"CRITICAL COMPONENTS"

"What You Need To Know About Rod Ends & Spherical Bearings"

Wayne Scraba

Photos: Wayne Scraba

Peer inside a modern racecar and you'll find all sorts of different rod ends and/or spherical bearings. Rod ends are critical components in any racecar and they also prove be rather practical problem solvers in plenty of hot rod and custom car applications too. Rod ends and spherical bearings can be used in any number of locations aside from common suspension and steering components (case-in point: shifter linkage, carb linkage, mechanical brake linkage and so on). Most often though, the suspension and steering systems are where you'll find rod ends as well as spherical bearings. Here, they're regularly charged with handling critical loads (for example, a rear suspension link). If a rod end in such a location breaks, then the car gets out of control. It's that simple.

At first glance, all rods ends look alike. And that's not good news. Until you dig a wee bit, you can easily pick up a cheap knockoff built in an off-shore sweat shop instead of a high quality aircraft spec job built in America. The reality is, that cheap off-shore built rod end is most likely junk and you shouldn't put your neck on the line using one.

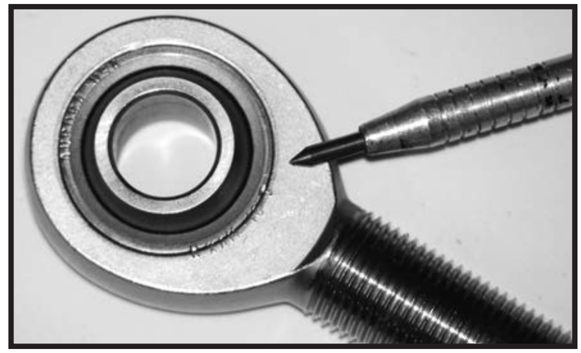
Knowledge is the key. Basically, a rod end consists of a spherical ball, which is engineered to rotate inside a housing. This ball is the bearing and the housing it's contained in is the race. Each side of the spherical ball is machined flat. The modified "sphere" has a hole bored through the center.

MONEY TALKS...

When purchasing rod ends for your project, you'll regularly find "economy" or "commercial" configurations. While there are plenty of various economy rod ends on the market (that's where most of the off-shore imports live and play), the only type you should even begin to think about for a high performance application are two-piece, fully swaged models. In the two-piece configurations, the body is formed (or "swaged") around the ball so that the race the ball rides on is actually part of the body. When considering inexpensive rod ends, this is the only less costly style that offers reasonable pull strength (radial strength) along with adequate axial strength. In case you're wondering, axial strength is the resistance of the ball being forced out of the side of the body.

This is a three piece ("aircraft") rod end. With this configuration, the race is formed around the ball, and then the race insert is staked into the body.

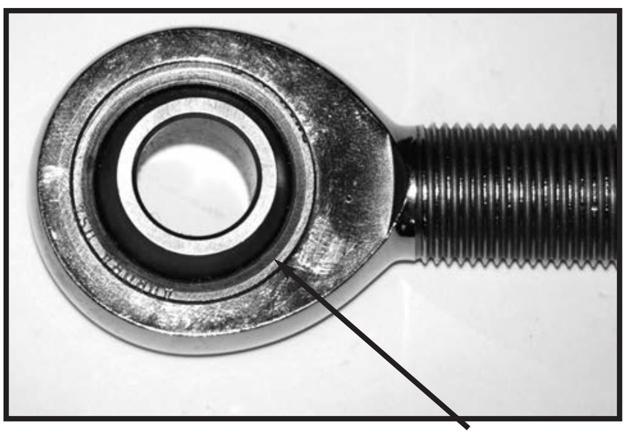
But we're certainly not done: When it comes to rod ends, you definitely get what you pay for. Better quality rod ends are most often based upon a precision three-piece configuration. This three-piece design is regularly referred to as an "aircraft" rod end. Here the race is formed around the ball. Next the race insert is staked into the rod end body. How important is this? Very. With this layout, the result is a much closer component fit (there's much more precision between the ball and the race). The three-piece design allows specific materials to be included while the rod end is manufactured. As a result, the manufacturer can now build a given rod end to match a given application. Additionally, the rod end race can be manufactured from mild, alloy or stainless steel, with bodies manufactured from mild, alloy or stainless steels, aluminum or even titanium. You might find rod ends with races built from brass or aluminum bronze, but due to their low strength, it's a good idea to avoid them at all costs.



