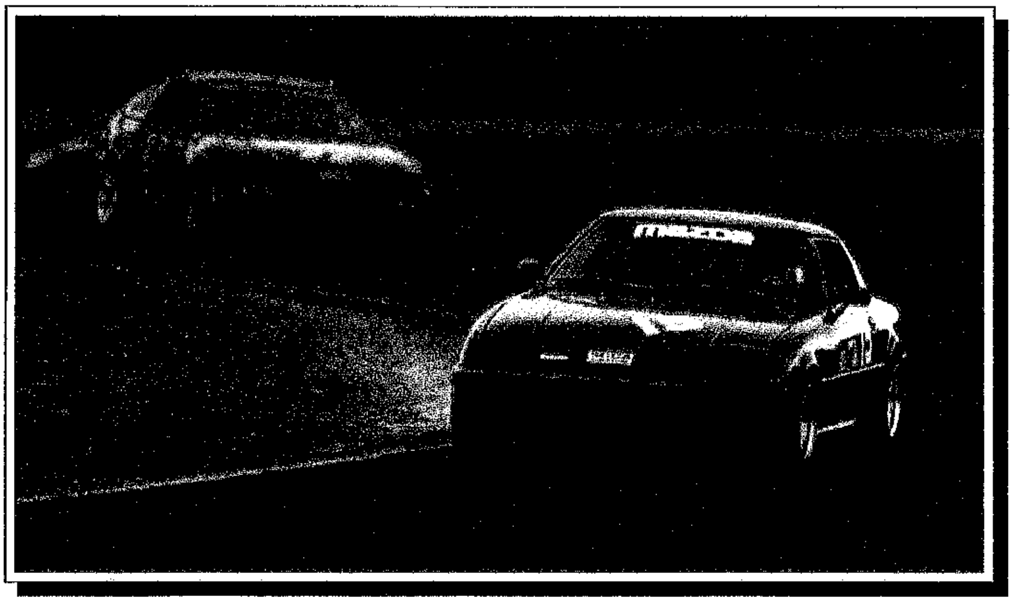
Tri-Link



Setup and Tuning of the Early RX-7 Suspension From A to Z©

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rev. 25

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In my racing efforts I am constantly learning and making small changes to the manual. However, the manual cannot do justice to all topics, and some items, particularly regarding shocks, are involved and continually under development. You are best advised to call me and discuss your needs as the updates can become quickly outdated, and the manual cannot cover all situations.

If for any reason you are not 100% satisfied, let me be the first to hear of it so I can correct any problems and improve my products and services. I take great pride in my work and my goal is to provide the most technically advanced, well engineered and quality manufactured components you can buy. And I stand by those components with knowledgeable, personalized assistance.

Thank you!

Jim Susko
G-Force Engineering

Introduction

These recommendations will help you obtain the optimum ride rates, roll stiffness, geometry and travel for your local race track or solo site conditions. They will also help you find the optimum balance of low vs. high-speed handling, both transient and steady state, an often overlooked aspect of performance that is critical to fast times. They were developed by the author, a Mechanical Engineer with over 20 years of competition and tuning experience, who has a national championship in Pro Solo and who currently races the RX-7 in Improved Touring competition. Research and design work was completed using a finite element static non-linear geometry modeling program (currently used at General Motors) plus a custom Tire Lateral Load Transfer analysis based on an SAE paper written by R. W. Topping of General Motors (also a National Solo II competitor) which was then programmed and enhanced by the author for suspension tuning. The setup was then tested and continues to undergo tuning by the author.

This is a unique publication. There are no secrets I reserve for my own competition. I try to fold every bit of knowledge I gain about the RX-7 into these pages. Information from my own research, racing and feedback from customers is included into this setup manual as soon as it is practical. When you place your order I print and assemble your individual manual at that time. So you can always be sure that you have received the latest information. What little information that may not be included due to practical realities is available by simply asking.

In past years the specific setup recommendations were applicable to both road race and solo competition. However, as of 1998 the Solo Events Board changed the Street Prepared rules to preclude the use of Turn-In spacers to alter front suspension geometry. So beginning 1/1/98 the front end setup recommendations no longer apply to Solo II Street Prepared competitors. The net differences in required setup for Solo II competitors will be restricted to the front end where without the Turn-In spacers swaybar stiffness will have to increase, more toe out and greater front swaybar weight jacking adjustment will be necessary. Call for newer, more specific recommendations as the optimal setup continues to undergo development.

Overall handling objectives continue to be very much the same for Solo II and road race competition. Ackerman and the low speed turn-in it promotes is absolutely essential in solo but is still extremely beneficial in racing. Slightly more oversteer is often desired in Solo II competition. Ride can usually be stiffer for improved transient response but only if one runs on smooth lots. A locked differential is only an option in racing. Brake cooling is usually not critical in solo. But in general the handling objectives are identical and the same setup makes for a good handling car in either situation.

Track conditions and driving styles have a much more profound influence on setup. Most racers reading these instructions will already have made investments in tires, shocks and springs which may differ somewhat from these recommendations. Therefore these instructions are not in the form of a simple list of spring rates and settings. Rather it is the author's objective to help you understand how and why the selections were made. That way you can adjust the setup to your particular driving preferences or hardware choices without venturing into unknown territory. But try it by the book first. You won't be disappointed.

Some background in the terms is assumed. As I continue to expand upon the publication to add value to my readers I see it has threatened to become a treatise on suspension design. So if you have questions or want help in your tuning effort feel free to call Jim Susko at G-Force Engineering.

Serious tuners discover early that a seemingly simple change has its effect on many other aspects of handling. For example, if you install a shorter, stiffer spring at one end, many critical setup parameters are effected. On many suspensions the roll center will go down much more than the car is lowered, influencing the roll stiffness and balance of the car. The added spring stiffness may or may not offset this change. Bump steer may be effected. Shock settings will be off. The sway bar balance and the car's total lean angles will change. That can cause initial camber requirements to change. The suspension may bottom. The changed initial camber and ride height will influence braking effectiveness, and brake bias may need adjustment to avoid lockup. The changed bias will cause differences in the heat input to front and rear brakes. And so on.

When one is working in a computer modeling environment most of these effects can be seen simultaneously and adjustments made for unwanted aspects of the change. But most racers make these kind of changes with no inkling of the many interrelated effects, or that there is actually a optimal order that one should use to go about making changes.

There is also a tendency for inexperienced drivers to measure handling based on a single yardstick--gross oversteer vs. understeer. Subtleties such as differences in corner entry, corner exit, steady-state turns, and high- vs. low-speed turn characteristics are overlooked. The notion of transitional performance is often overlooked. When a change is made which seems to correct one problem, there may be no questioning whether overall grip has been lessened or it has other unintended consequences. Conversely, when the right change is made and oversteer characteristics are worse, they may conclude that this is the wrong direction, when in fact it may be the right direction, but other unintended changes must be compensated for.

One needs to understand all the dimensions of what makes for a good handling car and that there is a priority to working through the tuning effort. You should also try to understand what aspects of handling to key in on when evaluating each change and how to anticipate and adjust for other related but unwanted effects. This will help you arrive at an optimal setup without chasing your tail.

As part of its mission this paper strives to help you understand that a suspension is best designed as a total package with components that work together. All of the sanctioning body's rules and the car's fixed design limitations are considered, corrections for serious deficiencies are made where possible within the rules and the remaining components and parameters are then adjusted to work together in a balanced fashion. The Tri-Link system of components and these recommendations are the result of such a disciplined and informed design approach. In addition, the author applied over twenty five years of competition driving experience in literally every combination of engine placement and driven axle made.

This doesn't mean that other combinations won't work. It just means you should understand the tradeoffs, that these settings work work well and provide the greatest driver feedback, and there are solid and proven reasons why they were chosen. You will understand best after you have completed the changes and actually driven the car.

Regardless of your driving style, the most important thing to keep in mind is that your setup should generally allow you to brake and turn into a corner without unmanageable oversteer, yet permit you to get on the power early out of turns without understeer. With understeer under power, you have to lift or delay acceleration to keep the car from understeering off the track. Especially in road racing, that is the single worst detriment to fast times. At the same time, the ability to power early out of turns should not be enhanced at the expense of tuning in high-speed oversteer (e.g. by the use of bar adjustments alone.) This tends to be destabilizing and difficult for most drivers to control at the limit. Shocks play the major role in these transient maneuvers.

Keep in mind that each of the three key Tri-Link components is designed to dramatically change the handling characteristics of your car. So if you cannot make all the changes recommended in this manual you should install certain key components as a group before competing or attempting to fine tune the car. Otherwise you may experience serious handling imbalances which could at worst be dangerous. In the least it will cause you to chase your tail getting the car to handle as you add each successive next component.

The most important changes correct the car's inherent geometry problems. These are accomplished with the Turn-In Spacers in front, and the GT Panhard and Tri-Link in the rear. Next select and install the recommended matched front and rear springs at the recommended ride heights, along with a stiffer-than-stock front swaybar. Set camber and toe to the recommended settings. When you get to the track, set your shocks on soft and make adjustments until the steady state performance in long sweepers is neutral. Finally, adjust your shock settings to tune transient performance, such as corner entry, corner exit, high speed transients, and stability over bumps. Getting these steps out of order can lead to confusion and a compromised setup.

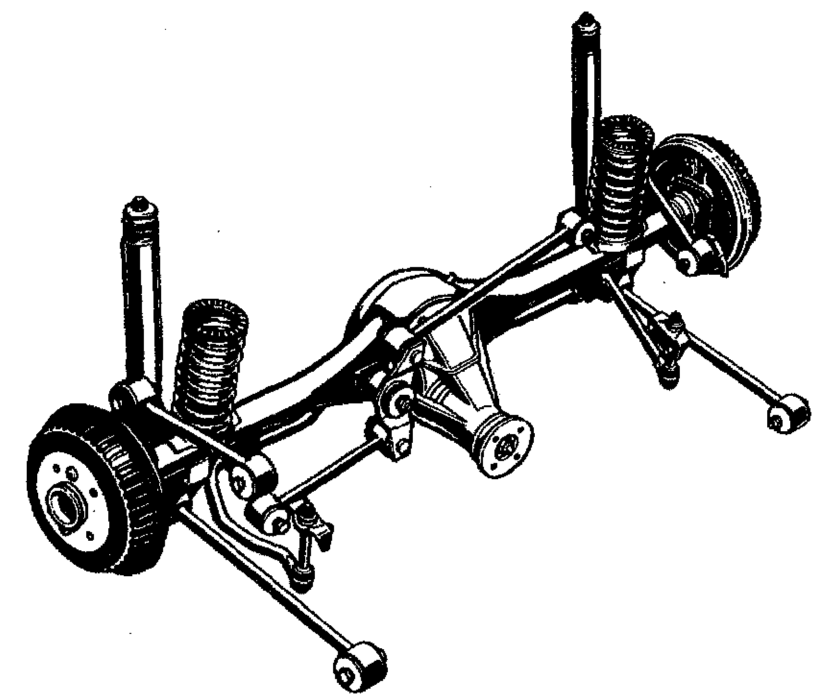
From this point, you can fine tune the car's performance by improving bushings, brake cooling, rear end ratios, and many other items..

Mazda Suspension Problems

Rear Suspension Binding

When the stock rear suspension rolls, the top links move it side to side. This is because they project outward, upward and rearward. Therefore they not only swing about a center in the side view but when viewed from the rear they also swing about an axis parallel to the car's centerline. The watts link, on the other hand, wants to restrict axle movements to a vertical path. This difference in motion paths leads to binding which is felt as a rising rate roll stiffness.

Another source of binding is due to the rotation of the axle with ride travel. When viewed from the side, the axle appears to rotate about a point forward of the axle. This point lies at the intersection of the two trailing arm centerlines, and is called the side view instant center. The axle appears to rotate about this point as if it were on a single virtual swing arm. At normal ride height the length of this virtual side view swing arm is already fairly short. However, when the suspension is lowered for racing the upper arms, being shorter, rotate at a much higher rate than the lowers, moving the instant center rearward and shortening the virtual side view swing arm even more. Because this new instant center is also below the axle on a vastly shortened virtual arm, the nose of the differential is rotated downward dramatically. As a result the inner and outer watts link bushings are no longer in the same plane, placing them into a severe bind.



Mazda Rear Suspension

This new rotation center has another effect. The natural consequence of roll motions is that one rear wheel is moved upward and the other downward. The lowered rotation center means that as a result the two sets of control arms try to rotate the axle in opposite directions. Naturally the only components that can deflect are the axle bushings. This is a third source of binding.

