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BIKE TECH

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DESIGN

Human-Powered Utility Vehicles

Trucks and Trailers of the Cycling World

The Next HPV Challenge?

Jan VanderTuin

(Now that designer Gardner Martin and rider Fred Markham have swept past the 65 mph mark and claimed the DuPont Prize, what will motivate the next round of invention in the HPV world? Perhaps the new frontier is to be found, not at the high end of the speed limit, but at the low end.

A new type of HPV, the human-powered. ***utility*** *vehicle (HPUV), is attracting the interest of vehicle-builders and riders, particularly in Europe. As the name suggests, human-powered utility vehicles are designed specifically for convenience and function in carrying heavy/bulky cargo. Actually, HPUV's are not new at all; an amazing variety of them have been used for decades all over the world. What is new is the recognition that HPUV's constitute a unique class of vehicle, a new species which is evolving from a mixture of ancestors including conventional bicycles, trailers, hand-carts, light trucks, and even rickshaws.*

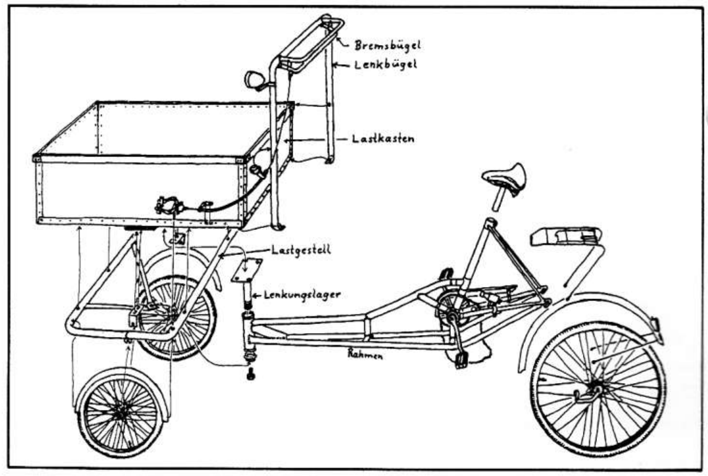
This article sets forth, for the first time, an overview of the HPUV world and identifies its unifying design themes. Anyone seeking to improve the utility of ATB's, city cruisers, and touring bikes will surely find inspiration here.)

Conventional bicycles and recumbents are sometimes pressed into service for hauling heavy cargo. They can carry surprisingly large loads; indeed, the commercial economy of many countries of the "Third World" depends on conventional bicycles for transport of goods.

But bicycles are really not intended for carrying anything but a rider and maybe a light, compact load. This limitation has prompted the invention, over the years, of all sorts of modified bicycles better suited to the task. So-called butcher bikes, baker's bikes, cargo trailers, and pedicabs fall into this category, but so do many other diverse and otherwise unclassifiable vehicles. I propose the term *human-powered utility vehicles* (HPUV's) as a convenient way to refer to all such machines. For purposes of this article, it is useful to define an HPUV as a human-powered vehicle (or trailer) which is *designed specifically for carrying cargo (or passengers) weighing more than 90 lb (40 kg) in addition to the rider.*

Figure 1: "Long John," a classic HPUV used throughout Europe for urban delivery services. The basic design originated in Denmark around the 1920's, and became so popular—the narrow frame maneuvers easily in traffic and provides full access to the load—that it remained basically unchanged ever since. The legal load limits (note sign) are 220 lb (100 kg) maximum weight and 47 inch (120 cm) maximum height. (Velo Bedarf + Technik, Hr. Jorg Vitelli, Davidsbodenstr. 19, CH-4056 Basel, Switzerland.)

IN THIS ISSUE



◀ **Figure 2: Moving a roomful of furniture or even a washing machine is an easy task with the sort of human-powered utility vehicle (HPUV) seen here. For touring/camping, a cot and tent arrangement can be set up in the front compartment, thereby providing the world's first 3-wheeled human-powered Winnebago! Designed and built by Christian Kuhtz, Dammstrasse 44 Hth, 2300 Kiel, West Germany.**

▲ **Figure 3: Construction schematic for the HPUV pictured in Figure 2. The front wheels are 20" diameter, with axles supported on both sides by the frame. The single rear wheel has a coaster brake; rim brakes on the two front wheels are operated by a bar on the steering arm. Plans and handbooks (in German) on how to build this and several other HPUV's using recycled materials are available from Christian Kuhtz.**

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Widespread Use

Many readers, especially those in the United States, may be surprised at the large number of HPUV's in use throughout the world, and at the ingenuity of their design. Literally millions of people use HPUV's daily in their work. A Canadian study estimated that, in Bangladesh, over 200,000 pedal-rickshaws are in use, primarily as taxis but also for food delivery.[1] In Europe, I have seen HPUV's used for:

— post office delivery
— farm-to-market food delivery
— commercial taxis
— child carriers
— transport for the handicapped
— street vendors
— refuse and recycling collection
— moving "vans"
— construction materials transport
— laundry pickup
— bulk milk transport
— touring/camping

As the name "utility" suggests, HPUV's are generally used for work, not sport (although "recreational" HPUV's have been built). Examples of the purely economic angle include:

— A study by the Swiss Post Office concluded that HPUV's are cost-effective for mail delivery. As a result, the Swiss Post now owns about 3700 utility bikes and more than 4000 heavy duty cycle-trailers.[2] They also maintain a system of independent workshops throughout the country to service these vehicles. If the U.S. Post Office adopted a similar system, and used as many vehicles on a per-capita basis, we would see 130 thousand utility bikes and 142 thousand cycle trailers in service.

— In Bogota, Columbia, a large bakery set up a fleet of 800 HPUV delivery vehicles in the early 1980's. The result was a reduction in distribution costs from 27% of overhead to 8%, according to reports in Zurich's newspaper *Tages-Anzeiger*.

Beyond the matter of economics, HPUV's raise new questions in the areas of design, production, distribution, and even social policy concerning transport.

Design

HPUV's are basically the trucks of the cycling world. The main feature which distinguishes HPUV's from conventional bicycles is the *cargo space*: an area where heavy and/or bulky cargo can be secured is an integral part of the structural frame of virtually all HPUV's. In contrast, the cargo rack and panniers of conventional bikes are add-on accessories.

Concerning the overall shape of the frame and number of wheels, the basic rule has been

[1] *Interpares Group, 209 Pretoria Ave., Ottawa, Ontario, Canada.*

[2] *Report dated 6.3.1986 from Automobil Abteilung PTT, Sektion Einkauf, Attn: Hr. Bolz, 3030 Bern, Switzerland.*

Harmut Wolf, Hamburg

Figure 4: This model is designed primarily to transport the handicapped, and was built in a small volunteer workshop. It has a stationary (non-pivoted) load chassis (the same configuration often used for pedal-taxis in Asia), and rim brakes on the front wheels. Note the basket under the front seat. Ottenser Werkhof, Gausstrasse/Ecke Nernstweg, 2000 Hamburg 50, West Germany.

Figure 5: On this semi-recumbent HPUV, the single front wheel serves as both driving-wheel and steering-wheel. To accomplish this, the frame is articulated via an ingenious hinge/linkage under the seat. Components include a 3-speed front hub, disk brakes on the rear wheels, and a removable cargo container. Overall length: 59 inches; overall width: 31 inches. The design has passed through several prototype stages and is under consideration for commercial manufacture. Designed by Ivo Lucic, Krankenhausstr. 36, 7910 Neu-Ulm, West Germany.

"anything goes." HPUV's have been built in all of the following configurations, among others:

— 2-wheel, 3-wheel, and 4-wheel cycles
— trailers: ranging from 1-wheel to 4-wheel
— sidecars attachable to conventional bikes

Certainly there are advantages and disadvantages to each type; a follow-up article is planned to cover the strong and weak points of the various HPUV classifications.

It is also clear that certain design problems are common to all HPUV's regardless of shape. Of these, I feel the following three are most important:

— **Wheel design**: in addition to the heavier vertical loads, HPUV wheels must withstand significantly higher side loads than conventional bike wheels. The problem is especially severe in 3-wheel and 4-wheel vehicles (which cannot bank into a turn the same way 2-wheelers can), and becomes even more critical on steeply beveled roads. Tiltable wheel linkages might be a partial solution to this problem, but they have the drawback of mechanical complexity. A direction that seems to be more promising is to use smaller wheels, and/or to modify the spoked-wheel structure itself (using different rims, spokes, and hubs), aiming at lighter weight and increased lateral stiffness. Tire interaction also is relevant: the

[3] *Institute for Transportation and Development Policy, P.O. Box 5595, Friendship Station, Washington, D.C. 20016.*

[4] *Swiss Center for Appropriate Technology at ILE, Varnbuelstr. 14, 9000 St. Gallen, Switzerland.*

Figure 6: The OxTrike, one of the first HPUV's developed in the West specifically for Third World use. Great efforts were made to tailor the design to the materials, skills, and transport needs of these countries. The brake (note "pedal" on the main frame tube) applies pressure to both rear wheels, and also acts as a parking brake. Drivetrain includes a 3-speed transmission and differential. The OxTrike is now manufactured in about a dozen small workshops in several countries. The project was initiated by IT Transport, Ltd., The Old Power Station, Ardington, Oxon., OX12 8PH, United Kingdom. Several other groups are also actively working to develop Third World HPUV applications.[1,3,4]

Swiss military bicycles, for instance, use a special wheel rim with a crease that interlocks with a fold on the tire. It's almost impossible to roll the tire off the rim, even when you want to change it!

— **Brake systems**: Compared to conventional bikes, HPUV brakes must handle not only heavier loads, but also more *unpredictable* loads, since the vehicle's center of gravity changes with the load and its placement. With utility cycle-trailers, the problem of brake *control* becomes important, not only to avoid jack-nifing but to minimize vibration while stopping.

— **Weight**: Commercially-made HPUV's are

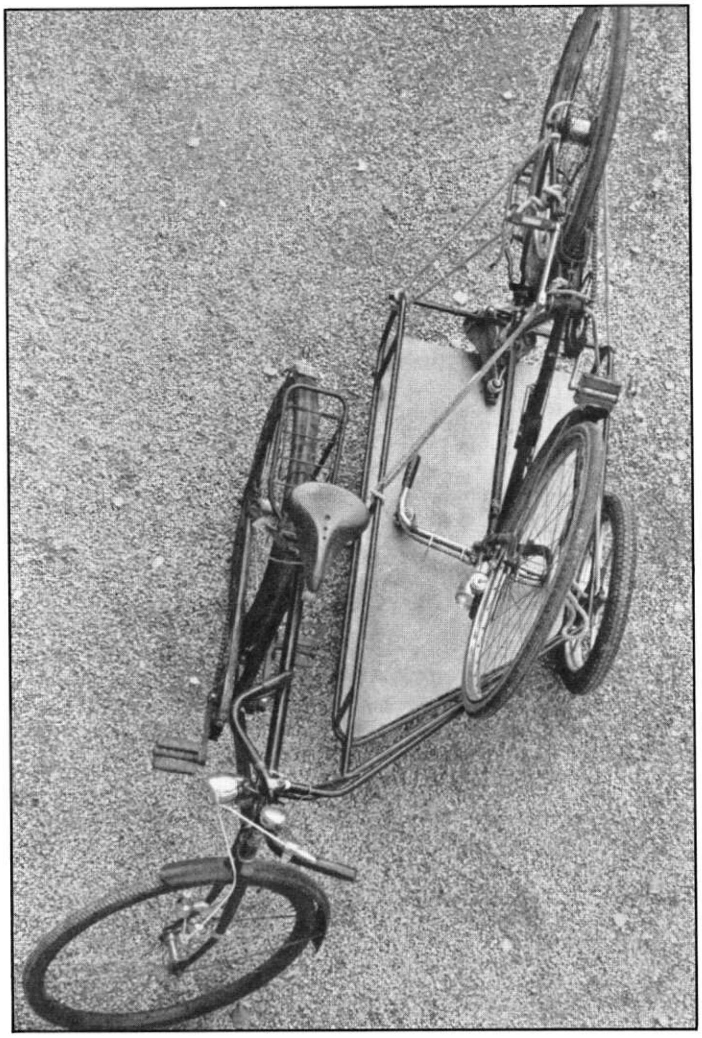


Figure 7: A detachable sidecar carrier, with two-point mounting to the bicycle. Sidecar's single wheel is a 20 inch heavy duty model. The bicycle shown here is the classic Swiss military type. Variants of this configuration, with a passenger's seat on the sidecar, are common taxis in Indonesia. Fahrradbau Stolz (small workshop), Allenmoosstr. 34, 8057 Zurich, Switzerland.