Because of the three piece configuration, various materials can be used in the construction of the rod end. This process allows the rod end to best match the application (which often boils down to strength versus load).

LUBRICATION MAKES A DIFFERENCE...

The Teflon liner option is something you'll soon discover when researching rod ends or spherical bearings. It's important because the liner allows the rod end to be self-lubricating. Just how critical is this? Give this some consideration: In almost any motor vehicle (car, truck, bike, airplane, boat) there are plenty of places where you simply cannot lubricate a rod end or places where you just don't want to. Yes, there are certain rod ends out there that are built with integral grease fittings, but you have to keep in mind that grease fittings will physically weaken the rod end (in essence adding a grease fitting mandates drilling a hole right through a critical part of the rod end - and as you can well imagine, that's not good). One more concern is the problem of dirt being attracted to the grease. Grit eventually finds its way in between the ball and the race and then wear escalates - sometimes rapidly.



The rod end shown here incorporates a composite Teflon liner. You can purchase two or three piece rod ends with Teflon liners. The Teflon liner is bonded to the race so that the ball actually rides on the liner. The move ment of the ball rubs Teflon on the ball, which in turn provides the neces sary lubrication.

The use of a Teflon (a trade name of DuPont) liner eliminates most, if not all of the issues associated with grit and premature wear. Teflon liners are made up with a carrier component, most often a fabric that provides compressive strength, a Teflon component providing lubricity as well as a collection of bonding resins. The Teflon liner and the race are bonded together. Because of this, the ball actually rides on the liner. As the ball moves, Teflon is rubbed on it. That's where the lubrication comes from. Two or three piece rod ends are commonly available with Teflon liners. When talking Teflon, consider that if virgin Teflon was used, you'd find the material proves to be relatively soft (approximately 10,000 pounds PSI compressive strength). On the other hand, a high quality composite Teflon liner (where "components" are added to the Teflon mix in order to increase strength) will have a compressive strength of somewhere between 40,000 and 60,000 PSI. A rod end with a quality Teflon liner will have a tighter fit. That's because a good Teflon liner eliminates clearance between the ball and race.

Of course, the simple addition of a Teflon liner to a rod end doesn't insure precision. It is certainly no guarantee of performance capability either. A big consideration is the term "beating out". What's that? Sounds simple enough, but it's actually two separate maladies. The first one is the deformation of low strength "self lubricating" liners. Many cheap economy rod ends are built with races constructed from molded plastic (and in some cases, the plastic is mixed with a fiberglass filler). To provide some lubrication, a bit of Teflon might be added. Given the mix of ingredients, these easy-on-the-pocket rod ends typically have a compressive strength of no more than 15,000 PSI. Given the poor compression strength, the race will deform long before the body sees any damage.

Another form of "beating out" failure involves the physical bond between the liner and the race. Since the liners are built with a self-lubricating material, it's sometimes tough for inexperienced (or poorly equipped) rod end manufacturers to bond the liner to the race. If this bond isn't strong enough, then the liner can become detached from the race. The problem is compounded if there is a mis-alignment of the rod end (more on alignment later). Bits of the poorly bonded liner tend to disintegrate. When this happens, internal clearances increase, eventually becoming excessive. Aside from MIL Specs for Teflon-lined bearings, there are no standards set for liner bond strength.

MATERIALS MATTER…

Teflon isn't the only material you have to concern yourself with. The base materials used in the construction of the rod end play very critical roles too. Earlier, we mentioned some of the materials rod ends can be built with. The actual spheres or balls are most often subject to the highest loads the rod end sees. Because of the high loading, the balls mandate the greatest hardness along with the greatest ultimate strength. Certain commercial rod end balls can be manufactured from bronze or even sintered steel materials. For the most part these materials aren't the greatest when it comes to strength, however you might find some sintered steels are fully up to the task. Provided a proper heat treat, sintered steels can be made to work in a light to medium duty rod end ball application. For the most part though, quality rod ends are manufactured with heat-treated steel balls (including balls made from stainless, chrome moly and 52100 bearing steels). The actual balls must be extremely hard in order to remain round (these balls are often chrome plated to provide a smooth bearing surface). The hardness of the ball coupled with the capability to remain round is absolutely critical in use.

What do you look for in a race? It too must be hard, but not to the level of the ball. The majority of three-piece rod ends incorporate a race manufactured from through-hardened steel alloy or from a stainless steel that can be hardened. In either case, the outer races are heat treated for both strength and wear resistance.

