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BIKE TECH

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COMPONENTS

The Next Unfair Advantage

The Browning Bicycle Transmission

Angel Rodriguez

I remember the first lesson I learned with my new ten-speed many years ago. "You have to ease up on the power to make the shift," the shop man kept saying. But I couldn't. I was shifting because I was slowing down to go uphill, and if I slowed down any more I wouldn't be going forward, and then shifting would be impossible. I finally mastered that paradox, but it took some mental anticipation and physical coordination. The shifting usually took only a fraction of a second, and if I made the shift in time, everything was fine. But heaven help me if I missed the shift.

Eventually I tried racing. And I quickly discovered the difficulty of shifting while riding uphill in a pack. I didn't have even a fraction of a second for a shift. If I sat down to let off the power, it was all over, and if I didn't shift it was all over too. What a deal. I often wished for something that would allow me to shift whenever I wanted, under full power, and with no possibility of missing a shift. What a dream.

The derailleur system, the most widely used transmission on today's bikes, is the source of these shifting problems. After all, pushing the chain off one chainwheel, in hopes that it lands on another, is a primitive, brute-force approach. Derailleurs were first conceived in France around 1934, and have remained virtually unchanged ever since. Their disadvantages are well known. A recent *Bike Tech* article stated: "conventional

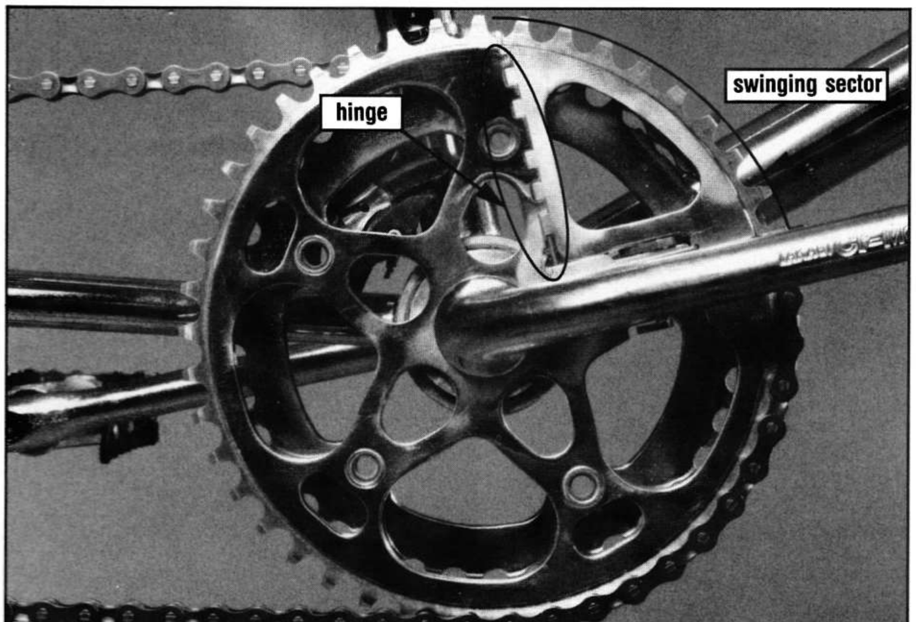

Figure 1: The Browning two-speed transmission, shown here in the middle of a downshift. Note chain engaged on both large and small rings simultaneously. The "ring cassette" assembly is comprised of two chainrings, hinge, and swinging sector.

IN THIS ISSUE

Note: Due to space limitations, the test report on bicycle headlights, originally scheduled for this issue, has been postponed to the next issue.

shifting components impose demands on the rider . . . the need to ease the pedaling force during the shift and the need for precision in moving the control lever."* The article reports that an incredible 20-plus kilograms (44 pounds, approximately) of cable tension was needed to shift the Campagnolo Super Record front derailleur while the bike was pedaled at what seems like an unrealistically low torque of 26 inch-lbs at the rear axle.

The second most common bike transmission is the internally-geared three-speed hub. This system uses planetary gears, which allow one to upshift and downshift by a certain ratio. The geared hub may be easy to use and reliable, but because it provides only three gear ratios (or five gears on some models), it is not suitable for modern touring and racing. And like the derailleur system, the internally-geared hub must not be under load at the moment of shifting.

The Browning Transmission promises to make these problems a thing of the past. The Browning system, which replaces the conventional front chainwheels and front derailleur, manages to shift the chain while keeping it *fully engaged on the cogs at all times*. How this is achieved is the subject of this article. The end result, in any case, is totally reliable shifting under even the heaviest pedaling loads, with negligibly small force (about 2 grams) on the shift lever.

"Biomechanics of Shifting Performance: Design of the Shimano New Dura-Ace Shifting System," by Shinpei Okajima, Bike Tech, *April 1985.*

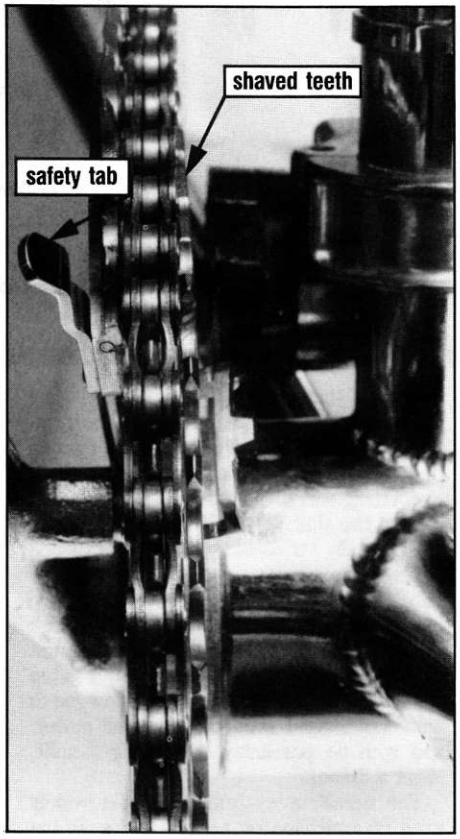

Figure 2: Front view of ring cassette, during the same downshift sequence shown in Fig. 1. Swing sector is swung *out* (away from small chainring), allowing chain to pass over shaved teeth (at arrow) onto small chainring.

Bruce W. Browning and his sons invented the transmission more than ten years ago (see sidebar), and refined it through extensive development and testing since then. A two-speed model for BMX machines is now commercially available, with a three-speed model for touring and all-terrain bikes (ATB's) scheduled for production soon. If the BMXers' enthusiasm for the Browning system is any indication, the conventional front derailleur may soon become extinct.

BMX racers have no use for derailleurs, finding them simply too unreliable. So when Darrell Young, a pro BMX rider, won the 1984 ABA Nationals on a Browning-equipped bike, the word was out. Here is the next unfair advantage; it's only a matter of time before the rest of the cycling world catches on.

Naming of the Parts

The Browning transmission has two basic components: a set of chainrings, called the *ring cassette* (see Figures 1 and 2), and a *selector assembly*, which mounts on the seat tube in place of a front derailleur (see Figure 3). (All photographs in this article show the *two-speed* BMX model **except figure 10*. I will explain later how the three-speed ATB model differs.)

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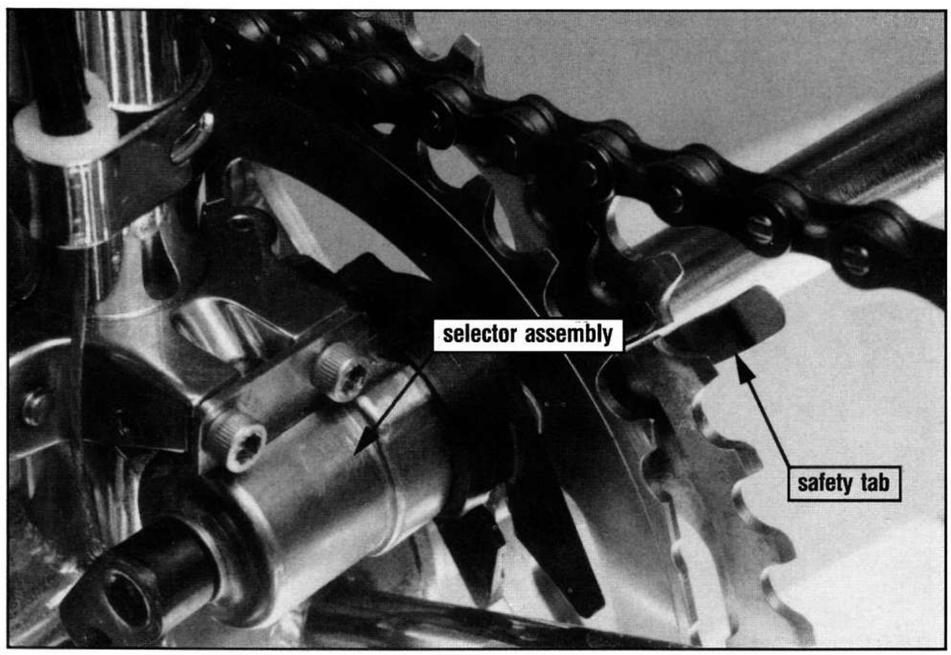

Figure 3: Selector assembly (at arrow) mounted on seat tube in place of front derailleur. Two cap screws allow for lateral adjustment. Note shift control cable at left, and shaved teeth on inner chainring at right. Also note safety tab on swing sector, needed to prevent another upshift when chain is on the large ring and an upshift is selected by the control lever.

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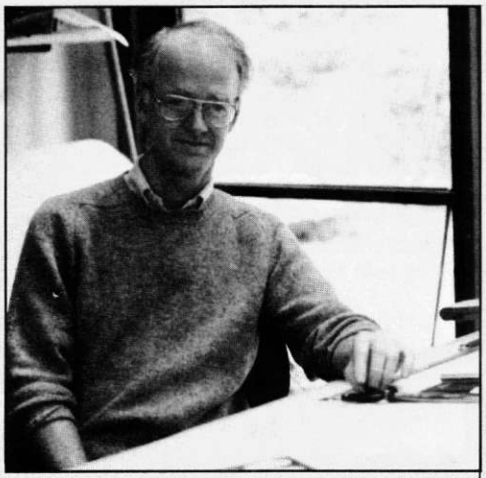


Bruce W. Browning at the drafting table.

Father of the Browning Automatic

Ten Years from Inspiration to Market

When Bruce Browning asked me to test his new shifting mechanism a few years ago, I assured him it would not work. But I tried it anyway and, to my surprise, it shifted flawlessly under power with not even a hint of missing a shift. Then I asked Bruce a hundred questions.

Bruce Browning worked until 1969 as a gun designer for the Browning Arms Company, a firm founded in 1925 by his grandfather, John M. Browning. You might remember that the Browning Company was marketing a bicycle for a short while in the early 1970's. As part of that project, Bruce was to design a better shifting system. The Browning Arms folks didn't appreciate a device that worked only occasionally under certain circumstances and only for skilled users. After all, the name Browning was synonymous with the world's most reliable guns; they worked all the time, every time, under all conditions, for anyone. Nothing less would do for the Browning bicycle.

In 1974, Bruce Browning and his sons Dave, Chris, Marc, Paul and Mike started a family "laboratory"; the sole purpose was to invent, prototype, test, and then sell ideas. Not your usual family business, but Bruce's background in mechanical design, drafting, and machining was ideally suited for this sort of venture. The Brownings were not serious cyclists in any sense of the word. But they would brainstorm in the evenings, making long lists of things to invent. One son said "Automatic Bicycle" and it got on the list. As the long list became a short list, it became clear that major changes were needed to make a bicycle truly automatic. Above all, it had to shift gears under every possible condition of speed, cadence, and pedaling force. This immediately left out any hope of simply making a better control mechanism for conventional derailleurs.

These inventors' jam sessions sparked the inspiration, in December 1974, of how to build an automatic chain transmission that *actually worked*. For the next two years Bruce and sons David, Marc, and Chris developed the idea, using drafting space and machine shop facilities in Mountain Green, Utah, rented from the Browning Company. The Brownings also formed Octo Company to manage their inventions, and signed an agreement with Browning Arms.

