

BAD VIBRATIONS

The First Part of One Chevy Fan's Quest for Smoothness

■ BY HIB HALVERSON

Chevrolets.

We love 'em, right?

Well...not always; sometimes, they make us crazy, cost too much money, cause wives/girlfriends to leave, and even (sharp intake of breath) get us thinking about selling them.

My '65 Malibu is like that. Okay, my girlfriend didn't split on me, but it was no secret: she didn't care too much for "that ugly blue thing."

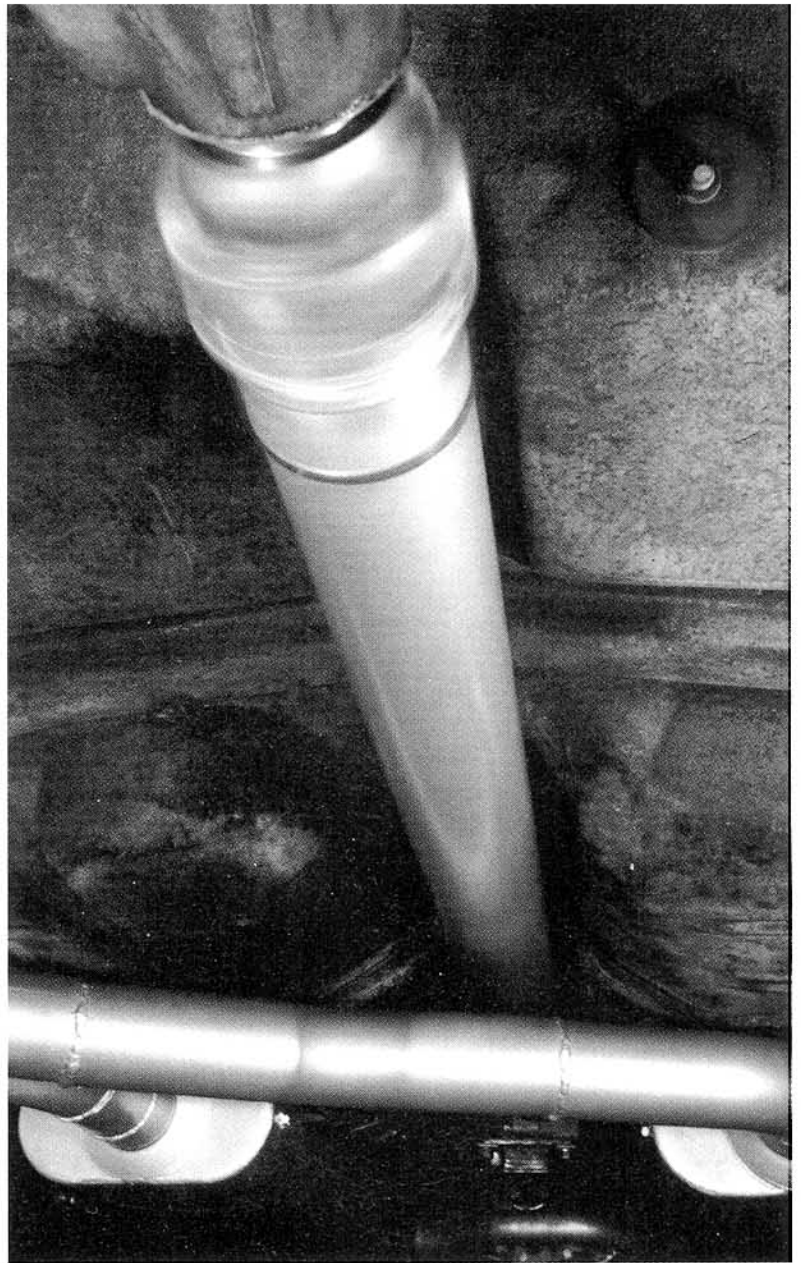
"Sweetheart, how can you say that about the 'Blue Bullet?'"

"Oh puh-lease. Bullet?! More like a slug—not even that, really, because slugs move. It doesn't."

Ouch. Tough crowd.

Of late, my Malibu has spent a lot of time in the garage. A while back, it developed a

vibration I could feel through the seat—often a sign of a driveline or rear-wheel problem. By 70 mph, it blurred the rearview mirror and it excited parts of the car's structure to buzz like angry bees. This vibration limited speed to about 65, making my Malibu anything but a hot rod.



