HUMAN POWER

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HPV DESIGN CONSIDERATIONS

Three Essays by Dave Agler

[EDITORIAL NOTE: Dave Agler is the builder of **Pacemaker**, an enclosed recumbent tricycle, which he has ridden in the road, as well as raced. - M.R.E.]

TWO-WHEEL vs THREE-WHEEL DESIGNS

To begin the essays on HPV design, I have chosen the pros and cons of two- and three-wheel design. The first consideration of designing an HPV would be to decide the kind of use it will get. Will it be used for commuting, racing, top speed, time trialing, or utility? Building an HPV is a matter of choice as to what you want. The more you know of the advantages and drawbacks of certain designs, the easier it will be for you to build exactly what you want.

I will deal only with the two- and three-wheel designs, since one wheel doesn't make a "vehicle" and four wheels or more are no more stable than three.

Two-wheel advantages

* Two-wheel designs will always be lighter than three-wheels using the equal materials. This leads to:
  a) better acceleration;
  b) faster or easier hill climbing.
* Two wheels give better maneuverablity; they can lean into turns and still maintain a relatively high speed; they have
* less rolling resistance;
* ease of entry and exit; and
* ventilation: a two-wheel recumbent without a windshield still has an aerodynamic advantage over a standard ten-speed. Two-wheel designs also
* take less room on the road: two-wheels can ride within 2 inches of the side of the road, leaving more room for passing traffic; and
* Cost less to make: less materials, fewer parts.

Two-wheel disadvantages

* All two-wheelers are affected by side winds, causing veering in some situations. Stability is affected in two other ways:
* balance must be maintained, or you fall. The two-wheel recumbent is more sensitive to over-lean, and can slide, especially in rain or snow. Further,
* seating position must be higher for stability than is needed for a three-wheeler, making more frontal area and side area.
* Only a partial fairing is practical for actual road conditions; thus losing the edge a full fairing can provide; and because you have no full fairing, you have
* no complete protection from rain, cold, or crashes.

Three-wheel advantages

* Full fairing is possible, giving much higher speeds; and also
* Protection from wind, rain, cold, and crashes.
* No balancing required, giving instant ability to ride vehicle. Three-wheelers are
* less affected by side winds; and have
* lower seating possible, giving less frontal area and side area.
* Front-end geometry is virtually the same on all designs.
* Three-wheelers give the ability to ride all year round. I have ridden in up to 4 inches of snow, and taken turns on icy roads at 15 mph.

Three-wheel disadvantages

* Three wheelers are heavier than most ten-speeds, with slower acceleration, and slower speeds up hills;
* generally less maneuverable in high-speed designs; and have
* more rolling resistance.
* Good ventilation to the rider produces more drag, slowing the vehicle; and three-wheelers
* Cost more for materials, bike parts, and fairing.

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IN THIS ISSUE

EDITORIAL

HPV-BUILDER'S GUIDE

Full credit for the majority of this issue goes to Mike Eliasohn. At the general meeting at the 1984 Indy championships there was expressed a strong sentiment in favor of a listing of sources of materials and help for builders of all types of HPVs. Mike volunteered to get it together. Many of you responded to a request for information, and others put their thoughts down, at Mike's request, on various aspects of HPV design and construction.

I think the result is magnificent. Undoubtedly you will find errors of omission or commission. Let Mike or me know about these. We all do our best in **HP**, but we can't claim perfection. Mike's laboriously typed listings are going to Pat Cummings, who has put in countless hours of volunteer work getting past articles into computerized form. When she does so with the Builder's Guide, it will make adding to it and correcting it relatively easy. We will aim, therefore, to publish an updated Guide next year, and perhaps annually. Keep your inputs coming.

EDITORIAL (IR)RESPONSIBILITY

Editors and publishers have a great deal of power. I know, because my usual role is that of a struggling author who has most of my offerings refused or, worse, ignored, and those of my articles or books that get published seem often to be mauled by unscrupulous editors. Now I find myself in a position of some little power (there is no IHPVA "management" keeping a close eye on me) and dealing with articles and letters of all types. Some (a small minority) are beautifully prepared and illustrated. Some seem to have been dashed out by people in the middle of lunch, on odd scraps of dirty paper with sketches that would be unacceptable in primary school, using a vernacular and a set of units that would make them unintelligible to most non-Americans. Sometimes I rewrite these, type them up and make passable drawings if I think readers would appreciate the message. I will be returning more of these to the authors for rework in the future.

However, the most important concern I have at present is what to do about articles or letters with which I strongly disagree. I could publish them without comment, reject them out of hand, or send them back to the authors with a request that they consider a change. If **HUMAN POWER** were a larger journal, there would be a panel of editors and a large number of reviewers, and the responsibility for avoiding biases on the parts of authors and publishers would be spread. A small volunteer organization cannot follow this expensive practice. So I'm trying different approaches. In particular in this issue, I've added my comments on recommendations that could, if slavishly followed, lead to injuries or worse. If you think I'm showing bias, write to **HP** at my address below.

David Gordon Wilson

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HUMAN-POWERED VEHICLES - SOURCE DIRECTORY
Vehicles, Plans, Components, Materials, and Data

by Mike Eliasohn

INTRODUCTION

PRECAUTIONARY NOTES: It was not possible to check with each business or person listed in this guide. Those listed came from a variety of sources, including many IHPVA members.

You may find some sources you contact are no longer in business; or they may deal only with manufacturers or retailers, not with "garage builders". Known wholesalers, primarily distributors of bicycle components, are listed as such. If you can't find a bicycle shop willing to act as your intermediary, contact the wholesaler and ask for the name of a dealer.

Availability of literature, its price, and whether or not a discount is given to IHPVA members is listed if known. Literature can range from a book-sized catalog to a single-sheet listing, and may include informative material in addition to listings of products. If you are seeking information and no mention is made of literature, I suggest a telephone call, or a written inquiry with a self-addressed, stamped envelope or postcard. ("SASE" in this listing means "self-addressed, stamped envelope of business size.)

In making inquiries from the U.S. to sources in Europe, I suggest you send an international postal coupon with your request. Overseas sources will be more willing to respond if they don't have to pay for the postage.

Sources within each category are listed in alphabetical order. The address, phone number, and catalog availability is repeated in each category when the company is listed in more than one category.

ADDITIONAL LOCAL SOURCE LISTINGS: In searching for "whatever", don't forget the Yellow Pages. Local bicycle shops may have some obscure parts, or be willing to order them. Shops that do a lot of bicycle motocross (BMX) business probably stock 20-inch tubular and 20x1-3/8 alloy rims and tires.

Mail-order sources are the only place for most people to get chrome-moly and aluminum tubing (most local steel- and aluminum-supply shops don't sell it), but frames have also been built from easily-obtainable exhaust-pipe tubing and electrical metallic tubing (EMT) and conduit, the latter two available from electric-supply stores.

Try plastic-supply stores (and some hardware and discount stores) for Lexan and other thin plastics for windshields. For fairings, heat-shrink plastic is available in colors from hobby shops (it is used for model-airplane covering) or in clear from numerous places (used for covering windows in winter). I also know of fairings that have been built from plastic-foam insulating panels, available at lumber yards and other places; posterboard and plastic foam-sandwich panels, available at art-supply stores; and corrugated-plastic panels of the type used for signs, obtained from printing-supply outlets.

Print shops and printing-supply stores can also be sources for the plastic "card" used for printing wallet calendars, etc., and for the heavy plastic used for silk screening, both of which have been used for aerodynamic wheel covers. Spandex available from fabric-supply shops has been sucessfully used for "foldable" fairings.

UPDATES, COMMENTS, FURTHER INPUT: Since this source directory will be updated "continuously", and a revised listing printed in the future (perhaps next year), I would appreciate it if you would inform me when you locate new sources of "whatever", or if you find that ones listed here have gone out of business, won't deal with individual orders, etc. Contact:

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HPV DESIGN CONSIDERATIONS

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LONG- AND SHORT-WHEELBASE TRICYCLES

Most people know that in bicycles, the length of the wheelbase gives some indication of how the bike will handle. A short-wheelbase bike will be responsive, quick to accelerate, and a good hill climber. It will also be harsher on long distances, and will not absorb road vibration as well. This holds true for the tricycle in many ways, and in some ways is different.

Much of the information I have learned has come from hands-on experience and may not be as detailed as engineering manuals.

I will list advantages and disadvantages of short- and long-wheelbase tricycles. I will also give some figures to let you know what limitations to expect with different wheelbase lengths. All the figures stated refer to a front-wheel track of 25-27 inches (625-680 mm) and a frame-to-ground clearance of 4-5 inches (100-125 mm).

Longer-wheelbase trikes are more graceful, and less sensitive to side winds. My first HPV tricycle had a wheelbase of 64 inches (11.7 m). It was stable at 67 mph (30 m/s) downhill, and was able to cruise at 27-32 mph (12-14 m/s) over a very rough and patched road. The rear wheel was lightly loaded and transmitted little road shock over long rides. The main problem was that the turning circle was large (37-38 feet, 11.5 m), making U-turns on two-lane roads impossible.

Because the rear wheel was lightly loaded, it also made braking on the rear wheel useless. Coasting at 5 mph (2m/s), I could lock up the back brake, and the wheel would merely skid. I depended only on the front drum brakes on that trike.

The last small disadvantage was the extra weight of the trike, because of its longer frame, longer chain, and added cable and housing.

A wheelbase of 52-53 inches (1.3 m) is the same as on the **Vector**, and has proved its stability. My trike was stable at over 55 mph (24.7 m/s) many times. It will turn in a circle of 27-32 feet (8-10 m). It is nearly able to turn in a two-lane road. This is the same turning circle as in many small cars.

This trike will weigh 3-4 lbm (1.4-1.8 kg) less because of the shorter frame and less chain, cable and housing. The braking on the rear is better than a longer-wheelbase trike.

A note on the amount of turning on the front wheels: last winter I maximized the steering to make it turn sharper (2-to-1 ratio). It now turns sharply, to the point where you are no longer turning the trike, but instead, actually trying to pedal while the wheels are at near-right angles to the vehicle. It will turn a 20-foot (6-m) circle, but requires the effort of a hill climb, and with the steering that sensitive, may not be safe at high speeds.

A wheelbase of 38 inches (1 m) can be made by using a rear wheel of 20-inch (510-mm) diameter. This makes a highly-maneuverable machine. It will turn a 10-to 13-foot (3-4 m) circle, and has good acceleration. It also has good traction because the rear wheel is closer to the rider. It has less flex and is the lightest of the three. This model is an excellent hill climber, not only because of the weight - it is very easy to get gears in the low 20s because of the small rear wheel. A small problem is that using a long-arm derailleur will leave about 2 inches (50 mm) of ground clearance if you use a 20-inch (510-mm) tubular. This means no stump-jumping or even twig-jumping!

The major problem is high-speed jumpiness. At 20 mph (9 m/s), I could pedal no-hands; at 25 mph (11 m/s), there was some jerky movement; and the maximum speed at which I felt safe was 33 mph (15 m/s). At or beyond that speed, it became very twitchy, and bumps could lead to uncontrollable problems (crashes and boo-boos). Reduction of the steering proved no help. I went as far as a 9-to-1 ratio, and all that did was to make it more of an effort to avoid road hazards, and the trike continued to be sensitive to bumps and any change in the front-wheel angle.

The best recommendation I can make for the short-wheelbase trike is to use it for commuting or joy riding. Long-distance riding becomes a pain because more road shock is transmitted to the rider.

CRASHES AND SAFETY: Having ridden a 52-inch-(1.3-m-)wheelbase and a 38-inch- (1-m-)wheelbase trike in the snow, I can tell some of the actions that happen in an accident.

While practicing doughnuts in the snow (tight-turning at speed), I found that in a "rollover" you don't actually roll over, but slide on your side. The best reinforcement would be a strong roll-bar around the sides, since this is the point of impact.

The other interesting thing is that with the longer-wheelbase trike, the rear wheel slides first in a turn, while the short wheelbase has all three wheels slide together. This would translate that in a swing to avoid an accident, the rear wheel of the longer wheelbase would swing around and back toward the collision, while the shorter wheelbase would slide sideways or tip over towards the collision.

The mid-range-wheelbase trike (45 inches, 1.1 m) would be made by using a 24-inch (610-mm) rear wheel. The **Windcheetah** has this design; it won the commuter vehicle competition at the Human-Powered Speed Championships in Indianapolis in September 1984. I saw it follow the corner of a sidewalk, and it was totally stable at speeds over 40-45 mph (18-20 m/s).

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FORK ANGLE

by Mike Eliasohn

In designing and building a recumbent bicycle (or a regular one, for that matter), one consideration is what fork angle and offset to use for good handling.

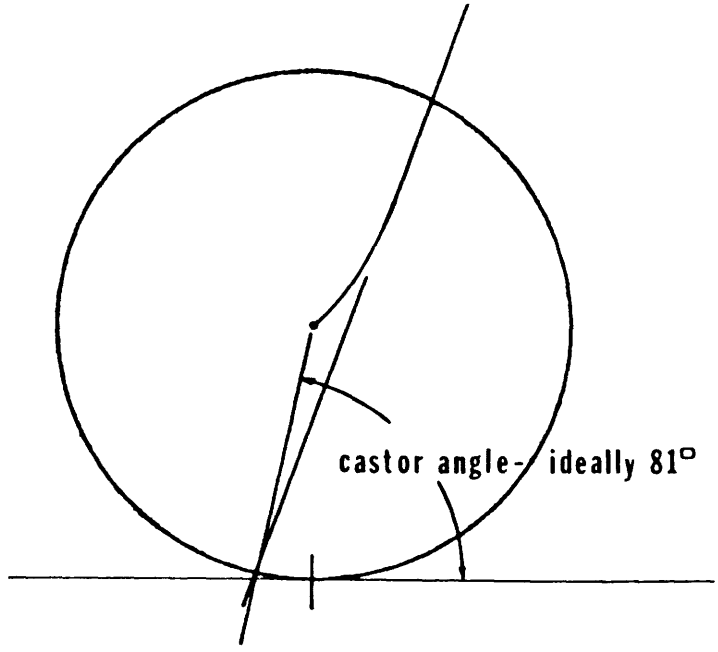
Here is a simple formula that works for Terry Hreno of Mooresville, Indiana, builder of the successful streamlined **Moby** bicycles, some of which have exceeded 50 mph in the HPV speed championships at Indianapolis. He says it works regardless of the head-tube angle and fork rake:

1) Set head-tube angle (on paper, of course).

2) Draw line at that angle to the ground. From where that line intersects the ground, draw a line to the wheel center. The angle between that second line and the ground (see drawing), called the CASTOR ANGLE, should be 81 degrees or close to it for best handling.

3) If the angle isn't 81 degrees, move the wheel center forward or backward (or change the head angle) so the castor angle becomes 81 degrees.

Hreno credits frame builder Georgina Terry of Penfield, New York, for stressing the importance of the castor angle.