Figure 8: A trailer designed by a German university group especially for owner-builders and for easy storage when not in use. When the two quick-release wheels are removed, the basic frame—including the side-hitch attachment to the bicycle—lies all in one plane, making a very compact, flat package. The frame is welded aluminum, but a riveted model was also designed. A modified automobile ball-joint trailer hitch is used for the coupling. In 1985, a television "how-to" presentation of the construction process brought in hundreds of responses. Universitat Oldenburg, c/o Falk Riess, FB8 Postfach 2503, 2900 Oldenburg, West Germany.

traditionally heavily-built, even over-built. The design of some products has been frozen for decades. Major weight reductions with no loss in strength may thus be possible by refining these structures for more efficient use of materials, and by switching to the light alloys (chrome-moly, aluminum) used in conventional bicycles.

Other HPUV design issues include: weather protection, security of cargo, and the need for modular, interchangeable body parts. In short, HPUV's present some unsolved design problems, some quite different from what one faces with conventional bicycles.

Traffic Planning

HPUV's are relatively unknown among traffic planners, even those who deal with bicycles. At the 1983 International Bicycle Traffic

HPUV Networking

When I first became interested in HPUV's several years ago, there were no central source(s) for information about them. In Europe, there are casual acquaintances among HPUV enthusiasts, but nothing more formal such as newsletters or books. This prompted me to start an HPUV "data base" of photos, drawings, articles, etc. to document as many vehicles as possible, along with the ideas and individuals behind them. At this point, I have data on roughly 100 different HPUV designs (both commercial and owner-built), but this is only a small fraction of the total.

I would like to expand this data base and also to share it with others who could use the information. One purpose of this article, then, is to ask for feedback:

— Readers who can contribute information on specific HPUV's to the data base are encouraged to send it, or to contact me directly.

— Those who would like to receive information *from* the database should also contact me.[5] I will try to accomodate requests for slide duplication, photocopying, etc.

My hope is that a more organized network of HPUV enthusiasts can grow not only in the U.S., but also internationally, to benefit all.

Interested readers may also wish to contact the Center for Low-Cost Transport.* in Delft, which is compiling information on HPUV's, as well as on all forms of inexpensive motor transport.

— J.V.d.T

**Center for Low-Cost Transport, Steinweg 1, PO Box 5048, 2628 CN Delft, Netherlands.*

Planning Seminar in Basel, Switzerland, for instance, only one speaker out of several dozen even mentioned HPUV's. This is no great surprise, since most of the participants were from the automobile-dominated countries of the West. Still, without proper planning, HPUV's are at a disadvantage in traffic. Planners need to be shown how HPUV's occupy the middle ground between bicycles and light trucks.

One positive note is that the European countries have established HPUV licensing and safety regulations. Specifications as to size, weight, load capacity, brakes, and lighting are set forth in detail.

This is positive because it provides HPUV builders and riders with exact guidelines as to what is acceptable. In case of an accident, no one can raise the blanket accusation that "HPUV's are unsafe." In the U.S., however, HPUV traffic regulations are a grey area, even more so than conventional bicycle regulations. For instance, officials at the Massachussetts Department of Transportation replied to a inquiry on this topic with a request for photos to show them what HPUV's look like. Definitely a case of starting from square one.

Future Directions

Clearly, HPUV's pose some new technical questions, and offer some new answers to problems of human-powered transport. The next step might be a cooperative effort among builders, riders, and component/material suppliers to improve the state of HPUV design, to at least equal that of today's conventional bikes. My hope is that the personal dimension, which has always been important in all human-powered vehicle projects, remains at the heart of future efforts to develop these practical utility vehicles.

Author Jan VanderTuin[5] first became involved with HPUV's four years ago when, working with a market-gardening cooperative near Zurich, Switzerland, he was looking for utility bikes or cycle-trailers to haul produce and milk. He found the commercially-made products to be lacking in various ways, so the co-op decided to design and build their own. This started a process of research and networking that eventually brought Jan into contact with workshops, manufacturers, and other organizations all over Europe, who were involved in HPUV's in some way. The article here presents some of Jan's observations from that process.

[5] *Current address: Jan VanderTuin, HPUV Project, P.O. Box 573, South Egremont, Mass. USA 01258 (phone 413-528-4374). Jan is now organizing a market gardening group in New England which, similar to the Swiss co-ops, plans to use HPUV's for delivery of produce. Contact: Community Supported Agriculture, Box 245, South Egremont, Mass. USA 01258.*

SHOP TALK

The N.E.C.A. Frame Alignment System

Rich Carlson

(Most of our readers are well aware of the handling and safety benefits of a straight-tracking frameset. But a frame can track well and still have a mis-aligned bottom bracket shell that can lead to or aggravate many types of joint injuries. Traditional shop tests for alignment, such as the string test or even a well-trained eye, won't detect this type of biomechanical misalignment. Better-equipped manufacturers and custom builders use expensive alignment tables to identify and remedy both types of misalignment, but what's the average shop to do? The Frame Alignment System, from Bill Farrell and the New England Cycling Academy, offers easy-to-use, state-of-the-art accuracy at a reasonable, though not cheap price.—Editor)

Bill Farrell has nothing against fancy paint jobs and designer decals, but when he examines a new high-quality frameset, it's the paint he *doesn't* see that gives him reassurance.

"I look at the bottom bracket and the head tube," he explains. If there's paint on the faces, I know right away the frame hasn't been properly prepared or aligned. It can't have been. You have to mill those surfaces before you can even start the alignment process."

Fifteen years of racing, coaching, and bike business experience have taught Farrell how important proper alignment is if a frameset is to perform up to its design potential. At the same time, he is aware that many riders, shops, distributors and even manufacturers don't really understand what frame alignment is all about. One reason for this, says to Farrell, is that proper alignment is not really visible to the naked eye, and so judgements are often made only on the basis of appearances, paint, decals, and lugwork.

"It's incredible that major component manufacturers can hold tolerances of a thousandth of an inch, yet so little attention is given to checking high-performance frames for proper alignment before they are sold," Farrell laments, adding, "We're not dealing with toys here."

To dramatize the point, he picks up a frame already destined for alignment. "How many times have you seen somebody do this?" he

Rich Carlson has been racing and writing about cycling since the early '60s. He rides in the Senior Men's (35-44) category and is a member, along with Bill Farrell, of the Middlesex Bike Club team. Last fall, thanks to a crash and the resulting bent frame, he learned about the N.E.C.A. Frame Alignment System firsthand.

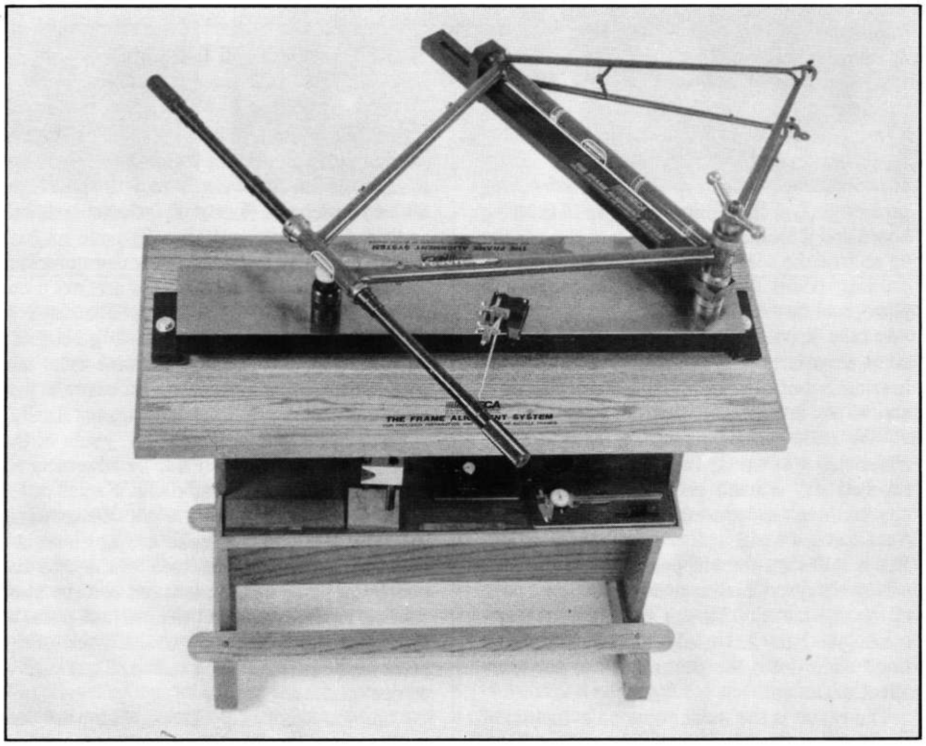


Figure 1: Basic components of the N.E.C.A. Frame Alignment system: bed channel, stabilizer bar, oak table, and Marchetti-Lange head tube alignment tool. Alignment starts by clamping the bottom bracket (drive-side down) to the bed channel. (See also Figure 7 for side-view of bottom bracket clamping detail.)

asks, while squeezing the rear dropouts between a thumb and two fingers. "They think they're testing to see how stiff the frame is. What they're really doing is throwing the rear triangle out of whack."

Farrell's solution is the Frame Alignment System: a collection of seemingly simple tools and fixtures that enables the shop mechanic or dealer to check and correct the alignment of virtually any bike frame, quickly and with a minimum of headscratching. The Frame Alignment System has been marketed since last fall by Farrell's New England Cycling Academy,* which is already well-known for the "Fit Kit" frame sizing system. In this article, we'll first explore Farrell's philosophy of frame alignment (see sidebar for definition of terms), and then look at the hardware and step-by-step procedure.

Grass Roots Origin

Both the Fit Kit and the Frame Alignment System resulted from Farrell's work with students at the NECA's training camps for bicycle racers. The idea for the frame alignment system was born when Farrell noticed some of his students experiencing high-speed wobble and other handling problems with their bikes even after the wheels were trued and their headsets adjusted. In addition, some students complained of hip, knee and ankle problems even after they had been properly fitted to their bikes and had their cleats correctly aligned.

Farrell deduced that these perplexing problems had a common source—poorly aligned frames—and his research indicated that the situation was not uncommon.