Strange vibrations and weird noises can be difficult problems for DIY enthusiasts to fix. My friend, Gary

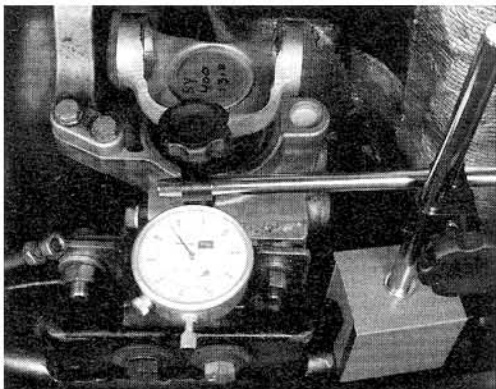
Lincoln stands have rack bars made of investment cast-iron rather than more common, ductile iron, so they have an safety margin I like. While the 6-tonners hold more than the car's weight, I wanted their 25-inch height for extra working space under the back of the car.

Peterson, and I chased my Malibu's vibration for a long time. We eventually solved it, but getting there was an ordeal.

The Chase Begins

First step: Rule out tire balance. I went to Tucker Tire Sales in Covina, California, and had the car's Goodyear Eagle F1 GSeS balanced. A road test showed the vibration unchanged.

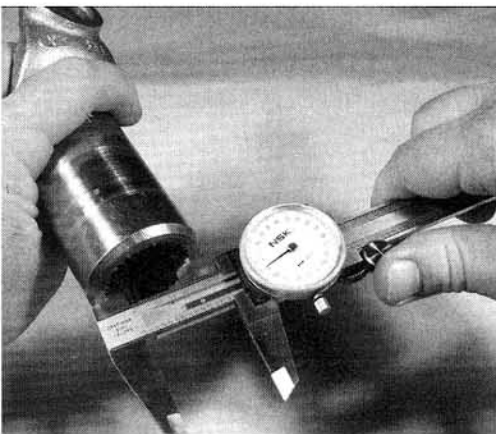
Next: Rule out rear brake rotors. For this, we needed the car in the air with the rear suspension at ride height. I use a Lincoln Automotive, 2-ton floor jack, because of its low pad height, 20-inch lift ability, and robust construction, as well as Lincoln jack stands. We set the front lower control arms on 2-ton stands and the rear axle housing on a couple of 6-ton stands. □



Here's the setup for measuring yoke free-play. Limited space around the tailhousing is a challenge when setting up a solid mounting for a dial indicator. We used a magnetic base on the car's center crossmember.

We spun the rear wheels at 65 mph and felt the vibration. We did the same with the rear tires and brake rotors off, and the vibration was unchanged. We pulled the driveshaft and had its balance checked by Inland Empire Driveline Service in Ontario, California. Inland's Jeff Gilroy reported no problem.

Suspecting a bad bearing, we sent the rearend to Tom's Differentials, which replaced all the bearings and shipped it back. The car still vibrated. We sent the axle to Tom's, again—250 miles later—to check for bent axles, which can also cause vibration, and they sold me a second



A dial caliper demonstrates the problem with the first yoke. Splines are measured two ways: major diameter, between tops of the splines on the shaft, and minor diameter, between the bottom of the splines on the shaft. The nearly .020-inch difference between the major diameters is why the first yoke was loose.

set of new bearings and new axles. Later, I found there was nothing wrong with the original axles. After having the rearend rebuilt twice, up on the Lincoln stands at 65 mph, the vibration persisted. Frustration and expense were building.

In an under-car inspection of anything that moves, my friend, Gary, noticed the front yoke was loose on the transmission output shaft splines. I set up my dial indicator, and sure

enough, free-play measured .008 inch. I pulled the driveshaft and temporarily installed a new yoke from Clippinger Chevrolet in Covina, California. It moved only .0015 inch.

Measurement of the two yokes showed their spines had the same minor diameter, 1.310 inches, but different major diameters, 1.395 for the bad yoke and 1.376 for new unit. We learned the .019-inch difference is a common, but sometimes undetected, problem for those using transmissions with the 32-spline output, such as Turbo Hydramatic 400s, 4L80-Es, later Muncie four-speeds, the ZF S6-40, and some aftermarket manual transmissions. That much free-play will cause a driveline vibration, and I thought we might be on to the problem. Unfortunately, we'll never know for sure, because we couldn't test the original driveshaft with the tight yoke.

