigone" by Martin Sörensen. You can see the rubber straps with hooks used to control the "bomb bay" foot flaps.

Wood and metal are both unsuitable materials for a light, stable, and safe fairing. Wood is not stable enough, and metal is too heavy. Although tin offers some utility, it offers more in the way of weather protection than speed gain.

Coroplast corrugated plastic board is a great recent addition to hard-shell fairing material options. It's cheap: about 15-20 dollars per 4 x 8 sheet of quarter-inch panel in the United States. It cuts easily with a box cutter and can be fastened with zip ties or duct tape. (Color-coordinated duct tape makes a nice finish seam). It bends easily, but only in one plane—with a heat gun you can make slight 3-D shapes. With it you can build a light, simple fairing, and realize significant speed gains. It's rugged, offers increased visibility (particularly if you use a DayGlo color), and offers crash protection. Several plans are available free online.

Fiberglass is the most common material. Easily molded, it sets quickly, can be sanded, bonds to wet surfaces, and it's cheap. The combination of fiberglass cloth and synthetic resin can be shaped into any form and requires less experience than working with the expensive hi-tech resins and fibers of the car racing field, airplane industry, or sailboat construction.

Fiberglass is available in two kinds of mat: fleece and webbed. Webbed consists, as the name suggests, of woven fiber threads. Fleece is unwoven, unstructured fiber matting. Mat strength is measured in grams per square meter. If you use epoxy resin, add the weight of resin to the weight of the mat. Resin and matching hardener is necessary to give a rigid form to the mats. There are two basic resins on the market: polyester and epoxy. Polyester resin smells bad (and it's poisonous) and hardens quickly. There's not much time to distribute the resin cleanly on the prepared mats.

Epoxy resin, on the other hand, costs more but gives you an hour for shaping, correcting, and connecting. It intertwines with the fibers better than polyester resin, so it is more flexible and more resistant to breaking. Its neutral smell makes it more pleasant to work with. But don't be fooled: It, too, can damage your health. Pay careful attention to the instructions and handling precautions!

Kevlar and carbon fiber can also be used for fairings. These miraculous materials make fairings even safer. They are more abrasion-resistant during falls and are less likely to come apart than fiberglass.

If you want to make the lightest and safest fairing possible, you can't avoid epoxy resin or even carbon fiber/Kevlar. Unfortunately, working with these improved products is complicated and requires greater care. They're also expensive.

After choosing a material, you'll need to turn your attention to the type of construction. There are three basic variants:

- layer
- rib
- sandwich

Layer Construction

Layered construction, in which layers of material are laminated together, provides stability at the cost of greater weight. It's best for smaller items like a nosecone or tailfin. A full fairing made of layered construction would probably be too heavy.

This is a relatively simple method, making it suitable for beginners.

To achieve sufficient stability to counter wind forces coming from all directions, layers should be laminated in alternating directions. Obviously, the more material you use, the stiffer your fairing will be.

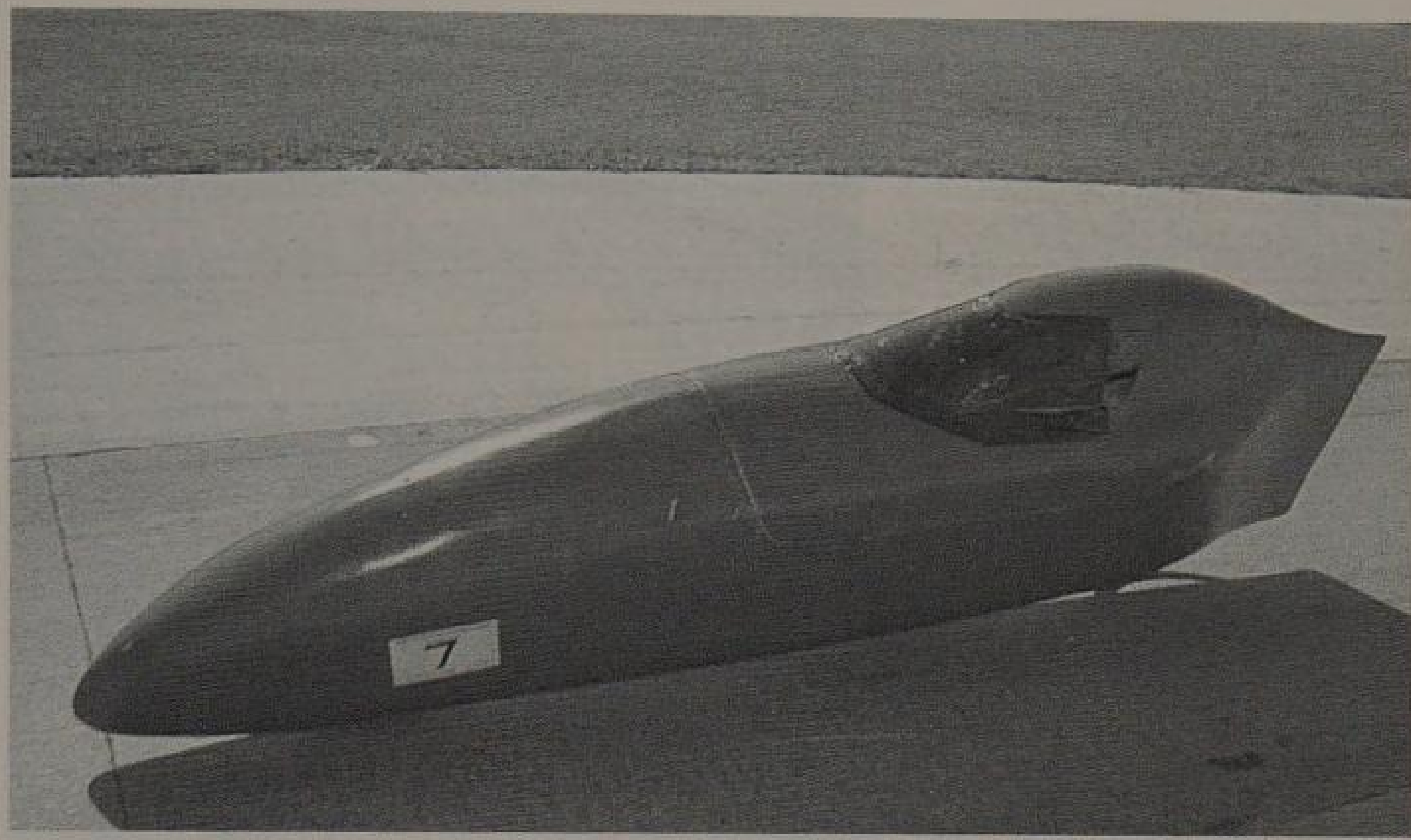
Rib Construction

Rib construction is similar to layered construction, except that you reduce the layers to two, which sandwich a core of ribs that are situated along the stress lines. The ribs are made by laminating fiberglass mat strips over Styrofoam forms. The lighter the ribs, the lighter the overall weight of the fairing.

A clever design can end up weighing less than 15 pounds.

Sandwich Construction

In sandwich construction, two thin, hard layers enclose a thick, slightly soft, but very light layer.



John Simon rides one of Terry Hreno's oft-replicated Moby streamliners. Built in 1981, this red bike once held the world record at 62 mph—and still wins races. Simon also uses it for fast daily commuting (without head canopy). Tried-and-true works with HPV's, too!

Fiberglass, carbon fiber, or Kevlar are used for the outer layers. The selected material must be able to take a lot of point pressure while being thin enough that it would sag if used by itself over a large area. The thick intermediate layer prevents that, resulting in overall stiffness similar to layered construction.

The result is light, capable of sustaining enormous strain, and is totally self-supporting. There is no need for additional stiffening, and only a minimum number of attachments are needed, which can open up the interior space.

In practice this means that the form of a well-constructed sandwich fairing does not lose its shape under the pressure of air resistance. It can even sustain falls on stony roads without any resulting holes or dents.

A tub-bike is a variant where the sandwich fairing is built thick enough that it can function as the bike frame (about an inch). Such a fairing be strong enough to stand on.

Building a fairing with sandwich construction is tricky work. It requires a careful hand and a lot of concentration. Moreover, the filling material between the two outer layers can be expensive and demands meticulous measuring.

There are three common approaches to

Getting out of a fully faired recumbent requires practice. Some streamliners even use landing gear for stable stops and starts.

sandwich construction, each using a different filling:

- web fiber/spray foam/web fiber
- web fiber/fleece mat/web fiber
- web fiber/honeycomb fill/web fiber

Spray foam filling can be very difficult to work with. It has to be sprayed very evenly, or every wave and drip will be mirrored in the outer layer of the fairing.

Fleece mat filling doesn't have that problem. This flexible filling adjusts itself to the big forms of the fairing and creates a constant distance between the two web fiberglass layers.

Honeycomb fill is self-sealing material. This prevents it from soaking up too much resin and tends to weigh less. The small hollows in the honeycomb do absorb some resin, however, but this guarantees the bonding of the individual elements. Perforating a small portion of the outer layer of honeycomb cells can also help create a soak-in area for good bonding. Just enough saturation for adequate bonding is all you want. Special attention should be dedicated to the maker's instructions with regard to the resin intake capacity and the resulting weight of the product, otherwise you might be unpleasantly surprised.

No matter which technique you choose, you'll need a releasing agent that will release the negative from the original mold form and later the positive from the negative. If you have a smooth surface after days of polishing, a release agent on its own will suffice. Using wax for this purpose would cause unwanted unevenness. On rough surfaces, however, wax can be used to fill in small areas of unevenness, to improve quality, prior to application of the release agent.

The final step is painting. But instead of paint, consider using pigments which can be stirred into the resin.

Detailing a Fairing

Here are some features to consider when creating a fairing for everyday use:

- quick and easy entering and exiting (possible use of kickstand)
- big, safe foot-flaps (bomb-bay doors)
- integrated light and signaling system
- integrated rear mirror
- sufficient interior space
- luggage compartment
- access to all bike parts
- ventilation, and rain and fogging control
- splash protection inside the fairing
- waterproofing
- small windshield, close to the eyes
- unobstructed steering angles

- good crosswinds *Cd* value (smallest lowest possible, with curved-side area)
- option to signal with your hands

Unobstructed entering and exiting, and adequate foot flaps, are vital for safety, as are mirrors, lighting and signaling. An entrance that is safe and practical has to be carefully designed or it will be a source of risk and annoyance. A side entrance with removable panel, for instance, is easy to make, but hardly suitable for everyday use. In case of an accident you have to be able to get out of the fairing quickly. In traffic it can be a life-or-death matter. Even riders who use a full fairing should wear bright clothing. In the unfortunate instance of an accident, you'll be more visible as you scramble out of the shell.

If your fairing has only one exit, and you fall onto it, the consequences might be disastrous. Consider a quick release for the entire shell, so it can be lifted or pushed away in an emergency.

To prevent such an emergency, think about brightly coloring your fairing. White is best for night visibility. During daylight hours, a bright color is better. A combination of two—white and red, for example—is perhaps most effective

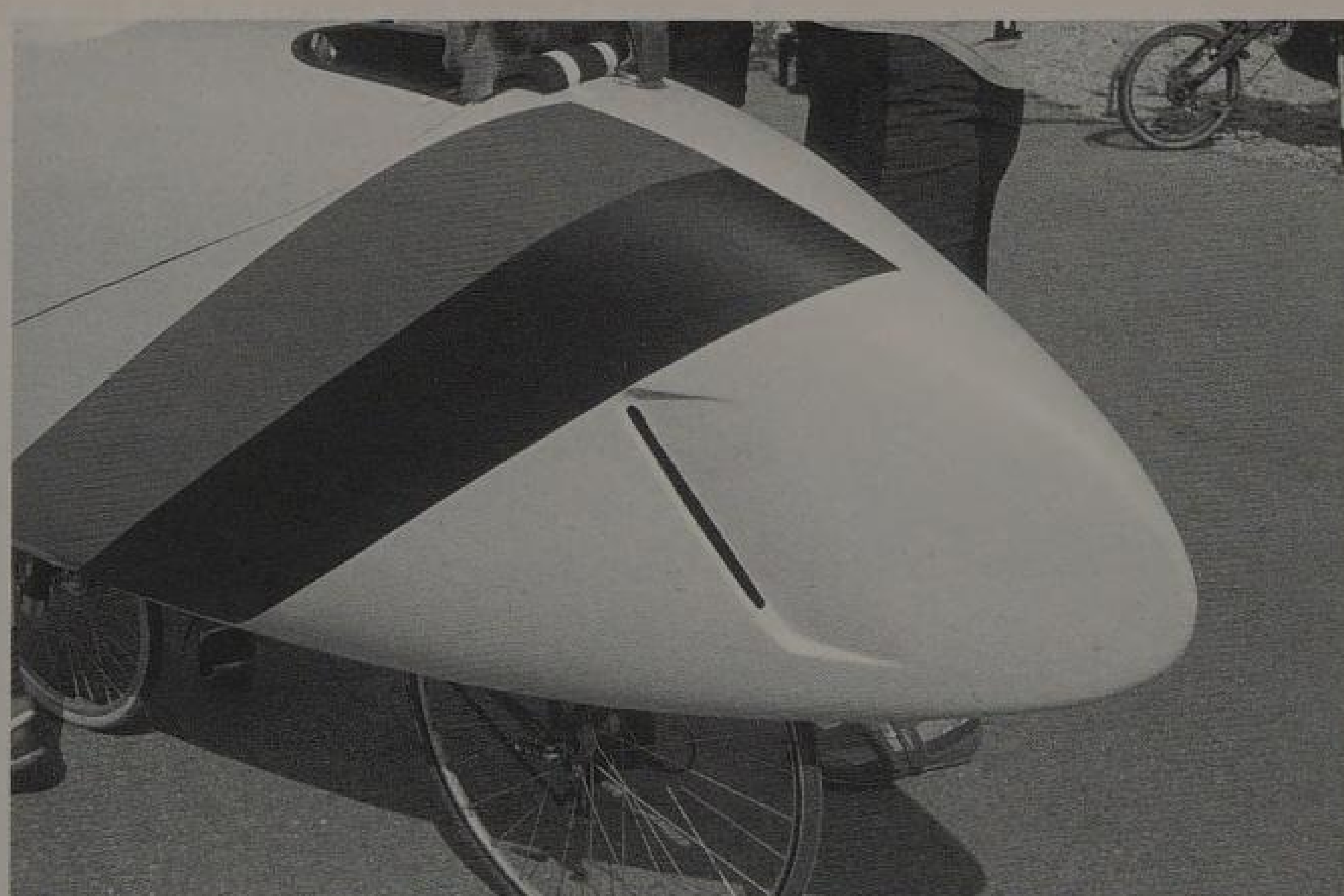
Trunk storage is very handy. For riders who commute long distances, especially in areas of changeable climate, a luggage compartment becomes necessary to accommodate changes of clothing and foul-weather gear. A trunk is most practical for this, as it's situated behind the seat, where there's dead space caused by the broadest width of the fairing. The seat should either fold forward for access or the fairing needs its own trunk opening. There might even be extra room in the hollows of side-panels for a small pouch or compartment.

Small windows built close to the face are extremely important for full fairings. Big windows that are distant from the eyes are expensive. The dirt, haze, and running water drops that accumulate on a window are more difficult to see through if the window is far from the eyes. Water drops and dirt cause light reflections from the sun, auto headlights, and street illumination.

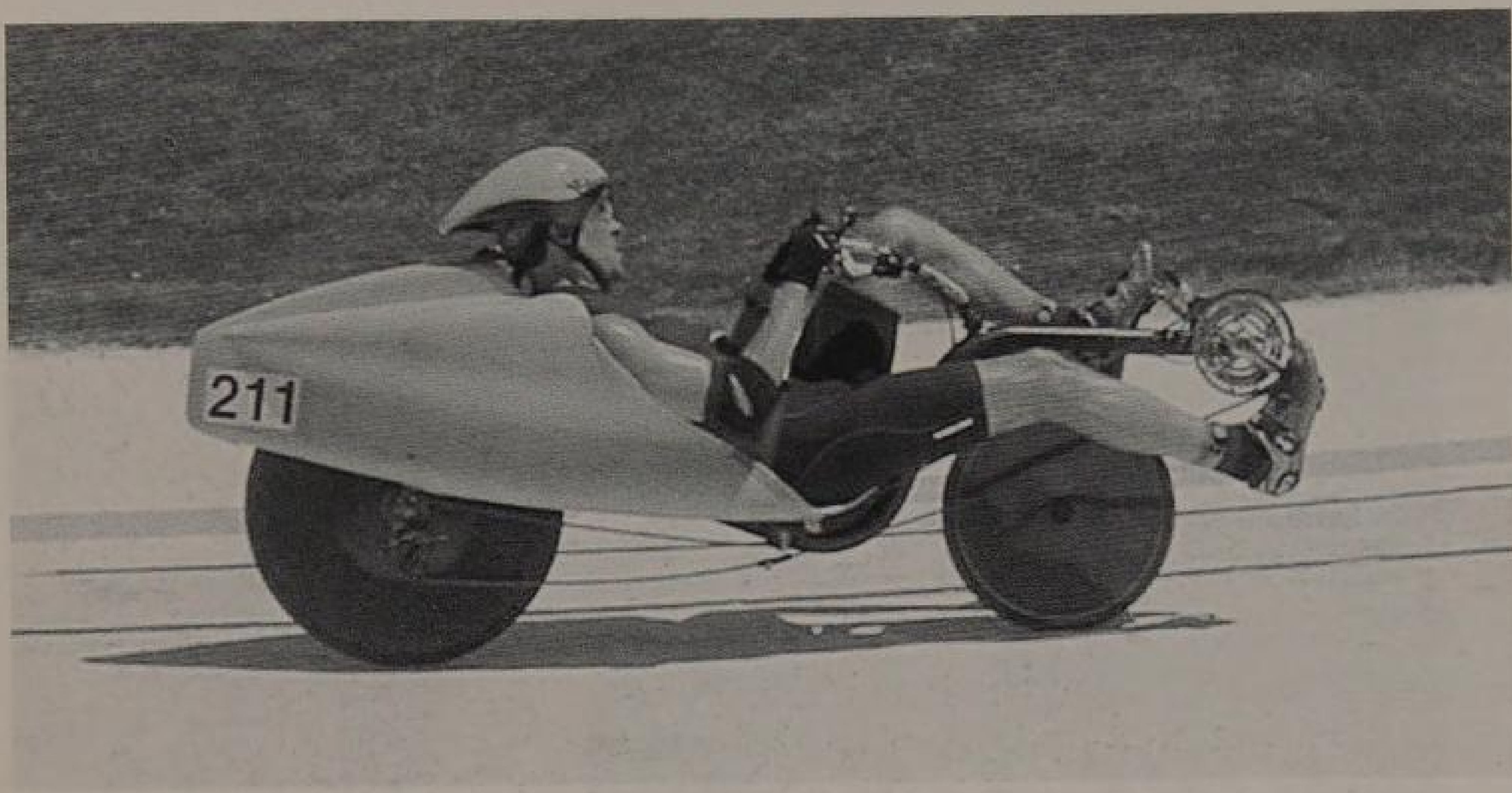
Windows close to the eyes are as uncomplicated as the face shields of motorcycle helmets. The eyes focus right through them.

The faster you go, the more important good visibility is. A little windshield also improves your ability to hear traffic by cutting down on wind noise, which at higher speeds can be deafening if the head has no shelter.

Finally, an all-weather fairing needs adjustable ventilation. Side windows, hinged with tape and closed with Velcro can help. If they're big enough you can put an arm out for signaling. Fairing builders often put a hole in the front of the nosecone to let in air. The hole can be covered in cold weather, and in hot weather a flexible hose can be attached and led back to direct air at the rider. If a ventilation duct is needed, a specially shaped NACA duct gives good results with low drag (details at Recumbents.com).



Detail view of a rear air channel for a fairing.



HPRA racer Alan Ariail races a Jester with an Optima tailbox installed. Production tail fairings are available which can be fitted to a wide variety of bikes, some include storage area and lids. Reclined lowracers don't benefit so much from a front fairing, but are significantly helped by a tail fairing.

Further weather protection is gained in several ways. A drive train that is fully enclosed within a fairing will stay much cleaner and last longer (due to reduced grit). If the fairing is painted white, it creates a very good sunshade and can even be cooler than riding unfaired. Clear plastic, however, lets solar heat build up quickly. This is good in winter but intolerable in summer—another reason why windshields should be small.

Racing Fairings

A racing fairing has to surround the rider as closely as possible. It should be light, low, and narrow. The form should have a small front surface and the best possible aerodynamics. Its measurements are determined by the outline of the bike and rider, the farthest reaches of the legs and arms, and the radius of the turning wheel.

Aerodynamics are crucial, but they are secondary to the needs of power transmission. The rider must first have sufficient space to pedal and breathe freely. This is especially important in long-distance racing.

Planning a Fairing Shape

A fairing's form determines its *Cd*-value and thus the amount of energy lost to air resistance.

The decisive starting points for the conception of a fairing are the "extreme points" for vehicle and rider.

They are:

- head width and position
- shoulder width and position
- foot tip rotation circle during pedaling
- heel rotation circle during pedaling
- steering mechanism height and width in normal position and at both turning extremes
- hip height and width
- vehicle dimensions, if they have not been captured with body measurements

Apart from a full fairing, there are many forms of partial-fairings:

- front fairing
- back fairing
- head out
- knees out
- heels out
- wheels out
- front wheel out
- full fairing with side areas cut away

The form must be decided before you plan. The full fairing is the fastest and offers the best weather protection, but it's also the most difficult to construct, and a small error might make it unusable. The "head out" variant relieves the rider from the feeling of being trapped, but it is less aerodynamic and weather-friendly.

If you're racing in a league, you'll need to consider the various class regulations. For instance, a front panel that extends past the hipline puts you in a different category in some clubs. In the HPRA in the United States, for instance, a fully faired HPV is allowed into the Super Street class as long as no parts are moved for entering and exiting. The Stock class means no fairings. And Super Stock allows front or rear fairing, but not both. However, in Europe the unfaired class allows tailboxes.

Regulations are always subject to change, of course. But racers can often be involved in crafting HPV regulations. If you're active, you may have some say in affairs. It's still a small scene, after all.

If you plan an everyday or touring bike, the calculation of the construction values need only be accurate to within an inch (in terms of over-sizing), since the fairing should have a little elbowroom.

A racing fairing, on the other hand, requires close tolerances.

Once the measurements are taken you have to form a smooth body from the sharp-edged initial design. This is a difficult job. You should dedicate your greatest efforts to minimizing frontal air resistance. Starting at the extreme point, the effective front surface must present a smooth face to the wind. A ball that equals the width of the front surface in its diameter is a good model for comparison.

Transitions between zones should be blended harmoniously, without sharp angles or bends. Once you get the theoretical form of the front part defined, you have to deal with the rear and the section in between.

The sides must be correctly handled as well. A rear that resembles a flat fin would seem to have the least impact on frontal air resistance. Unfortunately that is not the case. Crosswinds wreak havoc with such a bike. Air streams other than those directly from the front should influence your design. After all, hardly any breezes are directly head-on, and certainly few are on a looped course. Understand that a form that optimizes the *Cd*-value from the side will conflict somewhat with optimal frontal *Cd*-value, so you'll need to compromise.

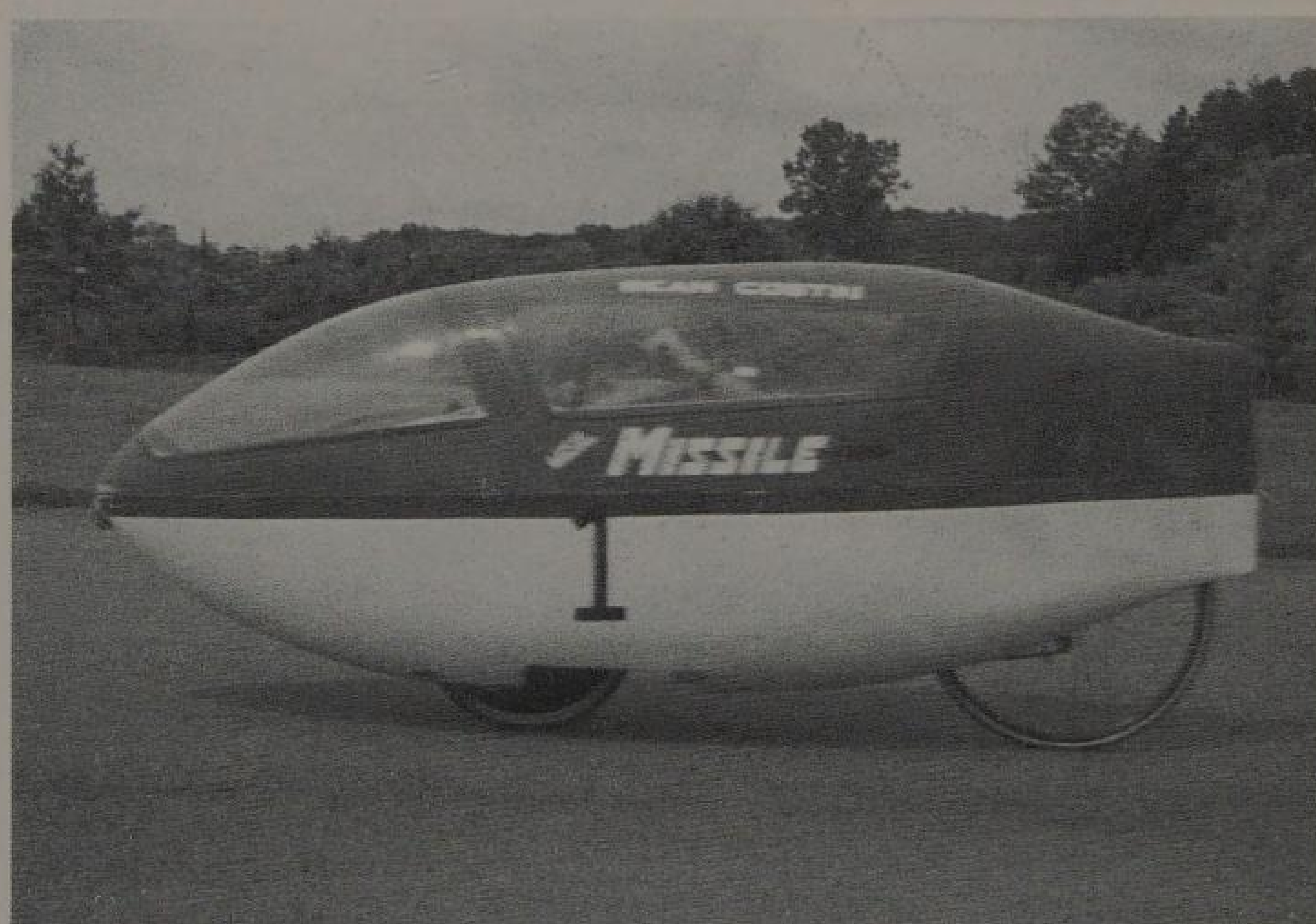
When it comes to record-attempt sprint bikes, crosswinds are largely ignored; if the sidewind is too strong, there's no point in starting. Designers of such bikes seek only to minimize air resistance at the front.

It is different with bikes for road racing, all-rounder or league racing. They have to be able to ride safely (and swiftly) in any wind just like any other bike. This is especially true for long distance and everyday models.

The nosecone area doesn't usually present much of a problem in crosswinds. But a perfectly aerodynamic rear fin can create an awful lot of turbulence in crosswinds. That is why it usually has to be altered to give a better *Cd*-value from the side (called *Cs*-value). In general, your fairing should have no flat areas—these hugely increase sensitivity to crosswinds.

The "pressure point" of a fairing—the point where all effective forces are united—plays a major role. The position of the pressure point is strongly dependent on the wind angle. Other factors are the fairing shape and size, speed, and vehicle position on the ground, which in the real world involves tilting and rocking, fore and aft, and side to side. It is very complicated and involves lengthy calculations to locate this pressure

The "Missile" streamliner, built by the Wisconsin/Illinois club WISIL, has a fairing constructed of top and bottom halves pulled from the same mold. This fully suspended bike recorded a top sprint of over 50 mph, but now adds commuting to its duties, with hinged side windows for signaling and an interior trunk for cargo. (photo: WISIL)



point. I would direct you to a report by Andreas Fuchs from Switzerland, available via the IHPVA.org website. If you want to calculate the pressure point and center of gravity exactly, you should look into the Andreas Fuchs article. Just to give you an overview: The pressure point for small wind angles (up to 15 degrees) is located at the first third of the fairing, close to the front wheel.

What consequences does the pressure point have on handling in 90-degree crosswinds? For a simplified answer, imagine a weathervane on a church steeple. The mounting rod is the vertical axis. If the surface of the rear part is bigger than the surface of the front part, the weathervane turns into the wind. This resembles what happens when the pressure point is behind the center of gravity of an HPV system (pilot plus vehicle and cargo). The same goes the other way: If the pressure point is located in the front area of the fairing—in front of the center of gravity—then the nose tends to veer out of the wind and to the downwind direction.

The weathervane's rod resembles the vertical axis of the recumbent. Surprisingly, this is only true with multi-track machines. It is different with a single-track bike, because a two-wheeler can lean to offset some of these forces and offer more resistance to turning around the vertical axis.

This Barcroft "Virginia" sport bike is set up with a Mueller Windwrap production windshield fairing. Note the two simple attachment points for the fairing.

If the pressure point is located in front of the center of gravity, the nose of the vehicle tends to turn downwind. Thus, to go straight, one has to lean into the wind and countersteer.

Matt Weaver tried to take advantage of this when constructing his record attempt vehicle, Cutting Edge. He extended the fairing's front until the pressure point was located in the direct area of the front wheel. At the same time he made sure the front wheel was weighted enough to give adequate traction. In practice he reproduced the phenomenon that resembles the way cyclists swerve when cornering. Racing cyclists sometimes swerve to the left before a sharp lean to the right, or at least put strong pressure in the bars toward the left to initiate a rightward lean. In this way a bike drops more easily into a right-hand power turn. So Weaver's Cutting Edge tends to turn its nose away from the wind in crosswinds, thus automatically leaning into the wind and keeping the bike going straight.

