13-v3n4-1985.pdf

HUMAN POWER

THE JOURNAL OF THE IHPVA ISSUE NO. 13 Volume 3, No. 4 Summer 1985

THE FIRST HPV BUILDER'S WORKSHOP

by Mike Eliasohn

It was appropriate that, on the weekend that saw the coldest temperature ever in Chicago, the "class project" at the first human-powered-vehicle builder's workshop last January was an ice cycle. And with the temperature plunging to 27 degrees below zero early Sunday, the greatest test of human ingenuity was getting cars started.

The Saturday and Sunday workshop at the Illinois Institute of Technology in Chicago was the brain child of IHPVA development director Blake Davis, an IIT graduate student in city and regional planning, and Terry Hreno of Mooresville, Indiana, teacher, and builder of the fiberglass-bodied **Moby Infinitys**.

Davis, who had received some on-the-job training in HPV construction from Hreno prior to the 1984 IHPVA championships at Indianapolis, thought it would be a good idea if others could share Hreno's expertise; thus the builder's workshop was born.

"Originally, we were thinking of 15 people," Davis said. Instead, 41 people from as far as Aspen, Colorado, and Fort Erie, Ontario, paid the $50 fee. There were an additional nine people there as instructors and helpers.

Davis, who coordinated, and Hreno, who taught the design session, were business partners in the venture with welding instructor Stephen Delaire, of Santa Rosa, California. Delaire built the **Cargo Carrier**, which he pedalled 2000 miles from California to Missouri on his way to the speed championships last year. He also builds the **Lightning** frames for Tim Brummer, and has made BMX and mountain-bike frames. The fiberglass-composites instructor was Dr. Ashok Bhatnager, an instructor and advisor to the HPV group at IIT, and former manager of a plant making composite fan-blades for cooling towers.

The first morning, each instructor spent an hour introducing his topic. The remaining time, each was to conduct a workshop in his specialty, though the plan fell apart somewhat on Sunday. Because many people arrived late Sunday morning (scheduled starting time was 9 a.m.) due to difficulties getting cars started, and because of the need to get the "class project" frame and body finished, only Hreno conducted a formal workshop that day. The other two sessions consisted of watching the experts at work and asking questions, though there were some opportunities for participants to help.

The workshop had some problems in addition to the weather. Because the welding and composite classes had to take place in the same workshop room, noise from one group (such as sawing or sanding) interfered with the other.

Future workshops will have the experiences of this to build on, so that such problems can be avoided.

Welding instructor Stephen Delaire tack-brazes the "class project" frame together. Frame is built of oval-section tubing.

Sharon Smith, Indianapolis, and George Cudney, Fort Erie, Ontario, sand the plaster male mold of the ice-cycle fairing. Two layers of Kevlar, plus fiberglass over the nose, were later applied.

Continued on page 4

IHPVA ***HUMAN POWER*** **Editor: David Gordon Wilson**
Design/Layout Editor: Patricia Cummings

EDITORIAL

This is the fourth issue of Human Power since I took over the editorship, and my - our - luck is still holding in providing us with striking developments in HPVs. In this issue the short report of the entry of a major sailboat-component manufacturer into the HPB arena is exciting in itself, and could be the forerunner of major expansions in the IHPVA's role in sports and recreation. The Phoenix inflatable aircraft could also start some more-general activity in HPAs, as distinct from the very specialized developments up to now, mainly aimed at record-breaking.

In this issue there are also less-dramatic signs of movements that may have great significance. Vehicles for handicapped people are becoming more highly developed and more appropriate for their needs, although there is a very long way to go. Des Messenger's article in this issue will be followed, if promises are kept, by several more on different vehicles and mechanisms in future issues. And the light-hearted pieces by Terry Hreno and Mike Eliasohn on the builder's workshop organized principally by Blake Davis are harbingers of an issue of HP that should be eagerly sought after. It will be a source directory of materials, components, and services for HPVs. It comes from a suggestion made during the general meeting at the last IHPVA Indy. Mike Eliasohn took up the challenge with energy and enthusiasm, and will earn our appreciation.

One other small development in this issue is a "letters" column. Send letters for publication (which we can't, of course, guarantee) directly to me at the address below. And send in your articles. Even though we plan special issues emphasizing one or two topics, we should, and we want to, publish articles on any topic in the field of Human Power of interest to our readers, such as John Stout's in this issue. Thank you and keep them coming!

David Gordon Wilson
15 Kennedy Road
Cambridge, MA 02138

CONTENTS

LETTERS TO HUMAN POWER

I. I am physically disabled. My short-term goal is to set a disabled land-speed record. In June 1984 I was scheduled to compete in the International Games for the Disabled in New York, but I was not permitted to use my recumbent tricycle because of its "futuristic" design. Unfortunately I am inexperienced in setting up HPV events. Your knowledge, help, and involvement would be a great asset to me and my endeavor. Enclosed is a money order for a one-year membership in the IHPVA.

Sincerely, Tim Saxton

Timothy L Saxton
1941 Briscoe Terrace
Fremont, CA 94538
(415) 656-8491

II. Here are three good questions on recumbents.
(i) A good suspension would extend the versatility of recumbents to include riding on hard-packed dirt roads. Recumbents seem pre-adapted to suspensions because mass of legs is moving fore-and-aft rather than up-and-down, and therefore less likely to start the bike bouncing. I would like to see a comprehensive discussion, and especially some line drawings.
(ii) What is the optimal seat geometry? I have built two **Easy Racer** types with the only real difference being about two inches (50 mm) in seat height, but this caused a remarkable difference in the feel of the bike. This geometry must be at least as critical as seat height on an upright.
(iii) Where are some objective data on the hill-climbing abilities of recumbents? Everyone says that they are slower, but is this true? Often home-builts weigh quite a bit more than uprights, and on hills, weight is critical. Has anyone compared a recumbent vs. an upright of the same weight, with an experienced recumbent rider? I have never quite believed the argument that goes "on a recumbent you can use only your leg muscles, but on an upright you can use both your leg muscles and your weight". Seems to me what goes down has to come up again.

Thanks, and keep up the good work.

Smiley Shields
6950 Bradfordville Rd
Tallahassee, FL 32308

III. CIRCUIT DESIGNER NEEDED FOR HUMAN-POWER ELECTRICAL GENERATING PROJECT

A recent issue of **Human Power** described an electrical generating system designed by one of David Gordon Wilson's students. This used a heavy flywheel to maintain pedalling speed over the top dead centers.

Conventional voltage regulators attempt to maintain constant electrical output regardless of generator speed, so you must push harder if you slow down - a poor match to human power. An appropriate voltage regulator would allow the user to set a minimum pedalling rpm below which electrical output would be drawn from a battery or capacitor rather than from the generator. To the pedaller, this would feel like a heavy flywheel, but it would weigh only a few ounces in circuit components.

I have equipped a bicycle with an automotive alternator, battery, and chain drive. The bicycle is rideable fully-equipped, and power can be generated while moving or stationary. Output with a rider in reasonable condition is 75-100 watts. This outfit would make a superb power source for a mobile PA system in a parade, for emergency communications or lighting, or many other possible uses. Commercialization of the product is possible, particularly as the generating system could be bolted onto any conventional bicycle.

I need someone with electronic cicuit design skills to work with me on building the "flywheel" voltage regulator to complete the system. I will make the generator/bicycle available, and draw up an equitable agreement about any profitable outcome.

John S Allen
P O Box 441291
W Somerville, MA 02144

AERODYNAMIC DRAG OF STANDARD AND RECUMBENT BICYCLES

by John E. Stout

[John Stout is a graduate student at Colorado State University studying wind engineering. He graduated from the University of Texas at Austin with a B.S. in aerospace engineering. - Dave]

Recumbent bicycle riders have often claimed better aerodynamic performance over standard bicycles due to the supine position. In order to quantitatively determine the possible difference in drag for one specific recumbent bicycle, windtunnel tests were performed at Colorado State University.

The tests were performed as follows. First, the drag of a male rider mounted on a high-quality racing bicycle was measured at both 30 and 40 mph (48.3 and 64.4 kph). Next the same subject mounted a high-boy recumbent bicycle (Figure 1), and again the drag was measured at these same speeds.

After these tests were performed, the same process was repeated with a smaller female rider, and slightly smaller bicycles. Both riders were dressed in proper riding apparel and assumed normal riding postures during the tests.

The drag was measured through the use of a platform-type force balance which was located at the leading edge of the test section to reduce boundary-layer effects. A special front-wheel brace was built to hold the bicycle in place and to keep it from toppling.

Results

Full results of the tests may be seen in Table 1.

The effective frontal area, $C_D A$, was calculated from the following equation.

$$C_D A = \frac{D}{(1/2)\rho V^2}$$

where D is the drag force;
ρ is the air density; and
V is the speed of the wind.

The value $C_D A$ can be considered to be a constant for small changes in velocity as long as the bicycle and posture remain the same. However, human beings often find it hard to maintain a given posture for very long, and therefore small changes in $C_D A$ occurred during the tests.

Results of Standard-Bicycle Tests

The drag of the male subject on the standard bicycle was 6.39 lb (28.4 N) at 30 mph (48.3 kph) and 11.40 lb (50.7 N) at 40 mph (64.4 kph). The corresponding effective frontal area is 3.47 ft^2 (0.32 m^2) and 3.49 ft^2 (0.32 m^2) respectively. This agrees well with the data taken by Nonweiler. (ref. 1) The female subject produced a lower drag of 6.20 lb (27.6 N) at 30 mph (48.3 kph) and 9.81 lb (43.7 N) at 40 mph (64.4 kph). This corresponds to a $C_D A$ of 3.37 ft^2 (0.31 m^2) and 3.07 ft^2 (0.29 m^2) respectively.

Results of Recumbent-Bicycle Tests

On the recumbent the drag of the male subject was 4.91 lb (21.8 N) at 30 mph (48.3 kph) and 8.32 lb (37.0 N) at 40 mph (64.4 kph). This corresponds to an effective frontal area of 2.67 ft^2 (0.25 m^2) and 2.54 ft^2 (0.24 m^2) respectively. This agrees well with the data taken by Nonweiler. (ref. 1) The drag of the female subject was slightly lower at 4.69 lb (20.9 N) at 30 mph (48.3 kph) and 7.81 lb (34.8 N) at 40 mph (64.4 kph). The effective frontal area for this case was 2.55 ft^2 (0.24 m^2) and 2.39 ft^2 (0.22 m^2) respectively.

(**Human Power** welcomes letters for publication, although we cannot publish all of them. Keep them as short and to the point as possible. Remember our non-US readers when about to use jargon or strange units. Send your letters to David Gordon Wilson, editor, **Human Power**, 15 Kennedy Road, Cambridge, MA 02138, who may have to do some editing on them. Forgive!)

Comparison

If we compare the average $C_D A$ value for the standard bike and the average $C_D A$ value for the recumbent we get a 25% drag reduction for the male and a 23% drag reduction for the female subject.

TABLE 1

BICYCLE	RIDER	VELOCITY (mph)	VELOCITY (kph)	DRAG (lb)	DRAG (N)	$C_D A$ (ft^2)	$C_D A$ (m^2)
Standard	Male	30	48.3	6.39	28.4	3.47	0.32
Standard	Male	40	64.4	11.40	50.7	3.49	0.32
Standard	Female	30	48.3	6.20	27.6	3.37	0.31
Standard	Female	40	64.4	9.81	43.7	3.07	0.29
Recumbent	Male	30	48.3	4.91	21.8	2.67	0.25
Recumbent	Male	40	64.4	8.32	37.0	2.54	0.24
Recumbent	Female	30	48.3	4.69	20.9	2.55	0.24
Recumbent	Female	40	64.4	7.81	34.8	2.39	0.22

Conclusions

The windtunnel tests show that a reduction in drag from 23-25% is possible by changing from the standard racing bicycle to a high-boy recumbent bicycle.