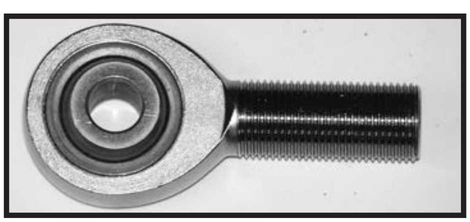
The bodies of economy or commercial rod ends regularly have bodies manufactured from low carbon mild steels. It is not possible to through-harden this material. Although a less costly material such as low carbon steel might work in a lightly loaded application, you'll find that a rod end body built from chrome moly steel or heat treated stainless steel is much more satisfactory for severe duty applications. There's something else to ponder too: When a rod end is built with a chrome moly or stainless body, then the size of the rod end can actually be reduced. The reason is (obviously) due to the fact the material it's made out of is significantly stronger. Some rod end bodies are also manufactured from 7075-T6 aluminum. If you do a bit of homework on materials, you'll find that 7075-T6 aluminum proves to be one of the strongest grades of aluminum available. It actually has a tensile strength slightly greater than mild steel. The truth is, if you compare the strength of two similar rod ends - one manufactured from 7075-T6 and the other from mild steel, you'll find they're similar. The trouble is, aluminum won't stretch or bend as much as mild steel before it breaks or bends. Factor a good quality heat-treated chrome moly or stainless rod end into the comparison and you'll soon see that the expensive rod ends are almost twice as strong as the aluminum counterparts. It's very difficult to beat a high quality heat-treated steel body rod end when it comes to ultimate material strength.

MULTIPLE DIMENSIONS…

Dimensionally, a manufacturer can build a specific rod end two different ways. In one, the shank (the threaded part) is built with a diameter that matches the hole in the sphere. As an example, a rod end with a 5/8-inch bore will have a shank with 5/8-inch threads. The other format has a shank diameter one [fractional] size larger than the bore. In this case, an example might be a rod end with a 5/8-inch bore coupled to a 3/4-inch shank. The big shank, small-bore rod end is stronger in applications where bending loads are (or could be) present. A good example is a trailing arm arrangement used on a racecar four link. Here, we have tubular bars acting as levers, transmitting considerable forces, and in turn often accepting equally considerable forces. In this type of application, a larger shank rod end design provides more strength along with a sizable amount of reserve strength capacity. Keep in mind, however, that some smaller size push-pull rod applications mandate the use of female, not male rod ends.

The rod end on the left is a standard configuration model, while the rod end on the right is a heavy duty model. The special HD model has a 1/2 inch bore while the standard version has a 3/4 inch bore. More in the text.

A rod end with an oversize shank is generally made by installing an insert one size smaller in the body of the part with the larger shank. In some extreme race car applications (drag race 4-link specials), the body is actually two sizes smaller than the shank. Because of this, (again using the big rod ends used for suspension pieces as examples) a 5/8-inch X 3/4-inch rod end exhibits higher load capability than a similar 3/4-inch X 3/4-inch rod end. Of course the caveat would be that each of these rod ends are manufactured from similar materials. The reason for this is because the 5/8-inch X ¾-inch rod end has more body material around the insert. Another bonus is the fact asymmetrical rod ends such as this provide superior wrench access in many applications. The reason for this is simple: It's due to the fact the fastener that passes through the ball bore is smaller.



This a close up look at a heavy duty rod end. The over size rod end is generally made by installing an insert one size smaller in the body of the part with the larger shank.

There is one exception to the above though: Some companies offer a rod end where a larger shank is added to a smaller body. Although on the surface this practice seems to serve the same purpose as the oversize shank rod end, it definitely provides less meat around the rod end ball, and that's something to ponder.

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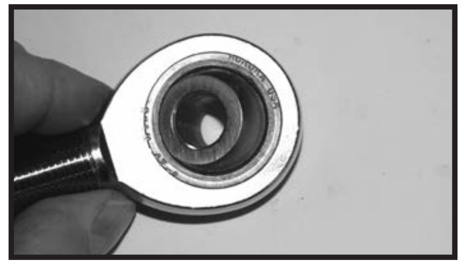
MISALIGNMENT PROPERTIES...