Essays by Dave Agler

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COVERING SPOKED WHEELS

Covering spoked wheels is the second most important method of drag reduction in an HPV. With the Olympics and the famous disk wheels, it is easy to see the benefit even if there is a weight penalty. At the IHPVA Championships, we saw non-faired and partially-faired vehicle using spoke covers. In the near future, we may see covered rear wheels on recumbents and bicycles in everyday use.

Fortunately for us non-U.S. Cycling Federation-members, there are simple and inexpensive methods that will give the same results as a $400 disk wheel.

The easiest method is by the use of drum brakes. Drum brakes make it easy to attach the cover directly to the rim and cut off any excess. You will lose some of the convenience of quick-release, and gain some added weight with drum brakes, but it will give you the easiet time of covering spokes.

METHOD FOR COVERING DRUM-BRAKE WHEELS: The lightest and easiest material to get would be heat-shrink Mylar. [Used for model-airplane coverings, it's available at hobby stores. - M.R.E.] This is the same material as the storm-window plastic, and will shrink using a blow-dryer. Heat-shrink Dacron [available from home-built-aircraft suppliers] is only grams heavier, will not tear, and will give the same result. It is just a matter of cutting a hole for the hub axle in the material, and then laying the covering on the wheel. Cut out the pattern using the rim as a guide. Then use contact cement on the braking surface of the rim. Place the cover into position, and shrink it up tight. Cut a circular hole at the valve and cover.

METHOD FOR COVERING RIM-BRAKE WHEELS: When covering wheels using rim brakes, it is difficult to mate the cover to the rim and to attach it below the braking surface. Ideally, the cover should be even with the rim for good aerodynamics. This method allows easy accessibility to the valve, and a fairly smooth surface with good aerodynamic qualities. You will need enough fairly stiff cardboard or plastic for the cover. You will also need Styrofoam, cut into blocks that are the width of the rim, and a half-inch to 3/4-inch (12-18 mm) thick. Finally, you will need some two-sided tape such as carpet tape.

As with the other method, take your material and cut a hole in the center for the hub axle. Place the cover on the wheel, and tape or hold in place. Flip the wheel over and mark the cover where it meets the inside edge of the rim. Cut the disk about 1/8 inch (3 mm) larger than the marks (i.e. about 1/4-inch (6 mm) larger in diameter). Next make a slit from the edge to the center-hole of the cover. This will allow the cover to form a cone and to follow the spoke pattern. Take the foam blocks and wrap them with two-sided tape. Place them on the inside edge of the rim. Next place your cover on the wheel with the slit at the valve hole. Start at the valve hole and work around the wheel until you have an overlap at the valve hole. Tape the overlap and you are done.

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[EDITORIAL POSTSCRIPT: In addition to the materials mentioned above, wheel covers can be made out of polystyrene (on which signs are silk-screened); and from the plastic "card" such as that used for printing wallet-size calendars. Check with a printer or printing-supply store. Thin aluminum offset-printing plates might also work; these are available from printers. The print is on one side only, so used plates might work.

Some bicycle shops may have in stock the 20-inch wheel disks that used to be manufactured for BMX racing. Harness-racing sulkies use wheel disks that are apparently quite heavy, but which might work on an HPV. I think standard wheel-size for racing sulkies is 26 inches.

Brummer Engineering (see source directory) sells fiberglass disks for 16x1-3/8 front, 700 C front and rear, and 27-inch wheels at $75 per wheel. - M.R.E.]

HPV MATERIAL SELECTION: Is the Best Material the Lightest, Strongest, and Most Expensive?

by Brian J. Bartter

DESIGN CONSIDERATIONS

Of paramount importance in HPV building is experimentation, which involves more than good drawings or extensive mathematical equations to prove the optimum design. "Feel" in an HPV design is just as, or more, important than what seems best from a mathematical or structural standpoint. A good example would be a direct-steering mechanism on an HPV that has no steering reduction. It is simple, easy to construct, and relatively lightweight because of few moving parts. The "feel" characteristic is another matter, however, small bumps at high speed causing the machine to waver unpredictably, or shimmy.

How does this relate to the materials used? At the lower extreme, an HPV built of used bicycle frames and muffler tubing can be easily transformed by the addition of some braze-ons to accept a steering damper or reduction linkage. At the upper extreme, making changes to an aluminum or carbon-graphite frame would be much more difficult, much less reversible, and would be more likely to threaten the strength of existing structural members.

EASE OF CONSTRUCTION

When the property of strength versus weight becomes more desirable, the difficulty of using these construction materials becomes greater. Used bicycle-frame tubing and muffler tubing can be successfully brazed with a hand-held torch. To derive the benefits of chrome-moly, an oxy-acetylene torch should be used, and with aluminum, a MIG or TIG welder. As the strength-to-weight characteristics of the materials become more desirable, the tooling and skill required to work with them becomes more complex.

INTRODUCTION: The following article and drawings are from the book Lets Go Karting, written by Spencer Murray, and published in 1959. It is being reprinted with the permission of Petersen Publishing Company, Los Angeles, California.

Karts, sometimes known as Go Karts (one manufacturer's brand name) are small, four-wheel, single-seat vehicles, usually with one- or two-cylinder engines, usually without bodies and suspensions, built primarily for racing. The basics of good handling that applied to karts in 1959 apply today to human-powered tricycles with two wheels in front for steering.

Portions of the original article that were without pertinence to HPVs have been omitted.

* * * * *

Steering is a king-size headache for the karting enthusiast. It has been pointed out many times that the inside tires on a curve must travel a shorter distance than the one on the outside. Therefore, the inner wheel must scribe a shorter-radius circle than the outer one. This holds true for all automobiles, trucks and so forth. This is accomplished through proper design of the steering arms.

Early kart builders didn't consider this fact too carefully, and had their wheels turning through the same number of degrees. Obviously, one wheel had to scuff sideways for the kart to negotiate a bend. A scuffing wheel has lost its traction; so in effect, a kart without proper steering geometry relies on only one of its front wheels to hold it while rounding a bend.

The more tire contact we have, the better the road-holding ability. Naturally, then, both front tires should contact the surface without slipping. The Ackerman steering system permits the inner wheel to steer more sharply than the outer one. The principle is that a straight-line drawn through the tie-rod end-bolt centers and the kingpin centers should, if extended rearward, converge at or slightly behind the center of the rear axle. If you have a

FIRST-TIME PERFECTION

The possibility of building a first-time machine that is mechanically sound, stable, and that adequately fulfills an individual's tastes for comfort and control is next to impossible for the home craftsman, or possibly even for an MIT engineering student. If the builder accepts the difficulties involved in building the first machine, the ability to change the machine's design becomes very important for that machine, but lessens as successive machines of the same design are built.

[EDITORIAL NOTE: Your editor tries to teach mechanical-engineering design at MIT, and can state with certainty that no MIT engineering student or instructor, nor anyone else he knows of, could design and build something that is satisfactory first time. As Brian states, experimentation is always the way. - D.G.W.]

PROGRESSIVE UTILIZATION OF MATERIALS

This article describes the tradeoffs involved in choosing materials. An excellent example of correct material selection is the evolution of the **Easy Racer.** This recumbent bicycle started out with a very heavy cut-up Schwinn tandem frame as its initial prototype. Next it evolved into a chrome-moly version and remained so for years under careful testing and design changes. Finally, the 1984 Easy Racer entry at the 10th Annual Human-Powered-Vehicle Championships was one step further in the evolutionary process, taking advantage of the strength and lightweight characteristics of an aluminum frame and Kevlar body.

[WARNING: Aluminum is prone to fail from fatigue. An aluminum Easy Racer frame suddenly snapped in two during a race at Hull in August, 1985. - D.G.W.]

RELATIVE STRENGTH, WEIGHT, COST RELATIONSHIPS

MATERIAL	STRENGTH	WEIGHT	COST
Muffler tubing (2-inch)	55,000 psi	1.343 lbm/ft	$ 1.50/ft
Chrome-moly tubing (2-inch)	90,000 psi	1.0021 lbm/ft	$ 5.69/ft
Aluminum tubing (6061 T6) (2-inch)	45,000 psi	.4225 lbm/ft (.58 w/t)	$ 3.06/ft
Bidirectional woven graphite	1704 lbf/in	10.9 oz/sq yd	$71.60/yd 42" wide
Bidirectional woven Kevlar	(lbf/in): 630 (warp) 650 (fill)	5.0 oz/sq yd	$13.90/yd 38" wide
Fiberglass cloth	250 x 200 lbf/in	6.0 oz/sq yd	$ 3.40/yd 60" wide

ADDENDUM

Kevlar, Fiberglass, and Easy Racer are registered trademarks. The tensile strengths listed for tubing in the above chart are from a booklet Stephen Delaire handed out at the HPV workshop in Chicago. The cost and weight of muffler tubing is from NAPA, a local auto-parts supplier. The rest of the strength, weight, and cost figures are from the Aircraft Spruce and Specialty Company in Fullerton, California.

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TRICYCLE STEERING GEOMETRY

by Spencer Murray
reported by Mike Eliasohn

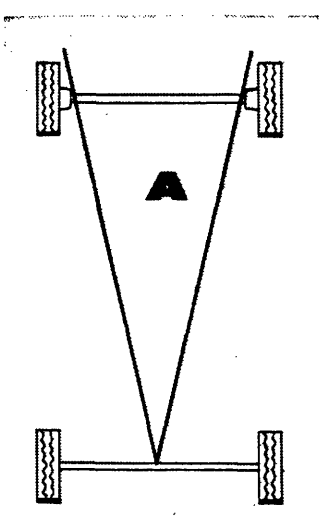
kart, stretch a string from the center of the rear axle to the center of either of the tie-rod end bolts. [See drawing.] If the string passes directly over the kingpin, your front-end geometry is correct. If not, a little modifying is suggested.

The average kart has its steering arms extending straight ahead from the kingpin. Obviously, the steering arms should be canted outward before the string will pass over the three points noted. In most cases, the inner edge of the tire prevents the steering arm from being bent out very far. If so, there's not much you can do unless the steering arms can be repositioned to extend from behind the kingpin. This will foul up your steering arrangement a great deal, so even more modifying is in order.

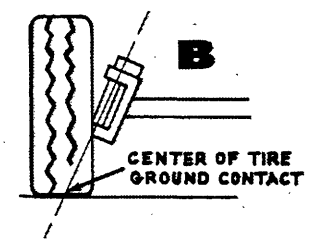
One solution: weld new steering arms behind the kingpins, locating them so the kingpin, tie-rod-end center, and mid-point of the back axle are in a line. Make certain that the steering arms are low enough to permit the one-piece tie rod, which is to be added, to pass below the frame side rails and the floor pan. Cut off one or the other of the original forward-facing steering arms, but leave the second one intact.

Now one of the original two tie rods can be used to connect the end of the steering shaft and the remaining forward steering arm. With the single-piece tie rod extending between the new steering arms, the wheels will steer as they should. When making up the new steering arms, make certain that the arms are the same length as the originals and have corresponding tie-rod bolt holes. If not, your steering ratio will be changed.

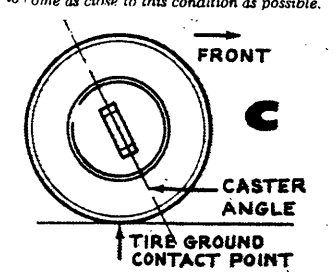
Certain front-end geometry factors should be carefully considered when building a kart. Of course, it isn't necessary to consider making all of th



Tie rod between front wheels must pivot at point of attachment with steering arms in a line which, if extended rearward, would pass through center of kingpin and intersect with center of the rear axle. Length of the steering arms, or whether they are ahead or behind of the front axle, is unimportant as long as the two are of equal length on both sides.



Exaggerated kingpin inclination. While it may not be possible to tilt kingpins so a center line would intersect with the tire's point of ground contact, an attempt should be made to come as close to this condition as possible.



Positive front wheel caster means throwing the weight that the wheel must carry ahead of that wheel's point of contact with the ground. The wheel then "follows" much as does the caster under a piano or a divan.

conditions adjustable, for without suspension they hardly seem necessary. So though the factors are important to a kart's handling ability, once they are built into the chassis design, they can be forgotten to a great degree.

First of all, there's caster -- the name comes from the little wheels used under a piano or divan. If

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TRICYCLE STEERING GEOMETRY

CONTINUED FROM PAGE 5

you've ever observed these wheels when the furniture is being moved, you will have noticed that the wheel tends to "follow." That is to say, the wheel assumes a position directly behind the point about which the wheel rotates. This allows the weight, which is actually being supported by the wheel, to be projected ahead of the wheel. A car's front wheels do the same thing. The weight being carried by the wheel should be projected ahead of the tire's point of contact with the ground. The wheel, as it does on the piano, then "follows" the weight, and as a result, does not tend to veer off course. Steering becomes easier and there is no tendency for the vehicle to wander when it should be travelling in a straight line. While it is possible to engineer a car which handles as it should despite its having negative caster, we recommend that the karter stick to the first description, which is actually that of a positive caster. [See drawing.]

To project the weight a wheel carries ahead of that wheel, it is necessary to install the kingpin at an angle so that an imaginary line drawn through its center would intersect the ground at a point ahead of the wheel's contact point with the ground. Experiments have proven that a kart should have seven degrees of positive castor for best handling. That is, the kingpin should be installed so that its top is tilted seven degrees rearward from vertical.

The matter of camber is still under heated discussion by enthusiasts who disagree whether a kart should have positive camber, negative camber, or no camber at all. Positive camber means that the tops of the front tires are tilted away from each other. Negative camber means just the opposite, that the bottoms of the front tires should be farther apart than the tops. Proponents of positive camber argue that with the tops of the tires canted outwards, the kart will tend to roll in a truer line and not have so much of a tendency to wander. The opposite side disagrees, and says that karts handle equally well with negative camber; moreover, less tire wear is experienced during hard cornering since the outside front wheel, which we learned earlier takes the brunt of the weight, tends to heel over to a more nearly vertical position, thus presenting more of the tire's tread surface to the ground.

Fans in a third group disagree altogether, and say that a kart's front wheels should be exactly vertical. Having experienced all three types of front-end settings on various karts, the author feels that the latter situation, that is, for the front wheels to have no camber whatsoever, gives better handling, less tire wear, and improved tire bite on curves. [Note: Karts use wide, flat, treadless tires, so positive-negative camber arguments may not apply with round-tread bicycle tires. - M.R.E.]

It is obvious that a tire that must turn freely about an axis, as do a car's front wheels when they are steered, must pivot about the point at which the tires contact the road surface. If this were not the case, the tire would have to scuff as it was dragged from pointing in one direction to the other.

It seems foolish that a tire should be allowed to scuff, since the traction would be lost and tire wear would result, but that is exactly what happens to a car whose kingpins are not tilted outward at the bottom. With the kingpins mounted at right angles to the ground, the car's wheelbase is actuallly shortened on the side toward the inside of a curve, and is lengthened on the outside. The natural result of this is poor handling: the car would require some fancy steering in order to negotiate a curve under precise control. The solution is for the tops of the kingpins to be tilted toward each other.