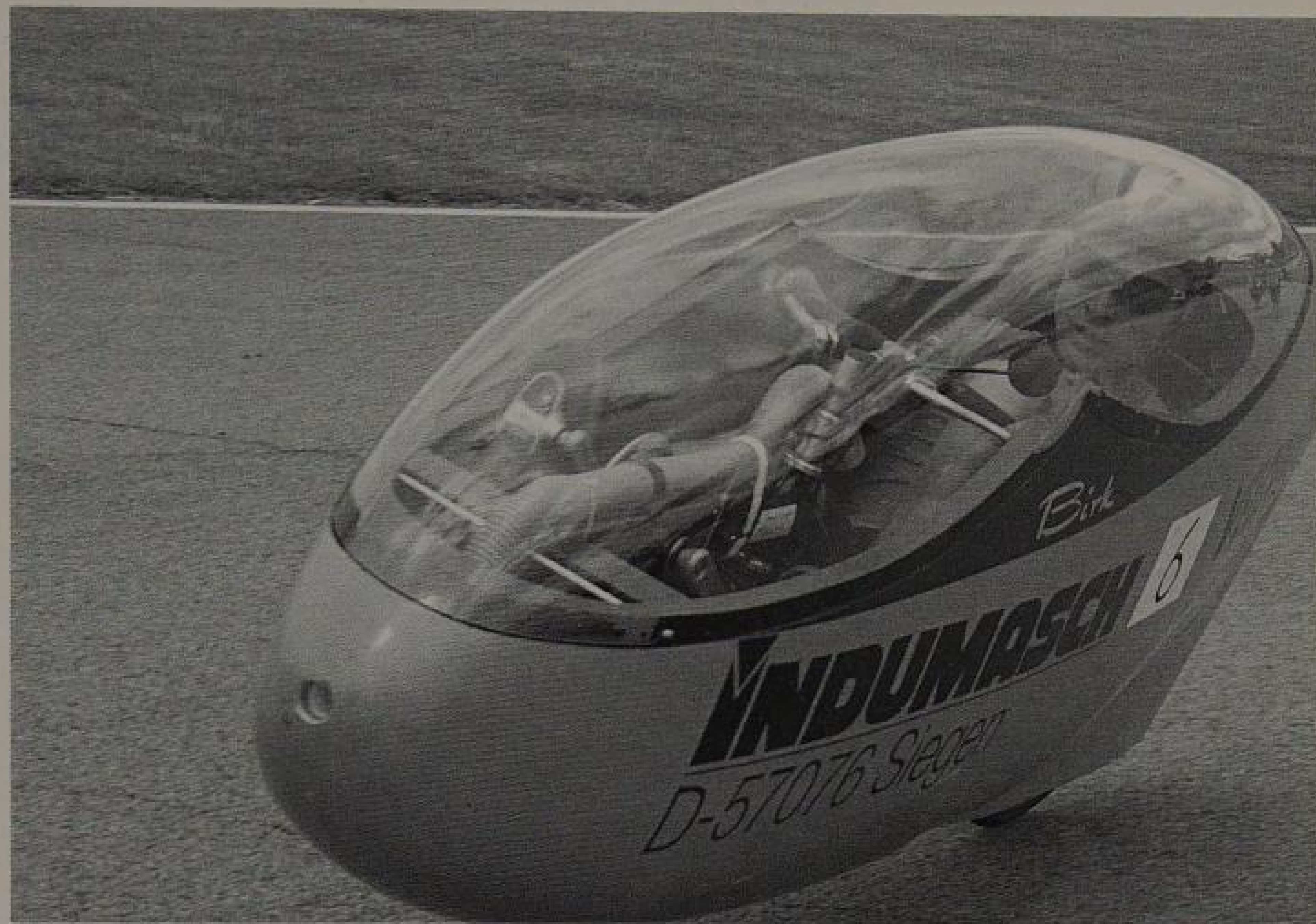
During unexpected gusts, especially when the vehicle is already leaning into a crosswind, lift—as with an airplane wing—can occur. In combination with vehicle vibration from road roughness this can cause both wheels to lose traction. This explains why full suspension is a great advantage for a fully faired recumbent. Suspension makes even more sense at high speeds where bumps and roughness are amplified and occur more frequently. Material fatigue also results, with a greater likelihood of frame and parts failures.

The vibration caused by constant ground contact makes the use of so-called micro-rough surfaces superfluous. They are supposed to generate a flat air turbulence layer as a cushion between the surface and the airstream, thus reducing the air friction resistance. But the theory doesn't hold water for HPVs since a fairing is being vibrated constantly already.

However, this is an area where Matt Weaver claims progress. He says that his new bikes achieve enough attached flow to result in a new speed potential of up to 100 mph. His perfectionism led him to discover that even a disturbance the thickness of cellophane tape can cause airflow to "trip" and snowball into greater drag. Note that attached flow is not the same as laminar flow, but it's still very fast!

Some general fairing design tips in conclusion:

- reduce openings and sharp edges to as few as possible
- avoid edges and openings, especially in the ground area
- flatten the ground or belly side of the body
- when in doubt keep the body too long rather than too short
- a fairing close to the ground has fewer problems with headwinds and cross-winds
- a fairing close to the ground vibrates more (with risk of airstream breakup)
- the widest part of the fairing should be between the end of the first third and the middle
- all edges, seams, openings, stickers, and flaps disturb boundary layer streamlining



Birkenstock offers the fully faired "Comet" version of their lowracer. Such high levels of polish give the potential of selling ad space on your bike. (photo: www.tim.be)

Bram Moens of M5 is proud of this bike, unveiled at the 2006 Cycle Vision expo: the lightest production recumbent, a 16.5-lb highracer. (photo: M5-ligfietsen.com)

Trondheim–Oslo: 540 Kilometers Nonstop on a Recumbent

Peeeeeeeeep—time starts running—the first turn of the crank carries me the first meter—539,999 are still to follow ...

My pulse is racing, and I transfer this energy to movement. Then I pass the most famous sign in Trondheim. All riders quickly glance at the magic number on it: 539 kilometers to Oslo (335 miles). Somehow I had never questioned the fact that I would arrive in Oslo in all the months of getting into shape. All preparations of mind and body had only been undertaken for this sole purpose. In the undertow of my fellow riders who look at me and shake their heads, I reach the first stop after about two hours. Until then, the racing cyclists had been looking down at me. They barely accepted me in their groups so that I felt sort of out of place. Quickly I tucked away bananas, juice, water, bread and muesli bars. Pushed by the helpers' stares, I start riding again. I avoid long breaks so that I do not cool off too much. What follows is a lonely passage of more than 200 kms. Well, not all alone, because enthusiastic Norwegians at the roadside try to motivate me with "Heya, heya, heya" shouting. This "heya" moves me so much that I almost cry. Then I finally find my inner peace. My seat position enables me to enjoy the scenery, the people, simply everything. A remarkable passage to Dombås leads me to a 90 km leg to the next stop in Lillehammer. Experts say quite rightly that the real race begins here. The last 180 km consist of little hills which pull the last reserves from legs which have already managed 360 km. Fortunately, some riders form a paceline with me, and in such a group it is easier to cope with the hills even as one is not less conscious of them. The "Belgian Gyroscope" runs as if well-oiled, and we simply pace along the asphalt. We all rotate together, which means overtaking is done on the right and at the left front you move into front position for a while. The overtaking phases get longer and longer as we acquire riders and the group gets bigger and bigger. Without this community, I wouldn't have reached the last 180 km in 16:54:24 hours. I finish in 17th place out of 320 in my age group and 240th overall out of 5282 people who participated. Moreover, I finish in one hour under my personal goal. This was a very special experience: fighting against the distance, against your own body, but most of all against your mind. It was a challenge that every cyclist should take—but watch out: the danger of addiction is very high!

—Axel Fehlau

Ch. 6 Building Your Own Recumbents and Fairings

Recumbents are becoming widely available and highly refined, but you still might not find the one that precisely matches your wish list. There are so many variables that it's inevitable you'll have to make compromises. Of course, many things can be altered after purchase—including seats or handlebars. But the more extensive your wish list, the less likely you'll find a existing bike that suits you. You might consider building your own recumbent, especially since it's relatively easy (well, easier than an upright), and one can be made from inexpensive materials.

Construction can be fun, gives you experience, and boosts your self-confidence and appreciation for the fine work of others. Nonetheless, there are only three reasons to consider building your own, otherwise I recommend that you buy.

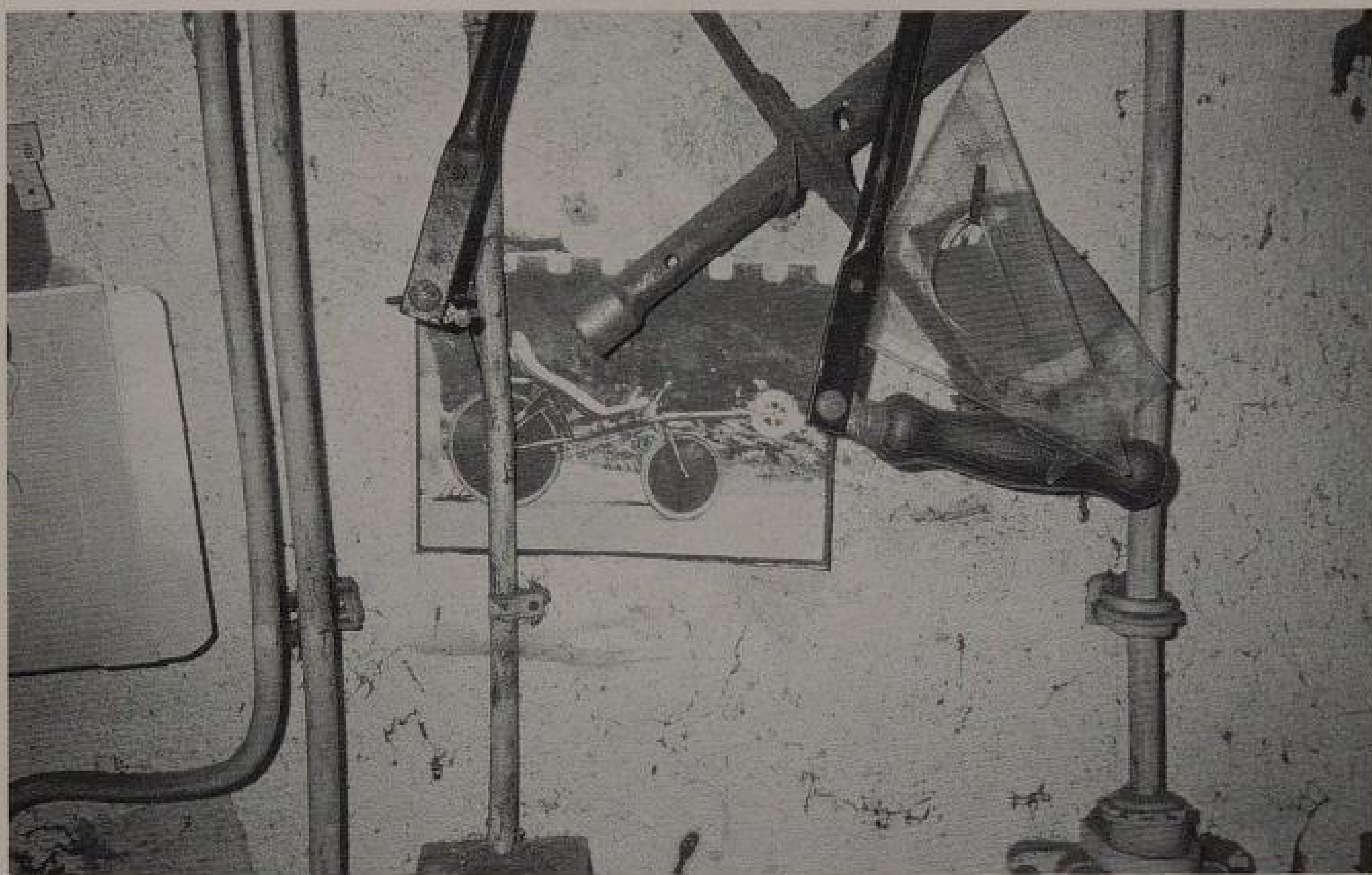
Kurt Pichler brazing a fork dropout. He's an expert builder and also produces the Pichlerrad line of bikes in Germany.

First, you may simply have an urge to be creative, inventive, or to exercise skills well suited to bike-building. The result of the endeavor—the bike itself—is only secondary, since the path is really the goal. In this case, few tears will be shed if your attempt fails or doesn't meet expectations. If it doesn't work out, the enthusiastic builder just tries again or turns to a new project.

A second acceptable reason is that the market doesn't offer the right bike for you. Perhaps you've already owned a recumbent—one that didn't exactly your needs—and now you have a better idea of what you really want. But your search for that bike has been fruitless: either the configuration is not right or the price is out of reach. If this is your motivation, be careful to set a realistic goal. Make sure you're not overlooking any essential compromises that the market has already made. Building, for you, is a means to an end. So make sure you are realistic about that end. If at all possible test ride another homebuilt bike that is close to what you plan to build. If you can't find one, or if you attend large HPV events and never see such a bike, this should give you pause. Discuss your plans online or with club members who have built bikes. They can shed light on design issues. Endless variants have already been tested and evaluated. Make yourself familiar with the broad spectrum of available models and you will benefit from the work of others before setting off on your own.

The third acceptable argument for building your own applies to only a few: those who have expert or professional experience in the field. Perhaps you work with bicycles or the materials used in building bikes in your day job. You're frustrated by market prices, and you make the experienced appraisal that you can build a dream bike tailored to your needs that is cheaper, faster, and just as good.

Otherwise, despite the temptation the



Keeping the ideal before you: for a little extra motivation during slow nights in the workshop.

facts speak against doing it on your own. As follow:

• It takes a lot of time. If the time you spend is worth as little as six dollars an hour, you can quickly reach the cost of a very good production bike. And if you compare end products, the quality of a purchased bike is often much better.

• Most likely your workshop is not equipped properly or set up for bike-building. This eats into efficiency, adding time and cost to your project.

• It's difficult even for experts to make a sketch of exact bicycle geometry on paper and then execute it correctly. Trial and error is the usual result. Most production bikes result from a protracted series of test bikes, which no hobbyist could afford to repeat.

A further option is that if your plans mostly relate to fairings, suspension, or accessories, you might be able to buy a bike or frame that can be adapted—but any frame structure changes would likely void a warranty.

This brings up a significant argument in favor of buying new. Most recumbent makers offer a warranty period, insuring you against defect. And many bike shops allow a grace period during which you can put your bike through the daily rigors typical of your riding style and local road conditions. Such bike shop warranties typically allow full credit toward the purchase of another bike.

In the unfortunate event of an accident due to weak materials or poor workmanship, you are better off with a purchased bike. If you file a medical claim, your insurer might deny it on the basis that you aren't qualified to build a bike.

If you decide to build your own recumbent— despite my warnings—your success is greatly dependent on planning. Mistakes on paper get transferred to the bike.

This brings up pre-designed plans and kits—there are resources listed in the appendix which can relieve the burden of knowing how to design a bike and even some work, as some plans and kits combine portions of "donor" bikes to create recumbents. (Of course, it's best if you can test ride a bike built from a plan or kit that you're interested in. It has to meet your needs just like a manufactured bike would have to.)

One thing that might give you comfort is that in some ways building a recumbent is easier than building an upright bike. The parts are less critically dependent on each other. Most parts of an upright frame, for instance, affect steering in some way. If one aspect is crooked, the rest is thrown off. And because speed is so dependent on weight with uprights, you use very lightweight materials, which are less tolerant. On a recumbent, the independence of various functions and the emphasis on aerodynamics over micrograms makes building somewhat easier. This also applies to making and modifying accessories and fairings for a store-bought bike. Of course professional polish is still difficult to achieve.

The first phase of planning requires an exact analysis of the desired qualities and capabilities of the bike as well as an honest assessment of your ability, time, and finances.

Most important of all, you should have an exact mental picture of the bike. Will the bike be used every day? Is it intended for touring, commuting, racing, or something else? Does it have to be carried into the basement or up to the third floor? Do you wish it to be foldable? Is its size, weight, or appearance important? How comfortable is it supposed to be? Will it have suspension in the front, back, both, or will you just use cushier tires?

Once you clarify these questions, think through your construction options and connect the dots between the features you want with the design possibilities. This will give you a pretty good idea of the compromises that must be made. Only after you've detailed all these parameters, is it time to start drawing.

Materials

The frame is the heart of a bike. The effects of various design traits are described in the previous chapter ("Basics of Design") so I will only elaborate on materials and building techniques in this chapter.

Steel

Steel differs from cast iron because of the addition of carbon. It is the most common material used in bike frame production. It is also the best: It can be welded, brazed, riveted, glued, and screwed.

Common Cro-Mo is a steel alloy containing chrome and molybdenum that is strong in tube form even with a very thin wall. Adding chrome and molybdenum to steel improves tensile strength without reducing toughness. These qualities make Cro-Mo the most common material used for bike frames.

Cro-Mo steel offers a drastic weight reduction. But because of its high carbon content, experience is crucial for success. As the amount of carbon rises, steel's melting point lowers. If it gets too hot during work, the chemical combination dissolves, and the steel is ruined.

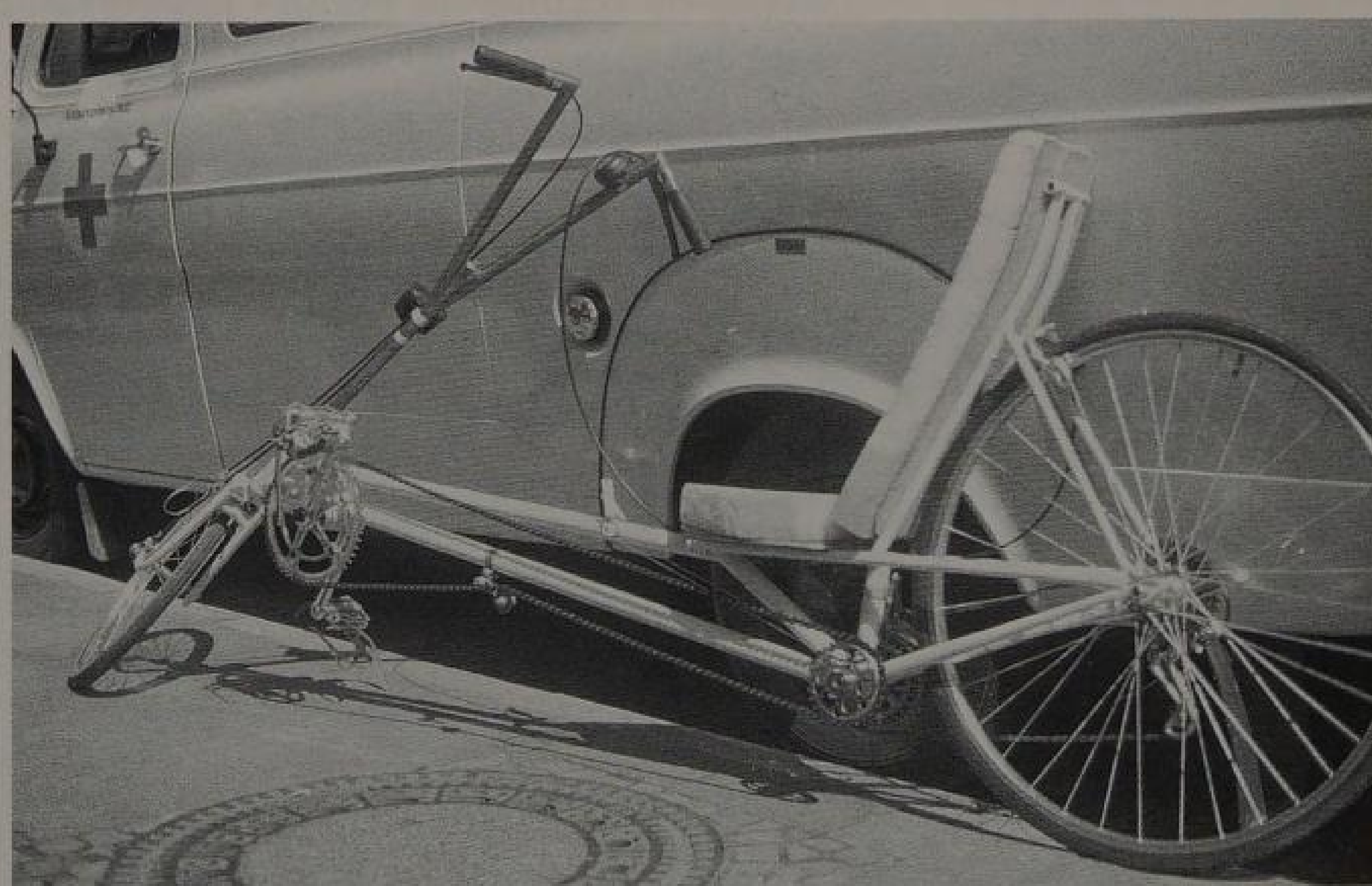
Simple steel, like ST 37 construction steel, which was used in the construction of the Empire State building and is common in bridges, makes a useful training material, as it can be worked easily and is very stable.

Alloyed steel, like the well-known Reynolds or Columbus 25CroMo4, offers high quality and enables weight reduction without influencing stability. But such steel is best reserved for experienced tinkerers.

Because it is available in all tube sizes typical in European and American bikes, steel is the best choice for beginners and experienced builders alike. It's easy to procure and, in unalloyed form, easy to work with.

Aluminum

Various combinations of alloy and heat treatment result in more than 300 types of aluminum, and it's almost impossible for nonexperts to differentiate between them.



Without its fairing, the famous 'Sweet Surprise' racing streamliner reveals a low-budget home-built bike. (Achieved 52mph in '88—58mph unofficially; see pg. 31.) (photo: Veloladen)

This makes it impossible to re-use old, nameless aluminum in the construction of bikes. Buying it "freshness dated" and labeled by type is your only option. But first you must decide which of the many varieties is most suitable and determine whether it's available in the desired tube or plate form.

Aluminum behaves totally different from steel. It is characterized by low weight, corrosion and temperature resistance, and weather (rust) insensitivity. These desirable qualities are offset by problems in workability. Aluminum neither creates sparks, nor does it turn red when heated, but it melts almost without warning. This makes it very complicated to judge temperature and to weld. Ingenuity and experience are vital for working with aluminum. All in all, aluminum is not a good material for beginners, particularly because worthwhile weight reduction is only achieved with expensive and difficult to work with aluminum alloys.

Plastics/Laminates

Ever since bike engineers discovered carbon fiber, Kevlar, and other plastics, the would-be recumbent builder is confronted with the question of whether to use these miracle materials. Their chief attributes are incredibly low weight and the creative shapes that become possible. But these materials are tricky to work with, and only the most clever are really able to build a frame that curves at the best locations and is bubble-free at stress points.

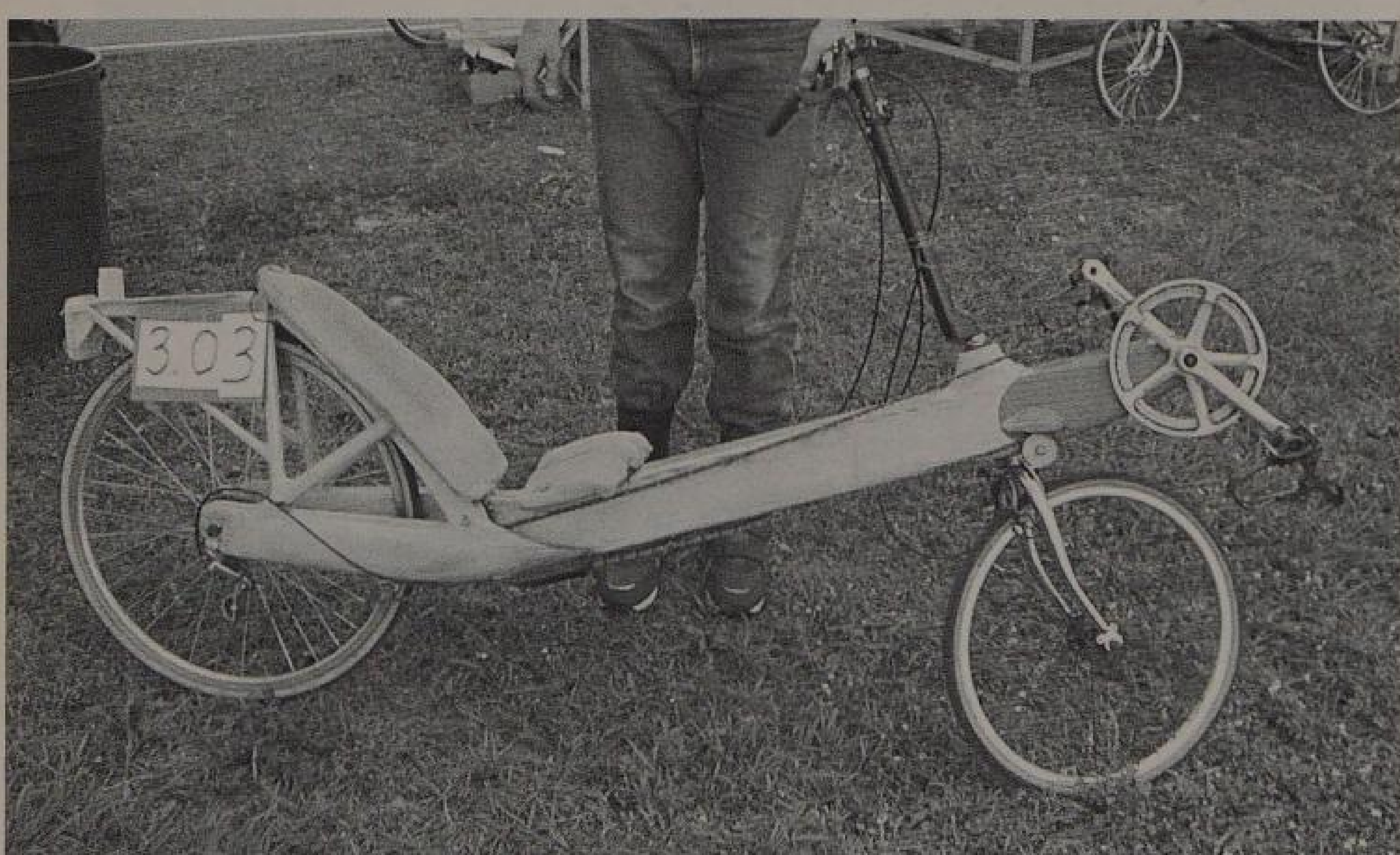
Therefore only an extraordinary frame form argues for such materials, by that I mean a frame shape not possible with normal tubes. If you want to pursue this avenue, you'll find helpful information and tips on various homebuilder websites (see the appendix), as well as publications relating to boat building, modeling, and surfboard construction.

The section on do-it-yourself fairings that comes later in this chapter gives a good sense of the effort and costs in dealing with these materials.

Wood

Charles Brown of Florida (and Michigan) has been building recumbents of wood for decades. He has optimized several designs and processes to come up with lightweight, good performing and simple-to-build bikes. Since his early efforts, builders worldwide have created dozens of designs and hundreds of bikes, including, for instance, a 32-pound lowracer from plywood and foam. Some highly refined examples, plans and explanations can be found on the Internet. (See the appendix for contact info.)

Charles Brown has built many wood recumbents and inspired many riders to build their own. Here is one of his recent versions. (photo: S. Bernard)



Processing Techniques

Welding

Welding of simple (unalloyed) steel is neither difficult nor expensive. Tungsten inert gas welders are very suitable for fabricating an inexpensive, stout, stable steel frame. The connections need only a few preparation steps, in contrast to brazing. A gap of 1 millimeter is acceptable. The difficulty of treatment grows with the quality of the steel. That it why it is advisable to gain some practice experience with steel castoffs from a scrap yard before working with high quality material.

A welded joint is not as elastic as a soldered one and tolerates only so much reworking for corrections. But thanks to TIG welding it is now possible to weld really thin tubes reliably. Unfortunately, the required welder is very expensive.

Brazing and Soldering

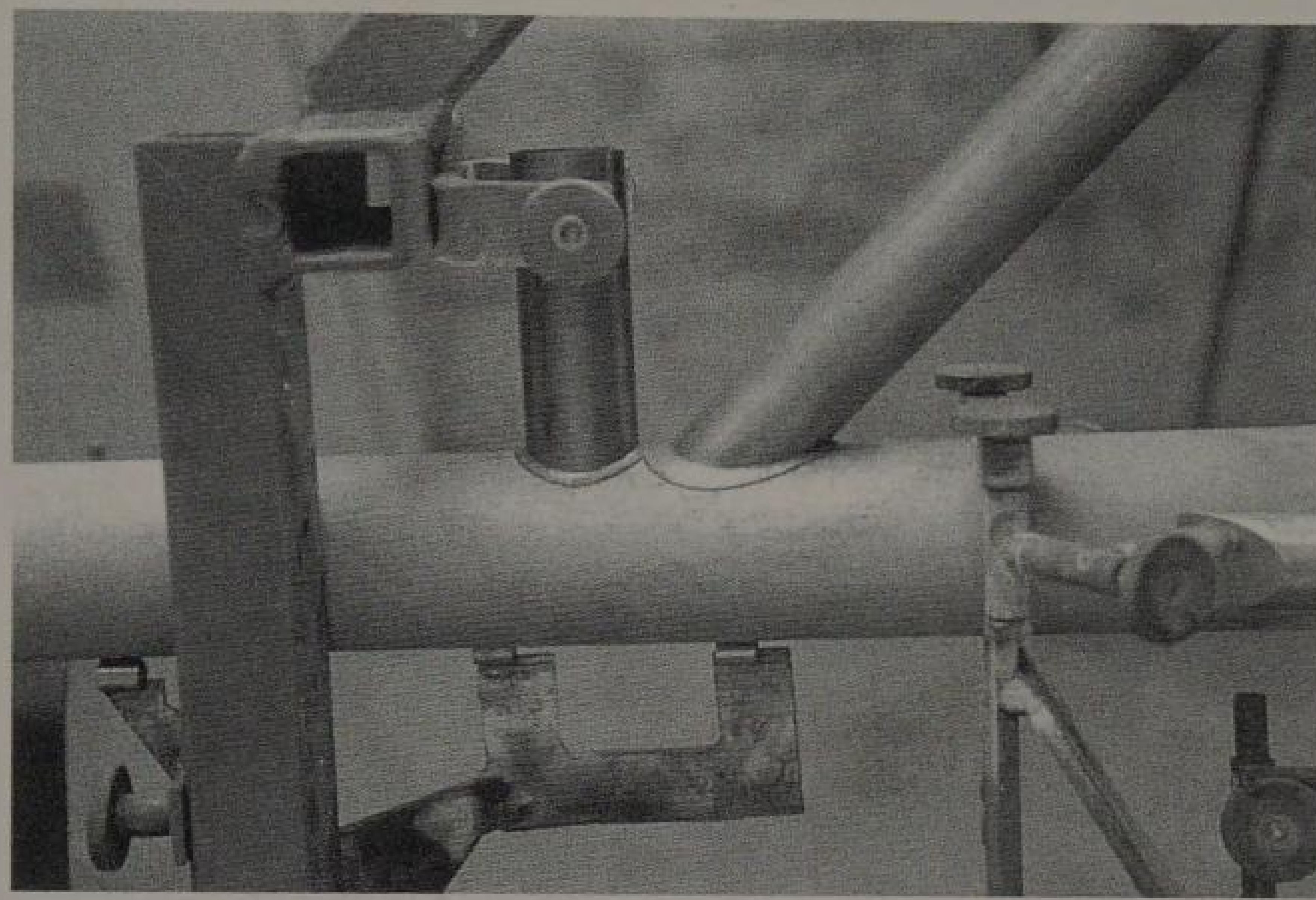
Brazing, or soldering, is done by means of a flame of acetylene, butane, propane gas, and oxygen. One "weld" causes the connection. When brazing, the question is: with lugs or without?

