

# Connecting Rods

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# Types of Connecting Rods

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## I-Beam Rods

The I-Beam rod is the most popular type of connecting rod. It is what almost every engine manufacturer uses as original equipment. They are cheap to make and very reliable. They can be made as strong as is needed for the application and are well supported by the aftermarket. Even stock I-Beam rods can handle much more power than they were originally designed for with some careful prepping.



With the aftermarket support today, you may find that the time and money spent on prepping stock rods is not the best option. There are inexpensive rods for most popular engines that can handle more power than prepped stock rods (as well as save you a lot of time).

## H-Beam Rods

H-beam rods are becoming more popular. They have some benefits over an I-Beam for certain applications. For high hp, low rpm engines, the rods need more strength in compression. For high rpm engines, rods need tensile strength. Today the use of nitrous, blowers and turbo's is getting very high hp at lower rpm levels, so tensile loading is not as much of a problem as it used to be. This is where an H-beam design can pay off.

With high rpm, the tension on the rods is pretty much straight, so when the rod fails, it's usually torn apart. The tensile strength of a rod is most dependent on the material and the cross section of the rod, so for that application the shape (I-Beam or H-beam), has little bearing on strength.

For compressive loads, it is a little different. When a rod fails from compressive loads, it bends. The compressive loads are not straight; this makes the shape of the rod critical to strength. The design of an H-Beam rod helps them resist bending more than an I-Beam design. Well, let me clarify that a bit, an I-Beam rod can resist bending about the same as an H-Beam, but the H-Beam can do it with less weight.



Many people have argued that H-Beam rods are not any better and are a waste of money, and their number 1 argument is that you'll never see an H-Beam aluminum rod and all big racers use aluminum. To make sense of that, just think about what an aluminum rod is designed for. They are designed to reduce rotating and reciprocating weight, for high rpm engines. Aluminum is a poor choice for a high output low rpm street engine like a nitrous, blower or turbocharged engine. My twin turbo small block makes peak power under 6000 rpm, ultra light reciprocating parts are not a big concern to me, but strength is. I chose H-Beam rods to handle the very large compressive loads.

## Aluminum Rods

Aluminum rods are popular among high rpm race engines. They are very light and strong, but they have a short fatigue life. In a limited use situation, they can last a long time and usually those types of engines see frequent tear downs anyway. They do not last many miles in a street car. They are not out of the question for a street car, if rpm is kept down to about 7000 rpm or under and doesn't see that rpm often, they can last quite a while. Even then, 15-20,000 miles will be about maximum.



In my opinion, high rpm is where aluminum rods offer advantages, so if you are not going to rev high, there is no sense in using aluminum. They also need more piston to head clearance due to more rod stretch, a typical aluminum rod can stretch up to 0.008" more than a steel rod in a high rpm application. Since aluminum stretches more than steel, bearing retention is also a problem; the usual tangs are not enough to be reliable. Aluminum rods must use a dowel pin to keep the bearings from spinning.

## Titanium Rods

Titanium rods have some real advantages over steel and aluminum. Titanium has the highest strength to mass ratio of all materials used to make connecting rods. On average, a titanium rod is about 20% lighter than a comparable strength steel rod. Some can be as much as 30% lighter.

The downfall is cost. Titanium is a very abundant metal, but also a very difficult metal to work with, adding to the cost. The most popular titanium rods are made from titanium 6-4 alloy, which contains 6% aluminum and 4% vanadium, which are added to improve machineability.

Titanium is also a very poor load bearing material. It has a tendency to gall and weld itself to anything it rubs against. This is not an issue for the big ends, since a bearing insert is used, and it is easy enough to bush the small-ends. The problem comes in with the side clearances. This is where the rod contacts the crank and other rod; of 2 rods share a common journal. To make them last, the rods need a surface treatment just like what is used on titanium valve stems to keep them from sticking the guides. This is totally acceptable, but again, adds to the cost.