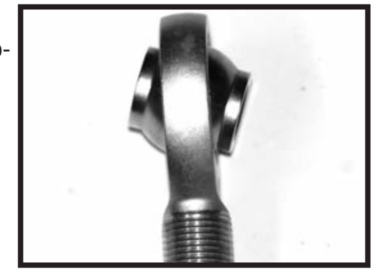


Examine the rod end in this photo closely. See how the ball isn't centered? This is essentially the "misalignment" that the rod end design can handle.

You'll often hear the term "misalignment" when folks discuss rod ends. What's that? Recall when the basics of rod end design (a modified ball or "sphere" inside a race) were detailed? In order to mount the rod end to something, then a fastener of some sort (most often it's a bolt) passes through a hole bored in the center of the sphere. With the bolt in place, then there's no way the sphere can rotate a full 360 degrees. Because of this, all rod ends have specific limitations regarding how far they can be misaligned before the sphere binds in the housing. The angle of misalignment is very important when choosing rod ends for specific applications. Not all rod ends can accept the same degree of misalignment. Most manufacturers publish a maximum recommended angle for a given rod end (specs are usually in the manufacturer's catalog).

If you exceed it, you'll get anything from premature rod end wear to outright rod end failure.

So far so good, but how do you determine what the angle of misalignment really is? It's not rocket science: Simply use a conventional protractor to check the geometry. Compare the measured angles you get with a protractor to the manufacturer's specifications. By the way, buying a bigger rod end to make up for misalignment won't help. Fixing the misalignment or using high misalignment rod ends is the answer (the accompanying photos show some high misalignment rod end options).



Misalignment is the degree of angular movement that a ball or sphere can accommodate without interference. This is a special "high misalignment" bearing (note the larger shoulder).

APPROPRIATE ORIENTATION…

When a pair of rod ends is used in a single component (an example is a single four link bar), the orientation of the rod ends on either end is rather important. This is most often referred to as "clocking". But before examining clocking, we should point out that even very small adjustments in any suspension link that sees pre-load could make a large difference in the way the car handles. In some cars, one-sixth of a turn at a time is sufficient to see a change in the behavior of the chassis. Because of this, it's a good idea to use the "flats" (flat sides) of the jam nuts as a reference point for adjustment.

This is how the small adjustment process works: One side of something like a suspension link is equipped with right hand threads while the other end of the link is fitted with left hand threads. If the jam nuts are loosened, then can lengthen or shorten the entire link, often by simply turning it. Essentially, this works like a factory tie rod adjustment.

So far so good, but where does the "clocking" come into play? Simple. When the rod ends are properly "clocked", that means they're physically aligned. This prevents binding of the suspension, and makes it easy to determine if the link is under tension by "feel". If you grasp the link by hand, and rotate it back and forth, you can tell if the link is "neutral" or under strain.

LIFE CYCLES…

Hands up! Have you ever attended a big swap meet? Odds are pretty good you'll eventually come across a box or two of "lightly used" rod ends. And the price will be right. Bargain! Maybe not. You see, just like any other piece of hardware, a rod end actually has a finite mechanical life. There is no way of knowing if a used or surplus rod end has reached the end of its life cycle. Another important consideration is that there is no safe way to repair or "tighten" a worn bearing. You simply cannot peen them to make them "tight". Additionally, any rod end that demonstrates any amount of stretching in the threads or in the head should be discarded. The same applies to any rod end bearing that has been dented in the race area or is bent. Rod ends such as these have definitely met their end.

Honestly, we're back to square one: At first glance it's nearly impossible to tell a junk rod end from a high quality piece. The only thing you can do is to examine each rod end in the same manner, as you'd look at any precision piece of hardware. Examine the machining. Examine the race. Examine the ball (sphere). In each instance, they should prove well machined and smooth. If the rod end is a non-Teflon configuration, does the ball fit inside the body precisely? Rotate the ball. Is there any bind or is it so loose that it rattles? Examine Teflon liners carefully. Look for areas where the liner is loose (the liner should be one continuous tightly bonded piece). Examine the threads. They should be high quality, rolled threads, just like a good bolt or capscrew. The quality of the rod end is right there in front of you. Use it to help you decide what's hot and what's not.

In the end, we're sure you'll discover (hopefully sooner than later) that good quality rod ends cost good money. Quality rod ends are those that are designed and built by way of proper engineering and then backed by rigorous research, development and testing programs. Remember you're buying a precision mechanical component, and it happens to be a piece you have to put your trust and safety into. These are definitely critical components.