An imaginary line extended down through the kingpins should intersect the ground at the exact point at which the centerline of the tire contacts it. [See drawing.] This is not always possible, what with the small tires and wheels that karts use, but an attempt should be made during construction to provide as much inclination as possible.

Even with the foregoing factors incorporated into a kart's front-end geometry, the wheels will have a natural tendency to roll away from each other though they are being forced to roll in a straight line. This condition, which produces a certain amount of wandering with a resulting steering-wheel fight to keep the kart going straight, can be eliminated by slightly angling the front edges of the tires toward each other. Most karts have adjustment clevises on their tie rods, but if you are building your own machine, be sure to add at least one to your tie rod so it may be either shortened or lengthened as required. Experienced kart drivers agree that toe-in should be set so that front edges of the tires are 1/16th-inch (1.5-mm) closer together than the trailing edges. Prolonged driving may cause a slight change in front-wheel setting, so check the measurement whenever you have the opportunity, and adjust accordingly.

Suspension has been tried on some special karts, with a little success, and a few manufacturers are beginning to offer suspension on their models. Suspension without a doubt will correct many of a kart-chassis' shortcomings, but to set one up properly means adding many parts. The resulting machine would be far heavier than originally intended, and we know that weight is the enemy of power.

Even with a good setup, the chances are that a springless kart with equal power could get around any given corner just as fast. While we are not trying to discourage the development of a successful suspension arrangement, we want to give the reader an insight into problems and perhaps keep a builder from spending valuable karting time on a project which may not give a better-handling machine.

Rather than go into actual springs or torsion bars, some builders of specials have designed their front ends so that the axle is allowed to pivot about a certain point. The rear axle is left solid. The front wheels can thus ride up and over bumps or hollows, eliminating a lot of a kart's inherent vibration.

This works fine for normal karting activities, but for hard race work, the arrangement just doesn't seem too practical. A car, when rounding a curve, looses some of its speed due to the increased rolling resistance of tires scribing an arc. This gives much the same action as applying the brakes, even though the car may be under full throttle. A weight shift occurs, upsetting the car's fore-and-aft weight distribution. A heavier load is placed on the front wheels as [the mass center is] shifted forward from the rear. Bearing this in mind, we must see that there is a side-to-side weight shift when a corner is negotiated. Therefore, with some weight-shifting forward, and more weight-shifting to the outside of the car in a turn, it follows that the outside front wheel must briefly carry far more weight than it does when the car is at rest.

With the centrally-pivoted front-axle setup, this weight shift dumps a good many pounds on the outside forward corner of the frame. As a result, the frame will drop downward because of the sudden additional loading, and the inside rear wheel will lift free from the ground. [In a tricycle, where the solid rear axle supports a single wheel, this frame-twisting activity during cornering may not have as pronounced an effect. Comments from experimenters are invited. - P.L.C.]

Some karts are built with small coil springs on the front spindles. When rounding a curve, the weight pushes down on the outside wheel and the inside rear one comes up. Obviously, if we could spring the rear axle so that the wheels would keep their contact, this lifting situation would be banished. But even if it is, we really haven't gained much, as this kart will round a corner with the frame tilted to the outside no faster than one with a rigid chassis.

A few karts were produced with semi-flexible frames, which, it was claimed, overcame the need for suspension, yet allowed the four wheels to stay planted on the ground over even rough terrain. But once again, the weight-shift situation occurred wherein the inside rear wheel either lifted completely free of the ground, or touched the ground with so little weight that it had practically no traction.

So there you have several points to ponder. The kart was originally intended to be as simple as humanly possible, and it would be wise to keep it that way.

Let's Go Karting,

Petersen Publishing Co
8490 Sunset Blvd
Los Angeles, CA 90069
(213) 657-5100

reported by:

Mike Eliasohn
Apt 307
2708 Lake Shore Dr.
St Joseph, MI 49085

GOODYEAR'S HPA?

The **Phoenix** inflatable HP aircraft is reminiscent of the Goodyear **Inflatobird** of the 1950s, mentioned and illustrated in "A Plane in Your Suitcase", chapter 11 of Michael F. Jerram's Incredible Flying Machines, 1980 (Exeter Books), pp 106-109.

This book also has a chapter about circular wings and their desireable properties. Would it be practicable to set up HPA wings in the same manner as umbrellas? This idea and many others are given in issues of the "Whole Air Magazine", "Hang Gliding Magazine", and "Skyting", which HPA constructors might like to review.

Yours,

Edwin G. Sward
215 Cambridge St
Worcester, MA
01603

TUBE-FRAME RECUMBENT SUGGESTED

Over the past years I've been developing two-wheeled bicycles, I found the seated (supine) position vastly superior - far more comfortable, safer, and faster. The long-wheelbase design makes a far better road vehicle than the short-wheelbase, and I find indirect steering to be only a small improvement for all the difficulties it gives. So the bicycles I built gradually evolved into a design much like the **Easy Racer.**

When I was developing the frame design I came up with some interesting facts. The conventional "ladder"-type recumbent frame has many times more vertical strength than it needs. This is bad at this extreme, for it is also stiffer, and reduces the frame's ability to absorb road shock, making for a less comfortable ride.

On the other hand, side-to-side (lateral) and twisting (torsional) stiffnesses are much less than desired. This makes the bike more difficult to move along, especially up hills, as some power which should go to the back wheel is expended in bending the frame. You can test this for yourself. Sit on a recumbent with the brakes on, and press hard on a pedal. The pedal will move much more than on an upright bike, showing energy wasted in bending the frame.

I worked on paper on ladder-frame designs which had two fatter, chrome-moly tubes placed closer together, trying to find what diameter tubes and how far apart would be best. I was quite surprised when they merged into one tube!

[I therefore concluded:] the tube frame is easier to make, much stiffer against pedalling stresses, has better torsional stiffness for better steering and stability, has more vertical flex for a more comfortable ride, and, in some materials, weighs less.

Because of the rigidity inherant in the design, rather more flexible materials can be used with good results. Because of the high vertical stresses placed on the frame, materials with poor fatigue rates, such as aluminum and glass fibers, do not work well.

I have done some math using the limited mechanical properties of various materials to make this rough guide to how much a tube frame in each would weigh. All are as stiff as I think appropriate, and designed to five gravities vertical loading.

Chrome-moly	7 lbm (about the same as a chrome-moly ladder-frame)
Stainless Steel	6-1/2 lbm
Titanium alloy	5-1/2 lbm
Balsa wood	5 to 5-1/2 lbm if solid 3-1/2 to 4 lbm if hollowed out Balsa wood is so successful due to its low density - other woods would weigh over twice as much. Carbon fibers could be used to reinforce where there is a lot of stress, such as in dropouts, seat mountings, etc.
Kevlar 49	3 to 3-1/2 lbm (more flexible than carbon fiber)
Carbon Fiber	2-1/2 lbm (This and the Kevlar are assumed to be wound into a single, Y-shaped tube.)

I like a really stiff frame, and I have found ways to stiffen the tube frame without adding weight. I built models from Play-Doh and stressed them, then when I had formed a few theories on where strength is needed and where it is not, I built several rideable bicycles out of flexible 2x4 wood to test further, and check out my theories.

This is what I found out:

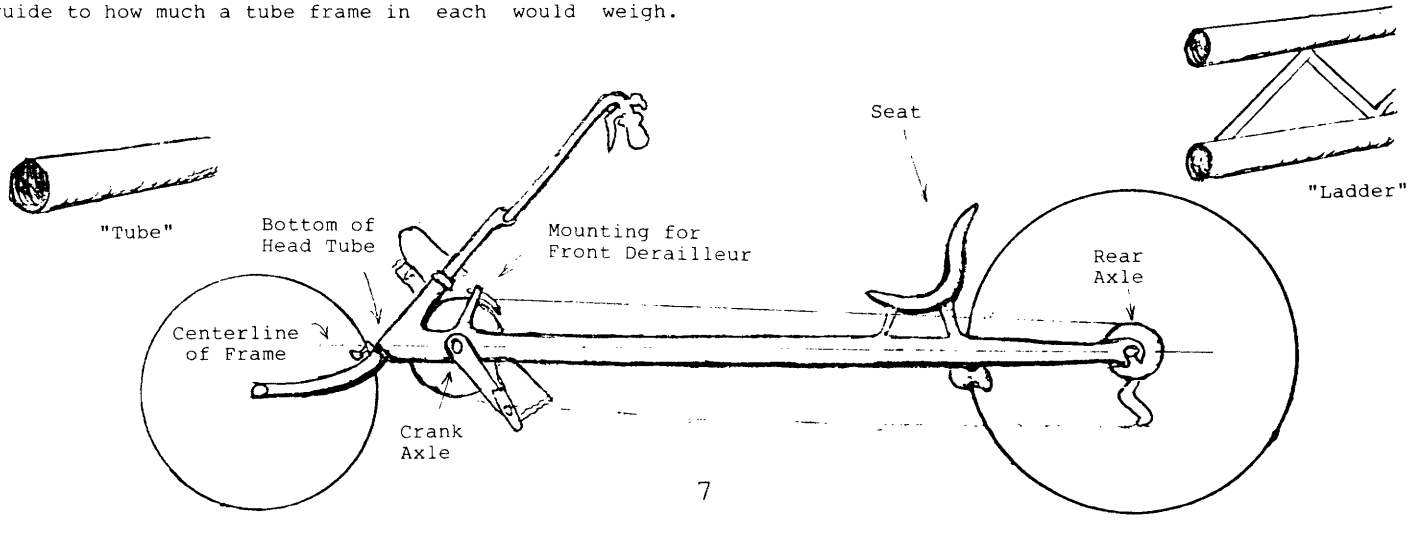
* For best steering, the main tube should go straight to the lower bearing in the headtube.
* Seat should be located as close to the frame as possible, and should preferably be less than 18 inches off the ground.
* Crank should be located right along centerline of main tube.
* Rear axle should be located right along centerline of frame.

In other words, you want the bottom of the head tube, crank axle, seat, and rear axle all lined up as closely as possible to the centerline of a straight frame.

By getting this printed, [I hope to insure that] no one can patent the idea, so we all can use it. If you're building a tube frame and need some help with design, let me know. My parents usually know where I am; their address is listed below.

Charles Brown
c/o Mr & Mrs Brown
22928 Oxford
Dearborn, MI 48124

[EDITORIAL COMMENT: Not all will agree with Charles Brown's assertions. Letters on this and other topics are welcomed. Any material, including letters, submitted for publication may be edited. - D.G.W.]



BUILDING HPVs

by Mike Eliasohn

So you want to build a recumbent bicycle or tricycle. I'm tempted to tell you to buy one instead, but that would make this a very short article.

When I started building my first recumbent bicycle in October, 1978, there was a good reason to do so. No one was manufacturing them. That no longer is true, which leaves only two reasons to build your own recumbent: the ones being produced are too expensive for your wallet, or none of the production models are like what you want.

The first recumbent I built had a 16-inch (406-mm) front, 24-inch (609-mm) rear wheel, 54-inch (1.3-m) whelbase, and above-the-seat handlebars. A friend of mine got inspired after seeing mine, and built his own, with 27-inch (685-mm) wheels front and rear, a 73-inch (1.9-m) wheelbase, and the same type of handlebars.

That inspired someone else to build a recumbent, with a 20-inch (508-mm) wheel in front, 27-inch (685-mm) in the rear, and under-the-seat handlebars. (Recumbent riders tend to be an individual lot - why else would they build and ride them?)

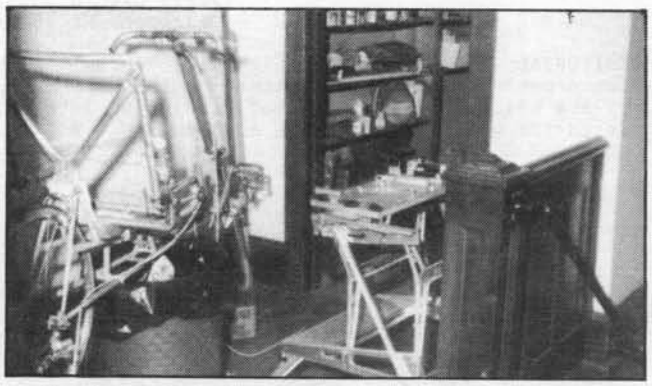
Those choosing to build their own today have one advantage I didn't have in 1978. Provided you are willing to use someone else's design, there are several sources for plans, which are listed in this issue of **HUMAN POWER.** It is an avenue I recommend exploring. You presume (and you hope) that the seller of the plans has worked out all the bugs in the design, which will save you a lot of grief. (One can always hope.)

Let me also present a warning. If you start building a recumbent from scratch, expect to build at least two: the first one to figure out what you did wrong, and the next one to correct the mistakes you made on the first one.

And if you want it perfect, expect to build a third. I have - so far - stopped with my second recumbent, which isn't perfect, but isn't bad enough to tempt me to build another. And I dare say, all the recumbent manufacturers built a few prototypes before arriving at what became their production model.

It isn't necessary to be an engineer or professional welder to build your own HPV. I am a newspaper reporter; my builder-friend is a bus driver. The last home-built recumbent mentioned above was built by a farmer.

Nor is it necessary to have a fancy workshop. I built two recumbents plus one other bike in the upstairs hallway and closet of the weekly paper where I was then employed. I didn't do the brazing, as I'll explain later. A friend of mine in California built a tricycle, including the brazing, on his upstairs apartment's patio. (No sawing or filing after 9 p.m.)



The author's "workshop", where he built two recumbents and one non-recumbent (located in the upstairs hallway of a weekly newspaper). Everything went in the closet during the day. Note use of wastebasket as assembly stand.

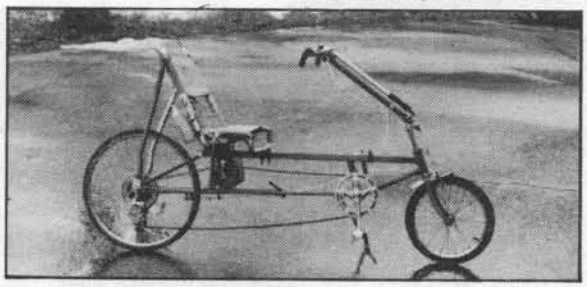
Some tools obviously are necessary. One I highly recommend, especially if you don't have a permanent workshop, and even if you do, is a Black-and-Decker Workmate, or one of its imitators. The Workmate has two moveable surfaces, with a groove down the mating edges, pefect for holding tubing.

I also recommend a heavy-duty drill press. I bought mine on sale for $73. It's bolted to a piece of half-inch plywood, to which a 2x4 is nailed at a 90-degree angle. This platform is then held by the Workmate. Trying to be cheap, I started with a 3/8ths-inch (9.5-mm) electric hand drill mounted in a drill-press stand, and found all it was good for was drilling holes in wood and, with effort, through thin-wall aluminum tubing.