John E. Stout
500 W Prospect # 11-G
Fort Colins, CO 80526
(303) 491-6787 (hm)
(303) 491-8469 (wk)

REFERENCES

1. Air Resistence of Racing Cyclists, T. Nonweiler, Report 106, College of Aeronautics, Cranfield, England, 1956.

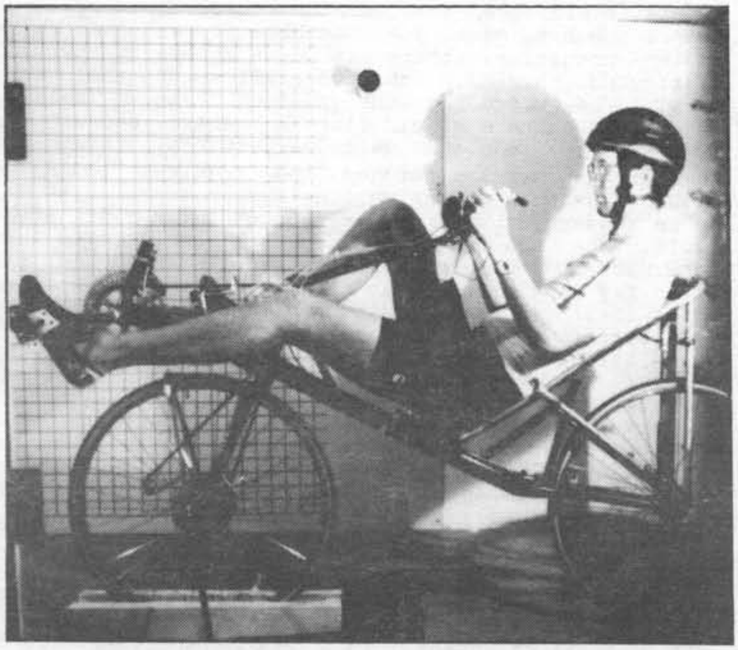


Figure 1. Male subject mounted on high-boy recumbent, built by Jon Lebsack of Fort Collins, CO, during tests.

DESIGN

Hreno began his presentation Saturday morning by saying that compared to the other two instructors, he was the "token dummy... I guess they got me here to prove even if you're not an expert... it's possible to build [an HPV]." Hreno has built six HPVs in three years, and has three on the drawing board. "I'm going for the title of the country's most prolific HPV builder," he claims.

Hreno's workshops combined the opportunity to design an HPV and learn basic fiberglass techniques. He discussed male and female molds and release agents in building fairings. Using a male mold, i.e., constructing a body over the mold, is the quickest, but it leaves the outside fairing surface rough, so that it has to be sanded, with filler added for smoothing bad spots. It is the method usually used for one-off bodies.

A female mold involves more work. First a smoothly-finished male plug is made. The female mold is built over it and then removed. After the female mold is done, finished bodies are made by laying fiberglass inside it. The advantage of female molds is that the finished bodies come out of it with the outside surface smooth. With either method, the hard part is getting the body off or out of the mold.

Participants in Hreno's session built 11-inch-long models of the Moby bodies out of one layer of fiberglass, using thin plastic female molds Hreno had made. Everyone first applied a coat of mold wax to the inside of the mold. Hreno recommends using mold wax, or a paste wax high in carnauba content that doesn't contain cleaning agents.

After that, a coat of polyvinyl alcohol was brushed on. A more expensive alternative is a silicone spray. The wax and PVA kept the layer of fiberglass, the last step, from sticking (too much) to the mold.

As part of Hreno's class, participants had an opportunity to design their own HPVs with T-square and drawing board. The "text" for the course was Hreno's article, included in this issue of **Human Power**.

WELDING

Participants in the Saturday-afternoon welding class had the opportunity to fishmouth a tube, then braze it to another tube. Sunday, Delaire worked on the "class project" ice-cycle frame while participants watched and asked questions. The frame, minus the drive train, was finished by Delaire by the end of the day on Sunday.

Delaire discussed the various ways of joining metals, and types of steel and aluminum.

His preference for joining steel is brazing. "Since the base metal does not have to be heated to a molten condition, there is less possibility of destroying the main characteristics of the base metal," he wrote in the handout text. Delaire recommends using a liquid flux in brazing because it is easier to clean the welds afterwards, though it does dirty hoses and torches, and requires adding a liquid-flux tank to the welding-system lines.

He suggested brazing frames on top of a flat steel table. When the frame is done, to align it, "You just take bars and bend it where you want." Some in the class may have grimaced at this, but those who had built their own frames using similar alignment methods felt better.

Delaire also talked about welding aluminum. He said if he uses 6061-T6, which has a 98-percent success ratio, two out of every 100 welds will fail "whether I like it or not." In contrast, 7075 aluminum has only a 75-percent success ratio.

Once an aluminum frame is done, it should be heat-treated - which is expensive and difficult to have done correctly - or anodized, which isn't quite as good, but is cheaper and fairly goofproof. The anodizing solution won't reach the frame wherever it is being held by the clamp. Delaire said that when he has a frame anodized, he usually has the clamp attached to a dropout, since this usually gets marred sooner or later anyway. It's also important to be sure that no air is trapped inside the frame. If there is, the frame will float in the anodizing tank, and will not come into total contact with the solution.

COMPOSITES

Bhatnager began his Saturday-morning presentation by talking about the three types of composite materials: fiberglass, carbon graphite, and Kevlar.

Fiberglass (reinforced plastic), he said, is low-tech. "You can do it in your garage." It is also cheap, and the cloth is easy to cut. Carbon graphite is much stronger than fiberglass, much more expensive, and has more bending strength, but little impact strength. In an accident, it will shatter more readily than fiberglass.

Kevlar is the strongest of the three in an accident. Unlike fiberglass, Kevlar cloth requires special scissors for cutting. It is hard to sand, and is expensive, but it is lighter than fiberglass. It was mentioned that DuPont, which manufactures Kevlar, plans to publish a booklet describing how to build fairings using the material.

Bhatnagar said epoxy resins are best, but polyester resins are half the cost, and will cure at room temperatures. Epoxy resins may require use of heat to cure. Polyester resin should be mixed with the hardener no more than a pint at a time, because the mix has a life of only 22-30 minutes; after that, it can start burning.

In laying of fiberglass, he suggested using layers of strand mat with continuous fiber to combine the best elements of each. With hand-layup of fiberglass, "once you do it, next time you're an expert." Problems can develop during fiberglass layup, he said, if there is moisture in the work area or on tools.

As for using fiberglass to bond other materials together, he said it works better with steel than with aluminum, but the best bond is fiberglass to fiberglass. To join two fiberglass panels, for instance, he recommended using fiberglass over the joint on both sides.

The Saturday-afternoon class built the male mold for the shell of the "class project" HPV. The fairing has vertical sides and a flat bottom. Two horizontal panels were cut earlier in the shape of the fairing. The top and bottom sheets were joined with vertical pieces of wood, then vertical curved pieces cut earlier were fastened to the top of the flat surface to form the rounded top. The top and sides were then covered with styrofoam, over which plaster was applied.

On Sunday, the plaster was sanded relatively smooth. Unfortunately, in some places the plaster was sanded through to the styrofoam. Had there been time, the ideal solution would have been to add more plaster. Since there wasn't, the mold was wrapped in aluminum foil, and the Saran Wrap, to get a smooth surface. Over that, two layers of Kevlar were applied, and over the nose, a layer of fiberglass over the Kevlar. It was complete by the end of the session at 5 p.m. Flaws in the Kevlar surface would be smoothed later with a mixture of polyester resin and flakes.

THE "CLASS PROJECT"

The HPV "class project" at the workshop was designed by Davis, Delaire, and some members of the IIT-HPV group. As mentioned, it is an ice cycle - built with the intention of making an attempt on the DuPont prize for the first single-rider HPV to exceed 65 miles per hour (29.0576 meters per second).

The supine recumbent will travel on three blades or runners, with propulsion originally designed to be a rotary saw-blade or gear. One runner and the drive blade would run in a straight groove cut into the ice by a machine to be built later.

As designed, the vehicle would have no steering or windows. If the testing goes well, Davis said, the record attempt will be made on a lake in the thin air of Colorado.

* * * *

Davis said the builder's workshop may be repeated, with one session on the east coast, and one on the west coast.

Mike Eliasohn
2708 Lake Shore Drive Apt 307
St Joseph, MI 49083

Most attending the workshop had their first experience with fiberglass during the weekend. Inside of molds were first waxed, then polyvinyl alcohol was brushed on. Fiberglass cloth was laid inside, and resin brushed on. The result after drying was both halves of a miniature model of the Moby fairings built by Hreno.

Terry Hreno (seated, center) shows some fine points of drawing an HPV to some of the students at the workshop.

Selected articles and excerpts from **Human Power** are available in electronic data form on The UNISON System, a multi-user electronic mail and conferencing system. UNISON is accessed through the TELENET system, so for most readers in the US and Canada, it needs only a local phone call to connect with **Human Power** online.

To use UNISON from home or office, you need only have access to a computer terminal, a microcomputer, or a communicating word processor. UNISON is a 24-hour service.

For more information about **Human Power on UNISON**, call with your address or send a legal-size SASE to:
Patricia Cummings
5785 W 38th Ave
Wheat Ridge, CO 80212
(303) 424-8841

THE BUILDING OF HPVs
...And Other Holy Quests

by Terry Hreno

"Write an article or two telling how to build an HPV" are words which strike terror into the heart. Most builders of these marvelous little streamlined plastic pea pods would sooner face yards of the fiberglass, gallons of smelly resin, and miles of stubborn tubing, than have to sit bellybutton to spacebar with a typewriter. This writer is no exception. How can one possibly condense all that is involved in building an HPV into a few pages?

Simple: listen to what your old English teacher told you! Limit your topic. That's exactly what we will do here. These articles will be focused at the first-time builder. Will this be an "everything you wanted to know about plastic pea pods, but were to dumb to ask" article? Nah! First, because I don't know eveything, and second, because you would be bored to death if I tried to tell you. What we hope to do here is to help you with a few basic guidelines. We certainly don't want to give you too much info and deprive you of the fun of making your own glorious discoveries. So gather up your wits, muster up some courage, and let's wade in with both feet. Always lead with your chin, because revelation comes much faster that way!

Let's start by breaking down this whole procedure into four main areas:

1) Research and Design
2) Chassis and Drive System
3) Body and Mounts
4) Testing and Development

Each of these topics will be covered not as a step-by-step "how-to", but rather as a series of hints, guidelines, and iron-clad commandments intended to help you work more efficiently, and avoid some of the pitfalls.

Research and Design

This is the single most important part of building an HPV. Take care here. Remember, progress is just a matter of getting our mistakes out of the systems. Mistakes made with pencil and paper are more easily corrected than mistakes made with fiberglass and steel.

Rule #1: **Builder, know thyself!**
The first bit of research done is to take a good peek inside your own head. What do you hope to accomplish with your fist HPV? A design intended to win the DuPont Prize will certainly be different than one you want to use to commute back and forth to work. Set a clear major goal for yourself. Next take a good look at your material resources. This includes not only money, but also time and space. Always allow more than you think necessary; double it. Set a timetable for every part of the project. Last, look at your abilities. Get in a little over your head! You'll be surprised at how clever you really are.

Rule #2: **Read as though your life depended on it!**
Develop a healthy file of magazine articles, clippings, and photos. Ask friends to save articles for you. Next, read outside your area. Look at magazines about ultralights, hang-gliding, boats, motorcycles and cars. The auto makers are going crazy over aerodynamics. Did you know that the model-airplane magazines have some dandy articles on aerodynamics that even you and I can understand? Look at the ads in the IHPVA publications, the bike magazines, and magazines like Popular Science. Buy some books, especially the ones from the IHPVA. Don't forget the reprints from the IHPVA Symposia. They're tops!

Rule #3: **Set your priorities.**
Now that you know what type of vehicle you want to build, take time to list vehicle traits you consider most important and those least important. Consider the following: visibility, ingress and egress, weather protection, handling, luggage capacity, lighting, top speed, ease of adjustment for other

riders, hill-climbing ability, comfort, handling in tight spaces, safety, crosswind sensitivity, ease of starting and stopping, and vehicle storability. Let's take some examples and see where they lead. (Compromise is about to rear its ugly head.)

Let's say you want a street commuter that's faster than a speeding bullet. Now we get to start deciding the actual vehicle layout. Shall we use two wheels or three? How about a full fairing? If we intend to be faster than a speeding bullet, we need a full fairing, right? Yes, but this is a street commuter, and a full body can be a pain to get into. How about stopping? Since it's hard to put your feet down with a full body, we better make this baby a trike. Since this trike is going on the street, we don't want to be eye-level with the exhaust pipe of a Buick. Better get 'er up off the ground a bit. Oops, tall trikes tend to tip. We better widen the wheels out for stability. Hey, this thing's getting huge!

...By now, I'm sure you see the problem. Every decision about layout affects other parts of the design. This leads us to our next iron-clad rule.

Rule #4: **Don't lock yourself into a design any earlier than necessary.**

Do some rough sketches, and make some notes on several solutions. Always give yourself many options on vehicle layout in the early stages. A little extra time spent evaluating will keep you happier later.

Steve Delaire illustrates Rule 3: Your best friend is your T-square.

Rule #5: **Your T-square is your best friend.**

Now that you have the final layout decided, boy are you in for a big surprise! Even if you've never used a drawing board and T-square in your life, you better learn now. Take the time to do some scale three-view drawings of your design. Draw everything from frame tubes to brake cables. Don't forget to allow for the movement pattern of a rider's feet and legs. You don't want to build the vehicle and find the chain passing through your left hip. Remember to allow space to turn wheels and handlebars.

