CONVERTING FV INTO FST

Bill Bonow Rev 3 January 2012

Before:

After:

Photos: Jason Steeb '72 Lynx B FV conversion and 2011 Hoosier Tire US Formula First Series Champion

Think you're ready for Formula First?--but you just can't see dropping big bucks on a brand new car? Read through this guide and you'll find some basic information about how to convert a Formula Vee into a fresh, low cost, low maintenance Formula First for a lot less money than buying a brand new Formula First.

Converting a race car from one configuration to another seems like a major project, so am I up to the task? Well, if you like to tinker with racecars, converting a Formula Vee to Formula First is really not difficult. There will be some minor fabrication involved, but in general, conversion is a 90% "bolt on" project capable of being performed by most "weekend hobbyist" type mechanics.

The first step is to understand just what Formula First is all about and why it exists. It all started with Formula Vee back in 1963. The original concept was a road racing formula car based on production parts from the 1961 to 1965 (40 HP) VW type 1. Formula Vee was really the world's first spec racecar and is the longest surviving, most successful road racing class in the world. Even today, Formula Vee is still one of the most popular amateur racing classes in SCCA National events. However, the age of the class is finally taking its toll as race entries in FV are slowly dwindling. A few years ago, a small group of FV racers looked into the "age" issue and concluded that it was a fixable problem. Formula Vee just needed some updating with later model VW componentry and modernization. But rather than disrupt the history and heritage of FV, it was

decided to start a new parallel class that would allow people to slowly update their cars and make the switch on their own accord.
The Formula First update concept is the best possible solution because of two major factors. Factor one, the rules were developed and written by Formula Vee racers that had been racing in the class for decades. A lot of thought went into the Formula First rules in the attempt to make improvements to fit the current racecar market. Here are some improvement examples.

- Allowing the cars wheelbase and over-all length to be longer. This provides a long car in the cockpit, giving tall people a chance to race, safely. The longer over-all length gives the car a better look and more flexibility on styling
- Letting the weight to go up to 1125 lb. to facilitate participation by larger drivers and avoiding excessively light components (improved safety)
- Mandating large cockpit opening (FIA F3 specification)
- Removing the obsolete rear body fan shroud rule
- Allowing standard VW 4 wheel disc brakes
- Restricting tires to a single hard compound slick
- Allowing rack and pinion steering
- Introducing electronic ignition and electric fuel pumps
- Allowing aftermarket parts where no performance advantage accrues
- Restricting expensive engine components
- Allowing dry sump oiling systems, dramatically increasing engine life
- Using a restrictor plate as an incentive to prevent exotic rebuilding of manifolds, carburetors and heads
- And the most important, allowing for the conversion of an existing Formula Vee into Formula First and maintaining a competitive status

Factor two was the decision to tap into the existing VW aftermarket for new components. In rest of the world, Formula Vee has evolved to include the later model VW 1600cc engine, rather than the 1200cc, which was last produced in 1965. Wider tires and disc brakes are commonplace in FV in other parts of the world as well. Globally, everyone still uses the VW front beam, but the rest of the world can use the ball joint variant. The Formula First update addresses all these issues. It takes advantage of the robust VW aftermarket industry, which services everything from airplane racing, desert racing, dune cruising, drag racing and street cruising. The VW aftermarket produces all the parts necessary to equip a Formula First with modern racecar parts. Formula First is a great extension of the original Formula Vee concept and the conversion process is not as hard as one might think. Its components are familiar, if slightly different. So what follows are what you need to do to make this simple conversion.

Buy a Good FV Conversion Candidate

The Formula Vee you start off with is important. A Formula First car needs to weigh 1125 lbs vs. 1025 lbs for Formula Vee, so if your plan is to purchase an old car to convert, the chassis should be one of substantial construction built by a major Formula Vee manufacturer.

If you're going to purchase an FV specifically for conversion, look for a car with lots of spare FV VW components. In many cases, the selling of the FV VW components (engine, trans, beam, ect) will fund a huge portion of your conversion parts shopping list.

Good Conversion Candidates:
Adams Aero, BRD, Caracal (Lynx), Citation, Crusader, Mysterian, Protoform, Vector, Vortech, VDF, Womer, Zink Z-18B

Not So Good Conversion Candidates:
Any FV built before 1969 (it has too much vintage value), Caldwell D-13, Zink Z-5, Z-12, Z-18A, Laser L-85 or any home built/one-off chassis could make your conversion more difficult.











Component Purchase/Project List

Listed is a complete major component/project list for a full Formula First conversion. Get components from a company that will help with any required technical support. Here is the full list of components/project and related tech info.