Spherical bearings are actually close relatives of rod ends. They have countless uses in cars. They're often used on custom suspension components particularly when composite materials are used for construction. Spherical bearings are available in a wide array of bore sizes, usually ranging from 0.1900 to 1.00 inch. In the case of quality components, they're manufactured under the same quality as military approved bearings.

ROD END INSPECTION

A race car's suspension can easily feature a few dozen rod ends, and these joints allow nearly unhindered motion. Over time, however, each one can become a ticking time bomb. Rod ends don't last forever, but knowing how to inspect them can keep a car on track and off the hook. John McCrory is with Aurora Bearing Company, one of the largest rod end suppliers in the free world, and he has some simple advice for racers and crewmembers.

Refurbishing an older race car really requires you to question and evaluate every component. Are parts worn, and how can you tell? Even if various parts do appear to be good, should they be replaced by newer, better-performing parts anyway? Rod ends are one of the many items that can cause headaches for the race car refurbisher.

Evaluation: When evaluating the rod ends on a race car's suspension, the first step is to eliminate joints that don't belong on a racing suspension in the first place.

Joints with brass, bronze, or plastic races should be eliminated right away. Races made of these materials have relatively low compressive strengths and a low tolerance for shock or vibratory loads—they tend to loosen up quite drastically under hard use. These races are sometimes acceptable for secondary linkage applications, but they really aren't up to the demands of a race car suspension.

Two other items to remove immediately: rod ends with grease fittings and rod ends with hollow shanks. While both features allow the rod end to be relubricated, strength is compromised.

Condition: Once you determine that a rod end can be reused, its condition must be examined. Start with the overall condition of the joint.

Is the body bent? Are there signs of stretching on either the shank or the head? Are there marks that indicate the part has ground against something else (maybe the track)? Does the outer face of the race have dents that indicate over-misalignment? Is the race loose in the body or partially pushed out of the body? These are some indications that the joint has been abused, possibly in an accident, and should be replaced. If the joint shows none of these signs of abuse, magnetic particle inspection—like Magnaflux testing—should be done to ensure that the piece is truly free of cracks.

The next thing to do is evaluate the amount of wear on the bearing portion of the joint. Any play in these joints will be more noticeable when the car is together, so shake each corner of the car and try to note any play relative to a joint and its mounting bolt. Touching a finger to both the joint and an adjacent surface should help you detect any relative movement.

Wear can still be evaluated with the parts off the car. On a unit lined with a nonstick material like Teflon (DuPont's brand name for PTFE), low breakaway torque (the force required to move the ball) is not necessarily a sign of a worn-out joint, although it can be. This contradictory statement is rooted in the fact that different bearings manufacturers use different PTFE liner designs. These designs each have different performance characteristics.

One brand of bearing may start out with a very tight fit, then gradually loosen up until it reaches a zero-torque fit and wears out. Others may start out tight, fall off quickly, then maintain a light fit for a long period of time. In either case, the important thing to look for is an absence of play either axially (side to side) or radially (along the direction of the shank).

Judging the wear on a metal-on-metal joint is a little more difficult, as all metal-on-metal joints start life with a small amount of clearance. Comparing your used joints to a new one is a good place to start. An unscientific method is to hold the rod end's shank and give it a good shake. If it rattles, it's worn out.

Looking at it from another perspective, if you car's suspension has metal-on-metal joints, why not replace them with PTFE-lined joints? Remember, lined joints are more precise because of their zero-clearance fit. They're also maintenance free.

One Last Inspection: Before reinstalling an old joint, there's one last factor to consider: the fatigue life of the rod end.

The body of a rod end usually fails for one of two reasons. The first is severe overload. Make a hard enough impact with a curb, wall or another car, and you can overstress a joint to the point of breaking. During your inspection, you may find a joint that's been stressed to, or close to, the breaking point.