Subsequently, Browning Arms Company decided to leave the bicycle business and to cut off funds for development of the chain transmission. In August 1976, the Brownings filed a patent application to cover the fundamental principle of the transmission; they received US Patent #4,127,038 on November 28, 1978. Additional patents have since been granted, and others are pending. In December 1976, they finished the first industrial model of their invention, "a crude transmission with electric controls," in Bruce's words. This early prototype generated great interest at several companies, but no money.

Octo Company moved to Bainbridge Island in Washington state, after parting with the Browning Arms Company in February 1977. By selling stock shares in Octo Company, the Brownings raised funds to build a small shop and office space. Here they labored for the next year and a half on a second industrial prototype, this time a five-speed model. Again their efforts produced much technical interest but no money. Again work stopped while the search for funds resumed.

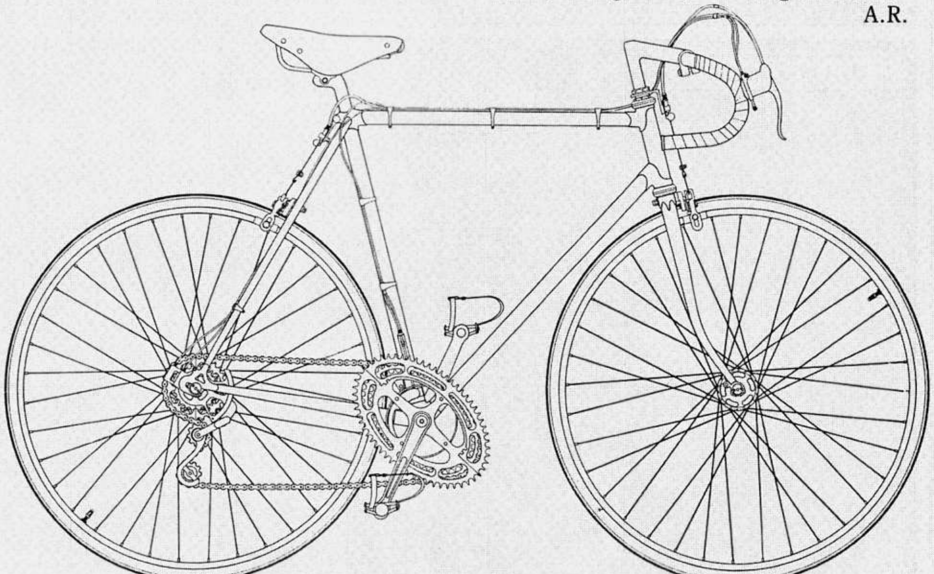
Finally, a partnership formed in 1980 with two other investors provided the funds and focus for continuing work. The goal was now to design a moderately-priced "automatic" bicycle and prepare it for high volume manufacture, a task that took two years. In January 1982, the second bicycle prototype was ready. It was a twelve-speed touring bike (see drawing) with Browning transmissions on *both* the front chainrings (oval, no less) and the rear freewheels.

The bike world was not ready for this. After receiving a cool reception from various dealers and cyclists, Bruce concluded that "our original design and market goals were faulty." The Octo Company realized that an overwhelming victory in the bike industry would call for more than just a technically superior machine.

The strategy then focused on the simpler task of gaining a foothold in the bicycle business. The idea of the "fully automatic" bicycle was put on hold, while marketing of the transmission itself was shifted into high gear. The first Browning BMX transmission was demonstrated at the Long Beach, California, Bike Show in fall 1982, and also exhibited to the American Association of Design Engineers in March 1983 at the request of *Design News*. At the same time, the Brownings completed work on a three-speed ATB and touring transmission.

Today, after more than ten years of work, the Brownings' invention is in commercial production. Remarkably, half of the last decade was spent, not in actual research and development of the product, but in searching for funds, demonstrating prototypes, and learning the bicycle business. In a low-key comment on the virtues of persistence, Bruce Browning said, "If it seems like we are proceeding slowly, it is because we must assemble the harmonious combination of finance, management, marketing and R&D."

A.R.



1982 Prototype, with Browning transmissions on front and rear. Note that the swinging sectors cover a full half of the gears, compared to only one quarter in the present design. Also note shifting controls mounted near brake levers.

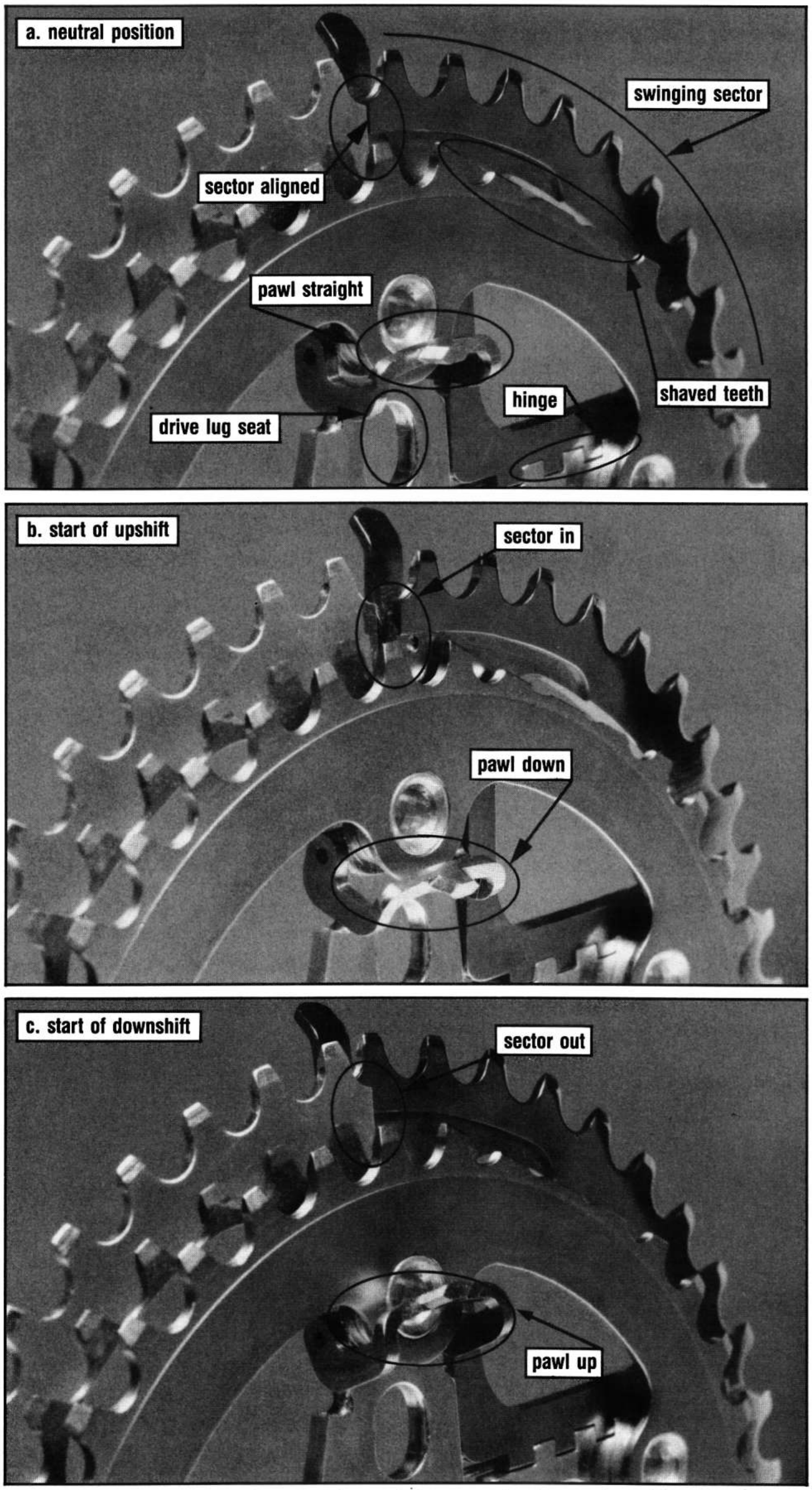


Figure 4: Position of hinged pawl (either straight, up, or down) controls position of swinging sector.

Continued from page 2

The two rings in the cassette are riveted together for reliability. The inner chainring is identical to a conventional one except that, for reasons to be explained, some of the gear teeth are cut away (see Figure 3). The outer chainring is unconventional: it has a pie-shaped *swinging sector* mounted on a hinge, allowing it limited freedom to swing from side to side. This swinging sector maintains control of the chain position at all times during both upshifts and downshifts.

Movement of the swinging sector is controlled by what's called the *chainring pawl.* The pawl is hinged onto one of the spider arms of the outer chainring (see Figure 4). When the pawl is moved radially outward ("up" in Figure 4), the swing sector moves "out" (away from the small chainring); when the pawl is moved radially inward ("down"), the swing sector moves "in" (towards the small chainring). After either of these motions, the pawl is returned to the center position, under force of a spring, and the swing sector moves to the neutral position (i.e., lined up in the plane of the outer chainring). This whole sequence of events is explained more fully below.

The position of the chainring pawl is controlled by the selector assembly. As the crank rotates, the pawl passes through two *cams* in the selector assembly (see Figures 5 and 7). The cams are moveable (in response to the shift control lever) and, depending on their position, route the pawl either up or down, and thus cause the swing sector to execute either a downshift or upshift (see Figure 7).

The two-cam setup provides an *interlock,* via the internal mechanics of the selector assembly, that eliminates the possibility of jumping the chain in case the rider backpedals during a shift. (Conventional derailleurs are all too vulnerable to this chain-jumping problem.)

Any conventional shifting lever and cable can be used to control the selector assembly. Some BMX riders like to use spring-loaded "twist grips" (such as Sturmey Archer #HSJ-763) for this purpose. Since BMX bikes have no rear derailleurs, a chain tensioner (such as Shimano #54801010) must be installed at the rear dropout, to take up the chain slack that occurs when shifting the front.

Gearing on the BMX model is 38T/44T, and the Browning BMX ring cassette can be mounted on any standard BMX axle (i.e., any one-piece crankset using a drive lug).

The three-speed ATB model works on the same principle as the BMX model. Of course, there are *three* chainwheels on the ring cassette, the larger *two* of which are made with a swinging sector as shown here. These two swinging sectors move *in unison* under the control of a *single* pawl and a single selector assembly. This triple cassette is geared 28T/38T/48T, making it useful for both mountain riding and touring. The triple cassette will mount on a standard (tapered end) cotterless crank axle, and the dimensions have been selected to allow the widest range of interchangeability with existing axles. Thus, the Browning system can be used with conventional bottom bracket components (bearings, axles, cups, retainers, etc.).

Solid Engagement

How exactly does the Browning transmission work? The explanation is deceptively simple. The important point to remember is that *the transmission is always engaged*. During a shift, the chain is seated momentarily on two gears at the same time. This is why the chain can carry a full pedaling load at all times during shifting. Of course, conventional front derailleurs keep the chain constantly engaged during a *downshift*. The Browning system achieves this constant engagement on *both* an upshift and downshift.