1. **Formula First Engine**
    - **A. Dry Sump System**
    - **B. Electric Fuel Pump**
2. **Engine Cooling Scoops**
3. **Formula First Gearbox**
4. **Ball Joint Front Beam**
5. **Disc Brakes and Wheels**
6. **Adjusting Rear Wheel Bearing Axial Clearance**
7. **Rack and Pinion Steering**
8. **Rear Suspension**
9. **Exhaust System**
10. **Bodywork Modifications**
11. **Alignment Settings**
12. **SCCA Homologation**

Each components/projects section listed above is detailed in the following pages

1. Formula First Engine

Formula First rules makers are experienced Formula Vee racers and are all too familiar with both the strengths and weaknesses of the current FV engine rules. Professional engine builders typically dominate Formula Vee because the rules allow components to be radically altered from stock VW designs. These practices have for the most part been removed in Formula First. This was done to allow for building engines without professional help. So go ahead and build your own motor. If it is not up to par, you can always send it to a professional. Last season engines were supplied by four professional engine builders and two “do-it-yourselfers” that built their own Formula First engines. Those in a position to know were unable to see any major differences between any of the motors. The engine rules seem to be working quite well.

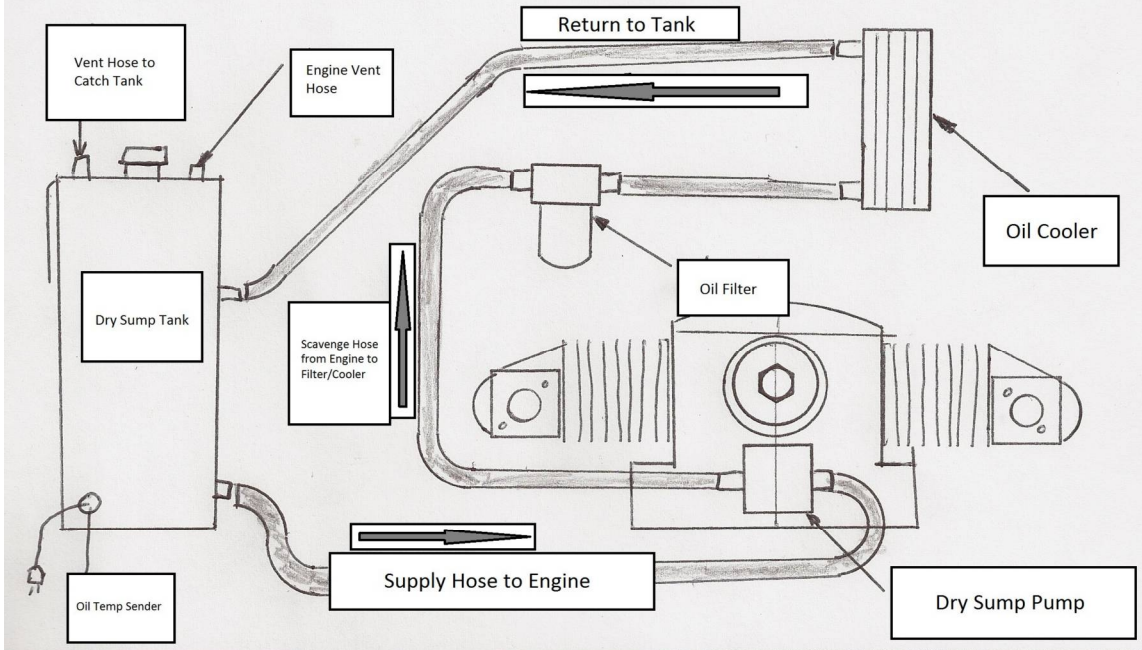
It is worth noting that other than the allowance of dry sump oiling, the Formula First engine rules are basically unchanged since the class inception in 2002.