Driveshaft Doin's

Two problems prompted me to install a new driveshaft. The tighter yoke requires a larger U-joint than used by my stock shaft. Researching information provided by Bob Parquet, manager of education for Dana Corporation's Spicer Driveshaft Group, I learned that since modifications increased my car's top speed, my problem unrelated to vibration.

Anything made of elastic material—and metals are elastic—has a resonant bending frequency. When a rotating shaft's speed approaches its resonant frequency, the shaft begins to vibrate as if it were unbalanced. If allowed to spin for very long in that speed range, known as "critical speed," the shaft will fail catastrophically. Don't be in the car when that happens.

Another noteworthy industry standard is "safe operating speed," defined as 75 percent of critical speed. Engineers (along with corporate risk management staffs, we figure) believe a driveshaft can run continuously at safe operating speed and be unaffected by resonant frequencies. Critical and safe

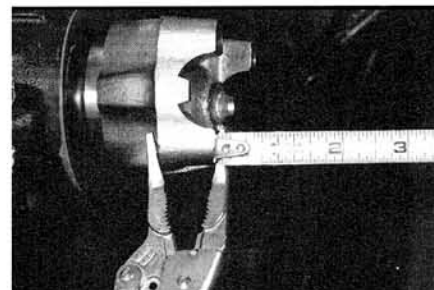


Inland Driveline's Jeff Gilroy offers the results of driveshaft failure due to operation at critical speed.

operating speeds are a function of a shaft's length, diameter, stiffness, and tubing wall thickness. Using a calculator on the Spicer Driveshaft Web site (www.dana.com) I found that the safe operating speed of my Malibu's shaft was 4,370 rpm. Dividing that by 0.75, I got a critical speed of 5,827 rpm. A slide rule version of this calculator is available at many Spicer dealers.

For a given driveshaft speed, vehicle speed is a function of axle ratio (in this case, 3.73:1) and tire diameter (255/50ZR16 F1 GS at 26.06 inches). Using the formula: speed = (tire diameter x driveshaft rpm x .002975) ÷ (axle ratio), I determined at the shaft's critical speed, vehicle speed would be 120 mph. As I'd seen 120 a few times, it was a miracle my Malibu's driveshaft hadn't blown right through the floor.

To eliminate this danger, Inland Driveline built us a 57.25x3.5-inch driveshaft out of .120-wall aluminum tubing and fitted it with



To build a driveshaft, manufacturers need to know the distance between the transmission and the rear axle. There are a couple of different ways to measure this, and it is important to measure the way the driveshaft service suggests. Inland Driveline wants the distance between the pinion yoke....

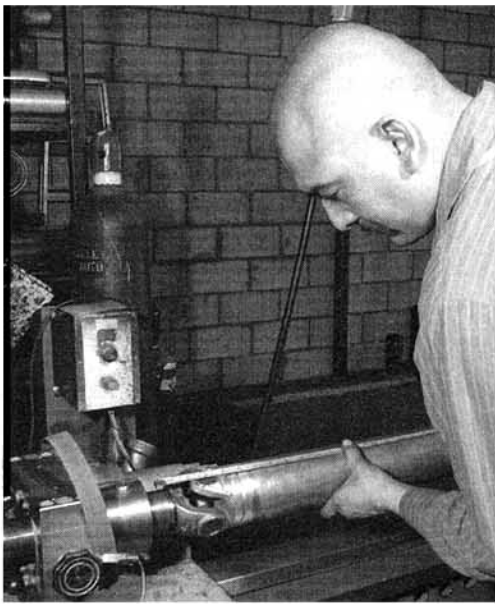
....and the rear surface on the transmission extension housing. A tape measure is adequate, provided it can be stretched tight between the trans and axle.



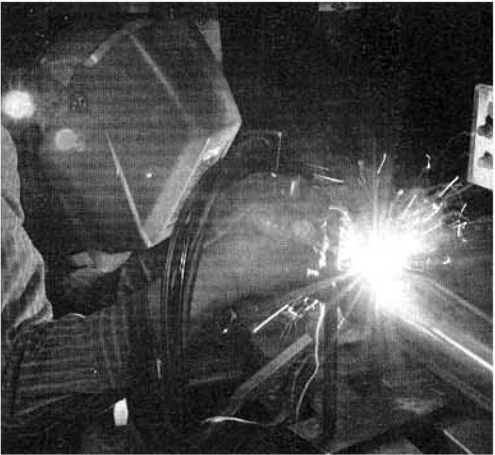
larger Spicer U-joints (PN 5-447X). Our new shaft's critical speed is 6,976 rpm, or 145 mph, and its safe operating speed is 5,232 rpm, or 109 mph. Though it was larger, as it was made of aluminum, there'd be no weight penalty. Inland machined the TH400 yoke to the correct length for the Malibu's transmission, a transplanted ZF S6-40 six-speed out of a '92 Corvette, and installed it on the new shaft.