<u>Chassis and Drive System</u>

Before starting the actual design of the chassis, let's take a look at what a chassis has to do. The purpose of a chassis is three-fold. First, it must carry a person. Second, it must transmit the power made by the rider into motion. Third, it must give the rider the means to control that motion. Control of the motion takes the forms of directional control, or steering, and speed control, which is a function of gearing and braking. Now there are a million exotic variations we can get into here which would have us redesigning virtually every part of the bicycle. The beginner has no business trying to redesign the wheel in a first attempt at building an HPV. This is where rule #6 comes into play.

Rule #6: **K.I.S.S. (Keep It Simple, Stupid!)**

In other words, don't complicate the task for yourself by designing something which will require a lot of time-consuming fabrication of special parts. Even if you have a full machine shop, make use of available parts as often as you can. There are too many lessons to be learned to start by complicating matters.

Take a good look at what is commercially available, and use or adapt as much as you can. For instance, my first recumbent used the front of a child's 20-inch (508-mm) frame grafted onto the modified rear triangle from a Huffy 27-inch (864-mm) ten-speed. Will one of the commercially available recumbents do? Problems of alignment and construction can be simplified greatly by using parts cut from old bicycle frames.

K.I.S(imple)S. One flat module (the frame base) lies on the table.

Now, if you have decided to construct your own chassis, don't start just yet. Try making a scale model of the chassis out of balsa wood or bass wood. The model will serve two purposes. First, it gives you a chance to check to see if everything fits. Second, it gives you the opportunity to twist and pull on the model to see if it looks like you will have a sufficiently rigid chassis. Did you know that race car builder Herb Adams uses balsa models of race-car chassis to test the stress loads which will go into the real chassis? Remember that progress is a matter of getting our mistakes out of the system. Balsa wood is much cheaper than steel tubing.

When you start the actual construction of your chassis, there are a few rules which can make life a little easier.

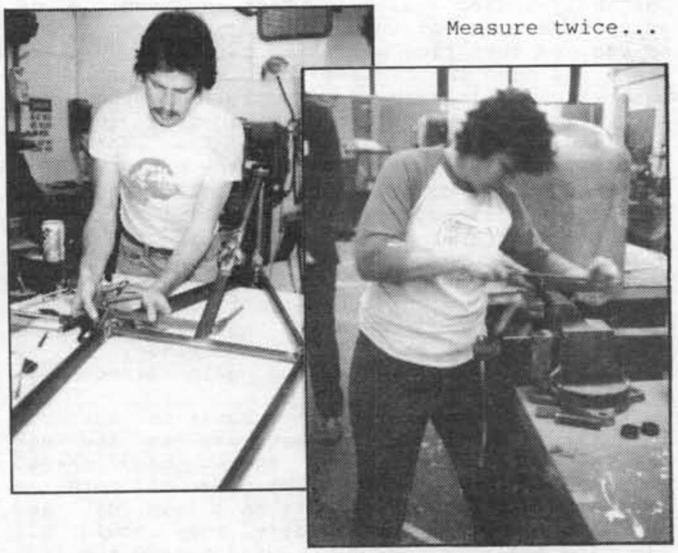
Rule #7: **Measure twice and cut once.**

You can always cut more off, but you can't cut more on! Take a little extra time in measuring and cutting pieces. The time spent fitting pieces will not only save creating expensive scrap, it will also result in a better-looking and stronger chassis.

Rule #8: **K.I.S.S.**

No, this isn't rule #6 again. Rule #8 means Keep It STRAIGHT, Stupid. Alignment is really critical. There are a number of methods of maintaining alignment. Most involve the use of a good straight-edge which is used as a baseline from which other measurements can be taken. For example, if you wanted to check to see if the rear axle was square, a straight edge can be put along the chassis parallel to the centerline of the chassis, and a carpenter's square then used to check the axle against the baseline. Measure everything and double-check every measurement.

By now, you may think that these hints are an attempt to slow you down. Well, here we go agin. When assembling the chassis, make a setup jig into which each piece of the chassis can be securely clamped while welding or brazing. Commercial builders use heavy metal building jigs, which are extremely expensive, and financially impractical for the



Measure twice...

...and cut once. Sharon Smith files a little off a body-mounting part.

one-time builder. A good solid wooden jig may not be ideal, but is far better than holding tubes in your hand as you weld. Sure, the jig takes a little extra time to make, but it will save a lot of grief over poor alignment. In some cases, it will even save time in the long run.

One other hint that may help, is to build sub-assemblies. In other words, don't try to build the entire chassis at once in a single jig. This is especially true for more complex chassis, such as trikes. the basic idea in sub-assemblies is to build a flat unit and later assemble it into a more complex structure.

Drivetrain components should be kept fairly simple at first. Things like idler pulleys and jackshafts may be necessary, but should be based on as many readily-available parts as possible. For example, an old rear gear-cluster can be used instead of a fancy machined jackshaft. Or, an old rear derailleur can become a source for idler pulleys. Further, consider a seven-speed rear cluster, as many designs make mounting a front derailleur difficult.

Body and Mounting

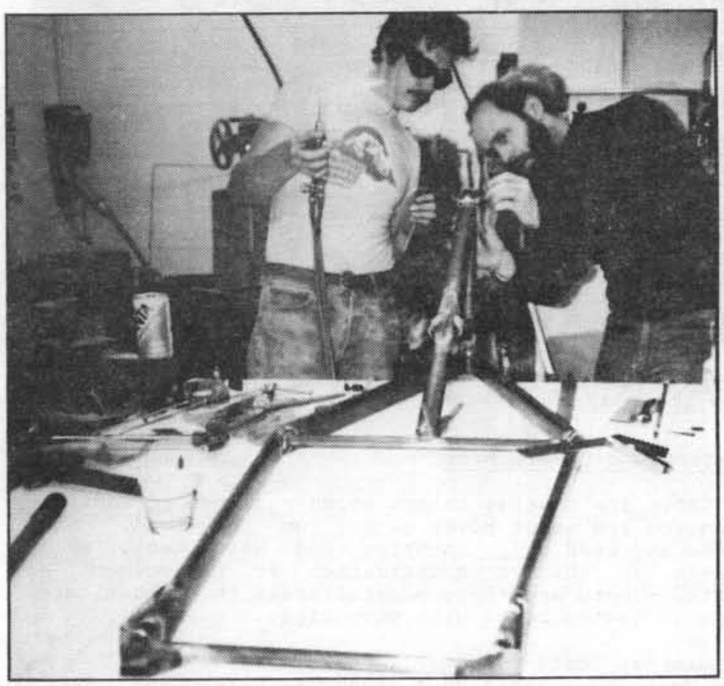
Under normal circumstances, the body on another type of vehicle is used primarily as a means of protection against the weather. Only recently have manufacturers begun to take advantage of the body as an aerodynamic device used to improve vehicle performance. However, the HPV uses a body almost entirely for its aerodynamic function. The simplest partial fairings may offer a one- or two-mph speed increase, while an efficient full body may offer a 50% top-speed increase. The full body offers the greatest performance benefits, but is also more difficult to make.

We have already mentioned partial and full bodies, but there are also hard- and soft-shell bodies to consider. Soft bodies are usually some sort of fabric or plastic film stretched over a framework. The soft bodies have the advantage of being light-weight while giving away a little in aerodynamic efficiency. Currently, most of the soft bodies are of the fabric variety, and are made of a stretch fabric such as Lycra or Spandex. Some very successful fairings have combined fabric sides with a plastic nose section, such as the large one made by Glen Brown of Zipper Fairings.

The hard bodies are usually made of some sort of fiber-reinforced plastic such as fiberglass or Kevlar. Here the construction problems get a bit tougher than with soft bodies. Fiberglass is usually made by laying up material in (or on) a mold. The problem of mold construction is outside the scope of this paper, and may well be outside the resources of most beginning builders. However, a good hard-shell body can be made by laying fiberglass over a foam plug. Here the main caution is material compatibility. Not all foams and resins are kind to each other. The common (and cheapest) resins are the polyester variety, but they absolutely ruin the common styrofoam sheet (also the cheapest). If using styrofoam, epoxy resins are a must. But epoxy is tricky to mix, and is much more costly to use than polyester. Epoxies can also pose a greater **health hazard.** The other choice for foam is the polyurethane group. These are a lot easier to work with than styrofoam, but lack the strength. They are about twice as costly. This type of construction is used extensively in home-built aircraft. By far, the most popular choice is urethane foam and polyester resin. I highly recommend this combination.

While on the topic of airplanes, let's move to the next screwball suggestion, which will initially look like a waste of time. Go down to the local hobby shop and buy a model airplane kit. I don't mean the boring plastic kind: get one of the balsa and tissue variety. Pick out a plane-model with a really nice streamlined body, like a Spitfire, a Thunderbolt, or a Focke Wolfe. The education you will get from assembling bulkheads, ribs, and longerons will give you some great ideas about how to build a foam master.

Once you build your foam master, fiberglass the outside and get ready to make some decisions. If you don't mind some extra work, try a single layer of 6-oz cloth (6 dry oz = approx. 0.18 kg) on the outside and open up the mold. Remove all the skeleton of bulkheads and longerons and sand the inside foam to a smooth inner contour. Put a second layer of 6-oz cloth on the **inside.** This is called sandwich construction or composite structure. It has the best strength ratio for a given weight, but it has a very fragile surface, and is a real bear to repair. If you are in a hurry and don't mind a little more weight,



K.I.S(traight)S. Alignment is tested against a baseline with a straightedge.

just put two layers of 10-oz cloth on the outside (10 oz = approx. 0.3 kg), then open it up and remove all the foam. This gives a heavier body, but it also gives a body which has a lot better resistance to all the minor dents and dings the vehicle may see in day-to-day use. It's also a lot easier to repair than the sandwich structure.

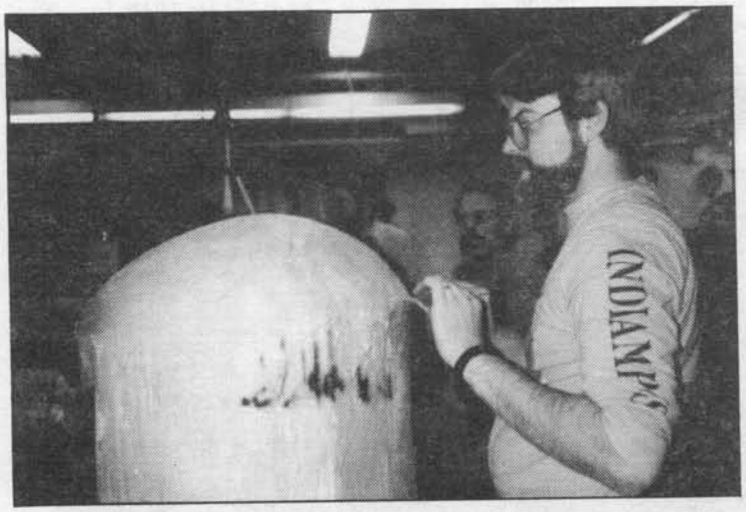
Okay, time for some final comments on bodies. Take time to do more study on body shapes. The whole secret of moving quickly is to do the least amount of work to push the air. There are two factors to consider. First, the bigger the body, the more air you have to push. Second, the cleaner the body shape, the easier it moves through the air. Most of the successful body shapes use what are called laminar-flow body-foils. This brings us to rule #9.

Rule #9: **Keep the body shape smooth.**

Air doesn't like to change directions. Keep the airflow as constant as possible. A nice continuous curve is much better than flat sides and corners. Since foam comes in nice flat slabs, this makes it a bit tougher to make that nice curved shape. (See why I told ya to get that model airplane?)

Now the final item on bodies - mounting the critters. Here again, you need to go back and look at rule #6. (Go ahead, I'll wait while you do.) Some of the body-mount systems in use today weigh more than the chassis. here are a few handy hints which you might want to use to help get an efficient and light mounting system that is easy to use.

- Keep all mounting tubes as short as you can to avoid weight and flex.
- Spread the mounts far apart to keep the body from rocking on the frame.
- Reinforce the body at all mounts to avoid tearing.
- Avoid using bolts with loose nuts on the inside. Braze the nuts to the frame.
- Think access. Make it easy to get the body off. You might need to change a tire or adjust a derailleur.
- Go to the local hot-rod or speed shop and get some Dzus fasteners. These are used to mount most race-car bodies - light, tough, and quick to open.



Indy's graphic artist Mark Baldwin applies Rule 7: Keep the body shape smooth.

Testing and Development

There are several things which you need to look at when you are about ready to get on the road. Some items may need only tinkering and adjustment, while others may involve modification or replacement of parts. There are three general areas to investigate. Each is listed below with some hints.