A. Dry Sump Oiling System

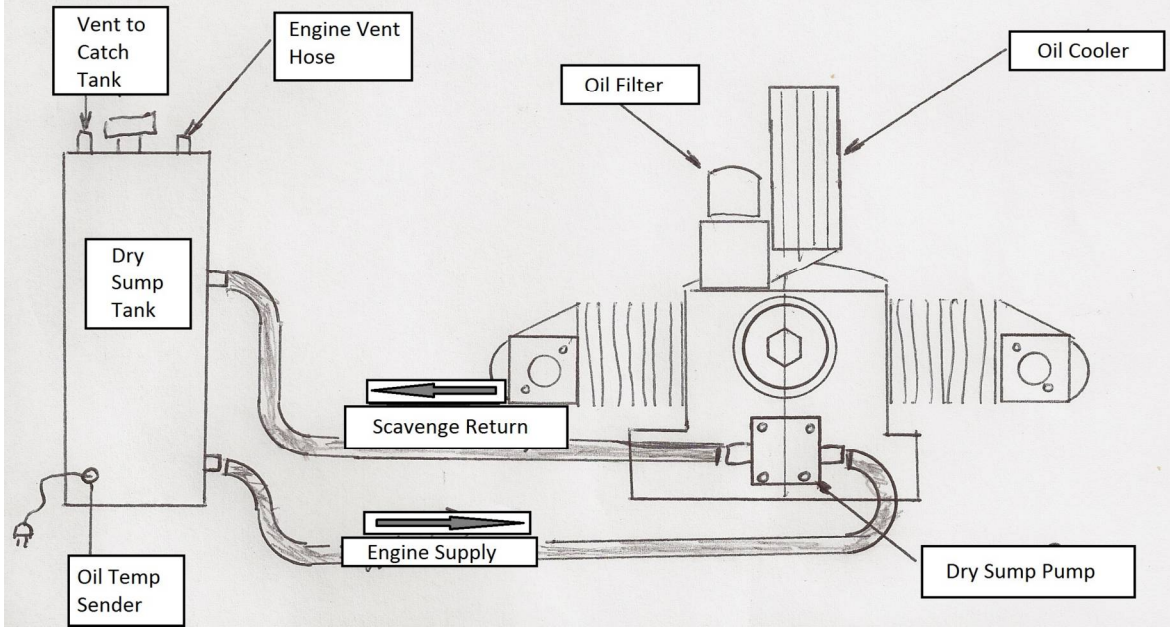
One of the greatest options available on your Formula First is the use of a dry sump oiling system. It became permissible in 2008 and really created a dramatic improvement to cooling and engine longevity. It is not mandatory, but it is highly recommended that it be installed on your FST. You will not regret it. We started testing dry sump in 2007 and found that oil pressure was very constant (never less than 35 psi) and was dependant on engine RPM rather than track position or G-loading. In addition, dry sump oil temperatures dropped as much as 30° F. The common dry sump pump used in FST is a standard aftermarket part that is a direct bolt in component making conversion from wet to dry sump extremely easy. Additionally, the balance of the system is just as simple in design and installation.

Two general themes are utilized, A) remote mounted filter/cooler and B) engine mounted filter/cooler. Both systems work extremely well. It seems to be more of a personal preference. Please review the schematic shown on the following page of the general layout of the two systems. Consult with your engine builder as to their preferred configuration. The biggest thing to consider in the construction of your system is that the supply line going from the tank to the engine is a suction line (not under pressure). Never use cheap hose for this application and avoid any kinks of hard bends in the hose routing. This can cause the supply hose a propensity to collapse under suction and starve the engine for oil, resulting a really bad and expensive racing weekend.

Remote Cooler/Filter



Engine Mounted Filter/Cooler



B. Electric Fuel Pump

An option available in your conversion is the use of an electrical fuel pump. The original VW mechanical fuel pump works quite well, but the low quality of the currently available replacement units. If you are fortunate enough to have a working mechanical pump (with steel level arm), it will function just fine on your FST engine. If you are getting a new engine from a professional builder, most probably you'll need to set up an electric fuel pump. The installation is simple. An inline filter must go ahead of the pump (filter fuel before the pump) and 12v power must be routed to the pump. Depending on your capability and skill level, the 12v power can be routed though the ignition switch, or on a separate switch and could be routed through a oil pressure warning light switch (low oil pressure switches off pump). Your pump should deliver 3 to 5 psi maximum. If needed, a fuel pressure regulator can be used.

Here are some images of various fuel pumps and components:

Facet "Pulse" Pump

Gerotor Pump

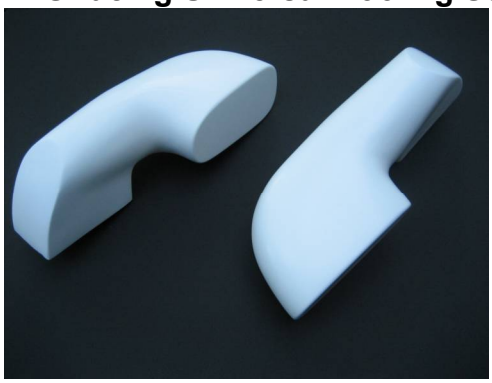
Pressure Regulator

Block Off Plate

Block Off Plate w/ Facet Mount

2. Engine Cooling Scoops

SRacing Universal Cooling Scoops, Installed on Adams Aero Jay



This can vary by the type of scoops on your FV. Most likely, the FV scoops were designed to cool the 1200cc engine. Some of these designs only marginally cooled the smaller engine. There is a strong likelihood that 1200cc FV scoops will not work for the 1600cc FST engine. A very few FV cars do have very efficient cooling and may possibly work for the new 1600cc engine. However, a clear majority does not and new scoops will need to be installed. In most cases, the Universal FST scoops offer by SRacing will bolt directly onto your FV conversion only requiring cut outs in the tail for the scoops to fit. They use stock VW cylinder tin work making the task very simple. If you have to build new ones, keep in mind that the 1600cc engine makes more heat. You need more cooling air delivered to the heads and cylinders, so the duct opening needs to be larger. There are two philosophies on scoop design at this point. One is that the VW factory engineers knew what they were doing when they designed the factory tins. So they use the factory lower tin and build scoops to deliver cooling air into the VW tin. The other thought is to design complete new ductwork built out of fiberglass or aluminum. One generalization all agree with is that about 20 square inches of intake area in clean air is needed as a minimum. Whenever you are developing a new cooling system, it is highly advisable to install a VDO cylinder head temperature gauge to verify the effectiveness of your ductwork. I would also recommend that the sender not be installed under the spark plug. Instead use a second nut and install it on the upper #3 cylinder head stud. That's the one just behind the intake manifold casting. In that way, the spark plug tension or threads are never in any danger of damage. With the sender in this location, the head temp should read a maximum of 325 F on hot days. Cool days will always reflect lower head temps. Also, you will notice the highest temps at the slowest part of the course and lowest temps at the fastest part of the course regardless of engine rpm.

3. Formula First Gearbox

This is the only major component carry over from Formula Vee. The only thing that is really changed is that Formula First rules allow the use of only one specific gearbox. That gearbox uses the 4.125 final drive, known as the long box. The gearing allowed is again restricted to the 1.26 third and .89 forth gears. The swing axles are the same used in Formula Vee.

Here is a simple procedure to check gear ratios:

To confirm the correct 3rd, 4th and final drive gear ratios in your transmission, perform this procedure with the crank pulley marked at 300° and 216°.

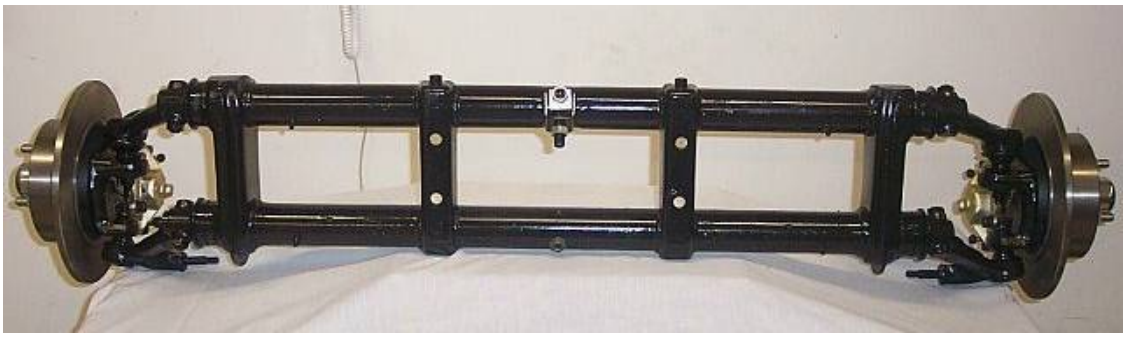
1) Raise one rear wheel off the ground.
2) Mark the tire to verify each full revolution of the wheel/tire.
3) If needed, mount a degree wheel to the crankshaft pulley.
4) Select 4th gear and rotate lifted wheel to bring the crankshaft to TDC.
5) Rotate the raised wheel one full turn. The crankshaft should rotate 660°
6) Select 3rd gear and rotate lifted wheel to bring the crankshaft to TDC.
7) Rotate the raised wheel one full turn. The crankshaft should rotate 936°
8) Reference the chart below to verify the correct number of turns and degrees listed for the 3rd and 4th gear. This will also verify the correct final drive gears as well.

Gear	Teeth	O/A Ratio	Trans Ratio	Final Drive Ratio	Crank Pulley Turns plus Degrees
4th	27:24	3.67:1	0.89	4.125	1 + 300° (660°)
3rd	23:29	5.20:1	1.26	4.125	2 + 216° (936°)

The only potential for modification is if you have an early 1200cc (6v) bell housing. The 1600cc flywheel is larger and material will need to be removed in order to install the engine. Most long boxes came from cars with the 200mm flywheel, but you can easily run into the small bell housings. A die grinder and a sharp bit is all you need to make it fit. Here's is a simple method to do it. Take an old 1600 flywheel and gland nut and bolt it to a crankshaft. Slip the assembly on the transmission's input shaft then turn the crank. Where you have to grind is apparent because the flywheel will scratch the case. Again mark those areas with a black marker. Using a die grinder, only take off enough material so the flywheel can spin freely. Minimize grinding under the starter bushing. The picture below shows a bell housing that has been modified.