Another item I recommend buying is a Sears Craftsman Angle Finder, which has a magnetic base, and measures angles for 360 degrees. It's perfect for checking whether surfaces are level as well as such things as fork/head-tube angles.

Also needed are round and half-round files, coarse and fine; hacksaws, one with a fine and one with a coarse blade; and a tape measure; plus a few items I'm forgetting. A worth**less** investment, I found, was a tubing cutter. Use hacksaws instead.

Author on his first recumbent.



The first recumbent.

Speaking of worthless purchases, expect to make several in building a recumbent from scratch. Now that my present recumbent is done - unless I make some changes - I have a large supply of such leftover "junk" as steel cables and clamps (for under-the-seat steering that didn't work), furniture webbing, lawn-chair webbing, canvas, steel tubing (new tubing and parts of old frames), two front derailleurs, 24-inch rear wheel, two shifters, and some extra brakes. In other words, be prepared to try things and find they don't work.

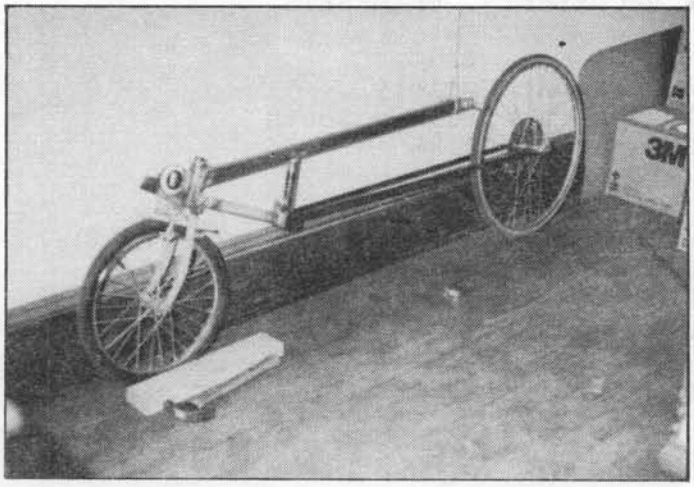
I built my two recumbents plus one non-recumbent while living in a town of 2300 people, which had advantages. Until I bought a heavy-duty drill press, I used one at a farm-implement store (until they went out of business), then one at an auto parts store. I didn't have to pay for the use of either. I also was fortunate in knowing someone who had a machine shop in his basement, who was willing to do some work for me.

I had my brazing done by a country welder who usually worked on farm equipment. I held the stuff while he brazed. I was there as long as two hours at a time, and I don't recall that he ever charged me more than $10. In a big city, a welding shop would probably charge you more than that when you walked in the door; and if you told them you needed to be there while they did the welding, they would likely tell you to go elsewhere.

Another recumbent builder I knew did his brazing in an evening adult-enrichment class, which is an alternative if you don't have the equipment or a place to do it.

My bus-driver friend did his brazing at the bus

garage. (All employers should be so cooperative.) Another alternative is to tack-braze everything together using a miniature brazing set, then take it to a welding shop to complete the job.



Second recumbent under construction: at this point, all but the horizontal rear stays were brazed together. To make vertical rear stays the right length, rear of frame was hung from window latch. A Sears Craftsman Angle Finder (with magnetic base) was stuck to the head tube to ensure it was at the proper angle.

The obvious first step in building your HPV is to design it. If possible, look at and ride designs similar to what you want to build. Take measurements. For instance, if the recumbent you examine will accomodate riders up to 6-foot-5 (196 cm) and you are 5-foot-6 (168 cm), shorten the wheelbase. It might be worth the money to buy plans for an HPV similar to what you intend to build, to give you a starting point. As far as I know, the only plans available are for unstreamlined, recumbent bicycles. [NOTE: E T Cycle, listed in Category 2 of the source directory, sells plans for two types of tricycle. - P.L.C.]

If you want to build something exotic, say, a linear-drive tricycle with front-wheel drive and rear steering, chances are that someone has already tried bulding it, or something like it. If you can find out who has tried it before, call or write - chances are they will give some helpful advice. (If the advice includes "Don't try it", don't say you weren't warned if you attempt it anyway, and it doesn't work.)

I advise including an easy means of moving the seat back and forth for adjustment. If you make a scale drawing first, don't assume your measurements are so good that the seat can be located perfectly in relation to the pedals, without a need for adjustment.

On my first recumbent, the seat was to be bolted to two 2x2-inch (51x51-mm) cross-pieces of tubing. From the center holes, the seat could be moved 1 inch (25 mm) forward or backward, which I thought would be enough. I ended up having to bolt 1x2-inch (25x51-mm) boards to the cross-pieces, so that I could move the seat about 2 inches farther back.

My California friend, when he was a college mechanical-engineering student, made full-scale drawings before building a prone recumbent. He thought he had the seat location worked out perfectly. Then the first time he got on the bike, he couldn't ride it. The seat had to be moved several inches forward, so it rested at the middle of the top tube, instead of at the triangulated joint where he had planned for it to be located.

I advise against using odd-size wheels. To keep my recumbents as short as possible, I used a 16x1-3/8-inch (406x35-mm) front wheel and 24x1-1/4-inch (610x32-mm) in the rear. Neither size is commonly stocked by bicycle shops. If you stick to sizes that are, you won't have to worry about getting new tires or replacement rims.

The new tubing I used was chrome-moly, mostly 0.035-inch (0.9-mm) thickness, the lightest normally available. It has been strong enough for me, though I weigh 135 pounds (61 kg), which no doubt reduces stress.

A big concern before I started building my first recumbent was what head angle to use. I ended up using about 70 degrees on my first and second, which seemed to be okay. I have no idea what the trail or the fork offset is. There may be a "perfect" combination of head angle, offset, and trail, but chances are, whatever you use will work adequately, if not perfectly.

Prior to designing my first recumbent, I measured myself. (Married people, or those with steady "opposites" have an advantage in this process.) I then made a scale cutout of each portion of my body (head, torso, upper and lower leg, feet, upper and lower arm, and hands), with an overlap at each end. The parts were then fastened with straight pins at the pivot points. Then by drawing potential designs to the same scale (1-to-8 was the one I used), I could trace the outline of my body in various positions on the bike.

My system wasn't perfect, in part, I think, because my measurements were off. The wheelbase of my first recumbent was too short, with the result that my posterior was too close to the rear wheel, which made going over bumps painful. (As mentioned previously, the seat had to be moved back from its originally-intended location.) My knees came too close to my chest, and it wasn't practical to lean the seat back farther because it would have put even more weight on the rear wheel. The result was that the bike was uncomfortable to ride.

Knowing what I needed to correct, I built my second HPV with only a sketch as a guideline. I made the wheelbase six inches longer (60 inches, 1.5 m), and used a square top-tube so the seat could be easily moved back and forth for adjustment.

Since there is a good chance, as my examples indicate, that your first effort might be far from perfect, you might consider building it from cheap materials, such as exhaust pipe or electrical metallic tubing (EMT), and Murray or Huffy frames ("el tanko"). Once you figure out your mistakes, then you can build a good recumbent of chrome-moly and pieces from better-quality frames. (But don't cut-up one made out of Reynolds 531.)

Once your frame is together, I recommend spraying it with a coat of primer, then installing the components and riding it. You might find you need to make some changes which require brazing, relocating a brake mount, or adding a bracket. It makes sense to do that before the final cleanup of the frame, and the good paint job.

As a final precautionary note, even if your recumbent isn't perfect, it will probably work. My second recumbent is not quite perfect. At about 35 lbm (16 kg), it's too heavy. The diagonal tube running from the single top tube to the right bottom tube is in the way of the chain. I had to install a bracket with a derailleur pulley to lift the chain above the obstruction. Some of the frame joints on my bike aren't perfect (lots of brass holds things together, and Bondo can hide the sins before painting), and maybe the alignment isn't perfect, but it's rideable.

It does work, and so far I have avoided the temptation to build a hoped-to-be-perfect Number 3.

Mike Eliasohn
Apt 307
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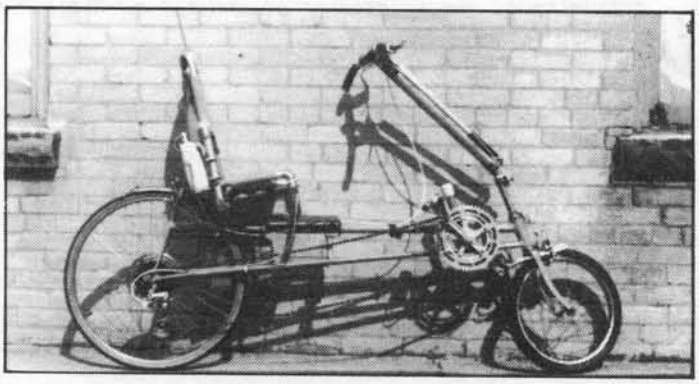
St Joseph MI 49085



The second recumbent.

HUMAN-POWERED VEHICLES - SOURCE DIRECTORY
Vehicles, Plans, Components, Materials, and Data

CATEGORY 1: READY-TO-RIDE RECUMBENTS, FRAMESETS

"LWB" here denotes "Long-WheelBase", "SWB" means "Short WheelBase". An "LWB recumbent bicycle"has the bottom bracket between the wheels, an "SWB bicycle" has the bottom bracket in front of the front wheel (both unless otherwise noted).

2-Wheel Transit Authority
401 Main St
Huntington Beach CA 92648
(714) 960-7621

*Note 2

Access Designs Inc
935 NW 19th Ave
Portland OR
(503) 223-2493

catalog: yes ; price: free

hand-cycle attachment for standard wheelchair, list $750.

Aerocoupe Cyclecars
P O Box 1008
Sierra Madre CA 91024
(213) 681-1116

catalog: yes ; price: free

recumbent tricycle, complete or frameset, fairing kits with polycarbonate canopy, wheel covers

*10% discount to IHPVA members

Al Mowrer
1500 W 92nd Ave
377
Denver CO 80221
(303) 426-6660

recumbent bicycle framesets, seats, and backs

*send SASE for details

Alan Carpenter Enterprises
P O Box 491
Lyons CO 80540
(303) 823-6432

catalog: no

Aerorad recumbent tricycle; Ecodyne and Cyclodyne trikes no longer in production; custom mountain bikes; dirt-seal components for standard bikes

Alternative Bikestyles
Ed Roeters
P O Box 1344
Bonita CA 92002
(619) 421-5118

catalog: yes ; price: free

LWB bicycles, framesets

Angle Lake Cyclery
208210 Pacific Hwy South
Seattle WA 98188
(206) 878-7457

*Note 2

Brummer Engineering
Tim Brummer
1304 W Willow
Lompoc CA 93436
(805) 736-0449

catalog: yes ; price: $1.00

Lightning SWB bicycle (full body available)

Burrows Engineering
Green Lane West
Rackheath
Norwich
Norfolk NR7 OPX
Great Britain
(0603) 721-357

Windcheetah recumbent tricycle kit (raw castings and special items, machine work required to finish), body shell available

CBS Cycle Frames Ltd
1820 Trafalgar St
Vancouver
BC V6K 3S2
Canada

custom recumbent bicycles, tricycles

CO-13
Raine Muller
Colmarestrasse 13
Basel
Switzerland

load-carrying tricycles; SWB recumbent tricycle may be available in 1986

Collins Cycle Shop
60 E 11th Ave
Eugene OR 97401
(503) 342-4878

*Note 2

Counterpoint Conveyance Ltd
James Weaver, president
P O Box 33475
Seattle WA 98133
(206) 365-6837

catalog: yes ; price: free

tandem bicycle: front rider semi-recumbent, rear rider upright position

NOTE 1: Arm-powered vehicles; source not verified as to whether still in business.

NOTE 2: Alex Moulton bicycle dealers (regular riding position, front and rear suspension, 17x1-1/4-inch wheels, take-apart frame. Dealers are a source for 17x1-1/4-inch wheels, tires. Not necessarily verified as still carrying Moultons.

DeFelice Recumbent Bicycle Corp
26 N Depot St
P O Box 321
New Palestine IN 46163
(317) 861-6145
catalog: yes ; price: free

LWB recumbent bicycle, arms-powered-only recumbent

*sold only through dealers

Dr Bike House of Recumbents
Little Red Bike Shop
7 Camp Ave
Merrick NY 11566
(516) 868-0100
catalog: yes ; price: $3.00

dealer: Hypercycle, Infinity, Landspeeder, Lightning, Roulandt, Tour Easy recumbents; frame kits, plans, partial and full fairings, Powercam, recumbent trainers, narrow wheels and tires

Easy Racers Inc
P O Box 255
Freedom CA 95019
(408) 722-9797
catalog: yes ; price: $1.00

Tour Easy and Easy Racer LWB bicycles

Ellefson Engineering Inc
1545 Bluff Creek Dr
Chaska MN 55318
Rowcycle rowed tricycle

Fatebe Fahrradtechnik
Bachman & Co
Rosenstrasse 9
CH-8400 Winterthur
Switzerland
catalog: yes ; price: free

LWB bicycle

*brochure in German

Foster's Sports Center
305 Bank St
Ottawa, Ontario
Canada
(613) 236-9611
SWB bicycle

also at (613) 235-4195

Future Bike
Glen Brown
Zzip Designs
458 Thayer Rd
Santa Cruz CA 95060
(408) 425-5147
Tour Easy, Alex Moulton dealer (besides the Zzipper fairings)

HUDYN Vehicles
P O Box 22444
Indianapolis IN 46222
(317) 293-0397
catalog: yes ; price: free

recumbent tricycles, bicycles, fairings, seats

*also (317) 923-6267

Hyper-Cycle
AVA Industries Inc (nat.dist.)
6001 Bandini Blvd
Commerce CA 90040
(213) 725-6498
catalog: no

SWB bicycle

Industrial Design Research
Mark Murphy
723 Laguna Canyon Rd
Laguna Beach CA 92651
(714) 497-7162
catalog: yes ; price: $1.00

recumbent tricycle, frameset

Infinity Bicycles
P O Box 326
292 W Harrison St
Mooresville IN 46158
(317) 831-8798
catalog: yes ; price: $1.00

LWB bicycle

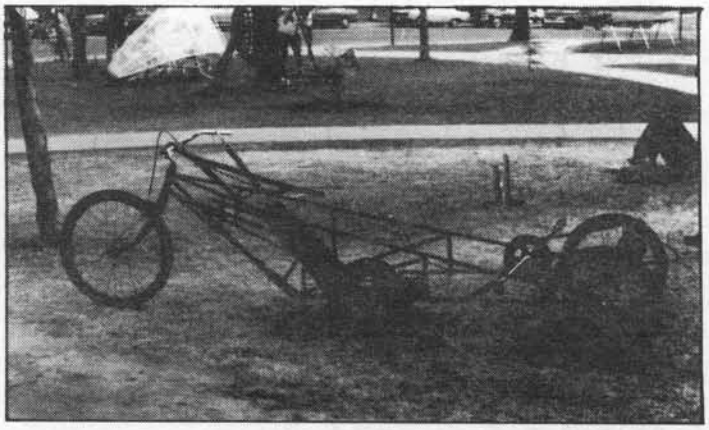
*5% discount to IHPVA members

J G Leibold
113 Jalisco Pl
Davis CA 95616
(916) 758-8055
catalog: yes ; price: free

full-bodied LWB bicycle, tricycle

Kann Manufacturing Corp
414 N Third St
P O Box D
Guttenberg IA 52052
(319) 252-2035
aluminum-frame LWB

*still in prototype stage as of August 1985



Writes Ed Sea, "This is a rear-steer tricycle. I have had a difficult time getting the steering to be stable at speeds over 25 mph (11 m/s). I have decided to incorporate front steering on the vehicle I'm now building." The open-bottomed clear fairing in the background, built by Ed and two friends, "grabbed a lot of air."