This is particularly true at higher roll angles. And all the effects worsen the more the suspension is lowered. The net result of all this binding is to cause rear roll stiffness to rise with roll angle in a

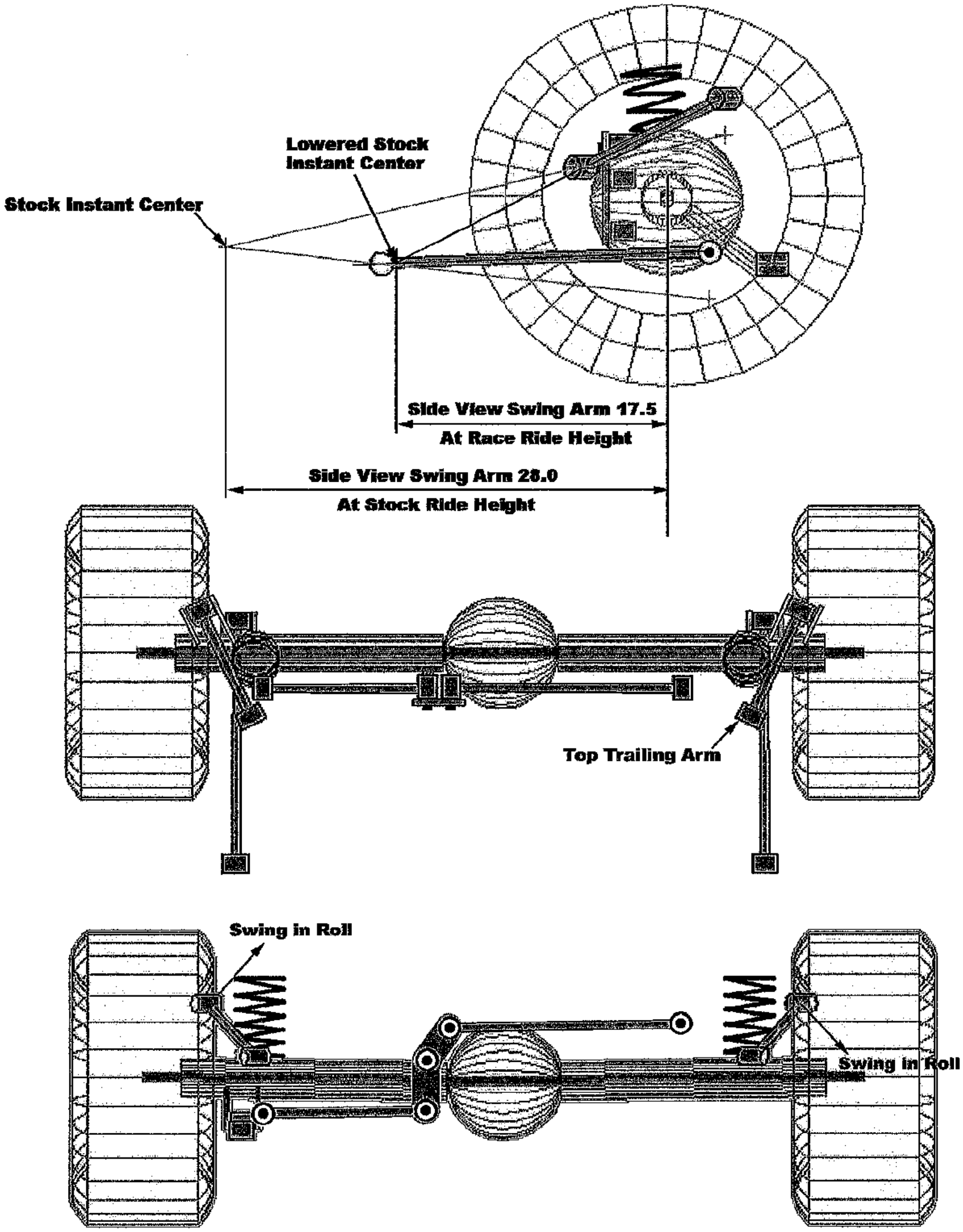


Figure 1.0: Lowered Mazda Rear Suspension

nonlinear fashion. It's like adding a swaybar that gets bigger and bigger the more the suspension rolls. And everyone knows that the effect of a bigger rear bar is oversteer.

Actually, what happens when you add a swaybar is to cause more of the leaning forces to be resisted by that axle. So the inside tire is unloaded more and the outside tire takes up the slack. Since you are essentially under utilizing the inside tire and overloading the outside tire, the axle can't generate as much total cornering force. That's why more roll stiffness in the rear causes oversteer.

Since this is all built into the original suspension, simple swaybar changes aren't enough to entirely eliminate the problem.

Common Cures

There are many "fixes" that have been tried to minimize these binding effects. One is to use spherical bearings in the watts link bushings. This eliminates the problems due to the out-of-plane watts link. However, there is less compliance side to side, worsening the binding due to the different motions paths of the watts link and trailing links.

Another fix is to leave the stock bushings in place and use a rear panhard rod to lower the roll center. The roll center is the point in space about which the car rolls in a turn. A lowered roll center has the effect of reducing the rear roll stiffness even if the ride stiffness remains the same (i.e. the springs are not changed.) This decreases cornering load transfer on the rear tires and lessens oversteer.

However, every after-market panhard I've ever seen uses rod end joints. With fewer rubber isolation bushings to accommodate the difference in motion paths, binding is actually worsened--just as it is with a heim-jointed watts link. Since the lowered roll center reduces rear roll stiffness more than the increased binding, the car may feel better balanced in steady state turns on smooth surfaces.

The problem is what happens when the outside rear tire hits a bump when you are at the limit. Remember that the rear end feels like it has a sway bar that gets bigger the more the suspension rolls? It's like someone just installed a bigger rear bar. With any bump or momentary increase in lean, weight transfer is dramatically increased. The result is that the car can suddenly snap into a tail out condition.

To avoid this the swaybars and/or spring rates typically have to be recalibrated for even greater understeer. This reduces net cornering ability at high speeds and induces severe understeer tighter turns, which means you can't get on the gas as early out of a low speed turn without understeering off the track. The penalty is lower cornering speed, later acceleration out of turns and slower lap times.

Another approach is to use extra stiff swaybars. The theory is that with less roll there's less binding. Unfortunately, the problems are only slightly masked and excessively high ride or roll rates come with their own penalties--like reduced cornering ability.

Some go so far as to eliminating compliant bushings completely. This is the worst possible approach. In fact, with all spherical bearings the rear suspension can only roll by deforming the chassis!

With all approaches, the binding creates the need to run much stiffer front bars and softer rear springs than would otherwise be prudent. I've seen cars that had so much front roll stiffness that the inside front wheel was lifted as much as eight inches off the ground in turns! Naturally one can't corner as fast using only 3/4 of the rubber available. Under these conditions one would also need extreme camber settings in front to keep the single functioning front tire even remotely flat to the ground. One prominent tuner following this approach recommends as much as four degrees front camber! Obviously inside shoulder wear and braking would be terrible following this approach.

With soft rear springs the amplified rear ride deflections contribute to more geometry changes under braking and acceleration than are desirable. This can effect roll stiffness, roll center height, roll steer, and so on. With these parameters changing rapidly under pitch motions, handling is not as predictable and most of the changes are unfavorable for the maneuver being performed. The severe spring rate mismatch can also lead to porposing, a pitching condition created by greatly different ride frequencies front and rear, and transient handling difficulties.

Rear Suspension Roll Steer And Anti-Squat

One aspect of the original suspension that is not well understood by most racers is rear roll steer. Roll steer geometry causes the rear axle to steer into or away from the turn. When the rear tires steer to the outside of the turn it is called roll oversteer. When they turn into the turn it is called roll understeer. Most stock suspensions are designed with a few percent of rear roll understeer, which is good, because it tends to stabilize the car in turns.

But as the stock Mazda rear suspension is lowered roll understeer can increase to nearly 20 percent. Initially, this can mask the oversteering effects caused by binding. It does this by generating more rear steer and resulting slip angle in the rear tires. But when the limit is reached, it is even more sudden and hard to recover, as most experienced RX-7 drivers will attest.

Another effect of lowering is to increase anti-squat. Anti-squat is a designed-in property of the rear geometry which uses the torque of acceleration to resist the tendency of the rear end to squat. In the stock suspension, anti-squat is about 30%. This means that about a third of the normal squatting action under acceleration is resisted. But once the car is lowered for racing, anti-squat can soar to as much as 225%! To the car, it appears that the rear springs are much stiffer under acceleration. In this case, more is not necessarily better.

Ironically, many find that the best solution to many of these problems has been to raise the car back up to its designed ride height! While this definitely eliminates geometry problems and reduces binding somewhat, rear cornering capability is still sacrificed because lateral weight transfer is increased.

Drive Train Problems

Another problem is associated with the lowered car's new side view virtual swing arm. Because the axle is rotated forward, the drive shaft U-joints are no longer properly aligned, causing vibration at high speeds. This worsens if you are running a higher numerical rear end ratio which increases driveshaft speed for a given road speed.

The shortened side view swing arm and its new, lower instant center also causes the axle to move forward and back with ride travel. With the soft springs usually needed both because of binding and the high rear roll center of the Watts link, this fore-aft motion can be considerable. This causes the driveshaft splines to plunge in and out of the tail of the transmission and accelerate wear of the rear bushing. The combined effects of vibration and movement on wear can be so bad that I've heard stories of serious racers having to replace these on a season-by-season basis.

Solving Rear End Problems

You've probably gathered by now that no matter what the band-aid, without major geometry revisions oversteer problems and a skittish rear end are inherent in the stock system. And the various fixes simply degrade other aspects of performance. The only real cure is to change geometry entirely. Fortunately, this can be done using the G-Force Tri-Link system.

The rear system consists of the Tri-Link, Panhard and lower arms with spherical bearings. The Tri-Link is used in combination with extremely soft upper bushings (i.e. upholstery foam!) This essentially eliminates the effect of the upper arms and changes the rear geometry to a three link design. With no restrictions except packaging, the location of this new arm may be chosen to completely change the characteristics of the rear suspension.

Now, without the original upper control arms the source of the suspension binding is eliminated. The new single Tri-Link upper control arm corrects anti-squat with its revised geometry. The solid bushings and a longer side view swing arm geometry eliminate driveshaft plunge into the transmission, a major source of driveshaft spline wear. This also reduces frictional losses which results in greater wheel horsepower. Wheel hop is also eliminated due to the combined effects of the improved swing arm and solid bushings.

The G-Force Panhard Rod eliminates watts link out-of-plane binding and reduces rear lateral weight transfer in corners by lowering the roll center. The Panhard also works in conjunction with the redesigned geometry to restore roll understeer to 7 percent when set to the correct ride height. And because the Tri-Link qualifies as a "Traction Bar" under the GCR, it is heim jointed to allow U-joint realignment. This realignment eliminates driveshaft vibration--the other source of tail shaft bearing wear.

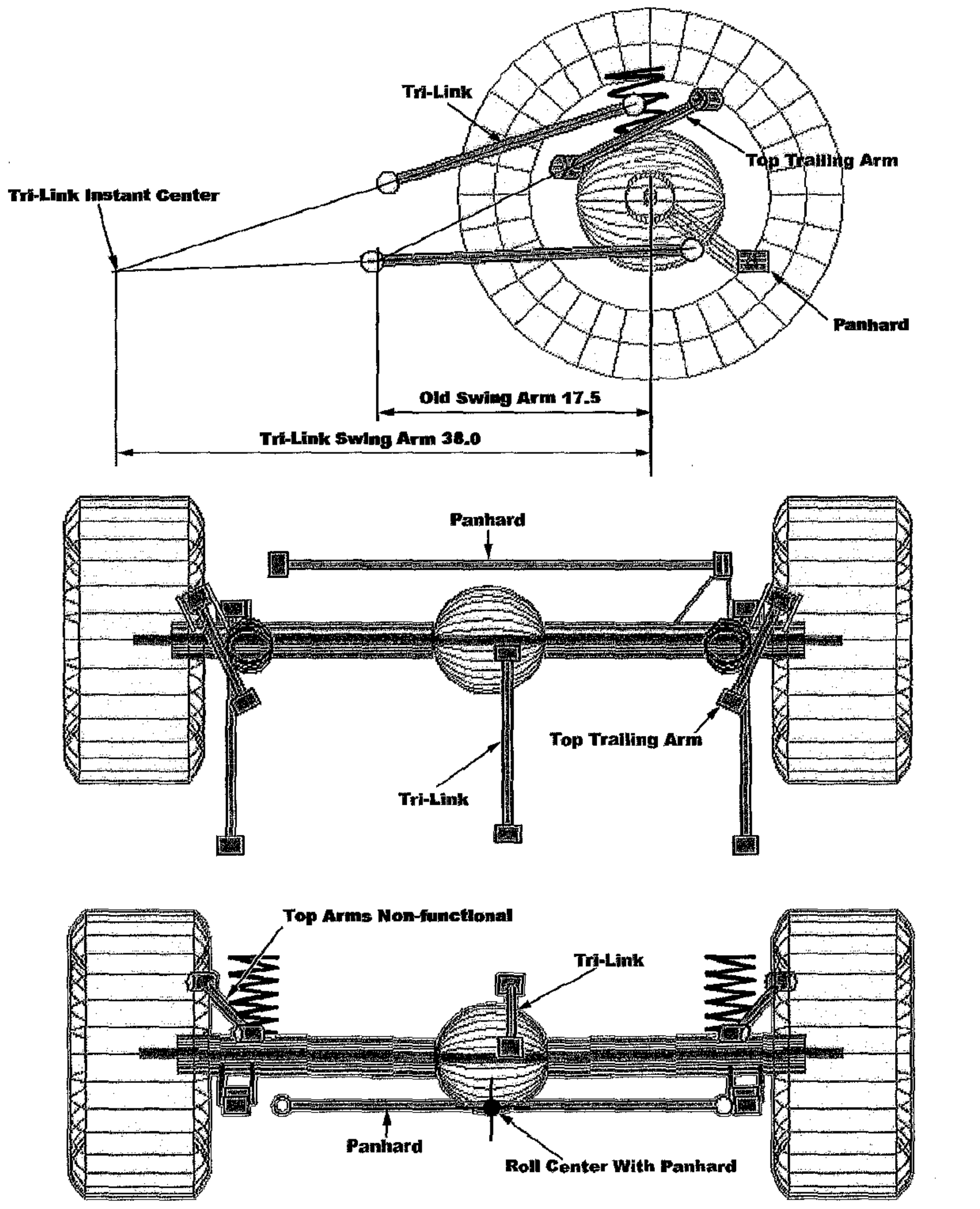


Figure 1.1: Tri-Link Race Suspension

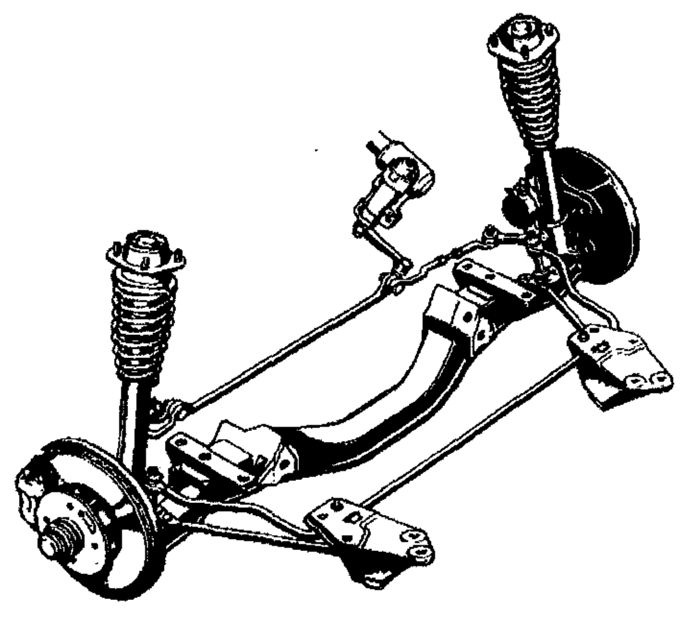
Finally, the lower control arms eliminate the last rubber bushings for absolute control of suspension movement. The net result is ideal suspension characteristics.

