Developing a do-it-yourself alignment measurement kit for GMC motorhomes

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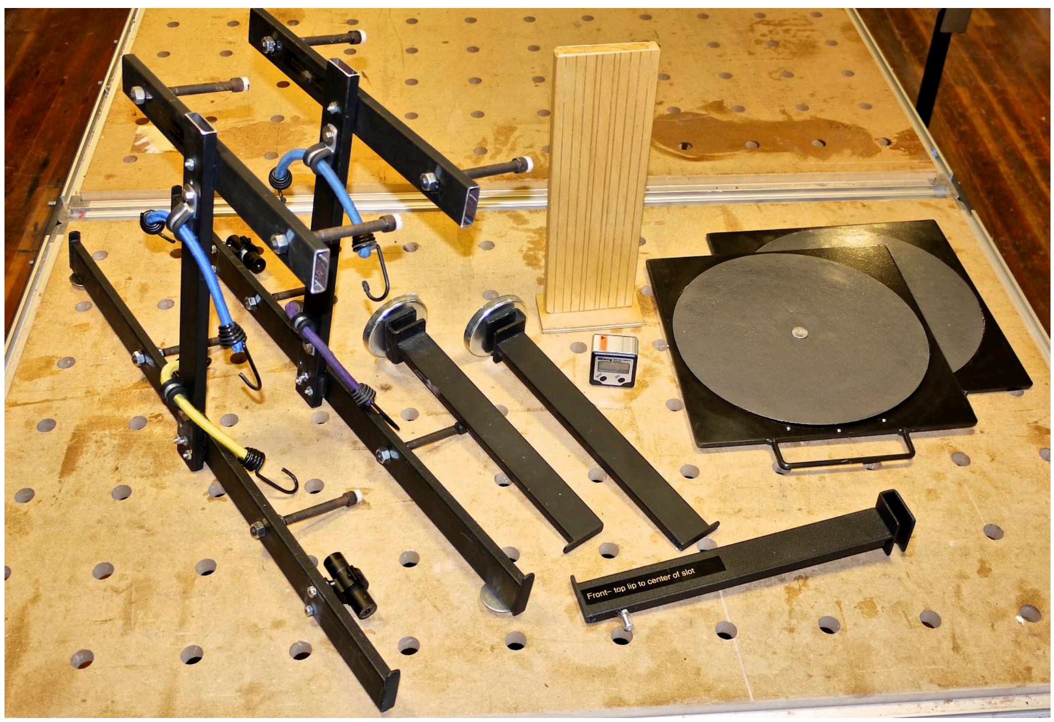
After learning first hand that even competent wheel alignment shops struggle to properly align our 35 year old GMC motorhomes, I set out to develop a kit that would allow any owner to accurately measure how their coach is actually aligned at any given point in time and, if they have the ability to do so safely, to achieve a better and more consistent alignment than is done by most commercial alignment shops.

Why is it hard for most commercial shops to do an accurate alignment on these GMC motorcoaches?



The GMC motorcoach is quite different from most cars and trucks that the commercial alignment shops normally see. The manually adjustable torsion bar front suspension coupled with the automatically leveling air bag rear suspension means that critical factors like ride height change dramatically any time the coach or the tires are jacked up. If the front suspension components like the shocks, control arm or sway bar bushings have been recently updated, it can take as much as 10 miles of driving before the suspension settles in to where it now will be normally as you drive.

If the ride height is off, either because the front torsion bars are set wrong, or the rear air bags raise or lower the rear of the coach by too much or too little, or the coach has not been driven far enough since last being jacked up, any alignment measurements taken will be different from what they will be with the coach going down the road. Therefore, any alignment adjustments made to try to achieve the desired alignment specifications will turn out to be wrong once the coach is driven for a while. Everything can look just fine to the tech while the coach is on the alignment rack, and the nice print out makes it look like the alignment adjustments were properly made, but the subsequent settling of the suspension may render all of the alignment measurements wildly wrong once the coach heads down the road. As a result, the coach may wander or be hard to control or the tires may wear in strange ways even though it was "just aligned".

To make matters yet more complicated for even the most competent commercial alignment shop, the mechanical automatic rear air bag suspension ride height controller will attempt to keep the rear ride height at set levels as weight carried in the rear of the coach changes during normal use. And, rear ride height changes will effect the front ride height in not always predictable ways.

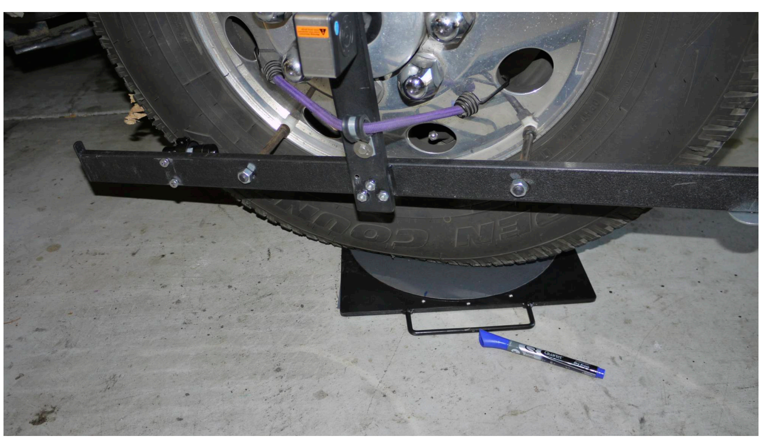
The alignment procedure used by most alignment shops requires repeatedly lifting the coach or the front wheels off the ground multiple times. Each time they do, the ride height changes and that throws everything off until the coach is driven far enough to settle the suspension to normal driving levels, something these shops almost never do. Most just jostle the coach up and down a bit and think that will properly settle the suspension.   On most of our coaches, jostling alone will not.

So, what does an owner need to do to accurately determine how their coach is actually aligned?

The first thing is to drive the coach at least ten miles to be sure the suspension is settled into a normal driving posture.   Next, the coach must be driven onto a level, flat, paved surface and all required alignment measurements have to be taken without lifting the coach or the wheels off the ground.

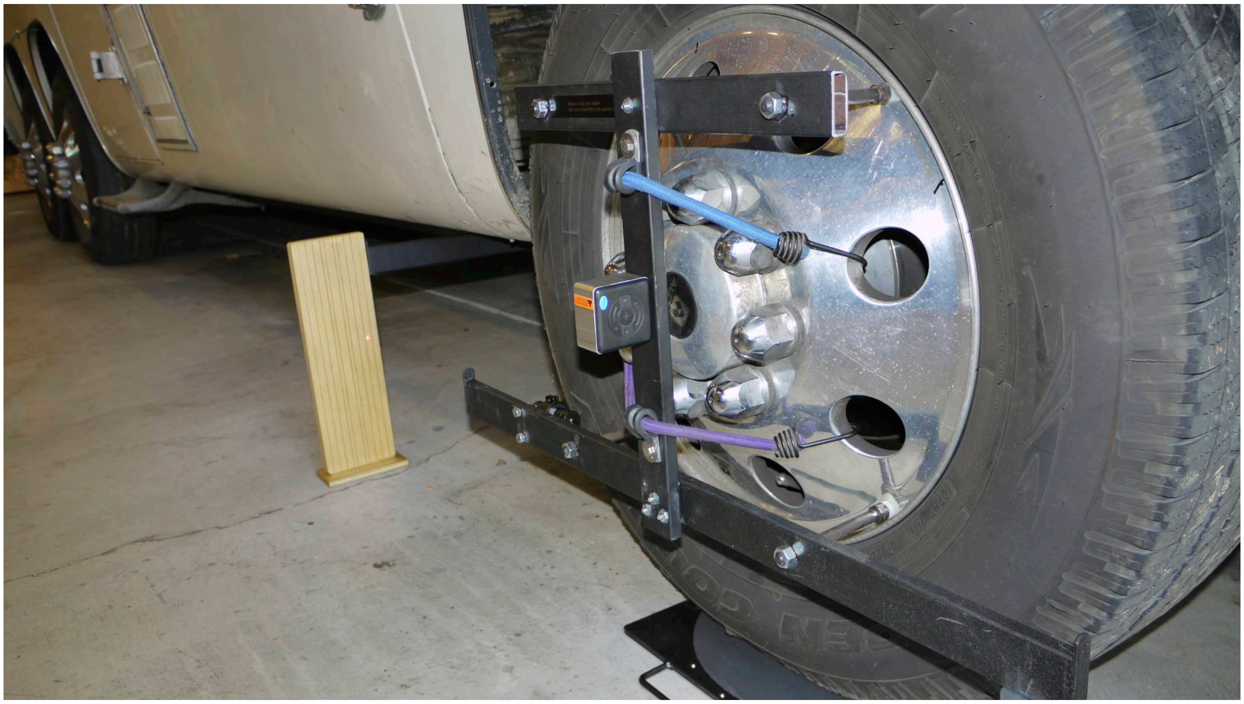
To accurately measure caster, the front wheels must be turned a precise distance (usually 20 degrees) in and out and camber on each wheel measured at these points. The difference in camber multiplied by 1.43 will be the effective caster angle. It is important that both front wheels have about the same caster angle somewhere between 2.5 and 5 degrees when the front wheels each have zero camber while pointing straight ahead.

To be able to reliably turn the front wheels the precise 20 degrees both ways requires the use of a turntable with angle measurement indicators. Most commercially available turntables are thick to accommodate ball bearings and side to side movement so require lifting the front wheels off the ground to get the thick turntables placed under each wheel. Those commercial type turntables won't work well for our GMC motorcoaches. We need turntables that are no more than 1/2" thick so the coach can be pushed or driven onto them without lifting the tires off the ground or overly affecting ride height for all the reasons covered in the section above.