Landspeeder Inc
David Wiener - Design
570 Riverside Ave
Westport CN 06880
(203) 226-7474
recumbent tricycles, fairings

*may no longer be in production

Leitra Aps
Box 64
OK-2750 Ballerup
Denmark
catalog: yes ; price: free

fully-enclosed recumbent tricycle for commuting, 50-litre luggage capacity

Mitchell Engineering
800 Pacific Ave
Petaluma CA 94942

Sofa Cycle SWB

*may no longer be in business

MonoRacer
Clarence Moore
311 Bayside
LaPorte TX 77571
catalog: yes ; price: $1 00

SWB bicycle, framesets

New England Handcycles Inc
228 Winchester St
Brookline MA 02146
(617) 277-3035
tricycle

*Note 1

Northern Lights
Jon Lebsack
500 E Magnolia
Ft Collins CO 80524
Econogator SWB bicycles

NYAB
5832 E Camden
Tucson AZ 85712
recumbent bicycles, framesets

Palmer Handcycles
Palmer Industries
P O Box 707
Endicott NY 13760
(800) 847-1304
tricycle

*Note 1

Personalized Transportation
1016 E Chauncey Lane
Tucson AZ 85719
special recumbent bicycles, tricycles, wheelchairs

Portland Bicycle Exchange Ltd
396 Fore St
Portland ME 04101
(207) 772-4137
*Note 2

R D Shomo
SFB Manufacturing Company
Box 2128
Dearborn MI 48123
(313) 291-4694
Para-Bike bicycle with outrigger wheels
Note 1

R+R Sales
966 N Elm St
Orange CA 92667
(714) 997-1952
Duo Cycle side-by-side tricycle

RANS
1104 E Highway 40 Bypass
Hays KS 67601
(913) 625-6346
catalog: yes ; price $

LWB bicycles (two models), framesets (finished and unfinished)

Renaissance HPV
Rob Henry
P O Box 524
Chapel Hill NC 27514
catalog: yes ; price $

Medium SWB solo and tandem, framesets

Rotator Bicycles
Stephen Delaire
5069 Oakpark Way
Santa Rosa CA 95405
(707) 539-4203
catalog: yes ; price $ 1.00

LWB fully-faired bicycle

Ryan Recumbents
Richard Ryan
58 Lyle St
Malden MA 02148
(617) 324-1921
catalog: yes ; price $ 1.00

LWB bicycle

Stan's Bicycles
3727 W Hemlock
Oxnard CA 93033
catalog: no

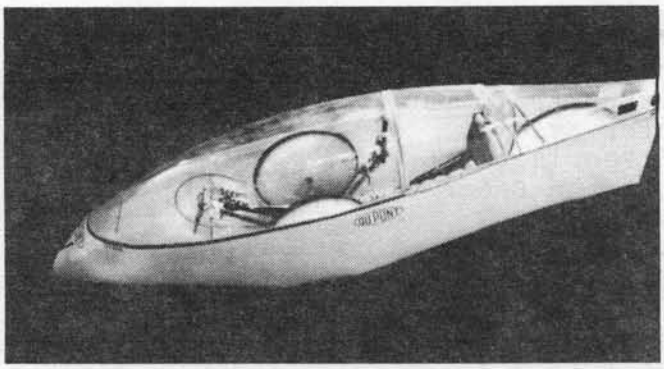
Custom recumbents, Tour Easy dealer

Sun Cycle Inc
133 Triangle Industrial Park
Tavares FL 32778
(904) 343-7500
arm-cranked attachment for regular wheelchairs

*Note 1

Syracuse Bicycle Co
632-A Sedgewick Dr
Syracuse NY 13203

*Note 2



Wolfgang Gronen's **Vector** displayed at exhibition.

Tandem Recumbent Cycle
Alan Matthes
5591 W Dunbar Rd
Monroe MI 48161
(313) 242-2432
catalog: yes

tandem recumbent tricycle, solo recumbent tricycle, tandem recumbent trike with rear pedals only for front rider without use of legs

$50 *discount for IHPVA members, send SASE for info

Tekton Corporation
Allan Koenig, pres
Route 116
Conway MA 01341
(413) 369-4367

Roulandt recumbent, $450 recommended retail

The Bicycle Center
1420 Mission St
Santa Cruz CA 95060
(408) 423-6324
*Note 2

The Bicycle Shop
Jack Kane
909 N Marine Blvd
Jacksonville NC 28540
(919) 455-1011
catalog: no

prone HPV (21 pounds)

The Unicycle Factory
Tom Miller
2711 N Apperson
Kokomo IN 46901
(317) 452-2692
catalog: yes ; price $

production and custom unicycles, parts

*phone first, after 5 pm

Thebis International Ltd
Robert Perkins
41 Roxborough St East
Toronto Ontario
M4W 1V5
Canada
(416) 967-4488

recumbent tricycle

Trail Mate Inc
6050 Palmer Blvd
Sarasota FL 33582
(800) 237-3982

funcycle front-wheel-drive tricycle, sold by dealers, or can be mail-ordered from factory

*(Florida only call (800) 282-9682)

Ultimate Vehicles
Mark Bannan
2159 Jarabec
Saginaw MI 48603
(517) 781-3252
catalog: yes ; price $

aluminum-frame recumbent tricycle, 20-inch-wheel aluminum bicycles with regular riding position

Velo Sport Moscow Bicycles
113 E Third
Moscow ID 83843
(208) 882-3537
*Note 2

Viking Sports Center
261 W Main St
Stoughton WI 53589

tricycles

*Note 1

CATEGORY 2: **PLANS**

Al Mowrer
1500 W 92nd Ave
377
Denver CO 80221
(303) 426-6660
catalog: no

plans for building recumbent bicycle from readily-available materials (old frames, etc.), $25/set.

Alternative Bikestyles
Ed Roeters
P O Box 1344
Bonita CA 92002
(619) 421-5118
catalog: yes ; price: free

SWB recumbent plans

E T Cycle
539 17th Ave SW
Calgary, Alberta
T2S 0A9
Canada
catalog: yes ; price: $ 1.00

no-weld recumbent LWB bicycle (adult and child-size), side-by-side tandem recumbent (two models): plans, $15 each

Easy Racers Inc
P O Box 255
Freedom CA 95019
(408) 722-9797
catalog: yes ; price $ 1.00

plans $25

Lee Special Interest Autos
Sport Trikes Division
P O Box 157
Orderville UT 84758
(801) 648-2501
tricycle plans

*may no longer be in business - write or call first!

Clarence Moore
311 Bayside
LaPorte TX 77571
catalog: yes ; price: $ 1.00

SWB bicycle - info $1 MonoRacer

Northern Lites
Jon Lebsack
500 E Magnolia
Ft Collins CO 80524
Econogator plans, $25

Robert Cotter
RFD 1, Box 84-A
Waldoboro ME 04572
plans $11

*may be out of business - write first!

Sportran Co
P O Box 7707-R
Endicott NY 13760
Bikecar, four-wheel recumbent, with or without electric power - plans, $7.95

Tom Traylor
22407 Warmside Ave
Torrance CA 90505
front-wheel-drive recumbent-bicycle plans, $10

HUMAN POWER PUBLICATIONS AND REPRINTS

ITEM	TITLE	AUTH/PUB	PRICE
M1H	Bicycle Science (hard cover)	MIT Press	$ 20.00
M2S	Bicycle Science (soft cover)	MIT Press	9.95
M2	Bicycles and Tricycles (soft cover)	MIT Press	9.95
B1	Human-powered Vehicle Construction Techniques	Blair	20.00
B2	Evolution of a Human Powered Vehicle Project	Blair	15.00
S1	Proceedings of the 1st HP Scientific Symposium	IHPVA	23.00
S2	Proceedings of the 2nd HP Scientific Symposium	IHPVA	23.00
H01 thru H12	-HUMAN POWER- the technical journal of the IHPVA	IHPVA	2.50 ea
R01	New Unified Performance Comparisons for Streamlined HPVs	D. Malewicki	3.50
R02	The Aerodynamics of HP Land Vehicles	Scientific Amer. Vol. 249, no 9	2.00
R03	Bike Tech HPV section	Rodale Press Bike Tech V 2, #1	2.25
N01 thru N12	-HPV NEWS-, Vol. 2 the newsletter of the IHPVA	IHPVA	1.50 ea

CATEGORY 3: **COMPONENTS**

Aero Sports Company
Chester Kyle
8216 Pennington Dr
Huntington Beach CA 92646
(714) 536-1302
products currently on drawing board: low-drag spoked (Olympic-type) wheels, high-performance pedals, hubs, cranks, and lightweight solid Kevlar wheels

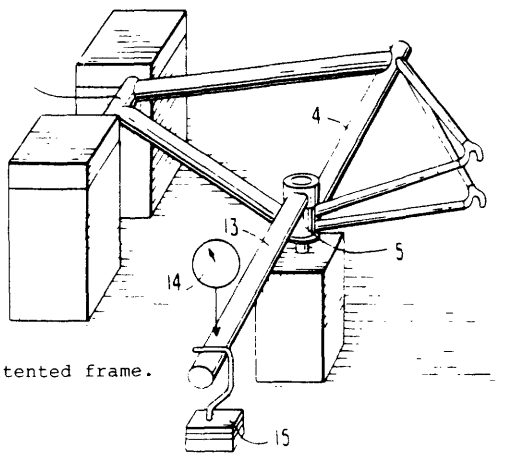
Alternative Bikestyles
Ed Roeters
P O Box 1344
Bonita CA 92002
(619) 421-5118
catalog: yes ; price: $

dual-front-wheel tricycle hubs (idler wheels from adult trikes)

Astro Flight Inc
13311 Beach Ave
Marina del Rey CA 90292
electric motors, batteries, battery chargers for electric vehicles

Berkeley Wheelworks
1500 Park Ave
C-104
Emeryville CA 94608
(415) 654-5399
ultralight small wheels, rims, custom spokes, hubs, fittings, general custom framework

*call first



Gary Klein's patented frame.

Bike Nashbar
215 Main St
New Middleton OH 44442*
(216) 542-3671
catalog: yes

usual mail-order stuff, Tour Easy, zip is 44442-0292; sponsors Cleveland Chapter IHPVA

Bill Matthews Co
23042 Alcalde Dr
Unit D
Laguna Hills CA 92653
(714) 855-1967
tricycle conversion axles, usually one- or three-speed - one-wheel drive

*wholesale only

Bird Road Cycle World
9541 SW 40th St
Miami Fl
(305) 221-2123
willing to order odd parts, will build odd-size custom wheels

Brummer Engineering
Tim Brummer
1304 W Willow
Lompoc CA 93436
(805) 736-0449
wheel covers, recumbent seat kits, chain idlers, 16x1-3/8 alloy rims, wheels, tires

Category 1 Cyclegoods
Westford Rd
Tyngsboro MA 01879
(617) 649-7599
catalog: no

20- and 24-inch tubulars and rims, hard-to-find parts

Cycle Goods
2735 Hennepin Ave S
Minneapolis MN 55408
(612) 872-7600
catalog: yes ; price: $ 1.00

in addition to usual mail-order stuff, items such as 16x1-3/8 wheels, tires, 16-inch forks, Sturmey-Archer parts

*Handbook of Cycl-ology $1

Cycle Imports
P O Box 287
Cornish ME 04020
frame-building supplies

Easy Racers Inc
P O Box 255
Freedom CA 95019
(408) 722-9797
catalog: yes ; price: $ 1.00

20-inch tubular tires and rims, handlebars, seats, Zzipper and Super Zzipper fairings

George Longstaff
80 Newchapel Rd
Rookery, Kidsgrove
Stoke-on-Trent
Staffs. ST7 4RT
Great Britain
double-drive trike axles, custom work related to tricycles

Howell Cyclebinding System Inc
P O Box 386
Winooski VT 05404
catalog: no

integrated shoe-pedal binding system, available March 1, 1986

Industrial Design Research
Mark Murphy
723 Laguna Canyon Rd
Laguna Beach CA 92651
(714) 497-7162
catalog: yes ; price: $ 1.00

taper-axle hubs for dual-front-wheel tricycles

Infinity Bicycles
Ace Tool and Engineering
P O Box 326
292 W Harrison St
Mooresville IN 46158
(317) 831-8798
catalog: yes ; price: $ 1.00

recumbent seats, seat mesh, 20-inch forks and components for cable steering, 20x1-3/8 alloy wheels and tires,etc.

*5% discount to IHPVA members

International Pro Bike Shop
859 E Franklin
Centerville OH 45459
(513) 433-6687
catalog: yes ; price: $ 3.00

hard-to-find items

Ken G Rogers
71 Berkeley Ave
Cransford
Hounslow
Middlesex TW4 6LF
Great Britain
tricycle conversion axles (left-wheel drive) for regular bikes, could be used for recumbents (two wheels in rear); dual-wheel drive may be available

Lee and Katz
Chicago IL
20-inch tubulars

*wholesale only

Lickton's Components
310 Lake St
Oak Park IL 60302
(312) 383-2130
catalog: yes ; price: $ 1.00

usual mail-order stuff, 20-inch tubular tires and wheels

Mel Pinto Imports Inc
P O Box 2198
Falls Church VA 22042
reportedly a source for odd-size tires and wheels

*wholesale only

Portable Bicycle Design
Gary Crooks
1103 Tyler St
Glendale CA 91205
(818) 244-1471
components for folding, portable, and take-apart bicycles

*good source of information for these types of bikes

Production Research Corp
10217 Southard Dr
Belteville MD 20705
(301) 937-9633

5/8-inch axle sealed-bearing wheelchair hubs usable for dual-front-wheel tricycles

*wholesale only

Proteus Design
9217 Baltimore Blvd
College Park MD 20740
catalog: yes ; price: $ 2.00

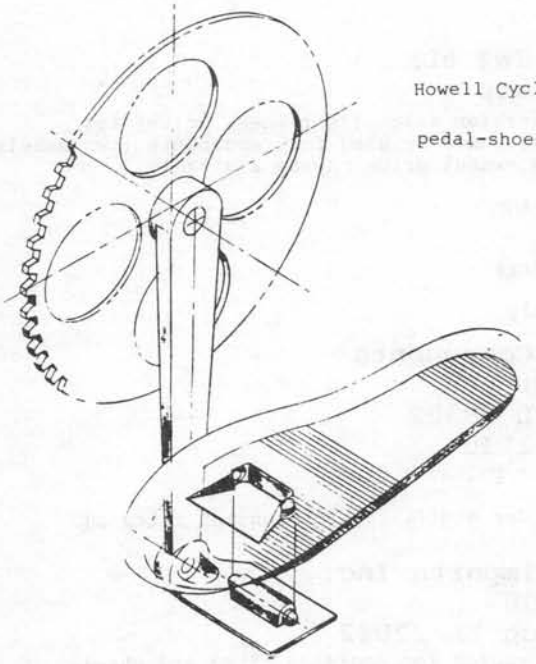
24x1-1/4 alloy rims, tires, frame-building supplies, frame-building book

Ralph's Bicycles
8039 E Imperial Hwy
Downey CA 90242
(213) 862-5142

18- and 20-inch tires and wheels

Ret Bar Cycle
Rt 2 Box 766
Sun City AZ 85373
(602) 975-2112
catalog: yes

tricycle conversion kits (two wheels in rear), differentials



Howell Cyclebinding

pedal-shoe system.