Lugs are rarely used anymore because of the time involved. Furthermore, selection is limited to traditional bike tube sizes and angles. Even for common oversize tubes, lugs are very difficult to find.

Brazing requires a lot of care and preparation, regardless of whether you use lugs or not. The connections have to be exact to within three-tenths of a millimeter for brass brazing and to one-tenth of a millimeter for silver brazing. Tolerances must be closer yet for quality lugless work, sometimes called "fillet brazing."

The connection has to be clamped absolutely tension-free, and must be oil- and grit-free in order to be properly brazed. The use of flux is indispensable. This chemical enhances the penetration of the brazing and cleans the metal of dirt and oil particles that cannot be removed during polishing and preliminary work steps. Assuming that the mitered joint has been fitted together accurately, flux ensures a brazed connection with the greatest stability.

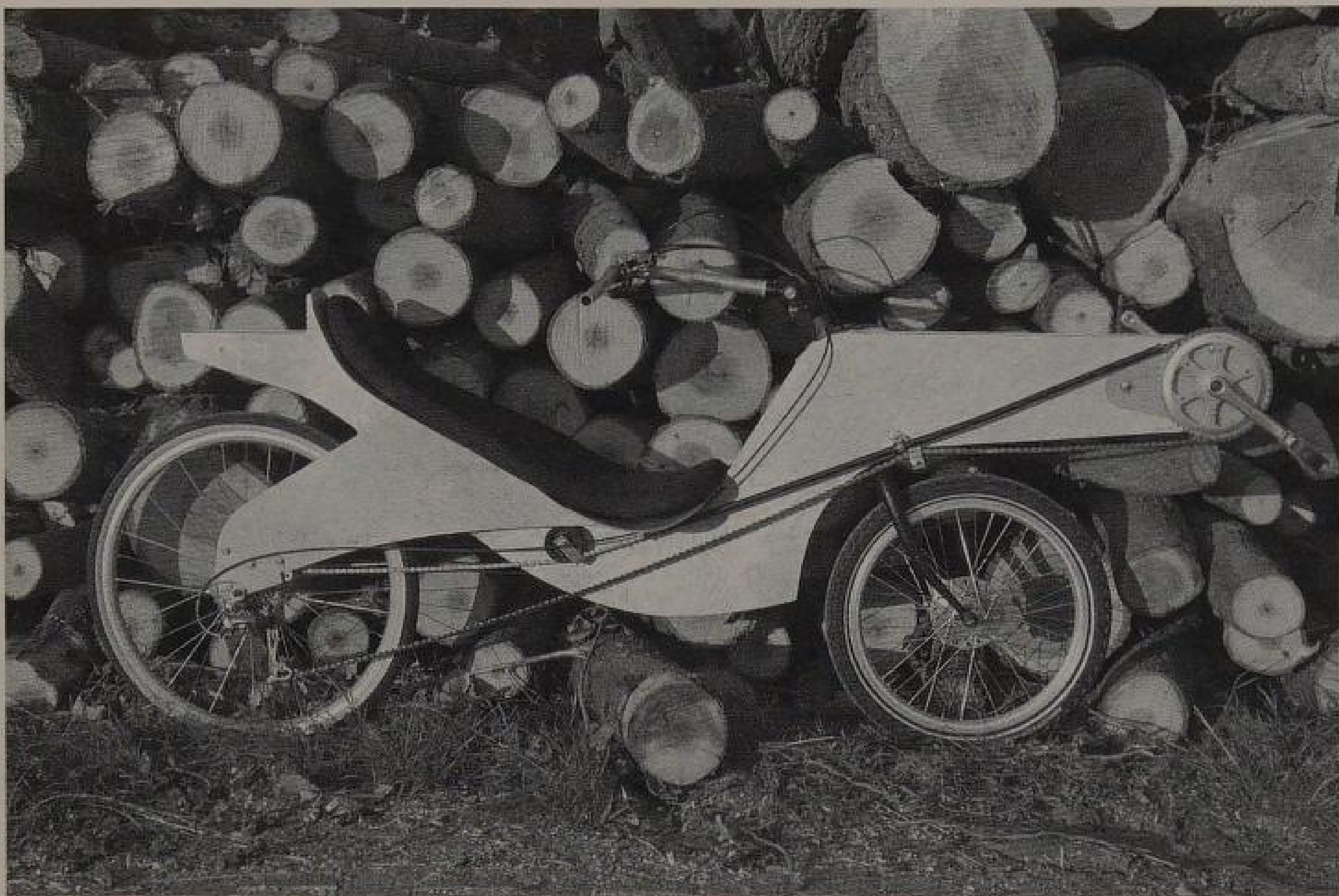
You need to be careful during brazing because heating the tubes can destroy their structure. A low-melting silver solder gives you the best chance to braze a high quality tube with the least possible loss of strength. Silver, however, brings about a higher penetration, which demands even smaller tolerances in joint gaps. Secondly, it is softer, which reduces its use to only a few places on the frame.



Clamp your connections securely when brazing to keep the gaps between tubes and lugs or fittings as small as possible. This is Manfred Harig's 'Lötblock' set-up—it even holds the solder.

Using lugs means also using silver, since the stability of the lugs in combination with the solder's penetration stresses the tube the least during the process and makes for the stiffest resulting frame. A definite advantage of brazing is that a joint can be corrected by reheating it (reducing strength though). Brazing is also more flexible than welding.

If you want to make a quickie frame to test geometry, you can rapid-weld the pieces without a lot of fuss. Make a real frame later.



Above, Dutch friends got together and built five plywood bikes (foam core) one summer at a workshop event. They got together again, in Slovenia, to build carbon bikes (below). Details at www.blids.nl. (photos: Sjaak Bloemberg)

First Steps in Frame-building...

Regardless of whether you decide to braze or weld a frame, consider the following suggestions for building a good frame under home workshop conditions.

First, keep a picture in mind of your desired end result through the whole construction phase: a rideable recumbent bike frame. Otherwise the frame will become a victim of time pressure, frustration, and improvisation.

Always build with full awareness and care. Any less and you endanger the project, even if the task at hand is as simple as drilling a hole. When you encounter a problem, stop the clock and give the matter your full concentration. A day or two of pondering can be highly productive. Good things take time. This mindset, along with careful preparation and a good plan, is the surest way to success.

Before you start brazing or welding, the tubes have to be fitted together. For beginners, a file is the tool to use. (Use high quality files; cheapies won't do you any good.) With a good file you can create a mitered joint—as the raw connection between tube and profile is called—with an accuracy of 3-8/100th millimeters, even without a lot of practice. Such cuts make the ends of tubes look sort of like fish mouths. This lets one tube fit flush against another curved tube for optimal welding.

When it comes to big curves or holes you can save a lot of work if you pre-drill your frame tubes. For precision, speed, and repeatability use a drill press—very handy if you're making a series of similar-diameter holes. Every mitered joint will be perfect and can be tailored for length and angle. But unfortunately (as is so often the case) such a tool is sinfully expensive.

A drill press also enables you to enlarge the radius of pre-drilled holes. Its size can be changed in 1/10th mm increments, which helps you to create tricky but round miters in very little time.

Inaccuracies can sneak in

The RecycledRecumbent.com website offers info, advice and straightforward plans, all for free, for building steel LWB clones from pieces cut from two road-bike "donor" frames. Frames are available for purchase if one lacks recyclable bikes. Above is the performance version called "Mach 2." (photo: Habitat 500 Bike Ride)

not only at the joints but also in lengths and alignment. Measurements should always be taken with a caliper and an accurate measuring tape. Remember the old carpenters' maxim: measure twice, cut once. Adding material with a saw is impossible.

For beginners the biggest problem is alignment accuracy. It is sometimes called "center accuracy." The center is a theoretical line through the center point of a tube or profile. Center accuracy means the relation of the individual centers within the tube towards each other. In geometrical frame sketches, for instance, the measures are given from center to center. Frame height, for instance, is measured from the center of the upper tube to the center of the bottom bracket. This method has developed from experience and has proven to be very practical. This way you can design a frame independent of tube dimensions, as only the centers get marked, which do not change if you switch materials and opt, say, for oversized tubing. This makes construction and comparison, as well as planning, much easier.

It's a little harder to determine the center position of oval tubes, like those sometimes used for chainstays.

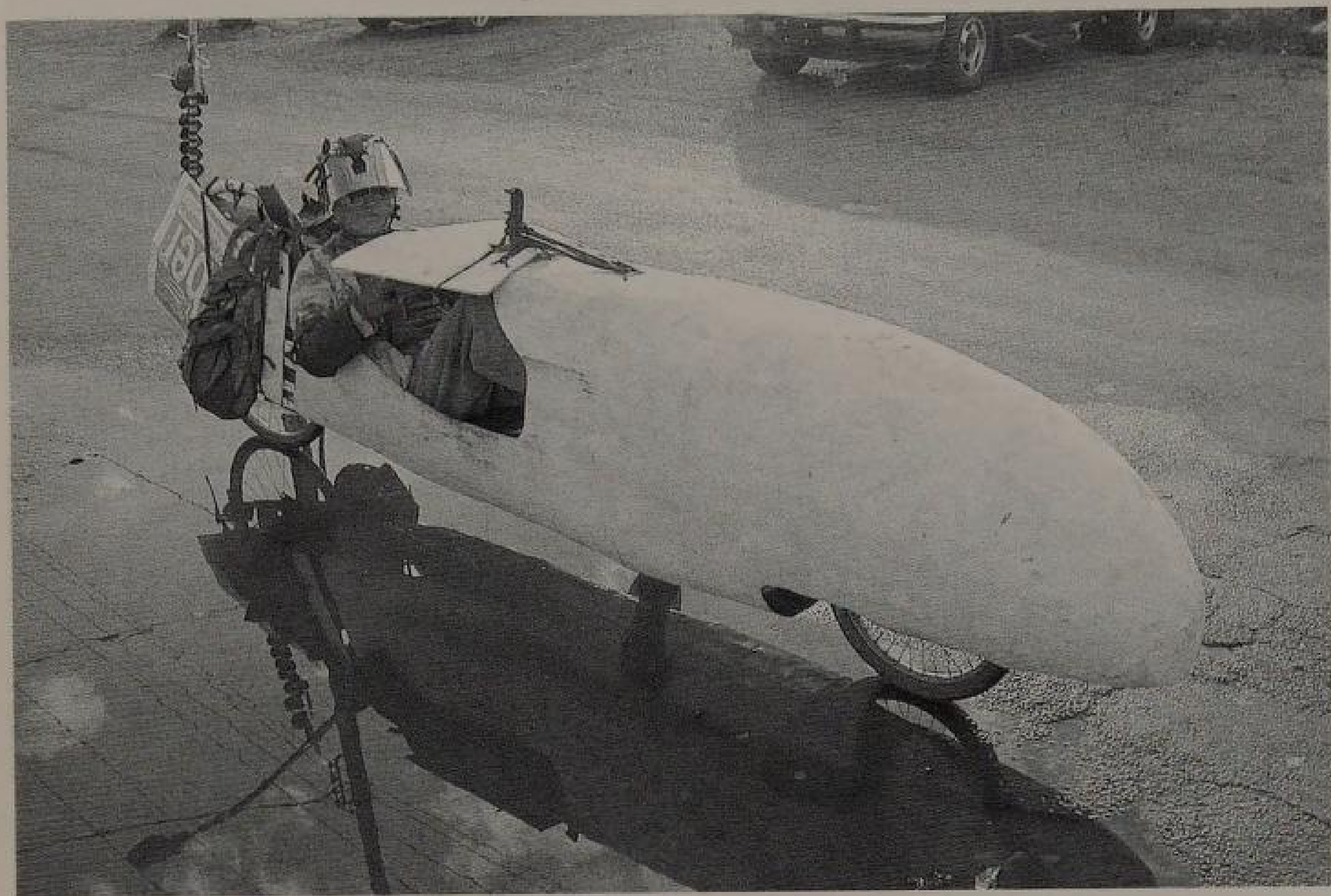
Minor mistakes can sometimes be adjusted, but be especially careful with the alignment of the wheels and the crankset. You have no margin for error here.

Wheels can be out of alignment in three ways. They can have a "dogleg," which is to say they are rolling on different tracks. They can be tilted out of true in the vertical plane, looking at the bike from front or back. Or the rear wheel may be twisted or "yawed" out of line with the center-line of the bike in the horizontal plane, as seen when looking down on the bike from overhead. This doesn't apply to the front wheel, as it is meant to point in different directions!

If the wheels have a dogleg they track outside their intended line of travel even though the axles are true and parallel when viewed from the side. They're just offset (when viewed from the back). If one rides through a water puddle, two tracks are left. In practice, this has negligible consequences. The bike still goes straight. A slight steering adjustment is perhaps all that is needed, but it does cause some inefficiency. You can correct minor dogleg by respacing the rear hub on the axle in the dropouts or by changing the wheel dish (position of rim relative to hub).

Lines stretched from upper to lower edges of the rims must be vertical (assuming a vertically positioned bike). If this alignment is off, the bike will indeed behave oddly. It may be possible to compensate by counteracting with steering or seat position, or you may just get used to it, but there will be costs in tire wear and a certain unpredictability of bike behavior.

Minor horizontal misalignment at the rear can be corrected if you use horizontal dropouts and simply reorient the hub in the drop-



Joe Kochanowski poses in one of the dozens of homebuilt recumbents he's made from mostly scavenged materials. His large vehicles thrive on rough terrain, heavy traffic, and inclement weather. He calls them "urban assault vehicles" and he and his friends use them mostly for commuting, but he also races them successfully. He wears heavy gloves, elbow pads, customized goggles, and a large visor because 'it all works well.' (photo: Dustin Wood)

outs. Vertical dropouts are more problematic because they demand more precision during construction—there's no easy adjustment; any change requires altering the frame and rebrazing.

Overall vertical wheel position is determined by the desired rider position along with the preferred weight distribution between the wheels.

A misaligned bottom bracket will definitely impact ride quality. But the consequences also show up in the area of biomechanics. The axis of the bottom bracket has to align with the axis of your pelvis bone. If it's otherwise, your legs have to distort their alignment during pedaling. This makes pedaling unpleasant, at best.

Constructing a frame with precise alignments is the crown of the frame-building art. And doing so is anything but simple, cheap, or fast.

Building a proper alignment jib to hold the frame tubes for processing is at the heart of the techniques you'll learn.

Longtime bike builder Martin Staubach reminds novice frame builders that their first frame will probably end up in the trash.

Do-it-yourself Fairings

As we saw in Chapter 5, planning an aerodynamically optimized fairing is complicated and time-consuming. And building it is even harder!

However, there is a spectrum of recumbent cyclists making quickie fairings of any suitable material they can find. They're usually short on strength, efficiency, and good looks, and they usually don't last for long. But these shaggy-dog experiments still offer speed benefits and more, such as warmth, weather protection, storage, and a degree of safety.

Tailboxes are a very popular area for this type of work. A common easy-to-use material is corrugated plastic board, known as Coroplast, which comes in various colors and thickness and is easily worked. Fabric and even cardboard can also be used.

Experience with quickie fairings will sometimes inspire a builder to make a "real" fairing. We'll focus most of our attention here on molded fairings since they offer the best performance gains.

The following steps are necessary for the production of a molded hard-shell fairing:

- Production of master body (prototype mold, from which copies are made)
- Production of negative form
- Production of positives

The mold is as critical to a fairing as a plan is for a frame. Moreover, the construction of a fairing is five to ten times as complicated as for a frame, and the end result is greatly dependent on the quality of the mold. Only the quality of processing can change the result after molding, and usually for the worse.

To build a proper fairing, count on a bigger time investment than what you'd expect for building a frame. Your costs will be higher, too. The basic tools and materials can total more than $1,000, not to mention the hundreds of hours you'll likely put into it. Thus I advise you to collaborate with someone or a whole club. The obvious benefit is shared costs, but you'll also gain by pooling knowledge and skills.

It takes the same work to make a mold prototype or plug—the basis of any fairing—for the molding of one final "positive" fairing as it does for a planned run of 3 or 20 fairings. The more fairings that spring from a single mold, the smaller the cost of each.

When constructing a mold, consider a material that is easy to work with. Polystyrene foam is a good bet.

It can be difficult to carve out a fairing shape from a big block (usually constructed of many blocks glued together). It's much easier to create the mold from many different layers.

Similar to slicing a loaf of bread, you "cut" the fairing's drawing with a pencil into many slices. (You'll convert these pieces into foam boards that you individually carve to the right shape then reassemble, creating the final fairing "loaf.") The thickness of the slices should be identical, and within the area of one slice there should not be much change in shape. Now calculate the full-size measurements of the slices, buy them in the form of insulation foam boards in sufficient quantity, and put two relatively big gaps in the middle. This enables the precise "cutting" of the slices.

Before you cut them, number them with a pen to match their numbered sections in the plan. The sections are now drawn in real size onto the boards and are cut out. Then the shapes are glued together in order. The Styrofoam body now has an "edgy" rough outline of the future fairing. Now you construct a simple tool. Glue a strip of rough sandpaper on a long board and you have an inexpensive but effective "file." Start filing! Very soon the mold will gain soft curves. Your workspace, however, will look like it has been hit by a snowstorm.

The highly experienced Team Infinity/Banshee homebuilders outfitted their Super Street class HPRA racing/commuting recumbents with fairings made of Coroplast and clear plastic nosecones. An opening on left side means that no panels need to be moved to enter/exit these versatile bikes.

Keep in mind that grinding and sanding produces hazardous dust. Wear a dust mask and work in a place with good ventilation.

If your fairing will have a hinging or detachable canopy or hood, it has to be created separately, but follow the same principle.

Next, seal the Styrofoam form with latex paint. Other types of paint can react to the product and ruin your work. Apply paint in layers until all holes in the base body are filled.

Follow the paint steps with of a layer or two of protective fiberglass, since Styrofoam dents easily.

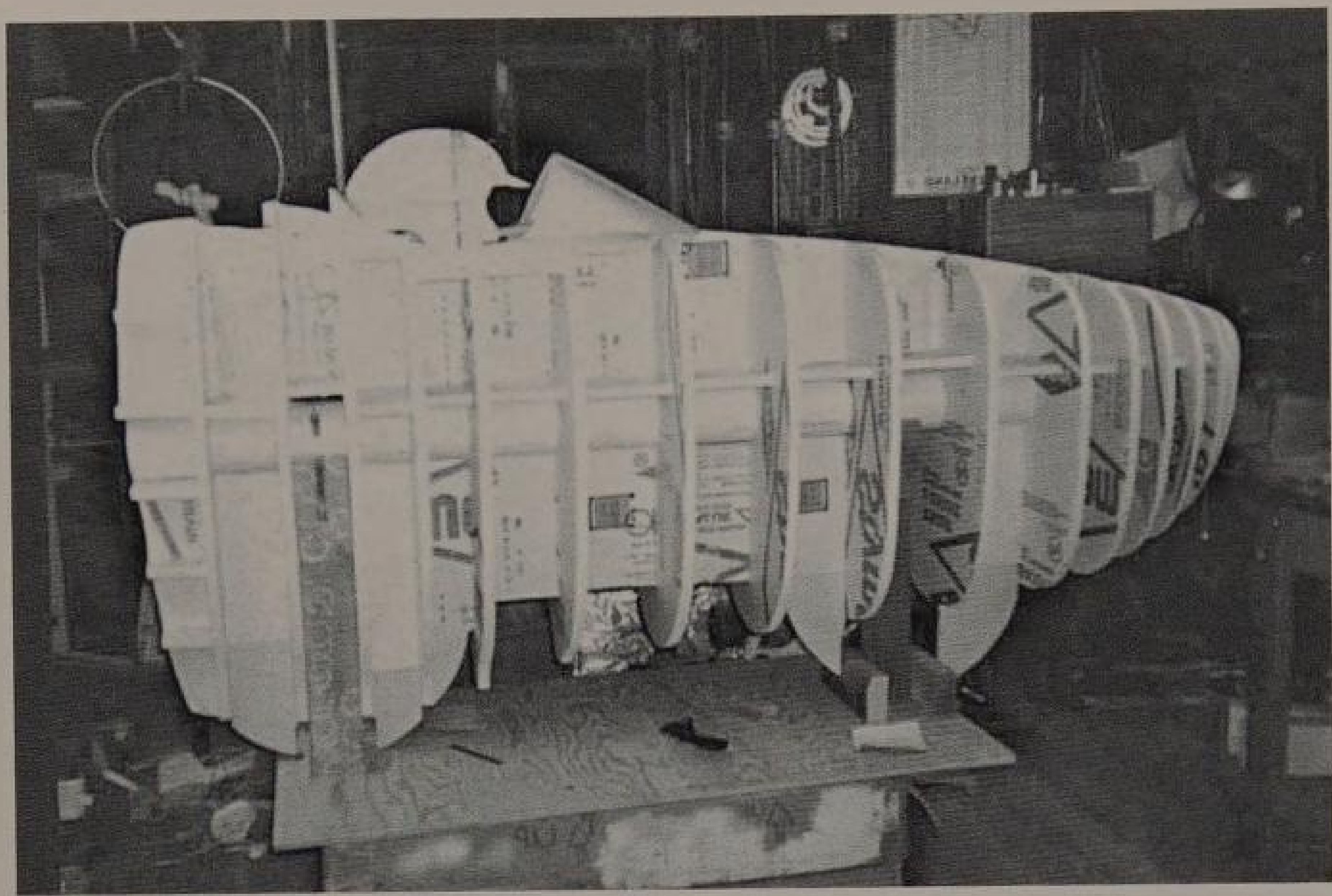
The most difficult and important step is next: covering the form with polyester filler, followed by polishing. All bumps, scratches, and waves must be removed. Whatever is not corrected will impair aerodynamics and take away from the fairing's appearance.

So...

- fill, grind, spackle, sand
- fill, grind, spackle, sand

...until you have a completely smooth form. The sooner you make corrections the easier the whole project is.

The endless cycle of sanding and filling can be simplified and shortened with a little trick: When you think you've reached your



A relatively simple mold for a Zote foam fairing (photo: J. Tetz)

goal, spray the sanded form with white glossy paint and watch how areas of uneveness become apparent. The bumps and waves that deteriorate *Cd*-value now reveal themselves as you pass a light over the surface. Count on some work-intensive weeks before you're finished.

If you're only building a single fairing, you next laminate the fairing over your mold, then grind and sand it smooth. Then you either destroy your mold inside the fairing or pull it out intact, if possible.

However, since it has taken you so much work to make the mold, think about producing some fairings for your friends, who can help defray your costs. Otherwise your one-off mold might prove to be as expensive (in time and materials) as buying a production fairing outright.

If you decide to make multiple fairings, you should make a second, negative mold. To do this you make your negative mold over the original positive mold then take it off. You can readily do this if you make the negative in pieces that can be easily taken off the positive plug then rejoined for molding positive fairings inside it. To do this, make stencil templates that mark every place the pieces will join. It's easier to understand this process by looking at the series of mold photos in the color section in the center of the book.

First, the separate parts should be symmetrical. Use simple cross-sections of the plug to make the stencils, i.e., from the front and side views as well as the width as seen from above. This way you can divide the negative mold into manageable parts that are easy to re-assemble.

On plywood, use the stencils to draw the fairing's exact cross-sections for each line of separation, then saw them out. Each board then aligns with its correct location on the mold.

Later, for each piece you not only laminate the fairing part of the mold negative, but also a 3-inch high flanged rim that laps up onto each wooden stencil (which is also coated with release agent). The rims will serve as clamping surfaces for adjacent pieces.

The contact surfaces should be clamped absolutely parallel to each other so that the parts do not put ridges into the fairing's smooth surface or shift position.

Each negative piece has to be created one at a time so that the stencil boards can be repositioned to create perfectly flush joints.

Material you use here should be cheap. Only the first layer, which will later determine the finish quality of the outside of the fairing, needs to be of the highest grade.

To create a negative mold:

Step 1: apply surface resin to positive (provides a smooth, hard surface)

Step 2: binding layer of resin and aluminum powder

Step 3: lay up pieces with resin-soaked fiberglass

Step 4: two or three layers of rough fabric can follow for the finish.

At all times, do your best to avoid bubbles, gaps, and air spaces between layers.

After a piece has hardened, it can be removed from the mold easily by sliding a thin, flexible piece of plastic between the form and the negative. The mold will jump out with a "plop!" From this point on, the negative form must not change its shape—not even by a tenth of a millimeter. If the negative form still flexes or is unstable and does not hold its shape by itself after Step 4, you have to follow up with additional fiberglass layers.

After separation the inside of each piece is covered with a release agent and polished (careful: do not apply too thickly). The type and brand of release agent depends on the type of negative material you have used. Ask ahead about the necessary chemicals for this stage of the game. If you're not careful you can run into large expenses in trying to keep up with the latest products and the ancillary chemicals they require.

If you build metal framing or wood laminates to support your negative form, you can save weight and money and simplify the later body production. Moreover you can also build thread and screw holes into the contact flanges so you don't have to fuss with clamps and clips.

Now it's time to make your fairings.

To cut weight from the final fairing, you might consider wet-in-wet construction, i.e. combining the individual pieces during the process of hardening. The fairing also ends up stiffer and more stable. The edges of the individual pieces fit to each other and harden together to become one piece. That makes them stronger than parts that are put together after hardening. A later lamination will never acquire the firmness of a wet-in-wet connection. Additionally, a wet-in-wet fairing can be warmed up from the inside with a heat gun during the hardening process, which makes the final stability even greater (a process called tempering).

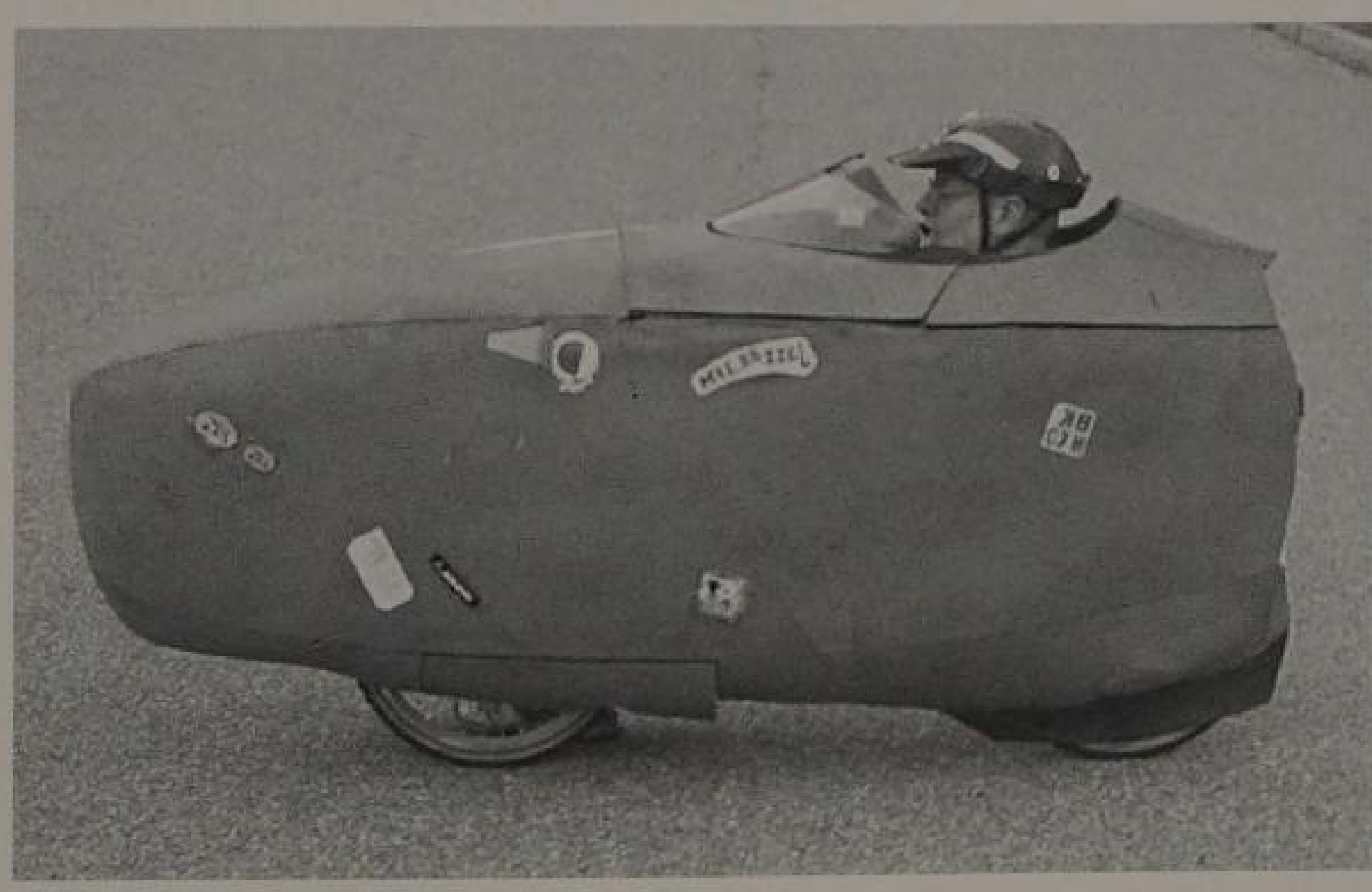
To do wet-in-wet construction you definitely need screw holes and flat surfaces for clamps on the rims of the various negative mold parts. The negative parts have to be joined with perfectly flush seams to take advantage of this method.