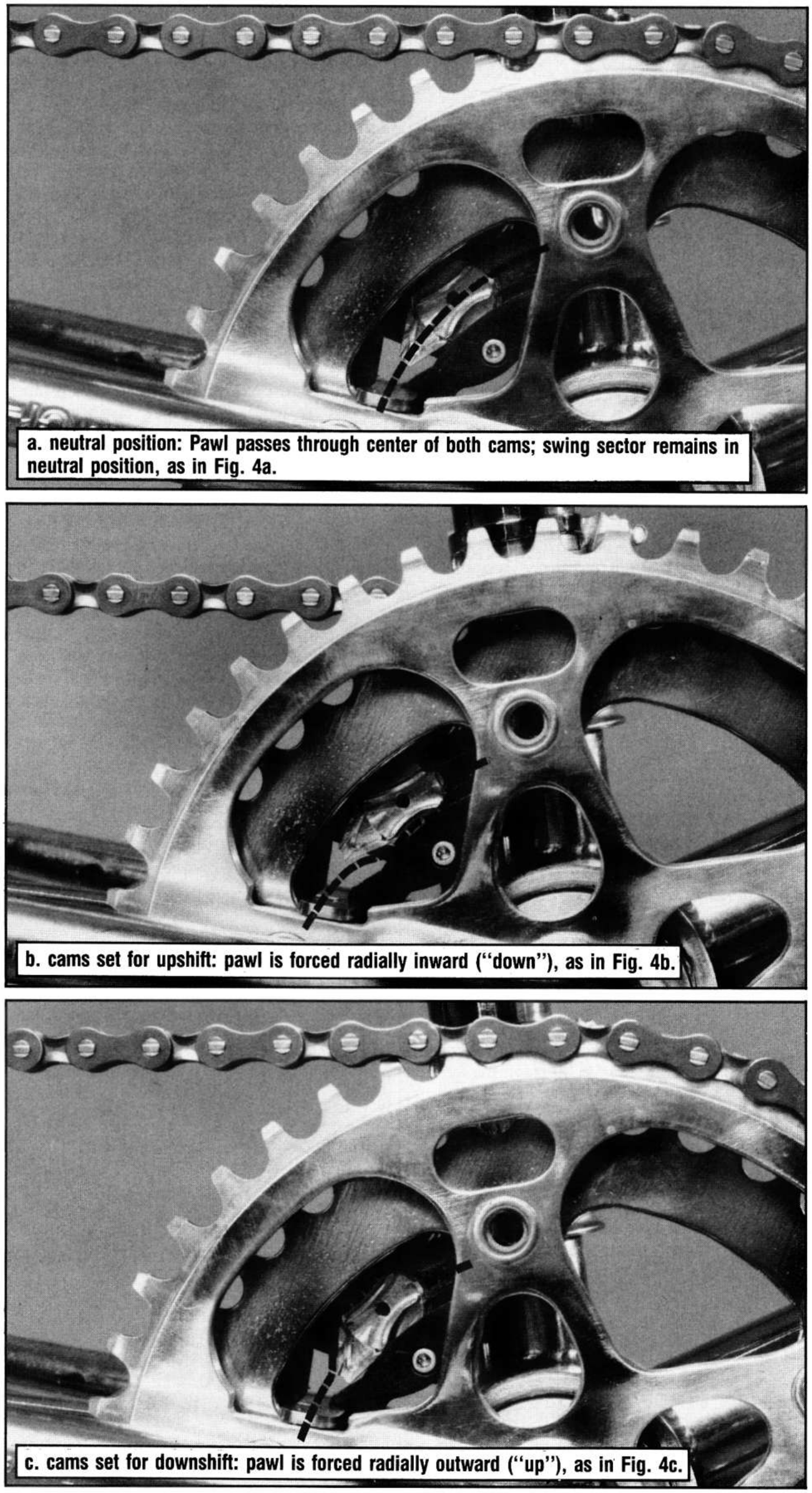
Think of how a railroad switch works. A train can be (momentarily) on two sets of tracks at the same time, with the process controlled by the switch. The switch moves a short set of tracks into (or out of) the train's way, in much the same way that the transmission's chainwheel pawl moves the swinging sector into (or out of) the chain's way. (Imagine if the railroads tried to make a train switch tracks by pushing it sideways with a big front derailleur cage!)

The swinging sector serves the same function as the moveable tracks in a railroad switch. During upshifting, the swing sector provides an essentially *spiral* path of teeth that lifts the chain off the small chainring onto the large one. During downshifting, it simply swings out of the way, allowing the chain to drop onto the small chainring by its own force. Here's a step by step look at these two processes.

The Up Switch

We'll start with the right crankarm at 9:00 and the chain on the small ring. At this point, the swing sector is between 6:00 and 8:30, and the pawl is in line with the crank at 9:00. As the crank reaches 10:00 (see Figure 8a), the chainring pawl meets the triangular cam which was set for an upshift by the selector (Figure 5b). The pawl is forced *down*, pulling the swinging sector inward toward the bike frame (Figure 4b) and into the line of the approaching chain. Shortly thereafter, the chainring pawl reaches the forward bottom curve of the reset cam, forcing this cam up and thus returning the triangular cam to its neutral position (Figure 5a).

When the crank reaches 11:00, the leading tooth of the swing sector begins to engage the chain (see Figure 8b). At 12:00, the swing sector has started to lift the chain off of the small ring, and the rider is now aware he is pedaling in a higher gear. By 2:00, the chain is well-seated on the swing sector, but is still engaged on the small chainring. When



a. neutral position: Pawl passes through center of both cams; swing sector remains in neutral position, as in Fig. 4a.

b. cams set for upshift: pawl is forced radially inward ("down"), as in Fig. 4b.

c. cams set for downshift: pawl is forced radially outward ("up"), as in Fig. 4c.

Figure 5: Operation of cams in selector assembly. Dashed lines show path of pawl.

the crank reaches 7:00, the transfer is complete and the swing sector springs back to its neutral (in-line) position.

The Down Switch

We'll start again with the crankarm at 9:00, but now the chain is on the large ring. When the crank reaches 10:00, the pawl meets the triangular cam (which is pointing down, see Figure 5c). As the pawl slides over the triangular cam, it is pushed upward, which moves the swinging sector out of the path of the approaching chain (Figures 4c and 5). At 10:30, the pawl has passed the triangular cam and reaches the forward (upswung) end of the reset cam, pushing it down into the neutral position (Figure 5a). The swinging sector remains swung out.

At about 12:00 the chain misses the outswung sector and "falls" onto the inner chainring (Figure 2). The shaved teeth of the inner ring provide the necessary clearance for the chain to move into position properly. If the teeth were not cut away, the chain would wedge between the two chainrings, as often happens when trying to upshift under load with a conventional derailleur.

While the crank is between 12:00 and 3:00, the chain is actually on both chainrings (Figure 1), like a train on two tracks at the same time. The switch is complete when the crank has reached approximately 3:00, and the chain is fully engaged by the small ring.

Shifting Loads

Because the chain is engaged at all times, the Browning transmission can carry full pedaling force during shifting. No conventional derailleur system has this capability. In tests conducted by Octo Company (see Figure 9), a Browning BMX unit showed no missed shifts after more than 64,000 up/down shift cycles under a constant load of one horsepower (this corresponds to constant 100 lb pedal force at 90 rpm cadence). By comparison, recent tests on Shimano, Sun-Tour, and Campagnolo front derailleurs were done at only 1/25 horsepower, which, under the reported test conditions, corresponds to pedal forces in the range of 7 to 15 lb. at 25 to 57 rpm (reference Figures 7 and 8 on page 4 of April 1985 *Bike Tech*).

Octo Company also performed destructive tests to see which component in the drivetrain fails first under outrageously large forces. These tests simulate the heaviest imaginable rider climbing a steep hill with loaded panniers. They calculated that a constant pedal force of 300 lb. represents this situation, allowing for a BMX rider capable of applying 330 lb. peak pedal force or a tourist using toe clips applying 500 lb. peak force. Under these loads, the Browning transmission showed no damage and continued to shift even while teeth were being sheared off the freewheel.

How much effort is required to shift? Since the shift is initiated when the swing sector is *not engaged* with the chain, a force of only 2.5 grams on the shifting cable is needed. In comparison, the Shimano New Dura-Ace front derailleur requires about 4,800 times more force to shift, i.e., 12,000 grams cable tension is needed (reference Figure 7 on page 4 of April 1985 *Bike Tech*). The 2.5 grams needed to shift the Browning transmission could be supplied by a battery-powered motor or solenoid, thus making fully automated shifting possible.

Production Methods

The Octo Company machines their prototypes by hand. The small chainring and swing sector are made of heat-treated AISI 4130 steel, with a finish of electrodeless nickel plating for corrosion resistance. The small chainring need not be made of steel, but it was chosen for the 38T/44T BMX application so that the 38T ring could be thinner, and thus placed closer to the 44T. In other applications, aluminum may be used.

For volume production, the chainrings and swing sector are made by a process called fine-blanking. This is a precision stamping operation, developed in Germany and Switzerland, using dies that are "deadly accurate" (a BMX term). Fine-blanking is one of the few mass production methods that can hold the close tolerances (plus or minus one thousandth inch) needed to make the hinge on the swing sector work properly.

The outer chainring (except swing sector) is made of 2024-T3 aluminum alloy by the fine-blanking process. It is then heat-treated to T8 temper, which results in properties close to those of 7075-T6. The 7075 alloy is not used in the first place because it is very hard on the fine-blanking dies.

Despite the extensive use of steel, the Browning system weighs about the same as a conventional chainwheel/derailleur setup.

In the BMX model the chainrings are assembled by a process called orbital riveting (see Figure 5). The designer felt that regular nuts and bolts were not reliable enough for the BMX market. In the ATB/touring model, the traditional threaded bolt system may be used for easy interchangeability.

ATB/Touring Model

Design of the BMX model was simplified by the fact that BMX bikes have only one gear in the back. With a multi-gear freewheel, the Brownings found that the wide angles of the chain caused it to derail off the swinging sector, especially when the chain was on the large rear cog during an upshift under heavy load. Consequently, the swing sector on the ATB/touring model is *bowed* in the following way: the teeth on the sector at the leading edge march in an arc away from the centerline of the bike, and at the same time lean into the bike's center line. The net effect is that all teeth help carry the chain laterally as opposed to only the last few teeth on the BMX model. The ATB model will

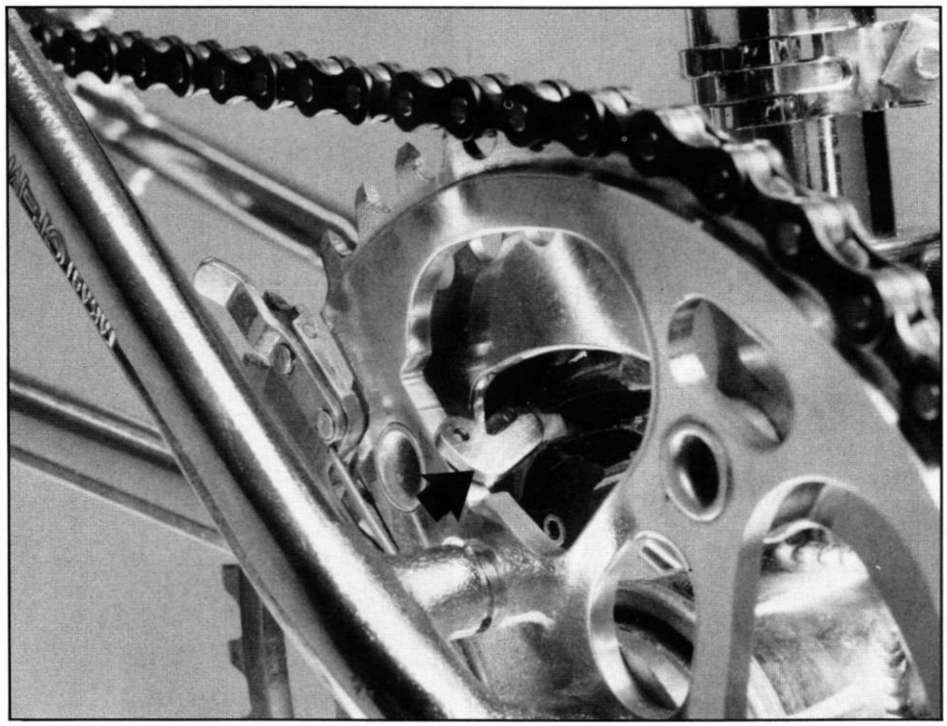


Figure 6: Chainring pawl (at arrow) shown passing through the control cams in the selector assembly.