With the elimination of binding, and with the lowered roll center the rear springs may be considerably stiffened without inducing oversteer. The effect is to minimize undesirable geometry changes under acceleration and braking. Ride movements in the rear cause roll steer to change. When the axle falls under braking into a turn, oversteer geometry is increased. When it rises under acceleration out of a turn, understeer geometry is increased. This is the exact opposite of what is desired. To get the power down out of a turn you must not have heavy understeer under acceleration. And for late braking passing maneuvers you would like mild understeer so you don't lose the rear end. So minimizing these changes helps handling.

The Front Suspension

The RX-7 also suffers from another deficiency which becomes more apparent once the rear end problems are corrected. That is the lack of ackerman in the steering geometry.

Ackerman is the property of a steering system that causes the inside wheel to turn at greater angles than the outside wheel. This is needed because the inside wheel is closer to the center of the turn. If you imagine looking down on a car doing "donuts" in a parking lot, the inside wheel traces a smaller circle and so must turn at a greater angle to avoid scrub or fight with the outside wheel. When this scrub occurs, understeer is promoted.



Mazda Front Suspension

Some quite knowledgeable and prestigious suspension theorists doubt the need for ackerman in road racing because the typical turn radius is large so the difference in turning radius is small. The tires are also cornering under high slip angles but the inside is lightly loaded. In theory this means the inside tire cornering angle must be reduced. Therefore they conclude ackerman is not needed. It's a very reasonable argument, one for which I haven't a theoretical response. However experienced drivers and race tuners do not debate the issue. In his book "Tune to Win," Carroll Smith suggests as much as 200% ackerman is useful!

Solo drivers regularly employ generous toe-out settings to improve low-speed turn-in. Toe out increases the ackerman effect. It not only increases the initial difference in steering angles of the two tires, but it favorably changes the steering arm geometry to cause this toe out to increase even faster as the wheel is turned--in effect increasing the ackerman geometry. The theorists may debate but real racers simply find it works.

Ackerman becomes most important in tight turns where the difference in turning radius of the front tires is greatest. Exiting tight turns under acceleration is also when a limited slip or locked rear end causes the greatest understeer to occur. In road racing the tightest turns typically occur before main straights. If understeer causes a driver to lift or delay acceleration in these situations lap times will be increased.

Another effect of ackerman is initial steering sensitivity. This is particularly useful in dicing or avoidance situations, and essential to good Solo II times.

The RX-7 is a so called "rear steer" car. This simply means that the steering rack is located to the rear of the front axle. On a rear steer car when the tie rods extend outward perpendicular to the car's centerline ideal or 100% ackerman is achieved when the steering arm axes point at the rear differential. In the RX-7 the steering arms point rearward of the differential for less ackerman. The tie rods also point slightly rearward as they extend out from the idler arms. This is unfavorable to ackerman as well. In fact, the net result is that there is only 30% ackerman in the stock car!

So why not just run lots of toe out? Solo drivers actually run up to 1/4 inch and more. But this sacrifices some straight line speed because of tire scrub. They can get away with this because in Solo the balance of turns versus straights favors low speed turn-in over straight line speed.

But at the higher speeds used in road racing lots of toe out can be destabilizing and lead to dangerous oversteer. And with the long straights the tire scrub can severely reduce lap times.

Correcting Ackerman Deficiency

To correct this deficiency in ackerman geometry, G-Force provides several thicknesses of "Turn-In Spacers" for Improved Touring and E Production racing. (Unfortunately, rules changes implemented in 1998 made the Turn In Spacer illegal in Street Prepared.) The Turn-In Spacer is placed between the strut and steering arm/ball joint assembly to change steering arm orientation. The G-Force Turn-In Spacer increases ackerman to 100%, greatly improving low-speed turn in. It is legal because any strut is permitted in Improved Touring classes. When bolted to the strut, the spacer can be considered as part of the strut assembly. The rules do not specify that "any strut" must be single piece and not an assembly.

Front Roll Center Location

Another problem with the front suspension comes when it is lowered to the ride heights desirable for racing. The effect of lowering is to change the inclination of the lower arms which moves the front roll center considerably downward. The roll center height determines the mechanical advantage of the springs in roll. Lowering it makes the front end less stiff in roll even when the spring and ride rate is not changed. This increases oversteer and lets the car lean more for a given ride rate. The ride and roll rates become out of balance.

Lowering the roll center too much also introduces other undesirable effects. On a strut type suspension if the roll center is moved too close to ground it moves around laterally as the car rolls. This movement can be measured in feet, not inches. This makes the car handle unpredictably in transitions because the front roll stiffness and instant center of the more highly loaded outside wheel is changing dramatically.

Also, if the roll center is too low one also loses the advantage of the shock absorbers in roll motions. Since the shock absorbers and springs act as a unit, anything that reduces the springs' mechanical advantage in roll also effects the shock action. Since the usual "fix" for a car that leans too much is to add a big sway bar, that means the roll stiffness is restored but there is no corresponding increase in roll damping.

Restoring The Roll Center

The G-Force Turn-In Spacers also function to move the roll center back to generously above ground by spacing the ball joint downward, restoring the original geometry of the lower arms. This eliminates the undesirable effects of a lowered roll center.

The Total System

The core system of G-Force Tri-Link components, which includes the Tri-Link itself, Panhard, lower rear control arms and Turn-in Spacers, allow a complete retuning of the RX-7 suspension to great advantage, eliminating the many compromises that must be made to accommodate the fundamental deficiencies of the stock suspension geometry.

The following guidelines, therefore, assume that these components have been installed. The result will be a "planted" rear end which won't break loose under rough conditions and will be easily recoverable when pressed beyond prudent limits. The car will also have greatly improved turn-in under power, and overall cornering speeds will be greatly enhanced.

Selecting Springs

Spring selection is always the first priority. When this is given careful consideration and other component and settings are then chosen to match, much re-engineering and wasted time is eliminated. A lot of racers I know just treat springs like a change of clothes, throwing them aside when they don't work right out of the box. Since so many other things are dependent on spring choice--sway bar size and balance, ride height limits, shock settings and so on--the wiser you choose in the beginning the quicker you'll zero in on that perfect setup.

Keep in mind that the rates shown here were primarily developed for IT and Street Prepared use. Rates for the newly introduced E Production cars are just being explored, but can generally be about 50-100 lb/in higher than the corresponding IT rates.

Depending on your application a variety of overall rates--from stiff to soft--are perfectly acceptable, but you should strive to maintain a specific balance between the front and rear rates in order to obtain optimal ride performance for those general conditions. To put it simply, under the premise that soft springs are best for rough conditions and stiff springs for smooth conditions, one would not normally spring one end for stiff and one for soft conditions. Keep in mind that the RX-7 has an almost 50-50 weight distribution. So for a given track condition any difference in front to rear ride rates is only needed to offset deficiencies somewhere in the system. Only a small difference is needed to accommodate the difference in front and rear suspension types, so the need for larger differences points to unsolved problems or an imbalance in other suspension system settings.

There is no one choice that is right for all applications. The one extreme is a Solo II car on a billiard-table smooth, grippy, hot concrete lot and using autocross compound tires on 9 inch wide rims. Here very stiff springs can be used to great effect. The wider rim allowances and autocross compounds can give tremendous stick and side loads, and these call for a stiffer suspension. The wider the tire the more it must be kept as flat as possible in order to generate maximum grip. So stiffer springs keep lean angles and suspension deflections within a reasonable range and help to give the car rapid transient response.

The possible down side is that as soon as you get on a rough, sealed asphalt surface--worse yet if it's cold and raining--the car may be unmanageable. The ride is not soft enough to soak up bumps and the surface cannot sustain the high peak loadings that result. The tires quickly slide and with a lower sliding coefficient of friction grip can't be re-established. What was an asset on concrete is now a liability.

So you may want to consider track surfance, which is your smoothest and roughest venue, and spring for those average conditions. Alternately, if you are a serious competitor who's only objective is to win one premiere event, then you may wish to accept a car which is too stiffly stiffly or softly sprung for other venues where there is less competition.

The other extreme is an ITA car on a high speed, rough, slick track in the rain. With narrower rims and road race compounds less grip is generated, so lean angles are not as extreme. Higher speeds make what would feel like gentle or rolling hills for Solo seem like rapid, violent large-amplitude bumps in ITA. The narrower tires on narrower rims are not as sensitive to camber control and soaking up the bumps is a higher priority to help stabilize the car for high-speed steady-state control. So softer springs, higher lean angles, greater suspension movements and slightly less camber control is often better. Again you need to decide if you are targeting for average conditions or a specific event.

I generally start tuning a car by targeting spring rates based on the car's undamped ride frequency. This is the body's natural frequency of oscillation without shocks. It is a car-independent calculation that considers the sprung mass and the total wheel rate. The total wheel rate is the effective stiffness of the whole suspension when the spring rate, tire stiffness and the mechanical advantage of the springs are all factored together. In other words, if the shocks were removed and you pushed down on the suspension the car would oscillate at the undamped ride frequency. A big car with big tires and stiff springs can have the same ride frequency as a small car with small tires and soft springs. The two rides will feel about the same if all other factors are equal.

I say other factors must be equal because other factors may determine what frequencies may be targeted. Cars with very stiff chassis and lots of down force may use astronomical ride frequencies. Cars with floppy frames and large unsprung weights like solid axles are not very tolerant of high ride frequencies.

I once asked Carrol Smith how he chooses ride rates. His simple answer, "Stiffen the car until it goes slower, then go to the last spring you tested." You must throw away all of your experience with street cars and your previous perceptions of stiffness. Street cars are tuned for passenger comfort, and consequently tire grip is severely compromised. Race cars are tuned for maximum tire contact with the road for greatest grip, and ride comfort is not a consideration.

Front ride rates of 400 lb./inch and above should be considered with shocks in mind. Premium double-adjustable racing shocks will now become a requirement for good performance over bumps and in transients. Without them, the car will bounce around violently in the rough stuff. You will need lightning reflexes, excellent car control and lots of confidence. Encounters with curbing are more violent and upsetting. The overall feeling is the car is too stiff, when the problem is shocks.

If you have a Production or Prepared car running bias ply tires it helps to soften the effects of stiffer springs, and higher ride rates may be considered. Bias ply race tires tend to have a very compliant carcass in ride and work at lower tire pressures. Since the ride spring and tire are in series, the tire's reduced spring rate will have a definite softening influence, particularly over rough pavement.

A very stiff cage structure may help the chassis deal with higher rates, too. Otherwise it may begin to flex and you can lose suspension control. The chassis acts as a big, undamped and uncontrolled spring. It gets "the shakes" like an old frame-chassis GM car of yore running over potholes or speed bumps. When the chassis loses that rock solid feel it's a signal you're venturing into excessive ride frequencies. Finally, with high rates you will probably have to use a revalved adjustable shock or a special racing shock to gain enough damping.

Front frequencies in the 350 lb./inch or less are on the softer side for most applications might be applicable if you run bumpy, slick conditions. Some drivers simply prefer the softer feel that comes with these rates. But transient response is less, and suspension control isn't as good.

Front rates less than 350 lb./inch are becoming fairly soft for competition. You will need to run higher ride heights to avoid bottoming, especially in road race. In fact, ride height is a direct tradeoff with spring rate. And higher ride heights make for reduced overall grip.

If you must run low ride heights and low rates, put a plastic tie-wrap around the front shock shaft and shove it down as far as it will go. Where it ends up shows you how much ride travel you are using. If it disappears you are definitely bottoming. If you bottom more than momentarily, massive understeer or oversteer can result, not to mention broken shocks and camber plates in the front. In the rear you should clearly hear when you bottom since you should have removed the bump stops, but you won't do any real damage.

If you are preparing an EP Mazda running under the IT suspension rules to take advantage of the 200 lb. weight break these same general guidelines can be helpful, but add 50-100 lb/in to the guidelines. Because of the slightly lower weight of the EP version the actual ride frequencies are higher than those for IT at the listed spring rates, and even higher if you go beyond those listed. But the EP version benefits from a much stiffer cage structure and uses bias ply race tires at low pressures, so the effective spring rate is less than it appears and chassis stiffness is not as much of a problem. Since the tires generate more grip and horsepower is increased over the IT version, you will find that slightly higher spring rates work well. However, racing shocks will be a must if you exceed the highest rates recommended for IT racing.

Once you've chosen your overall ride frequency, pick the rear to match the front within reasonable limits, using the table supplied. This will result in a generally balanced ride and swaybar setup, especially on a car with nearly 50-50 weight distribution like the RX-7. If you find you need the rear end extremely soft, like most RX-7s without the Tri-Link setup do, this is generally indicative of severe problems with the suspension at that end of the car. The mismatch is a "band-aid," and you should look deeper for the underlying problem and solve it.

On a car with fairly equal front and rear weight distribution like the RX-7 I try generally not to mismatch front and rear ride frequencies too much. In some cars severe mismatches can result in "proposing" over bumps and yumps--a severe pitching condition. What happens is that if the frequencies are too different the front is cycling up when the rear is cycling down and vice-versa. For typical highway cruising speeds when the front frequency is about 3-5 cycles/minute lower than the rear, the car will actually tend to ride over high-speed bumps without any pitching motions at all. This is called a "flat ride" in automotive terms. Using the table keeps you within a range where only fine tuning will be needed to account for driver style.

Looking at the table, one must wonder why a car with nearly 50-50 weight distribution needs different spring rates front and rear to attain the same ride frequencies and to handle neutrally. First, the solid rear axle is about 250 lb. of unsprung weight. The front has only about 90 lb. of unsrprung weight. Since the weight distribution of the car is nearly 50-50, this means that the rear sprung weight--the chassis above the rear axle--is not as heavy in the rear as in the front, especially in proportion to the unsprung weight of the axle. So the rear chassis is not as solid a platform to control the large unsprung mass. To match the bounce frequency of the two axles the rear spring rate must be proportionately lower than the front.

Another factor is that there is less camber available in the rear due to the solid axle. The heavier mass can't follow the ground irregularities as well. For these reasons you can't develop quite the grip as you can in front. So generally this requires a slightly softer ride to avoid high peak loadings over bumps and frightening tail-out occurrences.

Another factor is the leverage the spring has on the wheel, called the motion ratio. A double A-arm suspension may use springs that are 2-4 times stiffer than a strut suspension for the same ride rate. On the RX-7, the linkage ratios are different front to rear.

Once you've chosen your front rates, the following matching rear rates should be a good marriage of all the above considerations. These rates apply when the car is prepared to the weight limits of the rules and the Tri-Link, matching panhard, front spacer, recommended ride heights, stock front swaybar with the custom linkage described herein or the aftermarket 1 1/8 inch bar are used. It is assumed you are running camber plates.