Bent Housing

We pulled the rearend a third time to install an Inland Driveline pinion yoke which fits the larger U-joints, so new suspicions I had about the axle's effect on our vibration could also be addressed. After the second rebuild, pinion rotation felt rough, as if there was a bad bearing. Tom's Differentials told me to drive the



The measurements customers make are transferred to the driveshaft fabrication process. Here, Inland's Tom Aragon verifies the length of our new shaft just before he fires up the welder.



Aragon heliarc welds driveshafts on a machine specially designed and built by Inland Driveline.

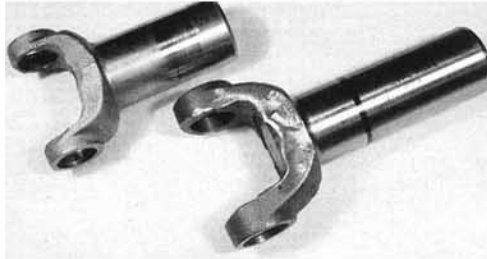
car 500 miles, and if the trouble persisted, call again. I believed there was a problem right then—time to try a different service.

Jim Cook at Performance Differentials in Ontario, California, tore down the axle. As I suspected, the rear pinion bearing was damaged due to either incorrect preload or improper installation of the bearing race. Worse yet, Cook found my axle housing was bent by .125 inch, which could cause a vibration.

Cook straightened the housing and installed new pinion bearings and the new pinion yoke. We put the rear back in the car, filled it with Red Line Heavy Shockproof Gear Lubricant, installed the new driveshaft, and went for a road test. I didn't get very far when, crossing a railroad track, I heard a knock on the floor.

Early Chevelles have a stiffening rib running across the body, under the floor, just aft of the front U-joint. As we'd lost 1/4 inch of clearance between that rib and the driveshaft when we upgraded to the 3.5-inch unit, the additional 1/8 inch of the front

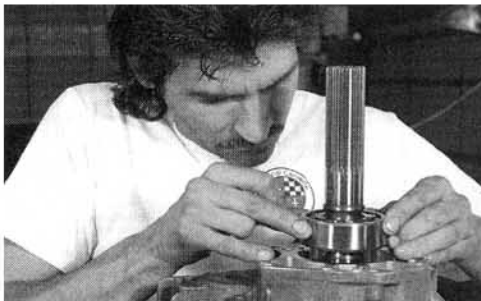
balancing weight protruded, and the weight was nicking the rib when the powertrain moved after the car hit a bump. I took the shaft back to Inland to have the weight moved. I was ready for a longer road test. Long story, short: the darn vibration was still there. Was I ready to give in? Nope.



Here are the old yoke (left) and the "tight" TH400 yoke. It's easy to see the difference in size of the required U-joint. We did a little deburring work, then marked it for Inland Driveline service to cut.



Many rear axle service shops recommend Timkin roller bearings, and that's what Jim Cook installed in our Malibu's 12-bolt, along with the new pinion yoke.



Boudreau pushes a Rockland Gear rear mainshaft bearing into our ZF six-speed. The rear mainshaft bearing experiences the highest load of any in the transmission. It was worn slightly more than the other four, but nowhere near where it would cause a vibration.

Transmission Trauma

That we'd been on this job for nearly six months and had either repaired or replaced everything from the transmission yoke back without solving the vibration started me

thinking transmission; maybe it had a bad output shaft bearing.

We pulled the Malibu's ZF and I took it to ZR51 Performance in Cave Creek, Arizona, outside of Phoenix, which is approved by ZF Industries to do overhauls on '89-'96 Corvette six-speeds.

Upon removal and cleaning of the transmission's five bearings, ZR51 Performance's owner, Bill Boudreau, did not find a problem. Though it wasn't necessary, I had Boudreau install a new set of genuine ZF Industries bearings (PN 1052BRGK) and a seal kit (PN 1052RBK) we ordered from one of the better sources for ZF six-speed parts, Rockland Standard Gear.