Heating Zote foam into shape for a trike fairing. (photo: J. Tetz)

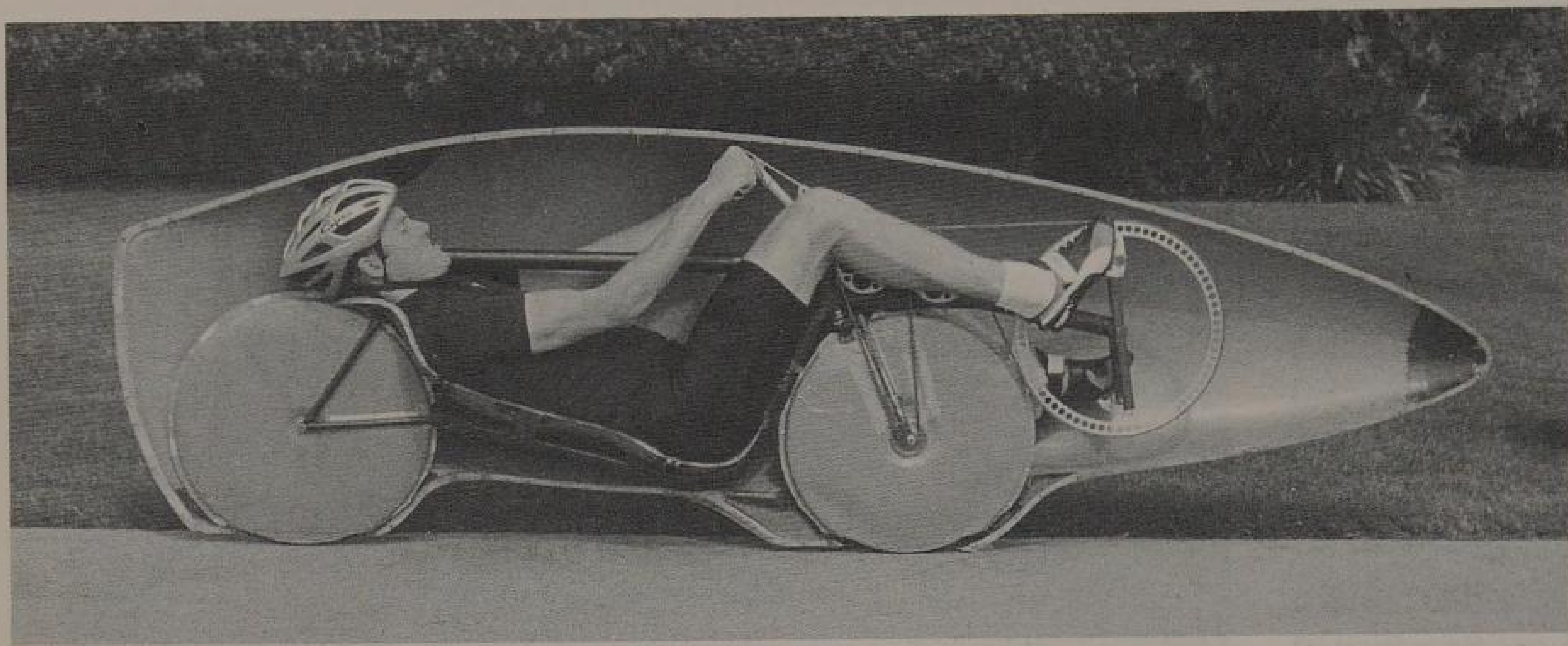
The temperature during wet-in-wet processing should be about 68°F. If it is colder, the resin is difficult to work with; if it is warmer, it hardens too fast.

With this method you "only" have to laminate the individual parts, laminate the seams, heat it up, let it harden, and plop it out—and your fairing is done!

...That would be nice. Your fairing at this point does not have mounting brackets or openings for your feet, lights, wheels, or ventilation. These various holes have to be sawn out carefully.



This finished Zote foam fairing weighs just 9 pounds and lets 74-year-old John Tetz's 24-lb homebuilt bike cruise 30+mph. It all fits into a hatchback car. (photo: J. Tetz)



With half of his fairing removed for the photo, Matt Weaver displays the tight quarters inside the 'Virtual Edge.' Outfitted with a video camera and monitor, sealed wheel-wells (to prevent vacuum suction), and a huge chainring, Matt reached 85mph with an 'Edge' prototype during an unofficial run in 2000. He predicts 100mph is possible with such ultra-smooth, minimally-seamed fairings. Matt designs on a computer using advanced engineering training and makes much of his own equipment.

First you saw out any holes or moveable panels as needed and install the brackets for mounting the fairing onto and around your recumbent. If they fit, you position and attach the fairing to your bike. If your fairing is self-supporting and stable, you only need two horizontal and two vertical anchors. These will provide a sufficient combination against the influences of pedaling power, air resistance, and ground unevenness. Practically, the vertical fastenings should be located in the front and the horizontal ones at the rear, so that the fastenings do not collide with either wheels or feet.

Large-diameter aluminum tubes or square channels as a connection between bike and fairing are light, stable, and unproblematic. They can be easily mounted to the frame (stuck in the boom end, screwed to a socket, or inserted into an additional braze-on fixture). Being oversize they have great stiffness and strength. The brackets on the fairing have to be flat and secure. Silicone glue works great as a buffer in the connections between rattling bike and secure fairing. It can even be used on its own as a floating connection, which harms neither frame nor fairing. It's very stable, plus it dampens oscillations, making the fairing significantly quieter.

Depending on your intended use, you might want breaks and openings for the following:

- Hood or canopy
- Side-door
- Front and rear lights
- Heel movement radius
- Ventilation in front of head and legs
- Access to shifters, gears, and derailleurs
- Access to trunk cargo space
- Access to brakes, lighting
- Access to wheels and tire valves
- Windshield mounting holes in hood
- Ports for hand signals
- Cooling holes for brakes

There are four common closing mechanisms:

- Hinge
- Velcro
- Shock cord / hook
- Tape

A hinge creates a very secure connection, being especially suitable for openings that are used often, like a canopy or luggage compartment. Any hinge gets laminated in, or glued to the inside of the fairing with silicone. Avoid rivets or screws as much as you can, because holes in the fairing result in cracks when you fall. Screws have another disadvantage: A screw head or point inside the fairing can cause injuries when you get in or out or fall.

Velcro is fastened with hot-melt or silicone glue and is more appropriate for less-often used openings like the access to components, brakes, and lights.

If any panels, doors or openings need to be able to be opened or closed while riding, then you can also use a looped or hooked shock cord that attaches to an aluminum hook. Cut a piece of flat aluminum measuring a half-inch to an inch and a half, file the edges dull, and bend it into a "J." Then laminate the long side to the fairing. A loop of shock cord can be attached with wire, rivet, glue, or bolt. This connection is light, reliable, and cheap. The tension hook option is also fine for hood or doors.

If you want to eliminate noise completely, your fairing must have a buffer that can isolate the fairing from vibration. Either you work one into the mold or you laminate it into the brackets later.

Every fairing needs openings for the feet, but you should ask yourself whether these should be open during your rides or closed with "bomb-bay" doors. Such flaps improve aerodynamics and weather protection. Installing such doors is relatively simple: you need hinges and a few inches of shock cord for each door. The hinges and cords get glued to the doors and fairing with silicone glue. The cords have to be fastened about 5 inches above the doors inside the fairing. Now the doors can be easily opened, and a light pull at the cords closes them again. A small damper here also prevents noise.

Last but not least is the duct tape option for fastenings. I don't need to explain how to apply it, other than to say your surface must be clean and oil-free.

The visor or windscreen of the hood should be incrementally openable for regulating ventilation. (Or use a nose-hole or other ducting, such as a NACA duct.)

Finally your fairing is ready for a ride. Likely you'll discover bugs to work out. Once those are taken care of you can put on your artist's beret and start painting. You have a big canvas: Be creative!

The Tape Method for Checking Aerodynamics

Here's a final tip in the form of a simple but effective method to double-check your aerodynamics.

Cover your installed fairing with 1-inch strips of old cassette or VCR tape. Tape them in vertical rows about 6 inches apart. Your fairing should look something like a fringed jacket.

With a video operator in a car driving alongside you, get filmed while riding down a long, empty road. The resulting video will reveal where the fairing has weak points. Side wind properties are especially easy to evaluate in this way.

Wherever the fairing has aerodynamic weak spots, the tape threads will not fly horizontally in the air, but will flap haphazardly. Be aware that rough pavement can distort the result.

Stethoscope Testing

Matt Weaver uses another method worth noting. He uses a stethoscope with the metal sound receiver removed. He puts the 'scope on his ears, then rides and moves the rubber end along the inside of his fairing. Places where airflow breaks down are noisier and easy to detect! The stethoscope lets him detect places where a fairing loses laminar flow and breaks into turbulence.

This bike, shown without its fairing, is distinctive for its frame triangulation (for rigidity) and its seat mesh made of auto seat belt webbing.

My favorite recumbent experiences ...

...when I started riding one for the first time...

...when it was repainted a bright red...

...when I finally reached more than 30 mph on level ground...

...when my thighs stopped feeling like balloons after every little effort...

...when I beat Greg Lemond (OK, that was just a dream)...

...when my steering mechanism broke off in the middle of Canada without any reason...

...when we arrived in Boston after a 200 km night ride without being tired (no dream)...

...when an elderly woman in a wheel-chair—similar position—waved at me...

...when somebody asked me whether I belonged to the tour group of a senior citizen's home...

...every time I meet people who share my interest...

...to be one among many at the European HPV Championships and not be constantly stared at...

...every time I go uphill and the blood gets flowing back in my legs as I set to work...

...hearing "*Oohs*" and "*Aahs*" and "*Look at that!*" ...as long as I'm in a good mood...

...after I rode a regular bike after having ridden a recumbent for half a year and not knowing after 30 minutes if I could stand the seat any longer...

...when it rains...

...when I found out that my brother could not use it because his legs were shorter than mine...

...that after I started riding one so many others have felt inspired to do the same...

...when my grandma saw my vehicle she was so surprised that when she wanted to say good-bye, she exclaimed: "Oh boy, good night!"

...when the truck who wanted to pass me on a highway had to take a long time to get enough speed to do so...

—Juergen Reimann

Appendix Recumbent Resources

At Long Last...

The small number of recumbents might lead one to think that they're likely not very far developed. That's far from the case. Since the first edition of this book in 1996 the recumbent market has grown hugely. Few other bike types today offer the unique advantages, features and diversity that one can currently find in the recumbent market.

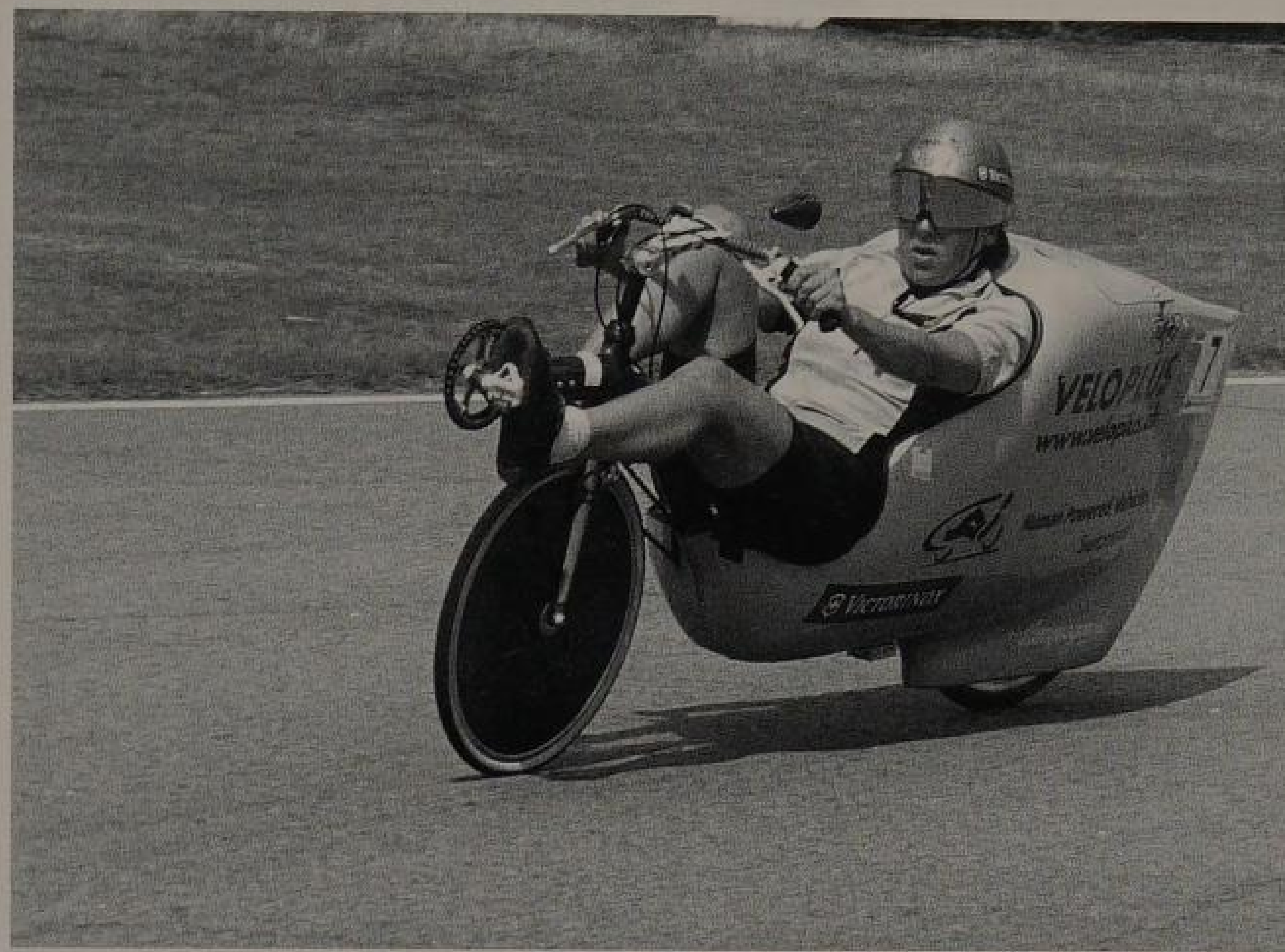
Partly the bike racing associations are to be held responsible for this situation because they still (!) ban recumbents from races. Also to blame are traffic planners and the laws which produce a traffic situation that makes the use of recumbents (and bikes in general) highly desirable but very difficult. And lastly, there are the cyclists themselves. They don't want to spend the comparatively high sum of money on such a bike. (Although they seem happy to spend it on any other type of bike.) Granted, the price-per-pound of a many recumbents can seem excessive. Thankfully, at least a few thrifty models are available.

Even so, if you prefer a mass-production bike from Taiwan to a small shop recumbent that has been manufactured meticulously by hand, you make David fight against Goliath...!

If you decide that an HPV is worth it despite the higher cost, you'll hardly regret it. The advantages of a recumbent are soon realized, and you'll learn to use and appreciate them—that is what makes riding a recumbent incomparable to anything else.

This book has accompanied recumbents all along their development and through the centuries, it has given you experiences and facts and has dared to look into the future (with hopes and wishes).

The normal bike loses its right to lead in so many fields given all the information and encouragement you've now seen.



Cycle Vision 2003 racer flying along "in" a stylish Swiss Birk "Comet." (photo: www.tim.be)

Are you interested in these rare but fascinating, practical as well as fast, beautiful and bizarre vehicles? Then set up a test ride with a dealer close to you and buy one, or go into your garage and unpack your tools! Visiting an HPV event is also a great opportunity to get infected with the virus.

Then, while lying down, take a ride over the countryside! —*Gunnar Fehlau*

A Note about Directories

Lists of manufacturers are outdated as soon as they are printed. This holds true especially for the recumbent market. The market changes quite a bit yearly. The Internet is the best place to search for current information, with BentRiderOnline.com offering the broadest range of information and reviews in one place. The best print resource is *RCN: Recumbent Cyclist News*, ($8 sample; RCN, PO Box 2048 Port Townsend, WA 98368) with its annual Buyer's Guide. Recumbents.com is another great resource, especially for racers and homebuilders.

A World of Manufacturers

USA

ActionBent Recumbents
17930 NE 127th St.
Redmond, Wa, 98052
ph: 425 881 3696
http://www.actionbent.com

Angletech
318 N. Highway 67, P.O. Box 1893
Woodland Park, CO 80866-1893
ph: 719 687 7475
http://www.angletechcycles.com

Bacchetta
4705 95th St. N.
St. Petersburg, FL 33708
ph: 866 364 9677
http://www.bacchettabikes.com

Backsafer
9703 S. Dixie Hwy, Ste. 2
Pinecrest, FL 33156
ph: 800 815 BACK (2225)
http://www.Backsafer.com

Barcroft Cycles
Falls Church, VA
ph: 703 750 1945
http://www.barcroftcycles.com

Bender Custom Bicycles
3287 NW Bungalow Dr #2
Bend, Oregon 97701
ph: 541 617 1628
http://www.benderbikes.com

BiGHA
4314 SW Research Way
Corvallis OR 97333
ph: 541 738 4340
http://bigha.com

BikeE
(website dedicated to these popular but discontinued bikes: http://www.simplecom.net/poleary/.)

Bike Friday
3364 W. 11th Ave.
Eugene, OR 97402
ph: 800 777 0258
http://www.bikefriday.com

Bilenky Cycle Works
5319 N. Second St.
Philadelphia, PA 19120
ph: 215 329 4744
http://www.bilenky.comviewpnt.html

Boulder Bikes
P.O. Box 1400
Lyons, CO 80540
ph: 303 823 5021
http://www.boulderbikes.com

Burley Design Cooperative
4020 Stewart Road
Eugene, OR 97402

Cannondale's full-suspension CWB is a well-built, American-made entry to the recumbent market by this large company.

ph: 541 687 1644
http://www.burley.com

Cannondale
16 Trowbridge Drive
Bethel, CT 06801
ph: 800 245 3872
http://www.cannondale.combikes/02/cusa/model-2BM.html

CarBent
P.O. Box 1043
Layton, UT 84041-1043
http://www.carbent.com

Cycle Genius Recumbents
6215-B Evergreen St.
Houston, TX 77081
ph: 866 901 2453
http://www.cyclegenius.com

Earth Cycles
1500 Jackson St NE
Minneapolis, MN 55413
ph: 612 788 2124
http://www.earth-cycles.com

Easy Racers Inc.
P.O. Box 255-W
Freedom, CA 95019
ph: 831 722 9797
http://www.easyracers.com

Haluzak
70 W. Barham Ave.
Santa Rosa, CA 95407
ph: 707 544 6243
http://www.haluzak.com

Huffy ("Venice" semi-recumbent)
Amazon.com and major chain retailers

Human Powered Machines
455 West First Ave.
Eugene, OR 97401-2276
ph: 800 343 5568
http://www.catoregon.org/hpm/

Human Powered Products
23825 East Euclid Avenue
Otis Orchards, WA 99027-9748
ph: 509 226 0317
http://www.asisna.comhppbikes/

Infinity
8433 E McDonald Dr
Scottsdale, AZ 85250

Lightfoot Cycles
179 Leavens Road
Darby, Montana 59829
ph: 866 821 4750
http://www.lightfootcycles.com

Lightning Cycle Dynamics
312 9th St.
Lompoc, CA 93436
ph: 805 736 0700
http://www.lightningbikes.com

Linear (c/o The Bicycle Man)
570 Main St., PO Box 186
Alfred Station, NY 14803
ph: 607 587 8835
http://www.linearrecumbent.com

Longbikes (formerly Ryan)
3535 S. Kipling St., Unit A
Lakewood, CO 80235
ph: 303 986 9300
http://www.tandembike.com

Organic Engines
1888 Mills St.
Tallahassee, Fl 32310
ph: 850 224 7499
http://www.organicengines.com

Penninger Recumbents
1015 Airpark Dr.
Sugar Grove, IL 60554
ph: 630 556 4325
http://www.penningerrecumbents.com

RANS Inc.
4600 Hwy. 183 Alt.
Hays, KS 67601
ph: 785 625 6346
http://www.ransbikes.com

Recumbent Barn Inc.
205 Beryl St
Redondo Beach, CA 90502
ph: 800 371 6587

Reynolds Weld Lab
(out of business)
http://www.reynoldsweldlabs.com

Rotator Recumbent Bicycles
3200 Dutton #215
Santa Rosa, CA 95407
ph: 707 591 0915
http://www.rotatorrecumbent.com

S & B Recumbents c/o Jack Baker
12901 Budlong, Unit A
Gardena, CA 90247
ph: 310 323 9395
http://home.pacbell.net/recumbnt

Sun Bicycles c/o J&B Importers
PO Box 161859
Miami, FL 33116-1859
http://www.sunbicycles.com

TerraCycle, Inc.
3450 SE Alder
Portland, OR 97214
ph: 800 371 5871
http://www.terracycle.com

Trimuter
3030 Caily Lane
Highland, IL 62249
ph: 618 654 6740
http://www.trimuter.com

Turner Enterprises
PO Box 18421
Tucson AZ 85731
ph: 520 290 5646
http://www.turnerrecumbents.com

Velogenesis
9765 Anchor Dr.
Longs, SC 29568
ph: 843 399 8786
http://www.velogenesis.com

Vision Recumbents
(out of business)

Volae Recumbents
3201 John Joanis Dr.
Stevens Point, WI 54481
ph: 800 233 4340
http://www.volaerecumbents.com

Wicks Aircraft Supply
410 Pine Street
Highland, IL 62249
ph: 618 654 7447
http://www.wicksaircraft.com

Worksman Cycles
94-15 100th Street
Ozone Park, NY 11416
ph: 888 394 3353
http://worksman.com/y3kwebpage2.htm

Australia

Flying Furniture Cycles
ph: +61 (0) 2 95502805
http://www.flyingfurniture.com.au

Freedom Human Powered Vehicles
478 Whitehorse Rd
Mitcham 3132, Melbourne
ph: +61 (0) 3 9874 8033

Modular Bikes
10 Abbott Grove, Clifton Hill, Vic 3068
ph: (03) 94818290; modularbikes.com.au

Austria

MCS Maderna City Scooter
Paris Maderna KEG Zeltgasse 12
A-1080 Wien
ph: +43 676 422 77 32
http://www.mcsbike.com

Brazil

Pedro Zöhrer
Rua Triunfo, 41
Rio de Janeiro - RJ - Brasil
http://www.zohrer.com.br/

Canada

Cambie Cycles
3317 Cambie Street
Vancouver, BC V5Z 2W6
ph: 604 874 3616
http://www.cambiecycles.com

CCM (Mikado, Evox, Quetzal, Procycle)
9095 25th Ave., St. Georges,
Beauce, Quebec G6A 1A1
ph: 418 228 8934
http://www.evoxcycle.com
http://www.quetzal.ca

Belize Bike
4010 St. Catherine St. W., Ste 200
Westmount, Quebec H3Z 1P2
ph: 877 933 2595
http://www.belizebike.com

Maxarya
1912A Avenue Rd.
Toronto, Ontario M5M 4A1
ph: 416 484 9540; http://www.maxarya.com

Varna Innovation and Research Corporation
RR2, Site 54, C 13
Gabriola Island, BC V0R 1X0
ph: 250 247 8379; varnahandcycles.com

Czech Republic

Azub
Alesˇ Zemánek, U Olsˇavy 1102
68801 Uhersk‡ Brod
http://www.azub.cz/en

Denmark

Hjordt
Granstien 4, Bregninge
DK-5700 Svendborg
ph: +45 62 22 62 31
http://www.liggecykler.dk

Germany

Aiolos Liegedreiraeder
Goethestrasse 7, D-10623 Berlin
ph: +49 (0) 30 31 80 60 13
http://www.aiolos.de

Brompton Recumbent Conversion Kit
Haferberg 2, D- 21059 Glinde
ph: +49 (0) 40 710 951 04
http://www.tu-harburg.de/~skfcz/Brekki/brekki_en.html

FluxFahräder
Kreuzbreitlstraße 8, D-82194 Gröbenzell
ph: +49 (0) 8142 53180
http://www.flux-fahrraeder.de

Hase Spezialraeder
Karl-Friedrich-Strasse 88
D-44795 Bochum
ph: +49 (0) 2 34 9 46 90 50
http://www.hase-spezialraeder.de

HP Velotechnik
Goethestrasse 5, D-65830 Kriftel
ph: +49 (0) 61 92 4 10 10
http://www.hpvelotechnik.com

Lohmeyer Leichtfahrzeuge
Geistingestraße 31, D-53773 Hennef
ph: +49 (0) 22 42 909924
http://www.leichtfahrzeuge.de

Noell Fahrradbau
Fischerweg 6
D-36041 Fulda/Kaemmerzell
ph: +49 (0) 661 54836
http://www.noell-fahrradbau.de

Ostrad Fahrraeder
Winsstrasse 48, D-10405 Berlin
ph: +49 (0) 30 44 34 13 93
http://www.ostrad.de/liegerader.html

Quantum Toxy
Fasanenweg 25, D-25364 Bokel
http://www.quantum-liegeraeder.de

Radius Liegerad Muenster GmbH
Borkstrasse 20, D-48163 Muenster
ph: +49 (0) 1805 723487
http://www.radius-liegeraeder.de

Senkels GmbH
Mariendorfer Damm 168
D-12107 Berlin
ph: +49 (0) 30 70 60 00 63
http://www.senkels.de

Speedbike (Kramer & Kislat GmbH)
Am Stadtpark 43, D- 81243 München
ph: +49 (0) 1718828176
http://members.aol.com/speedbikev

Veloladen (Scooterbike)
Stegerwaldstrasse 1
D-51427 Bergisch Gladbach
ph: +49 (0) 2204 61075
http://www.veloladen.com
http://scooterbike.com/start-e.html

Voss (BevoBike)
ph: +49 (0) 48 21 7 80 23
http://www.voss-spezialrad.de

ZOXbikes
Michael-Vogel-Strasse 3
D-91052 Erlangen
ph: +49 (0) 91 31 7 19 73 21
http://www.zoxbikes.com

Italy

Dolce Vita
Via Aspesi 164
21017 Samarate (VA)
ph: +39 (0) 331 234096
http://www.dolcevita-bike.it

Slyway Projects
Via Ghinaglia 47, Cremona 26100
ph: +39 372 29589
http://www.slywayprojects.com

Japan

ST Manufacturer Inc. (linear drive)
5-6-5 Mure Mitaka, Tokyo 181-0002
ph: +81 (0) 422 46 0491
http://www.stmfr.co.jp/STMFR/recumbent.html

Lithuania

VeloMR
Aukstabalio 6-19, Siauliai 5400
ph: +37041552335
http://www.velomr.projektas.lt

Mexico

Go-Ze! Industries
Carlos Gomez
ph: +52 (0) 11 525 2546911
http://members.tripod.com/recumbentes

The Netherlands

Advanced Cycle Engineering
Weurden 60, 7101 NL Winterswijk
ph: +31 (0) 543 530905
http://www.ligfiets.net/ace

Alligt
Vogelplein 4c, 5212 VK Den Bosch
ph: +31 (0) 73 6911388
http://www.alligt.nl

Challenge
Anklaarseweg 35-37, 7316 MB Apeldoorn
ph: +31 (0) 55 521 24 05
http://www.challengebikes.com

Cobra Bikes
http://www.cobrabikes.net

Dutch Speed Bicycles (conversion kit)
http://www.dutchbikes.nl/uk.htm

Flevobike
De Morinel 55, 8251 HT Dronten
ph: +31 (0) 321 337200
http://www.flevobike.nl

M5 Ligfietsen en Handbikes
Nieuwe Kleverskerkseweg 23
4338 PP Middelburg
ph: +31 (0) 118 628759
http://www.m5-ligfietsen.com

Nazca Ligfietsen
Castorweg 48, 7556 ME Hengelo
ph: +31 (0) 74 2592886
http://www.ligfiets.net/nazca

Optima Cycles
Gierstraat 55-57
2011 GB Haarlem
ph: +31 (0) 23 5341502
http://www.optima-cycles.nl

Rainbow
Barloseweg 28-1, 7122 PW Aalten
ph: +31 (0) 543 451677
http://www.rainbowligfietsen.nl

Roundabout
Hugo de Groot VOF.
Burg. Seinenstraat 57, 9831 PV Aduard
ph: +31 (0) 50 4031904
http://www.hugodegroot-vof.nl

Sinner
Walkumaweg 7
9923 PK Garsthuizen
ph: +31 (0) 595 464318
http://www.sinner.demon.nl

Ligfiets Shop Tempelman
De Morinel 53, 8251 HT Dronten
ph: +31 (0) 321 337200
http://www.ligfietsshop.nl

Thijs Industrial Designs (row-bike)
Koorkerkstraat 10
4331 AW Middelburg
ph: +31 (0) 118 634166
http://www.rowingbike.com

Wiegers Wheels
Korn 19, 4271 BM Dussen
ph: +31 (0) 416 391420
http://www.xs4all.nl/%7Ewiegers

Zephyr Ligfietsen
Postbus 27, 4486 ZG Colijnsplaat
http://www.zephyr.nl

Poland

Velokraft
Kamil Manecki
ul. Czysta 10/5, 31-121 Krakow
ph: +45 504 140 424
http://www.velokraft.com

Switzerland

Birkenstock Bicycles
Stampfstrasse74, CH-8645 Jona
ph: +41 (0) 79 428 20 08
http://www.speedbikes.ch

United Kingdom

MicWic Ltd.
12 Oaklands Industrial Estate
Braydon, Swindon, Wiltshire SN5 0AN
ph: +44 (0)1793 852484
http://www.swindonlink.com/MICWIC

Ultimate Bikes
Brazenhead, Bottom Lane
Sulhamstead, Berkshire RG7 4BJ
ph: +44 (0) 118 9305250
http://www.ultimatebikes.com

Recumbent Dealers

The following is a list-by-state of bike shops which are mostly recumbent enthusiast and specialty shops.