"There are all kinds of reasons for misaligned frames," he explains. "Sometimes a frame builder or manufacturer relaxes quality control in order to step up production. Pretty soon tolerances loosen up and you start having problems. You can design a bike on a drawing board and it looks great. Then you can set the jig so that the tolerances are exactly what the drawing board dictates, lock the tubes into place, and braze the hell out of it. But, when you take it out of the jig it goes out." With some manufacturers, re-truing the frame after brazing is not always as high a priority as it should be, in Farrell's view.

"We once had a frame come in where the chain stay was so far out that the crank arm touched it," Farrell continues, adding, "Of course the manufacturers blame it on the shippers. Sure, damage can occur during shipping. But is it always the shippers?"

Not always. Crashes are the leading cause of misalignment of frames already in use, according to Farrell. He adds that even a "routine" slide down the pavement can seriously affect alignment.

The result is the most common symptom of a misaligned frame—drivetrain trouble. "You have mis-shifting, or the bike will shift by itself," he explains. "You'll hear riders complain that they were climbing a steep hill out of the saddle and the bike shifted up by itself. They blame frame flex, but misalignment is usually at the heart of the problem."

New England Cycling Academy, Meriden Road Lebanon, NH 03766; 603-448-5423

Figure 2: First base (at seat cluster): scriber tool was adjusted for light grazing contact at Home Plate (bottom bracket); seat tube is then bent (using bending bar, a.k.a. "Big Bertha," in photo at right) to bring First Base to the same level.

Stress on the Joints

Another side effect of misalignment, Farrell points out, is premature wear of some components. Uneven tire wear is easy to spot. Less obvious is damage done to spindles, fixed cups and other bearing surfaces. "I have an axle from a bike with a misaligned bottom bracket, he says. "The bearing surfaces are worn out on one side and not the other. That kind of thing affects performance. People go out and train hard for an event like a time trial, and they end up losing 10 seconds because the machine they're riding is working against itself."

The rider's *own* bearings—the joints of the knee, ankle and hip—can also be adversely affected by poor frame alignment. Farrell notes that if the bottom bracket is out of alignment, the rider's knees can make a "figure eight" movement. "If you stand behind the bike and watch the pedal stroke, you can see the shoe moving to the outside of the vertical plane at the top of the stroke, and to the inside of the plane at the bottom of the stroke. The result is stress on the leg joints."

Common handling problems, like poor cornering and front wheel shimmy, are frequently cured after alignment of the tracking plane (see sidebar) has been corrected, says Farrell. In fact, Farrell believes that even the old mystery of frames going "dead" after several years of use can be traced back to alignment problems. "Sure they go dead," he says, "but they can be brought back to life by realignment." Citing his own racing bike, now in its seventh season, as an example, he says "Last year I took a spill during a criterium. I got back on, but I knew right away that things were out of line. The bike really did feel dead. I checked it later and found that the front wheel was tracking way over to the left. After I realigned the frame, no problem. It was as lively and responsive as ever, and I'm still using it."

Alignment Practice

A principal reason why frame alignment has remained shrouded in mystery is that, in the past, relatively expensive mechanical inspection equipment was needed to do a thorough job.

Simple methods of checking alignment provide some useful information, but they are often less than precise and generally incomplete. The standard "string test" is a good example. It's possible to check whether the mid-section of the seat tube is centered in the plane of the frame simply by running a string from one rear dropout around the head tube and back to the other dropout, and then taking measurements from the seat tube to the strings on each side of it. But this test reveals nothing about the frame's biomechanical plane, nor can it indicate if the steering axis is in line with the rest of the frame. The same holds true for using a straightedge or even eyeballing the frame.

"The problem with these methods," Farrell

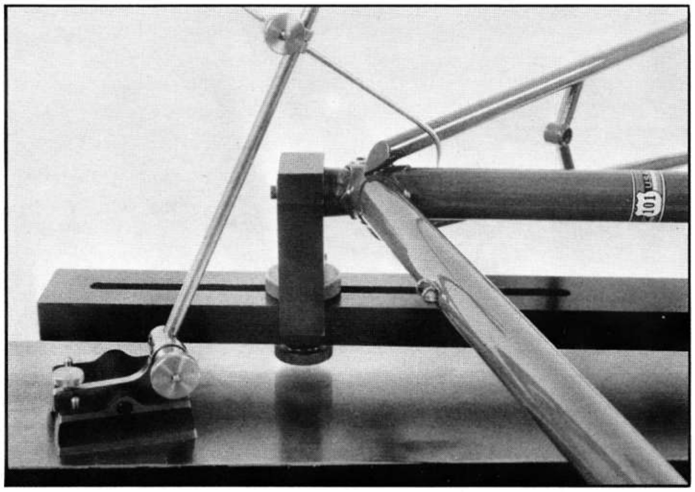


Figure 3: Seat tube is now locked into place using the plug assembly attached to stabilizing bar.

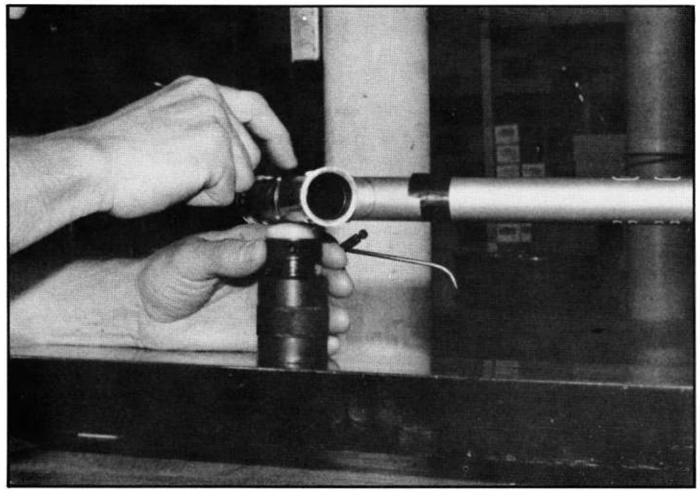


Figure 4: Screw jack is now installed under the head tube. Light "tapping" on the head tube indicates, by sound, when the nylon pillow is snug against the tube.

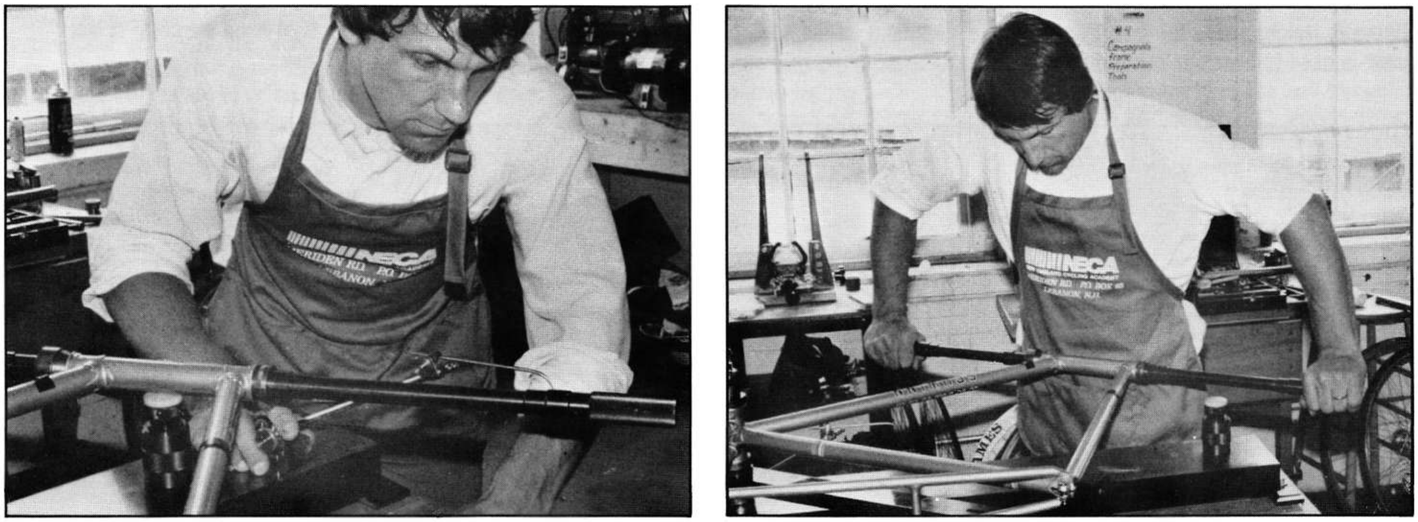


Figure 5: Second base, at upper end of the Marchetti-Lange alignment tool, is checked with the scriber; third base, at lower end of tool, is checked likewise. Then adjustments to head tube are made by pulling up or down on the alignment tool.

states, "is that they don't derive from the central movement of the bottom bracket. You can get what looks like a good reading with the string test. But the front of the bike can be over to the left, and the rear can be over to the right, and the bike is actually way out of alignment. On the other hand, the frame could be in good alignment, but a bowed seat tube can throw your string-test readings way off." It's true that Farrell uses the string test and also a straightedge to double check his work, but only after he has established the bottom bracket as the "heart" on the frame.

Sophisticated mechanical inspection systems, such as those using "Jo blocks" on a granite or steel surface plate as the reference bed, do allow for accurate measuring and aligning. In fact, they are standard features in many design shops. But Farrell points out their disadvantages for bike-shop use: set-up is time consuming and requires considerable skill and ingenuity. Further, such systems are bulky and non-portable. The NECA Frame Alignment System is Farrell's attempt to provide the same machine-shop accuracy with a more "dealer usable" technology.

Yankee Ingenuity

The heart of the system is the bed and post assembly (Figure1). The bed is a piece of structural steel C-channel, 36 inches long by 6 inches wide, which has been heat-treated for stress-relief and ground twice to achieve a flatness of one thousandth of an inch. At one end of the bed is the die post, a length of heavy threaded rod on which the frame's bottom-bracket pivots, supported by Andrews thrust bearings used as spacers. An aluminum stabilizer bar also pivots on the die post (Figure 7). A large wing nut clamps the frame to the die post, holding it perpendicular to the plane of the bed.

The bed and post assembly rests on a sturdy oak table. Fine leveling adjustments are made by four leveling screws at the corners of the C-channel bed.

A Starrett surface gauge or "scribe" is used to establish the position of various points on the frame (Figure 3). The scribe doesn't actually scratch the paint; it simply indicates "by feel" when its point is in contact with the frame. A dial indicator could be used in place of the scribe; in fact, it's necessary for certain specialized measurements. A height gauge and spacer plugs are provided for checking the width and alignment of the rear triangle (Figure 6). The plugs come in five-and six-speed widths and eliminate the need for taking actual measurements.

Bending and lifting of the front triangle is done with a Lange/Marchetti head tube alignment bar, which also provides reference points for determining the steering axis (Figure 5). A screw jack is positioned under the head tube

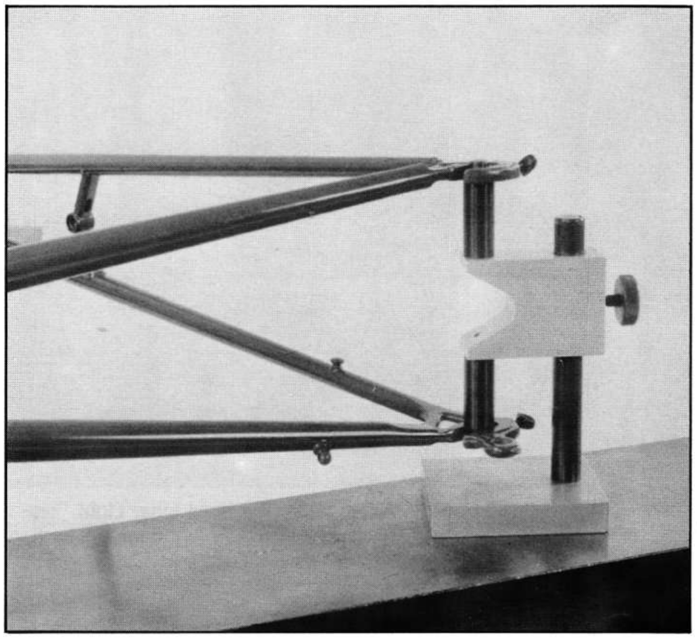


Figure 6: Height gauge for rear dropouts, after alignment on the seat tube, is used to check position of rear dropouts.