Mechanical Tests

- Test the chassis on a stand or workbench. Don't risk your neck on the street until you know chains won't jam and cables won't bind.
- Bounce the chassis around. Check for flex. Stress it. If you can break or bend it by hand, it sure won't last on the road.
- Hop on and test for clearing, fit, and handling. Make sure that you don't have pedal or steering problems. Go slowly and build speed gradually. There's no guarantee this puppy won't have some hidden handling traits - keep away from traffic for a while.
- Thoroughly test the chassis before mounting the body.

Aerodynamic and Body Tests

- Mount the body and test clearances. Make sure you have adequate steering with the body mounted.
- For bikes, test for adequate lean. Anything less than 45 degrees could be a good way to acquire some new scar tissue when you try that first hard corner.
- Crosswinds are the curse of many full- and partially-bodied vehicles. Test the vehicle in an open parking lot on a windy day. Park a car or van and then ride past it carefully. Start wide, and move in closer. If the vehicle is squirrely, don't give up. There isn't space for a full discussion, but we have had good luck by playing with the placement of the center of gravity in relation to the center of pressure. The c.g. should be slightly in front of the c.p. This is true especially if you have a lot of weight at the rear of the vehicle. I know that adding tail sounds as though it would make the crosswind problem worse, but it can help. There is no way to eliminate the effect of crosswinds, but the idea is to make them liveable and controllable. We can't lick crosswinds, so we have to figure out how to gain directional stability instead.
- The only aero-test that we will cover is tuft or yarn testing. This is a great way to see how airflow works along your chosen body shape. Every few inches, tape a short piece of yarn on the body. Go out and ride it on a calm day and see what the tufts do. Ideally, they should all lie nice and flat, and be pointed toward the back of the vehicle. If some flutter, you have turbulence at that part of the body. If they droop, you have a bubble of dead air where the airflow has separated. Try taping crushed newspaper onto the body, taping over the area with masking tape to smooth out the surface. In this way, you can quickly try new body contours in areas which look bad. Pieces of poster-board can also be taped over the body to modify contours. Remember what we said in rule #9 about air not wanting to turn corners. Keep the contours smooth.

Weight Reduction

This is another of the big problem-areas for streamliners. There are several areas to examine.

- Now that you have a working prototype, can you use lighter materials anywhere? (This usually means more money.)
- Can you use <u>less</u> material? Will a thinner body shell work? Thinner chassis tubes?
- Can some items be made smaller? Look at everything from the body to the wheels to the seat.
- Finally, see if some items can be eliminated entirely.

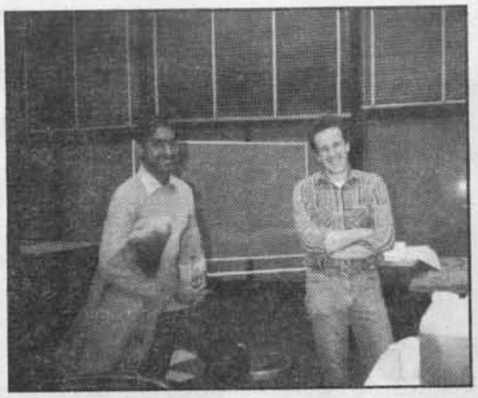
Summary

This advice has been presented not as a complete guide to every aspect of HPV building, but rather to help you see that building one of these streamlined plastic pods is far from impossible for most of us. Keep your eyes open, and never stop looking for a better way to get the job done. Plan carefully, and do your research well. As a final note, I'd like to pass on the most valuable lesson I've learned in building HPVs.

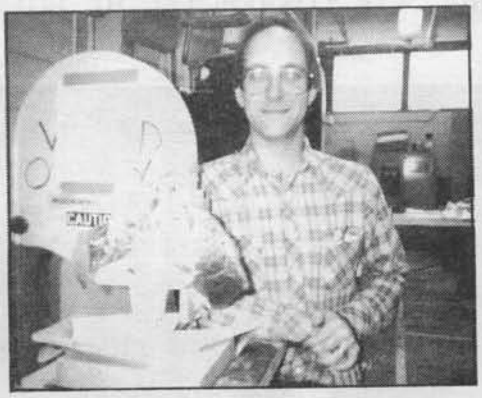
A friend of mine refers to himself as a master of quick-and-dirty design. Now, don't get the idea that he is sloppy or careless in his work. He's a superb craftsman, but he will use a piece of broomstick and a hose clamp every time if it will do the job. He has no use for spending dozens of hours and hundreds of dollars to make a fancy, machined, heli-arced chrome-moly piece **until he is sure that the piece will work.** <u>Then</u> he will make the good part.

Remember, we are pioneers exploring new territory. Give yourself the opportunity to cover as much ground as possible. Thanks for bearing witness - have fun, and let me know how things turn out!

Terry Hreno
56 Sunset Manor
Mooresville, IN 46158
(317) 831-7271



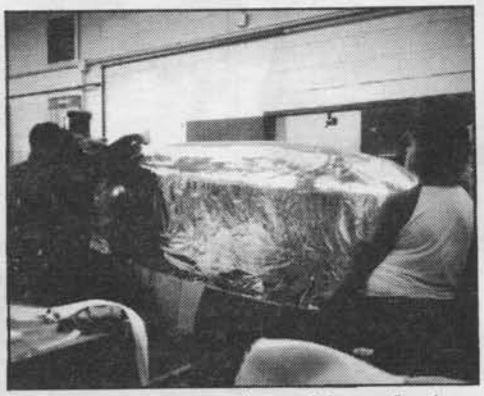
Workshop instructors Ashok Bhatnagar (l) and Terry Hreno (r).



Rich Wianecki of Chicago shows off his "oven", making a Kevlar-honeycomb "sandwich".

Dave Pearson gets a hand in.

Blake Davis checking the smooth surface of the HPV fairing built by the workshop participants.



"Quick and dirty" mold-surfacing of aluminum foil covered with Saran Wrap was necessary because of time limitations.

CALENDAR

AUGUST

9-11 Hull International Cycling Festival Hull, Quebec, Canada. (8th August, registration) 200 meter sprints, Tour de la Gatineau, Road Races. At least $5000 Canadian in prize money. "Promises to be better yet more relaxed than last year."
Contact: Dennis Taves (613) 238-2718 110 Frank St Apt 1 Ottowa, Ontario K2P 8X2

18 HPV Cycle Event Denver, CO. Sponsored by the Colorado HPV Club, event may include time trials, or a simple HPV demonstration/ride.
Contact: Dan Nibbelink, (303) 277-1882.

25 (tent.) HPV Event at Imperial War College England. BHPC in conjunction with Battery Vehicle Society.

31- Zapple Festival of Human Power Milton Keynes, England.
1 Sep Land, air, and water events, Practical Vehicle Competition. See the write-up in this issue.
Contact: Peter Selby, 13 Tristan Sq., London SE3, England.

31- First Deadline for Preregistration 11th Annual Human-Powered Speed Championships, Indianapolis, IN.
For inclusion in the program, preregistraion must arrive by August 31st. Fee for registration on or before this date is$40.00.

1986 - August 18-24, 12th International Human-Powered Vehicle Speed Championships EXPO 86, Vancouver, BC.
Human-Powered Transportation August 25-31, 1986. EXPO '86.
Contact: Klaus Schmitt (604) 736-6198, 1396 Laburnam St, Vancouver, BC, Canada.

SEPTEMBER

1- Deadline for Registration for Commuter Vehicle Competition, 11th Annual Human-Powered Speed Championships, Indianapolis, IN.
For competition in the Commuter Vehicle Competition, entries must be postmarked no later than midnight, September 1st. There will be NO walk-in registration for Commuter Vehicle competitors.
Applications received after September 1st (until the 15th) will be $45.00.

4-8 Mountain/Plains State Regional Bicycle Conference Austin, TX. No details available.
Contact: Kathy Walter or Joyce McAlister (512) 499-2475 or (512) 499-2476, Austin City Council, 8th and Colorado, P O Box 1088, Austin, TX 78767.

8 Front Range Century Denver, CO. Many HPV's ride in this LAW century sponsored by the Denver Bicycle Touring Club. An attempt is planned on the IHPVA 24-hour distance record.
Contact: Ken Cummings (303) 424-8841.

15 Deadline for Pre-Registration, 11th Annual Human-Powered Speed Championships, Indianapolis, IN.
Entries must be postmarked no later than midnight, September 15th to qualify for the $45.00 entry fee level. Entries mailed after the 15th, and walk-in registrations, will be $55.00.

15 HPV Cycle Event Denver, CO. Sponsored by the Colorado HPV Club, event may include time trials, or a simple HPV demonstration/ride.
Contact: Dan Nibbelink, (303) 277-1882.

26-29 11th International Human-Powered Vehicle Speed Championships Indianapolis, IN.

THE WATERBUG - A COMMERCIAL HP BOAT

Comfortable exercise and mobility on the water - you can start to watercycle right away, without formal lessons.

[Advertisements from Harken-Vanguard for an attractive one-person HPB have been displayed in boating magazines. I wrote to the Harken brothers to ask if they or Gerry Hoyt, the designer, would let us have an article about the **Waterbug** and its design. Gerry Hoyt replied as below. I have asked if he would send us some more design details for a future issue. Meanwhile, if any of you take the Waterbug for a spin and would send us a test report, we would welcome it. -Dave]

The **Waterbug** was conceived as a safe, simple, efficient, all-weather one-person craft that virtually anybody could operate. Speed was a consideration - but not the primary goal. It can be seen that these criteria dictate some rather different approaches. For example, rowing a shell is quite efficient propulsion, but it is neither safe, simple, nor all-weather. There has been some excellent progress in speedy propeller-driven designs, but these craft again fail to be safe, simple, or all-weather.

As a pilot, I was drawn to the idea of a streamlined capsule that could minimize aerodynamic and hydraulic resistance. Ballast became necessary as a feature of safety, and desireable as a means of preserving momentum and providing a lower aerodynamic profile. While minimizing the drag factors, we have paid special attention to maximizing the drive factor. The Harken resources in low-friction ball bearings were instrumental in producing a very efficient marine-drive mechanism that includes a gear shift to cut down leg motion.

In contrast to the many paddlewheel boats one sees at resorts, the Waterbug is highly maneuverable, and can easily move to windward against a thirty-knot breeze. And I am happy to report that pedalling a bug is aesthetically very pleasing as well as excellent exercise.

The Designer: Gerry Hoyt is the designer behind Freedom Yachts, innovative cruisers that popularized the free-standing spar for cruising boats. Hoyt has designed boats from 21 to 70 feet, and has patented a variety of his inventions relating to sailing gear. The Waterbug is a result of his lifetime study of movement through water - as a competitive swimmer, surfer, skin diver, and sailor.

Gerry Hoyt
Freedom Yachts
49 America's Cup Ave
Newport, RI 02840
(401) 847-7475

The Builders: Peter and Olaf Harken are primarily known for their low-friction ball-bearing blocks which are used on racing and cruising boats around the world. Their company, Harken-Vanguard, has also pioneered in the high-tech construction of racing-class sailboats, including the Finn dinghies that were used in the last two Olympics.