4. Ball Joint Front End

Complete Ball Joint Beam Assembly



Formula First rules allows for the update from the link pin beam to the ball joint beam. When you first get your new beam you will notice that the four mounting holes are not spaced the same vertically. You can use three methods, the first is to weld a plate over the beam holes then drill the 1200 pattern into the beam. The second thing is to use the bottom holes to mount to your frame and then re-drill the upper holes in the beam. You can go one step further and modify the beam mounting holes on the chassis and change the hole location to match the ball joint mounting pattern.

The standard ball joint torsion spring is a bit softer in use than the link pin spring. Aftermarket springs will work best for increasing front spring rate. You can also locate your ride height adjuster on the top bar for more room as most likely you're going to mount a new steering rack as well.

Another thing to remember is that really large diameter sway bars don't fit in the ball joint beam, so an 11/16" diameter bar is the maximum for the beam without internal modifications. Some builders have used a spring pack on both the top and on the bottom beam tubes with adjusters on both. The result is adjustment for both ride height and rate. In these applications an external sway bar makes for easy chassis tuning.

If you're building a ball joint beam with outboard shocks or a rocker arm arrangement, remember that front shock travel ratio on a ball joint beam travel is 1:2 versus 1:1 on a link pin beam.

The ball joint front beam has one huge advantage over the link pin beam in the caster camber eccentric. Caster and camber changes take seconds. In fact, assembly of a complete ball joint beam takes just a few minutes. When you rotate the caster/camber eccentrics, remember that both geometries are changed. Always set your caster/camber before adjusting toe as eccentric rotation will change toe. Buy the more adjustable eccentric.

5. Disc Brakes and Wheels

Front Discs: Standard VW (Ghia) disc brakes are mandated by the rules. You have wheel mounting options when buying disc brake kits:

1. Buy them pre drilled with the 4 X 130 mm VW wheel bolt pattern

2. Buy them blank with no holes for studs and build a jig for drilling them to your wheel's bolt pattern.

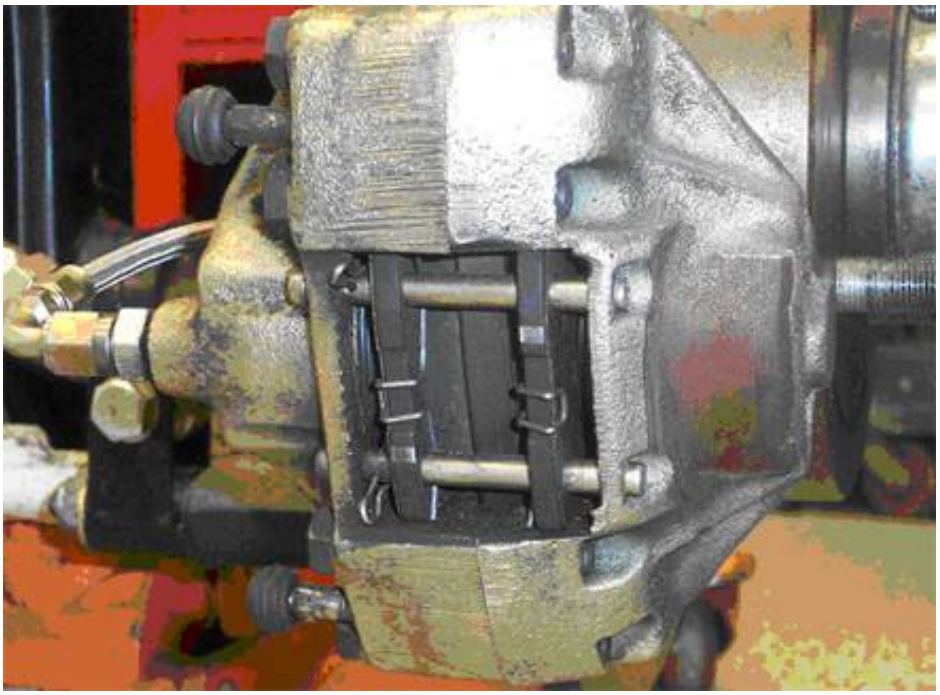
3. Buy them pre drilled for the 4x 4" standard Formula First pattern ready to screw in 1/2 –20 full thread bolts.

Option number one is the cheapest and option three is the most expensive. The difference will be in the cost of the wheels. Wheels using the VW bolt pattern are typically a few dollars more that a standard 4 X 4" mini stock steel wheel. Competitors use both, but the clear majority of Formula First cars use the 4 X 4" wheels. The advantage to that is if you are at the track and bend a wheel, you can always find a spare wheel from a fellow competitor.