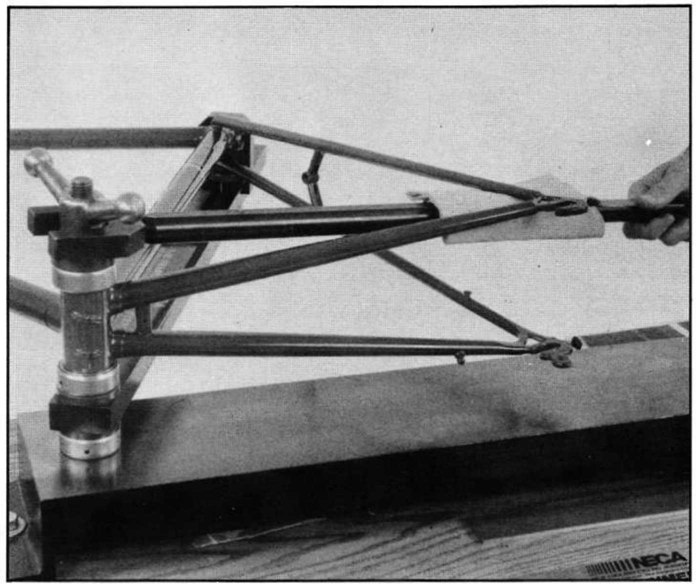


Figure 7: Rear triangle is adjusted with light hand pressure or the bending bar (a.k.a "the pickle fork") shown.

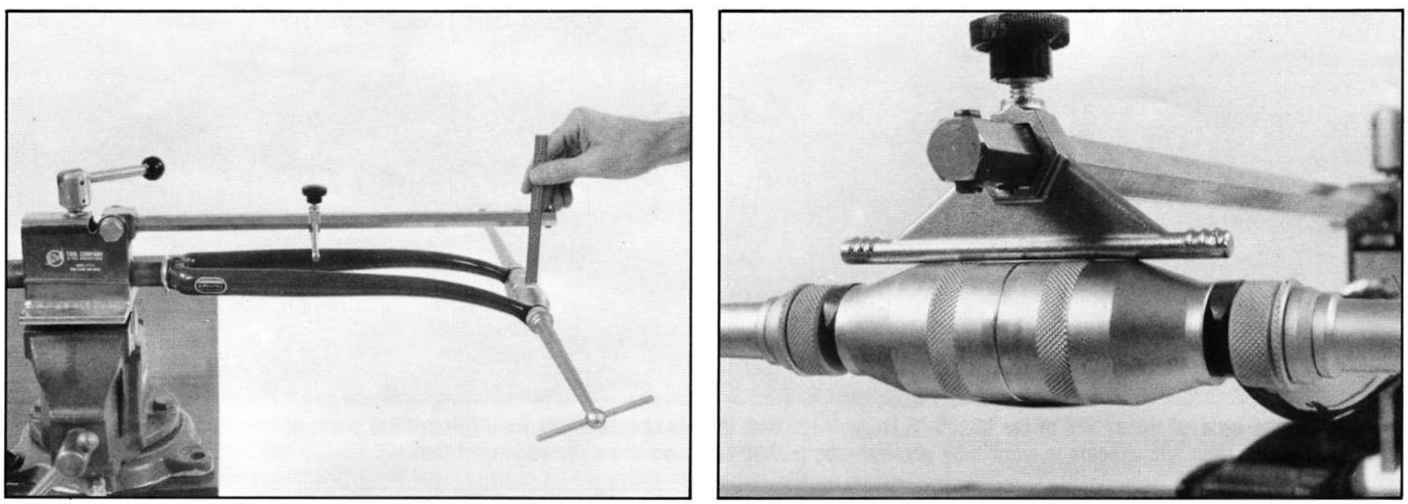


Figure 8: Fork alignment uses the Park FT-4 tool and Campagnolo H tools. Fork rake is measured by using the Park tool's midline determinant bar as a reference point (left). Alignment of dropouts is checked by holding the Park's sliding gauge against the Campy H tools (right).

during this part of the process so that the weight of the bar does not cause deflection of the head tube (Figure 4).

"Big Bertha," an iron bending bar with a forked tip at one end and a flattened surface at the other is used for most of the bending work on the frame (Figure 2). The flattened surface is needed for clearance when the bar is inserted into a seat tube with water bottle braze-ons.

A Park fork- and frame-tool package is used with the system for fork alignment and straightening. Also, a Campagnolo tool kit (preferably the complete package) or the equivalent tools from VAR, Gipiemme, etc., is considered an essential part of the Frame Alignment System. Supplimentary tools (calipers, frame builder's wheels, files, etc.,) are also available from NECA.

The basic alignment system costs approximately $2,400; if the Campagnolo tool kit, Park fork/frame package and supplimentary tools are added in, the cost can reach as high as $4,000. The NECA instruction package (including manual, video tapes, and user hotline number) is also supplied with the system. At present, there are approximately three dozen Frame Alignment Systems in use around the country. Most are in the hands of shops and dealers selling and servicing high-quality frames; one large manufacturer, Ross, has ordered a system to spot check quality on their overseas assembly line.

If the Frame Alignment System's Yankee roots are apparent, there is a simple explanation. In addition to Farrell, Frank Micalizzi, a frame alignment expert formerly of Rutland, VT, Fred Gallente of Technical Engineering, Inc., Rutland, and representatives of Starrett Tool Company, Athol, MA, all figured prominently in the design and development of the system.

Before the Beginning

We've all heard that "proper preparation" is the key to any job. Farrell is so adamant about the need for proper frame preparation before any actual alignment work begins that he produced a one-hour videotape on just this subject, narrated by John Sipay, technical support director for Campagnolo U.S.A.

A frame is considered properly prepared

when these six criteria have been met: 1) The bottom bracket has been tapped and faced with the Campagnolo threaded guides left in place and tightly turned to one another. 2) The head tube is reamed, faced and honed. 3) The seat tube is reamed and honed. 4) The gear hanger is chased. 5) The fork steering tube is chased. 6) The fork crown race is properly cut.

After this preparation, the frame is placed on the die post drive-side down, with the bottom-bracket sandwiched between the two thrust bearings, and the large wing nut is tightened (Figure 7).

On the Level

To keep things simple, Farrell uses baseball terms to establish the four reference points used in aligning the main triangle. "Home plate" is marked on the side of the seat tube with a grease pencil at a point about three centimeters above the bottom bracket. "First base" is similarly marked on the seat tube three centimeters below the seat lug. After setting the scribe of the surface gauge on home plate, the scribe is moved to first base. If the seat tube is above or below the level of of home plate, the bending bar is inserted into the seat tube and the appropriate amount of force is applied to bring first base level with home plate.

Next, the stabilizer bar (which pivots on the die post) is swung directly below the seat tube and a plug assembly is attached to the bar and inserted into the tube to lock the seat tube in place (Figure 3).

The next step is to align the head tube end of the front triangle. A screw jack is placed under the head tube for support, the Lange/ Marchetti alignment bar is inserted, and the "second base" and "third base" reference points are established. Second base is located on a collar on the part of the tool that has been screwed into the top of the head tube. Third base is located on a similar collar on the bar inserted into the bottom of the head tube. The collars are 1-1/8 inch in diameter, the same as many seat tubes. Bushings are available to compensate for circular tubes of different diameters and, in the case of oval tubes and other variations, Farrell can supply the information needed to make the appropriate adjustments. The goal at this point is to set second and third base level with one another, and then set the entire front triangle level with home plate.

When this is accomplished, the front triangle is aligned: the steering axis is now co-planar with the seat tube axis and is also perpendicular to the central movement of the bottom bracket. An experienced mechanic usually reaches this point in the process about 10 minutes after clamping down the frame.

Now it is the rear triangle's turn. The correct spacers (for either five- or six-speed spacing) are installed in the height gauge (Figure 6). The indented "V" section of this gauge is snugged against the seat tube near home plate and adjusted in order to establish the height of the frame plane from the bed. If the rear triangle is aligned, the height gauge and spacers will slide right into the dropouts. If not, the dropouts must be adjusted, preferably with hand pressure, until the spacing is correct.

The familiar Campagnolo "H" tools are used to ensure that the dropouts are parallel to one another, but first the surface gauge is used to make sure the face of the right (lower) H tool is parallel to the bed. Thus, when the left (upper) tool is installed and the two are pulled together, both dropouts will be parallel to the midline of the frame.

Forks, Too

After building and testing various fork alignment fixtures, Farrell decided that the Park Fork Tool package, used in conjunction with Campy H tools, offered the best combination of simple operation and reasonable cost.

Fork alignment begins by confirming, with a straightedge, that the midline determinant bar on the Park FT-4 tool is true. Then, the fork is clamped loosely into the fork tool and a reference point is obtained by moving the sliding gauge near the fork crown, pressing it against both blades and tightening the clamp. This step is repeated several times during the procedure to make sure any bending or twisting does not disturb the reference.

Campagnolo H-tools are then installed in the dropouts, and the midline determinant bar is lowered to the top of the H-tools (Figure 8). Without disturbing the bar, the fork is removed and flipped over in the clamp. A level is placed on the fork blades to ensure they are level. By measuring the distance from the top of the H-tools to the bottom of the midline bar and dividing these distance by two, the rake of the fork is obtained (Figure 8).

The frame's head tube angle is then measured using a bevel protractor. From this angle and the rake measurements, the trail of the front wheel can be determined by consulting charts supplied in the instruction manual. By re-adjusting the fork rake, the trail can be changed to make the steering either more or less responsive.

After reinstalling the fork in the clasp to the reference set earlier, one of the blades is selected to be the master blade. The other blade will be set to "mirror" the rake of the master blade. The Park tool is used to bend the blades accordingly.

The Campagnolo H-tools are then reinstalled, the midline bar is lowered and the midline of the fork is compared to the top of the H-tools. If the latter are not centered, the blades must be bent until they are. The edges of the H-tools must also be parallel to the sliding gauge to ensure that the dropouts are parallel not only to each other but to the midline of the fork. Sometimes a dropout slot must be made deeper with a file to accomplish this.

Final checks on the frame's alignment are made using a 180 cm straightedge and a NECA Rim Centering Device after the fork has been installed and a pair of builders' wheels are in place. The gear hanger alignment is also checked with a Campagnolo "R" tool.

Depending on the condition of the frame, the entire procedure can take as little as 30 minutes, but Farrell points out that while the process is easy to learn, a "feel" for bending the frame and fork blades must be developed over time. Frames will bend with surprisingly little force, thanks to the superior leverage afforded by the clamp-down system, so he advises beginners to "go easy" and practice at first on crashed or junk frames.