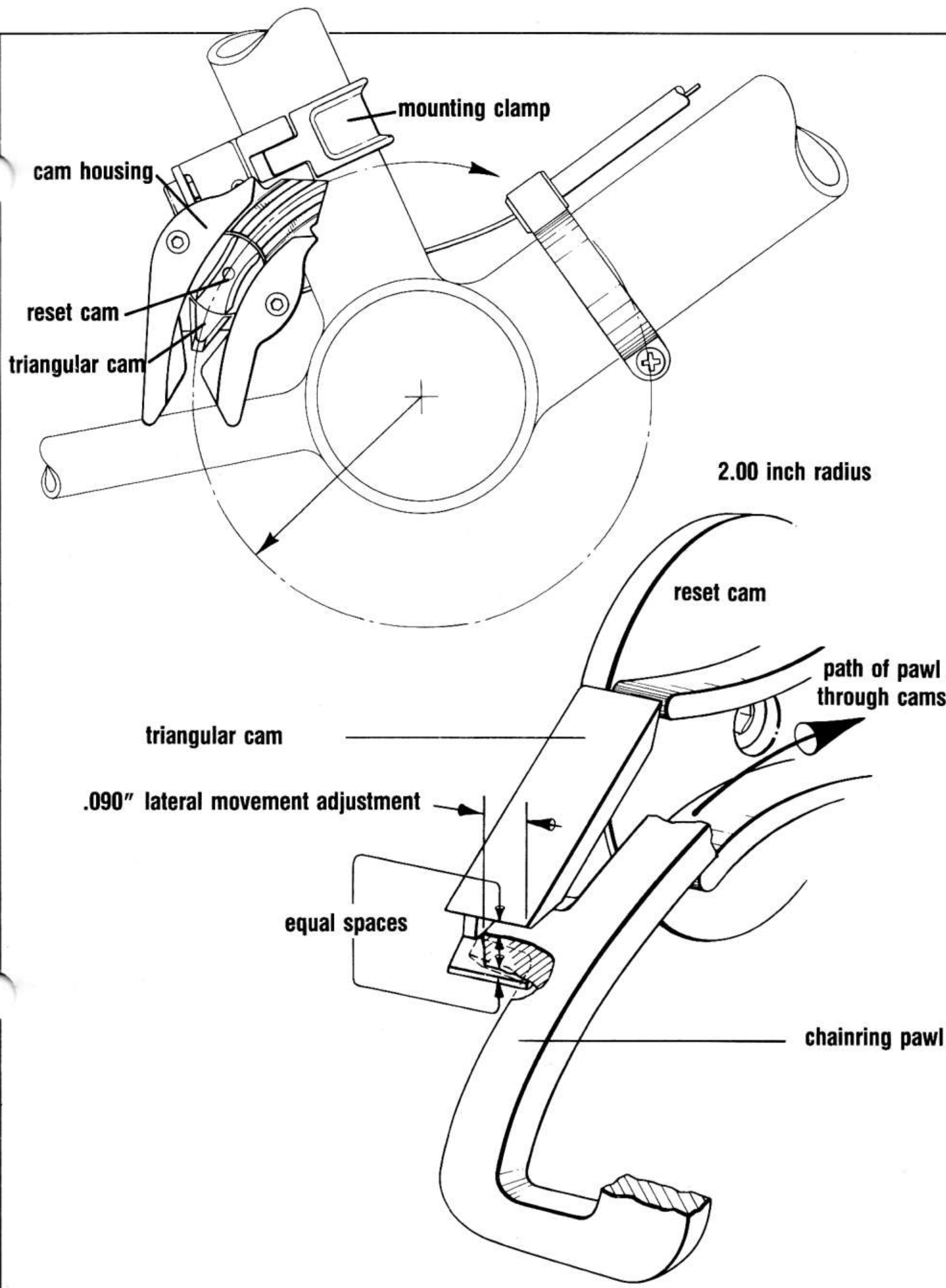


Figure 7: Selector assembly in position on seat tube (upper drawing). Triangular cam and reset cam control the path of the pawl. Lower drawing shows critical alignment between pawl and cams.

handle freewheels that fit in 121 mm rear spacing, giving the rider 15 or 18 speeds.

The shift lever for the three-speed ATB model works differently than a conventional front shifter. It has three positions (center, forward, and back), but the two outermost positions (forward and back) are *momentary*, i.e., a spring returns the lever to center position when the rider lets go. For example, moving the lever forward for an instant and then letting go is the signal to "call for a downshift." The transmission responds as follows: if in high gear, it switches to middle gear; if in middle gear, it switches to low; if already in low, nothing happens. Upshifting is similar. Thus, to call for an upshift, the rider pulls the lever back for an instant and lets go. If the transmission is in low gear, it switches to middle gear; if in middle gear, it switches to high; and if already in high, nothing happens. The benefit to this type of shifting control is that the rider wastes no time making fine adjustments to the lever position, as is often needed when shifting into the middle gear with a conventional front derailleur. The rider simply hits the lever "into the stops," and the shift happens automatically.

Dealer Support

The marketing plan for the Browning transmission was based directly on the successful approach of the Browning Arms Company. A group of well-trained, active dealers is the key. Browning transmissions are available to customers only through qualified bicycle dealers and shops.

Initially, only dealers are allowed to install and adjust the units; consumers will not be able to buy the units "loose" to install themselves. The reason is that the selector assembly must be aligned perfectly when it's first installed. If the chainring pawl does not go precisely into the triangular cam every time, serious damage could result to either the pawl or cams. Fortunately, this critical alignment process needs to be done only once.

The selector assembly is designed to snap off the mounting bracket for easy replacement. (Position of the fixed mounting bracket preserves the critical alignment discussed above.) If a selector ever needs service, the dealer simply installs a new selector from stock on the customer's bike, and returns the bad selector to Browning. Browning then ships a new selector to replenish the dealer's stock. The net result is that the dealer never faces the problem of opening up the selector, with its more than twenty small parts, for repairs.

Why BMX First?

Many would doubt the wisdom of trying to sell a new transmission into a market where, historically, shifting systems are distrusted. Besides, the first BMX unit carries a retail price of $250—quite expensive for what might be perceived as "nothing but two chainrings."

Despite these drawbacks, the Brownings saw BMX as the ideal challenge. If the new product could take the jumping, bumping, and dirt crashes, it could take anything. In short, the Brownings realized that their transmission could survive in any market if it survived BMX. Other factors also swayed the decision. The BMX market is not as tradition-bound as the mainstream racing/recreational market. And since there are no competing transmissions in BMX, defensive reactions from the derailleur manufacturers were not likely. Finally, if the Browning transmission failed to thrill the BMXers, this would not necessarily jeopardize its success in other cycling markets. So the Brownings decided to offer prize money to any BMX rider who wins a national event with their products and to pay for personal endorsements.

Now that a pro BMX rider won the 1984 ABA Nationals using a Browning transmission, other markets are in the Browning sights. The all-terrain bike seemed like the next roughest market, with the serious tourist in line shortly after that. As of this writing, prototypes of the ATB/touring model are going out for dealer evaluation.

The largest cycling market, recreational/sport riders, may be the slowest to accept the Browning transmission. After all, the average price for a department store bike last year was $89.

How Does it Ride?

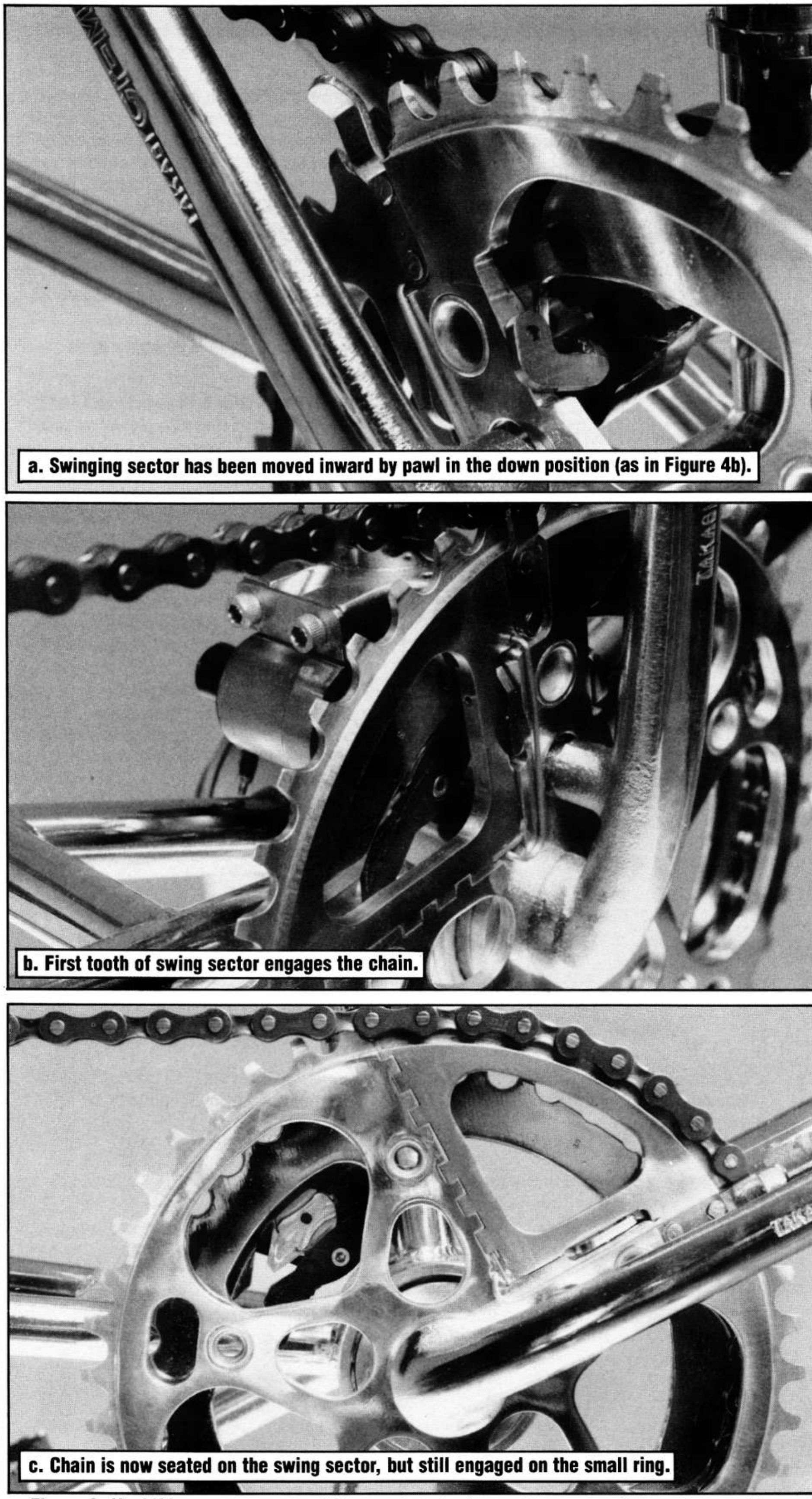
The way it works on the road is the very thing that got me interested in the Browning project. I have been going to trade shows for about 14 years and have tried all sorts of bike gizmos. For the most part, they are easy to discard for one reason or another: too heavy, too ugly, unreliable, etc.

The day I first rode the Browning transmission, my attitude was "I'll be polite and take it up the block." Well, that's all it took. I was sure these folks had something. The first time I shifted, I wasn't sure that the chain really moved. I was standing on the pedals when I tried that first shift, and I was sure that nothing was happening, so I tried it again, and got off the bike to confirm that the chain was in fact on the other chainring. At that point all I could do was smile, and try it again to make sure that it wasn't a fluke.

After a few minutes I could tell when the shift was happening and began adjusting to the new feel. Since the swing sector always picks up the chain at the same place, there can be a delay of almost a full revolution (a second and a half at slow pedaling rpm's) until the cranks come around. I had been expecting the instant rasping and grinding (generously called "feedback" in the April 1985 *Bike Tech*) that tell you the front derailleur is at work. Instead, I was disconcerted by the silence. Like switching to a new electronic typewriter that does not make the letter in immediate response to the key stroke, the small delay can be distracting for a while. Once you're used to that, it's great! Now I can't wait to get a Browning transmission for my personal tandem; no more trying to communicate and coordinate that difficult downshift while going uphill!