FRONT LB/IN	ITA REAR LB/IN	EP REAR LB/IN	LEAN DEG.	STIFFNESS	TRACK
600	375	350	1.4	Very Hard	Very Smooth
500	325	300	1.6	Hard	Smooth
450	300	275	1.7.	Medium	Smooth
400	275	N/R	1.8	Med.-Soft	Average
350	250	N/R	1.9	Soft	Rough
300	200	N/R	2.0	Very Soft	Extremely Rough

These pairings are chosen to exhibit equivalent oversteer/understeer characteristics. The lower rates will result in bottoming on rough surfaces at the recommended ride heights and although this is not sacred I generally don't recommended low rates for competition. You might go lower in rates for the street if you raised the car equally front and rear. The soft rubber isolation rings on the perches have been discarded.

For most tracks I run the Hard setting. It works well at the smoother tracks like Mid Ohio where I run most. It tends to be a bit more severe at Nelsen Ledges, a particularly rough track especially if you run off. However, the characteristics are such that I don't need to change spring rates.

For the front, 2 1/2 inch coil-overs of 8 inch length work well. To mount the bottom perch, you will probably need to grind off the small bracket that holds the brake line or you may not be able to get it low enough for the minimum ride height. With these springs, the bottom perch should be adjustable down to at least 9 inches above the absolute bottom of the strut body (excluding the steering arm/ball joint assembly.). With 10 inch springs you'll need to go 2 inches lower. There is no reason to use the taller spring unless you already own them in the right rates, but in that case they will work just fine.

In the rear, springs of approximately eight (8) inch length and 5 inch nominal OD. set directly on the stock perches will conveniently result in the recommended ride height. Remember that much higher or lower will result in undesirable geometry changes or bottoming. Adjustable perches can be installed but the additional hardware thickness may mean the adjustment range isn't low enough, defeating the purpose. I've not found shorter springs of this diameter. If you need to raise the rear for some reason (e.g. a Solo II setup with huge tires and no flares), adding a spacer is simple and straightforward for no more often than you need to change it. For EP, you can also modify your rear spring perches to accept the 2 ½ inch I.D. spring for less weight. The selection of spring lengths and rates is also greater. But don't fall prey to the perception that a coil-over shock is a necessarily better. On the Mazda it increases roll stiffness for a given ride stiffness, meaning you must run a softer suspension with greater ride deflections and geometry changes.

The stock rear springs are flat on top and coiled on the bottom, and the axle has a contoured bottom perch to match. The only after-market racing springs available in the rates needed are boxed and ground (flat on both ends.) These can actually be successfully used even though they don't really mate well with the bottom perch. But keeping them from falling out every time you jack the car up can be a problem.

In testing the only rear springs available in the higher rates, G-Force found that the actual stiffness was significantly greater than specified by the manufacturer! By removing a partial coil, the lower perch fitment problem was solved, but this changes the rate slightly as well. Because of the potential confusion of customers over buying the correct length and rate of springs, G-Force now offers altered, retested and rerated rear springs that fit the perch, called our "Red Dot" spring. These are engineered to be at the lower end of the ride height scale to allow corner-weighting shims to be added.

For EP use, I recommend using 2 ½ ID x 8 inch long springs in the stock rear location. Do not use coil-over-shocks in the rear as this adds roll stiffness where it is not needed. The spring seats may be altered to accept the lighter springs and a coil-over adjustment kit can be adapted for the top perch for height adjustability. One caveat: Do not use an adjuster that "shrouds"--either inside or outside--more than the dead coils of a spring. Because the rear axle moves through various angles, coils can catch on the edges of these shrouds and suddenly make the spring rate jump. Usually this happens during acceleration and excessive oversteer can result!

G-Force Engineering can provide Eibach 2 1/2 inch x 8 or 10 inch coil-over springs for $140/pair, and G-Force "Red Dot" modified and rerated rear springs. These can be purchased in rates from 225 to 325 lb/in in 25 lb. increments for $140/pair each at the time of this publication.

Shock Selection

Shocks are the next priority and should be carefully chosen to match your spring rates. As the spring rates change, so should your shock rates. For ease of tuning you should select a shock that is externally double adjustable. If you choose a shock with only rebound damping adjustment, you probably have less than a "real" race shock These pairings are chosen to exhibit equivalent oversteer/understeer characteristics.

Most adjustable street shocks are made to have sufficient adjustment to cover up to several times the stock spring rates of about 100 lb./inch. For the RX-7 this means roughly up to 350 lb/in front and perhaps 175 lb/in rear, but this is an experienced guess and I suspect this will vary with different brands. However, this does indicate a rough limit for an adjustable street shock. Shocks wear-- especially under road racing conditions--and you want enough adjustment left over to be able to restore the desired setting when this happens.

I run the higher rates in IT--450 front and 300 rear--I used to use the Koni 8610-1149 single adjustable non-pressurized universal racing insert for the fronts which will cover from 250-450 lb/in spring rates for $169 each. These can be custom revalved for even higher rates, and I recommend stiffer front compression rates than Koni normally provides. However these do not fit the stock strut and required quite a bit of fabrication to fit a larger strut tube. Plans for making and fitting new strut tubes for this shock only are inlcuded herein.

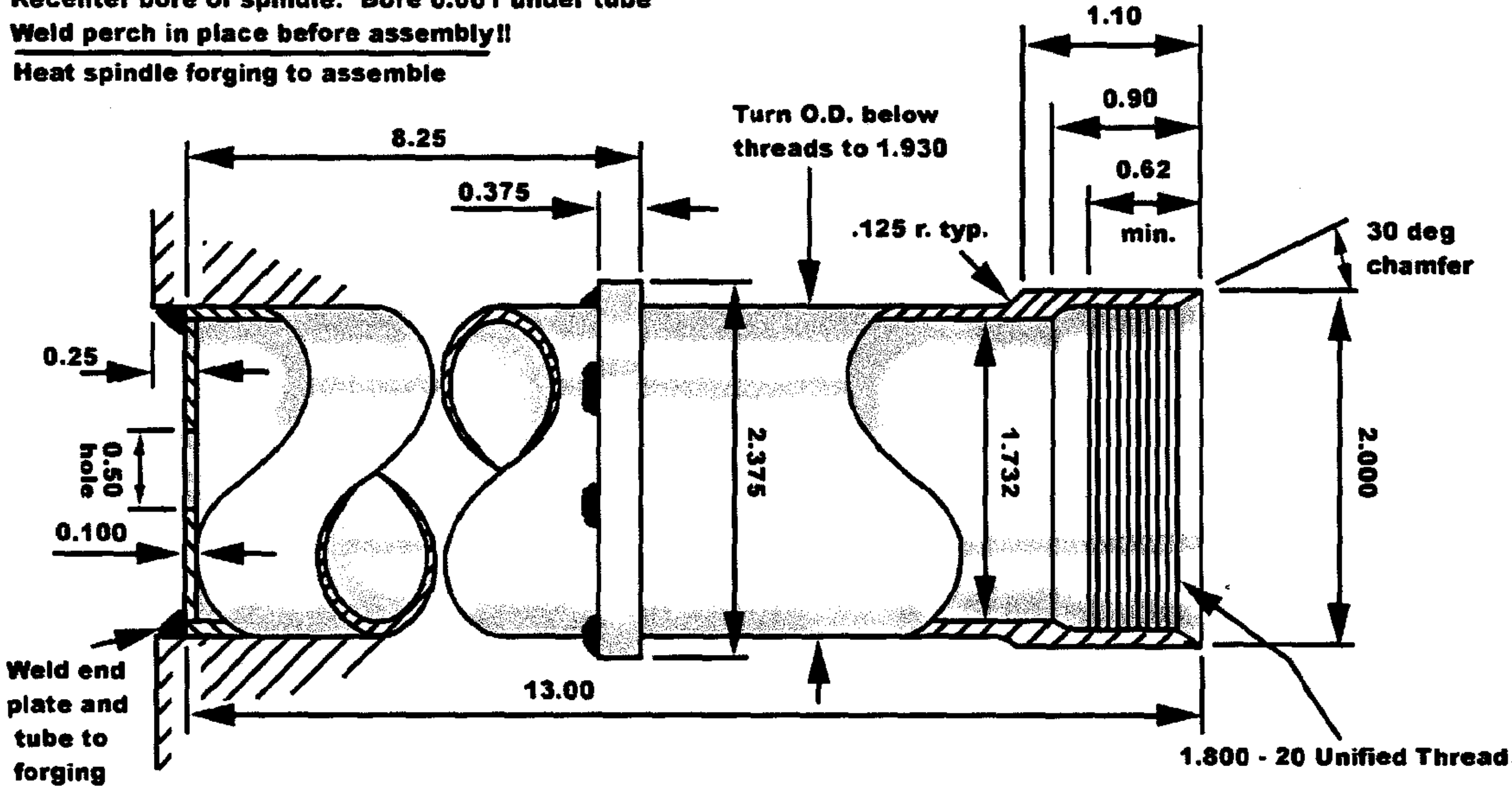
You will need to make new caps as well, as your local machine shop may not have the equipment necessary to turn metric threads, which is what comes stock and is in the caps supplied by Koni with their shocks. Plans for Unifed Threads are included.

The stock tube must be cut off and the hole in the spindle forging rebored. After boring the remaining wall thickness of the spindle forging will be considerably reduced. This hole is usually off-center, so to avoid getting excessively thin on one side your machinist may need to recenter the bore. The most critical part of the assembly: ***Don't forget to weld on the perch before assembling the tube to the spindle!*** Otherwise it won't fit over the top of the tube. Also note that the bottom of the tube must be capped with a washer as shown in the drawing. A 5/8 grade 8 flat washer may be used instead of a machined part. The hole is insure centering and distribute the load from point contact to line contact.

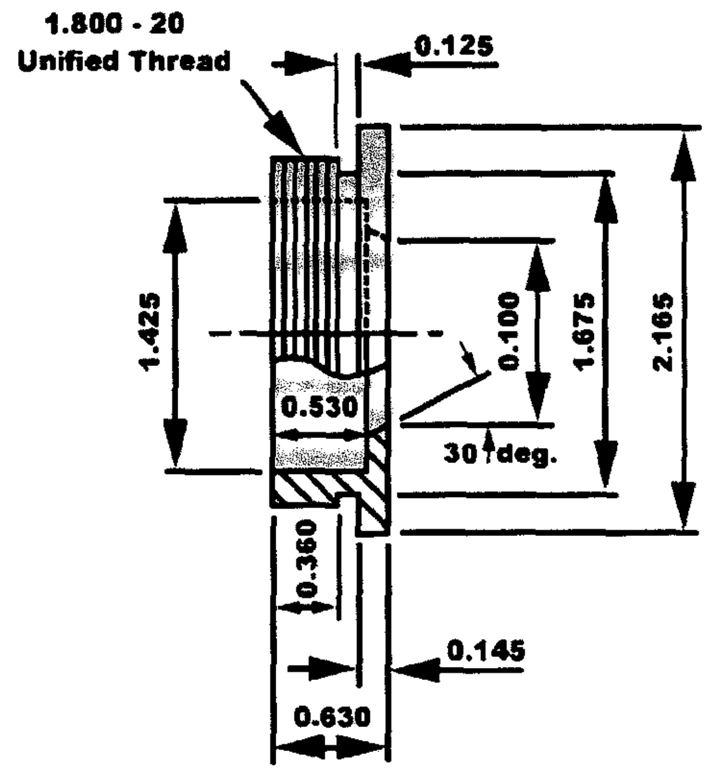
The Konis fit very tightly, so you'll have to remove the brand stickers, knock down any burrs or welding on the O.D., and lightly sand the exterior with 250 grit paper. Coat the shocks with silicone grease to help you remove them, prevent rust, and transmit heat away from the shock.

Finally, note that the clearance for the ball joint shaft and nut that nestles underneath the shock is slightly less than stock, so you must run turn-in spacers with this arrangement or you will have difficulty in reassembly.

Tubing: Dom 2.000 O.D. x 1.732 I.D. (#10 wall)
End piece: 0.100 mild steel
Perch: Dom 2.375 O.D. x 1.938 O.D (.219 wall)
Recenter bore of spindle. Bore 0.001 under tube
<u>Weld perch in place before assembly!!</u>
Heat spindle forging to assemble



STRUT TUBE FOR 13 INCH KONI RACING SHOCK



CAP FOR SPECIAL STRUT TUBE

Another option is a Koni double-adjustable shock, but the compression adjuster which protrudes from the bottom requires that the suspension must be partly disassembled to make changes. The tube diameters shown are also too small for this shock.

I now have available a new strut assembly and G-Force custom-tuned damping rate setup using the Advance shock on all four corners, which has both adjustments on the top of the shock. These are highly digressive shocks, meaning their damping curves are custom tailored such that tuning adjustments make large differences in handling feel without the shock becoming excessively harsh or soft over bumps. These are "real" race springs, more so than the Koni.

For the rear Koni has an 8216 aluminum bodied externally adjustable racing shock which comes in four lengths but it must be modified to be used in the RX-7. These sell for about $200 each unmodified. A double-adjustable Mustang Cobra R rear application, Koni number 8042-1134 Sport, can be made to fit by simply shortening the width of the metal tube in the bottom eye. Take caution with this shock, however. Because it was made for a much higher-powered, heavier car with different tuning requirements, only the lower range of available adjustment should be used.

Most racers run the Tokiko Illumina adjustable shocks available through Mazda Competition because they are relatively inexpensive and fit without modification. Racers like them and they seem to work well. However they are just adequate for the medium spring rates and are not the ultimate setup. These shocks adjust compression along with rebound, so when the fronts are set at full hard and the rears at about 2, turn in characteristics are good, though the rates are quite marginal. They are only an acceptable, inexpensive starter shock.

Bump damping controls the unsprung weight of the vehicle. It controls the upward movement of the suspension, preventing overshoot. If the tire continues to move upwards after the bump, tire loading and grip is momentarily reduced. If the shock is too stiff in bump it can act like too stiff a spring over rough pavement, skating over irregularities and reducing grip. Yet over slower more undulating track irregularities the softer springs required can still allow for larger suspension movement than is desirable. These permit larger geometry errors and roll center movements.

The ideal bump setting will vary with the unsprung weight and spring rate. The optimal steady-state setting is when "side hop" is minimized and the ride is not uncomfortably harsh.