To accurately determine when the front wheels are pointed straight ahead requires a way to measure the plane of the rim and how that relates to the frame of the coach. The plane of the rim will be parallel with the frame of the coach when the wheels are pointed straight ahead. Some use strings on stand-offs magnetically attached along the frame, but I find a well focused laser beam and a laser target positioned by magnetic stand-offs is easier for the average person to use for this purpose.

We also need a way to measure accurately whether both front wheels are parallel with one another (called zero toe).



At the rear we need to make sure all four bogie wheels are running parallel with the frame and that all have about one degree of negative camber when the coach is settled in at proper ride height.

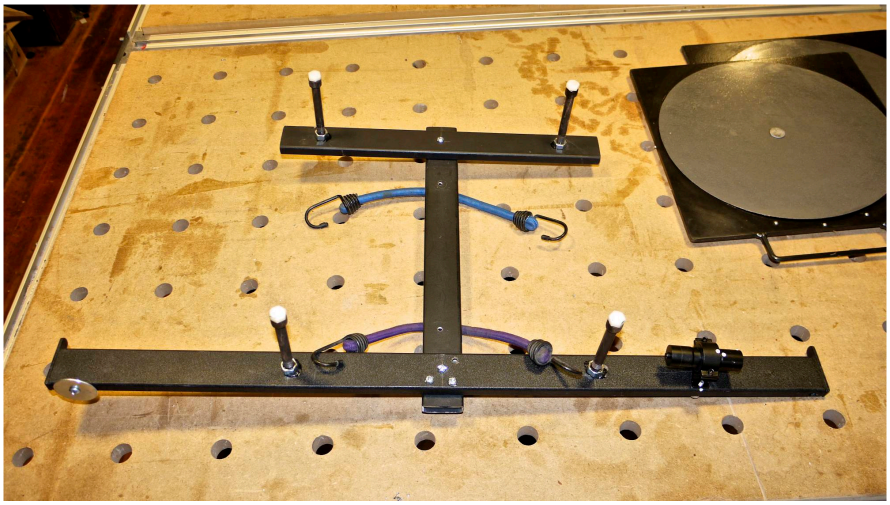
All of these measurements require jigs, fixtures and simple to follow measurement procedures not normally available to most GMC motorhome owners. That was the primary reason for the development of my owner-alignment measurement kit.

My objectives for the alignment measurement kit were that it be:

1) Simple enough that even non-mechanical owners could at least check their alignment anywhere they have a flat, level, paved area whether at home or at a rally.
2) Robust enough that the kit could be shipped or carried from user to user without damage.
3) Able to accurately measure ride height, camber, caster and toe to better than factory specified tolerances without needing to lift the motorhome or tires off of the ground.
4) Inexpensive enough that each of the clubs can afford to acquire one and make it available to their members and inexpensive enough that more mechanically inclined owners might wish to buy one for their own use. I set a target of no more than $500 for the complete kit and easily met that limit.
5) Optimized for use on coaches with Alcoa aluminum wheels as these are the most common of the 16” wheels. The old 16 1/2” steel wheels are so old, warped and bent that I did not think it would make sense to try to design around them.

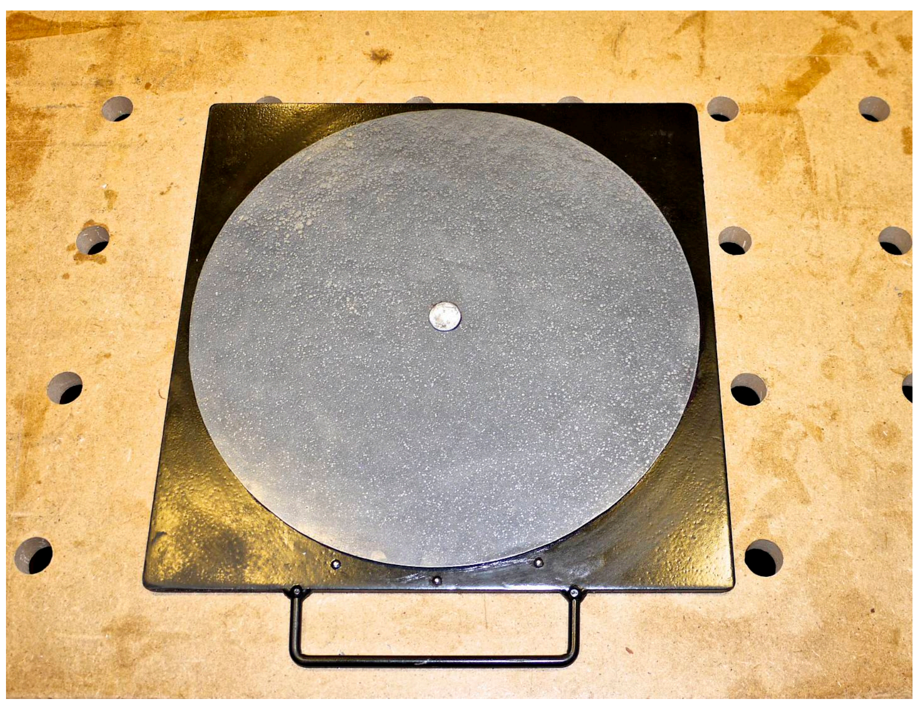
To meet these objectives and to be able to measure ride height, camber, caster and toe on the front wheels plus camber and toe on the rear bogie wheels I determined the kit would need to consist of five items:

1) stand-off plates that can be easily attached to the Alcoa aluminum wheels and which present a mounting surface for an angle measuring device that is planar to the rims. It needs to have lower arms long enough to clear the front and back of the tires to provide a means for referencing a tape measure to determine total toe and for mounting a laser beam to determine when the wheels are parallel with the frame rails.



I started by surveying the GMC literature sources to see what others had already done. I also surveyed a number of commercial offerings but found most wanting for one reason or another given these objectives. I wound up building stand-off plates from 1.5 x 0.5" rectangular tubes that are bolted and epoxied together to eliminate warping from welding heat. They appear to be very accurate and fit on the rims easily and repeatedly with attached bungie cords that cannot get lost. The lasers are gun aiming lasers that have a nicely made adjustable mount that allows the laser beam to be calibrated to be parallel with the long lower arms.

2) turntables that are no more than 1/2" high so the coach could be rolled onto them without lifting the tires or the coach off the ground. There have been many home made solutions proposed from a stack of garbage bags under each wheel to a couple of lubricated plates, but many of these lack reliable indexing to know for sure how far the wheels have been turned. The solution came in the form of a commercial offering from a race car equipment manufacturer. They are simply a piece of 1/4" plate steel with a rubber mat glued to the back and a round piece of sheet steel held to the plate by a center rivet. Grease between the plate and the sheet allow easy movement. The tire sits on the round sheet which rotates as the wheel is turned. Index marks on the plate show zero and 20 degrees each way. There



is no index mark on the round sheet. Once the coach is rolled up on these turntables a mark with a dry erase marker provides the reference required to reliably hit 20 degrees each way to do the camber calculation. These are simple, require little or no maintenance and should stand up well to rough handling by many users.

3) an angle measuring device capable of being zeroed to the level of the pavement upon which the coach is parked and which measure to within one tenth of a degree. There are many digital devices on the market. Some I looked at proved to be accurate in one orientation, but did not read the same when reversed. Others did not give the same reading when placed on the same surface several times in a row. A few of the somewhat more expensive units did appear to provide the accuracy needed. Some were easier to read than others.

I also looked at several of the commercial offerings that use adjustable bubble vials to read the angles we need. Only one of this type that I looked at provided a means for zeroing relative to the paved pad the coach is sitting on but it was built into adjustable stand-offs which were simply too flexible to be of much use. The digital units run from a very inaccurate $20 to a very accurate $350. An accurate and robust unit, like the Wixey and Craftsman units shown in the photo above, costs about $50. The Craftsman has both a digital angle meter and a reasonably accurate laser, but it is larger and I found it a bit more awkward to use for this application. In the end I wound up selecting the much smaller Wixey angle meter and adjustable gun sight lasers which could be hard mounted and calibrated to the long arms of the stand-off plates. I think this combination will prove to work well over time for this application.

4) a device for measuring front and rear ride height. While the factory specifies a ride height measured from level ground to the top of a slot cut in the frame, I thought it might be a bit awkward for some of our owners to bend over and manage the tape without much light to get a good reading, especially when the factory specs are in clumsy fractional inches such as the rear ride height which is specified at 11 11/16" +- 1/4". My solution was to make a go/no-go gauge that sits flat on the ground with pins on each edge, one at the height of the center of the front slot and one at the height of the center of the rear slot. The slot is 3/4" high. The spec is +- 1/4". Given the width of the pin, if the pin fits into the slot the ride height is within spec. If it does not, the ride

height is either too high or too low. Simple, repeatable and error proof. I like this solution.

5) The only other items needed are a tape measure, pad and pencil to record the measurements, and a case to hold it all. The kit contains everything needed for our owners to measure their alignment accurately with the coach suspension at normal driving attitude. If they have the skills and know the proper safety procedures, they can make all the necessary alignment adjustments (except for setting front ride height) without lifting the coach or the wheels off the ground. To adjust the front ride height REQUIRES the use of a special torsion bar unloading tool and the skill and knowledge to do so safely.

Everything can be done by one person, but it is faster and easier with two.

How to check all aspects of your coach's alignment accurately in nine easy steps. All it takes is a level paved parking area and 30 minutes of your time.

Step 1 - Measure ride height.

The first and most important step is to measure **ride height**. Start by making sure your tire pressure is set to the tire manufacturer's recommended inflation pressure for the weight each tire is carrying. The correct inflation will usually be less than the maximum inflation pressure stamped into the tire itself.

Start at the rear passenger side. Stand the ride height go/no-go gauge upright with the screw facing the slot in the frame behind the rear bogie. If the screw head fits inside the slot, you are at the factory recommended rear ride height. If it does not, add or subtract air in the passenger side air bag until it does.