Angel Rodriguez started work as a bike shop mechanic in 1971. In 1973 he opened his own shop, R+E Cycles, and a year later studied framebuilding in England. He has received several bicycle-related patents. Nowadays he is best known for building the Rodriguez Tandems. Angel has been a consultant to the Brownings on the transmission project since 1980.

This article was written in cooperation with the Octo Company research team and the Browning Automatic Transmission Company. Inquiries concerning the transmission may be sent to Browning Automatic Transmission Company, 105 West 2950 South, Salt Lake City, UT 84115.



a. Swinging sector has been moved inward by pawl in the down position (as in Figure 4b).

b. First tooth of swing sector engages the chain.

c. Chain is now seated on the swing sector, but still engaged on the small ring.

Figure 8: Upshifting sequence: upshift was started when selector moved cams into position as shown in Figure 5b.

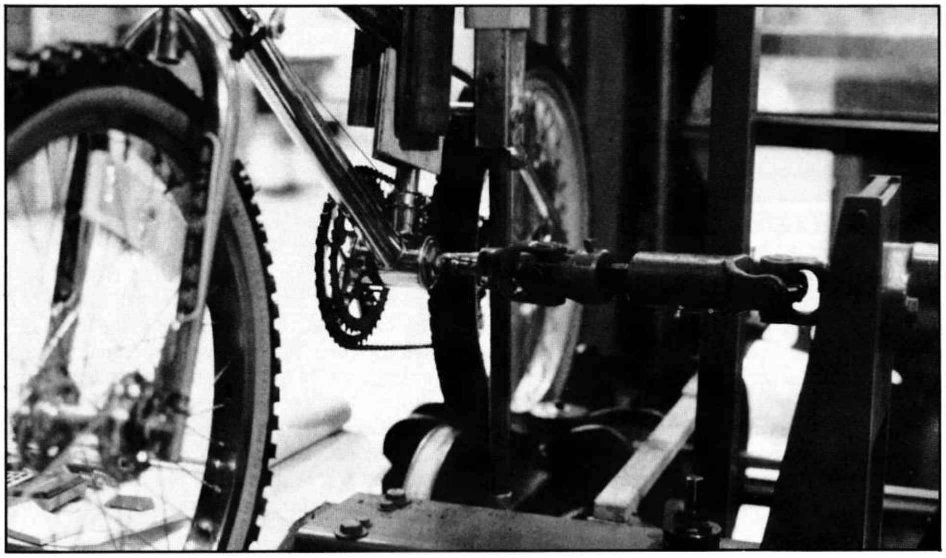


Figure 9: Two views of the main test machine at Octo Company. The fixture holds the bike upright and applies a load at the seat. A hydraulic motor drives the crank axle from the left side through universal joints. A friction brake attached to one of the rear rollers applies resistance. By measuring rotational speed and torque at the friction brake, power through the transmission is calculated.

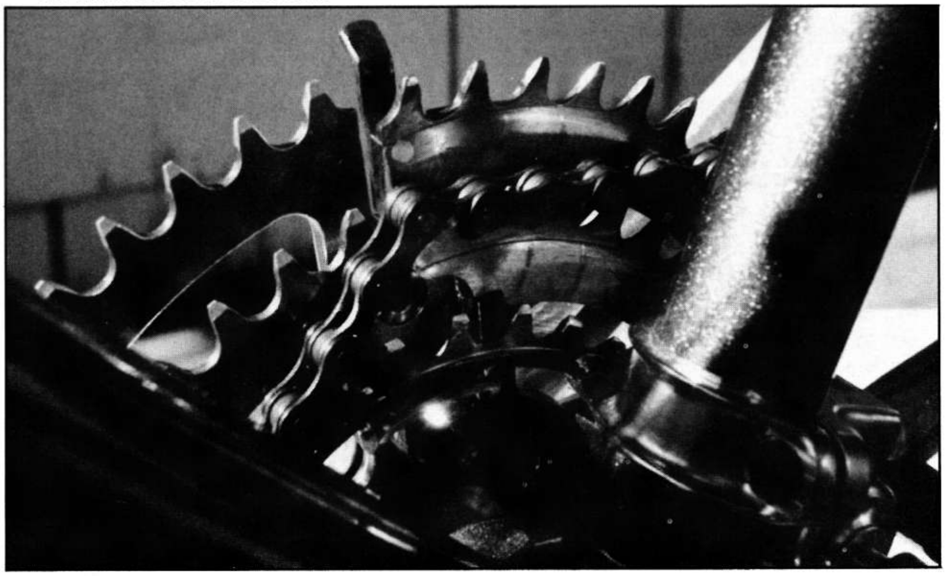


Figure 10: Bowed teeth on the swing sector for the ATB/touring model are needed to accomodate wide chain angles due to shifting on the multi-gear freewheel.

SPECIAL REPORT

American Frame builders: A Status Report

An In-Depth Survey of Twenty-Four Craftsmen

Mario Emiliani

A mention of the occupation ''frame builder'' evokes a host of visions: beautiful hand-craftsmanship, smooth-riding bicycles, custom fit, status. Frame builders receive their share of both admiration and envy; after all, they make something which is truly beautiful and yet very functional. Too bad we're not all so talented!

Except for those folks who are personal friends with a frame builder, most people's knowledge about frames and frame building is gleaned from magazines and books. Unfortunately, some of these sources have been inaccurate, misleading, or even highly biased.

For example, there has long been a myth that one has to have gray hair and speak Italian in order to produce a good frame. For that reason, many people have discounted as inferior the brilliant, young new breed of American frame builders.

Contributing to the problem is that American frame builders have never had much of a forum for informing the public about their craft, or to toot their own horn—as well they might. Fact is, American builders have made an immense contribution to the art of frame building. To be competitive with today's American-made frames, imported frames must now exhibit consistently excellent alignment, craftsmanship, and paint and chrome finishes. Most imported frames can't compete.

In an attempt to provide the sort of forum American frame builders deserve, I sent a long questionnaire last year to many leading American frame builders. Their responses, both facts and opinions, are summarized below with a minimum of editing. In a few places, I have added my own comments (clearly identified as such) to help put matters into perspective. The resulting status report is surely the most comprehensive view yet presented, regarding the American frame builders, their techniques, and their practices.

Anyone considering the purchase of a high-quality frameset or bike should find in our survey many good reasons to "buy American." The survey results should help you understand how American frame builders work, and may help you decide which frame builder is best suited to satisfy your riding needs.

Finally, those of you who have been tempted by visions of jigs, brazing rod and torches should find much valuable information about the frame building business in these pages. Good luck!

The Frame builders

The questionnaire was divided into four sections: 1) The Frame builder and His Business; 2) Frame Tubing, Frame Components, and Brazing; 3) Frame Failures and Product Liability; and 4) Miscellaneous Questions.

I sent the questionnaire to 32 American frame builders chosen on the basis of geographic diversity, range of experience, and production volume. Prior to sending the survey, I asked each frame builder if he would answer the questions, some very personal. To my surprise, nearly every frame builder was eager to respond to even the most sensitive questions. I received back 24 questionnaires, a 75 percent return rate. These builders are listed in the accompanying box.

I do not list individual names along with specific responses since I promised anonymity in order to obtain more candid and complete responses.

Two notes: Although Albert Eisentraut is making very few frames these days, he will be gearing up for increased production soon. Albert has a lot of experience, and I have high regard for his opinions. Also, Dave Moulton is still a British citizen but can be considered an "American" frame builder since he is working in this country.

On some questions, I sensed a general consensus of opinion, and tried to group the responses to reflect this. On other questions, there was a wide diversity of opinions, and I have tried to represent them all fairly.

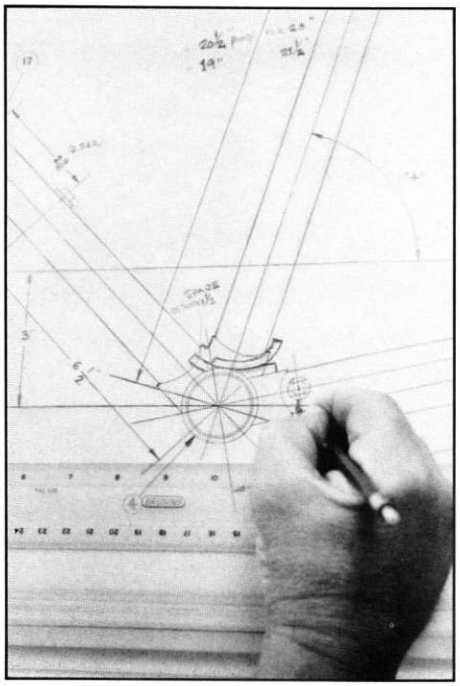
The Frame Building Business

Q: *How long have you been building frames? How long have you been selling frames?*

A: The 24 frame builders have been building frames for 3.5 to 27 years, with an average of 10.95 years. The person with 3.5 years experience had worked with a torch for 21 years as a designer and sculptor. The frame builders have been selling frames (mostly under their own names) for 3 to 22 years, with an average of 9.31 years.

Q: *Are you a full-time builder? If so, how long? If you're a part-time frame builder, what do you do for a living?*

A: Sixteen frame builders make frames full-time and have an average of 8.59 years of experience. Four builders work part-time



and hold such diverse jobs as hairstylist, machinist, railroad brakeman, and manager for the phone company. The rest divide their time between frame building and running their bike shop and/or import business.

Q: *Do you repair frames? Do you paint frames? Do you import cycling goods or engage in other types of business directly related to bicycles? How much of your business does each of these activities account for?*

A: All 24 frame builders repair frames to various extents. Some specialize in repairs, and a few do it as a service only to buyers of their frames. Twenty-one paint frames, and many refinish frames. Fifteen builders are involved in related activities such as importing, retail sales, wheel building, manufacturing custom touring racks and other components, research and development, and computer software for frame design. Only three builders derive over half of their business from selling or importing general "bike shop" merchandise; the remainder have very small retail or import businesses. So 85 percent of the typical frame builder's business is derived strictly from frame building, frame repair, and frame painting.

Q: *Are you the only frame builder in your shop? If not, how many people build entire frames? How many build just portions?*

A: Thirteen frame builders work alone, four builders employ others (two to six people) to build entire frames, and three frame builders employ one to three people to build portions of frames. One builder employs an apprentice, and the rest have up to three persons who do finishing work, i.e., filing lugs, sanding, painting, etc.

Q: *How many hours does it take you to build an average frame? How many frames do you build each year? How many frames have you built in your career?*

A: To build a standard ten-speed frame (minus the paint job) takes from 9 to 47.5 hours, with an average of 25.10 hours. Five frame builders make basic no-frills production framesets, which in one case takes as little as 6 hours.

The frame builders make from 5 to 400 frames a year, with an average of 118 frames a year. If the five builders who make over 100 frames are removed from the analysis, the average number of frames built is 53.

Over their careers the frame builders have made from 36 to 3500 frames, with an average of 843 frames. Clearly, some builders have made a *lot* of frames. If the eight frame builders who have made over 500 frames are omitted, the average number of frames built is 219.

Q: *What types of frames do you make? What is the average retail price of an average frame? Do you sell complete bicycles? If so, what percentage of your sales is made this way?*

A: Forty-two percent of the builders make frames for sport cycling, 40 percent make road-racing frames, 33 percent make touring frames, 10 percent tandem frames, 6 percent off-road frames, 5 percent track, and 6 percent other (i.e., recumbent, wheelchair, tricycle, mixte, etc.).

The average retail price of a custom-built frame is \$728. However, the price can exceed \$1,500 for special custom frames, or can be as low as \$475 for non-custom-fit production frames. Twenty of the frame builders sell complete bicycles, which account for an average of 44 percent of their sales as a group. The percentage of complete bikes sold ranges from 8 percent to 95 percent.

Q: *What guarantee do you give with new frames? Is it in writing? If you had your way, would your guarantee be any different than it is today?*

A: The frame builders give three types of guarantees: lifetime, limited-time warranty, and "case by case"; and these guarantees generally cover alignment, performance, and defect-free materials and workmanship. Thirteen builders give lifetime guarantees on their product, usually only to the original owner. Only two give warranties covering a fixed-year time period; one covers five years and the other covers one year. One frame builder gives a five-year warranty on racing frames, and lifetime on touring frames. The rest have no fixed policy, but make a sincere effort to do what they can to please the customer.