Frame Alignment: A Working Definition

What constitutes a properly aligned frame? According to Bill Farrell, the three major goals of frame alignment are: 1) Establishing the bottom bracket as the reference point for all measurements. 2) Making sure the midline of the seat tube is perpendicular to the central movement of the bottom bracket. 3) Making sure that the steering axis, fork, and center of the rear triangle are all in the same plane.

Alignment of the frame refers to two major planes—the *tracking plane* and the *biomechanical plane*. The tracking plane is correct when the rotational planes of the front and rear wheels both lie in the same plane as the midline of the seat tube, the steering axis, and the center of the rear triangle. In other words, the rear wheel must be directly behind the front wheel when the bicycle is moving forward in a straight line.

The biomechanical plane is correct when the central movement of the bottom bracket is perpendicular to the (previously established) correct tracking plane.

Fork alignment, an essential part of the procedure, is considered in two planes. The *fork midline plane* is simply an extension of the midline plane of the frame. The *mirror image "plane"* is a curved surface lying perpendicular to the fork midline plane.

The fork is properly aligned when the midline plane of the front fork is on the steering axis, each fork blade is a mirror image of the other, and the rake of the fork is set in relation to the head tube angle for desired handling results.

The frame alignment process must follow a well-defined sequence, since certain adjustments will affect the accuracy of later steps in the process. In general, alignment of the biomechanical plane is assured, first of all, by referencing all measurements to the properly-prepared bottom-bracket shell. Then, the frame main tubes are checked via the "home plate, first base" method (see text) to align the tracking plane. Next, the rear triangle and, finally, the fork are aligned.

—Rich Carlson

Testing of Bicycle Rim Brakes

Dieter Wobben

In West Germany today, there is growing interest in improving the safety of cycling in automobile traffic. Highway authorities are providing more suitable cycle routes, and there is a movement to upgrade the safety requirements of the bicycle and some of its components.

This movement is fueled in part by rising bicycle accident rates and inconsistent enforcement of safety standards. In tests conducted by the Technical University of Aachen in 1984, only 52% of 3000 bikes tested had brakes which functioned well enough to ride safely in traffic.

The recent concern with safety is also a reflection of the growing popularity of bicycling in West Germany. The number of bicycles on the road, and the proportion of road traffic accounted for by bicycles, have both increased considerably. There are now many more bicycles than cars in Germany; in 1985, there were 165 bicycles per 100 households, compared to only 110 automobiles. One unfortunate result is that more cyclists are becoming involved in traffic accidents. In the state of North Rhine-Westphalia, for example, cycling injuries increased from about 11,000 in 1975 to about 17,000 in 1983.

At Rhine-Westphalia Technical Testing Laboratories (TUV) in Essen, we have been studying the problems of bicycle braking performance since 1982. In particular, we have recognized the need to go beyond the minimum requirements of the existing German standard braking test (DIN 79100), which does not cover wet road conditions. Many bicycle brakes which work acceptably well under dry conditions become much less reliable when wet. The tests described here were thus commissioned for the specific purpose of comparing wet *versus* dry performance of a variety of common brake pads and rims.

Need for Compatibility

We have found that the question of overall *compatibility* between the wheel rims and brakes is also a matter that has not been given sufficient attention. Some manufacturers suggest certain pads for steel rims, others for aluminum rims, and still others (the so-called "universal" pads) are supposedly suitable for both types of rims. But there is no marking system to clearly designate which pads should be used with which rims. Also, rims are not marked with a clear designation as to material, surface texture, finish, manufacturer, etc. The situation is somewhat similar the tire/rim compatibility problem before the days of ETRTO/ISO standardization. As one rim manufacturer explained, "The surface texture is produced according to customer requirements. . . ."

Thus, in the tests reported here, we looked at ten different rims (aluminum, steel, and stainless steel) in combination with three brake pads (one for steel, one for aluminum, and one universal pad).

The tests, described in detail below, yielded the following general results:

—The shortest stopping distances were attained with smooth untextured rims. Corrugations on the rims caused excessive wear of the brake pads, but produced no measurable improvement in stopping distances in either wet or dry conditions.

—For best wet-weather braking, the friction pad should be matched with the rim material. In dry conditions, the "universal" pad performed about the same as the special pads for steel or aluminum rims, but in wet conditions, the universal pad performed significantly worse.

—Arcs and bends in the brake cable cause significant force losses and should be minimized in installation. The cables must be well-lubricated, and stainless steel cable housings should be used.

—The design of brake systems should be improved by stiffening caliper arms and by using a non-centric mounting to shorten the free caliper arm distance.

Dr.-Ing. Dieter Wobben is a member of the engineering staff of Rhine-Westphalia Technical Testing Laboratories (TUV) in Essen, West Germany, where he specializes in testing of brakes for a variety of light vehicles (bicycles, motorcycles, trailers, etc.).

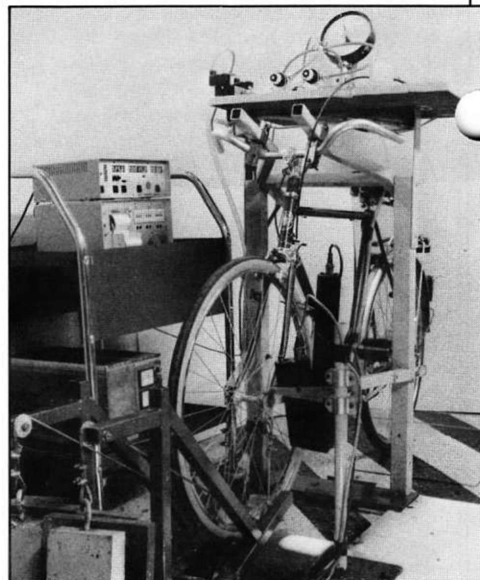


Figure 1: Bicycle brake test stand with test bike on inertia wheel.

Wet Brake Tester

The tests were performed on a custom-built Schenk bicycle brake test stand. A production bicycle is fixed at the handlebars and front axle by means of a holding device so that the front wheel rests on a roller (Figure 1). The rotational inertia of the roller is such that it corresponds to a linear-motion mass of 100 kg (220 lb). The front wheel is pressed against the roller with a vertical load of 75 kg (165 lb).

A Leitz-Correvit distance and speed measurement system is mounted next to the

TABLE 1: COMBINATIONS OF RIMS AND BRAKE BLOCKS TESTED.

WHEEL RIMS (used with both types of brake blocks)				BRAKE BLOCKS			
				"Special" for St or Al (made by Altenburger)		"Universal" (by Weinmann)	
Mfgr.	Model	Material	Finish	Model	Combo No.	Model	Combo No.
Schuermann	---	Steel	smooth	Super Stop 1098	1	SR 75/82	11
Schuermann	---	Steel	indented knurl	↓	2	↓	12
Schuermann	---	Steel	raised knurl	↓	3	↓	13
Schuermann	---	Steel	sandblasted	↓	4	↓	14
Schothorst	Inox	Stainless St	smooth	↓	5	↓	15
Schothorst	Inox	Stainless St	corrugated	↓	6	↓	16
Weinmann	218	Aluminum	bare	Super Stop 1090	7	↓	17
Weinmann	210	Aluminum	polished	↓	8	↓	18
Weinmann	716	Aluminum	anodized	↓	9	↓	19
Schothorst	801	Stainless St	corrugated	---	---	↓	20

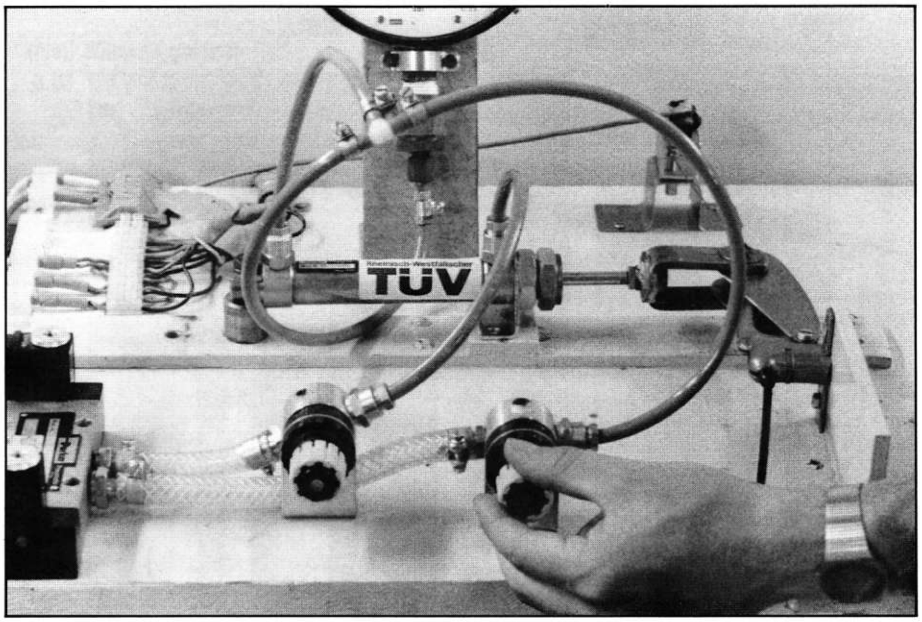


Figure 2: Pneumatic operating system with brake hand-lever.

front wheel. This records the speed, braking distance, and braking time; from these numbers (and the roller's known moment of inertia), we can calculate the deceleration force generated by the brake.

The operating force on the brake hand lever is applied by a pneumatic cylinder hinged 25 mm (1 in.) from the end of the brake lever (Figure 2). The operating force is adjustable by means of a pressure reducing valve. Data were taken at various discrete levels of applied force in the range of 50 to 200 N (approximately 11 to 45 lb).

In the wet braking tests, two jets of water (4 ml/sec per jet) were directed onto the rim immediately in front of the brake pads. Distilled water was used to avoid any effects caused by a variation in water quality. The water was switched on shortly before a braking operation commenced, and switched off again when the roller had come to a standstill.

A brake test runs as follows: The wheel is accelerated to a speed of approximately 35 km/h (21.7 mph) using the electrically driven roller. Then the drive is switched off. An electronic controller ensures that the rolling friction of the roller is compensated for from the point where the starting speed of 25 km/h (15.5 mph) is reached.

At approximately 25 km/h (15.5 mph) an electromagnetic valve is activated to move the pneumatic piston against the brake hand-lever with constant pre-set force. The distance and speed recorders are started by a trigger switch fastened to the brake lever; the recording stops automatically when the roller comes to a standstill. The average deceleration is calculated from the wheel's initial speed and the measured braking distance. All measured quantities are printed out on a strip chart recorder.

A test sequence consists of 10 preliminary braking operations, 5 dry braking operations per level of applied force, 2 preliminary wet operations, and then 5 wet braking operations per level of applied force. The data from each set of 5 braking operations per level of applied force were then averaged to obtain the overall results reported below.

More Difference When Wet

Table 1 lists the different brake pad/rim combinations tested. Plain steel and stainless steel rims with different surface finishes (smooth and corrugated) and aluminum rims (bare, polished and anodized) were combined with the special Super Stop 1098 pads for steel rims, Super Stop 1090 pads for aluminum rims, and SR 75/82, a so-called universal pad.

The variation in braking distance with applied hand-force is shown in Figure 3 for the smooth steel rim with the Super Stop 1098 and SR 75/82 pads. In general, braking distance decreased inversely with increasing applied force, as expected. The dry braking performance was almost identical for both pads but, in wet conditions, the Super Stop for steel (#1098) achieved braking distances about 10 meters (32 feet) shorter.