Since the rear ride height slot on the driver's side was removed on most coaches to make room for the generator, you need to measure from the ground to a known spot on the passenger side in order to check the driver's side rear ride height. Add or subtract air in the driver's side air bag to match the measurement you took on the passenger side.

Recheck the passenger side rear ride height again with the go/no-go gauge to make sure the screw still fits inside the slot. Adjust and measure until you get the rear of the coach to be level with both sides at the factory specified rear ride height.

Because the rear ride height directly effects the front ride height, you must set the rear first. Once it is correct on both sides, now move to the front. Place the ride height go/no-go gauge so the top tang faces the front ride height slot cut in the frame just forward of where the front clip bolts to the side frame rails. Look just to the rear of the front tires.

The parallax in the photo right makes it appear that the ride height is too low. It is actually right on as you can see in this close-up photo since the top tang fits inside the slot.

If the front ride height is off when the rear is correct, the only way to change the front is to adjust the front torsion bars. That REQUIRES the use of a special torsion bar unloading tool while the coach is jacked up and the knowledge to follow all the necessary safety procedures.

Do not attempt to do this yourself unless you are confident you know how to do it correctly and safely.

If you do adjust the front torsion bars, drive the coach at least five to ten miles to allow the suspension to fully settle in before you measure ride height again.

As before, start at the rear. Add or subtract air in the air bags until the rear is level and at the correct ride height. Now you can measure the front ride height and make additional adjustments if needed.

With the ride height properly set to factory specs, the coach will have a slightly nose up attitude. Some owners don't like that look and want to set a different front and rear ride height to achieve something they find more aesthetically pleasing. I strongly recommend keeping the ride height the factory engineers determined was best when they designed these coaches.

If you do decide to alter the ride height, know that you have to change the alignment settings as ride height has a great impact on camber, caster and toe on the front wheels, it effects the angle of the front drive shafts and how the inner and outer CV joints will move as they rotate, and it will impact the camber of the rear bogie wheels as well. In order to recheck your alignment later you will need to make sure the coach is at the ride height you established when you did your first alignment so make some form of measuring gauge like the one shown here.

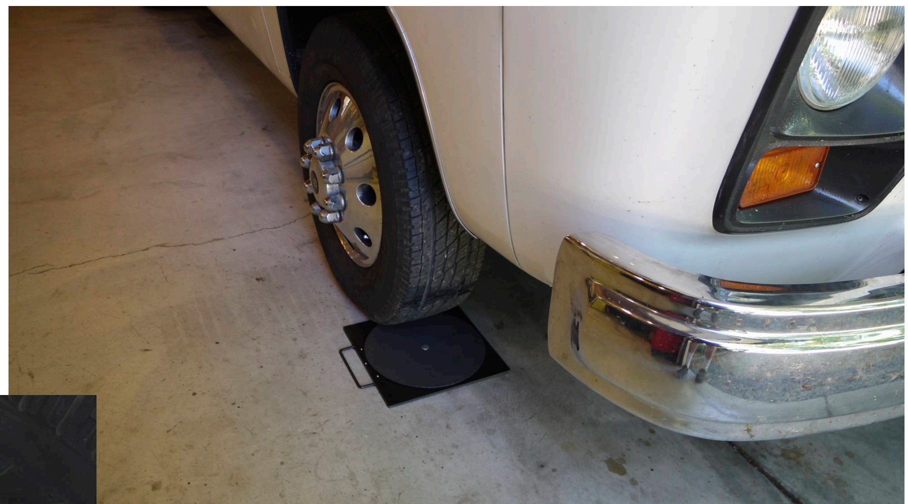
Step 2 - Roll or drive the coach onto the turn plates

Turn your front tires to be approximately straight ahead. Place one turn plate in front of each front tire with the carry handle facing outward. You want the pivot point in the center of each turn table to be about even with the center of your front tires.

Since the turntables are less than 3/8" high, it is easy to push the coach up and onto them. You can also slowly drive onto them if you wish.

Stop when the front wheels are roughly centered on each turntable.

The rubber matt on the back of each turntable is glued on. In the heat, that glue can soften and the matt may squirm a bit. Before rolling or driving onto the turntables, make sure the rubber matt is properly in place.

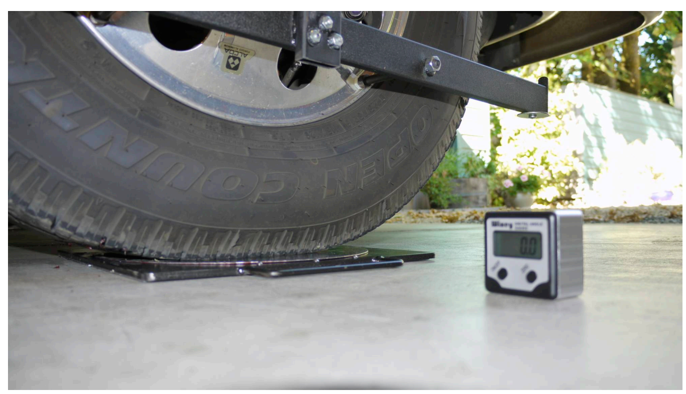


Step 3 - Attach the stand-off plates to the front rims and the laser stand-off arms to the coach frame

Hold the stand-off plate up to the rim with the long arm down and the laser pointed to the rear. Make sure each stand-off pin is seated on the flat area just inside the lip of the rim. The upper arm is free to pivot so it is easy to get all four stand-off pins properly in position. Now use the bungie cords to hold the stand-off plate securely. Check again to make sure the stand-off pins are seated on the flat area just inside the lip of the rim as shown in the photo above.

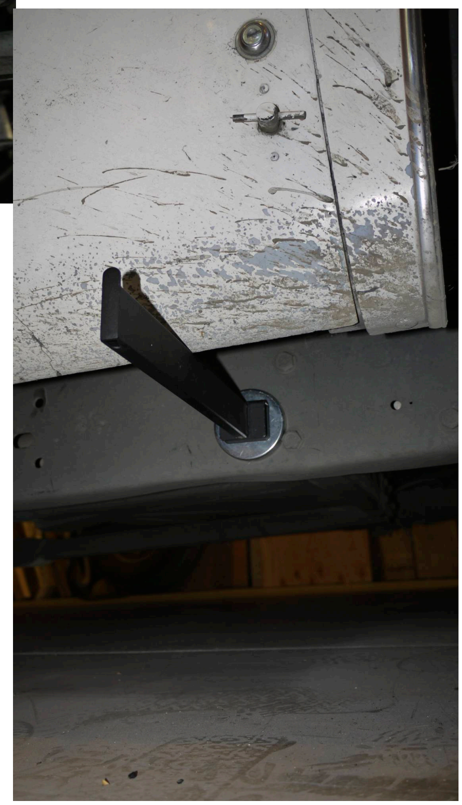
Place the angle meter on the ground parallel with the lower stand-off arm and zero the meter.

Place the now zeroed angle meter on top of the long arm and gently move the stand-off assembly to level the lower arm. That will also insure the upright member is exactly at 90 degrees to the parking pad surface.



Magnetically attach the laser target stand-off arms to the frame front and rear near the ride height measuring slots. Place the front arm inside the four bolts that hold the front clip to the side frame rails.

Place the rear arm a bit behind the rear bogie. Be sure the magnets are seated flat against the frame member and not cocked on one of the bolt heads that hold cross members to the frame.

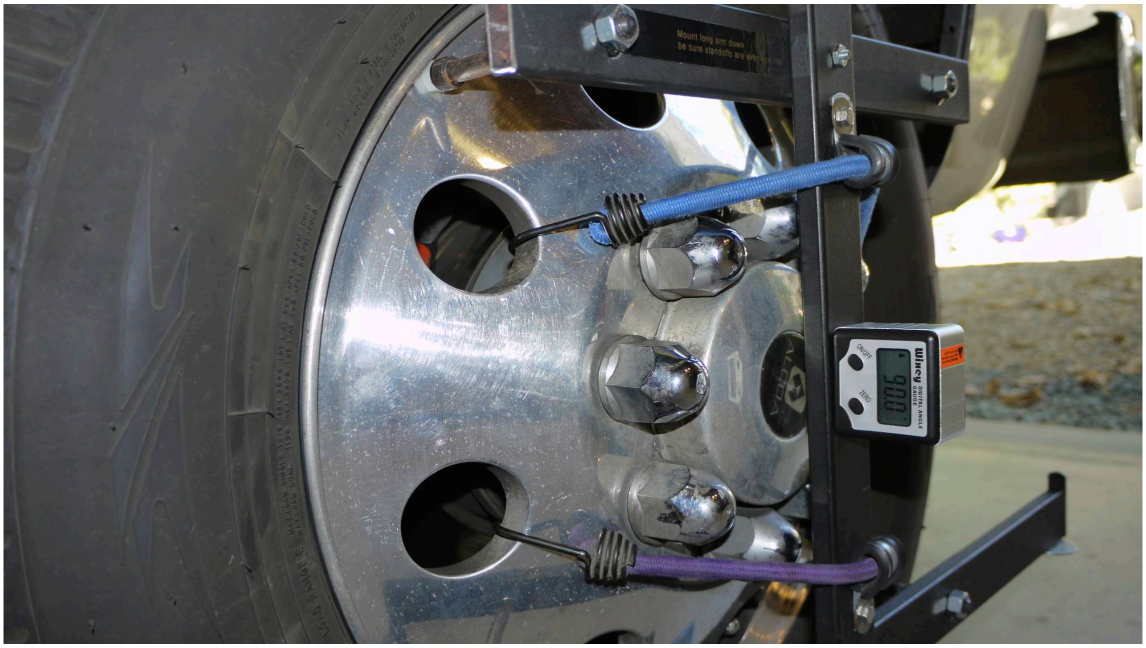


The next thing is to make sure your front wheel is parallel to the frame. To do so, turn on the laser and set the laser target against the end of the REAR stand-off arm. Note the line on the target the laser hits. Move the target to the front and see if the laser hits the same line on the target. If not, move the steering wheel one half the difference and recheck. When the laser hits close to the same line on the target front and rear, your wheel is parallel with the frame. No need for great precision here. Close is good enough.