If your shocks allow separate bump damping control, you can optimize your settings by conducting a test at your roughest track or solo course. Start with all four shocks at full soft. Ignore other aspects of ride like lean and response and concentrate on the "side hopping" over bumps. Keep stiffening the shocks until the ride at one end or another begins to feel harsh or hard over bumpy surfaces. Then back the settings off a couple clicks until side hop at that end is minimized. Continue stiffening the other end and repeat the above adjustment.

Among other things, rebound damping controls the car's lean when entering a turn. It doesn't limit the total lean, just how fast it occurs and how each end shares the transitional load. This is important because you can influence the car's turn-in and stability with rebound damping.

Too much rebound on either end of the vehicle will cause momentary loss of grip at that end during transitions or entering a turn. Too much at either or both ends will result in what Koni calls "jacking down." Jacking down is a condition whereby the suspension is not allowed to fully rebound before it hits even more bumps. In the extreme condition the car can be lowered to the bump stops over rough surfaces by excessive rebound settings.

To adjust rebound, start at soft and increase the rates until the car feels stable as it transitions or rolls entering a turn, and until it handles large bumps well under cornering loads. In the case of the RX-7, you will find that the car needs less rebound damping in the rear relative to the front. This is another way of saying don't get excessive with rebound damping in the rear. Too much rebound in the rear relative to the front will cause the car to wag its tail in high speed transitions or to oversteer on initial turn-in.

Why is this? A lot of it has to do with rear roll steer characteristics. If a car has no or little rear roll steer, the rear must assume a "tail out" attitude relative to the direction of travel to generate the rear tire slip angles and resulting grip. In high-speed steady-state cornering a certain amount of this can be an important aid to driver feedback, so he knows how close he is to the limit.

The downside of low rear roll steer is that under quick right-left or left-right transitional maneuvers, or on rapid transitions into turns, the tail must "wag" somewhat to generate the rear tire slip angles required for steady-state grip. This also takes a finite time to occur, in the neighborhood of 1/4 to 1/2 second. If the rear gains sufficient sideways momentum (more technically the car is gaining yaw momentum) during these transitions it can be unsettling and detrimental. This is particularly true with the smaller tires used for IT competition. The wider tires used in Street Prepared or E Production don't run at nearly as large a slip angle to generate the same grip and so the effect is not as pronounced.

The solution to this is to dial in some extra rebound and compression adjustment to the front shocks to provide a momentary gain in front roll stiffness as the car rolls into the initial part of the turn. Essentially the car is picking up the inside front tire a little faster than the rear and consequently transferring a little more load to the outside front. The result is a bit of initial understeer until the rear becomes settled and generates a slip angle. (In technical terms the buildup of yaw momentum is slowed.)

You might ask instead of handling this with shocks, why not add lots of roll understeer in the rear? That way, the rear would not have to take such a tail out attitude to generate the slip angles necessary for grip in the rear. The answer is driver feedback would be reduced, and the rear end would tend to steer itself every time it hit a bump.

The ideal situation is mild initial understeer on transitions into turns, particularly at high speed, which settles into a neutral condition. If you continue to experience excessive understeer in the middle of steady state high-speed turns, however, look to the swaybars to adjust this situation.

Swaybars

With the other changes included herein your total lean (including tire deflection) will be 1.7 to 2 degrees in a 1.3 g turn (peak loads obtainable with autocross compound tires) and slightly less with road race tires. You don't really want less lean. Using the optimal ride rates it would require excessively stiff sway bars. With these you begin to lose the effects of shock damping in roll because more and more of the roll stiffness is obtained by the use of an additional undamped spring member (the bar). Remember that, just as you can be too stiff or undamped in ride and not soak up track irregularities, you can also be too stiff and poorly damped in roll as well. So for an optimal balance of steady state cornering performance and response in dicing or avoidance situations it is best not to have an excessively soft ride with big bars.

On the other hand with much lighter bars than recommended you will experience more lean, bottoming can be a concern, response will be slower, geometry changes are increased and more initial front camber may be required. This will in turn lead to more rapid inner shoulder wear and a reduction in braking capability. Because the car lean angles are more heavily influenced by bars than springs, excessively high spring rates would be required to bring the lean rates back into an acceptable range.

Most racers use the 1 1/8 bar popularly available. Installation is simple, but this bar is heavy and attaches to the lower control arm, and therefore does not have much leverage on the suspension for all of it's beef. Adjustments are provided, but not much, and anything but the mid-range setting gives extreme linkage angles which I don't like. Also, all the loads are taken through the ball joint, which can lead to additional wear. Plans for an alternative are included later in this chapter.

If you run the thicker Turn-In Spacer, and for any reason can't lower the front to quite the maximum allowed, you may find need to run a small stock rear swaybar to eliminate understeer. Test the setup first before you undertake this addition, however. For most applications a rear bar is not needed unless you have no other form of oversteer/understeer adjustment.

If you decide to add the rear bar, it's effect can be made more precise by using rod ends for the attachments and MDS Nylon for the bushings. This will effectively stiffen the bar's effect giving the lightest assembly with the greatest sensitivity and linearity. If you add this bar you may want to go down 25 lb./in in the rear springs. This gives you the same roll stiffness but adds adjustability.

Details for a modifying the stock bar for adjustability are shown in figure 1. Modify the stock body mount for the links as shown, or fashion your own from angle iron. Make the clevis tabs and bolt them on a rod end using two 5/16 stainless washers. These washers are very hard and have a small O.D. to allow sufficient angular misalignment of the rod end without it bottoming or striking the edges of the milled slot. The slot must be long because as the suspension goes up and down the link pivots fore and aft, particularly when the car is jacked up.

With the clevis assembled and spaced properly by the washers, tack weld it to the modified body mount as shown with the nut on the frame side. Then tack the nut. Remove the rod end and bolt and do your final welding.

The links may be made as shown with a piece of internally threaded tubing and a pair of 5/16-24 jam nuts, or you can use female rod ends and buy a piece of 5/16-24 threaded rod and jam nuts Note all rod ends use fine thread and I advise its use for the all hardware.

Next cut the stock ends off the swaybar at the lengths shown and fabricate the new ends out of 1 x 1/4 bar cut to 6 3/8 length. Drill these with six 21/64 holes located as shown. To weld, lay the bar on a perfectly flat floor with the crossbar supported with both ends of the crossbar supported at a height of 3 1/2 inches as shown.

Place the two fabricated end pieces on the floor with 1 3/8 overlap at the undrilled ends and with the bar on the inside of the pieces. Make sure the end pieces are laying parallel looking from above, tack them in place, recheck them then make your final welds.

Delrin bushings are available from G-Force Engineering for $40/pair for either front or rear bars. Be sure you check the linkage at all possible ride and roll combinations for binding and sufficient articulation of the rod ends. Omit this step and you'll probably break something. It is relatively easy to remove the rear springs and articulate the suspension through all its ride and roll movements. In particular, check it at the shortest (stiffest) setting, where it is most likely to strike the passenger's side Watts link mount depending on your assembly variations and linkage length.

If you've already purchased the larger diameter front sway bar available on the after-market it should work with the other settings recommended but I recommend you use all the stock attachments, which cause it to behave like a softer bar. Otherwise it may be too stiff.

A better, lighter more responsive option is to use the stock swaybar--presuming you haven't thrown yours away--with delrin body bushings and a unique attachment method. Figure 2 shows what the attachment should look like. The improved mechanical advantage of the attachment method and the solid bushings makes the package more linear and sensitive, lighter, yet as effective as a thicker bar with soft bushings. As importantly, the attachment method allows you to adjust the bar to change its apparent stiffness, but only <u>depending on the tightness of the turn</u>. With this method you need an adjustable rear bar because the front bar adjustment is strictly a speed-dependent one. Why would you want to do this?

At high speeds slight understeer is the safest and most manageable handling characteristic. But with a limited slip or locked rear end it often means that you get understeer trying to power out of a tighter turn. And as I said getting the power on early is the key to fastest times. Therefore, the ideal situation is if you could have an "intelligent" front sway bar that knows whether you are in a high-speed or low-speed turn and adjust it's stiffness to give you the desired handling.

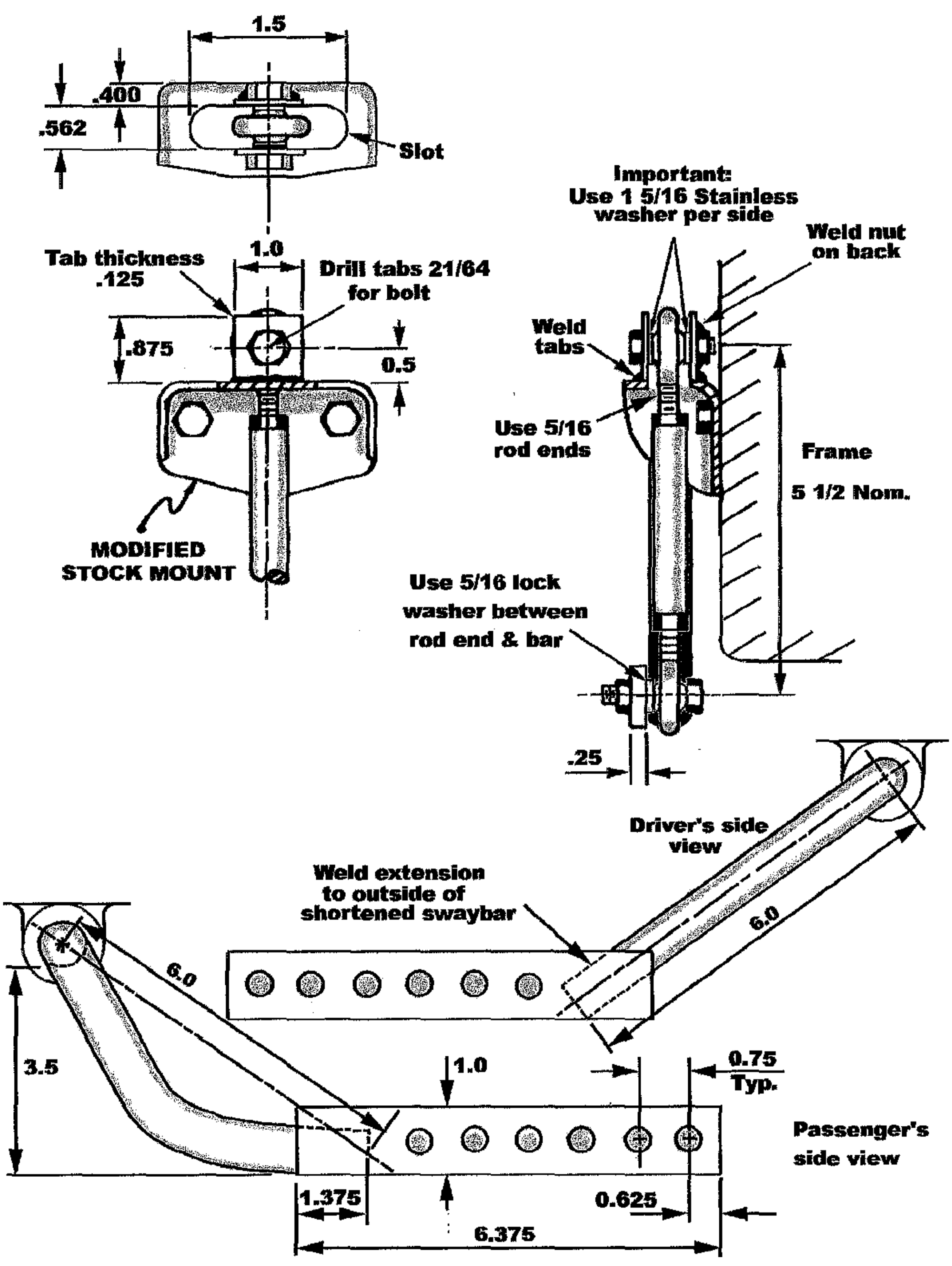


FIGURE 1: REAR SWAYBAR LINKAGE

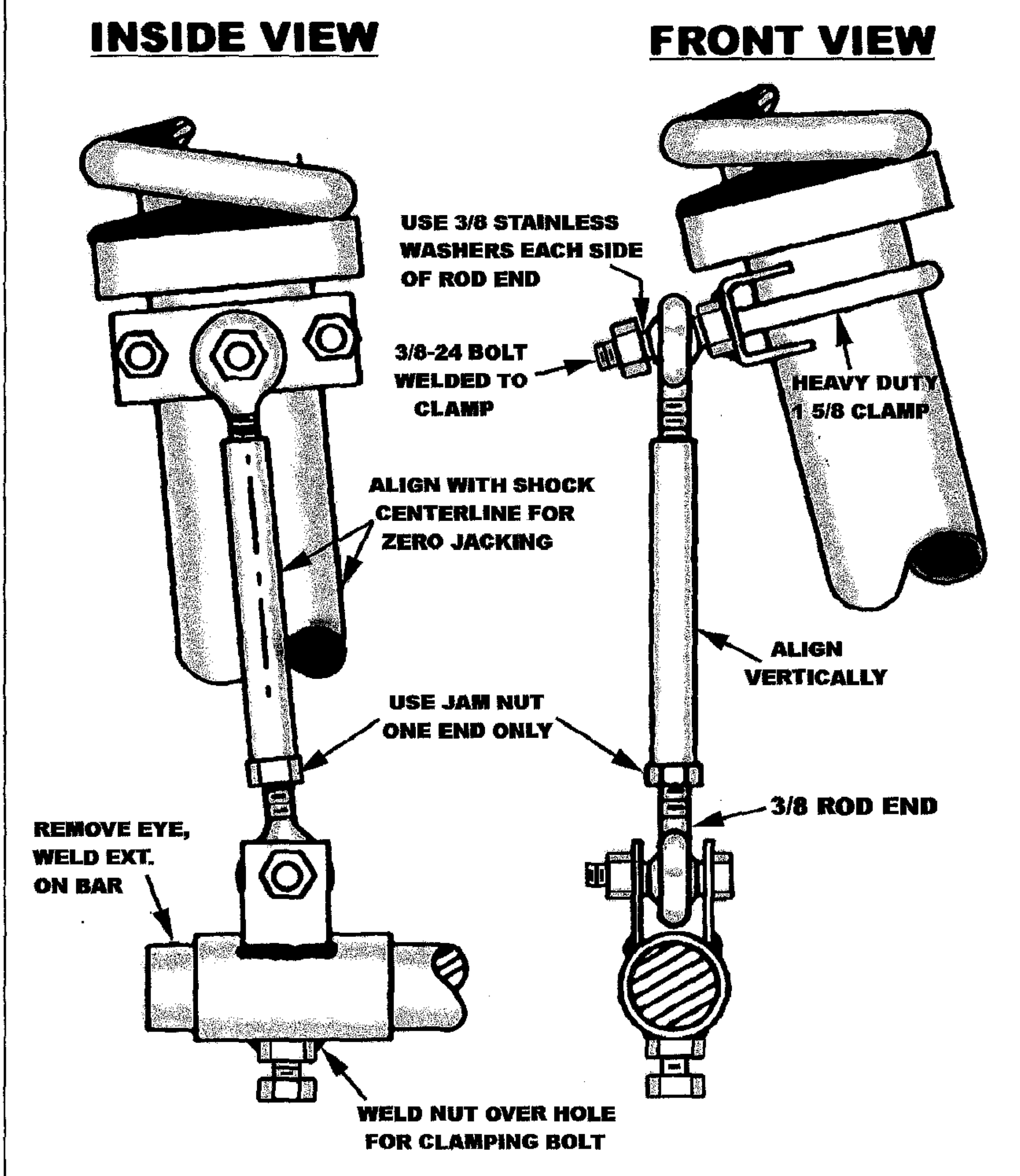


FIGURE 2: FRONT SWAYBAR LINKAGE

Changing the swaybar attachment from the lower control arm to the strut body accomplishes this. Slower speed turns are turns of tighter turning radius. That means you need higher steering angles. Therefore a linkage that softens the effect of the bar as steering angle increases is desired To make one, change the bar attachment to a nominally 6" adjustable link that goes up from the bar and attaches to the strut just below the bottom perch. By being on the strut the point varies in space depending on steering angle, which twists or untwists the bar depending on your selection of settings.