The same relationship is seen even clearer in a plot of deceleration *versus* applied hand-force (Figure 4). First note that in dry condi-

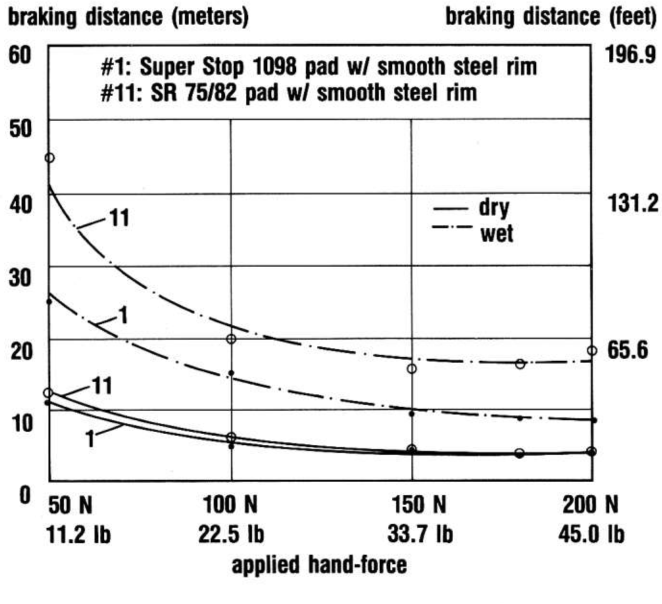


Figure 3: Measured braking distance as a function of applied hand-force for rim/block combinations #1 and #11.

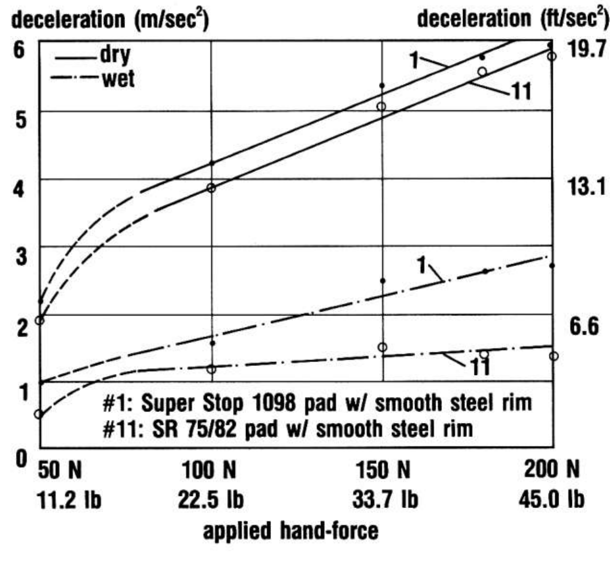


Figure 4: Deceleration as a function of applied hand-force (same rim/block combinations as Figure 3).

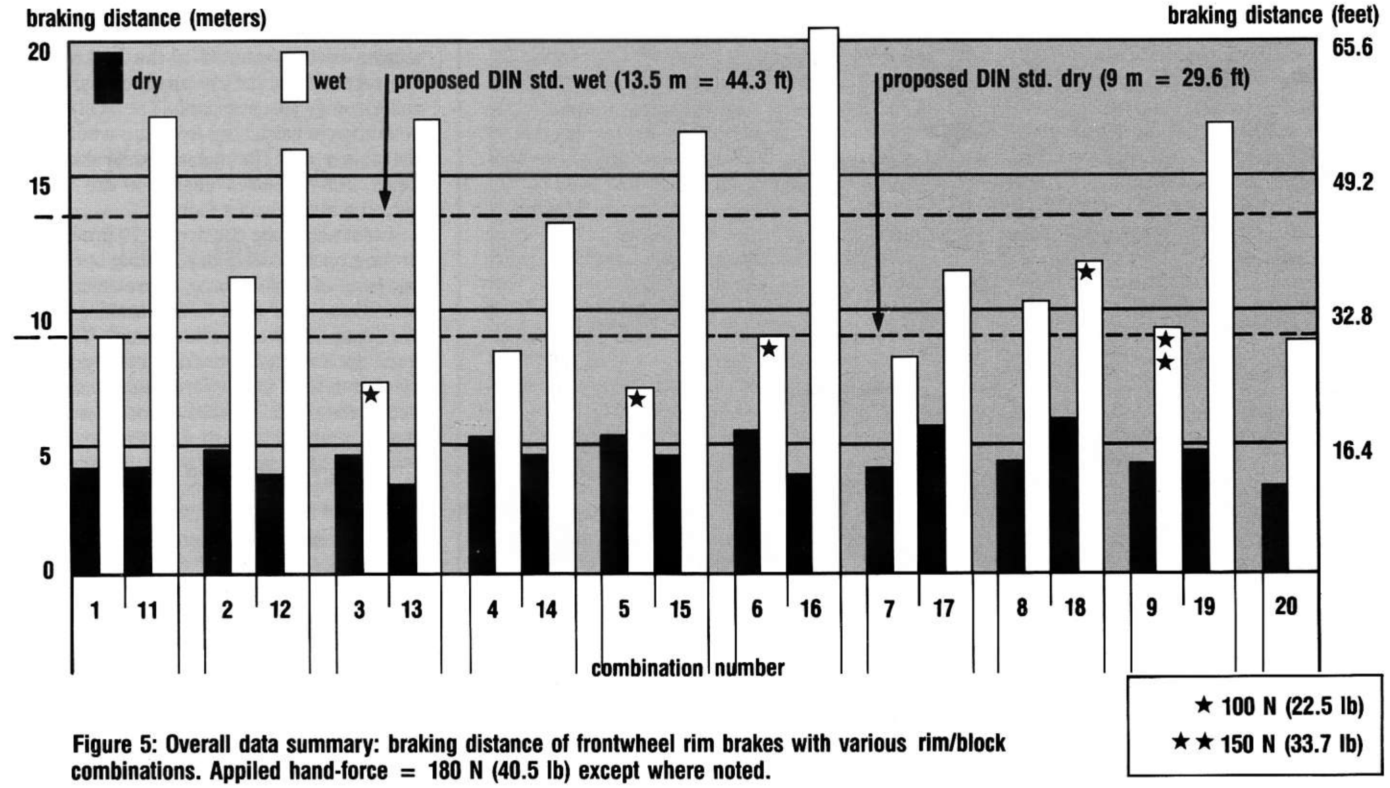


Figure 5: Overall data summary: braking distance of frontwheel rim brakes with various rim/block combinations. Appiled hand-force = 180 N (40.5 lb) except where noted.

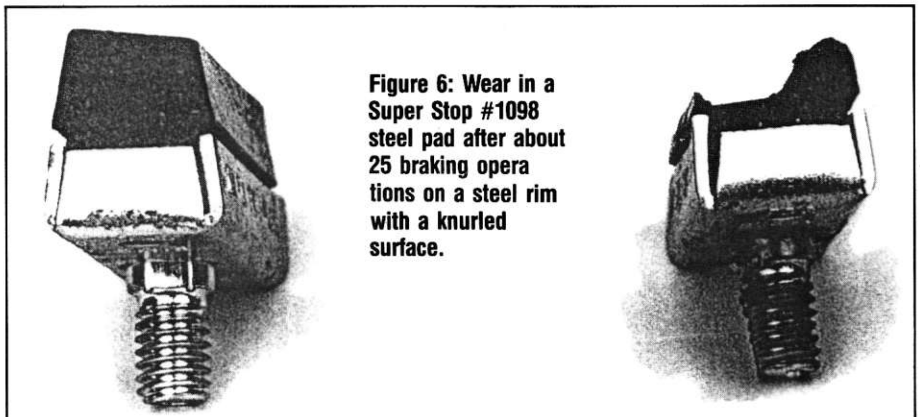


Figure 6: Wear in a Super Stop #1098 steel pad after about 25 braking opera tions on a steel rim with a knurled surface.

tions (solid lines), deceleration is a nearly linear function of applied force, a result which would be expected from theory. Second, note that in wet conditions (dashed lines), greater hand-force on the SR 75/82 pads (on smooth steel rims, combination 11) produces almost no increase in deceleration. By comparison, the Super Stop 1098 pads on the same rims (combination 1) generate substantially higher decelerations. Here is clear evidence, then, that two brake systems which perform nearly the same in dry conditions can behave very differently when wet.

Surface Texture Effects

For all the rim/brake combinations listed in Table 1, we tried to measure braking distances and decelerations with a fixed operating hand-force of 180 N (40.2 lbs.) as required by the existing German standard (DIN 79100). One problem was that, for 6 of the combinations under wet conditions, there was loss of adhesion ("skidding") between the tire and roller, making accurate readings impossible. We re-tested these cases (marked by notes 1 and 2) at lower hand-forces (100 or 150 N) to obtain the data shown in Figure 5. The dashed lines in the figure represent the maximum allowable braking distances proposed in the draft supplement to DIN 79100: 9 m maximum (29.5 ft) for dry conditions and 13.5 m (44.3 ft) for wet.

The effects of the rim's surface texture are seen by comparing wet and dry stopping distances in combinations 2 to 4 and 12 to 14. The results obtained with indented knurling on a steel rim (combinations 2 and 12) and the sandblasted rim (4 and 14) are almost the same as those for the smooth steel rim (1 and 11). Thus, corrugating or knurling the rim surface does not improve braking performance. In wet conditions, the water present in the rim grooves is apparently conducted to the friction surface and this decreases the friction effect. The initially rough surface of the sandblasted rim became worn smooth during the course of the test.

The raised knurling on the steel rim (combinations 3 and 13) had a severe abrasive effect, like that of a file, on the pads. Wear in the Super Stop #1098 pads was so great after approximately 25 braking tests, of which only one was with a force of 180 N (40.2 lbs.), that it had to be replaced (see Figure 6). The softer universal brake pad SR 75/82 did withstand the full series of tests, but it also displayed severe wear. For this reason we consider this rim surface unsuitable, in spite of its somewhat better braking effect.

The smooth stainless steel rim with Super Stop 1098 (combination 5) provided the shortest braking distance in these tests, even with the low operating force of 100 N (22.3 lbs.). It was not possible to achieve any higher deceleration figures without the tire slipping on the wet roller. Bright metal particles evident on the surface of the pad indicate that this good wet braking effect was achieved at the expense of rim wear or roughening. On this same rim (combination 15) the universal pad, SR 75/82, showed good dry braking characteristics, but some-

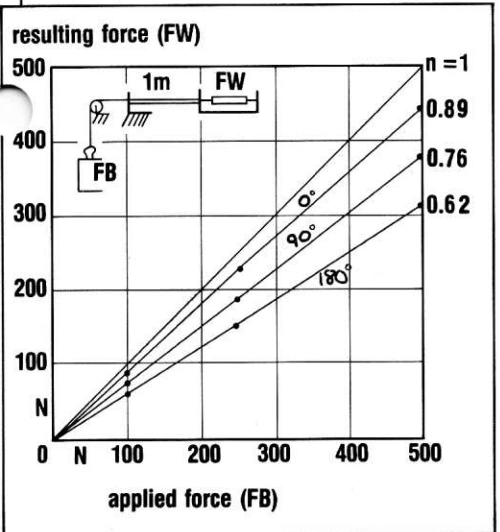


Figure 7: Characteristic force transmission curves for "Bowden" brake cable, showing the loss of efficiency in curved cables (90 deg and 180 deg) versus straight cable (0 deg).

what inadequate wet braking, similar to its performance on all the other steel rims.

The corrugated stainless steel rim (combinations 6 and 16) yielded good dry braking characteristics with both types of pad. But in wet conditions with the universal pad, it turned in the poorest performance in these tests. The roughness of this rim again resulted in an unacceptably short life for both types of pad.