Sachs Motor Corp Ltd
9615 Cote de Liesse Rd
Dorval, Quebec H9P 1A3
Canada
(514) 636-9180

Sachs-Huret Inc
14 Connor Lane
Deer Park NY 11729*
(516) 586-5303

hub brakes (work with derailleur)

*zip is 11729-7287; wholesale distributor

Specialized Bicycle Components
15130 Concord Circle
Morgen Hill CA 95037
catalog: yes ; price: $ 3.00

TA chainwheels up to 66 teeth and larger, lots of other stuff

*wholesale only

Sumner White Touring
40 Perkins
New Haven CN 06513

TA cranksets, 150-185mm crank arms, outer chainwheels 37-70 teeth, inner chainwheels 26-58 teeth

Swallow Frames and Cycles
2 Stannets
Laindon North Trade Center
Essex SS15 6OJ
Great Britain

tricycle conversion axles (left-wheel drive) for regular bikes, could be used for recumbents (two in rear; dual-wheel drive may be available

T I Sturmey-Archer of America Inc
1014 Carolina Dr
West Chicago IL 60185
(800) 323-9194

Sturmey-Archer 3- and 5-speed hubs, hub brakes, eccentric bottom brackets

*wholesale distributor only

The Third Hand
3101 N Old Stage Rd
Mt Shasta CA 96067
(916) 926-2600
catalog: yes ; price: $ 1.00

bicycle tools

The Wheel
Jow Zavora
615 Bemidji Ave
Bemidji MN 56601
(218) 751-5221

will order parts and provide other help for northern Minnesota HPVers

True Wheels
P O Box 75
South Milwaukee WI 53172
(414) 761-2029

narrow 20-inch wheels

Ultralight Bicycle Equipment
Box 363
Gambier OH 43022
(614) 397-4551
catalog: yes

TA cranksets, 150-185mm crank arms, chainwheels 26-68 teeth

*SASE for list

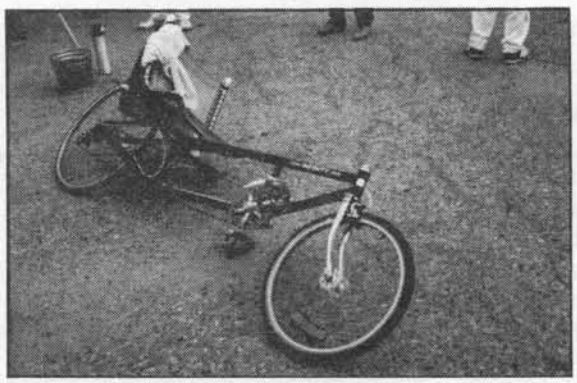


Photo by David Urquhart

Infinity temporarily abandoned during the 1983 Laguna Prix, Laguna Beach, California.

CATEGORY 4: CONSTRUCTION MATERIALS

Advanced Composite Technologies
P O Box 24722
Baltimore MD 21220
(301) 882-6051
catalog: yes ; price: $ 4.00

composite materials, tubing, vacuum-bag supplies, tie-rod kits, construction books

Aero Canoe
1081 Alameda
Box 57
Belmont CA 94002
learning project for composite techniques

Aircraft Spruce and Specialty
201 W Truslow Ave
P O Box 424
Fullerton CA 92632
(714) 870-7551
catalog: yes ; price: $ 4.00

tubing, composite materials, fabrics, etc

Airtech International
P O Box 6207
Carson CA 90749
vacuum supplies

Allied Resin Corp
Weymouth Industrial Park
East Weymouth MA 02189
(617) 337-6070
catalog: yes ; price: free

epoxy resin, urethane, silicone, fiberglass, etc.

*catalog may be $2

Alpha Plastics Inc
Rte 1 Box 231
West TX 76691
(817) 826-3639
composite fabrics and resins

American Cyanamid
21444 Golden Triangle Rd
Sangus CA 91350
(213) 625-0421

American Cyanamid
P O Box 262
Havre de Grace MD 21078
aluminum honeycomb manufacturer, strucural fabric and tape, wet resin and adhesives

*Note 3

American Klegecell Corp
204 N Dooley St
Grapevine TX 76051
(817) 481-3547
PVC foam, composite core materials, Kevlar

*Note 3

B & F Aircraft Supply
6141 W 95th St
Oak Lawm IL 60453
(312) 422-3220
catalog: yes ; price: free

steel, aluminum tubing, rod ends, bearings, cables, etc.
*catalog $3 in US, other countries, $4

Bicycle Lighting Systems
Ed Kearney
P O Box 1457
Falls Church VA 22041
(703) 941-0666
catalog: yes ; price: free

range of excellent lighting systems designed for bicycle safety

*call or send SASE for catalog

Blake Davis
HPV Supply
3101 S Wabash
Suite 701
Chicago IL 60616
(312) 842-0465
fiberglass, resins, chrome-moly tubing

Boeing Surplus
20561 84th St
Kent WA
(206) 773-9684
aluminum, titanium, honeycomb, carbon fiber, etc.

*"cheap, but no mail order"

Cadillac Plastics
4533 Willow Parkway
Cleveland OH
(216) 941-0570

California Power Systems
790 139th Ave
4-A
San Leandro CA 94578
(415) 357-2403
catalog: yes ; price $3.00

tubing, rigging, hardware

Ciba-Geigy Corp
Composite Materials Dept.
10910 Talbert Ave
Fountain Valley CA 92708
(714) 964-2731
glass-reinforced plastic, honeycomb, glass fabric, structural fabric and tapes, composite core materials, Kevlar
*Note 3

Clark Foam Products
25887 Crown Valley Pkwy
South Laguna CA 92677
catalog: yes ; price free

polyurethane-foam manufacturer, sandwich structures

*Note 3

Columbia Airmotive
P O Box 436
25700 NE Cherry Park Rd
Troutdale OR 97060
catalog: yes ; price free

4130 tubing, rod ends, U-joints, fasteners, etc

*catalog apparently $2

Columbia Plastics
P O Box 275-H
Columbia MO 21045
(301) 997-1119
composite fabrics and resins

Cowley Inc
Bldg 170
Mojave Airport
Mojave CA 93501
(805) 824-2368
aircraft canopies - can be used as fairings, or as layup molds for fairings

Cyro Industries
P O Box 1779
Clifton NJ 07015

polymethacrylamide-foam manufacturer

*Note 3

DIAB - Barracuda Inc
2001 108th St
Suite 102
Grand Prairie TX 75050
PVC-foam manufacturer

*Note 3

Dillsburg Aeroplane Works
RD 3, Sawmille Rd
Dillsburg PA 17019
(717) 432-4589
catalog: yes ; price free

aluminum, steel tubing, rod ends, etc.

*price list for 66 cents in stamps

Easy Racers Inc
P O Box 255
Freedom CA 95019
(408) 722-9797
catalog: yes ; price $1.00

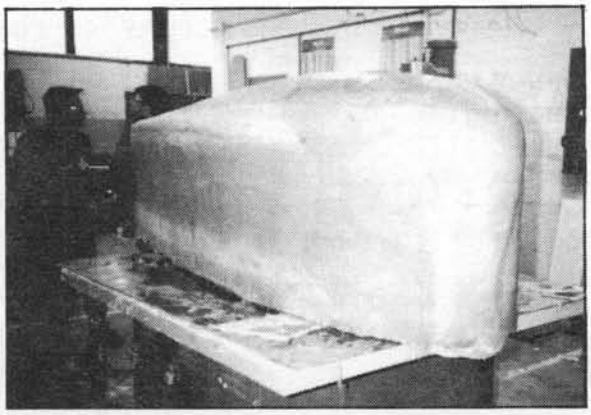
chrome-moly and aluminum tubing

Easy Rider Canoe and Kayak
15666 W Valley Hwy
Renton WA
(206) 228-3633
Kevlar cloth, carbon-fiberglass tape, Airex foam, etc.

Fiberite Corp
501 W Third St
Winona MN 55987
(507) 454-3611
Kevlar, glass, graphite fabrics

*Note 3

Fire Device Company
15835 E Main St
La Puente CA 91744
(213) 968-5597
timing tape switch for timing equipment



Fiberglass-and-epoxy fairing built at the first HPV workshop.

Force Engineering
5329 Ashton Ct
Sarasota FL 33583
(813) 923-1857
Nomex core panels

*Note 3

Fothergill Composites Inc
317 Northside Dr
P O Box 618
Bennington VT 05201
(802) 442-9964
Nomex core panels

*Note 3

Gee Bee Canopies Inc
18415 2nd Ave South
Seattle WA 98148
(206) 242-0332
aircraft windshields, canopies, etc.

General Plastics Manufacturing
P O Box 9097
Tacoma WA 98409
polyurethane-foam manufacturer

*Note 3

Goudgeon Brothers Inc
706 Martin St
P O Box X-908
Bay City MI 48706
(517) 684-7286
catalog: yes ; price free

epoxy system, carbon fibers, fiberglass WEST system; technical manual, $2 excellent source for anyone interested in building wood-structure HPV

Hawkeye Enterprises
7802 Airport Blvd
Los Angeles CA 90045
vacuum-bag-layup supplies

Hexagon Honeycomb
7803 Clayton Rd
Suite 201
St Louis MO 63117
Kraft-paper-honeycomb manufacturer

*Note 3

Hexcel Corp
17711 Dublin Blvd
P O Box 2312
Dublin CA 94566
(415) 828-4200
resins and adhesives, aluminum honeycomb, Nomex honeycomb, glass-reinforced plastic, Kraft-paper honeycomb, composite fabric weaver, structural fabrics and tapes
*Note 3

Hi-Pro Form
962 Devon Dr
Newark DE 19711
composite fabrics and resins

Honeycomb Structural Products
15100 S Valley View
LaMirada CA 90638
Kraft-paper honeycomb

*Note 3

Howe and Bainbridge
220 Commercial St
Boston MA
(617) 723-9000
nylon seat mesh

*large wholesale orders only

International Honeycomb
Manufacturers
4703 E 50th St
Los Angeles CA 90058
(213) 585-1397
Nomex honeycomb, Kraft-paper honeycomb

Note 3

Joseph T Ryerson & Son Inc
Box 1111
Boston MA 02103
(617) 782-6900
catalog: yes

steel, aluminum, plastics, etc.

*catalog may be free; stores in more than 20 other major cities

Kilsby-Roberts - The Tubing Co
Stewart H Glatfelter, sales
P O Box 437
23680 Research Dr
Farmington MI 48024
(313) 477-1400
tubing

Leading Edge Air Foils
331 S 14th St
Colorado Springs CO 80904
(303) 632-4959
catalog: yes ; price $2.00

steel, aluminum tubing, brackets, fabrics

NOTE 3: Manufacturer or primary distributor of the listed materials (many of these are from the DuPont Co. list of users of its Kevlar fabric and Nomex honeycomb. It is suggested that if you need composite materials, check first with the general suppliers. If they can't meet your needs, check with the "NOTE 3" companies, who may or may not serve individual (non-industrial) customers - due to publication deadlines, it wasn't possible to check with these companies.

M C Gill Corp
4056 Easy St
El Monte CA 91731
(213) 443-4094
Nomex core panels

*Note 3

Mark Lindsay Boatbuilders Ltd
Blackburn Center
Gloucester MA 01930
(617) 283-4141
Nomex core panels

*Note 3

McCann Adhesives
Box 429 Rte 14-A
Oneco CN 06373
(203) 564-4046
Kevlar, glass, graphite fabrics

*Note 3

Merkel Industries
Rd 1 Box 1218
Tamaqua PA 18252
(717) 668-2706
Miracle tape for repairs

Monnett Experimental Aircraft
895 W 20th Ave
P O Box 2984
Oshkosh WI 54903
catalog: yes ; price $2.00

steel, aluminum tubing, canopies, tools, etc.

MonoRacer
Clarence Moore
311 Bayside
LaPorte TX 77571
catalog: yes ; price $1.00

seat materials, seats made to order, aluminum, parts

Multi Enterprises
P O Box 891
Mercer Island WA 98040
composite construction materials

Narmco Materials
600 Victory St
Costa Mesa CA 92627
(714) 548-1144
Kevlar, glass, graphite fabrics
*Note 3

Northern Hydraulics
801 E Cliff Rd
Box 1219
Burnsville MN 55337
(800) 533-5545
catalog: yes ; price free

tie-rods and ends, jackshaft kits, trailer-building supplies, etc

Small Parts Inc
P O Box 381736
Miami FL 33238*
(305) 751-0856
catalog: yes ; price: free

small mechanical metal and plastic parts, bearings

*zip is 33238-1736

Stits Poly-Fiber Aircraft
Coatings
P O Box 3084-H
Riverside CA 92519
(714) 684-4280
composite supplies

Southern Composite Supply
22267 Powell Rd
Brooksville FL 33512
(904) 796-1874
catalog: yes ; price: free

fabric covering material, paints

System Six
Ken and Pat Cummings
4550 Wadsworth Blvd
Unit B-199
Wheat Ridge CO 80033
(303) 424-8841
catalog: no

iron-on, sew-on, and glue-on reflectorized material, reflective paint, Tyvek raingear, high-power safety HPV lighting systems (lead-acid and Ni-Cad batteries, lights and flashers, connectors, mountings, generators, chargers
*can order other safety gear; 10% discount for IHPVA members

The Airplane Factory Inc
P O Box 24035
Dayton OH 45424
(513) 849-6533
aircraft canopies - will sell "seconds", can be used as fairings or as layup molds for fairings

Thomson Industries Inc
Manhasset NY 11030
(516) 883-8000
catalog: yes ; price: free

ball-bushings for low-friction linear motion

TM Development
JEN Industrial Campus
2540 Green St
Chester PA 19013
(215) 485-3353
Nomex core panels

*Note 3

Torin Inc
125 Sheridan Terrace
Ridgewood NJ 07450
PVC-foam manufacturers

*Note 3

True Temper
871 Ridgeway Loop Rd
Memphis TN 38119
manufacturer of bicycle tubing

*reportedly will handle orders from individuals

Tube Sales
235 Tube Way
Carol Stream IL 60187
(800) 942-1251
catalog: yes ; price: free

all kinds of tubing

*offices in various cities

U S Industrial Tool & Supply Co
13547 Auburn
Detroit MI 48223
(800) 521-7394
catalog: yes ; price: free

*72-page catalog is free

Unicel Corp
1520 Industrial Ave
Escondido CA 92025
aluminum honeycomb, Kraft-paper honeycomb, Nomex honeycomb

*Note 3

Univair Aircraft Corp
Rte 3 Box 59
Aurora CO 80011
(303) 364-7661
aircraft canopies

Verticel Company
4607 S Windermere
Englewood CO 80110
Kraft-paper honeycomb

*Note 3

Wag Aero Inc
Box 81
1216 North Road
Lyons WI 53148
(414) 763-9586
catalog: yes ; price: free

rod ends, etc.