Olaf & Peter Harken
Harken-Vanguard
1252 E Wisconsin Ave
Pewaukee, WI 53072
(414) 691-3320

DESIGN AND DEVELOPMENT OF A WINTER TRICYCLE

by H Frederick Wilkie II,
reported by David Gordon Wilson

[As noted in the editorial of the last issue of HP, Fred Wilkie put me firmly into, and on to, recumbents. After I had organized an international HPV design competition in 1967-69, he wrote to ask for sketches and ideas on advanced HPVs, and built and used two recumbents. That story and its sequel are told in the Second HPV Scientific Symposium of the IHPVA. Fred left Berkeley and the study of English Lit. for Canada, the rigors of the weather and the study of engineering, part-time, at Algonquin College. The following piece is my attempt to do justice to his thesis for his 1983 diploma in technology. Fred didn't have time to write an article for us, as he was leaving for Bangladesh to introduce a new design of tricycle rickshaw. We will have something about that in the next issue. -Dave]

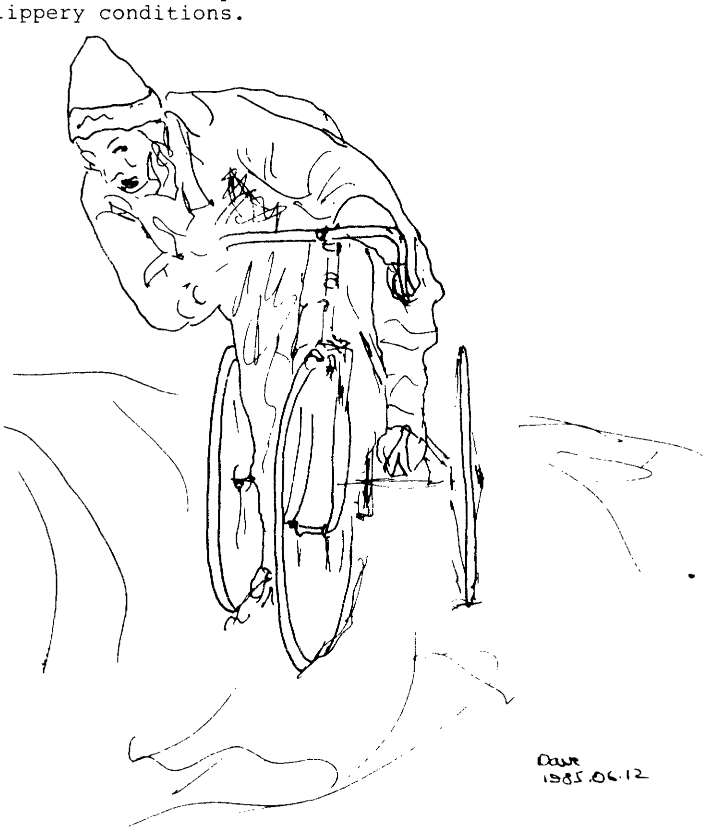
* * * *

Summary

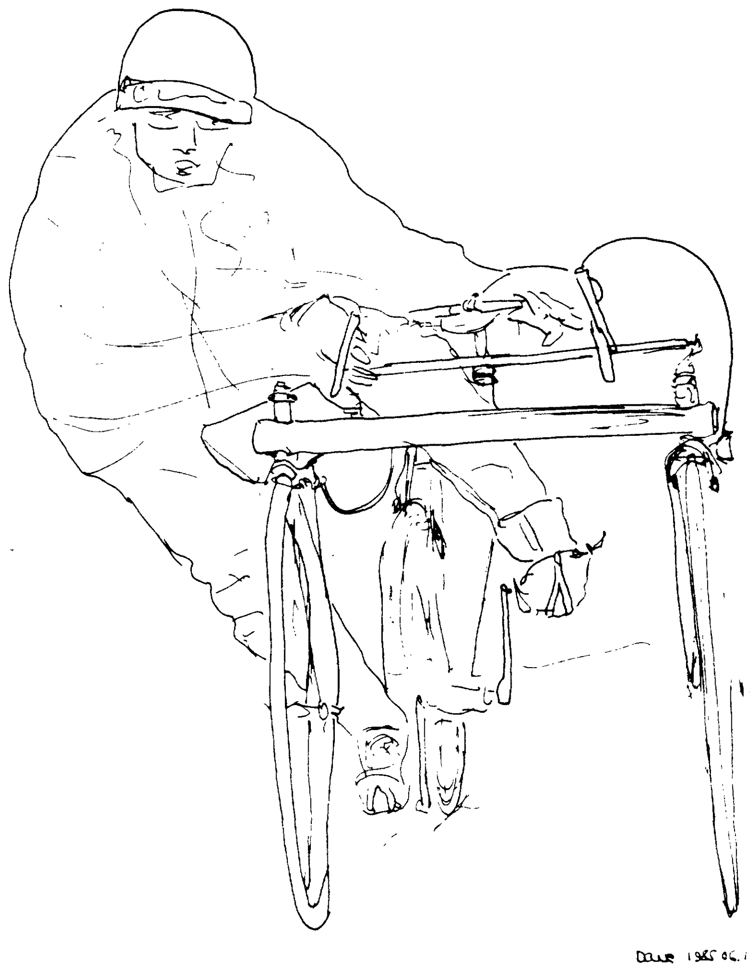
This is a condensed account of the development, over eight years (1974-82), of four tricycles for use in the snow, ice, and slush conditions of Canadian winters. It is a text-book case of engineering design, where each vehicle overcame disadvantages of its predecessor but introduced unsuspected difficulties. The fourth, an articulated tricycle with double front steering wheels and single rear driver, approaches the optimum design within the restrictions of current materials, one-off construction, and a limited budget.

Background

Ice, snow, and slush produce the risk to the urban cyclist of falls and of sliding into the paths of motor vehicles. Three wheels can produce a considerable degree of added stability. They can be configured in a two-track, sidecar arrangement, or in a three-track conventional tricycle plan. Despite the added energy requirement of having to compress a third track in snow, the tricycle arrangement was chosen because of its symmetry in right-hand and left-hand turns, and its potential for better traction in slippery conditions.



Tricycle 1 - Rogers Conversion Unit showing contortions required in cornering.



Tricycle 2 - An improvement over 1, but contortions still needed.

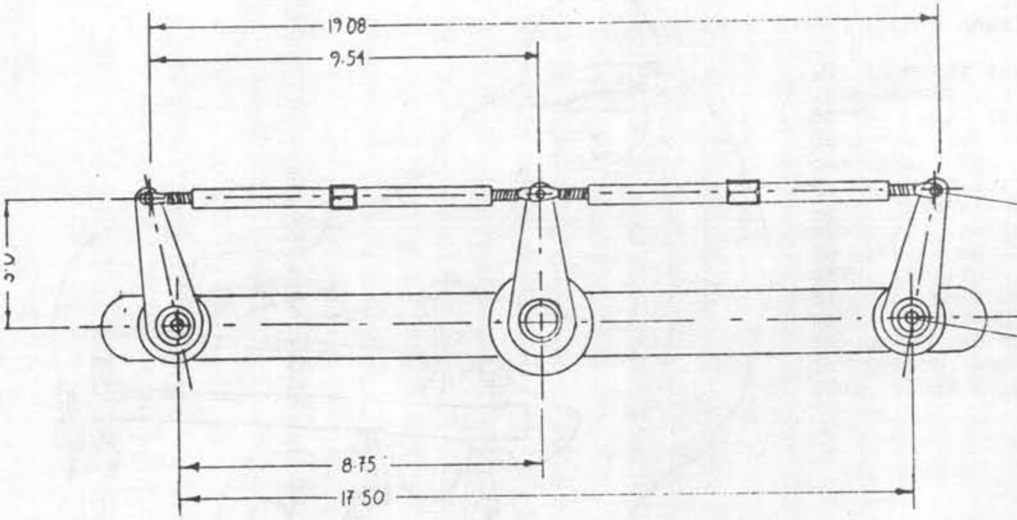
Conventional Racing-Tricycle Configuration

Tricycles can be made with the single wheel at the front or at the rear. The first of the four tricycles constructed in the sequence reported here was similar to modern racing tricycles, with a single steered front wheel and twin rear wheels, only one of which is driven. (Up to the end of the 1950s, tricycles were available with derailleurs and drive to both rear wheels, but the manufacturers went out of business.) To achieve traction on icy surfaces, the rider must lean his/her body mass over the single driven wheel while pedalling. Fred Willkie used this type of tricycle through two Canadian winters, and developed lower-back problems that were serious enough to require extended treatment, and that impelled him towards improved designs.

Single Rear Driver With Ackerman Steering

Although the incorporation of a differential gear would produce a balanced driving torque on both rear wheels, and eliminate the necessity for body lean over one wheel, there is still the need to steer constantly up the slope of a crowned slippery road, and the tendency of the wheel with the least resistance to loose traction on both. Willkie chose to change to a single rear-driving configuration, which enabled him to use conventional bicycle components, and twin steering wheels with automobile-type Ackerman linkage for the last three tricycles.

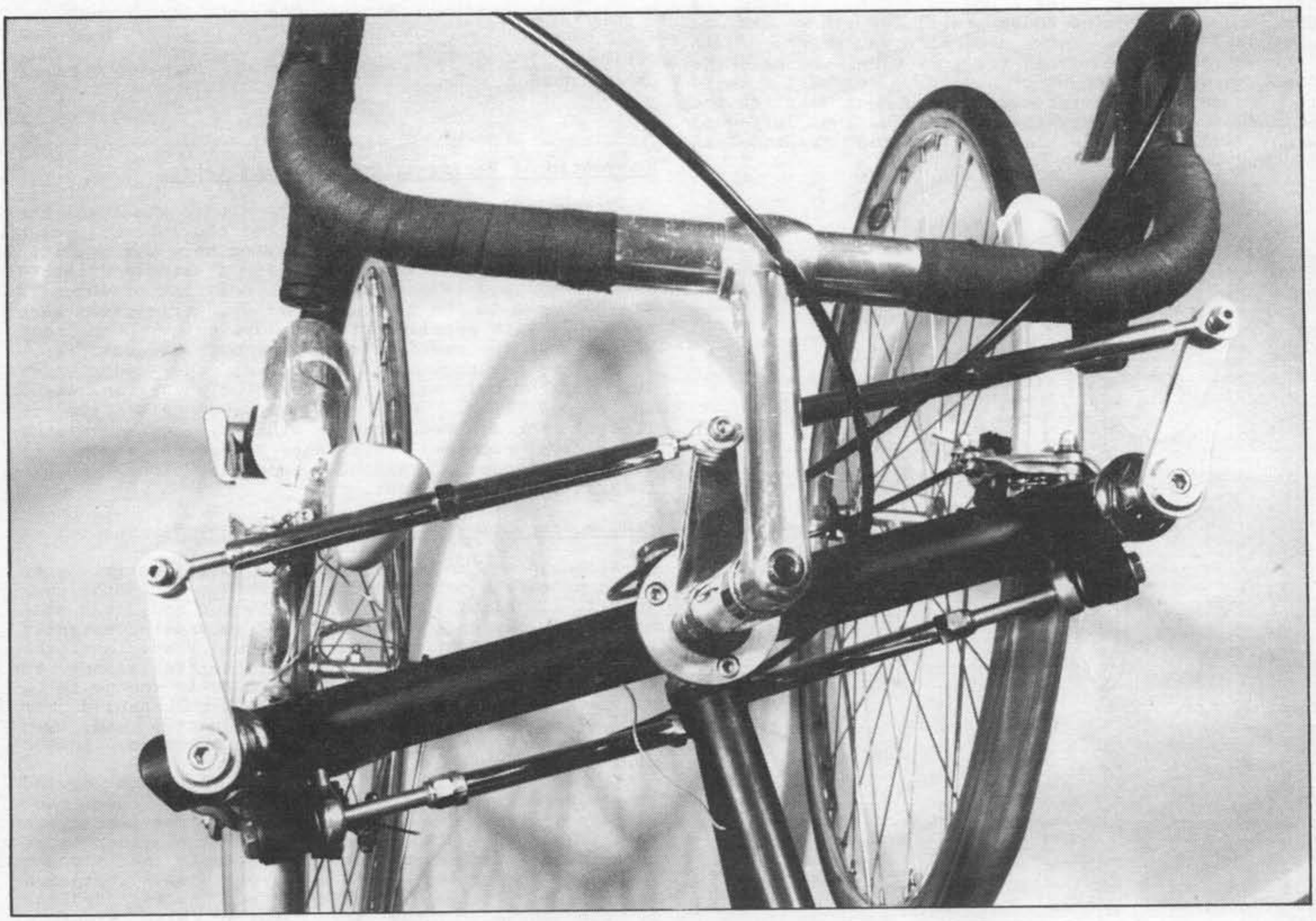
Unfortunately, this configuration, although giving some improvement, did not solve his lower-back problems. Tricycles of either of the first two types do not lean into a turn. Therefore the rider must perform an exaggerated lean to counteract the tipping torque. This action requires simultaneous rotation and lateral flexion of the lumbar and sacral regions of the spine. These are combined with vigorous



Ackerman Steering linkage, Willkie Tricycle-4.

Tricycle 3, with articulated frame, greatly reduced lower-back stress.

Overhead view of links and steering, Willkie Tricycle-4.



pedalling action of the quadriceps muscle of the thighs, with frequent road shock on the already stressed spine, and with very low, circulation-inhibiting temperatures to produce soreness and structural damage to the muscles, nerves, and vertebrae of the lumbar and sacral regions. Fred was plagued with these problems through the five winters from 1974-79.

Articulated Tricycles

The third and fourth tricycles greatly reduced lower-back stress by having the rear-wheel subframe with pedals and seat articulated to the steering subframe, allowing rotation about a horizontal axis. Thus the rider could lean into a corner as on a bicycle. The two front wheels and handlebars remained horizontal, however. Fred incorporated springs between the two subframes to control their relative rotation. Their action was approximately linear, and it became apparent that a highly nonlinear response was desireable.

The fourth tricycle incorporated two links, visible in the overhead photo, with springs consisting of skateboard-wheel tires in compression, to limit the degree of rotation between the two subframes. Fred would like to experiment with an added handbrake to enable the relative rotation angle to be locked temporarily when rounding a curve, so that the upper body can relax. This photo also shows the Ackerman steering linkage.