Eight builders put their guarantee in writing. The remainder don't because customers don't ask for it, or because they feel it's a worthless document. The frame builders are very concerned about preserving their good reputation, and they believe this is best done by giving their word that they will satisfy the customer completely.

Only two builders said they would like to change their guarantee. One would like to make it 15 years instead of the five years his lawyer recommended. He feels that this is a realistic warranty period, unlike lifetime warranties. The other frame builder who now gives a lifetime warranty would like to give a limited-time warranty. He believes that a frame can't be expected to last forever; frames are subject to rusting, wearing out, and simply deteriorating, just like other components on the bike, he says.

The warranty questions stirred up a lot of emotion. One frame builder said that lifetime warranties are ridiculous since so many builders have gone out of business and are no longer around to back their guarantee. But all frame builders felt that they would do whatever it takes to please the customer. One builder gave a free new frame to a customer whose old frame failed as a result of a mild crash. (I know that many frame builders will gladly repair the frames they build, at their own expense, even when the damage is not their fault. You won't find this kind of commitment with imported frames.)

Q: *Do you guarantee repairs made on your frames? On other brands of frames?*

A: Eighty-seven percent guarantee repairs made on their own frames, and 70 percent guarantee repairs made on other brands of frames. Most frame builders limit coverage to what was actually fixed—a tube that breaks next to a repaired joint wouldn't be covered, for example. Five builders said they would continue to warranty their own frame even after they had made repairs as the result of a crash. Some builders were not willing to guarantee even repairs they made on their frames if they'd been crashed because hidden defects could cause failure. Others refuse to guarantee temporary or "quick and dirty" repairs requested by the customer. Those who don't guarantee repairs on other brands of frames said they don't want to take responsibility for another person's work.

Q: *How do you fit frames to customers?*

A: All respondents employ a combination of methods to determine frame size. The most popular technique combines tape-measured body measurements, the customer's old frame size, the frame builder's catalogue of geometries he can build, and experience. Five builders also use the FIT-KIT, a system devised by Bill Farrell of New England Cycling Academy, Lebanon, N.H. Two frame builders also use their own measuring jig, and one also uses a computer program for frame design.

Q: *How do customers find out about you?*

A: While almost everyone agreed that word-of-mouth is the best way to attract customers, all but eight builders supplement this method with advertising in print, articles in cycling magazines, references in books, and appearances at trade shows, races, and tours.

Q: *What percentage of your sales are through bike shops?*

A: Five of the builders sell over half of their frames through bike shops, eight builders sell less than half through bike shops, and eleven sell all their frames directly to customers.

Q: *What are the main selling points of your frames?*

A: Nearly everyone mentioned quality control, fit (of rider to frame, and suitability for intended cycling use), workmanship, finish, ride, and the availability of custom features. Six builders, who had the capability to fill orders with little or no wait, said availability was also a sales feature.

Frame Tubing, Frame Components, and Brazing

Q: *What brands of tubing do you use? Why?*

A: All but one builder listed Reynolds and Columbus as their brands of choice. Seven also use Tange, Ishiwata, and generic AISI 4130 tubing for certain applications. Nobody uses Vitus tubing on a regular basis. Four frame builders use *only* Columbus tubing, while two use *only* Reynolds tubing. One builder says his choice of tubing is a "secret" and sells his frames without a tube identification decal.

Most frame builders explain their choice of a specific brand of tubing by citing "consumer demand" and "good availability." Other reasons were low price and high quality. One builder said he uses Columbus tubing because of the variety of gauges and tapers available.

Q: *How do you decide which gauges of tubing to use? Do you use ultra-thin tubing?*

A: All said they choose the tubeset according to height and weight of the rider, as well as the type of frame and riding conditions. Twelve builders said they're willing to follow customers' preferences for tube gauges, and three are concerned with the riding style of the cyclist.

Eleven of the frame builders prefer to avoid ultra-thin tubes, believing that weight savings are negligible and that such frames don't last long. Thirteen builders said they don't mind using thin tubes, but generally with the qualification that they use them only if the situation calls for it (e.g., time trial bikes). Many would warn their customers of the limitations of thin tubing.

Comment: Years ago, some American builders were willing to try anything—some of their frames were quite far from the norm. Thus they gained a reputation as either iconoclasts or frivolous amateurs. But these responses seem to indicate a reversal: American frame builders showing truly professional concern that customers get the proper size and weight tubeset—while many foreign manufacturers will mass produce ultra-light frames and sell them to all comers.

Q: *Do you use different filler metals on different areas of the frame?*

A: All use at least 2 or 3 different brazing alloys in different areas of the frame. Their choices depend partly upon the type of joint, i.e., lugged or lugless. There are two classes of filler metals: silver and brass brazing alloys. Most users of silver brazing alloys use them for lugged joints - that is, top tube/head tube joints, bottom bracket joints, fork blade-to-crown joints, etc. The silver alloys characteristically melt between about 1145-1350 degrees F and are favored because silver-brazing is quick, clean up is easy, tubes can be readily replaced, and tubes are distorted less by the heat.

Brass-brazing alloys melt between about 1630-1720 degrees F, and are preferred for joints with large gaps, such as dropouts. That's because these alloys have a wide melting range (i.e., the difference in temperatures at which the alloy is completely solid and completely liquid), and are thus easy to build up or fillet. Brass filler metals are also used to avoid remelting on certain joints that will be reheated to the silver-alloy range. For example, seat stays are often "capped" by brass-brazing and then the seat cluster is joined by (cooler) silver-brazing. Finally, brass is widely used because it is economical.

Q: *Do silver-brazed frames have greater sales appeal?*

A: Sixteen builders thought so, but their reasons varied widely. Five builders feel that silver-brazing really does produce a mechanically better joint, and thus its sales appeal is justified. They cited mostly correct reasons, including: easier clean-up and repair methods with silver-brazed frames, and less tube distortion due to lower silver-brazing temperatures.

One frame builder called silver-brazing a "sales gimmick," another thought it cost prohibitive, and another said consumers incorrectly assume price is synonymous with quality. Five builders who acknowledged silver's sales appeal said a skilled builder can make a good frame no matter what brazing alloy is used; I'm sure many others feel the same way.

Q: *What defects do you find in frame tubing? Which brands of tubing have the most defects? Which brands have the best quality control?*

A: The answers here depended on how many frames the builder had made; small builders see few defects, and long-time builders aren't likely to be bothered by a few defects because tubing quality is much better now than in the past. Also, users of only one brand of tubing will never encounter defects in other brands.

Overall, the frame builders didn't feel that tubing defects are a big problem, since the frequency of defects was very low (on the order of about 3 percent). As for quality control, the consensus was that Columbus, Reynolds, and Tange, in that order, were the best. But at least three builders felt that all the manufacturers have about the same level of quality control.

The most common defects mentioned were: out-of-round tubes, oversized tubes, slightly bent or bowed tubes, drawing tears (i.e., gouges along the length of the tubes), dents, rough surface finishes, spiral bulges caused by not pulling the mandrel out straight, and pits.

Because Reynolds and Columbus are the most popular brands, it's no surprise that frame builders would single them out when listing defects. The major defects are drawing tears in Reynolds 531, and bowed tubes in both Reynolds and Columbus. When asked whether they reject tubes at an "uncomfortably high rate," 79 percent said no. One person said the quality of all tubes except Reynolds 753 satisfied him. One small builder noted that all tube rejects hurt because he cannot absorb the cost. Another said rejects are part of the cost of doing business since it's too much effort to return a few tubes.

Q: *Do you find defects in frame components (i.e., lugs, bottom brackets, dropouts, fork crowns, braze-ons, etc.)? Are they associated with any particular manufacturer?*

A: Nineteen builders said the rejection rate for frame components isn't high enough to be a problem.

Common defects in frame components were: undersized outside diameters of lug sleeves (or oversized tubes!), pits in investment cast components, angles of the chainstay sockets in bottom brackets are off, and cable guide holes are off-center. Campagnolo dropouts were listed specifically by seven builders as having poor forging quality. Eight frame builders said defects weren't a problem (some fix minor irregularities), and nine said that defects weren't associated with any particular manufacturer. Those who did list manufacturers spread it out evenly over those producing frame components.

Q: *What guarantees would you like to have from manufacturers of tubing and components?*

A: Eight builders thought the existing warranties good enough, while six said that manufacturers should assume complete liability for defective products. Four builders thought that manufacturers should simply inspect their products better, three said no warranty is needed, one thought replacement of defective parts would be sufficient, and the rest didn't answer the question thoroughly.

Q: *Do you normally cold set frames and forks?*

A: Cold setting is a process used to align and straighten frames, forks, and dropouts by bending them to their proper position after joining (and sometimes at periodic intervals during joining). Also, forks and rear triangles are often spread apart a small amount after joining to compensate for thermal stresses which draw the dropouts together.

Consumers think that competent frame builders shouldn't "resort to" cold setting; they imagine that frames and forks come out of the jig straight as an arrow. However, frames rarely come out straight enough for no-hands riding because jigs aren't perfect, thermal stresses alter alignment, and tubes aren't straight to begin with. These all contribute to small amounts of misalignment, so cold setting must be done to ensure a proper ride. It's as much a part of the manufacturing process as is filing lugs.

Twenty-two builders said they cold set their frames and forks by "small amounts," typically less than 2 millimeters. Only two said cold setting a correctly brazed frame is unnecessary. One frame builder who said this noted that he cold sets his dropouts "occasionally" to make them parallel to each other, and the other aligns the rear triangle with his torch. (This torch method works - I've done it - but it is inexact and may cause the stays to spread farther than is needed.)

Two frame builders objected strongly to those who say they don't cold set their frames: They said that a frame builder who doesn't cold set is "either lying or kidding himself that his frames are straight." One noted that "all fork blades are ovalled and bent cold, so why are consumers so concerned about cold setting?"

The most prevalent reason given for the need to cold set is that it's the only way to obtain a near perfect alignment. Some frame builders said that even though they make very straight frames, their own standards for alignment dictated small corrections after joining. One builder expressed concern over frame builders who, by making large cold-set adjustments, can put bulges in tubes or cracks into brazed joints. In summary, builders would like to end the controversies about cold setting. They would tell you that, used intelligently, it's nothing to be concerned about.

What If . . . the Frame Fails

Q: *How many of your frames have failed? Did they fail consistently in any particular place? Was anyone injured?*

A: I was surprised that all but two of the frame builders answered this question. Five said they'd had no failures. The seventeen others averaged 4.5 frame failures, with four of the seventeen having only one failure. The greatest number of failures was 15 to 20 by one highly respected long-time builder who's made over 2000 frames.

Many pointed out that most failures occurred early in their careers and that they have long since corrected the way they make frames. In addition, many failures were attributed to defective components which frame builders couldn't have known about beforehand. I found no correlation between the number of frame failures and the number of frames built.

Only one builder had a failure which resulted in (minor) injury. Apparently the steering column separated from the fork crown. Ten builders said they'd experienced a similar type of failure in their frames, but all have made corrections in their fabrication process to prevent a recurrence.

Q: *If you had a frame failure caused by defective components, did the manufacturer of the components pay for repairs?*

A: Only thirteen frame builders answered this question, all saying no manufacturer has ever covered the cost of labor, repainting, or frame replacement due to a component failure. A few were able to obtain new parts free from the importer or manufacturer, but felt it wasn't worth the effort of proving who was at fault.

Some builders noted that importers don't handle claims for defects, and distance makes it impractical to seek restitution from foreign manufacturers. One frame builder said "most manufacturers will never accept responsibility, so there's no point in asking." He stated further that he repairs "about 10 cracked Campy 1010B right rear dropouts each year (on all makes of frames)," and believes those dropouts have a "design defect." Another builder said that "every self-employed person has to do some work for nothing for the sake of good customer relations."