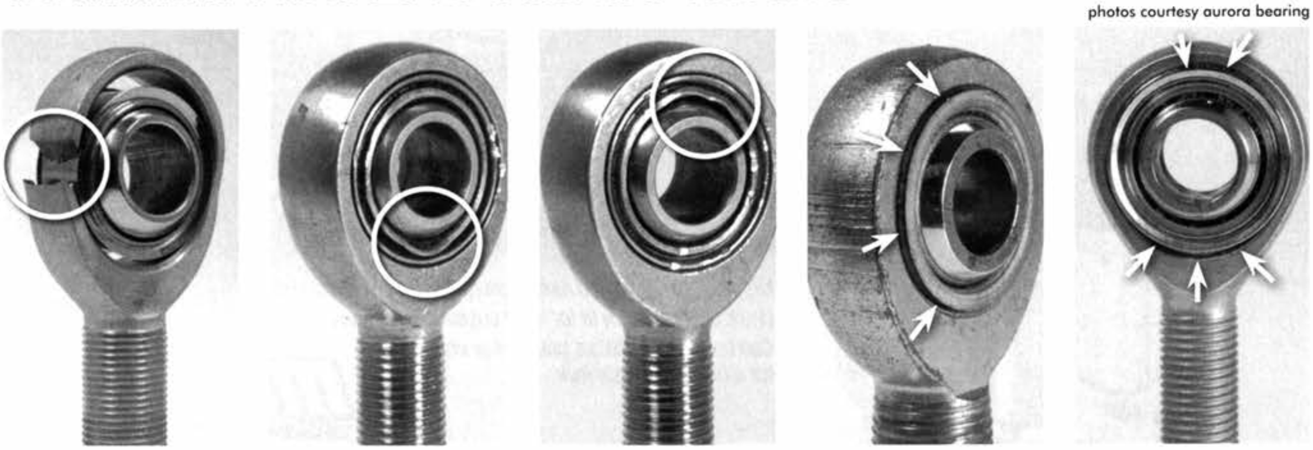
The second reason for failure is fatigue. Like any other metal component, rod ends are subject to wear. Unfortunately, there's no way to tell if one is too fatigued to pass inspection.

Rod ends can be loaded in many different ways, and each use affects the fatigue life of the joint. They can be loaded in straight tension or compression along the direction of the shank, as on a suspension pull rod or push rod. They can have a straight-line reversing load, as on a tie rod or radius rod. They can also have bending loads applied to the shank, as when a rod end is used as a ball joint. Or there can be a combination of loads in various directions.

So what do you do? The safest thing is to automatically replace any old joints with appropriate new joints. The most realistic strategy is to evaluate the physical condition of each joint, consider the stress it endures in its particular application, and figure out what your budget will allow. That should help you draw up a plan of attack.

Common Rod End Failure Modes

photos courtesy aurora bearing



Broken — Misalignment — Misalignment — Pushout — Stretched

LEFT: During a wintertime work session, we found that most of our car's suspension joints were rod ends of various ages and conditions. We junked them all and ordered replacements. RIGHT: While our suspension was disassembled, we repainted the trailing links and control arms.

per schroeder photos

ABOVE: We replaced our old rod ends with brand-new hardware sourced from Aurora. BELOW: The LeGrand also uses a pair of rod ends to support the steering rack. In this case, we used lightweight aluminum pieces from Aurora. We also took a look at our gauges—or, rather, we tried to take a look at them, but they were too hard to read. A new Stack ST 1800 display unit was the solution. It's a customizable setup, and we specced our tachometer with a 15,000 rpm rev range. Our old muffler was too loud, so we swapped it with a new two-stage unit from Burns. This should keep us from raising the ire of the sound police.

Grassroots Motorsports
THE HARDCORE SPORTS CAR MAGAZINE

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Grassroots Motorsports is more than just a magazine, it is a true multimedia publisher producing print magazines, digital and email content, as well as events to bring motorsport to your door.

After we had to replace a rod end at the Solo National Championships, we took a good long look at all of the rod ends in our LeGrand's suspension. We decided to replace every single one; that was the only way we could ensure we'd have a solid foundation going into our 2011 racing season.

We chose an old favorite of ours, Aurora Bearing Company's alloy steel PTFE lined rod ends, for most of the suspension joints. The car is mainly held together by the 3/8 inch versions, but ther are several larger and smaller sizes. We counted 22 joints in the rear suspension alone.

One we have the car back together, we'll need to do a full alignment and "squaring" of the car.

The old rod ends wer worn, and we could feel that several had some play in them. Not good for a suspension!