Various Wheels Available for Formula First

Rear Discs: The rear discs are the same diameter swept area as the fronts and use the same VW (Ghia) calipers. Rear disc kits come with the same wheel mounting options as listed above. Most kits will supply you with everything you need to change your rear drums to rear discs. You get discs, calipers with pads installed, caliper mounting brackets that take place of your old backing plates and two small spacers called swing axle bearing retainer shims (See: Adjusting Rear Wheel Bearing Axial Clearance) that take up the space between the bearings and the forged retainer. The caliper mounts are found in both stamped steel plate and aluminum castings.

Caliper with clearance grinding completed



Clearance Grinding Calipers: The 13” wheels used in Formula First will require some clearance grinding on the caliper. This project will go fast if you follow this procedure. Mount one caliper on the front right front. Yes the side is important because you want the sparks to go downward. Grind away at the caliper for a bit the loosely mount a wheel and observe whether it rubs. I applied black marker to the offending area to identify where I should grind. You’ll see where it is. Mark, grind and fit the wheel. Keep repeating until the wheel rotated freely. When you have done this so that the wheel can be torqued and no rubbing occurs you now have a template. Take off the caliper and use a contour gauge to delineate where grinding is necessary. Now for the easy part, put the rest of you calipers in a vise and grind them there and you’ll find duplicating the first one a simple task.

6. Adjusting Rear Wheel Bearing Axial Clearance

In our quest to update VW drum brake technology to a slightly more modern disc set up, we find a few minor “bumps” in the project that will need attention.

Before we get into the fixes, it is important to understand the function of the components.

The original rear wheel bearing system and drum brakes function with a very small amount of axial “float” in the bearings. This float is needed as the bearing retainer also bolts/compresses the drum brake backing plate to the rear axle housing and acts to accept brake torque. With the use of drum brakes, the amount of float is less critical and will not affect braking capacity as the drum moves in/out under cornering loads. The Germans are pretty picky about holding nice close fits/tolerances, so the original float is very small and rarely noticeable.

Now, we come along and bolt up our newer disc brake technology onto something it was never designed to have and a few troubles can show up. The common issue is that the manufactures of these kits build in plenty of bearing axial clearance to ensure the bearing retainer fully compresses down on the caliper bracket. The problem for us is that as cornering loads are applied, the increased axial bearing float allows the rotor to push the brake pads back. The next time the brakes are applied, the pedal has that much farther to be depressed to compensate for the increase in brake pad travel. It took a while to find this out, as it is not typically seen with the car stationary in the paddock.

The simple way to check if this needs adjustment can be done anywhere in this fashion. Pump the brake pedal to get maximum pedal height. Next, push very strongly side-to-side on the roll bar to simulate cornering load. Depress the brake pedal again and note any increase in travel. If the rear bearing float is too much, the applied pedal height change will be dramatic. By design, the bearing float must be present and some variation in pedal travel (1/4” or so) can be measured, but typically not noticed by the driver. The point of un-acceptability is typically when pedal travel is described as “it goes to the floor on the first pump, but then it’s OK”.

Now that we understand our problem, the solution is relatively easy. The rear axle bearing float needs to be minimized while maintaining sufficient compression on the caliper bracket. There are two ways to accomplish this. One method is to shim the bearing to the correct/desired float. The other method is the way we have done all of our cars to date, by machining the bearing retainer cap to size. Some of the disc kits come with various thickness bearing shims and will function just fine. It is preferred to machine the caps in order to get the correct float.

Figure # 1 – Depth Micrometer

Measurements are observed with a depth micrometer (Figure # 1).

Figure # 2 – Installed Bearing Height

Measure the height of the installed bearing in the axle housing with caliper bracket bolted in position. (Figure # 2)

Figure # 3 – Bearing Retainer Depth

Measure bearing retainer depth. (Figure # 3)

Figure # 4 – Machining Bearing Caps

The objective is to establish bearing float (bearing height smaller than retainer depth) of .005” minimum to.010” maximum. This will minimize rotor float and still maintain a good compression of the caliper bracket. For machining, we use a lathe to trim the flange end of the retainer. (Figure # 4) Never attempt to grind this adjustment with hand held grinder.