Aluminum Rims Stop Better

With the aluminum rims (combinations 7-9 and 17-19), our aim was to establish the effect of different surface treatments (bare metal, polished smooth, anodized) on braking. The Super Stop #1090 pad, which was specially developed for aluminum rims, showed good wet and dry braking characteristics on all three rims.

The SR 75/82 universal pad easily meet the dry braking requirements with all three rims, but exceeded the proposed wet requirements with the anodized aluminum rim (19).

For both pads, the braking distances are slightly longer with the polished aluminum rim (combinations 8 and 18) than with the plain rim (7 and 17). With combination 18, good wet braking was obtained even with a force of 100 N (22.3 lb), but the surface of the rim became scored during the braking operations.

With the Super Stop 1090 pad on an anodized aluminum rim (combination 9) good wet and dry braking characteristics were obtained with very little pad wear. The dry braking characteristics obtained for the SR 75/82 pad on anodized aluminum rim (combination 19) were good. The wet test, however, had to be run with an lower applied force (150 N, 33.4 lb) due to excessive skidding on the wet roller, even though no great degree of deceleration had been achieved. The relatively soft pad tended to suddenly grab the anodized rim, which had been slightly roughened by repeated braking operations, and skidding resulted.

Which Combo Is Best?

To summarize, we note that corrugations on steel rims did not improve the braking characteristics, wet or dry. The main result of corrugations was an increase in pad wear and, with the universal pads (SR 75/82), an actual increase in braking distances in wet conditions.

With the three aluminum rims, pad wear in all cases was low because the rim surfaces were not corrugated. The universal brake pad (SR 75/82) produced slightly longer stopping distances, both wet and dry, than did the special pad (Super Stop 1090) on the aluminum rims. Overall, the bare untreated aluminum rim seems to be the best friction partner for both types of pad tested.

The rim/brake combination of choice, then, is that which shows not only adequate braking in all weather conditions, but also acceptable pad or rim wear. Smooth steel or aluminum rims without surface variations are best.

Other Improvements

Transmission losses in brake cables are a common problem, but are relatively easy to correct. Figure 7 shows the results of a simple, static force-transmission measurement we performed on a commercially available greased "Bowden" cable (1 m length). Note, for instance, that a 180 degree arc in the cable caused a 38% decrease in force transmission (62% efficiency). Clearly, this should be taken into account when brakes are being fitted.

Additional tests showed that improvements are necessary in the brakes themselves. A simple, commercially available sidepull brake with arms approximately 70 mm long mounted centrally on the mounting bolt showed severe permanent deformation (Figure 8) after a few panic stops under high hand-lever forces (150 N, 33.4 lb).

Figure 9 shows, by means of a double exposure, elastic deformation of the braking arms under an operating hand force of 200 N (44.6 lb). When such distortions occur, the brake pad cannot make good contact with the rim. Improvements are urgently needed here, either in the form of more substantial (stiffer) caliper brakes or by means of noncentric mounting and hence a shortening of the free caliper arms, as with centerpull brakes.

This report is based on a paper delivered at the symposium "From the Bicycle to the Low-Energy Light Vehicle: Bicycle Research in the Federal Republic of Germany," held on September 27-28, 1985, at the University of Oldenburg, West Germany. A special issue of ***Pro-Velo: Das Fahrrad-Magazin,*** *magazine of the All-Germany Bicycle Club (ADFL), contains the full conference proceedings in German. Copies are available for 6 Deutschmarks from: ProVelo Buch- und Zeitschriften-Verlag, Am Broicher Weg 2, 4053 Juchen, West Germany. For more information on bicycle research in Germany, contact Dr. Falk Riess, Bicycle Research Group, Department 8 (Physics), University of Oldenburg, PO Box 2503, D-2900 Oldenburg, West Germany.*

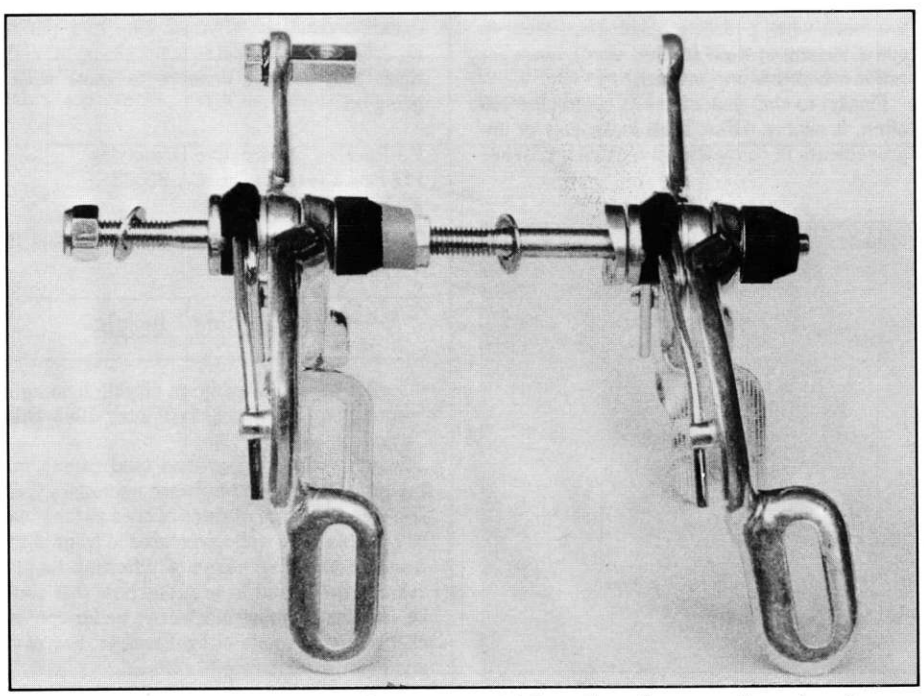


Figure 8: Caliper arm (on right) showing permanent deformation after a small number of stops, compared to undeformed caliper (on left).

The Beam-X Conversion

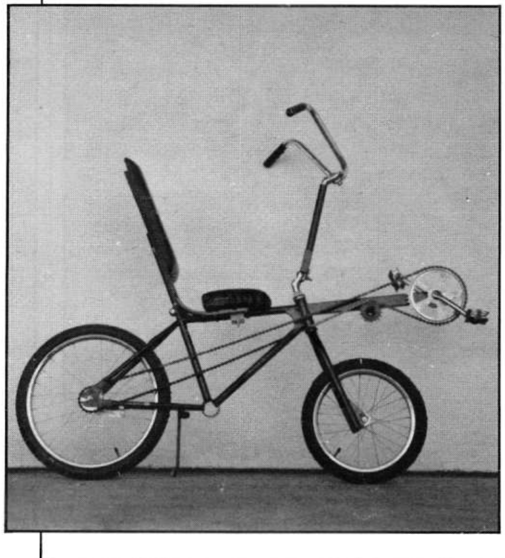
I was pleased to see a photo of the Roulandt recumbent in a previous **Bike Tech**, but I should point out that there are other low priced recumbents on the market. I build several such recumbent models ranging from child- to adult-sized, and also supply recumbent framesets, painted and unpainted, and construction plans.

Recently, I've designed what seems like the simplest and perhaps the only conversion of a conventional frame to a recumbent which keeps the original frame intact, the Beam-X (see accompanying photo). It is designed for young people from 4″-8″ to 5″-6″ and handles like most short-wheelbase recumbents (Lightning X-2 and others).

The Beam-X conversion will work with a variety of BMX frames, and it can be built to fit a range of rider sizes simply by changing the length of the extension beam. The seat can be made adjustable by eliminating the seatpost extension and adding a brace from seat to rear dropout. Complete kits, partial kits, and construction plans are available.

I've also been experimenting with a shock absorber mounted on a recumbent frame with a hinged rear triangle. I find it is phenominally comfortable riding on the street, but bounces too much when pedalling uphill. Next step: to add a locking system to stop shock absorber action when it is not wanted.

Finally, to shift gears here, a comment: Too often, it seems, **Bike Tech** looks only at improvements in conventional technology. While this is not bad, there are those of us in the industry who see the diamond frame bike as Indianapolis racers saw the Offenhauser engine a few years ago. Offenhauser dominated the scene because it was highly refined and accepted, but not necessarily best. You don't see many Offys on the circuit any more. However, had the USAC officials defined the racing machine in such restrictive terms as to outlaw anything but the Offenhauser, it would still be around. The racers, however, would have jumped ship to a more progressive organization.



The UCF has obviously chosen the restrictive route in its definition of the bicycle, and I believe it has hampered bicycle development tremendously. By contrast, the IHPVA, and the records set within their more liberal definitions, support a much better combination of rider and vehicle. There is plenty of grassroots research going within the IHPVA. It may not use all the scientific paraphenalia shown in some **Bike Tech** articles, but many projects use systematic trial and error methods in the best tradition of Thomas Edison. Including more **Bike Tech** articles on this type of research, even if it is not highly refined, would certainly keep reader interest high.

In short, there is plenty of creativity in cycle design. You just have to look past the Offenhauser of the cycling world, the conventional diamond frame bike. I can't believe that future changes in the conventional frame will have much effect on performance, or be cost-effective to the consumer. The megabuck Olympic bikes are about as different as a conventional bike can be, under UCF rules; and while the design may have provided the winning margin, the cost per tenth of a second saved was certainly no bargain. One cannot say that about "illegal" designs. A stock Easy Racer with fiberglass fairing would literally run circles around the Olympic bike in a pursuit race. The cycling field is still wide open, and I think your readers deserve to know what's going on.

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"Head Light" Insight

I offer some thoughts on bicycle lighting in response to the article in Winter 1985 **Bike Tech.**

Instead of hauling around (and paying for) the large amount of hardware necessary to illuminate "as large of patch of road as far ahead as possible", as well as the area in front of the front wheel, I've taken a different tack. I asked what I need to see, and how that could be illuminated most efficiently, under the cyclist's requirements of light weight, low cost, and high performance.

The answer is unequivocally the *helmet-mounted or head-mounted lamp.* With this device, I can scan for obstacles fourty-four feet or more dead ahead or fourty-four feet along a road or path curving sharply left, right, up or down. I can keep hazards spotlighted as I approach them, or even after I've passed them—a vicious chasing dog, for instance! In other words, I can see more with five watts directed at what I need to see, than with fifty watts indiscriminately blanketing an area ten times as big. A small piece of this field may be all my eyes can process at any give instant anyway.

My first headlamp was powered by a home-made battery/generator combination. A spiral wire (three feet long, extended) connected it to the back of the seat. When the bike stopped, the light didn't, and it proved invaluable for map reading, roadside repair, etc, as well as seeing me through such challenges as unfamiliar stream crossings in steep canyons.

I'm currently using a self-contained helmet light. It consists of a "Mag Lite" flashlight, made of machined aluminum with "0" rings throughout, and powered by two (NiCad) AA cells. It is ridigidly attached to the top of the helmet, but is removeable. It is so light I can't tell if it's on top of the helmet or not. It is so unencumbering and versatile I've taken to using it for setting up camp, walking, or working outdoors at night. Recently I made a head band for it out of 3/4 inch nylon webbing with "Fastex" buckles, for when I want the light without the helmet. With the "0" rings it could conceivably be used for diving.