For the top attachment, weld a 3/8-24 bolt to the bracket of a **1 5/8 heavy duty** muffler clamp (1.875 clamp ID) as a top attachment for the stock strut tube, and a **1 3/4 heavy duty** muffler clamp for the modified tube. The attachment point should be on the shortest radius from the centerline of the strut as possible. Be sure to use a very small diameter AN stainless washer on each side of the rod ends (no larger than the side of the ball) to allow the maximum angular misalignment. Then use a jam nut on only one of the two rod ends so the other can rotate on the threads to insure sufficient articulation in steering.

The bottom attachment shown is just one alternative. It's advantage is that the fore-aft position is easily adjustable over a larger range but it is more difficult to fabricate. Instead of welding an extension on the bar, you can also make the sleeve longer and extend it out to the length desired.

Another alternative is to cut the eye off the end of the bar and weld a 3/8-24 bolt on the bar as an extension, pointed in the same direction as the bar at the tip. Be sure to pre-determine where to cut the bar with the car setting on it's wheels. This can be done with the car's wheels setting on blocks or a lift. Keep in mind that if in the future you intend to make caster changes using the trailing rod adjustment because this will effect the fore-aft position desired. For most applications cutting just forward of the eyelet opening is just right, but check it first. With this method, a small amount of adjustability can be gained by cutting the bar about 1/2 inch shorter, using a slightly longer bolt and placing a jam nut on either side of the rod end to capture it where you want it.

Initially the linkage should be aligned with the shock centerline in side view. This gives neutral weight jacking. Now, to dial in a small amount of weight jacking, i.e. to soften the bar's action in low speed turns to promote turn-in, rotate the top mounting point forward of the shock centerline. The greater the rotation of the top attachment to the front, the greater the high-speed to low-speed weight jacking effect you get.

To test the jacking place blocks under each tire or put the car on a drive-on lift so you can get under it and observe the bar's movements. When you turn the wheel left about the same as you'd use in the tightest turn expected, you should see the left end of the swaybar go up. When you turn to the right the bar end should go down or stay the same. The net of the two motions is the jacking effect. A net twisting of the bar of 1/4 to 3/8 inch should be very noticeable. Why does this work?

When you turn left the body wants to lean right. Normally the bar is designed to resist this. The left side sway bar arm tries to lift the inside or left wheel. By having the attachment point towards the front of the strut this point moves upwards, forward and away from the bar as the strut rotates. This relieves some of the bar's force that is trying to lift the wheel, softening its effect. On the other side, the effect is reversed and that end moves down with the same result. The net result of this is to make the rear bar work harder, reducing understeer.

However, if the strut attachment is centered on the strut instead of rotated, both sides go up on either a left or right hand turn. The net jacking effect is zero. Even though the bar can be seen to go up and down it is not twisted and exerts no jacking force of its own as the wheel is turned. Conversely, rotating to the rear would promote increasing understeer in tighter turns, something you don't want.

To tune the car, start at a zero jacking with the front bar and dial in the rear bar adjustment until you establish neutral handling or slight understeer at high-speed conditions. (You should have completed all front ackerman and corner weight adjustments at this point as described later.) Then if you still need more low-speed turn in under braking or are still having problems getting power down out of a low-speed turn, start with a small amount of the jacking adjustment, say 1/4-3/8 inch net and experiment to see what works best for you. Don't wild on this, though, as you will quickly get out of the linear range of the effect. This will make the car transition poorly.

Tuning

When more years ago than I like to think about I first learned about the effects of sway bars I naively thought the explanation was completely backwards. Shouldn't putting a heavier bar on the front improve front grip because it reduces front lean and holds the tires flatter? No.

Yes, it reduces lean. But not just in front. Since the whole car is a generally rigid member the front always leans the same as the rear. It's the balance of suspension roll stiffness front to rear that is important to handling. What a front bar does is increase the load on the outside front tire, in a sense overloading it so it slips more. At the same time the inside front tire is unloaded, so whatever its cornering capabilities may have been under full load are also reduced, so it slips more, too. The higher slip angles of the two tires reduces net grip and causes the car to understeer more. This effect is called Lateral Load Transfer.

A car with identical front and rear tires and suspensions, identical unsprung weights, and 50/50 weight distribution will approach neutral steady state handling when the front and rear axles share the leaning forces equally, i.e. each have 50% Lateral Load Transfer. If you make the car heavier in the front then stiffer springs or bars will be needed in the rear for neutral handling. This is because the front tires are initially carrying more load resulting in greater front tire slip angles than the rears.

The RX-7 weight distribution is a nearly perfect 53% front and 47% rear when properly prepared. This means that all else being equal the rear needs slightly more roll stiffness than the front for neutral handling. But not all else is equal.

First of all, there is a solid rear axle with a large unsprung weight. There is also less camber available in the rear. The rear tires also have to deal with the driving force. This means that the rear axle generally will not be capable of generating the same side loads as the front. And even Solo cars should be set up with a slight understeer bias for stability. A certain degree of understeer is even more desirable for road race cars at high speeds when the consequences of a spin can be dire. Sufficient transient oversteer can still easily be provoked by power, braking and steering inputs. So on the RX-7 front Lateral Load Transfer should probably never be less than about 55%. Otherwise you will experience oversteer.

This concept of Lateral Load Transfer is the key to all tuning for oversteer or understeer. Increase a particular axle's stiffness in roll, and that axle's ability to generate side grip is reduced. At the same time the overall roll is changed, which must be considered to keep the vehicle within a desirable roll angle, usually around 1 ½ degrees for the RX-7.

There are a number of tuning elements that can be used to change the roll stiffness of a front or rear suspension. But before we consider these elements we must distinguish between transient and steady-state handling.

Steady state handling is what you feel when you are driving through a large, smooth, constant radius turn at the limit of adhesion. The car has taken a steady leaning angle, and has a stable attitude front and rear. The objective in this situation is to have neutral handling to slight understeer for stability. This is the first priority of setup, regardless of how the car handles elsewhere. Changes are made to the springs, bars, ride heights, roll centers, alignment and other items besides shocks to obtain this result.

Transient handling is what you feel then you approach a turn and begin braking and turning. The car's weight is dynamically shifting from the rear to the front axle, and from the inside to the outside tires. Initial corner exit is also a transient maneuver because he weight is now shifting from front to rear. High speed switchbacks or Solo II slaloms are also transient maneuvers. Hitting a large bump at speed in a corner is a transient event. All of these transfers of weight to one axle or another, or to one side to another, effects the balance of loads the tires are carrying and therefore whether the car oversteers or understeers. Since one cannot dynamically change the bars, springs and other steady state tuning items to control oversteer or understeer in these situations, the primary way of controlling how the car reacts in transient maneuvers is with shocks. Therefore one must first make changes to steady state-influencing components first, then adjust transient behavior with shocks.

Lets begin with how to make steady state tuning adjustments. The more obvious item is the sway bar. The stiffer the bar, the less grip is generated at that end, and the more grip is generated at the other end. A stiffer front bar creates more understeer, and a stiffer rear bar creates oversteer.

Another element is springs. Again, stiffen the front springs to create more understeer, stiffen the rear to create more oversteer. Soften the front bar to create less understeer, and soften the rear to create less oversteer.

On the RX-7 there is a caveat, however. When excessively low rear spring rates relative to the fronts are used with G-Force suspension components, a point is reached where the rear tires will not heat up. This actually creates a reversal of the normal rule and the car will begin to oversteer again. I have seen several customers who got in this trap, and tore their hair out trying to figure out why their usual approach wasn't working. When I advised them to raise their rates about 100 lb./inch, the rear end suddenly stuck.

Another tuning element is the height of roll centers. The roll center is the idealized point in space about which the car rolls in a turn. There is a front roll center and a rear roll center. The roll center has several influences on a car's suspension characteristics. First, raising the roll center increases the axle's roll stiffness. This has the same effect as stiffening a sway bar. The opposite is true. Lower the roll center to soften the roll stiffness.

The Turn-In Spacer is designed to raise the roll center in the front, which on the stock suspension is far to low at racing ride heights. The thicker the spacer you can fit, the higher the roll center. This means you can reduce sway bar stiffness and weight. Another advantage is better roll damping so you are more controlled over bumps and roughness in turns.

The GT Panhard has a bar height adjustment which can be used to raise or lower the roll center in the rear, eliminating the need to have an adjustable bar on the car. Raise the bar for more roll stiffness and less understeer, and vice versa. The change in roll center height is slightly less than the bar height change.

Raising and lowering the front end ride height has a profound influence on roll stiffness. The roll center moves up and down about 2 ½ times the ride height change. So if you have no other adjustments on your car, this is a handy way to tune once your spring rates are nominally correct. Be sure to realign your camber and toe after changes, though.

This dramatic change in roll center height is also another argument for running as stiff as possible. When you enter a turn under braking the front roll center dives. This has the same effect as softening the sway bar momentarily which promotes oversteer into turns. Conversely, when you exit a turn under acceleration the front roll center raises. This causes understeer and you can't get the power down as early.

When tuning for steady state neutral handling one should have the shocks set moderately low so as to not confuse what you are doing. Rarely is there a true, smooth sweeper at the race track and hard shock settings can change the feel of the car over bumps. This is not steady state.

Once you've gotten your car to handle about right in the sweepers, then turn to setting your shocks for corner entry, exit, bump or curb crashing-stability and high speed switch backs.

The effect of shocks is to exert a force only when the suspension is undergoing deflection movements. Under ideal steady-state conditions, the shocks exert no force. Generally, the faster the movement of the suspension, the greater the shock force exerted. Bumps encountered at high speed generate suspension movements of 10 inches per second and generate large shock forces to keep the tire on the ground. Turning the wheel to enter a turn is a far slower event, in the range of 1-3 inches per second, and generate much lower shock forces.

Good racing shocks change this equation. On double-adjustable shocks the adjustments primarily effect the slower suspension movements generated by driver input without changing the higher speed damping of the shocks. The purpose is to control transient body movements. The effect is to create "variable sway bars" or "intelligent sway bars" that more or less oversteer or understeer just where you need it--on corner entry, exit, and transient maneuvers.

Three, four, and five way adjustable shocks also allow you to change high- or mid-shaft speed characteristics of the shocks. However, car handling is less sensitive to errors in initial selection of the mid- or high-shaft speed damping rates of a shock, and is generally beyond the amateur's ability to select or tune.

The best reference for tuning double-adjustable shocks can be found on the Bilstein Shock Absorber web site at www.bilstein.com/motorsports/oval.html.

Travel

I use a 1/8 or 3/16 stainless steel braided cable from around the top neck of the rear shocks to around the bottom neck of the shocks to limit droop. I adjust the length until the suspension stops drooping just as the springs reach their free or unloaded length. Why? In a hard turn the inside tire stops drooping once the spring is unloaded. If the axle is allowed to droop beyond this point, the inside tire is no longer part of the sprung weight. Instead it may rest on the ground. Now, the outside tire is still carrying essentially the full mass of the rear through the turn, yet it doesn't have the benefit of the full weight of the car to help plant it. This reduces the outside tire's load carrying ability.

But in truth this probably isn't a situation that happens often, if at all. The real advantage of travel limiters so the springs don't fall out when you jack the car up. I also don't have to jack nearly so high to change tires, a blessing in the pits. I can't overemphasize how much I like this convenience.

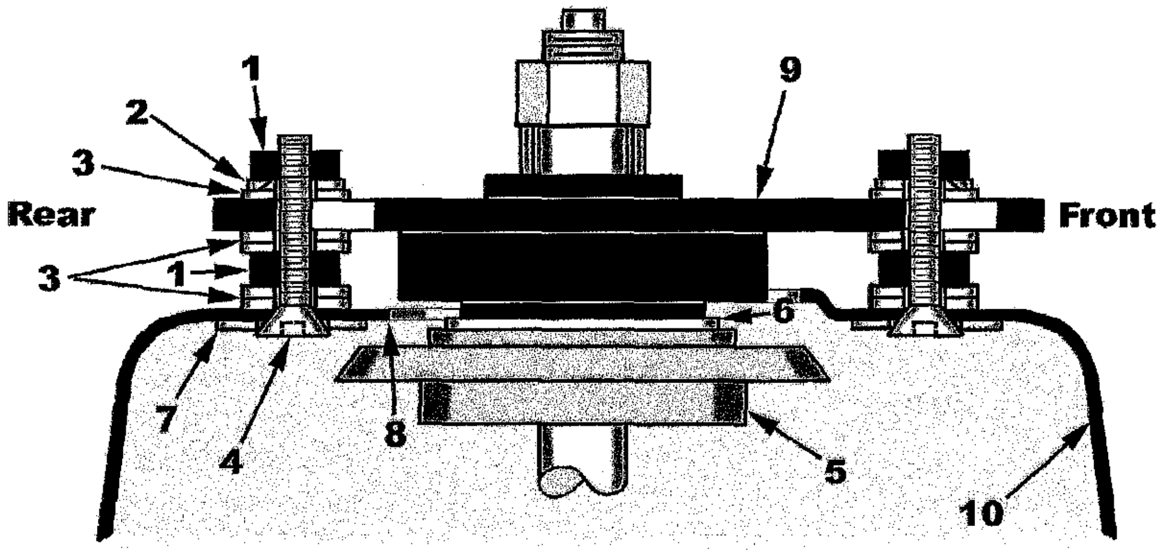
In SCCA Street Prepared or IT racing this change is legal as long as the cable is not attached to anything but the shock. Then it becomes "part of the shock," and "any shock" is allowed. A shock's normal function is to limit travel at some point, and a shorter shaft would have the equivalent effect. But it's a lot of trouble to modify an externally adjustable shock, and then you can't ever lengthen it.