My coach has the front wheels spaced out to be even with the rear wheels as part of the one ton front end conversion. If yours are in the stock configuration, you will need to slide the laser target further inward matching a line on the target with the end of the magnetic stand-off arms to make your readings. If you are making your own kit you can also mount the lasers to the outside of the lower arm so it will hit the target when the target is against the outside of the stand-off arms.

Step 4 - Measure camber and record.

Set the angle meter on the ground perpendicular to the center of the wheel, turn it on and zero the unit. That will make up for any slope in your parking pad that would otherwise throw off your camber measurement. Magnetically attach the angle meter to the stand-off plate upright to directly read camber. Camber is the angle the wheel tilts in or out at the top when the coach is at the correct ride height and the wheels are parallel with the frame. You want this to be as close to zero as possible.



You want the angle meter to be parallel with the upright so as to not throw off the reading.

Turn off the laser to preserve the batteries and for safety. A laser beam shining directly into the eye can cause eye damage so be careful anytime you are around a laser source.

Step 5 - Measure caster and record

Place a mark on the turntable platter matching the center reference on the turntable base plate. This will allow you to precisely turn the front wheel 20 degrees in each direction in order to calculate the caster angle.

Note the three rivet heads on the turntable base plate. They are set to be 20 degrees from each other. The dry erase marker provided will wipe off when you are through.

Caster is a measure of how much the front wheel steering axis is canted forward or rearward and determines how easily the coach will want to return to straight ahead after a turn. The more caster you have, the more the coach wants to go straight ahead but the harder it is on the power steering unit when you turn. Too much caster and the pressure release valve in the power steering unit may open causing damage to the unit. Too little caster and the coach will tend to wander side to side with road imperfections or from wind or passing vehicles.

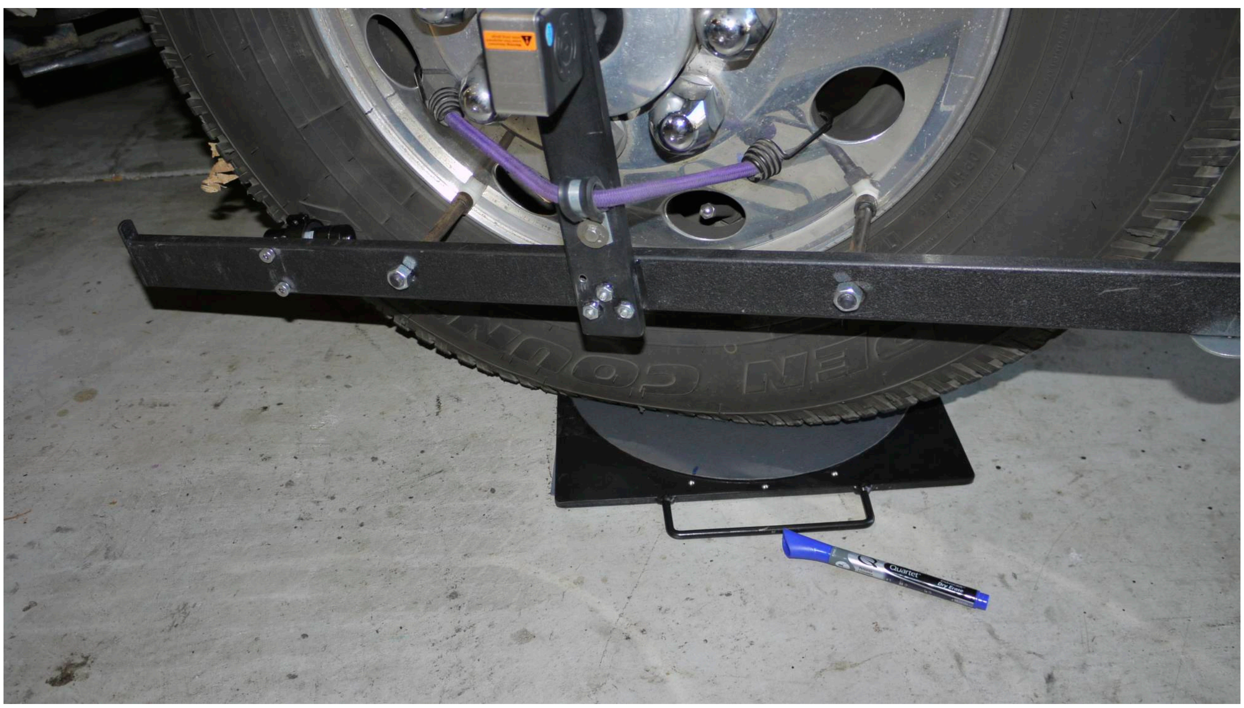
Some say to get as much caster as possible up to 6 degrees, but from all I can determine I think it is safer to set caster to be between 2.5 and 5 degrees when the coach is at the correct ride height and the suspension fully seated in to where it will be when the coach is normally driven.

Caster is adjusted by moving the rear upper control arm bushing towards the center of the coach to get more caster and away from the center of the coach to get less caster.

Not all coaches are the same. The point where the upper A arm attaches to the frame was welded in place during the manufacturing process. They were set with a jig, but we cannot be sure every one wound up in exactly the same place.

You cannot measure caster directly. Caster is calculated from the difference in camber when the wheel is turned 20 degrees inward and 20 degrees outward. This is where the turntables come into play.

Turn the wheel 20 degrees outward until the center reference mark on the turntable plate is pointing to the rear 20 degree indicator as shown in the photo below. This can most easily be done with the engine turned on and idling. Turn the steering wheel all the way outward and it will



generally return to center a bit on its own, usually leaving the wheels at about the 20 degree point. Turn the wheel a bit by hand to get as close to 20 degrees as you can.

Magnetically place the angle meter on the upright part of the stand-off plate (which at this point will no longer be at 90 degrees to the parking pad). Make sure the meter is at about vertical and zero it.

Turn the wheel 20 degrees in the other direction as shown in the photo to the right, position the angle meter to be about vertical and read camber change directly.

Multiply this camber change reading by 1.43 to calculate the caster angle on that wheel. Record that amount.

Step 6 - Go to the other side and repeat steps 3, 4 and 5

Record the camber and caster for that front wheel. The two sides should be quite close to the same. If they are not, you will need to adjust one side or the other until you do get them to be close to the same camber and caster readings.

Step 7 - Measure total front toe

Return the steering wheel to point the front tires straight ahead. This is easy to do with the turntables. Move the last wheel you measured to return the center mark on the turn plate to the center mark on the turntable base plate. Note, the wheel on the other side will turn a slightly different amount so its center mark may not be exactly on. That difference doesn't matter.

Once the wheels are pointing straight ahead, put one end of a tape measure on top of the end of the lower stand-off arm and measure to the same end of the lower stand-off arm on the other side pulling the tape taut as you make your reading. Repeat for the other end of the lower stand-off arms. These two measurements, one in front of the front wheels and one behind them should be the same. The difference between them is TOTAL TOE in or out.

Ideally you will want to adjust the tie rods on both wheels by the same amount until the total toe is close to zero.

Any slop or play in any part of your steering system will make achieving zero toe and keeping it there, difficult. Get it as close as you can to minimize tread wear on your front wheels.

The way the lower stand-off arms are mounted in this kit will allow the tape measure to clear everything under the coach front and rear, including a deep transmission pan. If the tape measure is not straight, the measurement will obviously be affected so pull it taut to make your readings.

Step 8 - Center the steering box and the steering wheel

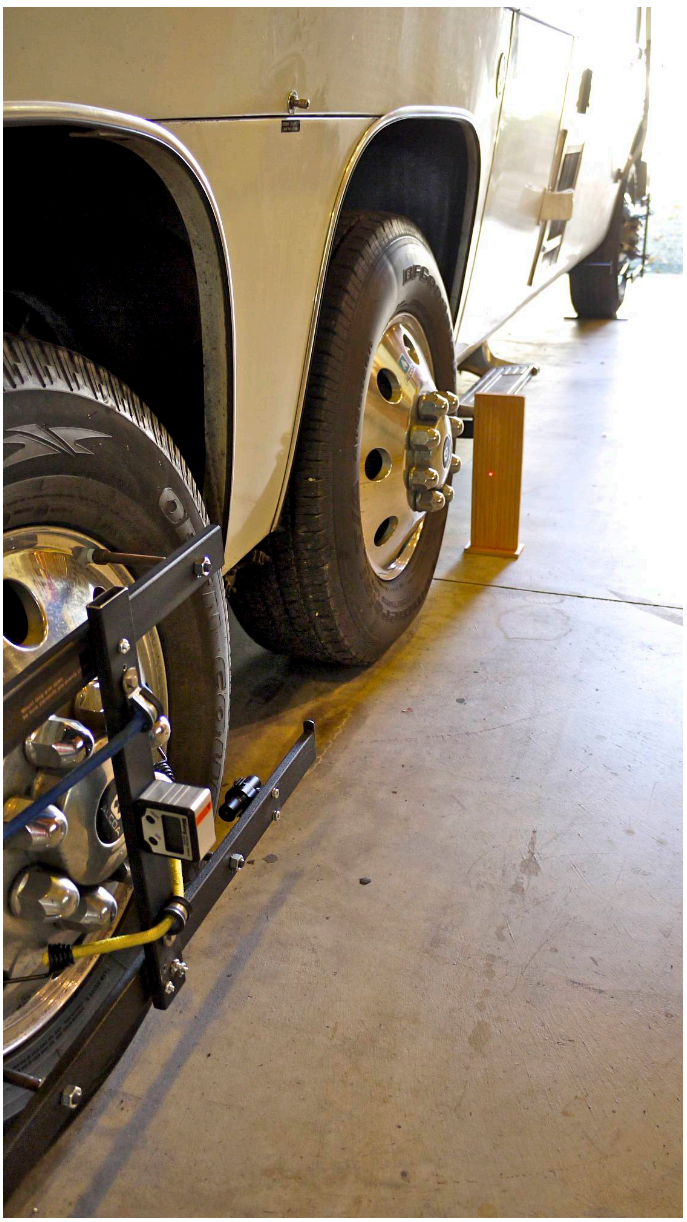
The final ***front end*** alignment check is to see if the steering wheel is centered when the tires are pointed straight ahead. With the stand-off plates fitted to both front wheels with the lasers pointing rearward, have someone slowly turn the steering wheel all the way to the left and mark a spot on the steering wheel so you can accurately count how many turns it takes to turn the wheels all the way to the right. Now turn the wheel back to the left ONE HALF the number of turns to place the steering box as close to centered as you can. Hold the wheel in that location. Turn on the lasers and measure the distance from the laser beam to the frame just behind the front ride height measuring slot and at the rear ride height measuring slot on both sides of the coach.