Comment: Even though failures are rare, frame builders spend more time and money than they'd like fixing frames which failed as a result of defective components. Many would like to see manufacturers assume responsibility for the components they make. But nobody thinks manufacturers will willingly change their "you-bought-it, you-own-it" method of doing business.

Q: *Are you incorporated? Do you carry product liability insurance?*

A: Only seven of the builders, most of whom also have retail or import businesses, are incorporated. They did so for financial and tax purposes, and to separate themselves from business liabilities. The rest, who aren't incorporated, either haven't looked into it or were advised by lawyers or accountants that their business is too small.

Fifteen frame builders have product liability insurance, with coverage ranging from $25,000 to $3,000,000 per accident. Most of those without coverage said that its cost was too high. But the costs mentioned by those with coverage were $0.69 to $10 per frame. To my mind, that's very little money for peace of mind in today's litigious society.

Customer Relations

Q: *Do consumers have realistic expectations when they want to buy a frame?*

A: Eleven frame builders said consumers' expectations were about right. They said today's customers are "well-informed," and that the builder's own standards are usually higher than the consumers' anyway. To my surprise, only four builders thought expectations were too high. One reason is that "customers aren't aware of the limitations of hand craftsmanship and the materials used." And problems with handmade frames do occur. The most common are minor cosmetic blemishes in brazing or paint.

Believe it or not, five frame builders thought consumers' expectations weren't high enough. The most sensible reason is that consumers "don't fully appreciate the effect of the time and effort put into custom frames." One frame builder said this is the fault of "magazines, books, and bike shops, which glorify inferior products."

Q: *Do you think frame building quality standards should be adopted?*

A: I asked this question because some frame builders feel that inexperienced part-time builders reflect badly upon their business. However, only four builders said they favor frame building standards, while two said "maybe," noting that minimum safety standards and assumption of liability by the builder would be desirable. The remainder said no standards should be set. Most felt that "hobbyists" don't affect their business much, and those who can make good frames deserve the business.

Q: *Would you support a frame builder's craft guild?*

A: Several years ago, an attempt to form a guild failed, partly because some builders suspected, rightly or wrongly, that the organizer (a frame builder and importer) was trying to monopolize the market for frame building supplies.

Fifteen builders thought a craft guild a good idea; most said it could increase their buying power for materials, advertising, and liability insurance. Two builders had no opinion, and the remainder were opposed.

The comments I received indicate that organizing a guild would be difficult, no matter how desirable. For example, one frame builder said he would join only if "four or five others whose work I respected would be the (other) members."

Q: *How many frames must a person make to become a competent builder?*

A: Many builders said that an exact number could not be specified, since differences in learning ability and investment in fixtures and equipment were also important. Others said that about 50 frames was the minimum, but noted that some builders have been working for years and still can't get it right.

Q: *Do you notice problems with imported frames?*

A: The frame builders felt, in general, that imported frames suffer from inconsistent quality and poor mitering, brazing, alignment, and finish. One builder said imported frames are "all hype, decals, and chrome; they may look as good as hand-crafted frames, but they are just cheaply built frames made from high quality materials." He also said "the public is led to believe these imports are the same quality" by extensive advertising.

Another comment on imported frames: "They all come from much larger shops than mine, and as such cannot give as much attention to details. The paint jobs on some of them are pathetic . . . alignment can also be a problem. I loved the ad a few years ago for a leading Italian frame that was designed to take either five- *or* six- speed rear hubs! I guess they put those dropouts somewhere in the middle and you just made up the difference with a little push and shove."

Another builder noted, "There are foreign builders doing beautiful work, but importers bring in the shoddy, fast-buck frames. These bikes have problems, all (of) which indicate a hurried building process." Another said he is impressed by the mid-priced ($500-$800) Japanese production frames, and noted that "their alignment, brazing, and quality control are far better than the European bikes in that (price) range."

Finally, one builder said that imported frames "sell because they are available." (A good point, I think; many customers are not willing to wait 2-6 months for a frame.)

Q: *How do you justify the higher price of your frames, compared to imports?*

A: Most said they don't justify it; one look is enough to convince people that their product is superior. But some builders said their "overall quality is better" because they spend more time on each frame and pay closer attention to details.

Some builders pointed out that they make production frames or relatively inexpensive custom frames that are competitively priced and higher in quality than mass-built imports.

Q: *Do you lose much business to the imported frame market?*

A: Ten frame builders said no, citing such reasons as: "I have all the business I can possibly handle," and "Our market is with people who want a finely finished frame. The import customer wants lots of chrome, stickers, and pizza sauce."

One builder said that "American builders must become automated if they are to compete with imported frames in the years ahead. They must use automation to decrease the time spent on machining, alignment, etc., thereby allowing an increase in time spent on the real craft of frame building; . . . hand shaping of lugs, finish, and customer interaction."

Eleven frame builders said they lose *some* business to imported frames. (One added ". . . but *they* are also losing some business to me.")

Conclusion

Conducting this survey was quite an adventure. Some frame builders who did not participate were nothing short of rude at my attempts to enlist their help. One builder said he couldn't fill out the questionnaire because it was suited only for "garage-shop amateurs." (He considers anyone building less than several hundred frames a year an amateur.) I asked him to change the questions to suit himself, but I never heard from him again.

Another frame builder declined to participate because he felt that "customers knew too much already." He said past technical articles told customers more than they need to know, and they ask a lot of questions he doesn't have time to or want to answer.

Aside from these few, all the other responses I received were sincere and helpful. American frame builders are definitely committed to the highest degree of technical excellence in their craft. In my opinion, no one can seriously claim that American-made frames are inferior to those of the European "master" builders. In fact, American frames as a group have the highest, most consistent, quality of any frames in the world.

Thanks to the frame builders whose responses to the survey made this article possible: **Matt Assenmacher,** Assenmacher Lightweight Cycles; **Bob Beecroft,** Bob Beecroft Cycles; **Ron Boi,** RRB Cycles, Ltd.; **Bill Boston,** Bill Boston Cycles; **Sam Braxton,** Braxton Bike Shop; **Bill Davidson,** Davidson Cycles; **Albert Eisentraut;** Glenn Erickson, **R + E Cycles; Bruce Gordon,** Bruce Gordon Cycles; **Jim Holly,** Cycles Griffon; **Skip Hujsak,** Hujsak Bicycles; **Tom Kellogg,** Spectrum Cycles, Inc.; **Chris Kvale,** Chris Kvale Cycles; **Boone McReynolds,** Doablo Cycles; **David Moulton,** David Moulton Bicycles; **Andy Newlands and Damian Bollermann,** Strawberry Cyclesport, Inc.; **Mark Nobilette,** Nobilette Cycles; **Peter Quellette,** Quellette Cycles; **Jim Oxford,** Oxford Design; **Chris Pauley,** Chris Pauley Frame Design; **Dave Plantenga,** Plantenga Framesets; **Angel Rodreguez,** R + E Cycles; **Richard Sachs,** Richard Sachs Cycles; **Peter Weigle,** J.P. Weigle Cycles.

Shimano's Shifting Psychology And Decision Overhead

Mr. Okajima's article on the Shimano New Dura-Ace shifting system in April 1985 *Bike Tech* is laudable for its clarity and breadth of coverage. I agree with Mr. Okajima that oxygen consumption is an important variable. But actual race performance is "the bottom line." Better performance on the Shimano treadmill test might *sometimes* translate into improved racing performance, but not always. My impression is that the Shimano SIS system provides a *psychological* advantage that is just as important, if not more so, than the *biomechanical* advantages that were reported in the article.

On a 2 to 5 percent upgrade at 15 mph, the limiting factors are more likely to be local lactic acid accumulation and leg muscle fatigue, rather than total body maximum O_2 consumption. This is clearly seen in exercises which require arm, leg, and other muscles to large degrees, e.g., swimming and cross-country skiing. (See reports by D.L. Costill, et al., referenced below*.) Thus, oxygen consumption savings will reflect decreased calorie expenditure, but not necessarily improved cycling performance.

Comments on the oxygen measurements: The description of the measurement procedure was not complete. For all purposes except rough estimates, measurements of expired gas *volume* are required as well as the gas analyzer readings. In the article, Figure 11 showed air collection bags, not the gas analyzer mentioned in the caption. The reader must assume that correct procedure was employed, and that conversion to standard temperature and pressure was made.

The Shimano treadmill test seems to be a good simulation of amateur road-racing conditions, but to be certain, we should know more about the subjects' maximal O_2 consumptions and body weights. For normal-weight subjects, the measured O_2 consumption at the 2 percent grade would be classed as "heavy" exercise, while the readings at 3 percent, 4 percent, and 5 percent grade fall in the "very heavy" category (Morehouse and Miller, 1976). I estimate that the riders' maximal O_2 consumption would be at least 4.7 liter/min (assuming that the reported readings were about 70 percent of maximal), compared to a world record of 6.24 liter/min set in 1968. Thus, the Shimano test was reasonably demanding on the riders *provided* they were of average or below-average weight.

Assuming that the O_2 measurement was in fact done correctly, I still believe Mr. Okajima's interpretation of results could be misleading. First, data from only one of the three riders is presented. Second, at only one of the four working levels (3 percent grade) did the Shimano system produce a statistically significant improvement, reducing a 1 in 20 chance to a 1 in 5 chance. The 75 percent confidence levels for grades of 4 percent and 5 percent would be viewed by most scientists as interesting but not statistically significant. The contradictory *increase* in O_2 consumption with the Shimano shifter at 2 percent grade is unfairly ignored. Over all four grades, the average O_2 consumption improvement is 2.65 percent (though this average may lack statistical significance). In short, the O_2 consumption data needs more analysis to demonstrate a solid case for the new system.

A genuine reduction in O_2 consumption of 2.65 percent would certainly improve bicycle racing performance. However, the Shimano testing required a shift every 5 seconds, a condition seen in no ordinary bicycle race or tour. Riders are more likely to shift about once per minute on the average. Thus, I would expect to see O_2 consumption improvements during racing of roughly 0.3 percent. While even a third of a percent improvement is praiseworthy, one readily sees how laboratory tests showing 3 to 6 percent improvements may not be borne out in field testing.

The real advantage of the Shimano SIS system, I think, is that it reduces "decision overhead." Here's what I mean: I have enjoyed riding a five-speed Sturmey-Archer rear hub coupled with a TA triple front. I can attest to the advantages of an open-loop versus closed-loop manual control: the S-A hub shifts quickly and cleanly. To me, this is worth the estimated 1 percent loss in mechanical efficiency. (I only wish that the S-A hub had held up to normal touring use.) I personally would prefer an indexed shifting system for *psychological* advantages as much as for presumed energy-saving reasons.

What are the psychological advantages? A rider is constantly making decisions regarding gear requirements, shift timing, body position, bike position, pacing, etc. A decision to shift results in benefits (e.g., riding efficiency) which must be weighed against its costs. Costs include the necessary muscular exertion, partial loss of steering control, and the possibility of a mis-shift. Another cost is the "overhead" of making the decision itself, which includes the time and attention needed to think about it. Knowledge that a mis-shift is very unlikely could greatly reduce this "decision overhead" for many riders. It is fair to say that a rider who has less reason to worry about mis-shifts has a psychological advantage.

Once a decision to shift is made, the SIS indexing system will definitely reduce the shift time, and will thereby reduce the period of steering instability, and the chance for mis-shifts, and may perhaps save a bit of power. Any time and effort saved may then be devoted to other tasks, whether they be positioning, cadence, vehicle dodging, or turning to look at a glorious stretch of scenery. These decisions are usually made almost simultaneously with a shift. While a conventional rider spends an additional third of a second per shift on the shift motions alone (not to mention the decision overhead), the Shimano rider has that time available for other tasks. In short, ease of shifting frees the rider for other activities. Finally, at a reduced cost, a rider can "afford" to shift more often, especially in marginal situations, and thereby perhaps improve efficiency. Such increased freedom of action is what I mean by a psychological advantage. This may be very important if the rider is operating near his behavioral limits.

Unfortunately, it is hard to *prove* that a psychological advantage exists, since we cannot observe the decision-making process directly. In fact, once we can measure and improve a behavioral/mechanical performance—like Shimano's shifting speed—we stop calling it "psychology" and call it biomechanics instead.