In the front, limiting droop is not a performance concern. That's because the heavier sway bar limits the inside droop. But a limiter is still convenient for jacking the car up in the pits. You can weld a grade 8 cap screw to the frame just above and projecting down through an existing hole in the lower control arm, then place a nylock nut and flat washer on it and adjust it so the travel stops just as the spring unloads. Be sure it is centered so it doesn't rub the sides of the hole under braking loads. This isn't technically legal for SCCA solo or racing because it is not part of the shock. But it also isn't any advantage except in the pits. In Street Prepared it might be considered to be a comfort and convenience item. But if you have rules Nazis in your neighborhood I suppose it could conceivably be used to try to throw you out so this is a personal choice.

At the minimum legal ride height, bump travel can be a problem. In the front, bottoming can easily occur, especially with the softer rates. And even if you don't think you've ever experienced this on the track just wait 'till you run off into the rough. You can easily destroy a shock this way unless you use a good bump rubber atop the shock, but the downside is that this further reduces ride travel and you can end up running on the bump stop, which induces severe understeer.

The solution is to mount the camber plate atop the strut tower, rather than underneath. This will give you an additional inch or more of ride travel, enough to permit a small bump rubber. Another advantage is that the camber plates may be removed and the springs changed from the engine compartment without removing the struts. If the caster setting of the plate is set to the max forward or rearward position, the operation can even be performed without the need for realignment if you are careful to bolt it down in exactly the same spot. Using studs held to the body with their own nuts, rather than a simple spacer, keeps them fixed in location.

Mounting Camber Plate for Maximum Ride Travel



NOTES:

1. **5/16-24 grade 8 nut (qty 16)**
2. **5/16 lock washer (qty 8)**
3. **5/16 SAE flat washer (qty 40)**
4. **5/16-24 x 1 1/2 flat head socket head cap screw (qty 8)**
5. **Top spring perch**
6. **A.S./SAE 3/4 heavy washer (as needed for clearance)**
7. **7/16 SAE flat washer (qty 8)**
8. **Trim outside rear lip to clear camber plate**
9. **Camber plate**
10. **Strut tower**

The illustration shows the fitment of the older style Ground Control caster/camber plate. While your installation may differ depending on what plate you've chosen, the example serves to highlight all of the installation objectives and issues.

Begin the installation by placing a 7/16 SAE flat washer over a 5/16-24 flat head socket head cap screw and then inserting it through the strut tower holes from below. The cap screw/washer combination creates a nearly flush installation for the maximum perch clearance underneath. Over the top of this place two 5/16 flat washers and a grade 8 nut. This will create studs on which the camber plate may be placed. Initially you'll find that the slight conical nature of the strut tower top will splay the studs away from the center slightly so it will be necessary to work the strut tower slightly with a hammer to bring these into parallel. Then you'll need to play with their positioning to line them up with the camber plate slots. Once this is done, tighten them for all you're worth, holding the cap screw in place from underneath and doing the actual tightening on the nut above. If you don't get these tight enough, the studs could loosen when you loosen the camber plate later on. Then place two more washers atop the studs before installing the camber plate itself.

You'll find you will need to cut down the flange on the rear of the strut tower hole and slightly enlarge the hole itself in this area to clear the sliding carrier on the underside of the camber plate. The carrier should then ride just above the strut tower itself. You'll never need anywhere near the maximum camber setting so it won't be necessary to trim anything off the inside of the flange. Two and one half degrees camber, a fairly nominal setting, is about the center of the adjustment of this plate.

When installing the shock and perch from underneath, you may need to use one or more SAE 3/4 inch heavy duty washers (the size needed will depend on your shock shaft diameter) to space the perch down enough to clear the cap screws and washers underneath. If you have too much clearance, you can space the camber plate upwards with more washers on the studs.

Ground Control has since changed their camber plate setup, making the large washer underneath a problem. This can be rectified by using a small length of DOM tubing with an ID the same as the smaller shock shaft and an OD the same or larger than the larger OD of the shock shaft. Another option is to use fewer spacers under the camber plate and cut more of the shock tower for clearance. However I don't like weakening the shock tower any more than I have to.

EP cars will face an additional ride height challenge. At the limit of lowering the 15 inch tires will begin to rub the frame member above. This can be relieved with a hammer somewhat. The maximum lowering will be achieved when one runs the stiffest springs suitable for track conditions.

In the rear, the limit of lowering is generally achieved with the use of 8 inch springs. Lower than this the stock spring perches will strike the inside frame rail. Being careful to center the axle using the rails and perches as your guide will often eliminate this problem. On ITA cars using Hoosiers, the tires may also begin to rub the fender lips in ride when softer rates or lower ride heights are used. In roll the tires rotate inwards as they go up because of the lowered roll center achieved with the G-Force panhard rod.

With the stiffest springs on the lighter EP car ride height is slightly higher and travel is reduced so it may be possible to cut a partial coil from the spring bottom. But be careful. For EP you may also run coil-overs and remove the stock perches to eliminate all bottoming problems, but as I understand the rules this comes with a weight penalty because the stock spring pickup points are not used, and the only real advantage to coil-overs is height adjustability. In fact, the wider spring stance in this case increases roll stiffness for a given spring rate, forcing you to run softer rear springs than listed and softer than I feel are advisable. With the stock perches you can still use spacers for corner weighting and once this is done you'll probably never need to change it.

Alignment And Geometry

Front camber should be initially adjusted to about 2 ½ degrees. This is what I am currently using on my ITA development/rental car using Hoosiers. You may need to tune this to your particular tire, but this seems pretty universal..

The use of a pyrometer to establish even tire temperatures has been the traditional method to establish optimal camber but more and more I am hearing from tire experts and find in my own competition that this is no longer valid. Even tire temperatures and tire wear do not necessarily correspond to maximum traction. So testing must be done to see what sticks best, irrespective of temperature or wear. Temperatures can be helpful to determine best inflation pressures, however. The center should be midway between the shoulder temperatures in this case.

Front ride height can be adjusted on the low side until you measure about 4 1/8 inches from the top of the rim flange to the top of the fender opening with the 45 series Hoosiers, or when the front of the rocker panel is exactly at 5 inches, the legal limit for Improved Touring competition.

If you are running a larger 14 inch diameter tire or have flared the fenders for Street Prepared then the fender lip measurement doesn't apply. In this case just lower the front as far as you can for tire clearance or legal minimum height. A slightly higher ride is no problem but your rear bar settings may need to be set ever so slightly stiffer because of the higher front roll center tends to slightly stiffen the front in roll.

I don't use 14 inch rims in ITA because they can only worsen fender clearance (fenders cannot be flared in ITA, but the lips may be rolled under) and raise the car's center of gravity. That requires more tire to offset the disadvantages. Since you are still limited to 7 inch wide rims which limits the tire section width you can put on it, I haven't found any evidence you can gain from 14 inch tires. In street prepared, however, you can flare fenders and use any tire width. In this case 14 inch tires may be very helpful if the size you need is available in the stickiest brand. So far however, I've seen competitors go back to 13 inch tires after trying the larger diameters.

Remember at the recommended ride height it is very important that you have spacers between the strut and the steering arm/lower ball joint assembly. If you are still using the Racing Beat spacers instead of the G-Force spacers handling will require some tuning to get proper oversteer/understeer characteristics.

If you are running Street Prepared, where the Turn-In Spacer is no longer legal, you may have to raise the front of the car some to keep your roll center above ground, run lots of toe out, a larger bar, and over shock slightly in front to keep roll damping under control. Since aerodynamics aren't as much of a consideration, it is not necessary to run a slight downward rake to the car.

With or without spacers, to get even a bit more ackerman shorten the adjustable front trailing arms as much as possible. This will reorient the rearward pointing tie rods more laterally which restores a small amount. It is also a legal adjustment for caster. This addition of caster also improves camber gain as the wheel is turned, improving lower-speed turn-in. The limit of adjustment is when the lateral control arm rubs the frame. Be sure that both the forward inclination of the struts and the wheel base is equal side to side. To check, place the car on four level blocks such that you can get underneath. With the wheels pointing exactly straight, measure the strut inclination with a Craftsman Magnetic Protractor or equivalent. Or use an alignment rack, which is more expensive and difficult, but is generally quite accurate.

With the recommended rear springs the rear ride height should be such that the lower arms are inclined about 1 1/2 inch down to the front. At this height you should have about 4 1/2- 5 inches from the top of the rim flange to the highest point on the fender lip with the driver aboard. This gives a very small amount of roll understeer. This is probably the preferred setting for IT because it helps stabilize the car in high speed maneuvers. The benefit of some rear end roll understeer is that as the car rolls the rear tires steer into the turn to generate slip angles and so the car doesn't rely as much on the tail swinging out to generate steer and therefore grip in the rear. This kind of tail-out dynamic can be unsettling for all but the most experienced drivers with lightning reflexes and big cajones. For Solo II much lower slip angles would be experienced because of the larger, wider tires and wider rims so not as much roll understeer is necessary. In this case the tail out dynamic may actually be helpful and you may find a slightly higher ride height is OK. At one time I sacrificed everything to the god of lowering but I've since found that geometry and handling characteristics are more important, so don't be concerned if your car is not the lowest one around.

If you are running another brand panhard rod it should meet several criteria. It should be horizontal at ride height. It should extend exactly lateral or perpendicular to the car's centerline. It should be as long as possible. It should be as rigid as possible. It should have no bends, which allow it to flex under load. And it should not be welded to the "frame" (or what looks like one--the car is a unibody) unless you use an extremely large mounting plate that will distribute the loads. Otherwise it will tear out, because the "frame" thickness is only about 1/16 inch. All of the calculations and swaybar recommendations in this publication assume a rear panhard bar height of 6 inches at the recommended ride height. If yours is higher you will need slightly less rear bar than recommended. If yours is lower you may experience roll oversteer, a very undesirable condition in road race.

For Solo II toe-out should be used. Without the option of the Turn-In Spacers, start with about 1/4 inch. This will exact a penalty in tire scrub and straight-line speed, but turn-in will be improved. Be wary because these settings may make the car transition too violently at higher slalom speeds when stability is important. For IT racing the front toe should be as close to zero as possible to minimize horsepower loss on the longer straights.

Rear Axle

The first step in improving the rear end for IT or EP racing is to substitute the limited slip, disk brake rear end from the GSL model. From there on, there are numerous choices.

Many racers disassemble these to increase clutch preload. To do this, they add another clutch disk and plate, then machine the faces of the pressure plate surfaces until they obtain about .010-.015 interference or preload. This essentially locks up the rear end, which on the plus side can result in fewer brake lockups and flat spots because it is engaged to some extent even under braking. On the down side, it also induces some understeer when exiting turns, which is not desirable. In ITA, you'll probably never have a wheelspin problem unless your rear end is just plain worn out. So I don't think this is the best alternative. I think it's generally done on cars with the stock rear suspension, where reducing oversteer is difficult, and the plusses outweigh the minuses.

A welded or locked rear end is another option for road racing, and is cheap. The rear end can't possibly unlock under braking when you don't want it to. You can then bias the brakes more towards the rear and gain braking capability. This taxes the front brakes less. Excessive front bias can crack front rotors and cook bearing seals due to overheating.

A disadvantage of the locked rear option is a car that steers like a truck in the pits and makes absolutely dreadful noises. In the wet, the locked rear end and the high-preload rear end are both poor choices because it makes the rear end slide unpredictably. Those rear tires don't have much traction to begin with in the wet and they must freewheel into turns. You'll wish you had the stock limited slip. Finally, I've talked to racers who've done back to back comparisons with the stock limited slip and claim there is some slight penalty in long sweepers where speed is scrubbed off by the locked rear end.

A better alternative is to substitute the racing disks and clutches sold by Mazda competition. These are more than adequate to prevent wheelspin even in a GT car. Set the rear end up with little preload, and you'll have freewheeling where you need it (on turn-in) and reduced slip under power out of turns. However, avoid using the full competition rear end. In addition to the competition clutches and disks, this includes more agressive ramps which induce even harder lock-up, too much even for GT cars. Fortunately, the competition rear end is no longer available from Mazda, although there are a number of them around.

Another good option for IT or Solo is to substitute a Torsen from a Miata. This is what I use. It doesn't induce understeer out of turns, so you can get the power down much earlier. It's action is consistent under power or power-off conditions. But I'm told it may not be as good for higher powered road race cars because the unit can wear out and you have to either specially prepare it with heat treating and stress relieving or just replace the whole unit when it does wear. However, this is not a problem with the lower-powered IT car. The Torsen is best in the rain because it acts the most like an open differential. It also has the least scrubbing action in sweepers and out of turns and should be quickest. So it is the best of all worlds except for cost.

To find a Torsen, ask for a rear end from a 94-96 Miata that has a manual transmission and power windows and mirrors--in other words a non-base car without an automatic. The differential carrier should bolt right into the 84-85 GSL rear end without modification.

In order to install a Torsen you must have the disk brake rear end from an 84-85 GSL model which has larger axles and splines. If you have already purchased a car with a GSL rear end but don't know what year it is, measure the OD. of the outer bearing housing just behind the backing plate. The early year, smaller axle version is about 2 7/8 inches and the one in which the Torsen will fit is a little over 3 1/4 inch in diameter.

Be sure to check the rear end for camber and toe. While the assemblies weigh about 250 lb. and seem deceptively strong, the housing without axles, bearings, gears, carrier and so on weigh only about 33 lb. This means they can get bent in service. I know one customer who discovered he had 3/8 toe and had to have his straightened. The camber and toe should also be checked after any type of welding is done on the axle. If you find it has been pulled one way or another, simply lay a similar bead of weld on the opposite side and recheck, repeating if necessary.