Broken Rod End at BRIC

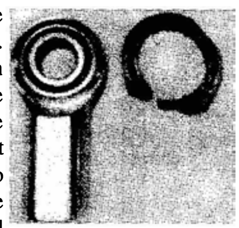
-by John McCrory
Aurora Bearing Company

At the end of this Summer's Brian Redman International Challenge weekend, a friend of mine flagged me down, and tossed me a metallic object. "Here," he said. "They found this as they were cleaning up the mess." The mess he referred to was the unfortunate pile up at the start of the Sunday Group 6 race. The object was the head of a rod end. To most people, it would be considered a piece of race track refuse. To me, it's a lot more. It tells me a lot of things that would concern me if I found this part on a car, and I'd like to share these things with you.

Portion of the rod end found at the track.

Before going any further, I will be up front that the part, or more correctly, the part that this piece was off of was not an Aurora part, and I work for the Aurora Bearing Company. The manufacturer of this part is unimportant, but I want to be honest about what I know. Also, I do not know anything as far as a direct fact as to what car it was off of, or where it was used. However, my experience with rode ends, race cars, and the types of cars involved in the incident, lead me down a certain path of reasoning.

The part was a two piece, commercial grade, female rod end, 5/8" bore. The profile of the head, with the spherical inner area is the obvious indication of the two piece commercial design. The female conclusion is drawn from the geometry on either side of the break that indicates a transition to a wide, barrel shape female body as opposed to the narrower cross section of a male body at the junction of the head and threaded shank. From this, I would suspect it was used as a tie rod end joint. The tie rods on most late model Detroit cars as in the field, i.e. Camaros, Mustangs and derivatives, Corvettes, etc. have a 5/8" male thread, so this is a logical place to see a joint as described used.



Rod end piece found, along with a complete unit.

I don't think this was the first incident that this joint, or car, was involved in. There are two big flat spots on the outside diameter of the piece. These marks occurred long enough ago that a coating of light rust has appeared. There are also a number of smaller gouges and dents that have discolored. There are also a few gouges that are shiny. These more likely occurred in the incident.

This part was not well maintained. If it had, the inner race would have had a coating of fresh grease. This part has a thin film of almost dry lubricant combined with dirt. There are a few areas that show through and are highly polished from the ball running dry on the race area. I would suspect that if you looked at the ball from this part, it would show discoloration or black scorch marks from running dry under load. The way the part shows the shank being tom from the head, and the ball being ripped out leads me to believe that the spindle/upright/wheel was tom from the control arm, with the rod end ball left on the steering arm, and the rod end body left on the tie rod.

The fact that the area where this piece separated from the rest of the part shows no evidence of rust, combined with the fact that you would not expect a piece of debris this large to have laid undetected on an active race track makes me conclude it was generated in the incident.

Gouges and dents from previous incidents (A), and previously ground down area (B).

So beyond the fact that I've proven I can make a lot out of a little, what have I shown that might be reason for concern?

This part had been in incidents before, had visible signs of damage, and therefore its integrity had been compromised. It probably had a noticeable amount of play in it. I would not want to see this on a race car, especially in the application presumed.

It was not well maintained, again as evidenced by the lack of grease. This would accelerate wear, and therefore development of play between ball and race.

I don't know if it would be the place of a tech official to object to this part being on the car. The car was certainly operating with the joint on it, and the damage to the joint (i.e. the body ripped in two) was most certainly an effect of the wreck.

However, I would argue that running the joint on the car was a questionable choice. Again, the joint appears to have been previously damaged, it had also been poorly maintained. It is reasonable to say that it no longer could be relied on to provide the same level of performance, structural integrity and safety it did when new.

2 piece commercial grade rod end. Low carbon steel body, 9500 lb. load capacity.

It is made from low carbon steel, and has a load capacity of about 95 lbs. It requires maintenance in the form of maintaining a coating of clean grease on the ball and race.

This joint could be replaced by a precision grade, self lubricating, heat treated alloy bodied rod end. This type of joint has a load capacity of over 17,000 lbs, and is maintenance free. While it's easy for the sales guy to spend the customer's money, the long term reliability and performance of the higher grade joint should be well worth the cost.

3 piece high strength precision grade rod end. Heat treated alloy bcdy, 17,000 lb. load capacity.

If there is one thing racers should take away from this, it's that a closer look at the condition of the rod ends on your car, and consultation with the manufacturer of the joints, and car builder if available, about the application, along with replacement when appropriate, will enhance the long term reliability of your race car. Again this joint appears to have failed because of severe stress caused by an accident. However, it was much closer to the end of its life than the beginning. For the sake of reliability and long term safety, it probably should have been replaced a while ago. ■