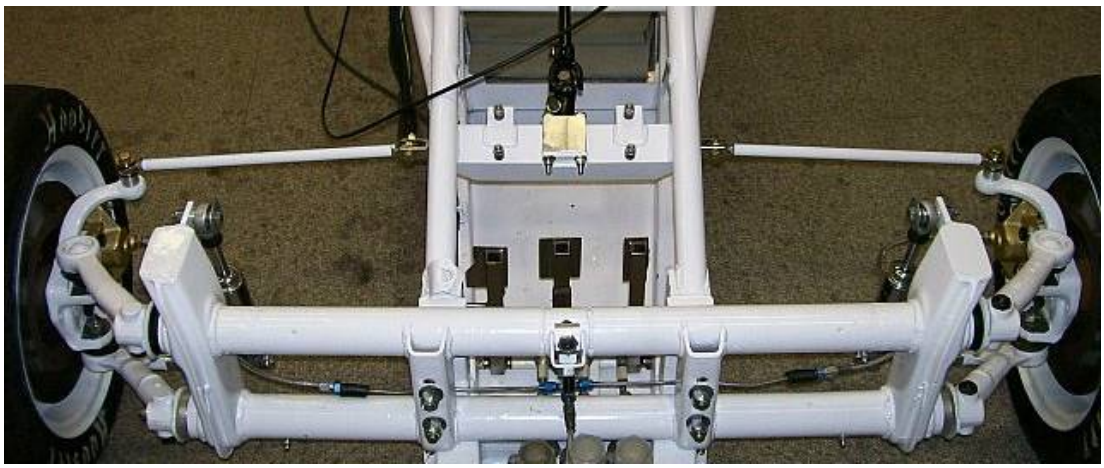
Once correct bearing float has been established, here are a few helpful tips for re-assembly. Make sure the bearing retainer threads in the rear axle housing are chased (10 x 1.5). Most axles are used and the last few threads are filled with years of rust and could give false torque indications. Use Loctite on the retainer bolts and torque them to 65 ft lbs. Also, do not use the thin spacer washer that comes with the rear axle seal kit. They were a replacement for the original oil seal failure cup that would keep gear oil off the brake shoes if the seal started to leak. We don’t need it and the quality of the current ones will only give you trouble by collapsing under the rear axle nut torque forces as they are not hardened.

Once the bearing float is correctly set, the pad push back issue becomes a non-issue and you can fully enjoy the benefits of maintenance free disc brakes in your Formula First.

7. Rack and Pinion Steering

If you're use to steering your FV with a VW steering gearbox you will love rack and pinion. Locating the rack will take some time, but the benefits outweigh the mounting hassles. The main thing to accomplish in the location of the rack is to minimize toe change through the suspension travel. Also, use a higher quality rack. Your driving at high speeds and don't want to loose steering at a point when you need it most.

Adams Aero Jay FV conversion with Rack and Pinion Mounted



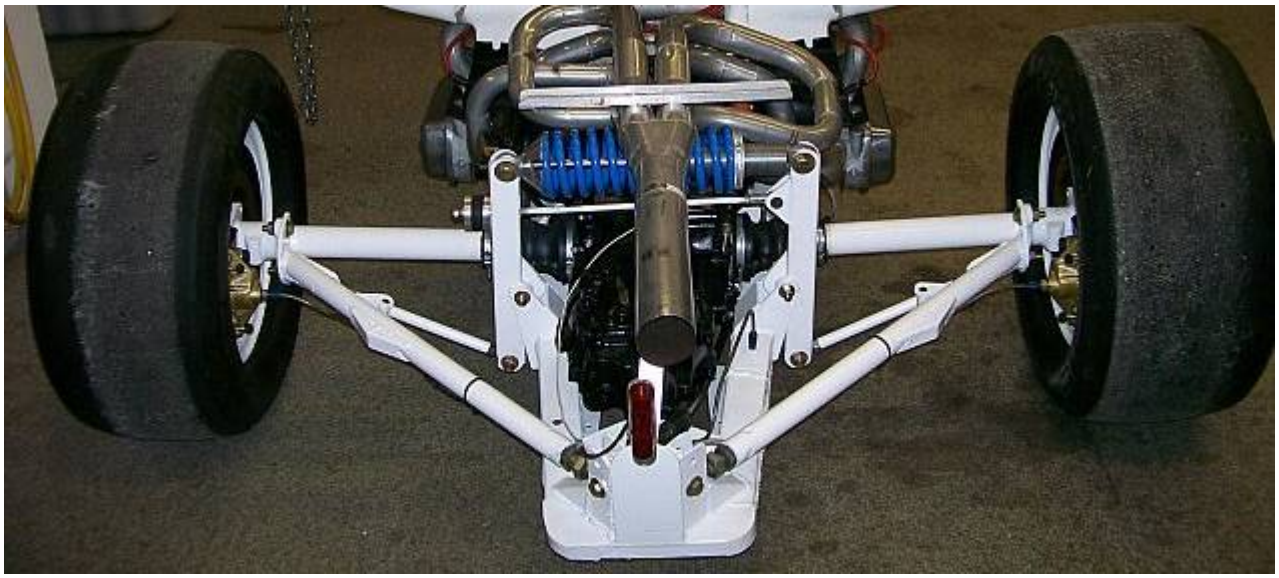
8. Rear Suspension

The rear suspension requires less work than the front suspension but there are things you need to be aware of. On most cars in Formula Vee trim the weight is right at 825lbs. without driver. That same car in Formula First trim weights 850 lbs. without driver. If we figure a 200 lb driver, the Formula First will now need an extra 75 lbs. in ballast to make minimum weight.