Some Details

Experiments showed that it is better to use thin-tire, large-diameter wheels in snow and slush than to try to use a large-enough tire section to "float" on the snow. The resulting drag from motocross tires was very large.

Fred Willkie is a master frame-builder and craftsman, and a designer with a meticulous attention to detail. Some of these details are evident from the two photographs. The use of a weather-proof oilcloth chain case keeps salt, dirt, and moisture out of the driveline components. (He used a Fichtel & Sachs two-speed hub.) The bottom bracket he fitted with a grease nipple, a Schrader air valve and a solvent-admission port so that he could clean out old grease and relubricate without disassembly. Other bearing incorporated grease nipples.

He experimented with the front-wheel track width and arrived at a compromise that gave him sufficient stability coupled with narrowness that enabled the trike to be ridden through narrow gaps and carried up apartment stairs: 17.5 inches (444 mm).

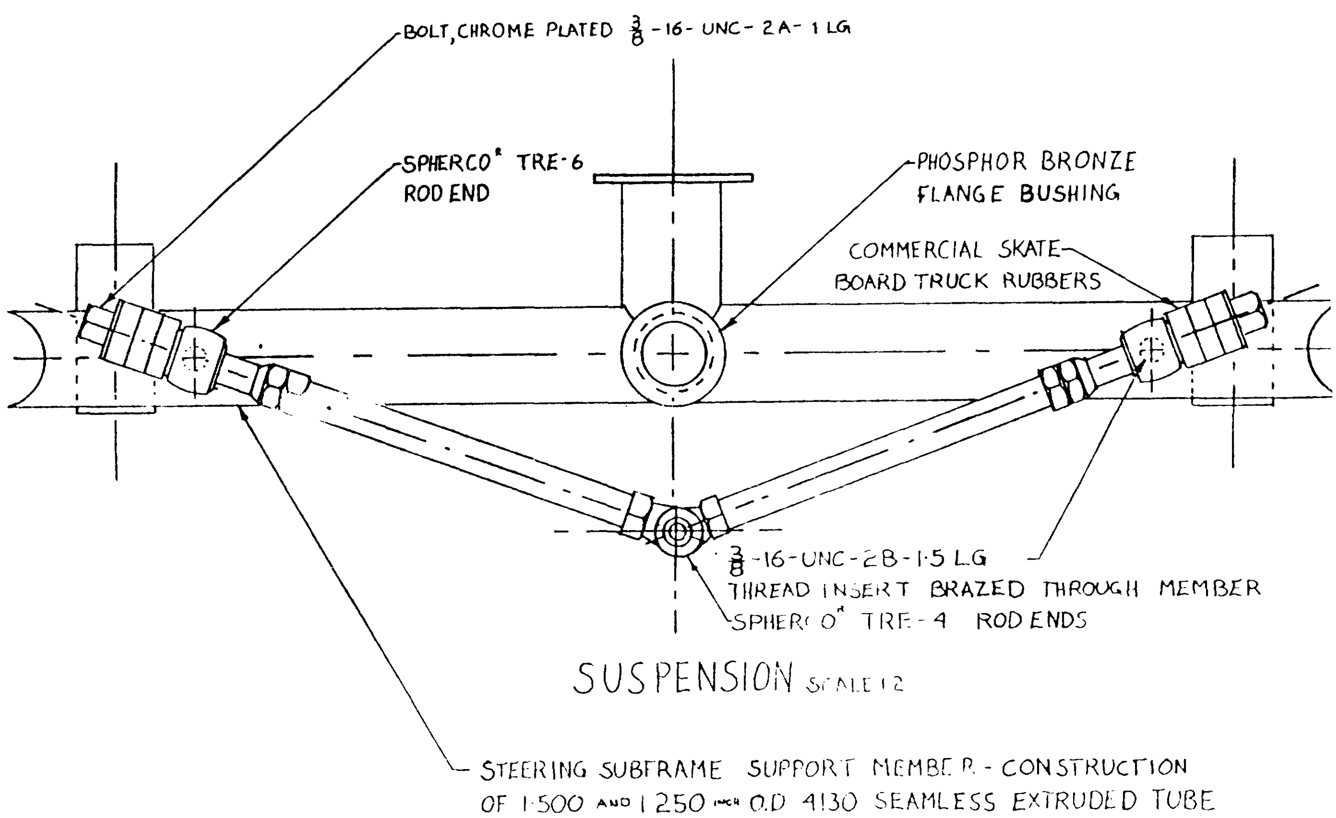
His thesis has discussions on materials, on the selection of optimum frame geometry, on muscular-skeletal effects, and construction details. The photographs and illustrations would be very useful to a builder, but my copy of the thesis is too blurred to enable much to be gained from the photos. However, I would be happy to have it copied at MIT and mailed - it has 83 pages, so a check for $10 payable to MIT would cover it. When Fred returns to Canada, probably by the end of the year, he should be able to supply better copies. If you use his work, treat it as copyrighted, and give full acknowledgement.

H Frederick Willkie
c/o Inter Pares
GPO Box 311, DHAKA
BANGLADESH

and later at:
Seven Heart Cycles
204 LaBreton St N
Ottawa K1R 7J1
CANADA

Send money for copies of Fred's thesis to

David Gordon Wilson
15 Kennedy Road
Cambridge, MA 02138



Relative rotation limiter on the fourth tricycle.

EASIER PEDALLING FOR THE HANDICAPPED: ADAPTATIONS OF THE **JOYRIDER** PEDAL MECHANISM

by Des Messenger

In an endeavor to arrive at a new approach to the problem of adapting the human engine most efficiently to the task of supplying motive power to a human-powered vehicle, certain basic facts have been accepted.

1. Nature is both the Supreme and a superb designer, and none of nature's creatures, except man pedalling a bicycle, propel themselves by means of a circular motion of the limbs. The nearest perhaps is the figure-of-eight motion of a bird's wing. (ref. 1)
2. The circular motion of the feet when pedalling a standard bicycle, because of the varying moment arm, must result in variable stress in the muscles if a constant torque is to be maintained on the chainwheel. This situation is further aggravated by the geometry of the leg motion which approximates that of a toggle joint with variable foot thrust for a given muscular effort as the leg straightens out.
3. The geometry of the circular movement of the standard bicycle crank is such that useful work can be produced only during about 100 degrees of rotation (28% of the total foot movement). By contrast, a reciprocating motion produces useful work for 50% of total foot movement.
4. Again referring to nature, most creatures propel themselves by rhythmical reciprocating actions of the limbs, thus lending credence to the argument that the muscles would work most effectively and efficiently when operating at a fairly uniform stress.

In view of the foregoing, and notwithstanding the fact that nearly all data on human power ability to date have been derived from the cycling mode, the writer decided to investigate the use of reciprocating motion of the legs to exploit the capabilities of the human engine.

The two prevailing arguments against this method have always been the difficulty of transforming reciprocating motion into uniform rotary motion, and the penalty paid for sudden load reversal at the end of the stroke. The matter of transforming reciprocating motion into uniform rotary motion no longer presents any real problem with the ready availability of many excellent types of form-sprag or over-running clutch bearings.

When considering the problem of load reversal it might be useful to look at the leg thrust generated by uniform muscle stress, and to compare this to the pedal loads necessary to produce a uniform torque on the chainwheel of a standard bicycle.

To arrive at the ordinates for the graph (Figure 1), two methods are suggested for the approximation of the leg leverage (thrust-generating) system. The first treats the upper and lower leg as the links in a toggle mechanism actuated by an exterior force applied

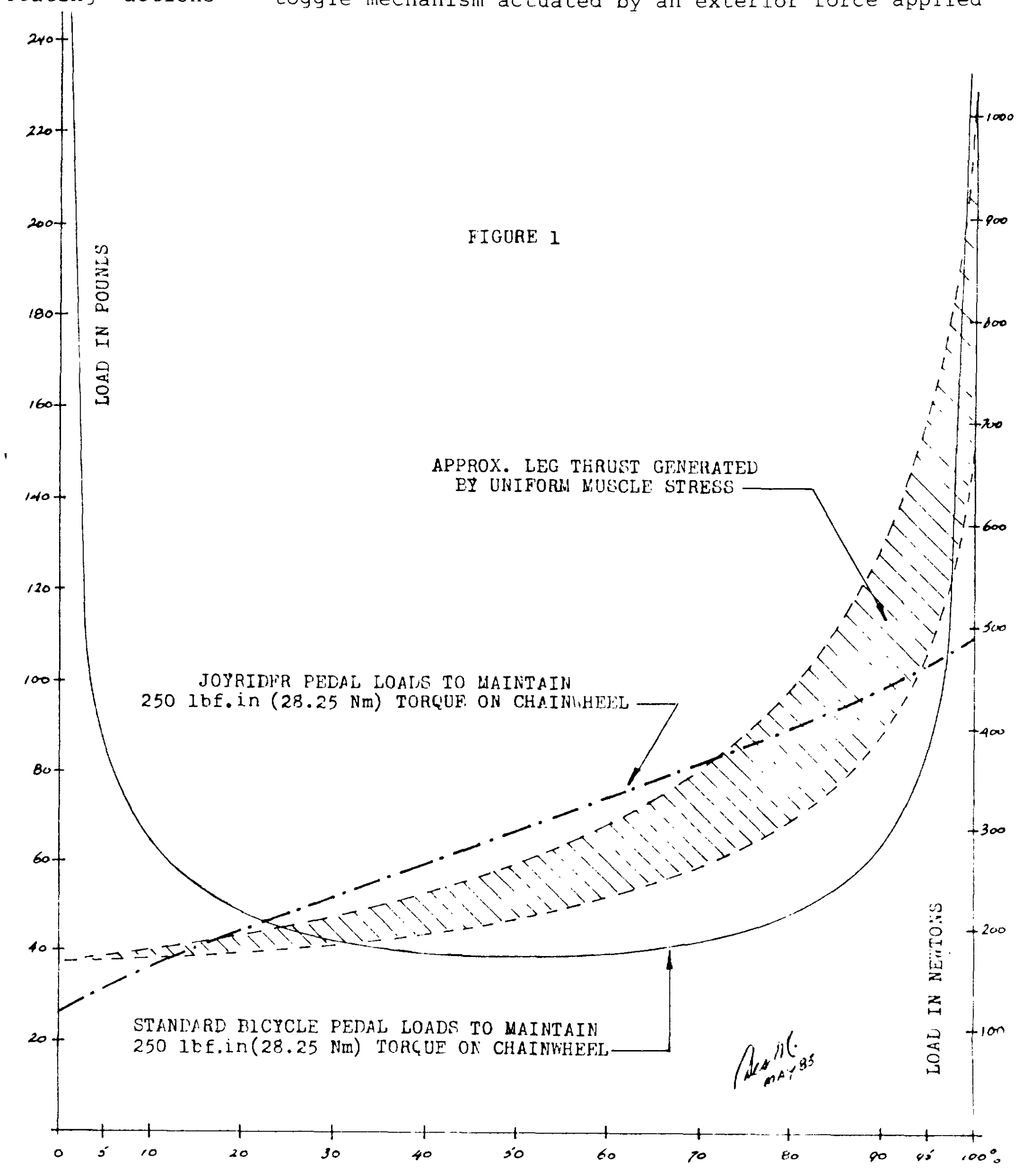


Figure 1. PERCENTAGE OF TOTAL PEDAL STROKE OF 13 INCHES (330 mm)

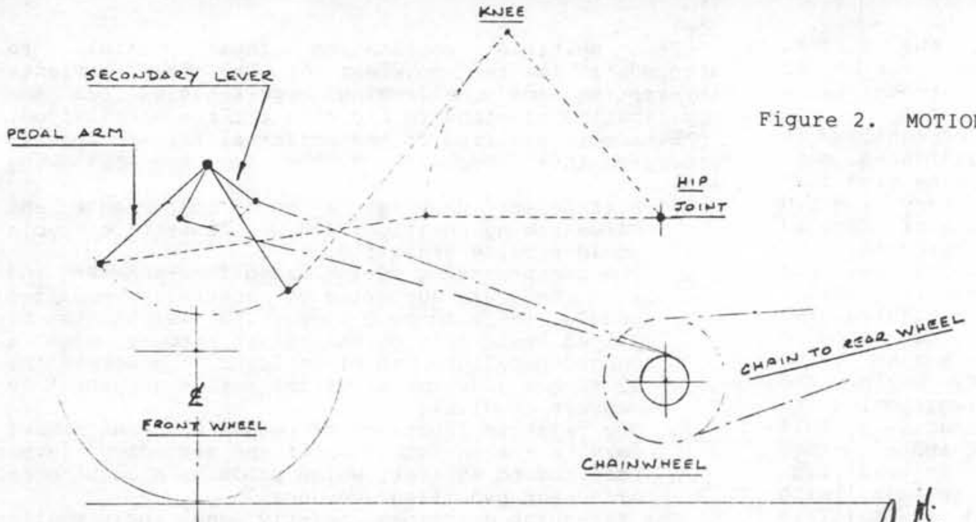


Figure 2. MOTION IMPARTED BY SECONDARY (RETURN) LEVER

to the knee. The second method considers the actuating forces to be contained entirely within the linkage, and is probably more accurate. Somewhere within the envelope contained by these two curves (shaded in Figure 1) probably lies the actual load distribution for uniform muscle stress. It is interesting to note that the diagrams on pages 269-270 of **Bicycles and Tricycles** bear a distinct resemblance to those obtained as above and the comments of Sharp (section 214) would seem to bear out the contention that muscles tend naturally to work at a uniform stress.