Slowly move the steering wheel until the difference between the front and rear on both sides is about the same. That will tell you where your steering wheel is pointed when the steering box is centered and both tires are as close to straight ahead as your total toe measurement will allow.

Step 9 - Measure parallelism and camber on the four rear bogie wheels

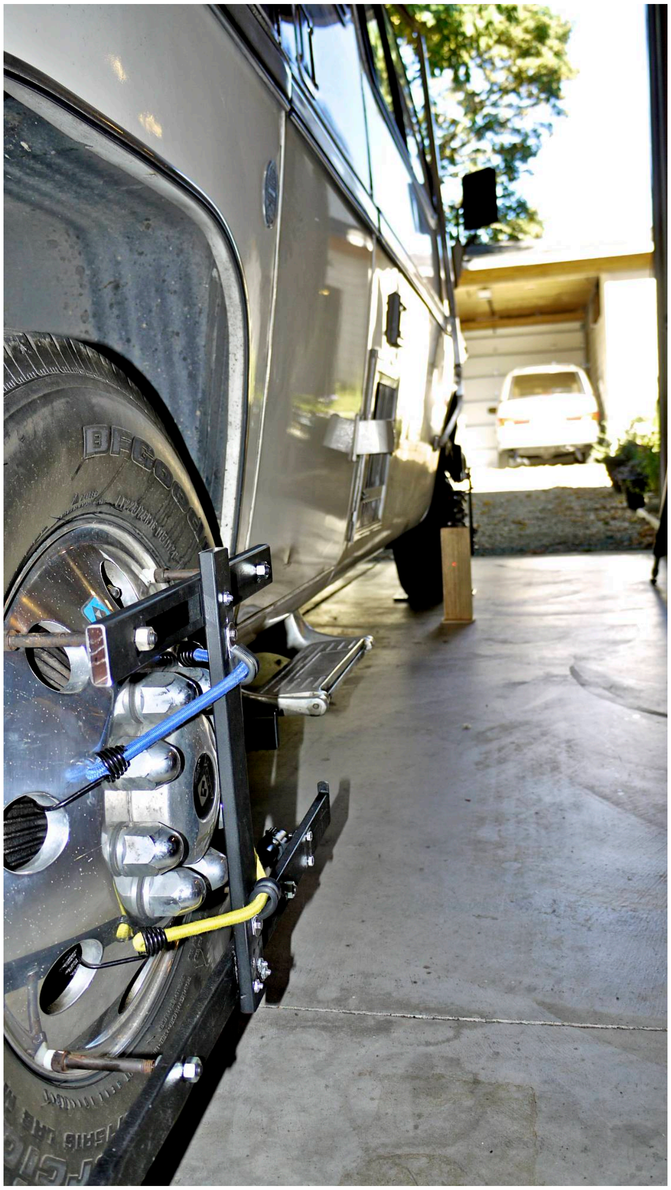
This often overlooked alignment measurement is critical to the handling of your coach and long tire wear for the rear four tires. With this kit it is easy to do.

Attach the stand-off plates to the rear bogie with the laser pointed forward. Place the angle meter on the ground parallel with the long arm on the stand-off plate and zero the meter. Place it on top of the lower arm and level and level it. Now place the meter on the ground perpendicular to the wheel and zero it. Magnetically attach the angle meter to the vertical upright member and directly read camber. Record that reading.



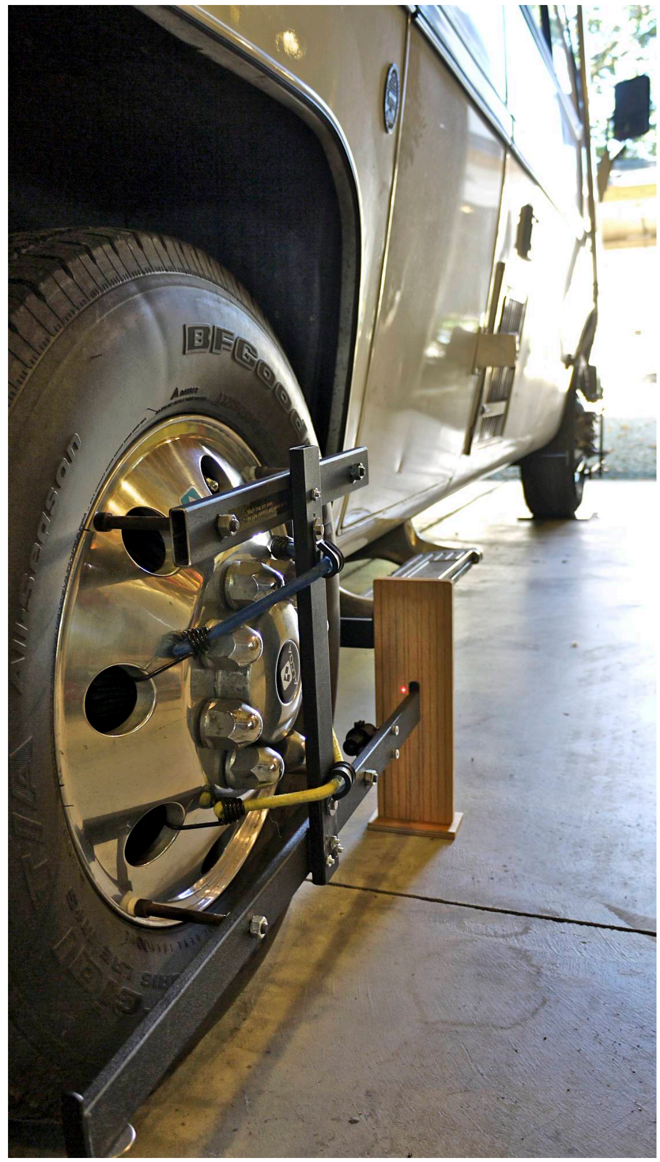
My understanding is the coach was designed so the top of the tire will be in by around a degree or two with the coach at proper ride height. If the camber on just one of the bogies is significantly off, then either your bogie pins or bushings are worn. If both rear bogies are off by the same amount, then likely the pins and bushings are ok, but the whole bogie mounting assembly will need to be shimmed to bring them into adjustment.

Next, magnetically place the laser target stand-off arms on the frame. Place one just ahead of the two rear bogies and the other near the front ride height slot. Place the laser target against the end of the ***front most*** stand-off arm. Turn on the laser and note which line it hits. Move the laser target to the rear and compare. If the laser beam hits the target at about the same line, then that bogie wheel is running parallel with the frame. If only one bogie is off parallel and the other is parallel it likely means you have a bent arm which will need to be straightened. If both are off by about the same amount, then the whole bogie mounting assembly will likely need to be shimmed to bring them into proper parallelism for longest tire life.



Repeat this process on the middle bogie wheel on that side. This will give you camber and parallelism on both bogies on that side.

Move to the other side and do the same thing. You may be surprised by what you find. These rear bogies take a beating in normal driving. With one leading arm and one trailing arm on each side it is not uncommon for one of these four to be bent, nor is it uncommon for one side or the other to be off parallel with the frame.



Do whatever it takes to get all four close to one to two degrees negative camber and all four parallel with the frame. Your four rear tires will last a lot longer and your coach will handle much better if you do.

The rear steers the front to a far greater extent than most realize.

Some observations on “accuracy”

I design and handcraft fine furniture and have done so most of my adult life. In the first half of my career (when I was in technology management) my furniture making provided a good balance for my otherwise overly cerebral life. About a decade ago I flipped and now make furniture full-time vocationally. In the community of professional furniture makers there is a great deal of chatter about setting up and adjusting machines to be “accurate”. Lots of manufacturers supply gadgets and gizmos for measuring all kinds of things. Some people seem to spend all their time measuring their machinery and far too little time actually using it to build furniture or other woodworking projects.

My experience and strong recommendation for that group is to measure the cut, not the machine. If a machine measures “perfectly” but produces a less than perfect cut, then it is out of useable spec no matter what the measurement gadget indicates. If the cut is perfect within your limits of measurement, then the machine is properly set up no matter how it measures.

In researching everything I could find about what is required to measure and align our GMC motorcoaches, I found much the same thing. Some in our community are really obsessed about measuring things like alignment to a very precise tolerance. That is ideal if you have the right instruments, know how to use them properly, and if your coach steering and rear bogie systems are factory tight, and if the coach suspension is fully settled to the ride height it will adopt while going down the road.

The problem is, our coaches are 35 plus years old and everything may no longer be factory tight. Additionally, the digital angle meters that are the measurement heart of this or any other alignment system are not all that accurate to begin with. Many state they are accurate to plus or minus one tenth of a degree which is plenty close enough for our use.