Alabama

Cahaba Cycles, 3120 Heights, Birmingham, AL 35243; ph: 937-767-2288; faris@cahabacycles.com

Tandems, Ltd., 2220 Vanessa Dr., Birmingham, AL 35242, ph: 205-991-5519; www.tandemsltd.com

Arizona

Ajo Bikes, 1301 E Ajo Way, Ste 117, Tucson AZ 85713; p 520-294-1434; www.ajobikes.com

Arkansas

Springdale Bicycle, 212 E. Emma, Springdale, AR 72761; 886-726-7245; springdalebicycle.com

California

Alan's Family Bike Shop, 1220 South Coast Hwy, Oceanside, Ca. 92054; ph: 760 722 3377; www.alansfamilybikeshop.com

Bent Up Cycles, 7828 Balboa Blvd., Van Nuys, CA 91406; ph: 818-994-4171; bentupcycles.com

The Bicycle Work Shop, 1638 Ocean Park Blvd, Santa Monica, CA 90405; ph: 310-450-3180; www.recumbentbikes.info

Gold Country Cyclery, 3081 Alhambra Dr. Suite 103, Cameron Park, CA 95682; ph: 530-676-3305; www.tandems-recumbents.com

Kirk's Bike Shop, 619 Main St., Ramona, CA 92065; ph: 760-789-4111; kirksbikeshop.com

People Movers, 980 N. Main St., Orange, CA 92667; ph: 714-633-3663; www.recumbent.com

Peregrine Bicycles, 11 Commerce Ct., #7, Chico, CA 95928; ph: 877-729-2453; pbwbikes.com

Richard's Cyclery, 11943 Valley View St., Garden Grove, CA 92845; ph: 714-379-2717

Spin Cyclz, "serving the Bay Area," CA; ph: 925-301-7043; www.spincyclz.com

Colorado

Angletech, 318 N. Hwy 67, Woodland Pk, CO 80866; ph: 719-687-7475; angletechcycles.com

Best of Bents, 7580 Grant Pl., Arvada, CO 80002; ph: 303-463-8775; www.bestofbents.com

High Gear Cyclery, Inc., 504 N. Main Street, Longmont, CO 80501; ph: 303-772-GEAR; www.highgearbike.com

Recumbent Brothers Cycles, 15180 Russell Dr., Peyton, CO 80831; ph: 719-683-2713; http://recumbentbrothers.com

Spring Creek Recumbents, 2111 S College, Unit G, Fort Collins, CO 80525; ph: 970-221-4838; www.springcreekrecumbents.com

Florida

Atlantic Bicycles, 6350 W Atlantic Blvd., Margate, FL 33063; ph: 954 971 9590; www.atlanticbicycle.com

Bicycle Outfitters, 11198 70th Ave. N., Seminole, FL 33772; ph: 727.319.2453; bicycleoutfitters.net

Hampton's Edge Trailside Bikes, 9550 E. Atkinson Ct., Floral City, FL 34436; ph: 352-799-4979; bentedge@earthlink.net

Power On Cycling, 4705 Water Lark Way, Valrico, FL 33594; ph: 813-661-6762; www.poweroncycling.com

Streits Cyclery, 1614 NW 13th St., Gainesville, FL 32609 ; ph: 352-377-BIKE ; streitscyclery.net

Georgia

Blairsville Bikes & Boards, 2759 #3 HWY 129/19, Blairsville, Georgia 30512; ph: 706-745-8141

Free Flite Bicycles, 2949 Canton Rd Suite 1000, Marietta, GA 30066; ph: 770-422-5237; www.freeflite.com

Silver Comet Depot, 4342 Floyd Road SW, Mabledon, GA 30126; ph: 770-819-3279; www.silvercometdepot.com

Idaho

CART, PO Box 1143, 11401 N. Gov't Way, Hayden, ID 83835; ph: 208-762-7110; www.sail-s.com

Illinois

Amlings Cycle, 8140 N. Milwaukee Ave., Niles, IL 60714 ; ph: 847-692-4240; amlingscycle.com

The Bike Rack, 37 W. 610 Campton Hills Rd., St. Charles, IL 60174; ph: 630-584-6588; thebikerack.com

Mill Race Cycling, 11 E. State St., Geneva, IL 60134; ph: (630) 232-2833; www.millrace.com

Rapid Transit, 1900 W. North Ave., Chicago, IL 60622; ph: 773-227-2288; rapidtransitcycles.com

St. Louis Recumbents, 2114 B S Center, Maryville, IL 62062; ph: 888-842-9375; www.stlrecumbents.com

Spin Doctor CycleWerks, 140 S. Hickory, Bartlett, IL 60103; ph: 630-289-7360; ww.spindoctorcyclewerks.com

Tyger's Recumbent Cycles, 510 W. Main, Dakota, IL 61081; ph: 815-449-2203

Village Cycle Sport, 1313 N. Rand Road, Arlington Heights, IL; ph: 847-398-1650; www.villagecyclesport.com

Indiana

Valley Bike & Fitness, 41 2nd Ave. NW, Carmel, IN 46032; ph: 800-730-9021; valleybikes.com

Iowa

Barr Bike & Fitness, 1710 NW 86th St., Des Moines, IA 50325; ph: 515-223-6111; www.barrbike.com

The Bike Barn, NW Sixth at Elm, Ogden, IA 50212; ph: 515-275-2981; www.thebikebarn.com

Xtreme Wheels, 12977 Conifer Ln., Council Bluffs, IA 51503; ph: 712-388-0800

Kansas

Heartland Cycle & Fitness, 111 N. Mosley, Wichita, KS 67208; ph: 316-682-4144

Hub Bicycle Shop, 803 Fort St., Hays, KS 67601; ph: 785-625-5685; thehub@ruraltel.net

Kentucky

Scheller's Fitness & Cycling, 11520 Shelbyville, Rd., Louisville, KY 40243; ph: 502-245-1955; www.schellers.com

Louisiana

Laid Back Tours, 625 Hagen Ave., New Orleans, LA 70122; ph: 504-488-8991; laidbacktours.com

Maine

Stillwater Recumbents, 459 Poplar St., Old Town, ME 04468; ph: 207-827-6461; stillwaterrecumbents.com

Maryland

College Park Bicycles, 4360 Knox Road, College Park, MD 20740-3171; ph: 301-864-2211; bike123.com

Mt Airy Bicycles, 4540 Old National Pike, Mt. Airy, MD 21771; ph: 301 831-5151; bike123.com

Massachusetts

Basically Bicycles, 88 Third St., Turner Falls, MA 01376; ph: 413-863-3556; basicallybicycles.com

New Horizons Sports, 55 Franklin St., Westfield, MA 01085; ph: 413-562-5237; newhorizonsbikes.com

Wheelworks, 480 Trapelo Rd., Belmont, MA 02478; ph: 617-489-3577; www.wheelworks.com

Michigan

Aerospoke, 1200 Holden Ave., Milford, MI 48381; ph: 248 420 0577; www.aerospoke.com

Ann Arbor Cyclery, 1200 Packard Rd., Ann Arbor, MI 48104; ph: 734-761-2749; annarborcyclery.com

Bicycle Headquarters, 3310 Bay City Rd., Midland, MI 48642; ph: 989-496-2810; www.bicyclehq.com

Holt Pro Cyclery, 2230 North Cedar, Holt, MI 48842; ph: 517-694-6702; holtprocycle.com

Village Cyclery, 148 N. Grand, Schoolcraft, MI 49087; ph: 269-679-4242; villagecyclery.com

Minnesota

Calhoun Cycle, 3342 Hennipen Ave. S., Minneapolis, MN 55048; ph: 612-827-8000; calhouncycle.com

Edina Bike & Sport, 4504 B Valley View Rd., Edina, MN 55424; ph: 952-929-2453; www.edinabike.com

Hoigaard's, 3550 South Highway, St. Loiuis Park, MN 55426; ph: 952-929-1351 F; hoigaards.com

Mississippi

Ride South Recumbents, LLC, 216 B Avalon Circle, Brandon, MS 39047; ph: 601-992-2490; www.ridesouth.com

Missouri

The Bike Center, 12011 Manchester Rd., St. Louis, MO 63131; ph: 314-965-1444; www.bikecenterstl.com

New Jersey

NorthEast Recumbents, 9 Wayland Drive, Verona, NJ 07044; 800-976-7494

New Mexico

Two Wheel Drive, 1706 Central SE, Albuquerque, NM 87106; ph: 505-243-8443; www.twowheeldrive.com

New York

The Bicycle Man, 570 Main St., Alfred Station, NY 14803; ph: (607) 587-8835; bicycleman.com

Gear to Go, 850 W. Clinton, Elmira, NY 14905; www.gtgtandems.com

North Carolina

The Clean Machine, 104 West Main St., Carrboro, NC 27510; ph: 800-369-5103; thecleanmachine.com

Neighborhood Transportation, 501 N. Liberty Street, Winston-Salem, NC 27101; ph: 336-722-7727; www.ntransportation.com

Ohio

Bike Corral, 605 S. 30th St., Heath, OH 43056; ph: 740-522-2708; cycle-brothers.com

K&G Bike Center, 4090 Marshall Rd., Dayton, OH 45429; ph: 937-294-6895; kgbikes.com

R-D Bike Shop, 128 Second Street NW, Barberton, OH 44203; ph: 330-848-2453, http://www.rdbike.com

Oklahoma

Pro Bike, 5820 NW 63rd, Oklahoma City, OK 73132; ph: 405-721-6707; okiebiker@aol.com

Oregon

Center For Appropriate Transport, 455 W 1st Ave., Eugene, OR 97401; ph: 541-344-1197; catoregon.org

Coventry Cycle Works, 2025 SE Hawthorne Blvd., Portland, OR 97214; ph: 503-230-7723; www.coventrycycle.com

Spin Cycles, 122 NE F St., Grants Pass, OR 97526; ph: 541-955-8807; spincycl@uci.net

Pennsylvania

Jay's Pedal Power Bikes, 512 E. Girard Ave., Philidelphia, PA 19125; ph: 215-425-5111; www.jayspedalpower.com

Recumbent Bike Riders, 1306 S. Atherton St., State College, PA 16801; ph: 814-234-4636; www.rbr.info

South Carolina

Tandem, Touring, and Recumbent Bikes, 1826 N. Pleasantburg Dr., Greenville, SC 29609; ph: 864-419-3181; www.ttrbikes.com

South Dakota

Harlan's Bike and Tour, 1740 S Cliff Ave, Sioux Falls, SD 57105; ph: 605-334-7666; www.harlansbikeandtour.com

Texas

Easy Street Recumbents, 4507 Red River St., Austin, TX 78751; ph: 512-453-0438; easystreetrecumbents.com

Planetary Cycles, 4004 S. Braeswood, Houston, TX 77025; p: 713-668-2300; planetarycycles.com

Stress Management Recumbent Cycles, 10609-B Grant Rd., Houston, TX 77070; ph: 281-890-8575; www.stresscontrol.com/recumbents

Virginia

Bike Zone, 4702 Virginia Beach Blvd., Virginia Beach, VA 23462; ph: 757-497-7971; www.bikezoneva.com

Bikes@Vienna, 128-A Church St, Vienna, VA 22180; ph: 703-938-8900; bikesatvienna.com

BlueRidge Cycleworks, 980 North Liberty St., Harrisonburg, VA 22802; ph: 540-432-0280; www.blueridgecycleworks.com

Washington

Go-Bent Recumbent Bikes, One Fifth Street Suite 110, Wenatchee, WA 98801; ph: 509 667-7777; www.gobentbikes.com

Wisconsin

The Bike Hub, 1025 N. Broadway, DePere, WI 54115; ph: 920-339-0229; thebikehubonline.com

Hostel Shoppe, 929 Main St., Stevens Point, WI 54481; ph: 800-233-4340; hostelshoppe.com

Lakewood Ski & Sport, 15684 Hwy. 32, Lakewood, WI 54138; ph: 715-276-3071; dgryboski@ez-net.com

Recyclist, 631 Saunders Rd., Kaukauna, WI 54130; ph: 920-759-1200; recyclist.com

Wheel and Sprocket, 5722 S. 108th St., Hales Corner, WI 53130; ph: 414-529-6600, www.wheelsprocket.com

International

B.I.E.R. Fahrradstudio, Zwei plus zwei Oesterreich, Jaegerhausgasse 20, A-2500; ph: +43 2252 47690; www.fahrradstudio.at

Bicycle Spokesman, 10212 A.Yonge St., Richmond Hill, Ontario L4C 3B6 Canada; ph: 905-737-4343; bikeroute.com/BicycleSpokesman

BikeFix, 48 Lambs Conduit St., London, England WC1 England; www.bikefix.co.uk

Cambie Cycles, 3317 Cambie St., Vancouver, BC V5Z 2W6 Canada; ph: 604-874-3616; cambiecycles.com

Fairfield Bicycle Shop, 1275 Oscar St., Victoria, BC V8V 2X6 Canada; ph: 250-381-2453; fairfieldbicycle.com

Flying Furniture Cycles (Ian Humpries), Watson ACT 2602, Australia; ph: 0419-697-405; www.flyingfurniture.com.au

FutureCycles, Friends Yard, Forest Row, East Sussex, England RH18 5EE England; ph: +44 (0) 1342 822847; www.futurecycles.co.uk

Kinetics, 54 Switchback Rd., Bearsden, Glasgow, G61 2JW Scotland; ph: +44 (0)141 942 2552; www.kinetics.org.uk

M5 Ligfietsen en Handbikes, Nwe. Kleverskerkseweg 23, 4338 PP, Middelburg Netherlands; ph: +31 (0)118 628 759; m5-ligfietsen.com

1Hp Cycles, 5995 Gouin Ouest, Montréal, Quebec, Canada; ph: 514-331-6222; http://www.1hpcycles.com

Recumbent shop Amsterdam, Waterspiegelplein 10-H, 1051 PB Amsterdam, The Netherlands; ph: (+31) 20 686 93 96; www.ligfietswinkel.nl

Oracle Cycle Works, 5-1621 McEwen Dr., Whitby, ONT L1N9A5 Canada; ph: 905-434-1409; oraclecycleworks.com

Triketrails, 1621 McEwen Drive, Unit 24, Whitby, Ontario L1R 2L6; ph: 866-587-4537; www.triketrails.com

Urbane Cyclist, 180 John St., Toronto, ONT M5T 1X5, Canada; ph: 416-979-9733; ucycle.com

The Yellow Jersey, 750 blv. Decarie, Ville St-Laurent, Quebec, Canada; ph: 514-747-2466; www.promocycle.net

Zöhrer Recumbents, Rua Triunfo 41 St. Teresa, Rio de Janeiro, Brazil 20240-320; ph: 021-91976526; zohrer.com.br

Accessory Websites

ATOC (car racks): http://www.atoc.com

Bike Parts: http://www.bikepartsusa.com

Bikesmith Design (short cranks): 5349 Elliot Ave S., Minneapolis MN 5541; ph: 612-824-2372; bikesmithdesign.com

FastBack Designs (hydration systems and seat bags): 1423 W. Mountain Ave., Fort Collins, CO 80521; ph: 970-221-4033; www.fastbacksystem.com

Free Form Body Sock fairings: 2565-D Mission St., Santa Cruz, CA 95060; ph: 831-429-5044; : fffashions@hotmail.com

Kucharik Bent Jersey, 1745 W. 182nd St., Gardena, CA 90248; ph: 310-538-4611; www.kucharik.com/recumbent.htm

Mueller Windwrap Fairings: http://www.mueller-hp.com

Novosport carbon fairings, seats, etc.: http://novosport.de/en

Power On Cycling (components & accessories): http://www.poweroncycling.com

Rotor Cranks USA, 3639 Midway Dr. #B102, San Diego, CA 92110; ph: 619-335-0180; www.rotorcranksusa.com

Terracycle (racks, bars, stems, idlers): 3450 SE Alder, Portland, OR 97214; ph: 503-231-9798; www.terracycle.com

Zzip Designs (fairings): POB 14, Davenport CA 95017; ph: 888-946-7276; www.zzipper.com.

Recumbent Associations

HPVA

The Human Powered Vehicle Association (HPVA) is dedicated to promoting improvement, innovation and creativity in the design and development of human-powered transportation in North America (http://hpva.us). It is a chapter of the IHPVA (http://www.ihpva.org). (Part of this Appendix info is courtesy of their online Source Guide.) Members receive the *HPV News* and *Human Power* (technical journal), discounts on books, papers and other items. (You can join online.) US dues: $32; HPVA Membership, PO Box 1307, San Luis Obispo, CA 93406-1307; Jean Seay, exec-vp@ihpva.org.

BHPC

British Human Power Club membership and newsletter contact: Dennis Turner, 7 West Bank, Abbot's Park, Chester, CH1 4BD, Telephone: +44 (0)1244 376665. The BHPC website describing their many services, events and publications can be found at http://www.bhpc.org.uk. (The worldwide list of bike and trike makers is provided in this Appendix in part by courtesy of the British Human Power Club.)

North American Club Websites

Arizona (BRAG--Bent Riders Arizona Group): sports.groups.yahoo.com/group/brag-az
Atlanta Recumbent Cyclists: sports.groups.yahoo.com/group/AtlantaRecumbentCycles
Easy Riders Recumbent Club: http://www.geocities.com/e_r_r_c
Michgian HPV Association: mhpva.org
Michigan Wolver-Bents: wolverbents.org
Minnestota: www2.bitstream.net/~mstonich
Nebraska: members.cox.net/armandg/Cruisersrule.html
New York (western): http://bluemoon.net/~padelbra/the_recumbenteers.htm
New York (metro): recumbents.com/mars
Ohio (Bent Trail Riders): http://www.siscom.net/~grindix/btr
Oregon HPV: http://ohpv.org
Ontario Canada (southern): hpv.on.ca
Texas (North): http://www.rbent.org
Washington, DC (WHIRL): http://www.recumbents.com/whirl
WISIL (Wisc./Ill.): pro website offers news, photos, reports; www.recumbents.com/wisil

Worldwide HPVA Affiliates

Australia: http://www.ozhpv.org.au
Belgium: http://www.hpv.be
Denmark: http://www.hpv-klub.dk
Finland: http://www.hpv-finland.org
France: http://ihpva.org/chapters/france
Germany: http://www.hpv.org.
Great Britain: http://www.bhpc.org.uk
The Netherlands: http://ligfiets.net/nvhpv
Switzerland: http://www.futurebike.ch
Sweden: http://hpv-sverige.just.nu

Recumbent Publications

Recumbent Cyclist News is the #1 magazine for anyone who has or wants a recumbent bicycle (recumbentcyclistnews.com). $8 sample issue (current issue only) via First Class mail. $20 for three most recent issues via Priority Mail. RCN PO Box 2048 Port Townsend, WA 98368. (The dealer list in this Appendix is provided in part by courtesy of *RCN*.)

'BentRider Online Magazine is the major online HPV news and product resource, at www.bentrideronline.com.

Easy Riders Recumbent Club magazine is a fine B&W mag all about 'bents, with an emphasis on Easy Racers. Full of photos, trip and event stories, race reports and equipment news. 48 pages. $10 to ER owners/$15 non-owners to: Connie McAyeal, 28009 NW Dorland Rd., N. Plains, OR 97133.

Recumbents.com, hosted by Warren Beauchamp, offers the best online coverage of HPV racing and homebuilding.

Velo Vision is the major UK magazine covering cycling alternatives. £6.50(UK)/£8.50(US) an issue. St Nicholas Fields, Bull Lane, York, YO10 3EN, UK, Tel/Fax: +44 1904 438 224; www.velovision.co.uk. Available from Calhoun Cycle in the US.

Encycleopedia publishes an ad-free alternative cycle buyer's guide and HPV video series (encycleopedia.com). £12.00(UK)/ £23.95(US). Encycleopedia Ltd, PO Box 317, Stockport, SK2 7YH, England.

E-Bent is an online recumbent touring resource: http://www.E-bent.com.

Books

Bicycle Technology

Abbott, Allan/Wilson, David Gordon: Human-powered Vehicles. Publisher: Human Kinetics Publishing, Ph: 1-800-747-4457, 217-351-5076. 1st edition 1995, 288 pages, 8.5x11", $45. ISBN 0-87322-827-8.

Brandt, Jobst <jbrandt@hpl.hp.com>: The Bicycle Wheel, Palo Alto/CA: Avocet Inc., 3rd Edition 1993. ISBN 0-9607236-6-8.

BHPC: "So you want to build an HPV?" 50 pages, booklet. £4.50/$7US. Dennis Turner, BHPC Membership Secretary, 7 West Bank, Abbot's Park, Chester, CH1 4BD, UK

Graham, Brad and Kathy McGowan: Atomic Zombie's Bicycle Builder's Bonanza. McGraw-Hill. ISBN 0-07142-267-6. 191 East Frederica St., Thunder Bay ON P7E3V4 Canada, 388 pages, $30USD.

Hadland/Hadland: Moulton Bicycle. Sold only by the Moulton Bicycle Club; send £9 + cost of add'l postage, cheque payable to'Moulton Bicycle Club' to: Malcolm and Jenny Lyon; 2 The Mill, Mill Green, Turvey, Bedfordshire MK43 8ET, UK.

Kolin, Michael J./de la Rosa, Denise M.: The Custom Bicycle. Rodale Press, Emmaus PA, 1979, ISBN 0-87857-254-6.

Schmitz, Arnfried: Human Power—the forgotten energy. (Memoir of HPV racing.) Available via bikefix.co.uk. Tony Hadland, publisher. 12.95£. ISBN 0-9536174-1-6.

Sharp, Archibald: Bicycles & Tricycles - An Elementary Treatise on Their Design and Construction. London 1896, Reprint Cambridge: MIT Press 1984. 533 Seiten. ISBN 0-262-19156 (paperback), 0-262-69066-7 (hardcover), available via IHPVA, $15.

Whitt, Frank Rowland/Wilson, David Gordon: Bicycling Science — Ergonomics and Mechanics. Cambridge, Mass., MIT Press [1974], 2nd Edition 1982. ISBN 0-262-73060-X. 247 pages illus. 21 cm.

Wright, Robert: Building Bicycle Wheels. World Publications, PO Box 366, Mountain View, CA ( ). ISBN 0-89037-106-7, 1977.

Frame Building

The Oxyacetylene Handbook, 3rd Edition, Union Carbide Corporation, Linde Division, New York, NY; ISDN 0-914096-10-9, 1976.

Paterek, Tim: The Paterek Manual for Bicycle Framebuilders, Framebuilders Guild: River Falls WI 54022, 1986, suppl. version. $79.50.

The Proteus Guide to Frame and Framebuilding Products, Proteus Design, Inc, 9225 Baltimore Blvd, College Park, MD 207040.

Talbot, Richard P.: Designing and Building Your Own Frameset—An Illustrated Guide for the Amateur Bicycle Builder, The Manet Guild, 1st edition 1979: ISBN 0-9602418-1-7, 2nd edition 1984: ISBN 0-9602418-3-3, 160 pages.

Related Topics

Costin, M./Phipps, D.: Racing and Sports Car Chassis Design, Robert Bentley, Inc, 872 Massachusetts Avenue, Cambridge MA 02139 ( ), ISBN 0-8376-0296-3, 1965.

Mellin, Bob: Railbike, Cycling on Abandoned Railroads. Balboa Publising, 11 Library Place, San Anselmo, CA 94960, Ph: +1 415 453 8886 Fax: +1 415 453 8888, $16.95 US, $22.95 CAN + $3 shpg.

Milliken, D. L./Milliken, W. F.: Race Car Vehicle Dynamics. ISBN 1-56091-526-9, Hardbound US $85.

HPV Research Archives & Data Compilation CD's

"Human Power": The full archives of the scientific journal (1977-2004) are available online as free PDF's suitable for downloading at ihpva.org/HParchive. This journal has covered most developments and news regarding HPV's. A CD version is available for a nominal charge.

HPV CD's: Oliver Zechlin offers CD's covering the HPV scenes in '99 and '01. From his intro: "I call this series 'a collection of data about land-, water- and aircraft.' Each CD contains thousands of pictures, text-files, QuickTime-movies...and much more." $10 ea. to HPVA members; $17.50 ea. non-members. Send to: PO Box 1307, San Luis Obispo, CA 93406-1307; exec-vp@ihpva.org.

Websites for Plans, Kits, Homebuilders & More!

Adventures of Greg (a blog of an ongoing attempt to beat the 24-Hour HPV record): www.adventuresofgreg.com

Atomic Zombie plans: atomiczombie.com

Benoit's carbon lowracer: users.skynet.be/benoit.dery

Bentech: http://members.aol.com/domerie/bentech.htm; P.O. Box 198, McKean, PA 16426

The Bicycle Forest (hundreds of homebuilt bikes, BikeCAD and more): bikeforest.com

Bike Rod & Kustom: bikerodnkustom.com

Bikebuilding Workshops (Wood and Carbon): blids.nl/gallery/PlywoodRecumbentBuildingworkshop2003; blids.nl/gallery/CarbonRecumbentWorkshop2005

Carbon bike project sites: users.skynet.be/benoit.dery/; http://www.jjscozzi.com

Coroplast material: http://coroplast.com

Cruzbike Kit (convert ATB into FWD/SWB): www.cruzbike.com; 2A Brisbane Terrace, Northbridge, Perth, Western Australia 6003 Australia; ph: +61 8 9328 3555

German Wood CWLB: liegerad.franken.de/bau/holzlieger

German Wood SWB: tor8.de/index.php?current=Experimentell

Riley's Ground Hugger: rqriley.com; P.O. Box 12294, Scottsdale, AZ 85267-2294

Handcycling: http://www.handcyclequest.com; http://www.handcycling.com

Human Power Boats: http://www.Human-PoweredBoats.com

Jim's carbon lowracer: jjscozzi.com

Joe Kochanowski's Amazing Homebuilt HPVs: outsideconnection.com/gallant/hpv/joe

LaBent by LaDue: http://www.radiks.net/~ladue; 1607 S. 84th St., Lincoln, NE 68506

Modular Bikes: modularbikes.com.au; 10 Abbott Grove, Clifton Hill, Vic 3068, Australia; ph: (03) 94818290

National Bicycle Greenway: http://www.bikeroute.com (Martin Krieg)

Recumbent Bikes Share Site: http://www.manytracks.com/recumbent.htm

Recumbent History: http://www.physics.helsinki.fi/~tlinden/winforb.html

Recycled Recumbent: Free plan for making Tour Easy clones: recycledrecumbent.com

Steve Robert's Nomadic Research: http://www.microship.com

Steve Robson Homebuilt Bikes: http://www.xcelco.on.ca/~stevbike

TALU: Information about Tandem Recumbents: http://talu.com/

Tour Easy Licensed Plans. $35 (includes a $10 fee sent to Easy Racers Inc.); Cornel Ormsby, 2058 Waverly Circle, Henderson, NV 89014-4593; www.boomspeed.com/lioninoil/plans.htm

Eric Vann's page: beezodogsplace.com

Unusual HPVs: http://www.geocities.com/rcgilmore3/

Varna 2- and 3-wheel recumbents, plans, also hand-power (see other listing)

Velomobiles: http://www.velomobile.info

WISIL Club Projects: recumbents.com/wisil/whatsup.htm

Wood Recumbents from 2x4's: http://mysite.verizon.net/res88kr1

XnTrik Cycles: homepages.nildram.co.uk/~talizmar/xntrick/2x4.htm

Glossary of HPV Terms

Main frame types:

recumbent: a type of cycle ridden while laying back, with weight on butt and back, with feet raised; to go "feet first"; sometimes abbreviated as *'bent*

prone recumbent: also called 'belly bike'; type of bike that supports rider laying down on belly; travels head first

LWB: long wheelbase, a 'bent with front wheel ahead of crank

MWB or *CLWB*: medium or compact wheelbase; typically city bikes; crank is close to or above the front wheel

SWB: short wheelbase, a 'bent with front wheel behind crank

highracer: a 'bent with two large wheels, usually 26" at the smallest, with 700c commonly at the rear

lowracer: a 'bent with a seat low enough that one can easily support oneself at a stop with a hand on the road; seat-base is generally below axle height and position down between the wheels

crank-forward: a 'bent with a seat low enough that one can easily support oneself at a stop with a hand on the road; seat-base is generally below axle height

Equipment and position terms:

adjust on the fly: a change made while riding

adjustable recline: seat back and base angles can be changed

boom: frame tube that holds crank with a SWB bike

bottom bracket (crank) height: how high off the ground is the crank bottom bracket axle center

closed position: seat and crank heights are set up so that rider gets power right in front of chest area, as in a racing upright bike while riding in the drops; can push hard against seat back; associated with low seat, high crank, upright seat angle

derailleur sprout: frame tube that supports front derailleur on an SWB bike

hardshell seat: a solid seat with any padding attached directly to seat

heel-strike: amount that heel overlaps front wheel when turning a SWB bike

idler pulley: a pulley that tensions and/or controls chain

intermediate drive: a two-chain set-up with a cogset (and sometimes a shifter) between crank and rear wheel gearing

landing gear: "training wheels" which are lowered from an unstable HPV to allow for reliable start-ups, stops and dismounts

mesh/sling seat: a seat made of a frame with fabric suspended from framing to support rider

monotube frame: a large diameter tube is the main frame for a bike

open position: seat and crank heights are set up so that rider finds power in lower, more extended range of motion; if push hard, rider tends to rise off seat base; associated with low crank height, reclined seat back

pedal steer: if crank area is flexible, pedaling hard can cause steering shifts

pivoting steerer stem: the handlebar stem pivots forward to allow rider to easily get on and off of bike *recline*: how far back a seat is reclined from the vertical (90 degrees is laying flat back)

return-side: the low-tension part of the chain which goes back from crank to gears

seat stays: tubing that supports the seat back, often attached to rear drop-outs

space frame: frame made of triangulated tubing, as in a diamond frame bike

strong-side: the part of the chain which is under pedaling tension, being pulled from gears to crank

toe-strike: amount toe overlaps front wheel when turning a LWB bike

tub bike: faired HPV where the fairing acts as the frame

velomobile: practical, all-weather HPV that performs functions of a car for short trips

Steering:

OSS: over seat steering

USS: under seat steering or under legs

chipmunk or *"begging hamster" position*: bike with OSS handlebars close to chest

direct steering: handlebar is attached to fork steerer tube

indirect steering: handlebar is attached to pushrod or cable which in turn is connected to fork assembly for steering

fork-flop: how much a front wheel tips over and front end drops, as handlebar is turned; relates to relaxed head-tube angle; makes a force to continue turning that must be resisted by rider

heavy steering: handlebars require firm control but don't change bike direction sharply

pushrod: rod attached from handlebar to fork assembly in indirect steering

superman or *tweener bars*: OSS handlebars used with arms in outstretched position, with knees moving between the arms/bars.

tiller: how much a handlebar moves from the centerline as it is turned; tiller steering usually means bars that swing considerably out of the line of the frame

top steering: another term for OSS

twitchy steering: very light handlebar pressure where small movements quickly change bike direction

Drive-trains:

FWD: front wheel drive

RWD: rear wheel drive

flex-chain FWD: type of FWD where chainline twists between crank and gears during steering; also called "rigid" because frame doesn't pivot.

pivoting or *"swinging" FWD* : crank and gears stay in constant relation during steering; pivot is usually located at the headtube, but can be located farther back, so that bike acquires "leg steering"

Misc:

bodysock: a stretch fabric fairing attached to the cyclist

Coroplast: thin, colorful, cheap, light, rugged, corrugated plastic paneling popular for low-tech, quicky hobbyist fairings

fairing: a device to shield a rider from the wind, giving higher speeds

foot trap or *foot suck*: what happens when foot falls from pedals of 'bent while under way and foot gets grabbed by pavement then pulled back under seat: avoid!

nosecone: a front fairing

recumbent butt: painful temporary condition for an untrained rider's rear end, often associated with prolonged riding with more weight on butt than on back; due to support pressure on the same muscles as are used in riding

recumbent foot: painful temporary condition for untrained rider, usually associated with prolonged riding with elevated feet

tailbox, tailfin: a rear fairing, often includes cargo area

wheelcover: a disk fairing for a wheel, covering the spokes

Acknowledgements

I'd like to thank the following people for their cooperation and contributions.