## Powdered Metal Rods

This is a technique that has gained quite a bit of popularity lately. Rather than melt steel and pour it into a mold (cast) or heat it up just below the melting point and stamp it into shape with several tons of force (forge), the rod is made from powdered metal. The powdered material is compressed into a mold; it is then it is heated to the melting point to fuse it into one piece. This technique is said to make a stronger rod by reducing internal stresses.

Since the rods are formed from powdered metal before being heated, the shape can be very precise, reducing waste and therefore weight. It also minimizes the amount of machine work. The caps are not cut of the rod, but precisely broken in a unique process known as "cracking". This makes for an irregular surface rather than the usual smooth machined surface of a conventional rod. That uneven surface provides a perfect fit for the cap to the rod so no further machining of the split face is required.

The theory is sound, but I have no real experience with this type rod in any performance application. I have heard of several powdered rod failures though, so at this point I do not recommend them in a performance build. I do have a feeling that as this technique is improved on, it will produce a superior rod. Right now it seems as though manufactures are going through a learning curve on powdered metal rods much like piston manufacturers went though with hypereutectic pistons.

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# Long Vs. Short Connecting Rods

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## Rod Length-to-Stroke Ratio

In most large cubic inch engines it is hard to get a very high ratio. A Stock 350 Chevy has a 1.64:1 RL/S ratio, which is not very good. By increasing the rod length to 6" the ratio increases to 1.72:1, which is much better and right in the range that has been proven to be best for an acceleration engine. You can squeeze a 6.1" rod in a 350 with little trouble, but longer than that requires plugging the piston pin bores after assembly to support the oil rings. It is not worth the extra expense for the little gains, so a 6" rod in a small-block Chevy has become common because everything fits right in.

With endurance engines, longer rods are always better. Most endurance engines are using a RL/S ratio of at least 1.9:1 and some as high as 2.2:1. Before you go out and buy longer rods, let me just say that the gains are very small. They are real, but small nonetheless. This debate has been argued for years and will not end anytime soon. In my opinion, if you are building an engine and need new rods and pistons, a longer rod will cost about the same. That makes the small benefits worth it. I would not waste my money buying longer rods if you have a good set of rods that you can use. Use that money to make more power elsewhere in the engine.

## Rod Angularity

A longer rod reduces the maximum rod angle to the cylinder bore centerline. Less rod angle will reduce piston side loading; there will be less friction and less bore wear. Less rod angle also gives better average leverage on the crank for a longer period of time. A 5.7" rod with a 3.48" stroke (stock Chevy 350) will have a maximum of 17.774° rod angle. Switching to a 6" rod will reduce that to 16.858°, assuming that the wrist pin has no offset.

## Piston Pin Height

A higher pin height (also known as a reduced compression height) will reduce piston rock and aid ring seal. Please do not email me arguing anything about a tighter ring pack; I am talking about pin height and pin height only. Moving the pin closer to the center of gravity of the pistons makes the piston more stable.

## Piston Ring Pack

As the compression height is reduced, the space for the ring pack also gets reduced. This can be a problem on some engines. It is good for power to have the top ring as close to the top as possible, but this is limited to the strength of the top ring land. As it becomes thin, it becomes weak. High output engines (especially nitrous engines) need a thicker ring land to keep the cylinder pressure from pinching the top ring. In my opinion, if you have to compromise ring location, it would be better to run a slightly shorter rod.

## Piston Skirts

Shorter skirts are usually combined with a shorter piston when built for a longer rod, but they are not really related. There is no reason to reduce the size of the skirts just because the pin location changed. Shorter skirts are used to reduce friction and lighten the piston. The cost is a little less stability, but it is arguable that a lighter piston with a higher pin height does not need the extra stability.

For a street car, I would increase the rod length if it meant a reduction in skirt size. Most of the things listed here are for competition motors to gain a few hp, not worth a lot of effort for most street engines. For long stroke engines, shorter skirts may be unavoidable to gain piston skirt-to-counterweight clearance.