When I dug deeper into the fine print on all the units I examined for use in this kit, I found many only claimed +- 0.1 degrees at zero or ninety degrees and a far greater error band at all the intermediate settings we are more likely to see. Additionally, I could not find a single unit other than very expensive laboratory instruments that could consistently pass what I will call the 180 degree test. Place any of these devices on a flat surface and zero them. Turn the unit 180 degrees and the reading will most likely be up to 0.3 degrees off zero.

We don’t know where the round up or down point is within even the +- 0.1 degree spec so we don’t know whether a reading that is off from another reading by two or three tenths of a degree is really different or just different due to the sensor or the rounding algorithm.

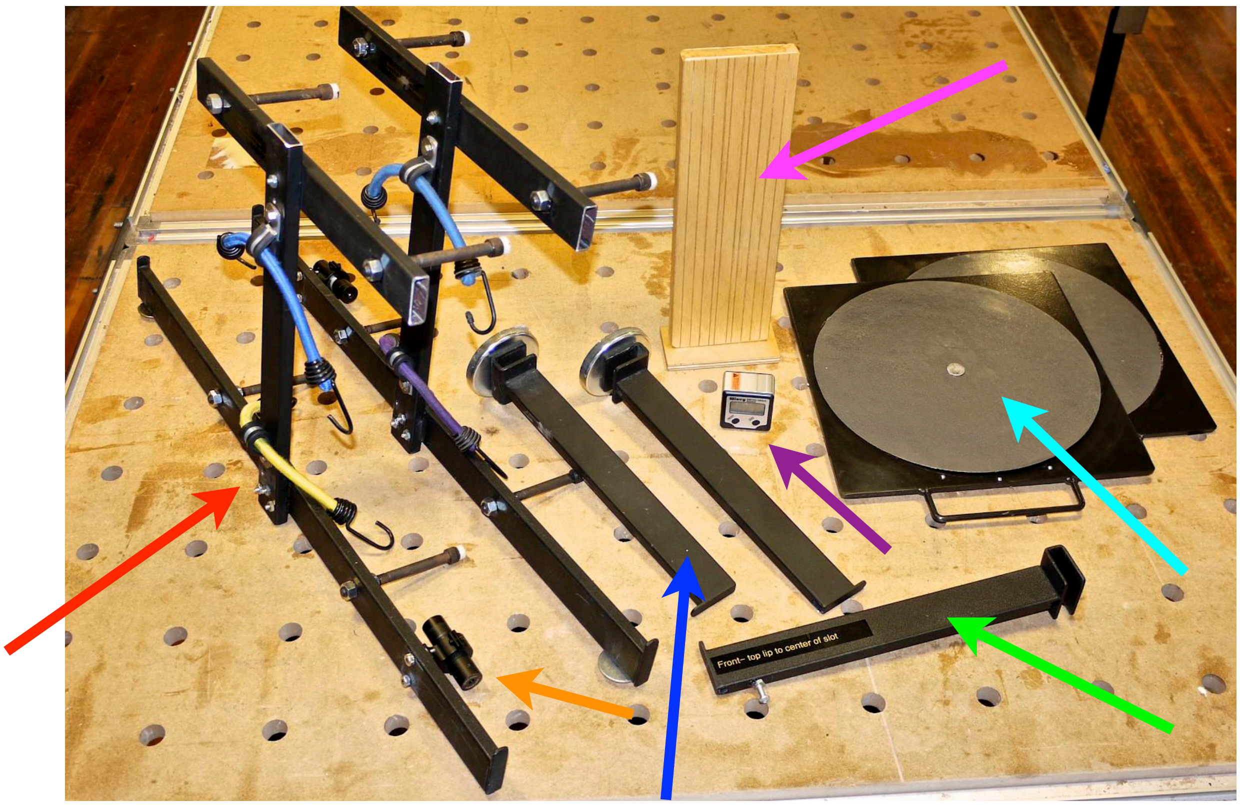
Given the age and likely condition of our components, these angle meters are close enough for our use and, given the work procedure outlined here, can allow you to get your front and rear geometry as close or closer than all but the very best professional alignment shops.

So, my suggestion is to not sweat “accuracy” too much and instead concentrate on making sure your coach is at the proper ride height after the suspension is fully settled into the stance it will take while driving down the road. That will have way more impact on the actual alignment geometry front and rear than any “error” that might be introduced by the jigs, fixtures or meters used in this kit.

How to build a do-it-yourself alignment kit for your GMC club

In this section I will outline how I built and selected components for this kit which hopefully will be helpful to you in building one for your use or for donation to your GMC club for the benefit of all your club members.

This photo shows all the components laid out on one of my Festool multi-function tables. The holes in the tables are 20mm (a bit over 3/4") in diameter and are 96mm (about 3 3/4") on center to give you a relative notion of the sizes of the different pieces.



There are only nine parts to the kit - two bungie cord attached stand-off plates (red arrow) each with a gun sight laser mounted to the inside of the lower arms (orange arrow), two magnetically attached laser target stand-off arms (blue arrow), two turntables (cyan arrow), a go/no-go ride height gauge (green arrow), a laser target (magenta arrow) and a digital angle meter (purple arrow).

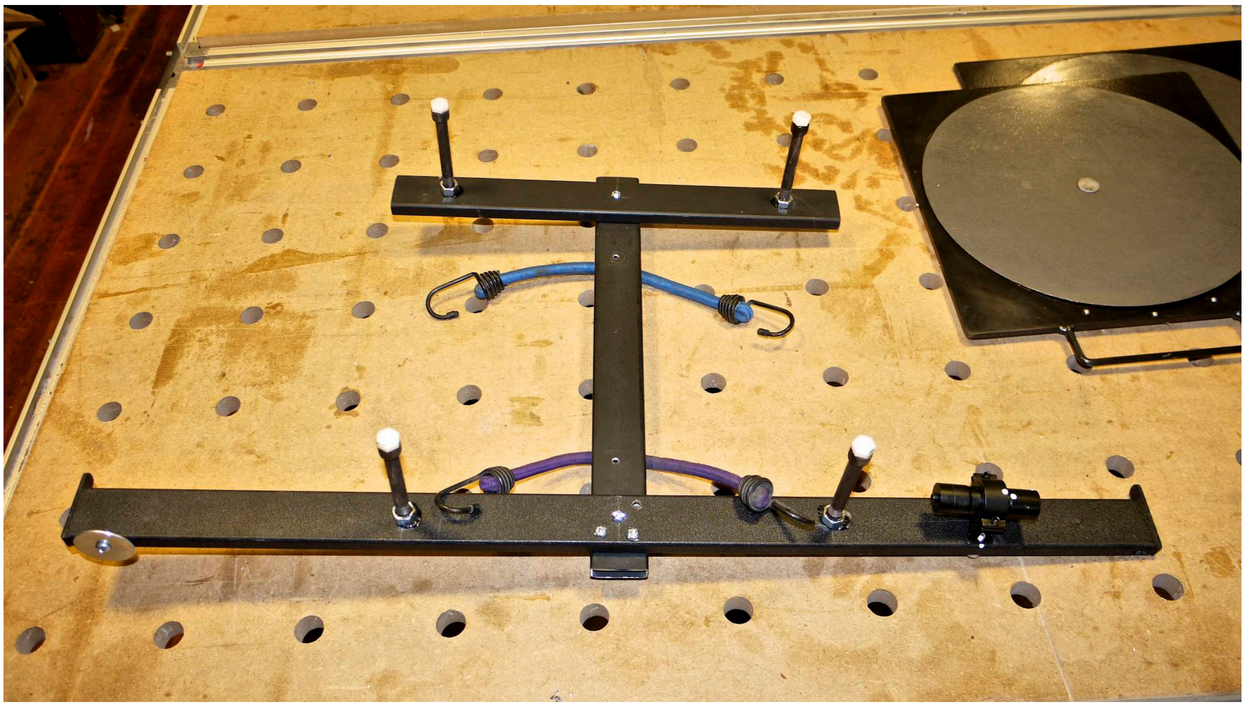
The etched lines on the laser target are symmetrical side to side, 10mm (about 3/8") apart with the center most pairs 5mm apart so they are easy to read and quite accurate. The beam spread on the laser is about 3mm (~0.060") so is easy to match up with these etched lines or the space between them. Absolute accuracy is not required here.

A) making the stand-off plates

The purpose of the stand-off plates is to present a magnetic surface that is on the same plane as the rims on the coach to serve as a mounting point for the magnetically attached digital angle meter. I elected to make mine with four points of contact on the flat part of the rim just inside the lip. Some will argue that three point stand-offs may technically be more accurate, but I found the four point units to be easier for most people to mount and get right.

The arms and upright members are made from 1.5 x 0.5" rectangular tube. They are quite uniformly flat and straight. You want about 90mm (~3 3/4") of stand-off from the back of the arms to the flat on the rims. That will clear the lug nut covers and center cap with ease. I had some hardened hex head machine bolts so used those.

To establish the locations for the stand-off pins use a compass to draw a circle on a piece of paper 16" in diameter (8" radius). That is the size of the outside of the Alcoa rim. Measure the width of the lip and reduce the compass radius setting by that amount and draw another circle. That will be the inside edge of the lip where the flat section on the Alcoa rim begins.