A week later, with the transmission back in car, we took a road test. The vibration was still there. Rats.

The Right Angle


Most driveline vibrations are either one excitation per revolution, typically coming from imbalance or run out, or two excitations per revolution, which is usually caused by a problem with universal joint angles.

I began to wonder about the car's universal joint angles. Gary and I found that the car's rear upper control arms were not Chevrolet items. They were stamped "PONT" which I figured was an abbreviation for Pontiac.

Not having a set of stock Chevy arms as a standard and figuring these Pontiac arms could be of a different length, which would change the rear U-joint angle, I ordered a new set of reproduction Chevrolet arms (PN AU64RP) from Year One. I had them reinforced by Global West Suspension, painted them with Eastwood's Chassis Black paint (PN 10025Z), and installed them. The U-joint angle was unchanged. Several months later, I found out by checking the angles on a bone-stock early Chevelle at Auto Craft, a shop in Rialto, California, that specializes in restorations, the rear U-joint angle on my Malibu, 2.8 degrees, was nearly the same as the OE 3.0 degrees I measured at Auto Craft.

Thanks to the generosity of the Autocraft guys in letting me crawl around on their floor for a while measuring the driveshaft angles of their Chevelle with a Dana AngleMaster II, I found the vibration was not being caused by a driveline angle problem.

Well, it was nice to know what wasn't the problem, but that's really all I had at this point: a lot of potential causes that were not causing the trouble.

I'm going to keep beatin' on this problem until it's fixed because I believe persistence always pays off. Next month, in Part Two, you'll find out whether it pays off or not. 

BAD VIBRATIONS

PART 2

Finally...the End of One Chevy Fan's Quest for Smoothness

BY HIB HALVERSON

In last month's issue we introduced you to my '65 Malibu. Remember? The hot rod station wagon (with a fuel-injected, 400 small-block, ZF six-speed, Global West suspension, four-wheel disc brakes, and Goodyear GS F1s on early-IROC 16-inch wheels) to which my significant other lovingly refers as either "that ugly blue thing" or "a slug?" My god, these women really know how to hurt a guy.

Do you feel my pain?

Okay. Enough of the sob story. This is also the '65 Chevrolet Malibu with the darn vibration I can't fix—at least so far.

In the first part of this story, while trying to eliminate the car's vibration troubles, we looked at everything from the rear tires to the transmission. But when we were through, we had nothing to show for our many hours of effort out in the shop, other than a couple of clues: 1) installation of a new driveshaft had altered the vibration slightly, but nothing we'd done had reduced it. 2) both the transmission output shaft and the rear axle pinion shaft seals were leaking—evidence the problem was driveshaft-related, because a shaft with a serious vibration may cause lip seals to leak.

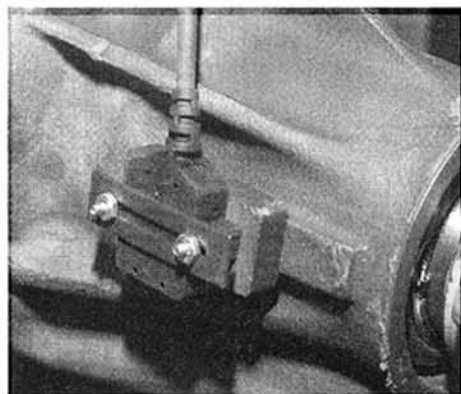
RUNOUT RUN-AROUND

Obviously, we'd missed something so I went



back to basics with some runout measurements. With the driveshaft installed on the vehicle, I measured .006 inch at the rear of the shaft, certainly not a large figure but possibly capable of causing vibration. On a whim, I tried an old trick: rotating the driveshaft 180 degrees. I road tested the car and viola! For the first time, the vibration lessened a bit. Finally, we were on the right track.

At the front of the shaft I measured .017-inch runout. That was unacceptable, so I sent the shaft back to Inland Empire Driveline Service, which built us the driveshaft for last month's article. Jeff Gilroy agreed the runout was excessive, blaming less-than-desirable tubing quality and warpage caused by rewelding the front weight. Inland built us a second unit which, measured off the car, had .002-inch runout, front and rear, well within tolerance. With the second new shaft installed, the vibration was about the same as after I flipped the first shaft on the rear yoke. The vibration began about 60 mph and peaked at 70-75 mph. We contacted Inland




The basic SPX Kent-Moore EVA2 kit. Tire size, axle ratio, and the speed at which the vibration is felt are entered with the keyboard. The car is then road tested at that speed, and the EVA2 screen displays the type of vibration and its intensity. Optional are a second sensor, which makes localizing some types of vibration easier, and a strobe light that allows the user to balance a driveshaft on the vehicle.