## Piston-to-Valve Clearance

A longer rod decelerates toward TDC and accelerates away from TDC slower than a shorter rod, so piston-to-valve clearances are tighter with a longer rod. This may require deeper valve reliefs in the piston (but probably not). A short rod is just the opposite, there is more clearance because the piston decelerates toward and accelerates away from TDC faster. These are very small differences, but should be checked.

## Piston Velocity

A longer rod reduces peak piston speeds slightly and delays peak piston velocity until the piston is further down the bore, which gives the intake valve more time to open before peak airflow

demand. Peak piston velocity is usually somewhere around 75° ATDC and since most cams cannot fully open the cam until at least 106° ATDC, it leaves the valve as a major obstacle when airflow demand is at its greatest.

By delaying peak piston velocity, even if it's only 1 or 2 crankshaft degrees, it can allow the valve to open another 0.010-0.015", before peak airflow demand is reached. Not a huge help, but a step in the right direction. With a 350 Chevy, switching to 6" rods from 5.7" ones will delay peak piston velocity from 74.5° to 75.5°.

## Piston Acceleration / Deceleration

Reducing piston acceleration / deceleration from and toward TCD will reduce tensile loading of the rod, the number 1 cause of rod failure. A Chevy 350 with 5.7" rods will have a peak piston acceleration rate of 101699.636 ft/sec/sec at 7000 rpm. Swapping in 6" rods will reduce that to 100510.406 ft/sec/sec at that same rpm. That is a reduction of 1189.23 ft/sec/sec.

## Intake Runner Volume

Since it is easier for an engine to breath with a longer rod, less runner volume is needed. This allows more room for an intake system and, if the engine is raised, more room for an oiling system. This will be fractions on an inch, but can really help in some race classes, such as Prostock. A 1/2" lower hood scoop can make a large difference in aerodynamics. The reduced piston velocity makes for less pulsing of the intake charge and a smoother flow (this is a very small gain, but it is real).

## Exhaust Gas Scavenging

A longer rod is moving slower as it passes TDC, which reduces the speed of the exhaust gasses during the overlap period. This reduces the scavenging effect at low rpm and reduces low rpm power slightly (makes the engine run more cammie). A short rod on the other hand moves faster past TDC and increases the scavenging effect and help low rpm power.

## Ignition Timing Requirements

Due to the fact that the longer rod moves past TDC slower, it gives the charge a longer time to burn. So you need less timing for peak power. Using less timing also reduces the chance of detonation; so higher compression ratios can be used. Switching from 5.7" to 6" rods on a 350 Chevy can allow as much as 1 full point increase in

compression. In other words, if you could only run 9.5:1 with 5.7" rods, you could run 9.6:1 with 6" rods.

## 5.7" to 6" Rod Comparison for a 3.48" Stroke Chevy 350

Measurement	5.7" Rods	6" Rods	Difference
Crank Angle at Peak Piston Speed	74.5° ATDC	75.5° ATDC	+1
Peak Piston Acceleration	101699.636 ft/sec/sec	100510.406 ft/sec/sec	-1189.23
Rod Length to Stroke Ratio	1.637:1	1.724:1	+0.087
Maximum Rod to Crank Angle	17.774°	16.858°	-0.916
Maximum Piston Velocity	110.7801 ft/sec	110.3769 ft/sec	-0.4032

## Longer Rod Pros

- Less rod angularity
- Higher wrist pin location
- Helps resist detonation
- A lighter reciprocating assembly
- Reduced piston rock
- Better leverage on the crank for a longer time
- Less ignition timing is required
- Allow slightly more compression to be used before detonation is a problem
- Less average and peak piston velocity
- Peak piston velocity is later in the down stroke
- Less intake runner volume is needed

## Longer Rod Cons

- Closer Piston-to-valve clearances
- Makes the engine run a little more cammie at low rpm
- Reduces scavenging at low rpm