Ewald Fehlau, Clara Fehlau, Axel Fehlau, Jasmin Fischer, Martin Sörensen, Werner Stiffel, Martin Staubach, Caroline Schemensky, Michael Pohl, Michael Malich, Angela Molclenhauer, Andreas Pooch, Gisela Daubitz, Francine and Georges Mochet, Jürg Hölzle, Gottfried Graupner, Johannes Dychhoff, Frau Rinkowski, Manfred Kops, Klaus Schroder, Manfred Harig, Michael Bollschweiler, Olaf Muller, Karin Knauf, Klaus Bartelt, Ulrich Troyer, Wolfgang and Andre Gronen, Herrn Steinhach, Mike Burrows, Frangoise and Bernard Magnouloux, John Kingsbury, Jurgen Reimann, Christian-Uwe Mischner, Peter Bruggen, Palle Lindvig Frederiksen, Thorsten Rähse, Christine Ahrendt, Ulrich Knaack, Jon Schwartz, Matt Weaver, Ingo Kollibay, Gardner Martin, Arnfried Schmitz, Walter Eubus, Marek Utkin, Andreas Fuchs, Paul Atwood, Rick Pope, David Gordon Wilson, Chester Kyle, Mats Nilson, Andrew Letton, Paul Rudin, Jonathan Woolrich, Paul Craig, Brett Poirir, Hanz Scholz, Bernhard Klar, Wolfgang Scholz, Wolfgang Schoppe, Paul Pancella, Paul Goodrich, Peter Eland, Bryan Ball, Robert Bryant, John Tetz, John Clary, Nick Hein and many others.

...And these firms and organizations:

Recumbent Cyclist News, Recumbents.com, the IHPVA email list, BentRiderOnline.com, VeloVision, IHPVA, BHPC, Veloladen, Vam Bike, Liegeraddatei, HPV Deutschland, Moby Dick Verlag, Bundesanstalt fur Strassenwesen, Bundesminister fur VerEehr, ADFC, SWF 3, Atari, Coca Cola, Bieletelder Verlagsanstalt, Foto Hauser, IGP, den Herstellern, Beratungsstelle fur Verkehrstragen des Landes NRW, BDR, HPV France, NHPVA, Danemark HPV, DTU, Futurebike, Berliner MUSCUm fLir Technik und Verkehr, Einbecker Fahrradmuseum.

I apologize if I forgot anybody. If this is the case, it must have happened accidently. The order here, furthermore, does not reflect any priority, but is simply random.

—*Gunnar Fehlau*

This M5 is one of their first designs and is still produced. It's a steel-framed classic with standard rear elastomer suspension. (photo: M5)

Index

A

B

C

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

Z

The "Out Your Back Door" Catalog

What is OYBD?

It's a resource for hard-to-find books and media at a high level of cultural development, with an emphasis on the outdoors. They're so hard to find that if I didn't present them, you'd likely never see them. For instance, no other US publisher dared to do a recumbent book, even though it's a hugely important cycling topic. Also, distribution for innovative and relevant titles is difficult—owing to a trend to sameness in today's book trade. I rely mostly on direct sales, then comes quality shops, the Net, and word of mouth. Please check out this catalog and support it if you're at all interested. If you're not usually into a subject here, you might be surprised: OYBD is cross-training for the brain. And if you know anyone who might be interested, please let them know. I've read most of what's been done in each area, found a big something lacking, backtracked to the writers who rise to the occasion (often unknown, under-represented or out-of-print) and publish them for you, or acquire inventory to resell. Get your hands on an OYBD item and you know you have something. Be the first on your block. I've done the *OYBD* zeen since 1991, a large website since 1995, and OYBD books since 1997. Visit OutYourBackDoor.com to discover more than the usual.

—*Jeff Potter, publisher*

Topics

- Bike Culture
- General Outdoor Culture
- Fiction & Philosophy
- Luggage, Stickers, Music & More

How to Order

Credit cards and PayPal accepted—cash, check, or MO also work. Shipping included.

Mail orders: OYBD Press, 4686 Meridian Rd., Williamston MI 48895

Phone: 1-800-763-OYBD (6923)

Online: OutYourBackDoor.com

Retail/group orders: 40% off multiple copies, pre-pay.

Email: jeff@outyourbackdoor.com

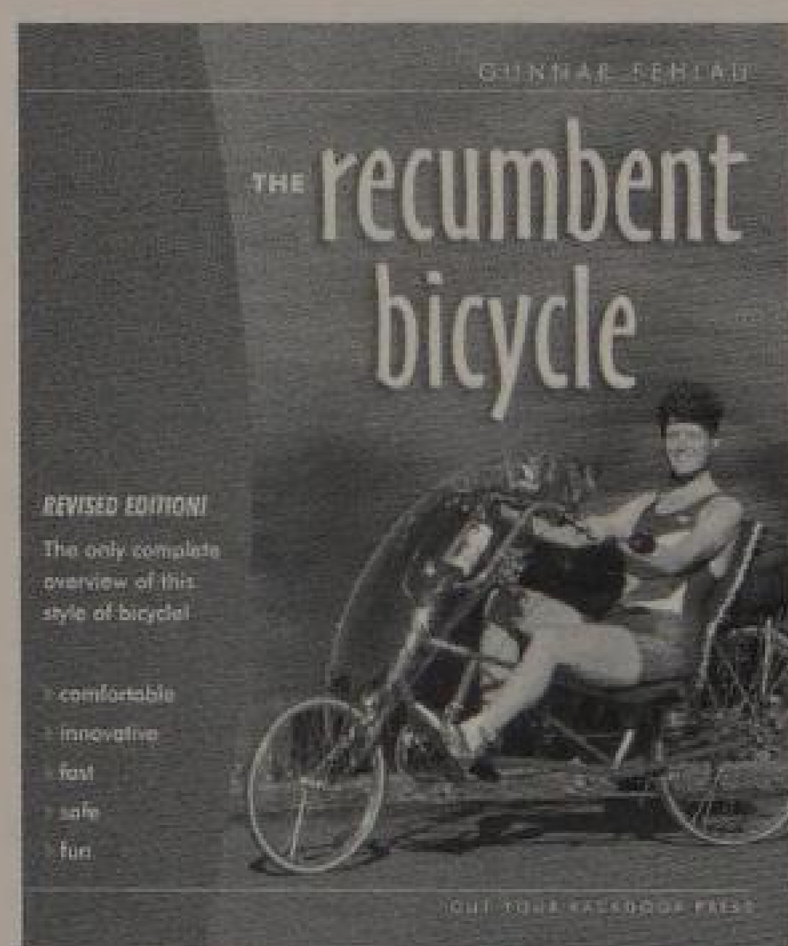
All titles in "Books in Print" and available via Amazon, Barnes&Noble, and Borders, who take more than half the proceeds. Best to order direct from me!

Many titles available to the retail trade from the following wholesalers: Baker & Taylor, Partners, AlpenBooks, Great Outdoors.

Bike Culture

The Recumbent Bicycle

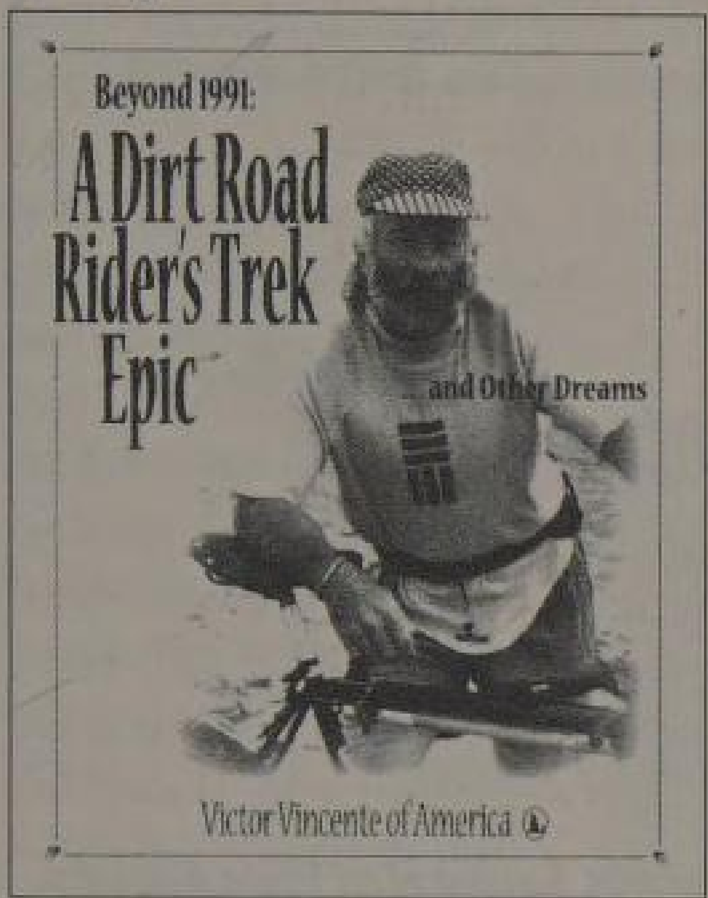
AUTHOR: Gunnar Fehlau, ISBN:189259059X, PAGES: 193, LISTPRICE: $21.95, DESCRIPTION: This is the fully revised and updated 3rd edition of the only complete book about an amazing, creative side of bicycling: recumbents and HPVs. This book covers Features, History, Racing, Touring, Physics, Construction and more, of the diverse world of recumbents. Over 200 black&white photos plus 12 pages of full color.



REVIEWS: *"A super book, full of photos, wisdom on every aspect of recumbents, and resources for riders and builders alike!"*—D. G. Wilson, author Bicycle Science. *"The best, most complete book on recumbents and HPVs ever written!"*—Warren Beauchamp, editor Recumbents.com. *"No other book deals with recumbent bicycles in this breadth and depth. It also helps that it is extremely readable and full of cool pictures. Well-suited to anyone who might be interested in these bikes, even if they have no previous knowledge."* —P. Pancella.

A Dirt Road Rider's Trek Epic

AUTHOR: Victor Vicente of America, ISBN:1892590506, PAGES: 100, LISTPRICE: $15, DESCRIPTION: If you're a bike buff, you know how rare bike literature is. Here's a bit of storytelling to savor, *A Dirt Road Rider's Trek Epic* by Victor Vincente of America, a bike cult guru hero. This book presents the many media offerings of a unique *victor*. The *Epic* is showcased in this volume along with media reprints from VVA's heyday as first US road racing champion, first modern-era Euro winner, first ultra-distance record holder, and early mountain-bike innovator, dirt guru, events host and then some. Illustrated with his own art from many projects, including bike-making, coin art, posters, and stamps. Sports today seem one-dimensional: why? Here's a fantastically different take: the world of a champ who explores widely. Among many surprises, you'll find that offroad riding offers a treasure of lore and insight. Our author has mined a wondrous chunk of life. His notorious So. Calif. newsletter was the first home of his prose-poem about days and nights in the natural and cultural outback.

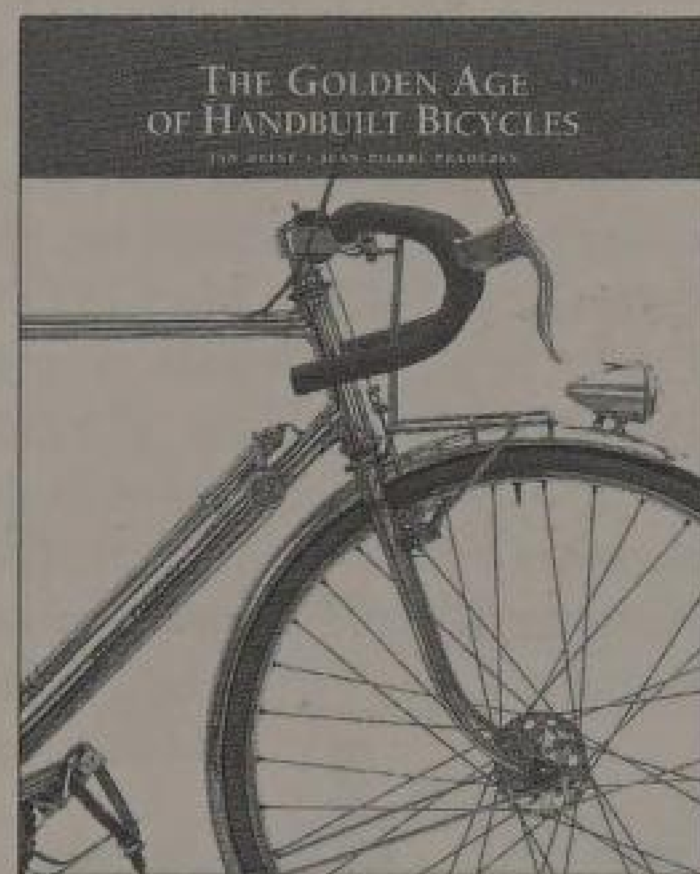


Fold-It! —The World of the Folding Bicycle

AUTHOR: Gunnar Fehlau, ISBN:1892590573, PAGES: 170, LISTPRICE: $19.95, DESCRIPTION: The world's only book with everything you need to know about folding bikes. Covers history, development, features and the various models offered, with pro's and con's. With so much new technology readily available, the scene is booming, and the future of the folding bike never looked better! Elegant established models are still inspiring and holding their own, while gorgeous new models are coming out to challenge rigid bikes in every way—but especially in convenience! Find out for yourself. *(Due to be released Nov. 2006.)*

The Golden Age of Handbuilt Bicycles

AUTHOR: Jan Heine, Photographer: Jean-Pierre Pradères; Vintage Bicycle Press, ISBN: 0976546000, PAGES: 180, LISTPRICE: $60.00, DETAILS: 10x12, sewn hardcover & coated paper, DESCRIPTION: This is the most beautiful bicycle book of all time. It exuberantly showcases an age and type that offered the pinnacle of craftsmanship and innovation. I'm happy to offer it to you. This book has crossover appeal to any lover of craft and beauty. It will also likely influence a revival in the kind of versatile, integrated bike it celebrates. (Jan also edits the small magazine "Vintage Bicycle Quarterly.") FROM BACK COVER: "With lavish color photography [many pages offer a single, large image], *The Golden Age of Handbuilt Bicycles* charts the development of these machines from the early 1900s through the present day. Here you find machines with a level of craftsmanship that never has been surpassed. With renewed interest in "real world" bicycles that combine the speed and excitement of racing bikes with unmatched reliability and versatility, *The Golden Age of Handbuilt Bicycles* provides a timely review of what bicycles can be." REVIEW: *"An instant classic. Stunning. I'm reeling from the impact."*—M. Grimm, Kogswell Cycles.



The Dancing Chain

History & Development of the Derailleur Bicycle

AUTHOR: Frank Berto, ISBN: 1892495414, PAGES: 384, DETAILS: hardcover, 9x11, LISTPRICE: $55, DESCRIPTION: Here's a big hardcover history of the derailleur bicycle. Hmmm, a bit dry, no? You'd think. But really it covers the whole histories of all the major bikes of the modern age—their starts, their stellar years, their sorry declines as something new and beyond their imagination overtook them and left them behind. It includes the cultural, social, business and sporting impacts of each of them as well, as the derailleur bike has developed along thru the years. It covers what the stars rode and why and what happened to

them as they did so along the way. The development of the bike has been as competitive and influential as the races between hero cyclists. It's full of great cycling photos, as well as pics of bikes and their parts. Where has all this bike stuff come from, anyway? Oh, there's a great story there, indeed. It's quite dramatic reading. If you're a bike buff it's a must-have. I read mine cover to cover with great appreciation.

BikeLore 1 & 2

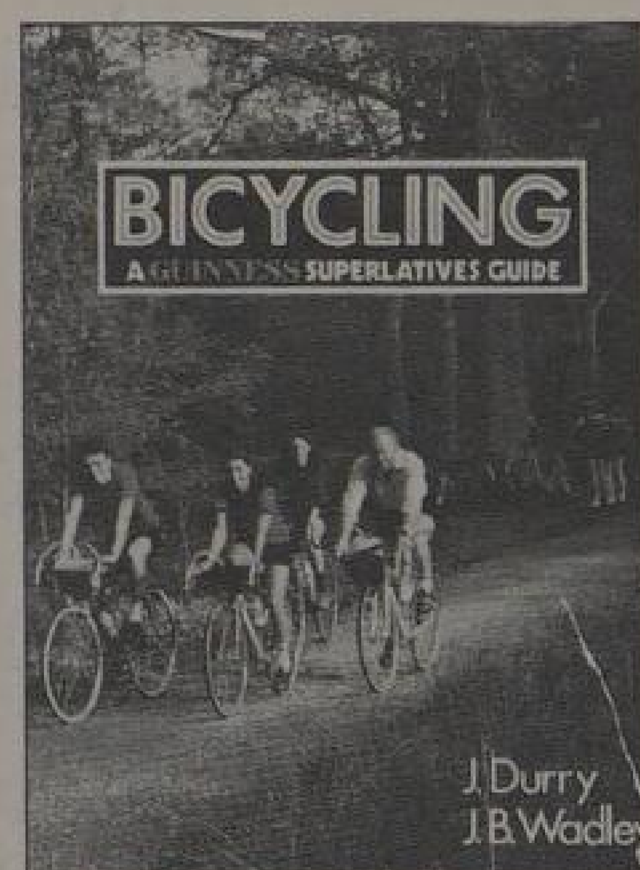
EDITORS: Gabor and Melanie Konrad (10+ contributors); published by: On the Wheel Publications, PAGES: 175, LISTPRICE: $14.95 ea., DETAILS: paperback, 6"x 9", B&W photos, ISBN:1892495325 & 1892495384, DESCRIPTION: Two collections of heritage and heroes put together by the editor of the bike culture magazine "On the Wheel." Written by 16 renowned cycling writers, such as Jan Heine, Raymond Henry, and Richard Yates—who have hundreds of articles and books between them, mostly of European publication. These are rich treasuries of vintage cycling, touring, and racing lore that even buffs don't know yet. But they're sure to please! "BikeLore 1 & 2" show the spirit behind the Tour, and extending every other direction in cycling. If your interest in outdoor culture needs a little uplift, more connection to the best of the past, this series delivers. The only heritage books of their kind in print.

The Data Book: 100 Years of Bicycle Component and Accessory Design

AUTHOR: Noguchi, PAGES: 212, ISBN: 1892495015, LISTPRICE: $40, DETAILS: hardcover, 7x10, 1200 B&W illus., DESCRIPTION: Classic sketchwork of great bike stuff. This book is a celebration of the pinnacle of the art of technical sketching, as represented by Daniel Rebour. It emphasizes bike features and parts from the heyday of bike creativity (30s-50s). Shows numerous older designs that have been presented as "new" in recent times. Notice the B.O.B. trailer predecessor and the early "Aheadset" stem—which has the added feature of a screw-cap exposing a tool-stash. "The Data Book" is a fascinating pictorial survey of the development of bicycle component and accessory design.

Bicycling: A Guinness Superlatives Guide

(Only collector copies available.) AUTHOR: Wadley, Durry, PAGES: 215, PRICE: $30, DESCRIPTION: The all-time best "allbike" book. This hardcover 8x12 coffee table book from the early 80's covers the WHOLE world of bicycling like no other. It has the best writing, the best background and tons of classic photos of every main kind of cycling. (OK, mt-biking wasn't invented at that time and recumbency isn't covered.) Wadley and Durry are basically the best cycling writers in English and French, respectively. Not a bad team-up. I suppose that technically the best part of the book is its racing section—it gives wonderfully written backgrounds of the history and heroes of all the major races (tours and classics). Then it covers all the styles/disciplines and aspects of racing and includes both training and execution tips aplenty in a more savvy way that even contemporary books. It gives good coverage of track and cyclo-cross. It also covers the Euro basis of touring and rando movements. It gives a good look at the best of 70's-style bike technology: lugged frames and Campy rule, along with fendered city and rando bikes. Brilliantly written and illustrated. (The only semi-rival to this book is the "Tour de France Complete Book of Bicycling," a paperback of basically half the status but still good merit. "Bike



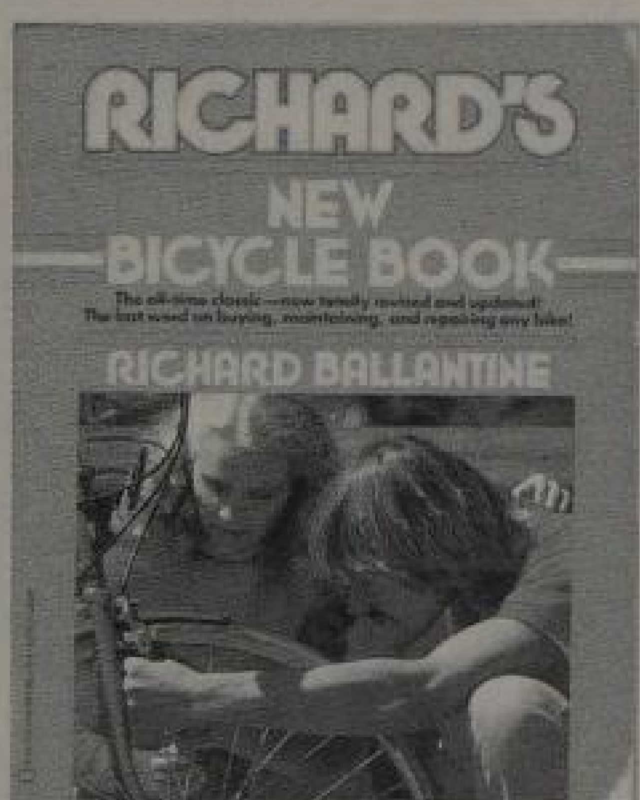
Cult" is also a "complete" book, but has a social-politics-eco-citybike slant.) I resell good used copies to keep this book in good hands.

The Need for the Bike

(Only collector copies available.) AUTHOR: Paul Fournel, PAGES: 100, PRICE: $12 — lightly used. DESCRIPTION: Great writing about bike riding. Fournel is a French avante-garde literary fellow—who loves bike riding. This is his thin volume of glimpses into his world of riding. He covers all the senses, all the needs he can think of. He's a middle-aged rider now but he brings us up with his riding as he came up with it. Descriptions of French riding, roads, scenes, food, wine and friends. The complex simplicity of the road, the heat, the wind and rain. A marvelous little must-read for the cycling buff.

Richard's New Bicycle Book

(Only collector copies available.) AUTHOR: Richard Ballantine, PAGES: 350, DETAILS: paperback, 7.25"x9.25", PRICE: $15 —good condition, a bit scruffy, but quality paper. DESCRIPTION: There are quite a few general bike books. Even Richard has written more than one. His latest two are very nice. "Richard's 21st Century Bicycle Book" is spiffy and up-to-date. His second to the last one "Richard's Ultimate Bicycle" is huge and full of gorgeous photography. But his "Richard's New Bicycle Book" from the early 80's is still his best—and the best all-time general American bike book. It's full of wonderful bike art and sketches. It describes the rainbow of wonderful bicycling. His newest book revives some of the same sketches that made his older book so great, but they're SMALLER. It's just so nice to see this artwork printed full page as it deserves...and got in this book. It's also wonderfully opinionated, yet generous. Personable, is what it is. It brings history to life and connects it to today and also shows how the diverse cycling scene really represents one coherent spirit. Most bike media today doesn't do this. It's an honest, candid, and realistic book. So what if it's now a bit out of date. Many of these bikes and their parts are still out there. Bikes aren't really rocket science—a grasp of older, simpler, easily described mechanisms and approaches to tools and repair puts you in good stead for learning about newer stuff. It's a must-have for bike buffs, basically.



The Bicycle Wheel

AUTHOR: Jobst Brandt; Avocet Press, ISBN: 0960723641, PAGES: 150, DETAILS: hardcover, LISTPRICE: $24.95, DESCRIPTION: This all-time classic book on bike wheels shows how to become a proficient wheel builder using a step-by-step system that works for any lacing pattern. It answers wheel design and component questions by explaining structural theory and the practical methods used to build strong wheels. Jobst is a bike legend who developed slick tires and also helped design the early Porsche car.

VeloVision

[magazine] $8, 10x12, 62 pages, full color, 6X/yr. "VV" is the only all-round bike culture magazine. From the UK. Lovely, thoughtful, innovative, diverse. Full of art and ideas covering every aspect of the humanized wheel under the sun.

Vintage Bicycle Quarterly

[magazine] $8.50, glossy B&W, 8.5x11, 28 pp. A thriving journal of bike heritage and exploration of quality craftsmanship. Racing and touring history, as well as contemporary coverage of traditional and classic cycling subjects.

The Rivendell Reader

[magazine] $3, 32 pages, color cover, B&W, 8.5x11, 4X/yr. "RR" is published by Rivendell, the maker of a line of gorgeous, versatile bicycles. They promote the tried-and-true values of sustainable bike culture. Interviews & info that give a rare look into the glories of a world on two trusty wheels. Business and manufacturing included, too. Description, discussion and letters about new products. Wool clothes and canvas luggage, too. And all the things one might do with suchlike.

Recumbent Cyclist News

[magazine] $4, 32 pages, 2-color cover, B&W, 8.5x11, 6X/yr. "RCN" is the only magazine all about recumbent bicycles and tricycles. It's been around 10+ years, covering the innovative HPV scene with integrity and candor, encouraging quality and openness in this young market. Bikers are better for it! Full of rider-reports and opinions and DIY at-home projects and bike-construction info. Not many markets encourage so much customer participation, but the HPV scene has been a great one for sharing info all along. "RCN" keeps this spirit alive!

Outdoor Culture

Momentum: Chasing the Olympic Dream

AUTHOR: Pete Vordenberg ISBN: 1892590565 PAGES: 200 LISTPRICE: $17.95 DESCRIPTION: "The best XC ski read, ever." (*Master Skier* magazine) An inside look at life as an elite XC skier. Vordenberg is a 2X-Olympian, Natl Champ and a current US Team Coach. The most interesting picture to date on what it's like to ski...and live...really fast. (With dozens of black&white photos.) Vordenberg says: "We have seen the Olympics through the filter of mass media. But at the edge of the screen there is another figure. When the camera zooms out you can see him, almost too small to recognize. This is the story of the figure at the edge of your screen. It's a voyage following the pursuit of my dream to win an Olympic gold medal. It travels the world, crossing from childhood to the precipitous edge of adulthood. It shares the quixotic humor, excitement, and poignancy inherent in the pursuit of dreams. It is not a retelling of the little engine that could. Rather, it is about why the little engine even tried." REVIEWS: *"The marvel of Vordenberg's book is that it appeals to the non-skier as well as to ski racers past and present. Healthy doses of self-revelation, touches of* On The Road, *and remarkable insights make this a unique book. It's supposedly about skiing—but it's more about life and seizing it."* —Bob Woodward, veteran XC ski journalist. *"The most compelling athlete's book I've ever read. It may not have the drama of Lance's return from near death, but it's got as much guts and more real life. McKibben's* Long Distance *is a bit more polished, but Pete's book is much more compelling. Pete is the real thing."* —Ken Salzberg

DreamBoats: A Look at Small Boats in the Heritage of Seafaring Peoples

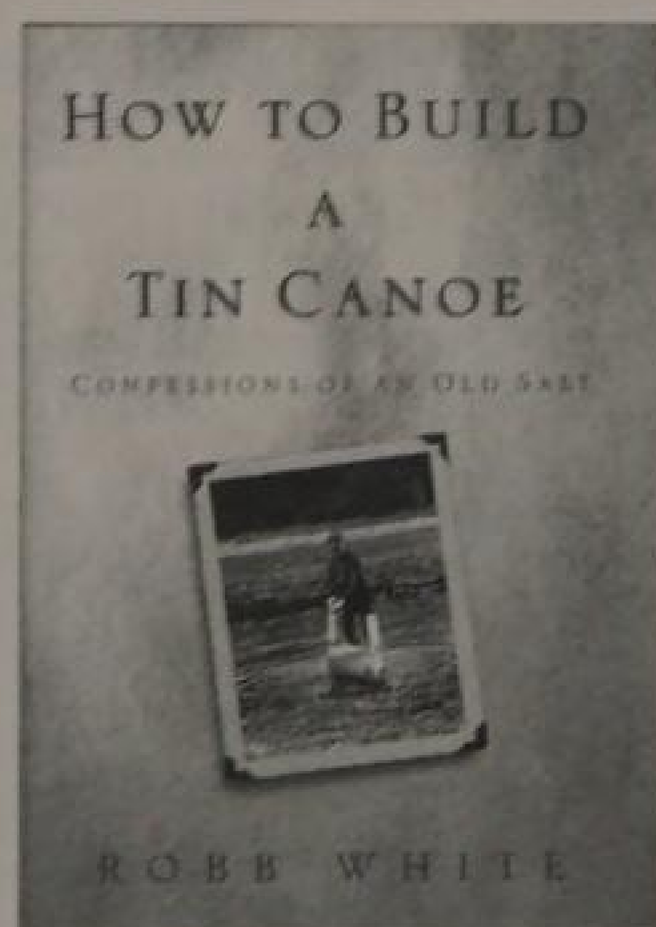
Memories, Explanation and Innovation with Coastal Craft, Junks, Dhows, Outriggers & More... in the eyes of an old salt. AUTHOR: Richard Carsen, ISBN:1892590549, PAGES: 80, LISTPRICE: $10, DESCRIPTION: There aren't any books about the exotic sailboats of seafaring peoples for the lay reader. And there sure aren't any on how and why they do what they do and how their methods might help the average backyard boater. 3rd World sailing: who'da thunk it? Richard Carsen did. He's 83 and traveled the world. He writes up his experiences with indigenous boats and rigs in the magazine *Messing About in Boats.* This book is a compilation of Carsen's columns as they appeared in *MAIB.* The anthropology of boats is fascinating and relevant: Western boating developed with expendable crews for maximum profit; 3rd World boating is about sustainability, family, and bringing 'em back alive with enough to live on. It still works this way. Whose heritage or reality seems better to you?