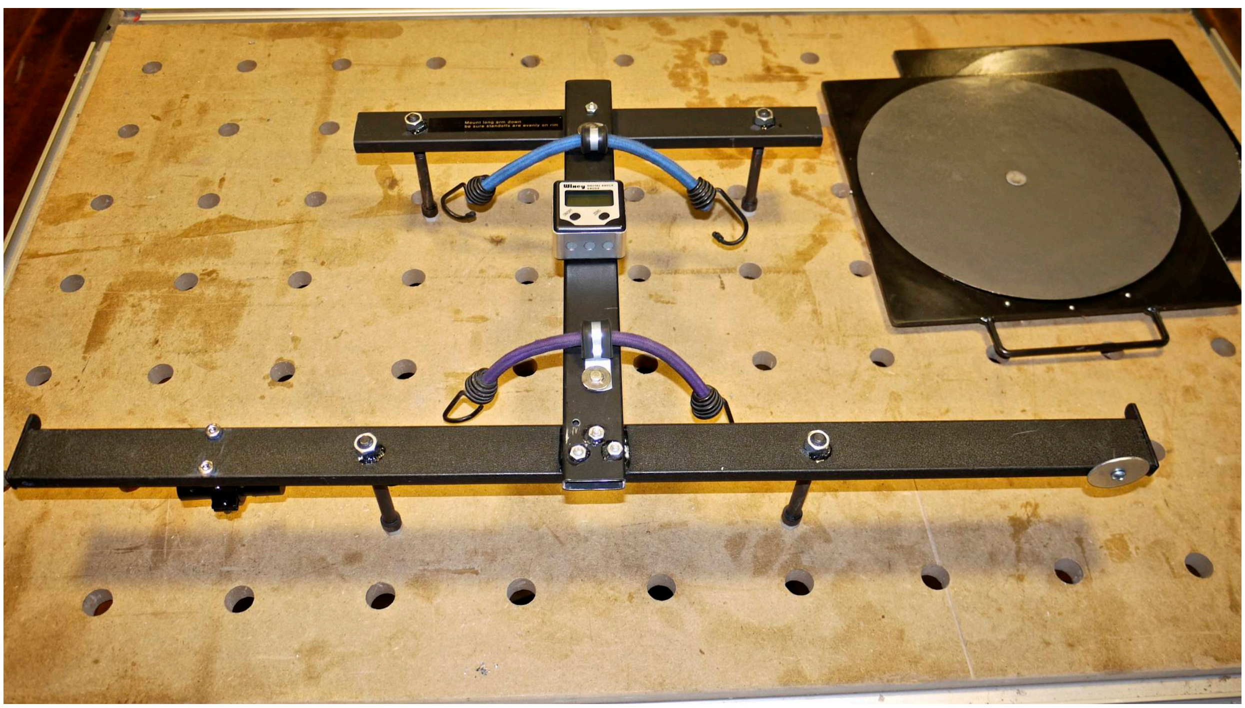
Determine the diameter of the contact point for your stand-off pins. I wanted non-marking stand-off points so cut off most of the thread on hex head nylon screws sized to fit into the hex on the ends of my stand-off bolts and epoxied them in place. The nylon head becomes the contact point on the rim and will not mark the aluminum. Once you know the diameter of the contact points, subtract half that amount from your compass radius setting and draw a third circle. That will be the center line for the four stand-off pins.

Select a point on that circle and draw a line through center and onto the other side of the circle. Use calipers to accurately scribe a second line to be perpendicular to the first line. This will give you four equally spaced points around the perimeter of the circle. These will be the center points for your stand-off pins. Use dividers to walk around the circle hitting each of these points. When you return to the beginning point, if you are a bit long, reduce the divider setting and walk around again. You want to wind up just short of the beginning pin.

Transfer that setting to the stand-off arms and you will accurately locate the position of the stand-off pins. The two lower arms need to be long enough to project clear of the tires front and rear while the upper arms need only to be a bit longer than the distance between the stand-off pins. I suggest you mark a center line on all four arms and clamp them together, aligned at the center. Use your dividers to establish the location for the stand-off pins on the center of the top most of these four arms. Use a sharp center punch and a drill press to drill the two holes through all four arms at the same time. The diameter of the hole should be the tap size for the threads on whatever you use for stand-off pins.

Now tap all four holes to receive your stand-off pins. Put a locking nut on a stand-off pin and thread the pin into the tapped hole in the arm. Project enough to also get a locking nut below the arm.

Use a fixed height jig about 90mm long to set the height of each alignment pin. Do not try to use a caliper or ruler as tipping will throw your measurements off and you want each stand-off pin to be as close to the same length above the arm as possible. The threads will make it relatively easy to get all four pins adjusted to be the same when firmly clamped by the locking nuts above and below the arms. Secure the stand-off pins and locking nuts with thread locker or CA glue.



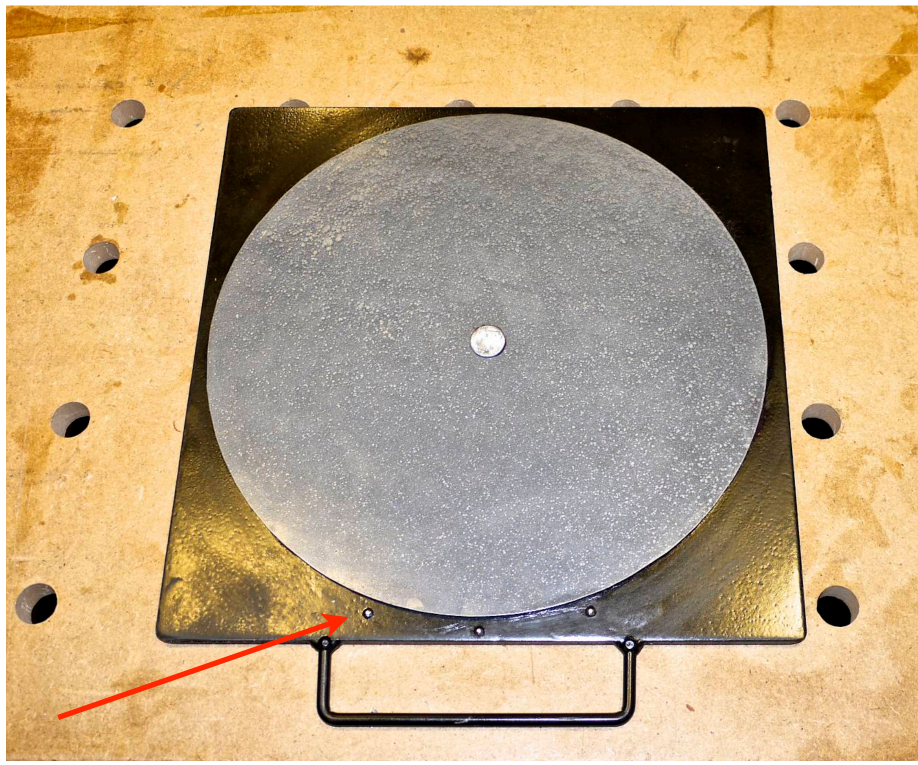
Cut a vertical member a bit longer than the divider setting plus the width of the two arms that will be attached to it. Use the divider to establish the location for screws that will hold the two arms at the correct location on the vertical member. I elected to epoxy and screw the lower arm and vertical member together rather than risk warping them from welding heat. The lower arm and vertical member were mounted in a 90 degree jig then drilled with holes matching the diameter of the 10x24 machine screws I used. Drill one center hole, mix and apply epoxy to both faces and screw them together. Place the unit into the 90 degree jig before the epoxy kicks off and drill two additional holes to make sure the vertical member remains exactly 90 degrees to the lower arm. Screw in those two and keep the assembly in the jig until the epoxy cures. I used 5 minute epoxy and then added fillets of thick CA glue to the edges where the lower arm and vertical member meet and also applied thick CA glue to keep the machine screws from loosening.

The upper arm needs only a center screw and no epoxy since you want it to be able to pivot a bit to make up for any imperfection in your measurements. When you are through, you want the two stand-off plates to register snugly on the flat of the rim just below the lip. If the upper arm stand-off pins do not fit the rim properly, re-drill the center hole in the upper arm a bit larger and try again. You will quickly get a good, snug fit of the stand-off pins to the flat on the outside of the rim just under the lip.

Use electrical conduit clamps to secure bungie cords to the bottom and top of the vertical member on the side away from the stand-off pins. I found this to provide the best location to achieve a good tight fit of the stand-off plates to the rim. The hooks on the bungie cords fit into the openings on the Alcoa rims.

All this is way faster to do accurately than to describe!

B) Make or purchase the turntables



The best thin turntable design I found is a simple one. It uses a 1/4" steel base plate with three rivet heads positioned at 20 degree intervals (red arrow). A heavy piece of steel sheet metal is cut round and loosely riveted to the base plate with a coating of grease in between. The sheet steel will turn easily but not slide off of the base plate. Weld on a handle and glue on a rubber matt to the back of the steel base plate to complete the turntables.

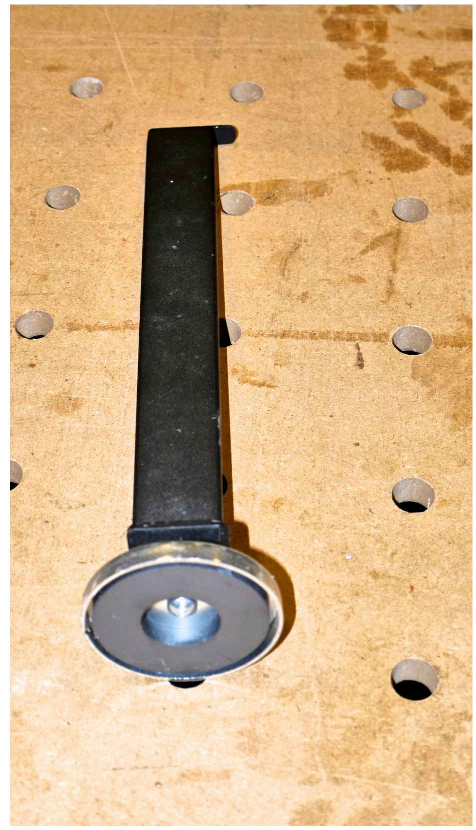
Or, do what I did and buy these for $50 a piece including shipping.

C) Make the ride height go/no-go gauge

Add a tang to the end of a piece of steel or aluminum and cut that piece so the top of the tang is 12 3/4" off the ground. That will be the center of the frame front ride height slot when your coach is at the factory specified ride height. The tolerance specified is +- 1/4" so it is easy to see if the tang fits into the slot with the right clearance above and below the tang.