Western Aircraft Supply
623 Markerville Rd NE
Calgary, Alberta
T2E 5X1
Canada
(403) 276-3087
general supplies

Wicks Aircraft Supply
410 Pine St
Highland IL 62249
(618) 654-7447
catalog: yes ; price: $4.00

tubing, cable, composite supplies, fabrics, etc.

Williams Co
5301 Grant Ave
Cleveland OH
(216) 441-1000
1020 carbon-steel tubing, aluminum tubing

Wood Dimensions
12710 Triskett Rd
Cleveland OH
(216) 941-0570
epoxy resins and fiberglass

Wynn and Graff
225 Boscobel St
Nashville TN
Texron nylon seat mesh

CATEGORY 5: SERVICES

Al Mowrer
1500 W 92nd Ave
377
Denver CO 80221
(303) 426-6660
custom-built framesets (recumbent bicycle); will also provide assembly aid to builders

Bicycle Repair Collective
1912 SE Ankeny
Portland OR 97214
shop space to work on HPVs, tools available, parts sold

Bruce O'Halloran
P O Box 11296
Ellerslie
Aukland South
New Zealand
bicycle tours of New Zealand, general assistance to HPVers visiting New Zealand

Brummer Engineering
Tim Brummer
1304 W Willow
Lompoc CA 93436
(805) 736-0449
catalog:yes ; price: $ 1.00

custom construction work

CdA Design
Morris Chandler
16809 E Goodfellow
Sanger CA 93657
Thermoforming, form and mold development, reinforced-plastic construction (glass, graphite, Kevlar); custom bike components

Centaur Cycle Works
Randal Gordon-Gilmore
125 Sunset Circle
50
Benicia CA 94510
(707) 745-6243
recumbent research and prototype building

HUMAN POWER comes together - slowly - in Pat Cumming's living-room.

Counterpoint Conveyance Ltd
James Weaver, president
P O Box 33475
Seattle WA 98133
(206) 365-6837
catalog:yes ; price:free
design and manufacture of experimental bicycles

Covell Manufacturing
1920 Lafayette
Unit N
Santa Clara CA 95050
(408) 727-5588
fabrication, welding, machine work, experienced with plastics and composites

Dana Barlow
Race Preparation Mark.
11920 SW 35 Territorial
Miami FL 33175
(305) 221-4872
can make odd parts, frame welding, etc.

Dave Plantenga Custom Bicycles
407 W Taylor
Kokomo IN 46901
custom machine work, builds English-type racing tricycles (two wheels in back) and regular frames

Dunning Plastics Company
2910 Franklin Blvd
Sacramento CA
(916) 452-4633
makes blown and draped windshields, Plexiglass

Glen Brown
Zzip Designs
458 Thayer Rd
Santa Cruz CA 95060
(408) 425-5147
computer simulations of speed runs (specify vehicle weight, tire drag, drag coefficient, frontal area, slope, power, altitude)

Granlund Custom Bicycles
1900 McArthur
Saginaw MI 48603
(517) 792-5946
brazing, machine work, bottom brackets tapped, odd parts, frame building

GVA Consulting
Dale Frank
1421 Hartsough Ave
Plymouth MI 48170
catalog:yes ; price: free

aerodynamic testing and development, product design and development

Human-Powered-Vehicle Aerodynamics
c/o Serafino Carri
121 Spring St
Port Chester NY 10573
free consultation to HPV builders in aerodynamic principle basics; suggestions on possible fairing designs, construction techniques

Industrial Design Research
Mark Murphy
723 Laguna Canyon Rd
Laguna Beach CA 92651
(714) 497-7162
catalog:yes ; price: $ 1.00

vehicle design and development; can also make wheel covers, canopies, full fairings

Jack Kane
The Bicycle Shop
909 N Marine Blvd
Jacksonville NC 28540
(919) 455-1011
catalog: no

fabrication, machine shop, welding

*stocks various metals

Jeffrey Bock
929 N 4th St
Ames IA 50010
(515) 232-9593

custom frame builder - will build recumbents

John W Mills
4912 Cimarron Way
Antioch TN 37013
(615) 834-8216

welding, custom-built pedal and handicap vehicles

Mark Nobilette
Cycle Cellar
1241 Main St
Ann Arbor MI 48105
(313) 769-1115
custom frame builder; has built recumbents

Marshall Consulting Inc
2147 Wilmington Dr
Walnut Creek CA 94596
(415) 945-6051

composites seminars, seminar textbook; may possibly advise for a fee

Metals Engineering and Testing Labs
3629 N 40th Ave
Phoenix AZ 85019
(602) 272-4571
catalog: yes ; price: free

metallurgical services, weld certification, mechanical testing, etc.

Personal Transportation Inc
Robert C Turner
Rte 4 Box A-42
Wautoma WI 54982
(414) 787-3560

component design, machine shop, welding thin-wall tubing

Rotator Bicycles
Stephen Delaire
5069 Oakpark Way
Santa Rosa CA 95405
(707) 539-4203
catalog: yes ; price: $ 1.00
custom machine work, welding

Ski's Mobile Welding
42nd and Adams
San Diego CA
described as "super frame welder"

Sports Equipment Technology
406 Newport Ave
South Attleboro MA 02703
catalog: no

engineering, resin casting, custom machining

Stan's Bicycles
3727 W Hemlock
Oxnard CA 93033
catalog: no

custom construction work

TIC Industries Inc
W-332 Delafield Rd
Oconomowoc WI 53066
fiberglass-fairing experts

Tom Welding and Light Machine
5003 N Muscatel
San Gabriel CA 91776
(818) 285-6764
custom HPV work: sprockets, hubs, frames, etc.

UNISON Computer Network
Mile High Media
3542 E 16th Ave
Denver CO 80206
(303) 329-3113
catalog: yes ; price: free

international computer network which carries text of -HUMAN POWER- articles, some -HPV NEWS-, up- and down-load of articles and news to Pat Cummings for inclusion in IHPVA publications.

*may be discount for IHPVA members

UrquhART
David B Urquhart
3301 S Bear
57-B
Santa Ana CA 92704
(714) 662-3451

will custom-design vehicle names and logos for your business
*very reasonable rates from an inventive professional packaging and marketing designer

IHPVA
INTERNATIONAL
HUMAN POWERED VEHICLE
ASSOCIATION, INC.

CATEGORY 6: **ODDBALL TRANSMISSIONS**

Alenax Corp
50 Spencerport Rd
Rochester NY 14606
(800) 828-1431

Alenax lever drive manufacturer, complete bicycles, normal seating position

Cambiogear
Excel Group Inc
9375 Chestnut St
Franklin Park IL 60131

catalog: yes ; price: $
small sprockets in front "chainwheel" move in and out to provide different ratios (made of polyester and nylon)
*discount to IHPVA members

Deal Drive International
Ketts House, Winchester Road
Chandlers Ford, Eastleigh
Hampshire SO5 2FZ
Great Britain

Deal Drive automatic transmission: variable-diameter front "chainwheel" gives automatic shifting through wide range

Kik-Shift
Worksman Trading Corp
94-15 100th Ozone Park
New York NY 11416
(212) 322-2000

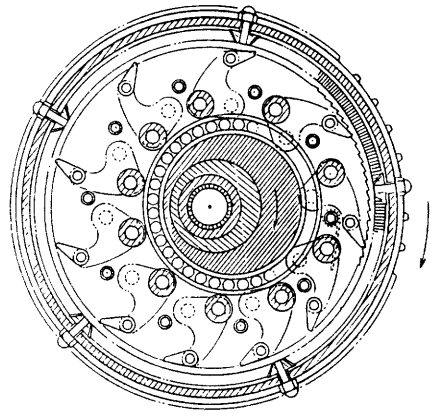
Kik-Shift three-speed transmission (no cables)
*also at (718) 322-2000 (?); not known if still in production

Winfred M Berg Inc
511 Ocean Ave
East Rockaway NY 11518
(516) 599-5010

catalog: yes

plastic and steel cable-drive chains used in human-powered aircraft, sprockets, U-joints, couplings

Bridgestone stepless transmission
(no further details available)



Powercam-Houdaille Inc
2410 Minnis Drive 120
P O Box 1038
Fort Worth TX 76117
(800) 433-2937

catalog: yes

drive system and complete bikes
*in Texas call (800) 772-6502

Radialgear
Saroy Engineering
P O Box 615
Lisle IL 60532

catalog: yes

small sprockets in front "chainwheel" move in and out to provide different ratios (made of polyester and nylon)

CATEGORY 7: **ADD-ON FAIRINGS**

Aerocarrier
National Cycle Inc
2200 Maywood Dr
Maywood IL 60153
(312) 343-0400

-small- fairing for regular bikes

Breeze Eeze Inc
P O Box 611
Big Rapids MI 49307

catalog: yes

for regular bikes (extends from front-wheel center to above handlebars), can be adapted to recumbents

Future Bike
Glen Brown
Zzip Design
458 Thayer Rd
Santa Cruz CA 95060
(408) 425-5147

catalog: yes

Zzipper fairings for regular bikes, big Zzipper for Alex Moultons, Super Zzipper for Tour Easys and other recumbents, Lexan bubble canopy -experimenter- kits

Robert Cotter
RFD 1 Box 84-A
Waldoboro ME 04572

-Bubbles- for regular bicycles

*may be out of business

CATEGORY 8: **BOATS (all pedal-powered)**

H H Payson and Company
Pleasant Beach Rd
South Thomaston ME 04858
(207) 594-7587

catalog: yes

"Madeleine" paddlewheel boat

Haarken-Vanguard
1252 E Wisconsin Ave
Pewaukee WI 53072
(414) 691-3320

catalog: yes

"Waterbug" propeller-driven solo boat, open or closed cockpit

Hydra Products Co
Richard Ott
Rd 4 Box 85
Northampton PA 18067
(215) 262-8967

1-, 2-, 4-person propeller-driven boats, pedal-powered Mechanical Mule for gardening, Energy Cycle for household tasks

Point Strategies
P O Box 308
Hopkins MN 55343

propellers, propeller-driven boats
write to get on mailing list

Saber Craft
Jon Knapp
1501 W Dry Creek Rd
Healdsburg CA 95448

catalog: yes ; price: $ 2.00

propeller-driven boats, gear boxes, U-joints, propellers, etc.

Stewkie Aerodynamics
Manor Farm
Melbury Osmund
Dorset DT2 0LS
Great Britain

lightweight inflatable floats; an inflatable propeller-driven catamaran will be available in 1986

*"long delivery time"

Theodore Schmidt
C F Meyer-Str 6
CH-4059
Basel
Switzerland

custom-made water propellers
*"very long delivery time"

CATEGORY 9:

Note: Some suppliers to home aircraft-builders of tubing, composites, etc., listed in Category 4: CONSTRUCTION MATERIALS also sell books that may be of interest to HPV builders.

ADAM
P O Box 2653
Santa Barbara CA 93120

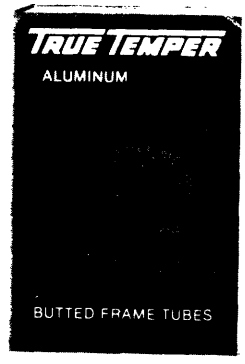
Anthropometric Data Application Mannekin, 1/4-scale human-body template, useful in HPV design

Aircraft Spruce and Specialty
201 W Truslow Ave
P O Box 424
Fullerton CA 92632
(714) 870-7551

-Moldless Composite Homebuilt Sandwich Aircraft Construction- catalog/guide, $14.50

Akikaze Motorcycles
P O Box 881
Downey CA 90241

booklet describes simplified plug/female mold fiberglass-fairing construction, $10



Alcoa
Pittsburgh PA

-Aluminum: Its Forms, Alloy and Tempers- and other booklets on using Alcoa products

FREE

Almac Plastics
1588 NW 159th St
Miami FL 33169
(305) 624-2123

Tuffac Polycarbonate Forming and Fabrication Manual (PL-1422) free to customers

*also available at Rohm and Haas Co (Plexiglass dealers)

BOOKS

Aviation Book Co
1640 Victory Blvd
Glendale CA 91201
(818) 240-1771

Aviation Publishers
One Aviation Way
Lock Box 234
Hummelstown PA 17036
(800) 441-7527

books include -Composite Construction for Homebuilt Aircraft- by Jack Lambie, $17.95 plus $2.95 postage

Bicycle Bookshelf
202 Main St LA
Branford CN 06405
(203) 488-0482

catalog: yes ; price: $ 1.00

E I DuPont de Nemours & Co
Textile Fibers Dept
Industrial Fibers Marketing
Centre Road Building
Wilmington DE 19898
(302) 999-4693

booklets -Design and Fabrication Techniques for Honeycomb of Nomex Aramid Sandwich Structures- and -Kevlar for Canoe, Kayak and Small Boat Construction- other booklets may be available

IHPVA
P O Box 2068
Seal Beach CA 90740

catalog: yes

books and technical papers pertaining to HPV and bicycle building and design, reprints of -Human Power- and -HPV NEWS-, membership lists by area for IHPVA members

Jack Lambie
209 Adams
Orange CA 92667

-Composite Construction for Homebuilt Aircraft-, $15.95 autographed (also available from other sources); -How to Make Fairings-, 1975 reprint of -Bike World- magazine article, $3

John Wiley Inc
605 Third Ave
New York NY 10157

catalog: yes

-Road Vehicle Aerodynamics, Second Edition- by A.J. Scibor-Rylski, 260 p, $29.95. Contains new data on flows around wheels and wheel cavities, and airflow during acceleration and turning maneuvers. Though motorized vehicles only, may be useful.

Manet Guild
Box 73 E
Babson Park MA 02157

catalog: yes

-Designing and Building Your Own Frameset- by Dick Talbot, $26 postage paid in US, $36 postage paid all other countries

McGraw-Hill Publishing Co

-Composite Materials Handbook-

by Mel M Schwartz (1984)

Midvale Books
155 SW Midvale Rd
Portland OR 97219

catalog: yes ; price: $ 1.00

bicycling books

NASA
P O Box 8757
Baltimore-Washington
Int'l Airport MD 21240

-A New Surface-Streamline Flow Visualization Technique- by L.S. Langston and M.T. Boyle, in Technical Support Package #LEW-13875. Free.