Driveline Service again. They stated the second shaft was perfectly balanced and were at a loss of what to do next.

From Page 71

Until we used vibration analysis equipment, we couldn't differentiate between first- and second-order driveshaft vibration. When we measured the stock U-joint angles, they seemed incorrect. We spent more than a month fooling with these angles because we'd incorrectly assumed there was a problem with them. We should have examined a bone stock early Chevelle sooner than we did.

The most significant lesson of this project was: had we had access to the Vetronix MTS 4100 at the beginning; we'd have fixed the car in a week. 

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We needed a service facility that could analyze vibration from a whole-vehicle perspective. Jim Cook, owner of Performance Differentials, which did the rear axle work detailed in Part One, suggested Powertrain Industries in Garden Grove, California.

ANOTHER NEW SHAFT

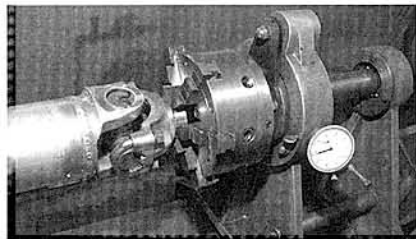
Powertrain Industries' Operations Manager, Brian Arvizo, wanted to start with a new aluminum shaft built in-house, which the guys at Powertrain manufactured before we arrived. A drive-on hoist made the swap go quickly. Soon, we were back out on nearby Interstate road testing. The vibration was unchanged.



Powertrain Industries' Brian Arvizo measures pinion yoke runout. Mount the dial indicator securely. You must index as close to the center of each U-joint cap as possible and make sure the plane of the U-joint cap is 90 degrees to the dial indicator pintle when the reading is taken.

Brian took dial indicator measurements of the rear U-joint caps which showed the pinion yoke was machined such that the centerlines of the pinion shaft bore and the universal joint were not concentric. This would cause runout at the rear of the driveshaft and could be a reason why a shaft that balanced perfectly off the car would vibrate on the car.

Brian decided to rebalance the driveshaft with the rear yoke attached so the balancing process would compensate for the runout. We hadn't done this before because, up until we took the car to Powertrain Industries, the capability wasn't available.



Not all driveshaft services can balance a shaft with a pinion yoke attached. However, if your pinion yoke has run out, that method may be your only solution.

Powertrain's Danny Paz marked the pinion shaft and the nut, then removed the nut and the yoke. On Powertrain Industries' balancer, Miguel

Flores spun the shaft with the rear yoke in place. There was an obvious imbalance, which he fixed with slightly more weight. We slipped the yoke back on the pinion, tightened the nut until the marks lined up, popped the shaft back in the car, and went out for another road test.

Miguel Flores adds weight to the Malibu's aluminum shaft to compensate for pinion yoke runout. Spinning the driveshaft with the weight held by tape validates weight changes. Once the proper amount of weight is determined, it's heliarced in place.



Wow! Progress! For the first time, the vibration had decreased significantly. In fact, below 65 mph, I couldn't feel it.

MTS 4100, THE FINAL SOLUTION

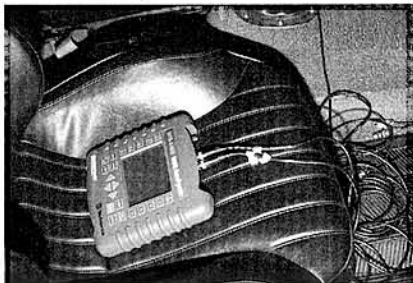
The Vetronix Corporation of Santa Barbara, California, is well known to Chevrolet service technicians for its TECH 1A, TECH 2, and Mastertech scan testers. In the fall of 2001, Vetronix introduced the MTS 4100 NVH Analyzer, a piece of electronic equipment that will revolutionize noise, vibration, and harshness (NVH) testing at the dealer and aftermarket service, performance tuner, and even DIY levels.