UNLIMITED! "Clean Oxygen-Fed Sport"

PRODUCERS: XCZONE (trailer at: www.xczone.tv), David McMahon, Lise Maloche, LISTPRICE: $29.95, 2-DVD set: feature film + XC ski instruction, ISBN 0968566685, DESCRIPTION: This 4-hour 2-DVD set presents the first and only movie showing the whole year of outdoor sports. See top athletes kickin' out the jams in gorgeous locales. Yet it's not extreme or in-your-face. Heck, it seems as though many of the athletes featured are...OLD! (That is, of Masters age...they have kids, they're doing sport for fun now.) Most people do a variety of sports during the year. They just haven't seen them put all together like this with great music before! UNLIMITED is catchy, addictive and provokes repeated watching. Production values are top-notch. It's high energy, with great current music. I think this DVD came to be because the film-makers, Lise Meloche and David McMahon, are, one, Canadian and, two, a husband-wife team with kids...and, three, are athletes themselves who are in the film. All 3 reasons help explain the casual, friendly style...and why they include everything that outdoor lovers know should be included. It's a rare film that has athletes in charge of the camera! Their talents shine both in front and behind the lens. Now, the emphasis here is on XC skiing, which has never been shown right on screen until now. Thus, it's also the best-ever XC movie. XC works well as a theme because XC skiers are so likely to do all the other sports. REVIEWS: *"MOVE OVER WARREN!"*—Explore Magazine, *"Fun, fluid and exhilarating!"*—Running Times, *"Spirited and energetic! Ignites your primal energy!"*—SKITRAX and PEDAL magazines

How to Build a Tin Canoe

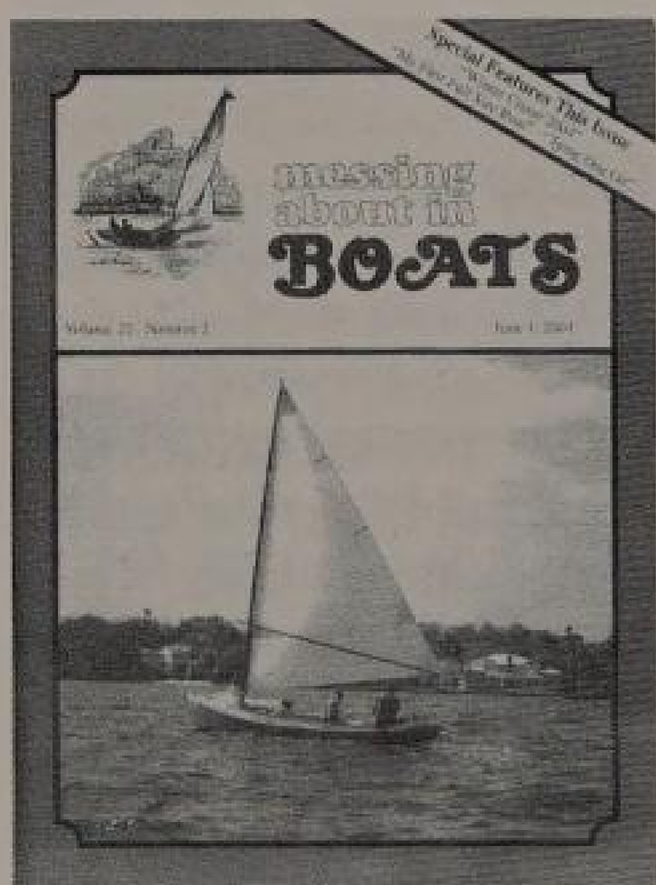
AUTHOR: Robb White; Hyperion, LISTPRICE: $24, DETAILS: 6"x 9", hardcover, classy untrimmed outside pages, PAGES: 240, •ISBN 1401300278, DESCRIPTION: This is rare'n'tasty candid writing about life by the sea. By an old fart and master boatbuilder. Robb White and his cohorts grew up wild on the flats of the Florida Panhandle, and he seems to know everything worth knowing. But don't worry, he's generous, discerning and subtle. It's a fascinating form of erudite folksy bombast that owes something to the fertile South where he was raised. The way they cook seafood down there, in particular, is simple, direct and inspiring. You'll want to try his family's fish soup. I discovered Robb White, who must be in his 70's, in the pages of the world's best little boat magazine, "Messing About In Boats." He writes a lot of words most months for them—and everyone eats them up. He's considered one of the best, most legendarily digressing boat writers, but it's not the boating that gets them. He's a real writer, and character. "Tin Canoe" is a highly regarded book from a big-ad-



vance high-end NYC publisher. Why am I selling it? They dropped their big planned PR campaign like a hot potato when his famous writer sister lost her job at NPR. So it's still fresh and new! REVIEW: "This memoir rarely fails to delight and sometimes even informs. There's plenty of talk of keels and tumblehomes. Mixed in are his observations on how television rots children's minds, and the ways in which the Enron scandal resembles cannibalism in the Pre-Columbian Antilles. Like many skilled storytellers, White wanders a bit. His childhood, which he spent building boats, getting into trouble and exploring the South's swamps and ponds, resembles his adult life." —Publishers Weekly

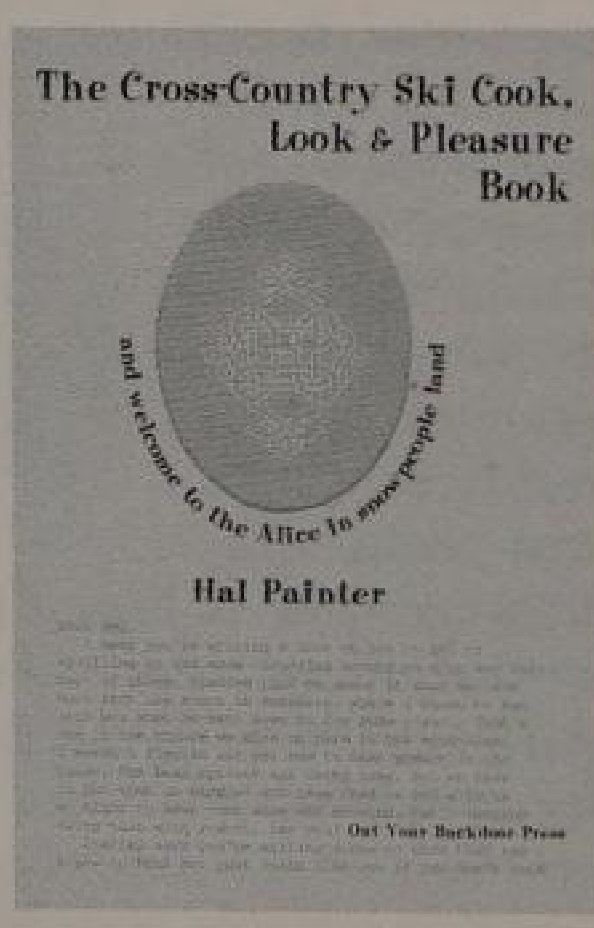
Messing About In Boats

[magazine] $3, 8.5x11, 42 pages, 2-color cover, B&W, $24 for 24-issue yearly sub. "MAIB" has been known for the past 25 years as the world's best boating magazine by its thousands of subscribers and fans. It is candid, casual, friendly and all about boat culture, with an emphasis on small, affordable craft, projects and trips. 70+-yr-old editor declines advertiser requests to soup it up. We're the better for it.



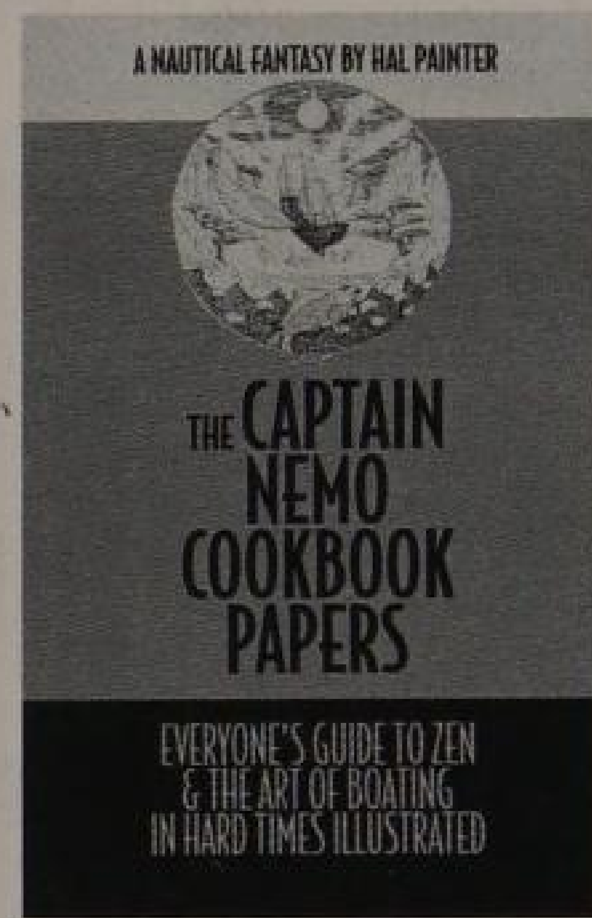
The Cross Country Ski, Cook, Look & Pleasure Book

(Only collector copies available.) AUTHOR: Hal Painter, ISBN:1892590514, EDITION: 2, PAGES: 154, LISTPRICE: $20, DESCRIPTION: Reprints and originals available of this 60's-style classic from the late 70's. A unique literary art book on cross country skiing capturing the spirit of the outdoor culture heyday in the US. Zen and the art of skiing. An antidote to consumerism in skiing and an energetic attempt to reconnect skiing with its roots in fluidity, friendship and just plain fun.



The Captain Nemo Cookbook Papers

Everyone's Guide to Zen and the Art of Boating in Hard Times Illustrated, A Nautical Fantasy (Collector copies available.) AUTHOR: Hal Painter, ISBN: 18925905522, PAGES: 135, LISTPRICE: $20, DESCRIPTION: Reprints and originals available of this comic 60's look at boating through the eyes of a variety of escapees from the rat race. Zen nuggets, marina etiquette, boat fixer-uppers and an appearance by a wildly mythic hero of boating all combine for a rare literary addition to the boating bookshelf. A great, once-*censored* 80's period piece that offers wit and antidotes to the consumerism that's overwhelming modern boating.



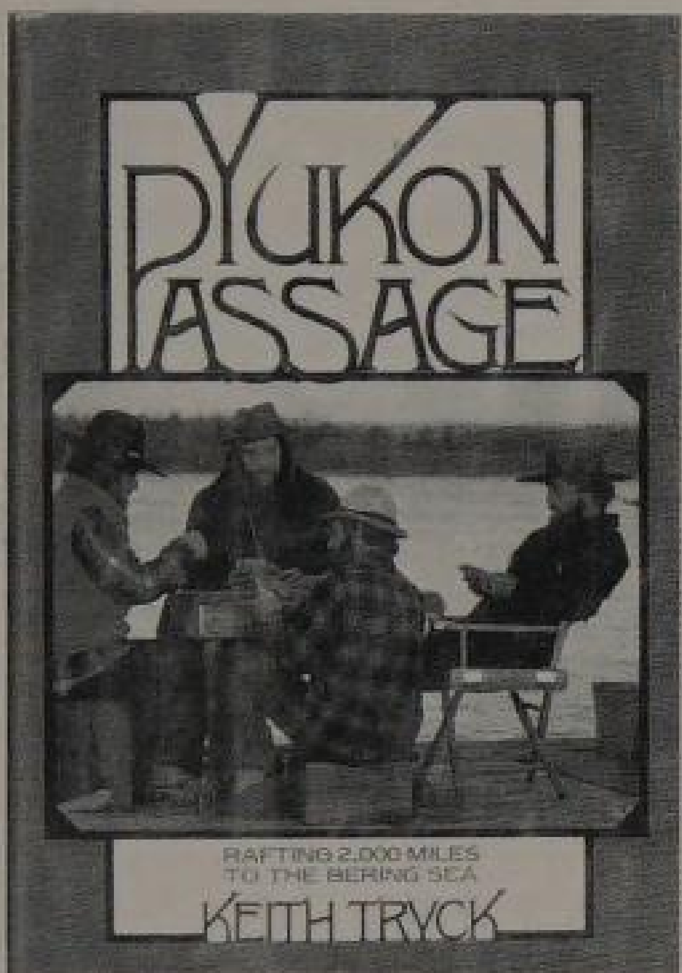
Waterwalker

AUTHOR: Bill Mason, LISTPRICE: $22, DETAILS: 90 minute DVD movie, DESCRIPTION: Waterwalker is a great movie that everyone who loves water, canoes and the wilds should own. Mason paddles a well-used old red wood&canvas canoe on an old-style solo tour in this movie, through the seasons, along Lake Superior and up and down some lovely rivers that emtpy into it. He does a dandy voiceover of the quiet scenes, with wry Canadian humor. There's an early Bruce Cockburn soundtrack throughout. Bill cruises the old way, wearing red-plaid wool, with campfires, ax, and a big open front canvas tent. It's nice to see. He also includes all the seasons. What true-blue paddler doesn't love a jaunt in the winter with the fresh air and crystal waters? The narrative content is fresh, understated, candid and complex—something rarely seen in American outdoor culture filmmaking. Mason made the movie of the "Paddle to the Sea" book that we read and watched in elementary school and which was an early inspiration for me. (It got an Oscar nomination.)

Yukon Passage

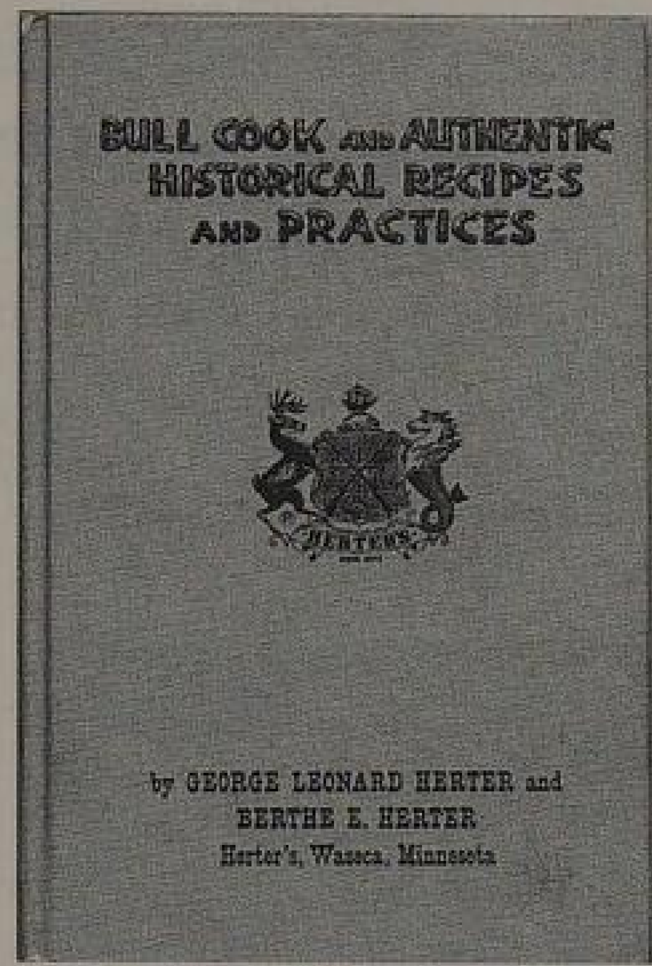
Rafting 2,000 Miles to the Bering Sea

(Collector copies available.) AUTHOR: Keith Tryck, PRICE: $20, PAGES: 220, DETAILS: Hardcover, with B&W and color photos, DESCRIPTION: "Yukon Passage" caught my eye years ago because of its cover. It shows a group of guys playing cards around a table. ...On a raft. Floating down the Yukon. I looked inside and saw other attractive photos—of a canvas tent on the raft, with oil lamps and bookshelves. If you're interested in a change of pace from Mt. Everest-style extreme adventure, speed, big air, derring-do—well, this is a fine tale for you. These kids got an idea, let their pals know and everyone saved up and fit it in between jobs. One was a lumberjack, another worked on a fishing boat, another did surveying. The author had a grampa who was part of the Gold Rush and he wanted to see for himself where his gramps went. In the middle of their tale they're broke then get the idea of approaching National Geo. They use the last of their money to fly to the NG office and ask. No query letter or appointment. They're turned away but loiter until someone takes pity and considers their project—and they end up with a deal. The result is obviously why the book has such nice photos and punchy editing. A fine tale from 1980, with nice historic backgrounding. I like to keep notions like this alive. Build a raft and float it with yer pals.



Bull Cook and Authentic Historical Recipes and Practices

(Collector copies only.) AUTHOR: George & Berthe Herter, original edition, PAGES: 350, PRICE: $25, DETAILS: Hardcover, gold embossed cover (some brown); rare Vols 2/3 also available, $40, DESCRIPTION: This is a scarce, hilarious, sincere, amazing book of food lore. There was a recent paperback put out that is sometimes available, but that's not the one you want. You want the original gold foil hardcover from the mid-60's! (Or the yellow-brown cloth—what you get is what I have on hand.) Herter ran a huge sporting goods store in Minnesota. He published a yearly catalog full of every kind of sporting goods and much else. His listings were over-the-top hyperbole. Everything was the Model Perfection International. And he sold everything. Silk, gems, cured salmon, maple syrup, snowmobiles, boats, guns, bows, traps—all under his own brand. He also wrote and self-published a dozen books. He sold them only direct. I bet he sold hundreds of thousands of copies. Bull Cook is full of recipes, histories and declarations about every kind of food; great restaurants are covered, too. Herter was a partying friend with Hemingway. The style is confident and sources never attributed. He gives many standard recipes as being related to classic personages. I enjoyed making his Eggs Mendel, supposedly invented by the guy who invented genetics (it's cottage cheese stirred into eggs as you fry them). I like George's confidence. Good cocktail party source material.



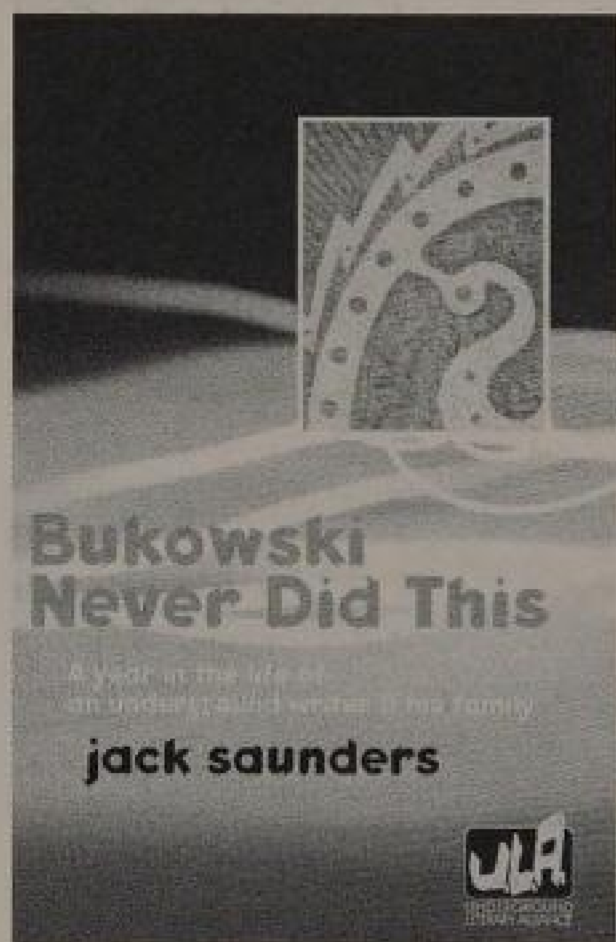
Phooka

(New edition due Fall 2006.) $10, 28 pages, 4x5, color cover, B&W, nice paper, a classy art edition. "The Journal of the Overland Mallet Club. Founded in 1891, the OMC sought out members who shared three very distinct interests: overland croquet, hard liquor, and the natural history of the Fairy Kingdom. Overland croquet is an odd combination of the traditional game and other sporting endeavors like polo, rugby, and small game hunting." Inspiring and hilarious. Stephen Potter and Flann O'Brien reborn! A treasure of the zine scene.

Fiction

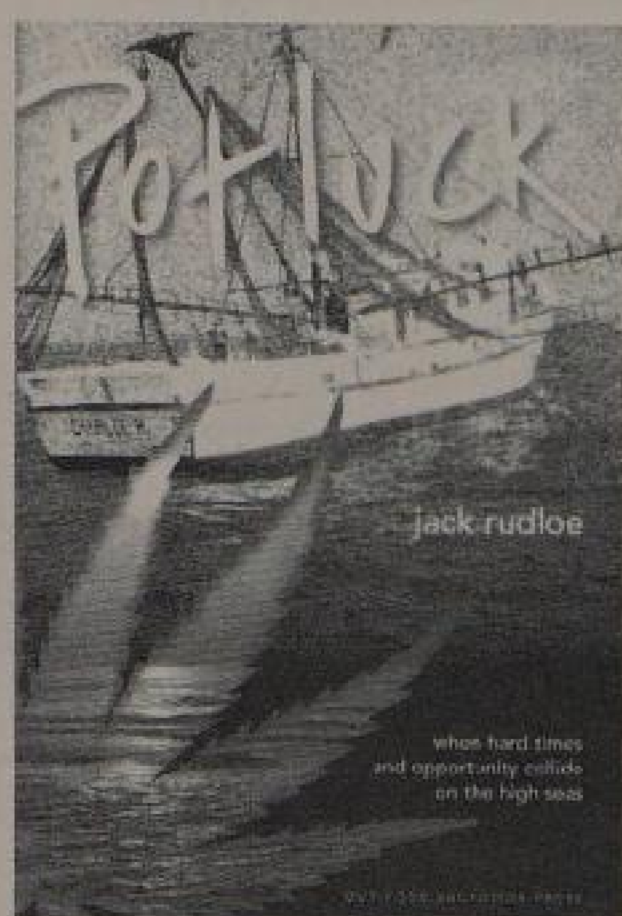
Bukowski Never Did This: A Year in the Life of an Underground Writer & His Family

AUTHOR: Jack Saunders, from LitVision Press (2005), LISTPRICE: $15, PAGES: 288 pages, ISBN 097671535X, DESCRIPTION: Charles Bukowski is the ultimate underground writer success story. Publisher John Martin gave him an allowance to quit his job at the post office and write a novel, *Post Office*, which became a huge success in Europe. Bukowski toured Europe with a personal paparazzo to document his journey, and wrote a book called *Shakespeare Never Did This*. He was still largely unknown in the United States, where he's better known for the movie he wrote about himself, Barfly, than for his many novels and books of poetry. One of the things Bukowski wrote about was going ten rounds with Hemingway. In *Bukowski Never Did This*, underground legend Jack Saunders writes about going ten rounds with Bukowski. Writing over 250 books while working full-time jobs, taking on the literary establishment, and raising a family isn't easy.



Potluck

AUTHOR: Rudloe, Jack, ISBN: 1892590375, PAGES: 264, LISTPRICE: $14.95, DESCRIPTION: Hard times and opportunity collide on the high seas. *Potluck* is a page-turning thriller about a decent captain who decides, in extremity, to take a big risk. It's the only realistic picture of small family commercial fishing on the Gulf Coast of Florida and the problems and temptations that confront it. Corrupt forces on all sides are pushing this stalwart breed of Americans into desperation or extinction. But they still do their best to feed us. If you've ever wondered what the lives are like behind the few fishing boats you still see along the coast, look no further. A rare look at the broad and surprising impacts of drug smuggling, mis-guided regulation and realtor greed along the coast. Author Rudloe is the pre-eminent conservationist of the Florida Gulf Coast, author of highly regarded naturalist books, and operator of the only independent (and thus frequently bureaucratically besieged) marine institute in the region. REVIEW: *"Jack Rudloe's non-fiction account of living on the Gulf Coast,* The Living Dock at Panacea, *is a Florida classic that ranks with* Cross Creek. *In* Potluck, *Rudloe proves he can handle fiction with the same energy and insightful style."*—Randy Wayne White



Tales From the Texas Gang

(First edition 1972 collector copies available; new printing forthcoming.) AUTHOR: Bill Blackolive, ISBN: 1892590387, PAGES: 339, COLLECTOR: $30, NEW PRINTING LISTPRICE: $21.95, DESCRIPTION: Wild Bill's writing is in the tradition of Melville... and Keroauc and Castenada and Abbey. It's a bit like Cormac McCarthy as well, only more realistic, authentic and candid. If you like the thrust of those other writers, you'll be thankful for *Tales From the Texas Gang*. It's one of the rare significant additions to American literature. And it's based on real life, and a real life gang. It's set in the late 1800s. It's an outlaw gang gunfighter novel...but so much more.

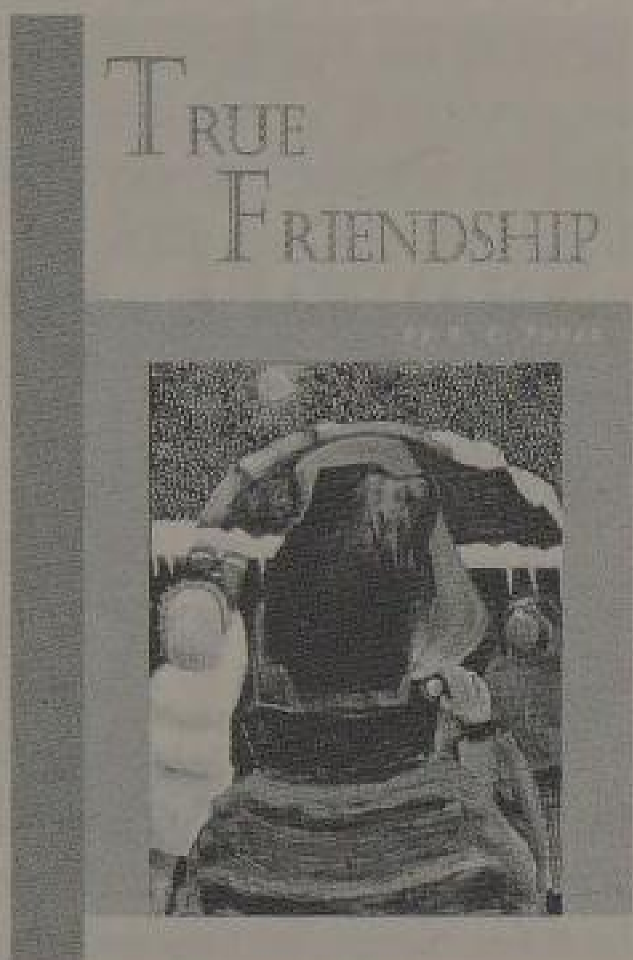
The Emeryville War

AUTHOR: Bill Blackolive, ISBN: 1892590395, PAGES: 109, LISTPRICE: $12.95, DESCRIPTION: If you liked *Confederacy of Dunces*, you'll like this. Only, it's real. An amazing tale of actual life in the fringey, unhip edge of Berkeley in the 60s. You've never seen neighbors, cops and city officials like these, nor an observer like Wild Bill—dogs, barbells, wrecked cars and all. (*Due Winter 2006.*)

Philosophy

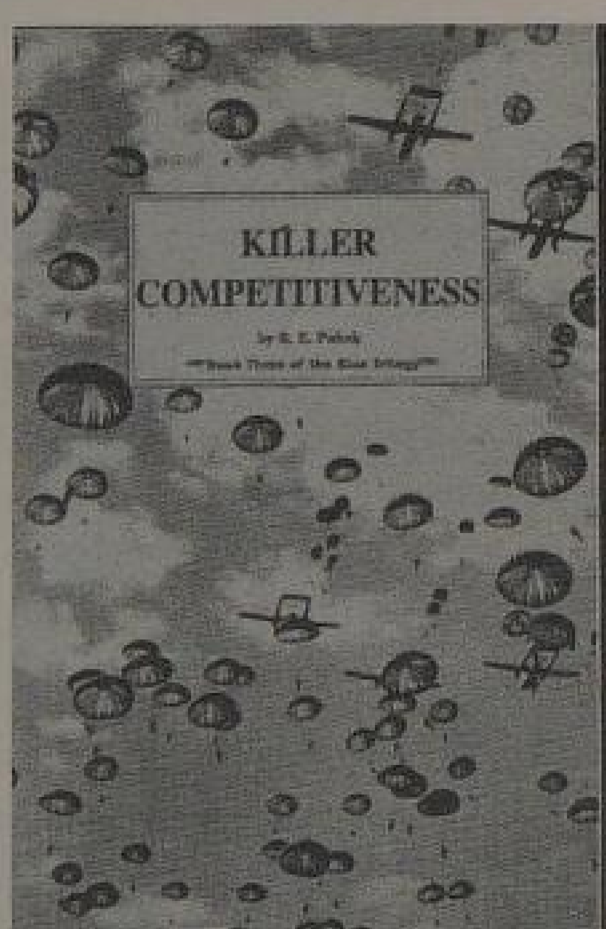
True Friendship

AUTHOR: Ronald E. Puhek, ISBN: 1892590166, PAGES: 80, LISTPRICE: $15, DESCRIPTION: Among the most delightful, rewarding, and beautiful things in life is true friendship. It is the highest form of love between two individuals. Even the bonds of marriage are blessed to the highest degree when a partner is a friend. All friendship is spiritual in the sense that it is based not on what others can do for us, nor on what they are in themselves, but on what they mean to us. It's the meaning that stimulates the spirit. The quality of the friendship depends on the quality of the spirit, but the quality of the spirit depends in turn on the quality of the meaning. This book explores the highest kind of spirit and the truest form of friendship—and how we can reach them both.