In any case, whatever we call it, the Shimano lab testing has definitely made some crucial discoveries about bicycle shifting systems. But to go further with this research, I think it is necessary to correlate the O_2 treadmill measurements with real world performance on the racing course.

Frederick J. Rayfield, Ph.D.,
Associate Professor of Psychology
Roosevelt University, Chicago, IL, and
President of Rayfield Equipment, Ltd.
(a manufacturer of computer interfaces and spirometers for oxygen consumption measurements)

**References:*

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Mr. Okajima replies:

I appreciate Dr. Rayfield's letter, which explains clearly what the Shimano SIS system can do during shifting. I agree with most of his notes, but I have some comments and extra data to clarify the disputed points.

In the April Bike Tech *article, the full O_2 measurement system was not shown in detail due to space limitations. We used Douglass collection bags and a spirometer to measure the volume of expired gas. Then the composition of a small sample of gas was determined by the gas analyzer. The correct procedure, as he assumed, was employed. For complete objectivity, a professor on the faculty of a sports college designed all the experimental set-ups and conducted the data aquisition and analysis.*

The subjects were all experienced riders. Their maximum O_2 intake measured on the bike treadmill was 3.8 to 4.9 liters/min (at 20 degrees Celsius), which, accounting for their weight, equals 65 to 75 ml/kg/min. In the U.S., they would be rated with those who could finish the National Championships but not necessarily in the top twenty. All had enjoyed training and racing for many years with Campagnolo derailleurs. Thus, they were typical of riders who have raced for a few years.

I agree with Dr. Rayfield that a reduction in O_2 consumption does not always mean better cycling performance. In fact, lower cadence (under 60 rpm) often decreases O_2 consumption, but racers still prefer higher cadences (over 100 rpm) for better performance. They may feel better using higher cadences in racing to go faster.

However, our study was controlled so that all facets of the riders' performance (i.e., work load, cadence, posture, shifting action, etc.) were the same *in all trials. Therefore, reduced O_2 consumption in our study* does *indicate that the subjects could ride easier or faster with the SIS system.*

Our procedure was designed so that fatigue and anaerobic factors would not affect the results. After the warm-up period, 5 minutes' rest before starting each test was standard; resting O_2 consumption was measured in the last minute of the 5-minute rest. Riding on a treadmill at 2 percent grade is very similar to easy spinning on the road. (Some energy is required even to ride on level ground.) We monitored the subjects' heart rates to avoid possible risk. Heart rate stablized in about 30 seconds after each change in upgrade of the treadmill, till 5 percent grade was reached. Heart rates of a weaker rider did not stabilize at grades of 6 percent or more. The test riders could withstand grades of 8 percent to 9 percent. For example: the work rate at 5 percent grade is about 0.33 hp, which an experienced rider can maintain for an hour, and increases to 0.6 hp at 9 percent grade (65 kg rider's weight + 10 kg bike's weight = 75 kg, 24 km/hr = 6.6 m/s, thus, 9 percent x 75 x 6.60 = 44 kg-m/s = 0.6 hp). For comparison, the great champion, Eddy Merckx, could maintain 0.5 hp for an hour in trials at Cologne University.

It's true that after one period of riding, the riders may be fatigued or have accumulated lactic acid. However, our experimental procedure was designed so that this would not affect the results; we alternated the order of testing (i.e., SIS, contentional, conventional, SIS) and averaged the results.

There was a typographical mistake in the article: The data in Figures 14 and 15 was from 3 riders, not just 1. I agree that the 75 percent confidence level is not significant, *but* is *of interest. I did not discuss the "contradictory" difference at 2 percent grade because it was statistically insignificant. (Editing of the article for* Bike Tech *aimed at making it less tedious than a doctoral thesis.) However, the nonsignificance at 2 percent grade suggests the oxygen savings came from the legs (through more efficient rhythmic pedaling) rather than from the arms (through less force on the shift lever). In fact, we have collected electromyogram data from the riders' leg muscles which supports this view. This EMG data was not reported in the* Bike Tech *article because we felt that more analysis was needed to properly correlate it with the O_2 measurements.*

The average 2.65 percent O_2 savings calculated by Dr. Rayfield does *have statistical significance because of the large number of data points. I realize that this 2.65 percent improvement might be overshadowed by other factors in the race; but then again, it might* be increased *if there's a lot of shifting in the pack or other conditions that would be more demanding than the 17T to 19T repetition in our test.*

The bottom line in racing is not to lose the winning break. An attack is often made out of the corner or on a hill, where frequent shifting is required.

Field testing, as Dr. Rayfield suggests, is interesting and logical. I personally want to do it, but Shimano's research is for product development, not for just academic study. For field testing, we would use a portable data recorder or radio transmitter to obtain signals from EMG, ECG (electro-cardiogram), torque, strain, displacement, etc. But we already get feedback from some of the thousands of riders, along with several sponsored racing teams, professional and amateur, who use the New Dura-Ace components. Frequent communication between Shimano and these U.S. and European racing teams is important.

Dr. Rayfield's letter explains the psychological advantages of the SIS system more clearly than I could. In the future, we should study the physical reasons behind them. I thank Dr. Rayfield for the advice, and will continue efforts to seek better measurements and critical variables.

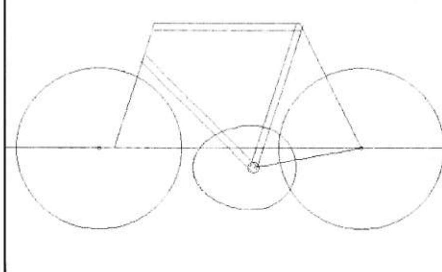
BIKEDRAW Frame Graphics

Readers of *Bike Tech* might be interested in a simple computer graphics program I have written to aid in the design of bicycle framesets. I am an amateur frame builder, engineer, and active cyclist, and I wrote the program ("BIKEDRAW") to streamline the early phases of design where various layouts are considered.

As input, the program asks for nine parameters (wheelbase, tube lengths and angles, etc.), and then produces a line drawing of the frame on the computer screen (see illustration). This immediate feedback allows me to inspect a large number of designs very quickly. A half-inch variation in bottom bracket height, for example, affects the overall frame design in many ways. The program will also plot the frame layouts on paper at any specified scale via dot-matrix printer. I use this feature to generate full-scale plots of the frame joints, which I then use in making blueprints of the final design.

The program is written in BASIC for the NCR Decision Mate V personal computer, and is easily adaptable to other PCs capable of dot-addressable graphics. Interested readers may obtain a copy of the program by contacting me at:

Mike Cambron Cycles
1123 Gomber Ave.
Cambridge, OH 43725



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1030 STL=62              'SEAT TUBE LENGTH
1040 TTL=58.2            'TOP TUBE LENGTH
1050 SANGLE=72.5         'SEAT TUBE ANGLE
1060 HANGLE=72.5         'HEAD TUBE ANGLE
1070 BBH=25              'BOTTOM BRACKET HEIGHT
1080 RAKE=6.35           'FORK RAKE
1090 WHEELBSE=105        'WHEEL BASE LENGTH OF THE FRAME
1100 WHEELRAD=33         'WHEEL RADIUS OF BOTH WHEELS
1110 DTI=5.8*2.54        'DOWN TUBE INTERSECT OF HEAD TUBE
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Plot and dimensions of long-wheelbase ATB frame.

newsline

COURTESY AERO SPORTS

OLYMPIC WHEELS SPINOFF: Aero Sports Company is a new venture founded by developers of cycling equipment used in the 1984 Olympic games. Chester Kyle, Ph.D., Don Guichard, and Scott Gordon (members of the group that designed the US Team's aero bicycle and equipment) have joined forces with Gary Hooker and Dave Spangler (Chairman of the Board and President, respectively, of Hooker Industries). Hooker Industries, best known for its Hooker headers (automotive racing exhaust systems) also manufactures equipment for the aerospace and aircraft industry.

The new company's first product will be low-drag spoked racing wheels (see photo at left) similar to those built by Gordon and used by Mark Gorski and Nelson Vails in the 1984 Olympics. Other products on the drawing board are high-performance pedals, hubs, cranks, and lightweight solid Kevlar wheels.

Don Guichard designed and built the disk wheels used by the 1984 U.S. Olympic Cycling Team, and also built the first HPV to exceed 55 mph (a record set in 1979). Chet Kyle, founder of the International Human Powered Vehicle Association, led the group that designed the US Team's aero bicycles, helmets and uniforms. Gordon, Hooker, and Spangler are all currently active in bike racing and triathlon competition.

◄The Aero Sports wheel was developed in hundreds of wind-tunnel tests conducted by Dr. Kyle. Aero Sports Company provided data from those tests to demonstrate the superiority of their new design over conventional spoked wheels (see table below). (Admittedly this data shows that disk wheels offer a greater drag reduction than do aero spoked wheels. For example, using a disk front wheel could save over one minute in a 25-mile time trial.) Note the following results:

— Narrow tires are better: A narrow 18 mm racing tire has about 30 grams less drag than a 1- or 1-1/8 inch tire. This means 10 seconds saved in a 25-mile time trial.

— Fewer spokes are better: Each spoke removed reduces the drag force by about 4 grams. This means that a 28-spoke wheel has about 32 grams less drag force than a conventional 36-spoke wheel, with a time saving of about 10 seconds.

— Flat ("aero") spokes are better than round: Aero spokes have about 0.6 grams per spoke less drag than round spokes of the same weight or gauge. This means 17 grams less drag for 28 aero spokes versus 28 round spokes, with a time savings of 7 seconds.

— An aero rim is better than a standard flat rim: The aero rim gives about a 30 gram drag reduction, or about a 10 second time savings.

— The benefits of the combined system are greater than the sum of the parts: A complete wheel built with 27-inch aero rim, 18 mm tire, and 28 aero spokes has about 106 grams less drag, for a total time savings of about 39 seconds. This is for the front wheel only; adding an aero rear wheel would be even better. But since the rear wheel is drafting in the wake of the frame and front wheel, the savings from an aero rear wheel would probably be less than half that of the front wheel.

DRAG REDUCTIONS and TIME SAVINGS with AERO WHEEL COMPONENTS (compared to a standard 27-inch wheel with 36 round spokes, flat rim, and 1 inch tire):

Wheel design:	Drag Reduction at 30 mph	Time Savings in 25 mile time trial
Disk Wheel (same weight as spoked)	180 grams	66 seconds
Aero rim, 24 aero spokes, 18mm tire	120	44
Aero rim, 28 aero spokes, 18mm tire	106	39
Aero rim versus standard flat rim	30	10
18mm versus standard 1 inch tire	30	10
Aero versus round spokes (28 spokes)	17	7
Aero versus round spokes (24 spokes)	14	5

(Aero Sports Company, 8216 Pennington Drive, Huntington Beach, CA 92646, telephone 714-536-1302).

◄**The DUTCH-MADE ROULANDT RECUMBENT:** Designed by A. J. Roulandt, the Dutch frame builder and designer, and manufactured in Holland by Ziciani B.V., the Roulandt Recumbent (see photo at left) is now available in the U.S. Its relatively low price ($450 recommended retail) makes the Roulandt perhaps the only recumbent in the same price range as high-quality conventional sport-touring bikes. With a total weight of 32 pounds, the Roulandt has the same overall length as that of conventional bicycles, thanks to its 16-inch front wheel and the rider's position over the 28-inch rear wheel. To accommodate various sized riders, the entire crankset assembly is moveable forward or backward on the "downtube." Twelve-speed gearing is provided by a six-speed freewheel combined with a two-speed internally-geared rear hub, with all drivetrain components by Sachs. Reviewers report that the Roulandt shares many of the same advantages (e.g., comfort) and a few of the drawbacks (e.g., handling) of other recumbents of similar design. Others have commented that use of chrome-moly tubes for building the frame would have been a better choice than the relatively heavy low-carbon tubes that were used. The Roulandt is available in the U.S. through Tekton Corporation (Allen Koenig, President), Route 116, Conway, MA 01341 (413-369-4367).