The MTS 4100 is based on a device Vetronix makes for car company assembly line use. Vetronix President, Jim Zaleski, explained to us that, "Vetronix is known as a company that delivers leading-edge technology to the automotive service industry. The MTS 4100 NVH Analyzer brings to the aftermarket the same accuracy and speed in noise-harshness-and-vibration analysis that original equipment manufacturers use for end-of-line quality control."

We found that the MTS 4100 is unlike any other vibration analysis tool in its ability to isolate and identify hard-to-find NVH problems originating from the wheels, driveline, or engine. During a demonstration by Vetronix engineer Kevin Gehris, I was impressed by how quickly and easily the 4100 analyzed engine vibration from a sample vehicle. Gehris stated that, with many cars, it can just as easily balance driveshafts while they are installed in a vehicle. At that point, I challenged Gehris and his 4100 to fix my Malibu's problem.

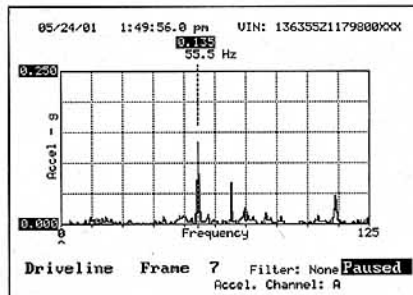
Several weeks later I was back at Vetronix with the Chevelle. Gehris took 15 minutes to attach its accelerometer vibration sensors to the

passenger seat rails and program the device for use. Then, off we went for a 15-minute road test. As I drove at speeds of 60-80 mph in 5-mph



The Vetronix MTS 4100 is wired for road test use in the Malibu. When this image was recorded last June, the 4100 was still in the final stages of development. Since then, it was introduced to the market and promptly named to the Motor Magazine "Top 20 Tools" list for 2002. One nice thing about this device is its ergonomics. You hold it securely with two hands, using your thumbs to push buttons at the side and along the bottom of the screen.

increments, Gehris used the MTS 4100's data-recording feature. At about 70 mph, I heard Kevin say, "Well, there it is." He held the 4100 towards



Here's the MTS 4100 data recorded during our first road test. The tall spike at 55.5 Hz below the dotted-line cursor indicates a first-order driveshaft vibration at about 70 mph. (Image Vetronix Corp.)

me, and I quickly glanced at the screen. It showed a vibration spike at 55.5 Hz, the frequency of a first-order vibration at 3,330-rpm driveshaft speed or 69.21-mph vehicle speed.

Back at Vetronix, we got the car up on jackstands. Gehris put a piece of reflective tape on the driveshaft near the rear U-joint. He set the



After running the car on jacks at 70 mph, the 4100's solution is presented to the operator. It tells the amount of weight necessary to balance the shaft and where it is to be positioned. (Image Vetronix Corp.)

4100's optical sensor on the shop floor and aimed it at the silver strip. The tape strip triggers the optical sensor giving the 4100 the driveshaft's rotational position at the time of the trigger incident.

The 4100's sophisticated computer hardware and software allows on-car balancing of the driveshaft in two radial planes, front and rear, independently. While more time consuming than a single-plane balance, a two-plane balance is the best choice for a vehicle with a long driveshaft turning at high shaft speeds. Gehris selected the 4100's two-plane balance mode and we began the process.

We ran the powertrain at an indicated 70 mph—or a little over 3,330-rpm driveshaft speed. The MTS 4100 processes the periodic triggers from the optical sensor. Then, the vibration sensor inputs the data from its built-in timer and displays on its screen the amount of imbalance, the amount of weight necessary to balance the shaft, and where, in relation to the silver stripe, to place that weight.

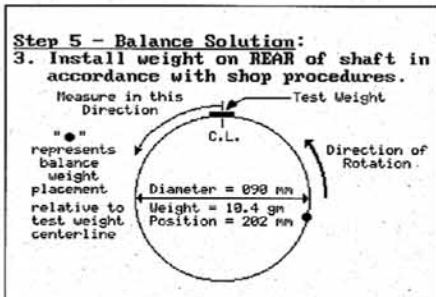
The front imbalance was 13.5 grams per centimeter (g/cm). The amount of weight needed to correct that was 3.0 grams. (0.106 oz). The weight was to be positioned 7 mm from the silver stripe in the direction of shaft rotation. The rear imbalance was 44.9 g/cm. The amount of weight needed was 9.9 g (0.349 oz.) positioned 268 mm from the stripe.