Due to extra weight and stiffer rear wheel rates required by the wider tires the rear spring rate may need to be increased. This can take place in “tuning” after the car is converted and racing.

Otherwise the FV rear suspension remains unchanged.

Adams Aero Jay conversion: Rear Suspension



9. Exhaust system

One good thing is that you will be able to use the existing FV exhaust system. The 1600cc Formula First engine exhaust ports are 1/4" wider per side than the 1200cc engine. In most situations, the exhaust will go on snug the first time. After one our two heat cycles, the pipes will re-fit themselves to the new engine. No kidding!

Formula Vee (1200cc) installed on a Formula First engine (1600cc)

10. Bodywork Modifications

Silver Bullet Bodywork on a Caracal "C" Conversion

The requirements for bodywork modification will vary depending on the amount of conversion you decide to take on. The rear or tail body would be really minimal. You may need to open up ductwork holes or add oil cooler ductwork. Mid sections should be just the same except that you might have to make cutouts for rack and pinion tie rods. The front or nose, however, might be more of an issue depending if you stick with the original link pin beam or switch to the ball joint beam. The reason for this is the ball joint beam upper tube is one inch higher than the link pin beam. On most cars that have a lot of room up front inside the nose such as D13's and Citations it's usually no problem. Cars with very small noses like Protoform P-2's you need to do a bit of trimming and maybe fiberglass rearranging because the beam is taller the tubes are farther apart. If you have a car with beam covering wing-lets such as a Protoform or a Laser then these winglets should be cut off or re-spaced. You might even do a new nose if you want a really clean front end. If you just don't care you can just tape it up with racers tape and get out on the track.

11. Alignment Settings

Here is some basic chassis setting info that many have found to be a good base line. Over time, these numbers may change. But for now, they will get you in the general area.

Beam Caster (measured across the upper and lower tubes): 2 to 3 degrees (top tube tipped back)
Note: Always set the caster/camber eccentrics to minimize caster with correct camber set. Always set caster/camber before toe.

Front Camber: 1/2 to 3/4 degree negative each side
Front Toe: Zero to 1/32" out

Rear Camber: 1/2 to 3/4 degree negative each side
Rear Droop: Zero to 1/2 degree positive (total)
Rear Toe: Zero to 1/32" in

Tire Pressure Range (Hoosier R60):

Front: 12 to 13 psi cold
Rear: 14 to 15 psi cold

At these settings, your car will be pretty happy. Of course your own settings may be adjusted to whatever fits your liking. Drive the car and start adjusting as needed.

12. SCCA Homologation

It is of utmost importance that when you purchase your FV, make damn sure you get the SCCA log book and SCCA homologation papers. As of 1/1/2012, SCCA simplified the re-homologation process for conversion cars. You will need to send your homologation document to SCCA (make copies before sending!) and they will send you a new homologation as an FST for free. If you wish dual homologation (FV and FST), send in $25 dollars with your old document and your good. It's that easy. If you need to homologate a new car, the steps aren't quite as easy.

Conclusion

The conversion of a Formula Vee into Formula First will not be as difficult as building you own space shuttle. However, many of the details can be time consuming. It's best to plan on a least a couple of months of part time work to get the process done right. You don't want to start converting in May when your first race is in June. Some tasks like bolting on disk brakes are simple. Other jobs like grinding the calipers are more involved but can be simplified by following the procedure we have outlined. Other jobs like mounting the steering rack may take a touch of engineering savvy and above average fabricating skills. If you allow yourself at least three months from start to finish, you will be in great shape. In this article, we have not dwelled on the cost conversion at all because they are too variable. I have heard estimates ranging from $2,500 to $8,000. The lower estimates always come from people who build their own engines. Without a doubt, the engine will be the biggest cost incurred.

SCCA Homologation needs to be planned for as well. You will need to allow a minimum of two weeks for this process. Start early and get familiar with the process by contacting SCCA and see what all needs to be done. They claim to have made the process easier, but I'd want to know how the process works well before I'm going racing. If your car is homologated as FV, it costs nothing to re-homologate as FST. If you want dual homologation as FV and FST is $25 dollars. This is an easy process and the SCCA people are great, but you have to leave yourself plenty of time for the process.

Enjoy converting your new Formula First!