The non-GSL axles I've measured have varied from 1/2 to 3/4 degree negative camber. I am not aware whether this is from service, is partly built in from the factory or is due to the lighter axles bending. But I have found that due to slop in the bearings and splines they will safely tolerate about one degree negative camber without binding inside. Beyond this and it is probably best to have them straightened.

Finally, on GT cars you should consider a floating axle setup. With the stock axle, the loads that try to tuck the wheel under in turns actually bends the axle, and you lose negative camber, especially out of turns. The answer to this is to install a floater. This consists of a double row of outer bearings and a short spindle that is supported by the bearings. A floating axle--one with splines at both ends that engage the rear end and the spindle--then supplies the torque only, instead of acting like a stressed suspension member. This way, the bending loads are carried by the axle tube instead of the axle shaft. In constructing this, the axle tubes are typically cut away and 3 inch diameter chrome moly axle tubes are welded in their place. All the parts to complete the project except bracketry and replacing the stock shock and suspension pickup points can be acquired through Speedway Engineering.

You can have one built by David Steele of Autocon Engineering, 1040 S. Andreason Dr., Escondido, CA 92029. His phone number is (760) 739-0507. You can visit his web site at www.autoconracing.com.

I have been attempting to also market a less expensive kit for converting the stock rear end. It just bolts on to the stock axle flanges. My supplier has just completed the project, and interested parties are encouraged to check with me on this potential option. You may see it on my web site soon.

Brakes

The stock RX-7 has a tendency to lock up rear brakes and cook the fronts, especially if you've installed the GSL rear end, which results in a different brake bias. Part of the lockup can be eliminated using a locked rear end or more clutch preload as described previously. A Tilton brake balancer is also helpful. This limits pressure to the rears. However, as much rearward brake bias consistent with stable braking should be used as possible so as not to overwork the fronts, as long as the fronts always lock first. With excessive front bias and no cooling, however, however, the fronts have a tendency to crack rotors and cook grease seals.

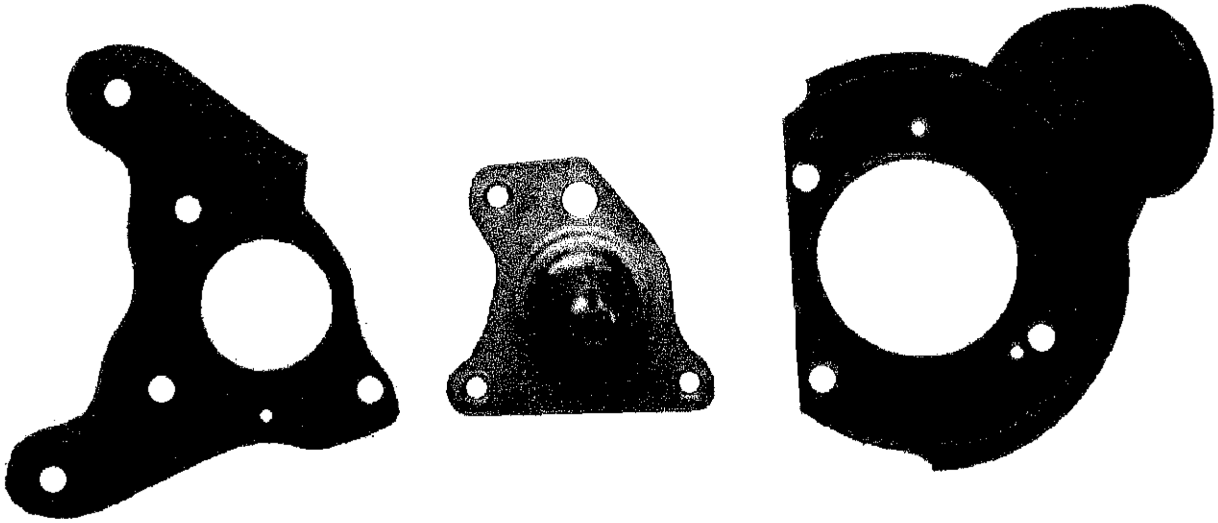
Brake cooling is an obvious necessity. Mazda Competition sells two types of brake cooling ducts. The best one is from the IMSA GTP car. It is both better designed and less expensive of the two options offered. The seeming downside is that a big chunk of the backing plate and spindle boss must be removed to make the installation. However this is legal because any strut is allowed. And I found it is actually quite easy to do and results in no structural weakness whatsoever. Use a band saw to cut the spindle boss and backing plate. Don't try to grind the material away unless you don't have anything better to do.

To create an inlet, remember that you are not authorized to cut holes in any existing body work until '99. Provisions in IT or SP which allow adding a spoiler don't say you can remove the original to gain duct passage. However, the GS model has a spoiler fascia which contains inlets. Technically, this must be used to get air in even if you fashion a spoiler in front of it. Many racers overlook this point.

Another method is to duct from behind the grille itself. There is access just behind the bumper to allow 3 inch diameter ducts to extend from the sides of the radiator inlet into the wheel cavity. Don't use dryer duct. This is flimsy and cheap and will fly apart in service. Purchase a quality wire-reinforced high-temperature rubber duct from a rubber supplier or racer.

You will find that when the recommended ride heights are used not only is the front rocker panel exactly at the minimum 5 inch height requirement but the stock front spoiler panel below the grille opening is already a fraction below the lowest point of the wheel rim, the minimum clearance for an add-on spoiler. While it probably has some aero advantage, I have elected for the convenience of being able to put it on the trailer without snagging and not having to replace it every time I go off course.

Trimming For Brake Ducts (Right Side)



Tires and Rims

Tires. A hot tire pressure target of 28 front 25 rear works well with BFGs on the 7 inch wide ITA rims. These tires build about 4-5 psi from dead cold. Grippier tracks take up to a couple pounds more, slick tracks less. Hoosiers need about 43 front and 42 rear hot, and about build about 7 psi from full cold. The Hoosiers need far more air pressure than the BFGs because of their lighter construction and wider tread which on a 7 inch rim is not as stable. Less pressure will result in extremely rapid tire wear. If you are running a competing brand, call your sales representative for pressure recommendations.

If you are running Street Prepared and using wider rims, these pressures can be adjusted downward by as much as 5 psi because you need less pressure to support the tire. The wider stance helps stabilize it in cornering.

On the ITA setup that uses the narrower rims, the G-Force Turn-In Spacer should be used to be sure you don't rub the steering arm knuckle on the inner sidewall of the wider Hoosiers. There is no clearance problem with the BFGs. With the Hoosiers at the lower ride height, wheel spacers cannot be used because even with the outer fender lip turned under the fender already needs quite a bit of coaxing to avoid severe rubbing. Even then some minor rubbing is typical. With wider rims for Street Prepared, assuming the same backset, then the clearance problem is solved because the tire is stretched towards the outside, but you'll need to flare your fenders.

Rims. Rims for ITA competition should be 13x 7 inch with a 4 inch backset if you plan to run the wider Hoosiers. These will allow just the right inner and outer clearances. I use American Racing Wheels but these are no longer offered at the time of publication. Street Prepared rims are unlimited and up to 9 inch wide can be used with available 13 inch tire sizes.

The Panasport styles are cool looking, but the are smaller inside because they are cast. I prefer a spun outer. It also allows using the largest turn in spacer for best handling.

I question whether larger diameter tires would be beneficial because of the raised center of gravity unless some especially grippy compound or massively wide tire is available only in those rim sizes. This is not an option in Production class, however. At the time of publication none of the manufacturers make a tire with an adequate load rating in the 13 and 14 inch sizes, and all recommend the 15 inch tire.

General Tuning issues

Corner Weights. Careful attention should be paid to corner weights. Each wheel of the same axle should, if possible, carry the same static load. Why?

A tire's cornering capability falls off the more it is asked to carry load beyond its design limit. Two tires on an axle can carry the maximum cornering force when they are loaded equally. This never really happens, however, because centrifugal force causes transfer of the car's weight from the inside to the outside tire. Therefore the inside tire's cornering capability is limited because it isn't held against the ground well enough to generate the cornering it is capable of, and the outside is overloaded. This is why lowering a car's center of mass is important. It reduces weight transfer and maximizes overall grip.

Understeer results when the outside front is overloaded relative to the rear. Oversteer results when the outside rear is overloaded relative to the front.

In modeling suspensions, I calculate the balance of lateral load transfer from the inside to the outside tires that occurs from centrifugal force in a turn. The balance front to rear helps me predict whether a car will oversteer or understeer due to one or another outside tire being pressed beyond its load capacity. Over the years I've modeled then driven hundreds of setups and have developed a feel for how much additional load on a single tire can be felt by a skilled driver as it effects handling. I've found that as little as 20 to 30 pounds is easily noticeable. This is regarding an IT or Street Prepared setup, which due to a relatively flexible chassis compared to a "real" race car is not as sensitive.

This means that if you are running 350 lb/in springs, as little as 20/350 = .057, or about a sixteenth of an inch of error in setting perch heights, swaybar links and the like can make a car handle slightly different in left and right hand turns.

If possible, use scales set up on a perfectly level surface to measure the weight on each tire with the driver aboard or an equivalent weight in the seat. To simultaneously check for minimum weight, do this with a near empty tank as well. Disconnect one end of both sway bars and measure the loads. Add up the total weight on the fronts, then the rears, and calculate the percentage of weight on each axle. If the front axle weight is 1267 lb and the rear is 1132 then the distribution is 1267/2399 x 100 = 52.8% front, 47.2% rear. Now add up the weights for the left side and then the right side. Here the left side is 1268 lb and the right is 1131.

At this point it becomes obvious that moving some weight from the left to the right side is the first order of priority. Note that this CAN'T be done by raising the left side! It can only be done by moving heavy objects around within the car, whatever may be legal for your class. You can consider a heavier exhaust on the right side, ballast in the passenger seat area, a passenger side door bar, cage bracing on the right side and so on. You might also look for ways to lighten the left side, like a smaller battery, or a diet for the driver. But for now let's assume you've done this, and typically in IT for example the left side car will still be heavy because the driver, engine, transmission, battery and gas tank are biased to the left. But you CAN get the car to handle equally in left and right hand turns by working with diagonal weights.

To assure equal handling in right and left hand turns, we need to get the same percentage weight distribution from front to rear on each side. To do this we need to get the diagonal weights as close as possible.

If you have variances, you will see them appear as a heavy diagonal. For example let's say your left front and right rear is heavy, which is pretty typical of an RX-7. You need to move closer to the ideal values by lightening left front weight, typically by lowering that corner. However, this will lower the entire left side of the car as well, so you need to restore this to retain correct left-to-right suspension travel and geometry by simultaneously raising the left rear. Since the rear spring is softer than the front, it must be raised more than the left front is lowered to keep the left side ride height the same. The result will be that the total diagonal weight from left front to right rear will be reduced, and the other diagonal weight total will be increased. Repeat this process until the car is both level and diagonal weights are as close as possible. You will find that when this is accomplished the percentage of front weight on both sides will also be identical. Now reattach the sway bars, adjusting the links to avoid any preload that would jack weight from one side to the other.

Most RX-7's are in fact very heavy on the left side. The left front may be as much as 180 lb greater than the right. A typical corner weight for an IT car would be:

686	581
582	550

LF-RR total weight = 1236
RF-LR total weight = 1163
Percentage of front weight, left side = 54%
Percentage of front weight, right side = 51%
Left side weight = 1268
Right side weight = 1131

This accounts for some definite difference in handling left to right, making the typical RX-7 understeer more in right hand turns.

While the reader is cautioned that every car is different, here is a tip on getting your corner weights as close as possible if you don't have a scale. Essentially we are starting by simply getting the car level. First place the car on a perfectly level floor (a water level and shims work well for creating a level surface.) Be sure you have the equivalent weight of the driver in the seat and tire pressures are correct. Measure from the top of the rim lip to the highest point in the wheel arch on all four corners. The fronts should be the same and the rears should be the same. Adjust front spring perches until these are as close as possible.

Now lower the left front perch 1/4 inch and place a 1/2 inch shim under the left rear spring. Your corner weights should now be fairly close. But be sure to check it when you get to the track.

Chassis Stiffness. Chassis stiffness is also important to handling. For the suspension to work well, it needs a rigid platform. When a chassis flexes, it becomes part of the suspension. Trouble is, it doesn't have its own shock absorbers. That is why some "real" race cars seem to work with negligible lean and suspension travel but it won't work on your street car.

Of greatest difficulty and concern is resisting twisting of the chassis. Cage attachments should tie in as close to suspension attachment points or associated structures as close as possible. Every plane of the structure should incorporate generous use of triangulation or diagonal bracing. Braces should meet structures at nodes and not in the unsupported middle of a tube. Portions of the chassis which become part of the total cage structure should be examined for strength. Still, with all of these precautions it only takes one spot in an entire cage to introduce lots of flex. Unfortunately, these weaknesses are hard to spot in a complex structure.

If you don't have access to a mathematical model, try building a model of straws with superglue. Portions of the chassis like the floorpan which become part of the structure can be simulated with posterboard. Subject it to twisting motions to identify weaknesses.

If you are really serious, G-Force Engineering can analyze and optimize cage and tube frame stiffness using NASTRAN, a finite element modeling code used by NASA, major car corporations and aerospace companies.

Reading Tires. Tires that are "hooked up" show a grainy microtexture much like the surface of windblown sand dunes. If tires on one or both axles show a smooth, polished look then this is indicative that your setup is wrong. For example if you have far too much understeer dialed in you may not realize it. Once the car understeers the driver learns this limit and pushes the car no harder. The fact that he is very far from the ideal setting may not be obvious. In fact, because the rear tires are not carrying enough lateral load transfer they may not even be heating up to optimum temperature, and under certain transient loadings like heavy braking may actually exhibit oversteer. But if you look at the rear tires and see they are smooth, this is an indication that they are sliding under minimal loads and not gripping. Actually increasing the rear bar substantially may "plant" the rear end by working the tires up to operating temperature. However, it may also mean that rear shock settings are poor, or spring rates are excessive, or a combination of these.

Conclusion

This manual is occasionally updated as I fold in lessons from my own racing and feedback from customers. Each time I update information and correct for errors or omissions it tells me that at no point will it ever be absolutely perfect or complete. Nevertheless, it is my goal to make it so, and I apologize for any errors you may find.

Your experience and impressions can be an invaluable aid in continuing this process. In return for your feedback, you may call me with your questions and request updates from time to time at no charge. I hope that as a result the community of Mazda owners will pull together to make the early Mazda the fastest in the land.

Thank you.

Jim Susko