Ronald Steven Blair
747 Nipomo St
San Luis Obispo CA 93401
(805) 544-1552

-HPV Fairing Construction techniques- (being revised), -10 years of HPV Racing- (available soon), HPV gearing chart (available soon)

Rutan Aircraft Factory
Building 13
Mojave Airport
Mojave CA 93501
(805) 824-2645

-Moldless Composite Homebuilt Sandwich Aircraft Construction- catalog/guide, $14.50

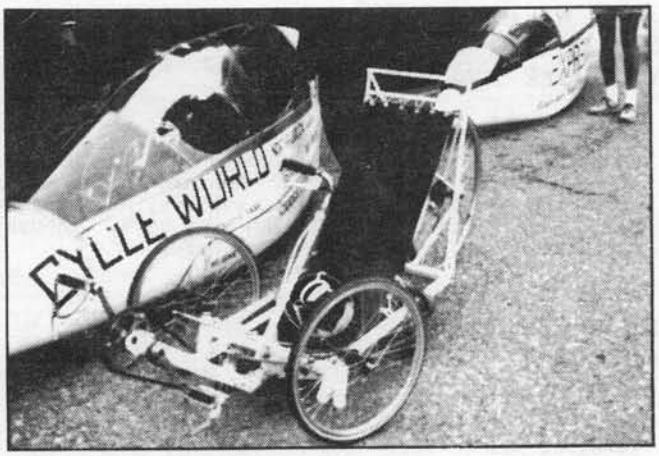


Photo by David Urquhart

Land Shark and unfaired SWB trike incidentally paired between qualifying laps of 1983 Laguna Prix.

Sutherland's Bicycle Shop Aids
P O Box 9061
Berkeley CA 94709
(415) 843-1438

-Handbook for Bicycle Mechanics- tells which components are compatible

TAB Books Inc
Blue Ridge
Summit PA 17214

catalog: yes

various technical books

*catalog may be free

Zenith Aviation Books
P O Box 1
Osceola WI 54020
(800) 826-6600

catalog: yes

Publications are listed on page 14

Posters ($3 each) available from the IHPVA:

P09 #42 ON THE SPRINT. Artist: K. Atkins. 18x24, four colors; blues predominate.

P10 EASY RACERS AT THE VELODROME. Artist: R Garriott-Stejskal. 18x24, four colors yellows predominate.

P11 AROUND THE BEND. Artist: C Michael Lewis 30x15, four colors, greens predominate.

NW1 IF LEO HAD RUN OUT OF GAS. Artist: Kevin E Cain. 18x24, three colors, red, yellow, black.

Posters will be mailed folded unless $1.50 per order for protective mailing tube is added.

ORDER

ITEM	QUANT	PRICE

TUBE _____
Memb. DUES _____
TOTAL _____

Date _____

Mail to:

IHPVA
P O BOX 2068
SEAL BEACH, CA 90740
USA

Name _____ Age _____
Address _____
City _____ State _____ Zip _____
Occupation _____ Built a Vehicle? _____

Dues are $15 per calendar year for addresses in USA, $17 for Canada or Mexico. All other countries, $20.

A NEW RICKSHAW FOR BANGLADESH

by Fred Willkie

CHIEF PROBLEMS WITH CONVENTIONAL RICKSHAWS

Excessive torque requirement of one-speed (61-inch, 1.5-m, gear) transmission. The rickshaw pullers have strained ankles, knees, hips, and chests.

Inadequate braking, with one stirrup-type rod brake on the front wheel. Frequently these stop the wheel but not the load, with the result that the front fork breaks off at the crown.

Structural inadequacy of the frame causing failures, accidents, and lost time.

High percentage of foreign-made components bringing loss of foreign exchange, and lost employment for Bangladeshi workers.

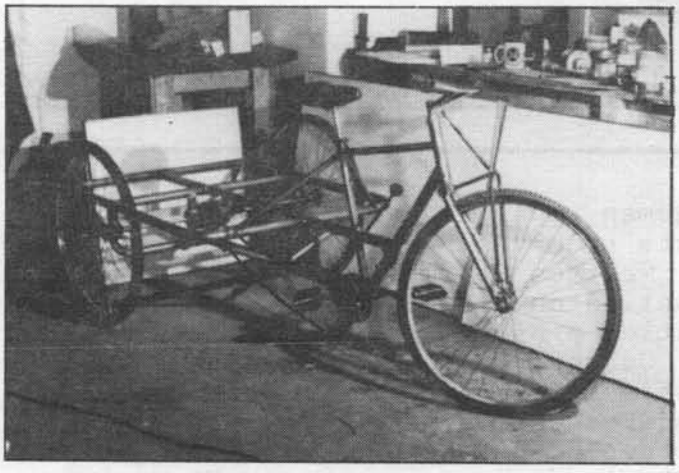
Very high unladen weight - 200 to 250 lbm (90 to 110 kg).

NEW DESIGN

The new design is intended to deal with these problems. It has:

* A three-speed (fourth gear - underdrive low - could be added) transmission made of conventional, low-cost bicycle parts. There are no cables for bicycle use in Bangladesh, so the shifter uses a tubular handle. You backpedal to change gears, pushing the stick forward to shift up, backward to shift down. Because there is a freewheel on the rear axle, and shifting is accomplished by backpedalling, the driver can shift from any gear to any other while the vehicle is moving, or while it is stationary. This last point is very important. It means that the driver can get back into low gear for regaining momentum after being forced to stop while travelling in high gear with a heavy freight load. The shifter could be locally made with local materials.

* A band brake operated by a foot pedal and bearing on a brake lining of woven asbestos and brass (coefficient of friction 0.43) that is riveted to the turned outer surface of a differential center section. The differential is quite simple and could also be locally made. It allows braking of both back wheels at all times. This more effectively slows the load, not just the wheels. The differential also allows continuous driving of both wheels for superior traction compared to the conventional single-side drive. Also, the differential improves steering. There is no unbalanced veering moment from propulsive effort, and the turning-circle radius is only 67 inches (1.7 m). The wheel base is 64 inches (1.6 m). Track is 40 inches (1 m). Overall length is 96 inches (2.4 m), overall width 48 inches (1.2 m).



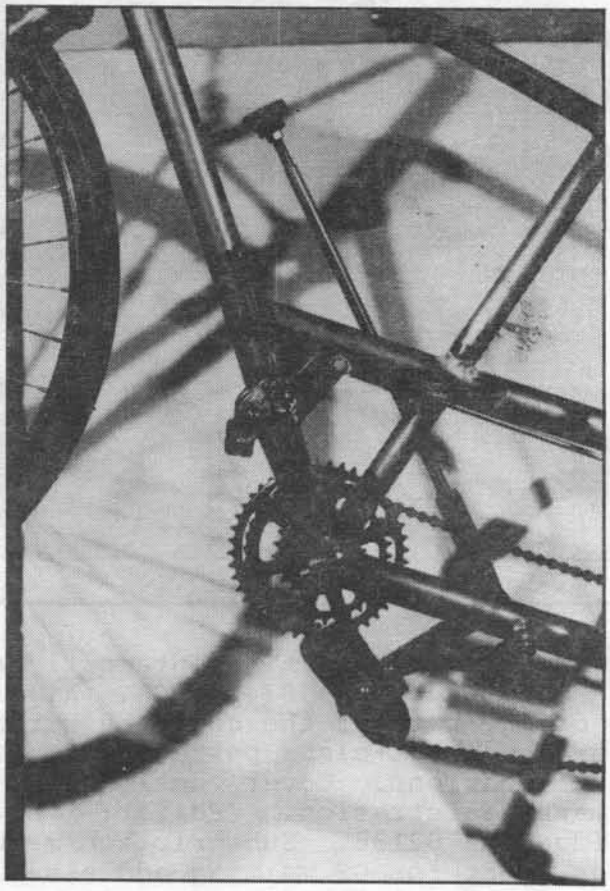
Willkie rickshaw chassis.

* The frame is a tubular construction of ERW 1010 mild-steel, bronze-fillet welded. The tubes are 7/8, 1, 1-1/8, and 1-1/2 inch (22, 25, 29, 38 mm) O.D., 16 ga. The 1-1/2-inch (38-mm) tube, from which the frame is mostly made, is the same tubing used to make exhaust systems for Japanese motor vehicles, commercially dominant in Bangladesh as here. So, it should be possible to make this frame from local materials, with local tooling and labor. The bottom-bracket shell and the fork crown are made of 1.5-inch (388-mm) o.d. 0.125-inch (3-mm) wall mechanical steel tubing.

* The front fork can be made of entirely straight-gauge, non-tapered tubing. It incorporates a pre-stressing screw to reduce the net bending moment of the load at the fork crown by making it possible to load the crown with an opposite moment.

* As you see it in the pictures, the cycle-truck chassis weighs about 98 lbm (44kg), 115 lbm (52 kg) with load-carrying bed and mudguards. So, it is from 40 to 60% of the weight of the conventional Bengali rickshaw (198-242 lbm, 90-110 kg, empty). This should help to save strain on the pullers, but probably will just allow them to haul 100 to 140 lbm (45 to 64 kg) more paying freight per trip. This last advantage should have some economic importance for the fleet owners who might buy them. It is an economic advantage to offset an anticipated slightly higher cost.

Something interesting about the steering geometry is that, on Sharp's advice [Bicycles and Tricycles, obtainable from the IHPVA], it gives zero trail. Rocking of the chassis over rutted roads does not make the front fork flutter. Turning the front fork to 90 degrees to either side requires lifting the steering



Manual shift-lever allows shifting while vehicle is stationary.

head 1/4 inch (6 mm). So, the weight borne by the steering head imparts stability in the absence of trail. It is easy to ride no-hands. This geometry and the differential drive together give the sweetest tricycle handling I've ever experienced. Good old Sharp!

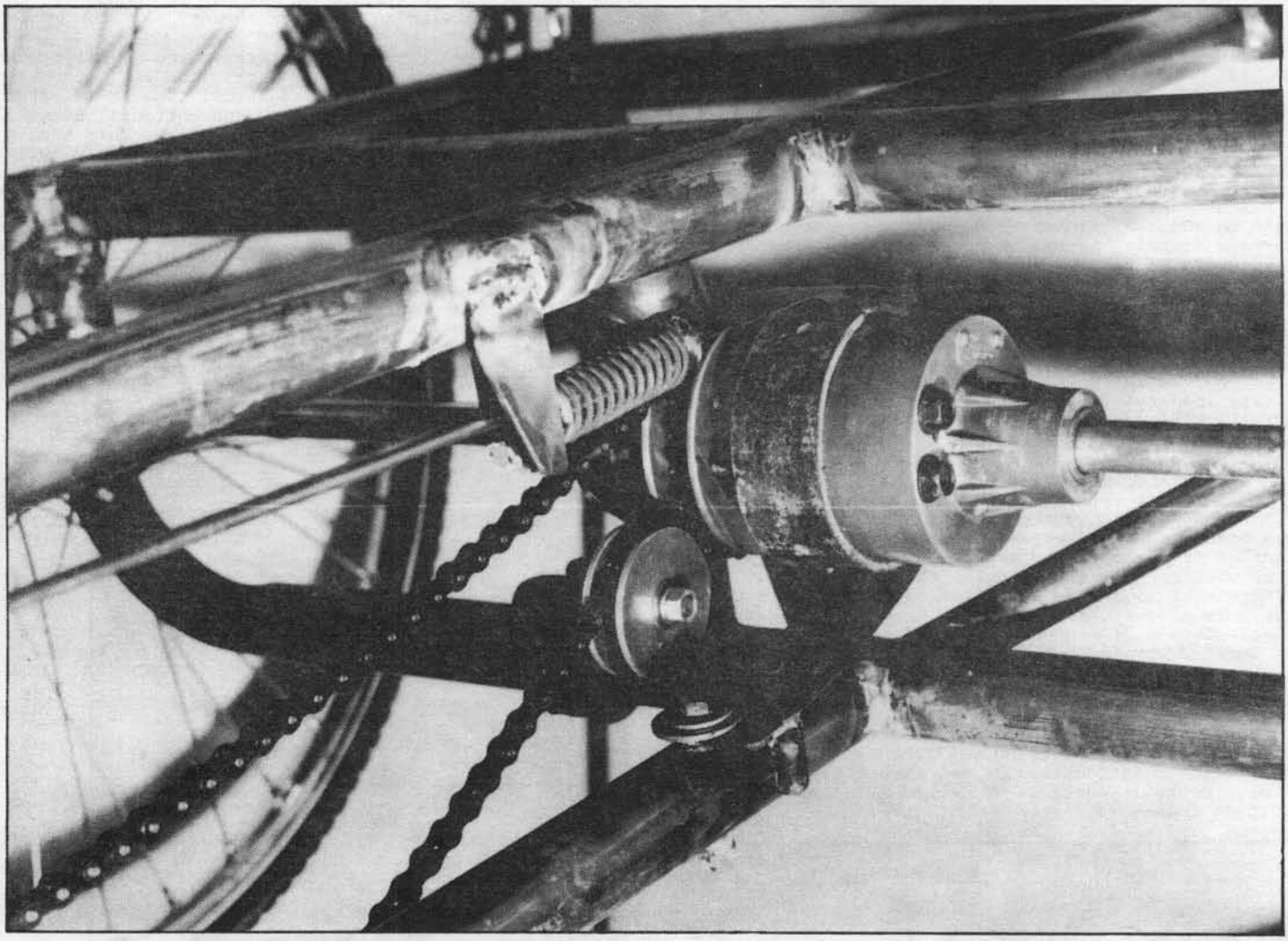
Here in Ottawa I am waiting with impatience for the slow-grinding wheels of Bangladeshi bureaucracy to turn me up a visa. When I get one, I'll be gone within a week. I'll be there for at least three months, probably six, and possibly nine. My addresses are given below.

Frederick Willkie

Canada:
Seven Heart Cycles
204 LeBreton St North
Ottawa, Ont K1R 7J1

Bangladesh:
Cable: Kalpataru
Mail: c/o Inter Pares
G.P.O. Box 311 Dhaka
Physical: House 4
Road 15 Dhanmondi R/A
Dhaka-5
Telephone: 31 31 07

Closeup of rear-axle differential. Spring connects to heavy-duty brake which bears on brake lining of woven asbestos and brass.



 Editor: David Gordon Wilson, 15 Kennedy Road, Cambridge, MA 02138. Subscription/membership information: Dues are US$15 per calendar year for US mailing addresses. Addresses outside the USA, please remit: US$17 for Canada and Mexico; all other countries US$20. Please make your check or money order payable to the IHPVA. Send dues to: IHPVA, P O Box 2068, Seal Beach, CA 90740, USA.