## Shorter Rod Pros

- Increased scavenging effect at low rpm
- Helps flow at low valve lifts (a benefit if the heads are ported with this in mind)
- Slower piston speeds near BDC
- Allows the intake valve to be open longer with less reversion
- More piston-to-valve clearance
- Can allow for a shorter deck height

## Shorter Rod Cons

- More rod angularity
- Lower piston pin height (if the deck is not shorter)
- Taller and heavier pistons are required (again, if the deck height is not reduced)
- More ignition timing is required for peak power
- In general, the pistons are heavier
- More intake runner volume is needed

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# Prepping Stock Rods

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## Rod Selection

If you intend on using stock rods in a high performance engine, count on going through quite a few rods to find a good set. The first thing to look at is the small end; if the hole is machined off center leaving one side thin, reject it (at least 25% of the rods you'll find will have an off center small end). Avoid any rods with anything more than surface rust, rust causes pits that make stress risers.

Look for a set of rods that visibly look the same, rods will vary depending on the dies that they came out of. If rods differ in appearance they will most likely also differ in weight and you want the assembly to balance easily. Look at the balance pads on both ends. If they are small, it is a good indication that the rod is heavier elsewhere (like the critical beam section). If the balance pads are big, the beams will most likely be thinner and weaker, so choose a set of rods with the smallest balance pads (but still find 8 close to the same). It is also a good idea to find 9 or 10 matching rods, just in case the machine shop finds 1 or 2 bad ones.

## Reconditioned Rods

Stay away from reconditioned rods from auto parts stores. These rods are rarely good for performance use. Normally when reconditioning a rod, the rod and cap are ground at the split face a few thousandths, then the cap is tightened in place and the big end is resized. This process will leave the area near the split face untouched; this is not a bad thing, but it is visible. Auto parts suppliers care how the rods look and want the entire rod to clean up, so they mill the rod and cap at a slight angle. When the bolts are tightened, the side get pulled in a few thousandths and the rods will then completely clean up when honed to size. This puts bending loads on the rods (the same bending loads that the bolts see at higher rpm) and the rod bolts will fail sooner.

Most rods will come from the factory with a rough finish on the split face, if the split face is very smooth; it is a good indication that the rod has been reconditioned. It's best to avoid reconditioned unless a reputable shop reconditioned them with performance in mind.

## Balance

Before you start any grinding you must make sure that you can keep all the rods in balance with each other. The best way to do this is with a

rod fixture and a precision scale. You prep one rod and bring all the others to the same weight. Not only do all of the total weights have to match, all the big ends must match and so do the small ends. If you don't have a precision scale that will measure grams, APT offers a rod fixture that that will get you very close. It used two rods that mount opposite each other; if one is heavier it falls and lifts the lighter one. It is a long process since you have to find the lightest rod and make all the others mach (big and small ends), but it's ok if you only plan a doing 1 or 2 sets of rods.

## Rod Lightening

The goal here is not only to lighten the rod, but also to reduce stress risers. It is possible to strengthen the rods by removing metal. The first step is to deflash the flanks of the beams, remove any sharp edges. This should be done moving lengthwise with the rod to avoid any grinding marks from making a stress riser across the rod. Use a grinding stone to get the larger stuff off then switch to a sanding drum for the finishing touches (still working lengthwise). Do the same for the big and small ends.

Do not take metal off the sides of the big end at the split face, this material is very important to minimize elongation. The balance pads should be as small as possible (as long as all rods weigh the same) since they don't contribute to the strength of the rods.

## Big Ends

As rpm increases, tensile loads will make the big end elongate into an oval shape. This ovalization, puts bending loads on the bolts. Good aftermarket rod bolts are recommended in for any performance application.