As the figures obtained by the methods referred to are only ratios of pedal thrust relative to the initial thrust at the beginning of the stroke, they have been adjusted to compare with the pedal-load requirement of a standard bicycle mechanism producing a uniform 250-lbf.inch (28.25 Nm) torque on the chainwheel.

As will be readily seen, uniform stress in the muscles will not produce uniform torque for the first 25-30% of the pedal movement. The momentum of the leg is maintained when spinning, but there is nevertheless a dramatic increase in power necessary at the beginning of the down stroke if constant torque is to be maintained on the chainwheel, and this may well be as tiring as an actual load reversal. In fact, of course, the muscles cannot produce this sudden power surge at the beginning of the stroke, and consequently the chainwheel torque is not uniform.

To overcome this deficiency, it is necessary to introduce another element into the mechanism to compensate for the variable leg force generated by uniform muscle stress and to minimize the variable moment arm of the standard 6-1/2-inch (165-mm) crank. This is accomplished by adding a secondary lever between the reciprocating pedal arm and the bottom bracket, the correct placement of which imparts a variable mechanical advantage to the pedal action in inverse ratio to the leg forces. This is shown in Figure 2.

The pedal loads necessary to generate a uniform torque of 250 lbf.inch (28.25 Nm) on the chainwheel with this improved linkage are also plotted on Figure 1, and are seen to be compatible with the leg thrust generated by uniform muscle stress. Indeed the muscles can start to relax at the end of the stroke, thus recapturing some of the kinetic energy of the feet.

The foregoing briefly describes the rationale for the design of the **Joyrider** mechanism for a recumbent bicycle. During the development of this system it was deemed advisable to try out the actual drive-barrel unit which converts reciprocating to continous rotary motion before proceeding too far with the overall project. Accordingly a retrofit was designed to convert an ordinary bicycle from rotary pedal motion to reciprocating pedal operation. This proved to be a neat and easily-fitted unit, and is illustrated in the accompanying photographs. A Raleigh sports bicycle was the machine chosen for this conversion and it was subjected to severe usage by several riders in 1984 with no discernable wear, slippage, or backlash developing.

In May 1984 the mechanism was assembled on another machine which was entered in the 15-mile HPV road race at the International Cycling Festival in Hull, Quebec. Morgan Lemen of Barrie, Ontario, rode it to place first among the Canadian entrants, and it also placed in the Practical-Vehicle competition.

The adaptation of the Joyrider pedal mechanism to accomodate handicapped riders was not originally contemplated, although there are many who, because of injury or amputation, are unable to ride a standard bicycle. In some cases it is a question of limited joint movement, in others it is the difficulty of

Figure 3. PROTOTYPE MECHANISM ON STANDARD BICYCLE

returning the injured leg to the top of the stroke. For those who ride with one leg only, the problem of returning the good leg to the top of the stroke is a very real one.

Once the prototype was actually in operation, it was realized that this pedal mechanism addressed many of these concerns, and it was about the same time that I was introduced to an amputee who had very limited angular movement in his knee joint because of damaged muscles, and could not ride an ordinary bicycle. He tried out the bicycle described above, which by this time had been mounted on a stationary exercise stand, and observed that if the movement of the injured leg could be restricted, he would find the machine comfortable to operate. The Joyrider mechanism lends itself ideally to such modification. By moving the fulcrum point on the return lever, and lengthening one tie rod, the resulting linkage now produced a full 13-inch (330-mm) stroke for the good leg and a 5-inch (127-mm) stroke (at the bottom) for the injured leg. Further, because it is more comfortable to pedal with the instep of an artificial leg, and to maintain clearance between the toe and the front wheel, the crank on that side was shortened.

A Raleigh sports bicycle fitted with this modified Joyrider mechanism has been in constant use since the summer of 1984, and was ridden around the Indy 500 track during the IHPVA championships last year by its owner, Mr. John Dudra of Orillia, Ontario.

Later in the year, another bicycle was modified for a young lady in Barrie, Ontario, who has a fused knee. The only vertical movement of her leg is that which can be generated by movement of the hips - about 2-1/2 inches (63 mm). Again, by moving the fulcrum-point of the return lever and lengthening one tie rod, a reciprocating pedal linkage was produced which permits her to enjoy once again the pleasures of bicycling.

When fitted to a standard bicycle, the Joyrider mechanism produces a reciprocating up-and-down motion of the pedals, and as these are interconnected by short tie rods and a rocker-arm (the return lever), the downward movement of one pedal produces upward movement of the other. Because this reciprocating motion is converted to continuous rotary motion via a sprag-type clutch, the actual stroke of the legs can be chosen at will from within a certain range (i.e. long, slow strokes, or faster, shorter ones). The mechanism also free-wheels.

The multiple combination thus possible to accomodate limited movement in the legs presents interesting and challenging opportunities for the modification of standard bicycles for the handicapped.

Even more exciting is the potential for recumbents embodying this pedalling system for the following reasons.

1. A recumbent provides a more comfortable and safer riding position, and a recumbent tricycle would provide stability.
2. The reciprocating motion being fore-and-aft, and with the heels supported by specially modified pedals, there is much less leg weight to be lifted vertically on the return stroke; also a longer pedal arm can be employed to generate the 13 inches (330 mm) of useful motion (approx. 90 degrees angular).
3. The relative locations of pedals and chainwheel permits the introduction of the secondary lever referred to earlier, which produces a much more efficient pedalling sequence.

The foregoing describes briefly one individual's ideas for extending the pleasures of cycling to some of our handicapped friends, but there must be many other approaches and solutions to these problems. Surely within the IHPVA, whose members have created human-powered machines to fly the English Channel, attain land speeds of 60 mph, and out-perform the racing shell, there are those whose talents, if directed to this challenge, could help ease the mobility problems of so many of our brothers and sisters.

Perhaps this article will be a catalyst for such action. I hope so, and freely offer any help I am able to give those so motivated.

Des Messenger
P O Box 254, Orillia,
Ontario L3V 6J6 CANADA
(705) 326-9423

REFERENCES

1. **Man-Powered Flight,** Keith Sherwin, Model and Allied Publications 1971, p.156.

2. **Bicycles and Tricycles,** Archibald Sharp, MIT Press 1982, pp.269-270.

Figure 4. CYCLIST OPERATING PROTOTYPE

THE PHOENIX INFLATABLE HP AIRCRAFT

Summary by David Gordon Wilson of a paper by F. E. To

[In February 1984, a rather remarkable symposium on human-powered vehicles was held. It was remarkable not only for its content, but particularly for its location and context. The location was Detroit, and it was part of a congress annually given over entirely, in the past, to petroleum-fueled vehicles by the Society of Automotive Engineers (SAE). The person who deserves full credit for this delightful development is Jeff Huston, a member of the engineering science and mechanics faculty at Iowa State university and, of course, the SAE. Two of the papers have been been published in Allan Abbott's Second Scientific Symposium (IHPVA). Another has already been published in HP in a shortened version, and another will, I hope, be given in the next issue, if the author responds to my request. However, all attempts to elicit a response from F. E. To, president of the Air Plane Company, Ltd, in London, UK, have failed. His paper was so interesting, and in particular the slides and a movie shown by Ian Parker, pilot and flight manager (To himself did not come to Detroit) were so fascinating, that I am summarizing it here. The full paper can be obtained from SAE Publications Division, 400 Commonwealth Drive, Warrendale, PA 15096, for a fee (I believe $3.00), quoting Paper no. 840028. -Dave]

* * * *

Problems of HPAs

Human-powered aircraft suffer from three very severe drawbacks preventing their general use for recreation: their large wingspans require that they be stored in enormous, expensive hangers; they must be accompanied by a ground-crew who can take the frail craft into the hanger whenever the wind rises above a light breeze; and a minor crash can result in very expensive repairs. Dan Perkins, an engineer at the Royal Aircraft Establishment at Cardington, UK, decided that inflatable-wing aircraft would avoid all these problems. We built four before his death; the last and most promising was the **Reluctant Phoenix** (Fig. 1). It was transferred to F. E. To, who formed The Air Plane Company, Ltd, in 1978 to develop the system further.

Materials for Inflatable Wings

Perkins was using polyurethane-coated nylon fabric, which was expensive. F. E. To switched to polyester film because of its impermeability, its good strength-to-mass ratio, and its dimensional stabiltiy.

Structure, Shape and Planform

High-lift-drag-ratio airfoils cannot be produced with inflatable wings, of course. There are two

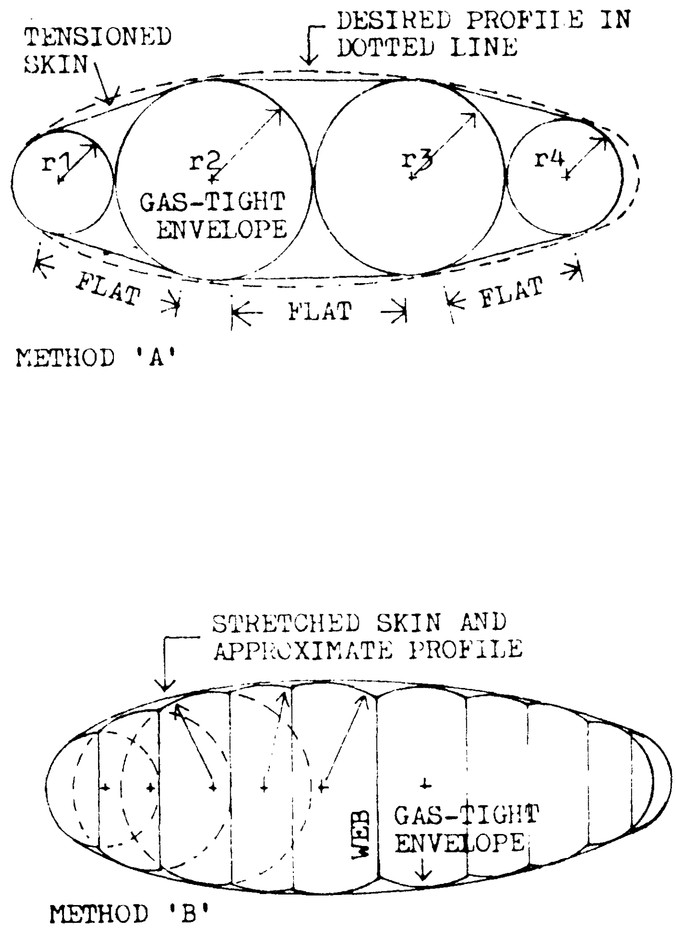
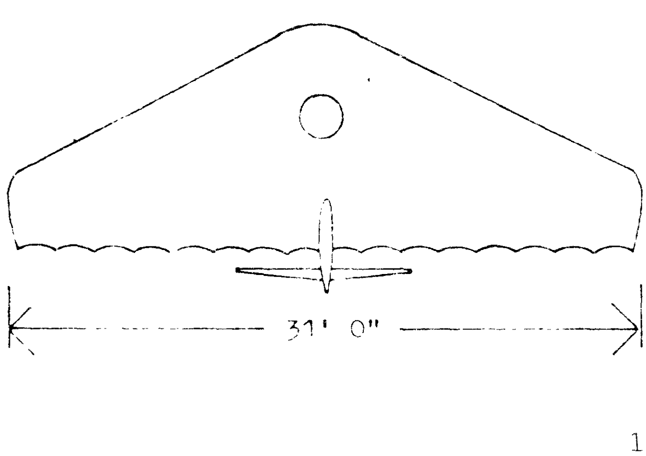


Figure 2 Methods of Construction



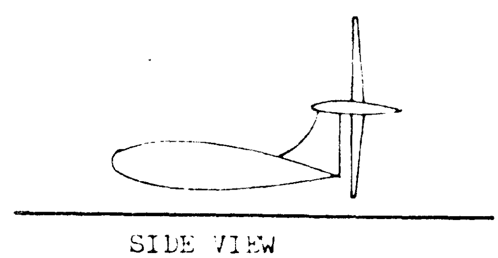


Figure 1 Reluctant Phoenix.

general methods of construction (Fig. 2a & 2b), and 2b was chosen for its greater torsional rigidity and the smaller "flats" in the surface film. Nevertheless, during initial testing a serious flow separation was found near the leading edge of the wing, requiring the insertion of spacers between the inflated tubes and the envelope.