With the NiCads, the light shines at almost constant brightness and then suddenly quits. Thus three pair of batteries are needed: one pair in use, one to carry along and pop in when the first quits, and one at home in the charger. My total investment is about $31 - $12 in batteries, $6 for the charger, and $13 for the Mag Lite, after which the only expense is for bulbs.

For being seen: I use my "head lamp" in conjunction with a tailight, (ideally rapidly flashing or otherwise calling attention to itself) and reflectors. Researchers may dump on reflectors, but I still *see* them everywhere, often brighter than lights. Arm and leg bands are #1 in light weight and versatility for highlighting, pedaling, signaling, fist-waving—unmistakably indicative of something alive.

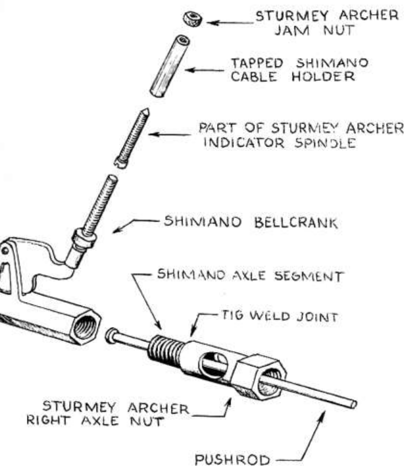
Finally, in case anyone might miss the gyrating wheel, pedal and leg reflectors, and the front and arm reflectors, I can use my headlight to "sweep" any cars at my front or side, or shake my head quickly from side to side at anyone in a particularly threatening position. This police-searching/UFO effect cannot escape any but the numbest motorist's attention.

Art Ludwig
Recycling Bike Shop
Santa Barbara, CA

Dave Sellers comments: Your helmet-mounted headlight sounds like a great idea. Spelunkers, miners, and other cave-dwellers use a similar set-up; some of their equipment, which is often sold by outdoor/sports suppliers, might be adapted to cycling use. Extreme example: a carbide-powered mining lamp burns in-

credibly bright, and avoids the problem of battery burn-out on those long night canyon explorations.

Sturmey-Archer Meets Shimano



I would like to elaborate on one of the points made in the excellent "Shop Talk" article, "Internal Hub Gear Interchangeability Tricks" which appeared in December 1982 **Bike Tech** (page 13).

In the article Mr. Allen advised people in search of a Sturmey Archer bellcrank (as I was recently for an S5 hub I've acquired) to improvise by brazing the mechanism of a Shimano bellcrank to a Sturmey Archer right axle nut, which could then operate the pushrod on the left side of the S5 hub.

I was about to follow this procedure when I realized that after the brazed-together nut and bellcrank were torqued down against the bicycle dropout, Murphy's Law would come into play, and the bellcrank cable fixture would probably not be pointing in a convenient direction for attaching the cable or operating the bellcrank.

So I modified the method as follows (see illustration): I had a machine shop cut off about 7/16 inch of the hollow end of a Shimano 3-speed axle—this is made of hardened steel which is very resistant to ordinary hacksaw blades but not to a cut-off wheel—and then TIG-weld this segment onto a Sturmey Archer right axle nut, being careful to align the two pieces on the same axis.

This joint permits the Shimano bellcrank to thread on to the axle nut and swivel, and also allows me to "fine tune" the length of the pushrod and replace it if necessary.

As a further convenience, I modified the brass cable fitting on the bellcrank to connect to a Sturmey Archer cable linkage as follows: I removed the threaded fitting, which is shaped like a drinking glass with a hole in the center of the bottom, and drilled out the hole and tapped it with a 5-40 tap (if you tap it from the inside the new threads will be aligned almost perfectly). Next I took a Sturmey Archer indicator spindle and cut off the chain and the part that inserts in the hub, so that I was left with roughly an inch of threads with a smooth fat part at one end (where I had made the cut). I then cut a slot in the fat end so that a small screwdriver can turn it as far as possible into the Shimano brass piece. At this point, the Sturmey Archer threads protrude maybe 3/4 inch from the bottom of the "drinking glass," which can now be screwed back onto the Shimano bellcrank. The whole arrangement is now compatible with standard Sturmey Archer cables and fittings.

I hope these modifications prove interesting and useful to fellow Sturmey Archer enthusiasts.

Nick J. Ackermann
Bowie,MD

PROTOTYPES

The "Orthopedic Bicycle"

Ollie McKagen

Editor's note: With all the talk these days about "anatomic" hand grips and skin shorts, we sometimes wonder when designers will start getting anatomic where it really counts: namely, in the pedal/drivetrain system. Now Ollie McKagen, a design engineer in Needham, Mass., is testing a radically new drive linkage that does just that. A rich variety of force/velocity/displacement relationships are available with his system, although it's mechanically quite simple. As you can see from the accompanying figure, commercial "variable-ratio" products like Biopace and Power Cam look positively tame by comparison.*

Conventional bicycle drive systems are not particularly well-matched to the human's leg-power output characteristics. The alternative system I am developing has the advantages of a variable force-velocity relationship between pedals and cranks, extra adjustability by reversing or re-positioning of the links, and a more natural pedaling curve than a circle.

I use the term "effective crank length" to characterize the non-circular shape of the pedal path. Effective crank length varies from 68% to 118% in one prototype I have built, and from 76% to 121% in another. (The percentages are relative to 170 mm cranks.) The variation in velocity is proportional to the effective lengths, and varies continuously from maximum (point 1) to minimum (point 2) to a second maximum (point 3) and a second minimum (point 4). Variation in force is inverse to velocity.

What's most interesting is that the force/velocity variations are NOT coupled to the slope of the curve explicitly, but instead are products of the *overhang ratio* of the crank legs (items #36 and #38 in figure) times the actual crank length. This overhang ratio is projected differentially during rotation, and thus produces a smooth variation in effective crank length.

I am hand-building a few of these prototypes as an activity parallel to seeking a manufacturer. Testing so far bears out the riding advantages I am hoping to achieve.

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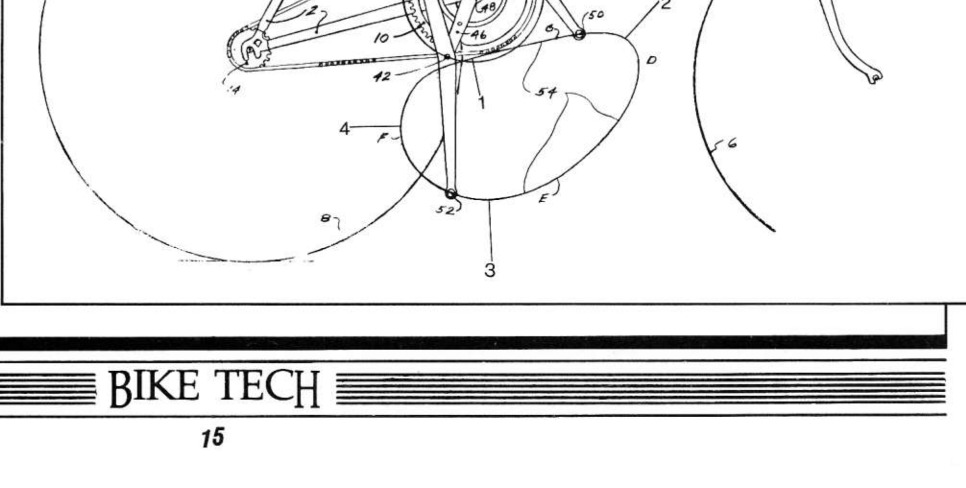

NEWSLINE

PHYSIOLOGY IN BICYCLING: This short (109 pp.) information-packed new book will be welcomed by serious riders, coaches, and researchers who need detailed scientific data on the physiology of cycling. The book is basically a digest of recent research on topics such as muscle physiology, metabolism, fluid/electrolyte balances, and training strategies. Much of the research was carried out with professional cyclists in France and Denmark, and is not reported elsewhere in English. One of the authors, Ed Burke, is well-known to Americans as Director of Sports Medicine for the USCF. The four other authors (Sjogaard, Nielsen, Mikkelsen, and Saltin) are Danish exercise physiologists affiliated with University of Copenhagen. ($13.95, Mouvement Publications, 109 East State Street, Ithaca, NY 14850. Telephone 607-272-2157.)

◀ **CAST MAGNESIUM FRAME**: In the auto industry, magnesium castings are commonly used wherever strong, lightweight parts are needed—high performance wheels, for example. It is natural, then, that auto engineer Frank Kirk, venturing into the production of bicycle frames, selected cast magnesium as his medium of choice. High production rates are a big advantage, according to Kirk, who claims that the automated equipment he uses can turn out one complete, fully-aligned frame per minute. His frame design (see photo) is comprised mostly of solid-section members (similar to I-beams in cross-section), although the downtube and head tube are hollow. Due in part to the downtube's unusual high placement, the magnesium frame's torsional stiffness is 50% greater than that of conventional steel racing frames. (Kirk Precision Limited, Unit 3, Brewery Fields, Great Baddow, Chelmsford, Essex CM2 7LE, England.)

LOW-COST STRUCTURAL DESIGN: Structural analysis software for microcomputers continues to drop in price. Programs now available for less than about $250 offer the same capabilities as those which were priced at several thousand dollars a few years ago and which could run only on expensive minicomputers or mainframes. For stress analysis of bicycle frames, and especially for exploring new ideas in joint design (welded/brazed connections, lugs, gusset plates, etc.), this low-cost software is ideal. New offerings include:

— **3D FRAMES** ($99.95): This program analyzes 3-dimensional frames, calculates displacements and rotations in three directions at each joint, and solves for stresses/forces in each member. Available for IBM and compatibles, TRS-80, MacIntosh, and CP/M systems. (Dynacomp, Inc., P.O. Box 18129, Rochester, NY 14618. Telephone 800-828-6772. Their catalog lists many other low-cost mechanical engineering programs.)
— **BEAMS & FRAMES** ($149.): Similar to **3D FRAMES** (above), but with capacity for larger structures and more complex load conditions. (American Society for Metals, Metals Park, OH 44073. Telephone 216-338-5151.)
— **STRESS-PAC** ($250.): Similar to **BEAMS & FRAMES** (above), but reports stress distributions in greater detail, and also handles cylindrical shell elements and beam elements of nonuniform cross-section, including tapered, oval, and curved tubes. (American Society for Metals, see above.)
— **STRUCTURAL ANALYSIS ON MICROCOMPUTERS** ($25.): This new book is a review of the use of matrix methods in structural analysis. What sets it apart from many others on this topic is that it contains 12 programs in the BASIC language, ready to type in and run. The programs, which perform tasks such as 3D space-frame analysis, limit analysis (plastic deformation), inversion of banded matrices, and analysis by subassemblies (method of parts), can be applied to the task at hand as needed. Clearly, engineering skill is needed to do this, but the low price can make this an attractive alternative to the packaged programs mentioned above. (MacMillan Publishing Co., Front & Brown Streets, Riverside, NJ 08075. Phone 800-257-8247.)

BRAIDED COMPOSITES HAVE LOWER FATIGUE LIFE THAN LAMINATES: A recent study by Lee Gause and co-workers at the Naval Air Development Center (Warminster,PA 18974; phone 215-441-1330) indicates that multidirectional braided graphite/epoxy composites have reasonably good fatigue properties, but shorter lives than the baseline laminate. For further details, request AD-A162-572/2 (NADC Report 85022-60) from NTIS, 5285 Port Royal Road, Springfield, VA 22161. (This item was reported by **Composites & Adhesives Newsletter**, published bimonthly by T/C Press, P.O. Box 36A28, Los Angeles, CA 90036. Phone 213-938-6923.)