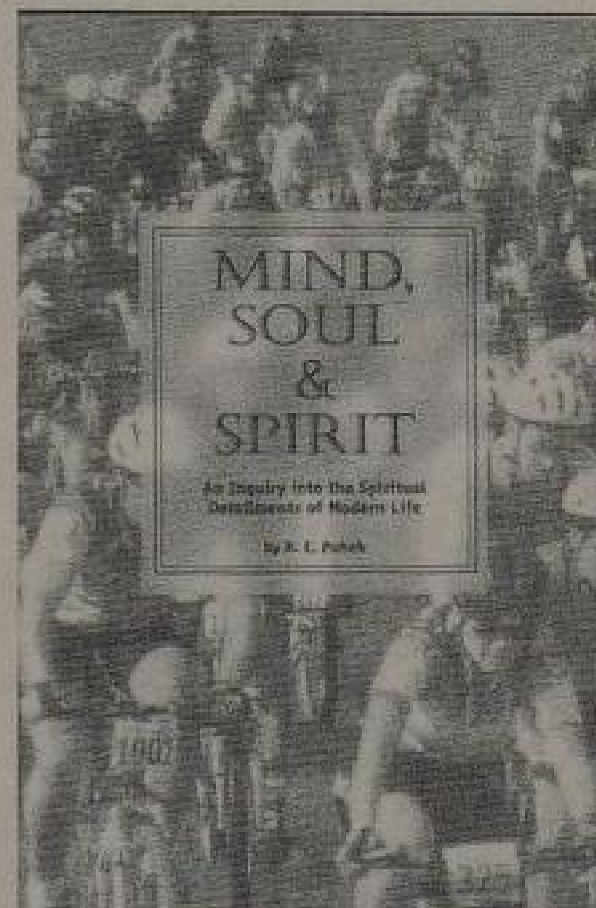
Killer Competitiveness

AUTHOR: Ronald E. Puhek, ISBN: 1892590085, PAGES: 130, LISTPRICE: $15, DESCRIPTION: *Killer Competitiveness* accounts for how it is possible for us today to exist so long under meaningless conditions without realizing it. So empty is life without meaning that it could continue only with the help of an extremely powerful illusion. This compelling illusion is generated by competitiveness in nearly everything we do-even in our supposed efforts to cooperate, or function independently. Competitiveness generates the illusion of value. Therefore, we do not see the valuelessness of our lives even as we suffer from it.



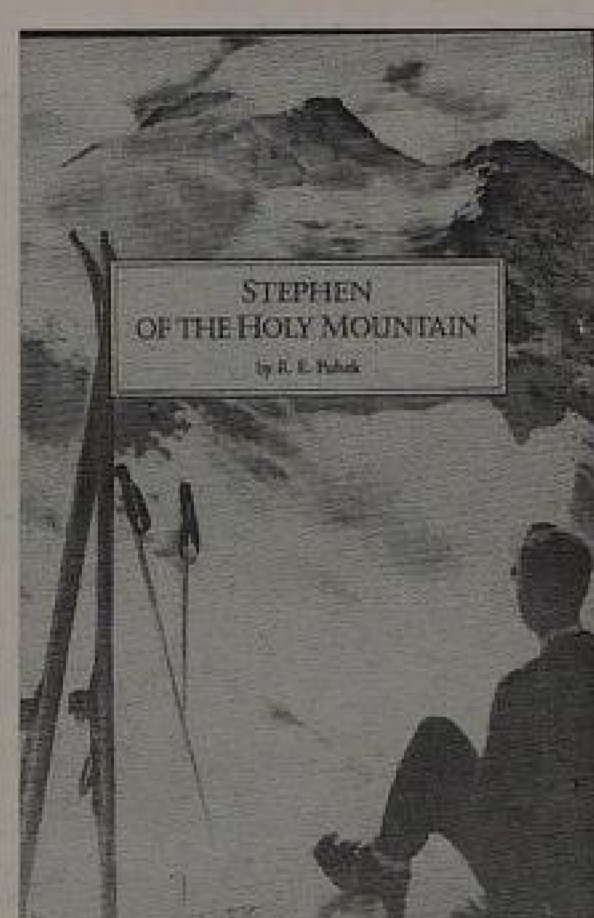
Mind, Soul & Spirit

An Inquiry into the Spiritual Derailments of Modern Life AUTHOR: Ronald E. Puhek, ISBN: 1892590026, PAGES: 148, LISTPRICE: $15, DESCRIPTION: The prevailing styles of living today require the "derailment" of our energies. The spirit or energy that life grants us to fulfill our destiny is seized, imprisoned, and then turned away from its natural direction, usually to be amplified for ulterior motives. The various derailments of spirit operate unconsciously upon their victims. We today are particularly vulnerable to blindness here because of our ignorance of the dynamics of spiritual life-even as many of us pretend to spirituality and feel energy which we trust to be helpful. Spiritual knowledge is almost completely absent in all contemporary education, and, as a society, we are nearly bankrupt spiritually. This book maps out the many ways our spirit gets diverted without our knowing it. We must take back our spiritual birthright.



Stephen of the Holy Mountain

AUTHOR: Ronald E. Puhek, ISBN: 1892590018, PAGES: 94, LISTPRICE: $15, DESCRIPTION: An inner journey, outwardly masking itself as a sojourn up the side of a high mountain, Stephen of the Holy Mountain seeks answers to the most perplexing questions that come to those who have awakened from the sleep of ordinary existence. The mysterious figure of Stephen acts as a guide both to the author and to many others who climb Stephen's mountain to find him. His advice is often too harsh for many who think they seek it. Unfailingly kind, however, Stephen does his best to aid all who come to him.

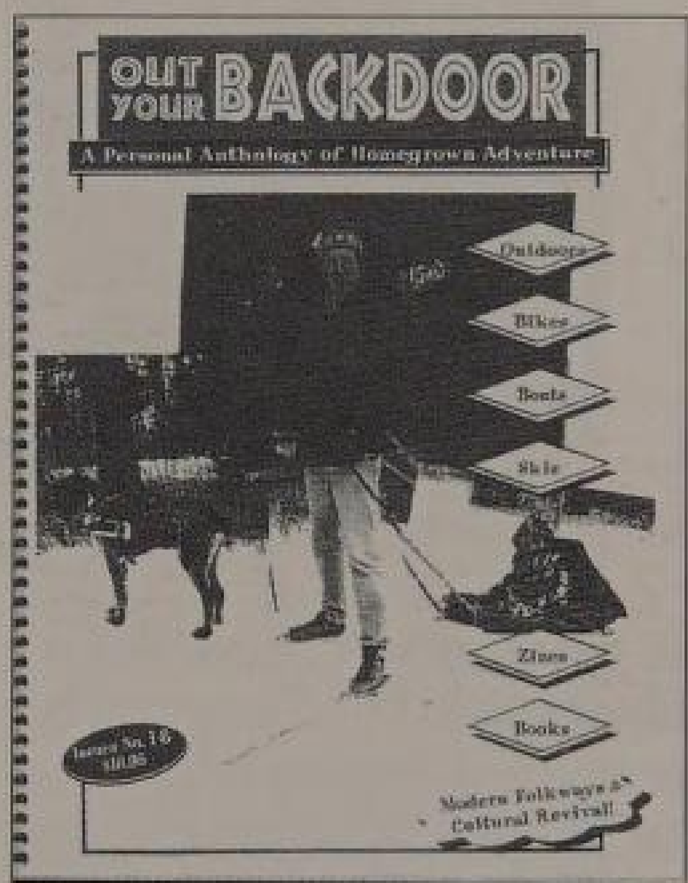


Out Your Back Door

The Magazine of Homemade Adventure, Modern Folkways and Cultural Rescue

Anthology Volumes 1 & 2

Vol. 1 is a 200-page collection of issues #1-8, $20. Vol. 2 is the huge 75-page issue #9, $5. *OYBD* has been covering the neglected aspects of modern folk culture since 1991. The latest issue is Vol. 2 of the anthology. The previous 8 issues form Vol. 1. *OYBD* is the back porch of culture, where people hang out helping each other find the nifty things that people really do. (The front door being for salesmen and authorities.) *OYBD* revives the jaded, helps those who've 'been there, done that' to get to the next level. *OYBD* is for all-rounders and generalists, like most people are. It works against the alienating specialties that society uses to split us from ourselves and each other. It creatively explores all sorts of things, including: biking, books, boats, movies, zines, religion, skiing, fishing, hunting, garage sales, getting by, making do. Get the picture? Big website at OutYourBackDoor.com.

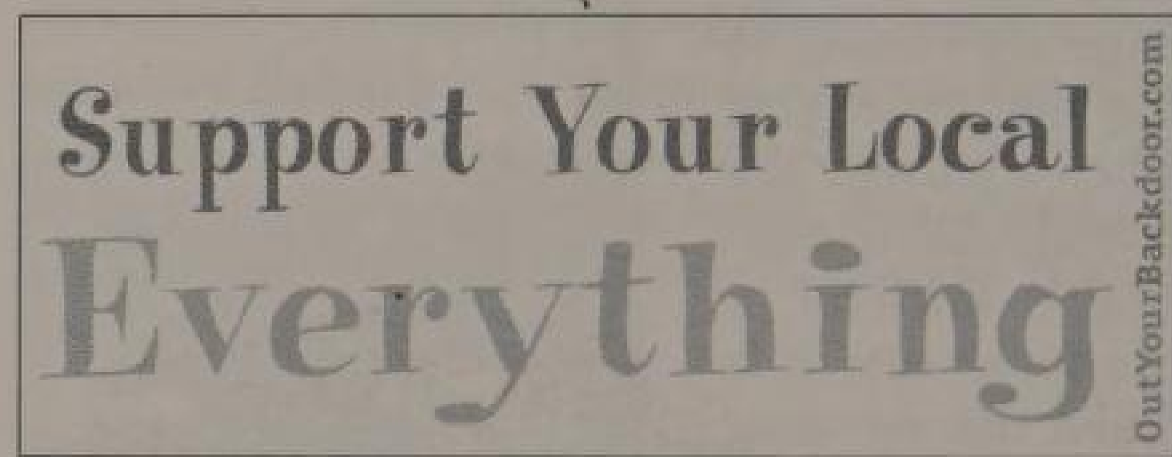


OYBD #10

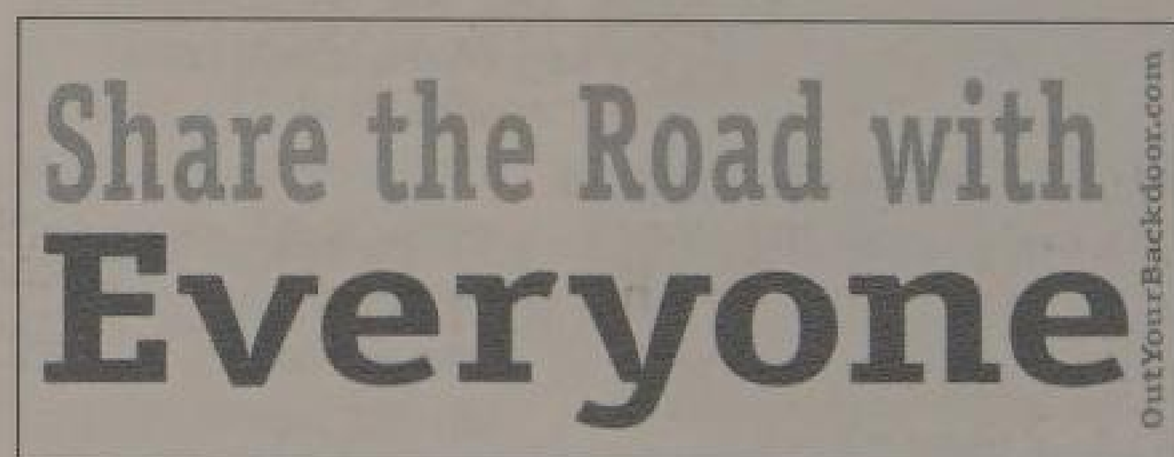
EDITOR: Jeff Potter, PRICE: $5, PAGES: 82, DESCRIPTION: Biggest-ever *OYBD* issue. Color cover. This has to be about the only magazine of authentic, informal, do-it-yourself, indy adventure. It's a combo magazine/catalog, which is why I call it a "catazeen." It has a dozen articles plus listings for all the books, mags, videos, music, and drygoods projects I'm doing. I've written most of the articles but there are several standout articles by others. ($5 will also get you on the list for OYBD11.)

OYB Bumperstickers

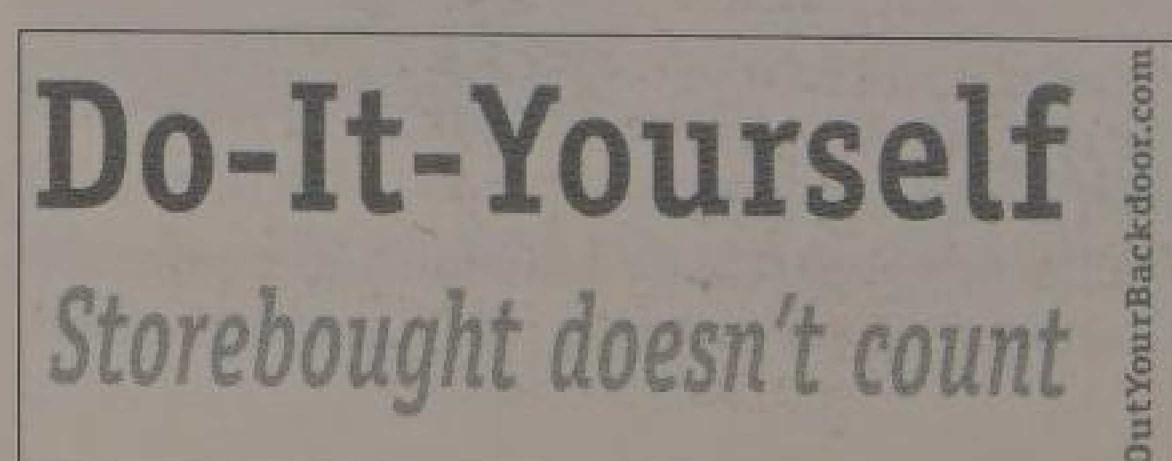
$2 each. I used to think that bumperstickers weren't for me. I didn't care to say anything to motorists. But I finally realized that we spend so much of our lives trapped in dull steel boxes, staring at



other steel boxes, that we might as well say something. These boxes are better billboards than they are most anything else. We're cut off from each other in these boxes, but by reclaiming their exterior space for ourselves we don't have to be. We can communicate with each other and stand up for fun, creative, neighborly life. We can liven up those zombified stoplight intersections. Notice that OYB



sticker messages exclude no one. No segregation. No "us versus them." They're unpolitical. They're inclusive. Unity, for a change. They *do* trash the Un-culture, and might make greed-heads feel bad, but a corporation isn't a person. These stickers point a way out, or make a challenge, that no one else seems to be doing, not in the same way anyway. (Road-sharing is promoted, I know, but in a legalistic way.) They all use the same aqua and red colors.



Move•It! ...the Social Magnet Game

PRICE: Magnets $2 each. Play the "Move-It" game! Here's how: Order these waterproof, vinyl, pro-quality magnetic stickers. Then put em on your car bumper, fender...or refrigerator. The simple interactive game concept is printed on each sticker, so if anyone asks, tell em! Here's what the sticker text says:

"If You Like Me... Take Me!... Keep Me Moving!"
"Move-It!" the social bumpersticker
Public Property outyourbackdoor.com

Who knows where they'll end up! People can take em! —But this isn't a bad thing. If yours gets taken, just keep your eyes peeled. Maybe it's just been moved elsewhere on your car. Maybe you'll see it around town. When you get *your* chance, grab it back!

Information wants to be free, right? Watch the message move!

If you've ever thought you're the only one trying to have fun driving around in boring carland, maybe someone else out there will surprise you! Say Hi to folks who have similar interests just by driving your car, or by displaying these stickers anywhere—the frig!

These magnets promote a "small world" vibe, physically showing how a Net-like autonomous flow of data can increase community life.

Buy a few just to make sure you keep one. (Size: 3x5 or 3x7.)

Local Spirit! ...a Sticker and Directory for Indy Biz

Here's the small text on the sticker:

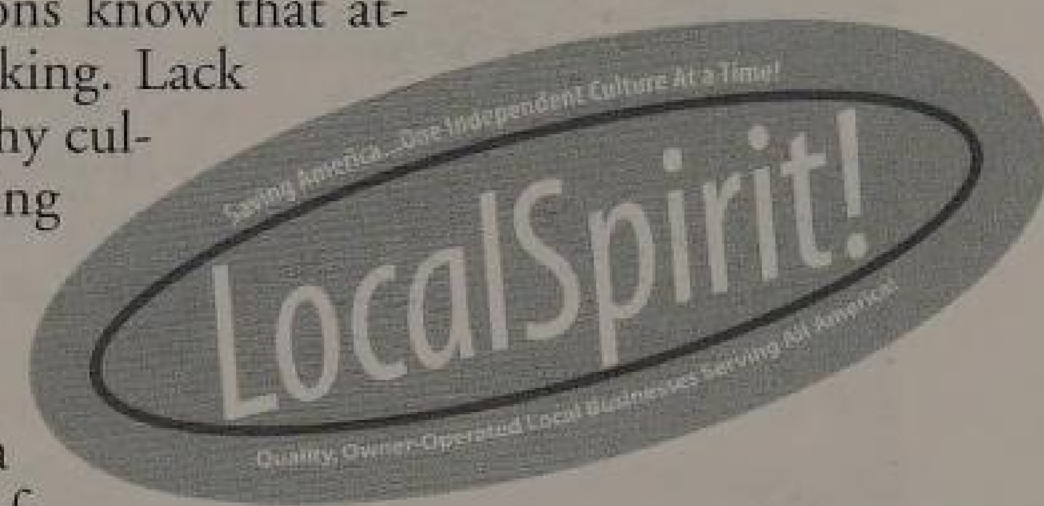
Saving America! One Independent Culture at a Time / Quality, Owner-Operated Local Businesses Serving All America!

What is the Local Spirit program?

What you do is order these hi-quality vinyl stickers to put on your car, for one thing, to show that you support the cause. Then you give others to worthy businesses to display. Then, via the OYB Local Spirit Forums, let us all know who you've given them to. Qualifying businesses can also order them direct.

So, what's the cause? And what are the businesses?

The cause is to support culture. The more people that know about good places, the better. Corporations know that attention is king. Lack of PR is why culture is being run out of Dodge.



This is a revival of the old Duncan Hines concept of using a sticker and directory to ID decent places to stop around the country to get a meal.

So, what are Local Spirit businesses? They are owner-operated and offer local products and services. They don't charge so much that locals can't use their services.

They could be multi-generational ("old") places. They wouldn't be messing up their own bed or hockeying in their nest, forcing their children to flee or be exploiters or underlings. They'd be blooming where they were planted and making their town a better place to be.

The OYBD 3-Way Shoulder Bag!

PRICE: $30. That's "possibles kit" to mountain men, pardner. Or "man purse" for the bold. These are handy places to stash stuff so it doesn't jam pockets, so you look trim and cool and don't jangle and spill when you bend over.

The OYBD bag is the world's only 3-way combo shoulderbag, bicycle saddlebag and handlebar-bag (w/ 3 extra straps for bike use). At 10"x8"x4" it's great for daily-use goodies, even a bottle of wine.

I make them out of "character"-condition used Swedish military surplus shoulder bags—by sewing my groovy new OYB patch to them, modifying them to work on bike seats and tossing in 3 nice leather straps. They're greenish/brownish canvas with brownish/greenish leather. $30. (Somewhat-similar bags are $50-100, albeit spanking new.)

Here's what an owner had to say:

"I got the purse yesterday—very nice! I used it this afternoon when taking my little daughter and two dogs to the park. Having a small bag to stow keys, phone, binoculars, dog leashes, and one that doesn't swing around and hit whatever is in front of you when you bend over is a great benefit. I'm debating ordering another one as an inexpensive but capacious handlebar bag."

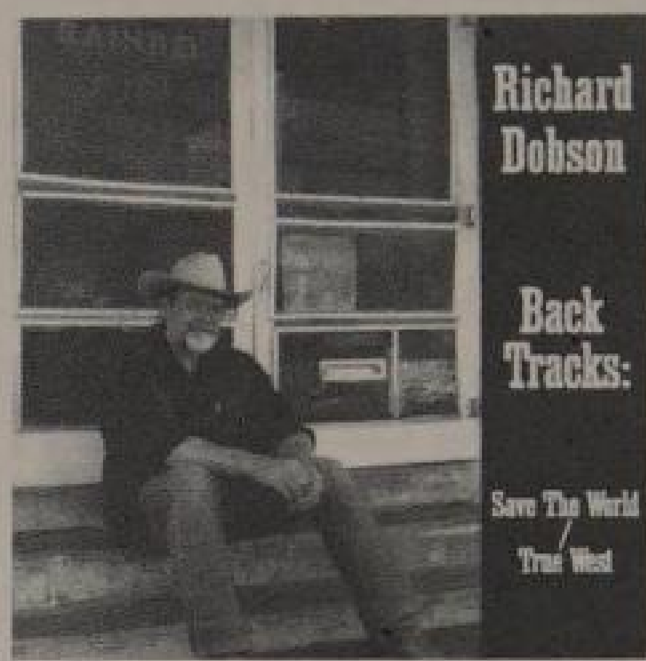
Here's the bag-size scoop: A man-purse is fine for day-use, but 15x10x6 is your minimum size for overnights and books, but that's a mite big for jiffy day-carry.

Bags are the ultimate grab'n'go. You won't ever be without handy items. Have an annoying outing you can't say no to? Grab the bag and join the fracas...but feel half as trapped as before because you have relief goodies at your side. To always be prepared, keep yours stocked as follows: water bottle, notepad, pen, paperback, flask, leatherman, digicam, cell, lighter, powerbar, pipe, tobacky, mini-light, aspirin/chapstick/bandaid, hanky, ducttape, sunglasses.

OYBD Music ...& More

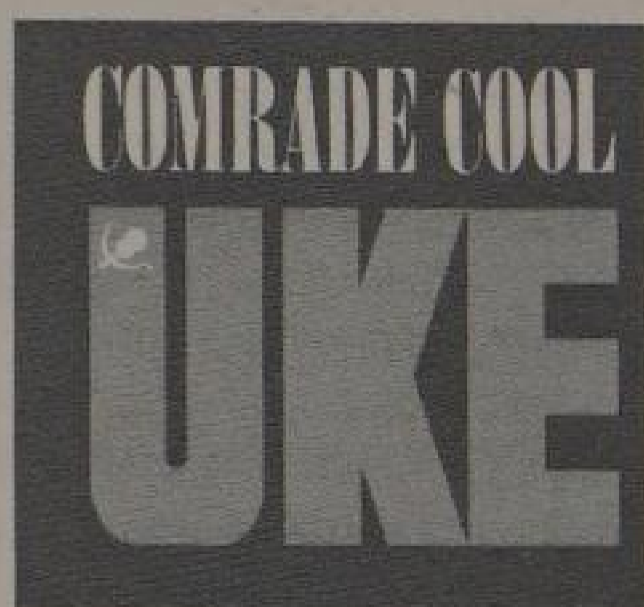
Back Tracks: The Best of Richard Dobson

ARTIST: Richard Dobson PRICE: $12 CD; 21 songs; $1 per song download and free samples online at OYB website. DESCRIPTION: Richard Dobson is one of the gang who started today's Austin Texas music scene. He says it's "folk and rocking country music." (Say it fast.) I call it great music that I hadn't heard before. Here's what a few people have to say: *"His rhythms and ideas are great. His words are precise and never wasted. He's one of my favorite songwriters."*—Townes Van Zandt *"Richard Dobson is a great songwriter."*—Steve Earle *"Richard Dobson is one of the best songwriters in Nashville—make that the whole U.S."*—John Prine *"Richard Dobson is the Hemingway of Country Music."* —Nanci Griffith



Gulf Coast Boys

AUTHOR: Richard Dobson PAGES: 177 LISTPRICE: $15 DESCRIPTION: I learned about Dobson's memoir from Jack Saunders. Richard played hard-driving bar music with the toughest guys around, spending extremely wild years on the road with the likes of TVZ. Between tours he worked on oil rigs and shrimp boats. This is a fine story of those days, about a level and place of culture that isn't published about often. After I read it, I bought his music (backwards, but it worked just fine). I think there's something special about artists who work in several media.



U.K.E.: Comrade Cool

ARTIST: Bart Casad PRICE: $12; 11 songs; downloads and samples at my website. DESCRIPTION: Welcome to U.K.E., the land of Bart! It's socially relevant ukele clever-fest, ensemble-style. (U.K.E. = "ultra kitsch ensemble.") He's a lively, astute singersongwriter. There's great instrumentation and nifty production values on this album, too. Quirky, with a beat, and country in its bones. Bart is a PhD biochemist, lawyer and singersongwriter with folksy Kansas expressions. Bart and Friends had recorded "Comrade Cool" a year earlier and played it around Ann Arbor. They also made a couple videos which were aired on MTV. They played some big venues. He then brought the first (and only?) Soviet rock band to the U.S. in 1988. The tape has since sat around, entertaining us. But why keep it to ourselves?

Slim McElderry: The Blue Sun

ARTIST: Slim McElderry PRICE: $12 CD; 18 songs; $1 per song download and free samples, art and lyrics online at OYB website. DESCRIPTION: Rich, twangy swamp blues with worldclass lyrics courtesy of Mac's decades of global wandering and busking with his 12-string dobro. It's something like Leadbelly, say. In the vein of Woody. With a Kerouac vibe tossed in. This music has been hiding under a bushel since the 70s. Here's your chance. Mac also created a "Blue Sun" songbook of over 100 songs and art plus essays on the wandering, loving, radical life fully lived—look for it here soon. Mac is now 70+ and still rocks. He lives in a no-power barracks in Panacea, Florida

Dread Clampitt

ARTIST: Dread Clampitt, PRICE: $15, 10-song CD, on their own label. (Info and samples at DreadClampitt.com.) For $5 extra get the chapbook about the roots of this roots band, "Root Doctor," by Jack Saunders. DESCRIPTION: Gulf Coast funky roots music, popular with young and old, locals and cognoscenti. A gang of trailer kids and broke-down car dudes play the virtuoso swamp tunes that only the truly commited can. I suppose they're something like a harder-rocking Old & In the Way; Phishy but more traditional. Recent mainstream reviews call them "up and coming." Their touring is going farther and wider. They're opening for bigger and bigger acts (such as Donna the Buffalo), playing NYC for New Year's.

From "Granny Brown":

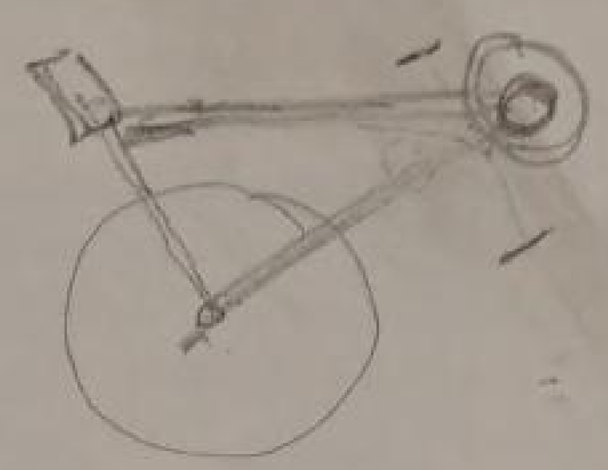
I said, "Granny, tell me about the Depression" /

She said, "There weren't no such thing. We always lived that way /

"We had our pride and our music, weren't supposed to have nothing /

"So much fun to be had, quit your cryin' and your fussin'."

Their debut CD hit #2 on the Gulf Coast charts, but they have 2 more CD's out now. These guys have played daily (and nightly) since high school. Balder Saunders was first-chair trumpet in the All Forces band but prefers his home-built electric mando now. Guitarist Kyle Ogle grew up down the beach spear fishing. Fiddleplayer Justin Price-Rees was multi-champ of Australian bluegrass fiddling. Bassist and mentor Duke Bardwell played with Elvis. Really. They play originals, relatives' songs and standards for raving fans.



the recumbent bicycle

The recumbent has lived in the shadow of other bicycles since the beginning of cycling. And despite amazing successes, it still battles prejudice and misunderstanding. But a recent burst of innovation coupled with a diverse range of brands is bringing fresh, new life to this corner of the cycling world.

Outfitted with modern components, and offering speed and comfort superior to uprights, recumbents are enjoying a surge in popularity. Racers are attracted to the aerodynamics. Tourists appreciate the comfort. And utility cyclists benefit from the weatherizing and cargo options.

Every year more shops offer these bikes, but only this book lets you fully understand what is available.

Author Gunnar Fehlau examines the full spectrum of design styles and brand names, explaining how they work, what to look for, and how to choose (or build) your dream bike. He presents a fascinating historical overview of the recumbent's early beginnings and traces its development to the present day.

All facets of cycling are given equal treatment, with discussion of everyday use, record-breaking HPV racing, and everything in between. Chapters on bike selection, the performance traits of features, physics, biomechanics, home-building and a huge resources appendix complete the book, giving you all the information you need for a thorough overview.

OUT YOUR BACKDOOR PRESS

ISBN 1-892590-59-X
52195
9 781892 590596