The joints between the inflatable tubes were made using nylon-fabric Tee-tape (Fig. 3), and contact cement that was allowed to dry completely. The adhesive was reactivated with a hot iron. This procedure was so successful that the design and construction of, first, a 20-foot- (6.1-m-) span model, and then a full-size 100-foot- (30.5-m-) span craft was rapidly carried out. The film for the structural tubes was 23-microns thick and that for the envelope was 6 microns. A rectangular-planform wing was used because of the low Reynolds numbers (based on chord) of HPA wings (Fig. 4). Tapering the outer wings would further reduce the Reynolds number and thereby increase the drag. The chord was 16 feet, 8 inches (5.1 m), giving a flying-wing design. The full-size aircraft initially weighed 85 lbm (38 kg) but carried along 200 lbm (90 kg) of air inside the structure, and additional "virtual mass" in the associated external air. Repairs and stiffeners added another 20 lbm (9 kg). The wing control surfaces are shown in Figure 5.

Winglets were fitted to increase the effective span and to decrease the effective height above ground, thereby increasing what is known as "ground effect", a region where increased lift can be given at low drag. Also some directional control could be produced.

Rigging and Human-Powered Flights

The uninflated aircraft could be taken around on the roof-rack of a small European car. Inflation by vacuum-cleaner exhaust took 20 minutes, and deflations took 30 minutes. The rigging (assembly) method is illustrated in Figure 6. First flight was made by Ian Parker on March 28, 1982 in a parking lot at the London docks. Because of the large mass of the aircraft and associated air, acceleration took a long time, but several flights of about 20-seconds' duration were made that day. Cruising speed is 8 mph (4 m/s). In a movie shown by Ian Parker at the SAE symposium, the whole sequence of arriving, unpacking, inflating, and rigging was shown, followed by launch and flight. It all seemed delightfully easy. When the wind came up, during one flight, the large and surprisingly graceful craft was actually travelling backwards over the ground. A crash seemed a completely harmless event.

We will continue trying to learn about further developments. Let's hope that they have tried filling the wing with helium.

No valid address is available for F. E. To

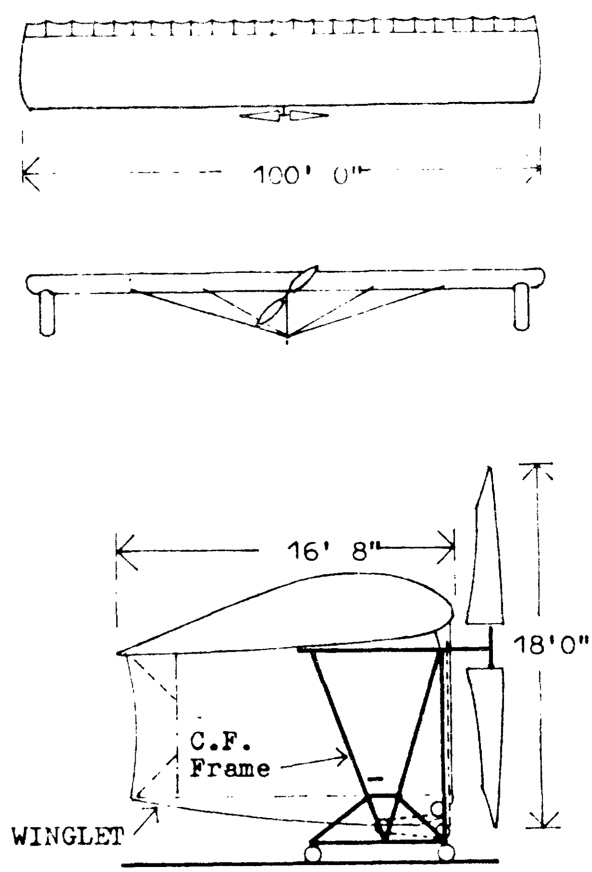


Figure 4 Full-size Phoenix

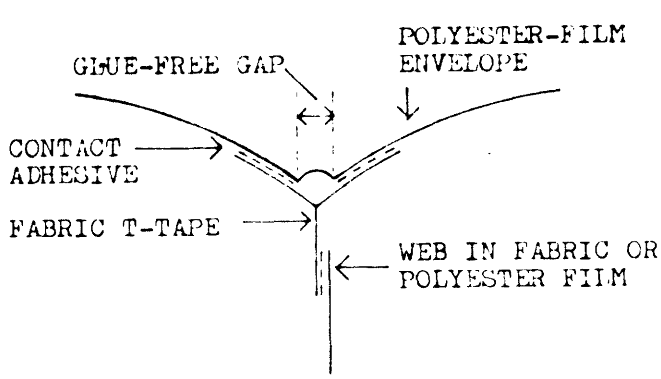


Figure 3 Use of fabric Tee-tape

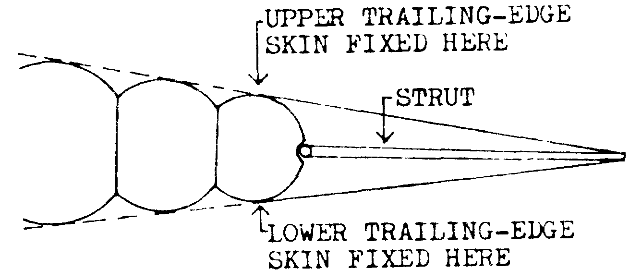


Figure 5 Control Surfaces

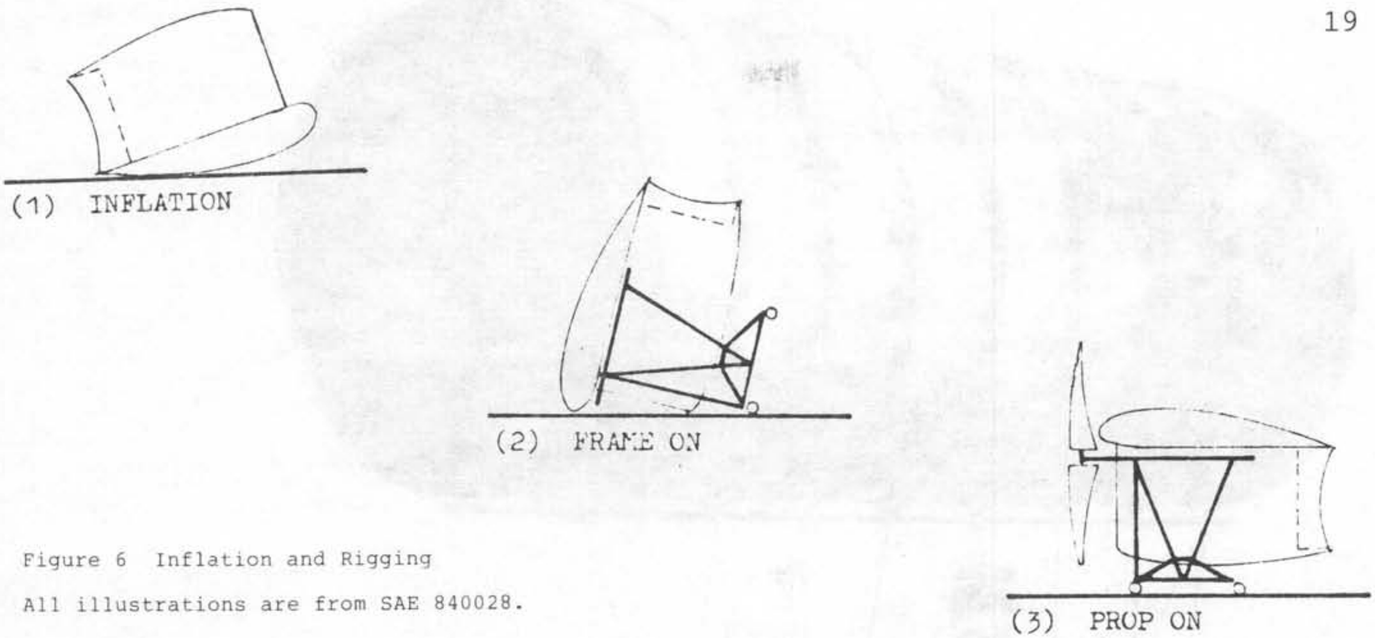
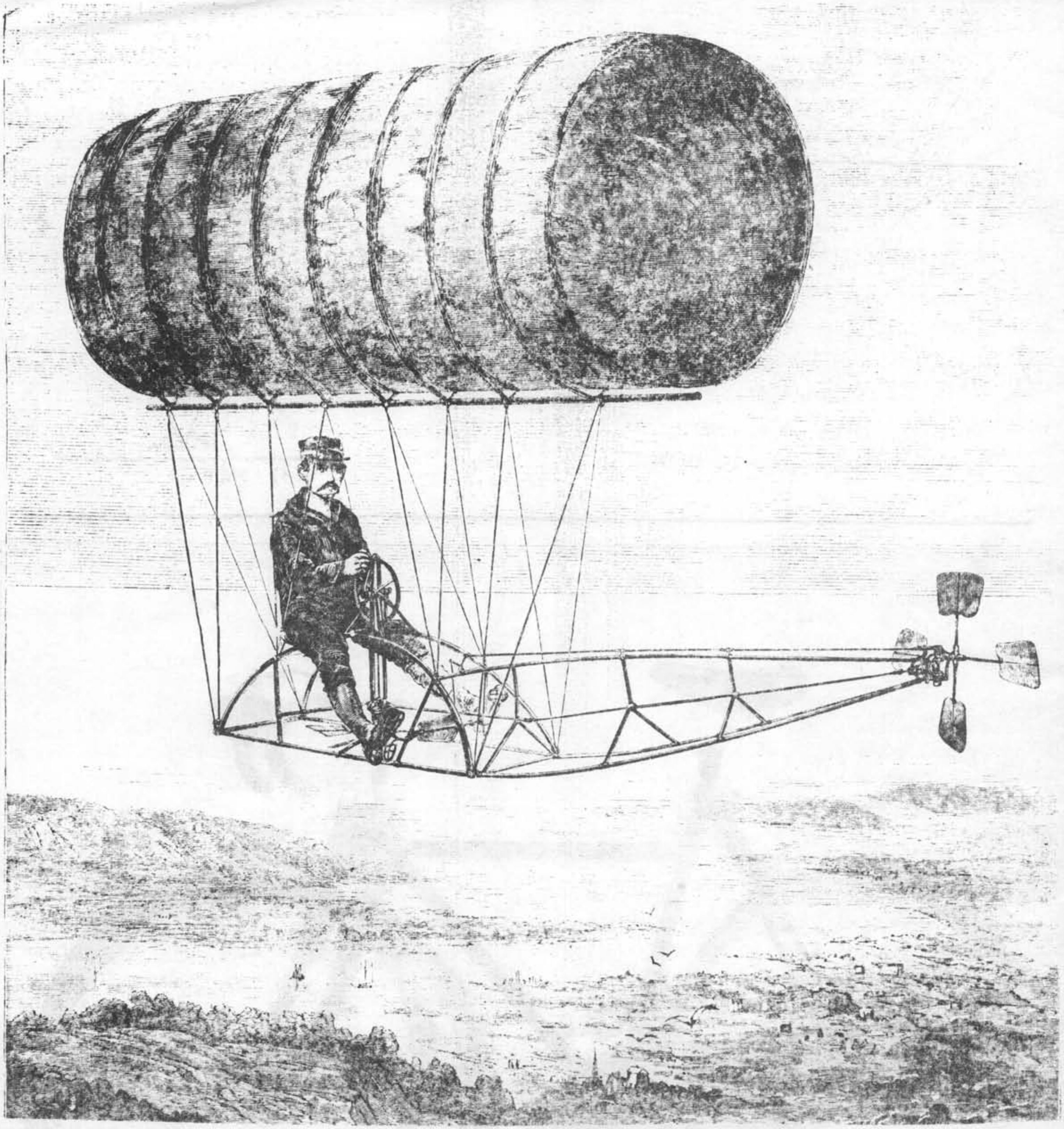


Figure 6 Inflation and Rigging

All illustrations are from SAE 840028.



A PREDECESSOR TO THE **WHITE DWARF?** from a DOVER publication, Transportation

 Second- and first-class postage paid at Huntington Beach, CA and additional mailing locations. Cover design and title protected by US and foreign trademark registration. 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.