Most rods will have a notch at in the top of the big end for the bolt. This notch makes a stress riser and should be chamfered to spread the stress point out. By making a radius in the corner of the bolt head notch, the stress is not pin pointed to one spot and the fatigue resistance will be a little higher. Have your machine shop check that the bolt head face is square; this will further reduce any bending loads on the bolts.

After you install the new bolts, you are ready to resize the big end bore. When sizing the bore, make sure that the shop flat grinds (and not angle grinds) the rods. After grinding they should take a file to give the edge near the bore a small chamfer (just enough to take off the sharp edge and no

more). When honing, they should use course stones to better aid bearing retention and they should size them at the lower limit to maximize bearing crush (also help hold the bearing in place). Contrary to popular belief, the tangs do not hold the bearing in place; they just locate them during assembly.

It was popular at one time to mill the rods and caps at a slight angle (opposite of how reconditioners mill) to get the sides of the rods to flex outward. What this does is bend the bolts in the opposite direction and make the big bore have a slight oval at rest, then under high rpm the bolts would straighten out and reduce bending loads and the bore would be closer to round. This technique does work, but it's too expensive to do all the machine work, when stronger aftermarket rods can be had for the same price (or even cheaper). It is now becoming popular to squeeze the rods with a clamp while sizing them to get the same effect. This method gives the same result with less stress on the bolts.

## Small Ends

Most stock wrist pins will be held in place by an interference fit. A press fit pin is harder to assemble and disassemble. If the rods have been shot peened or heat-treated, you should not heat the rods to assemble them. It is very hard to press a pin in or out of a rod without doing damage to the piston.

For most street engines a press fit will work fine. In higher output engines, the heat in the piston can arc the piston more and require an extra 0.0005" pin clearance to prevent galling. Full floating pins eliminate the need for this. Full floating pins flex more and the pistons need to be stronger around the pin bore. It is possible to use a full floating pin with a stock rod, but we run into the question, is it worth it? If it's a drag only car that sees very few miles, the rods can be honed out so the pin rides directly in the rod. With good oiling, this steel-to-steel fit can last a long time in a drag car, but shouldn't be done in a street engine. If you want to bush the small ends (you must have a good set of rods with enough meat around the small hole) you have to bore it .050" oversize to accommodate a .025" wall bushing.

Some engine builders drill holes in the top and bottom of the pin bores for oil, but this can

weaken the rod, it's better to just file a .010" slot on each side of the bore to let oil in (this works whether you use a bushing or not). Again, check the aftermarket, they might not be out of your budget by the time you have your stock rods prepped.

## Shot Peening

Most engine parts will fail from tensile loads opening up surface flaws (stress risers). Shot peening is when tiny steel shot is impacted on the surface of the part. Each shot will leave a small spherical dent that compresses the surface, which makes it denser and gives the parts better fatigue resistance. If done right, it can increase the strength and life of the part.

On connecting rods the biggest mistake done is to leave the bolts in when shot peening. With the bolts in place, the critical weak bolt notch does not get shot peened because the bolt is covering it. You need to remove the bolts, but install thinner bolts with ground heads, something to hold the rods together, but not cover the bolt notch.

## Rod Bolts

Rod bolts not only have to deal with extreme tensile stress, they must also resist fatigue. Most stock bolts are more than strong enough to hold high rpm engines together, but only for a short period. Stock bolts fatigue quickly. A high quality aftermarket bolt does not necessarily have a higher tensile strength, but it will last longer due to better resisting fatigue. Most people out there will torque the bolts with a torque wrench, and for the most part this is a satisfactory method. A good high-pressure lubricant like moly lube should always be used on the threads when torquing bolt. This cuts down friction and gives more accurate clamping pressure.

The best method for tightening rods bolts is to measure the bolt stretch. Most aftermarket bolts will require around 0.006" stretch (check the manufacturer's recommendations). If you don't have a stretch gauge and have to use a torque wrench, you should lube the nut, torque it, then remove it, relube it and torque it again, then do this for a third and final time. This is the technique recommended by ARP.

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