Flip this gauge over and measure up from the bottom 11 5/16”. This will be the center of the rear ride heigh frame slot. Add another tang or screw at this location as well. Now you have an easy to use go/no-go gauge that tells you with unerring accuracy whether your coach is set to the factory ride height or not.

If you are one who insists on setting up your coach to a ride height different from the factory design, make such a gauge based on your ride height standards so you can always start from a known ride height front and rear.



D) Make magnetically attached laser target stand-off arms

These arms are designed to allow you to position the laser target a known distance away from the frame rails so you can tell whether your tires are running parallel with the frame or not. Screw a strong magnet to one end of these stand-offs and use that to attach them to the frame. Length is not critical, anything 12 to 15” will work just fine. You can find inexpensive round magnets at most big box or junk tool stores. All you care about is that they are the same length and mount easily to the frame rails.

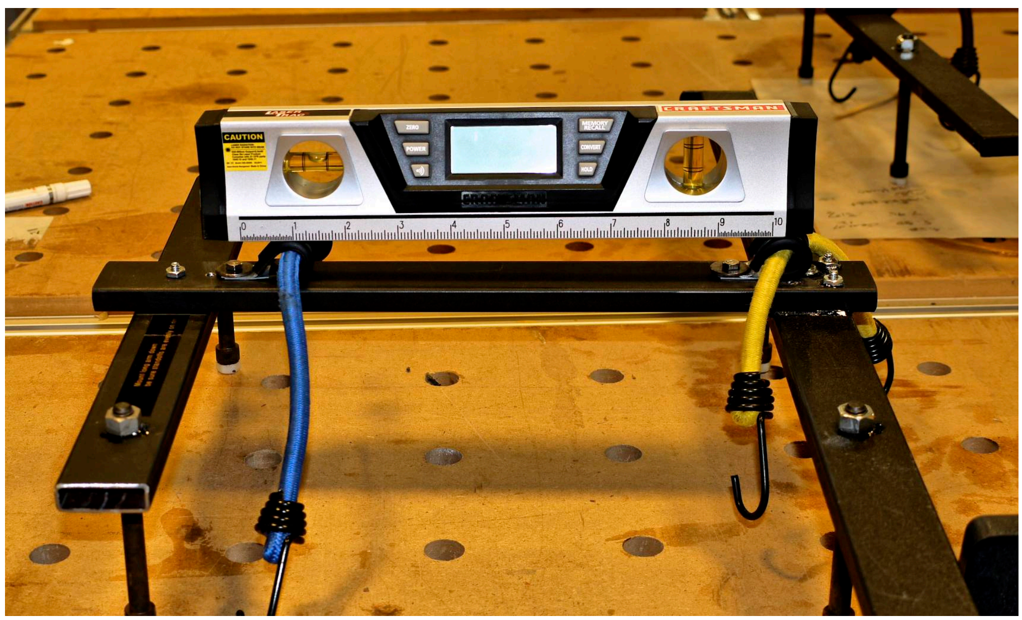
E) Make a laser target

Use a piece of flat stock about 4” wide and mount a foot so it can stand easily upright on the parking pad. Scribe evenly spaced lines on both sides as a reference. I cut mine on a router table 10mm apart using a pointed sign-making scribing cutter. Finish this piece with paint, oil or wax to keep it free of finger prints.

F) Select the angle measuring device and laser you want to use

As discussed earlier there are many digital and analog devices from which to choose. I found the various digital brands differ widely in actual repeatable accuracy. After reviewing and rejecting a bunch of these, I wound up working mostly with a ~$50 Sears unit that featured an integrated laser and different brands of ~$50 small digital cubes that all appeared to be made by Wixey.

While I found the back lit Sears unit to be easier to read, it was also large enough to be awkward on my stand-off plates requiring the bungie holders to be mounted to the back of the vertical member where they were less effective in holding the stand-off plates securely to the rims as shown in the photo on the right.



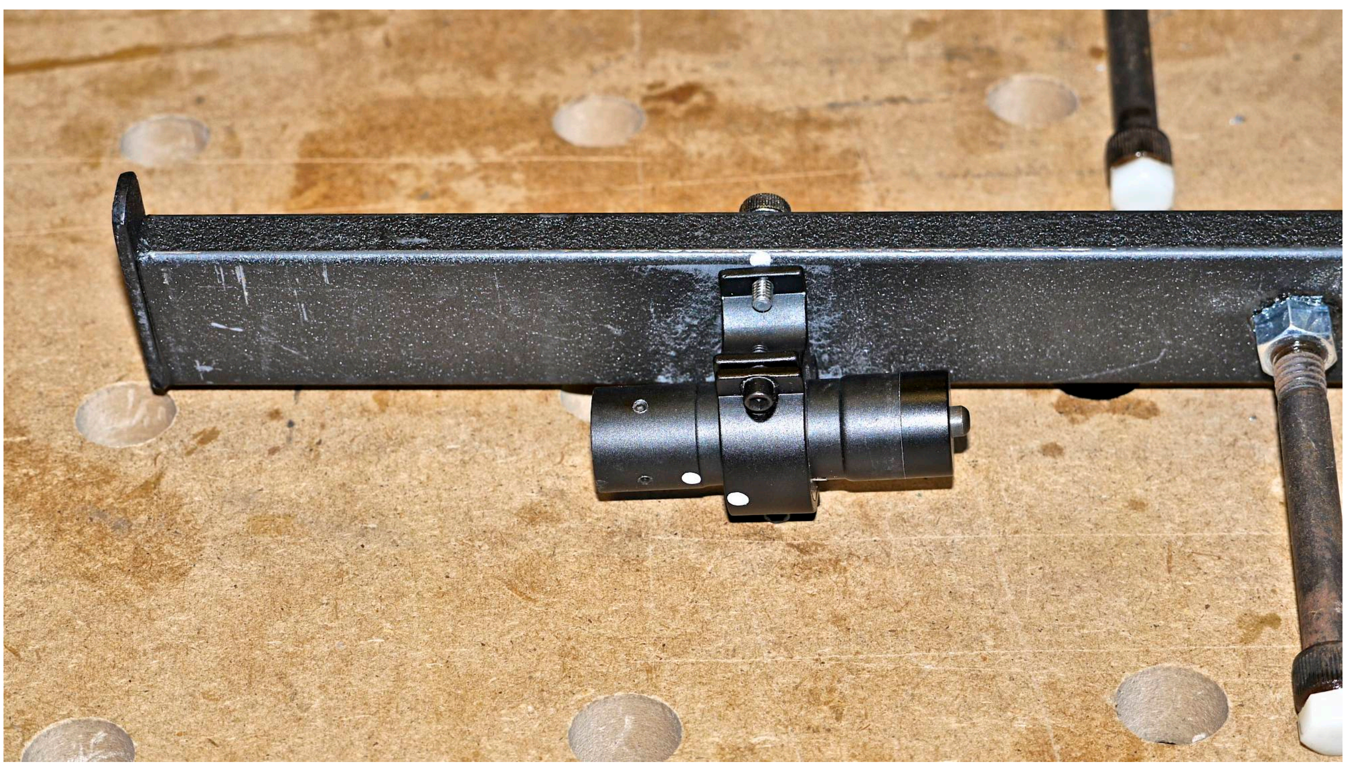
That unit also was heavy enough and long enough that the magnets would not hold it reliably on the outside face of my lower arms when making parallel measurements. I added a large fender washer to the bottom of the lower stand-off to keep it from slipping off the face of the lower arm, but that seemed like a rather clunky solution.

I could have made the lower arms longer so the magnets on both ends would hold it more securely, but that would make the stand-off plates harder to store and ship.

In the end I elected to use the much smaller Wixey digital cube for measuring angles and to buy laser gun sights and hard mount them to the inside of the lower arms for measuring parallelism to the frame. This combination seems to work well, consistently and accurately.

The laser gun sights come with a handy mounting collar and shock mounts to protect the lasers from the bumps of normal use. The lasers are adjustable by rotating the laser housing in the mounts so you can establish a laser beam that runs very true to the lower arms on the stand-off plates.

I used a long Stabula level and a metric rule to set the beam true to the mount and then rechecked it again once the units were mounted to the insides of the lower arms as shown in the photo below.



Once the beam was adjusted to be quite parallel to the mount, I put two white paint dots, one on the laser body and the other on the mount so the user can tell visually whether or not the laser has been knocked out of parallel.

That completes the building of a very accurate kit that will allow you to achieve alignment measurements that are at least as good as all but the very best commercial alignment shops and far better than most.

Feel free to substitute materials, or devices or processes to fit what you are comfortable using.

I will be happy to make these kits for you or your club if you wish. Just let me know and I will send details on price and availability.

Keeping track of your alignment measurements over time

It is a good idea to re-check your alignment measurements once a year or anytime you experience odd tire wear or the coach just feels different to you. To make that easy to do, I have included a form on the following pages that will print on the front and back of a piece of paper if you have a printer that does duplex printing. Each page of the form gives you space to record two different alignment check dates.

Each time you record these measurements, compare to the recent past to see if anything changed dramatically that will require your attention. You will also be able to see slow changes that may be hard to feel but which could shorten tire life.

GMC Alignment Record

Date__________	Specification	Driver Side	Passenger Side
(Use tire mfg	Tire pressure front	____________	____________
(weight/pres.	Middle bogie	____________	____________
(chart)	Rear bogie	____________	____________
(13 1/8” +-)	Front Ride Height	____________	____________
(11 11/16 +-)	Rear Ride Height	____________	____________
(zero)	Front Camber	____________	____________
(2.5 - 5 even)	Front Caster	____________	____________
(zero)	Front Total toe	____________	____________
(0 - 2 deg in at top)	Middle bogie camber	____________	____________
(parallel to frame)	Middle bogie toe	____________	____________
(0 - 2 deg in at top)	Rear bogie camber	____________	____________
(parallel to frame)	Rear bogie toe	____________	____________

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(parallel to frame)	Rear bogie toe	____________	____________