The EVA2 and the MTS 4100 can balance driveshafts on cars, but a significant difference between the two is the 4100's ability to supply positional information for weight placement. What supplies position information is this optical sensor, being set up by Vetronix's Kevin Gehris, and a silver stripe placed on the driveshaft.



Kevin temporarily affixed those weights to the shaft with cable ties, and we ran the car again. On the 4100's screen, the 55.5Hz vibration was, for practical purposes, gone. Imbalance had been reduced from 13.5 g/cm to 2.9 g/cm at the front of the shaft and from 44.9g/cm to 4.6 g/cm at the rear. Both are huge improvements.

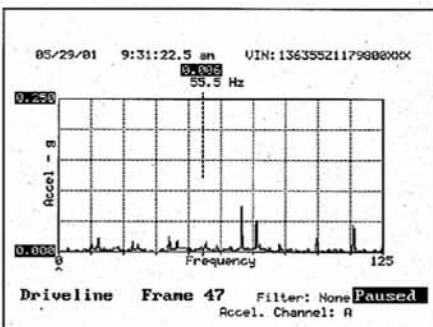
At the time this article was written, Vetronix was still developing the method it will prescribe to 4100 users for permanently attaching weight to a driveshaft without welding. Our Malibu was part of a test to validate the procedure of



The key to making on-car driveshaft balancing practical in the field is a secure, durable method of affixing weight to a driveshaft without welding. The method Vetronix has developed and is testing (using our Malibu and a number of other vehicles) is small lead weight(s) held to the shaft with a stainless steel and epoxy adhesive. A special tool is used to tighten, then lock the band.

attaching the weight to the shaft with an epoxy adhesive. A stainless steel band, similar to that used to retain CV-joint boots on front-wheel drive cars, was put around the shaft and over the weight. In four spots, the inside of the band was epoxied to the shaft.

With the driveshaft rebalanced, we went back out for another test drive. At 60, 70, then 80, and even 90 mph, the vibration was finally—gone. I was just about speechless. I'd been working for a year and spent several-thousand dollars trying to solve this vibration with, at best, only partial success. Gehris had completely eliminated the problem in a single, two-hour session using the MTS 4100, a little over a third of an ounce of lead, and a couple of steel bands.



Here is the 4100's graphical display during a final road test with the rebalanced driveshaft. There's little sign of the 55.5Hz vibration.

At this writing, about two months after my visit to Vetronix, the banded-and-epoxied weight has withstood operation at 110 mph, and both the car's transmission output shaft seal and the rear axle pinion seal have stopped leaking. The car is vibration—free and once again a hot rod.

CONCLUSIONS

Ninety percent of the time, the process used by most driveshaft services does a reasonable job of balancing. This article was about that other 10 percent. Our Malibu driveshaft and rear yoke,

as a unit, appeared to be balanced at 2,500 rpm off the car, however, when run at 3,000 rpm or higher on the car, it vibrated.

Most driveshaft balancing machines hold the shaft assembly in floating mounts. An electric motor spins the shaft at about 2,500 rpm. With balancers that are not properly maintained, there will be a measure of inaccuracy or lack of sensitivity. Lastly, we think that the 2,500 rpm or so that many balancers' shafts spin might not be fast enough to demonstrate small imbalances that can be enough of a factor at 3,000 rpm or above to cause a noticeable vibration.

In the case of this Malibu, its driveshaft was very long for a one-piece shaft, 57.25 inches. In many cases the longest shafts driveshaft shops can make are 60 inches. Many vehicles with drivelines that long use two-piece shafts. With a 57.25-inch shaft that's 3.5 inches in diameter, a small, out-of-balance condition can be amplified into quite a vibration simply due to the shaft's length and mass.

Chevrolet transmissions with 32-spline output shafts may have slip yokes—even new ones—that are loose because there are two "versions" of this spline design. If you have a yoke with a 1.395-inch major diameter but a shaft with a major diameter of only 1.375, you've got the wrong yoke and the resulting .020-inch free-play will cause a vibration.

Rear-axle pinion yokes for older Chevy 12-bolt and 10-bolt axles, especially aftermarket parts, may have too much runout to run vibration-free unless the driveshaft and the yoke are balanced as an assembly. Pinion yoke runout specifications for older vehicles are tough to find, but GM often suggests maximum runout and a method of measurement for newer vehicles. If you check runout the way Brian Arvizo at Powertrain Industries did with our Malibu, with shaft speeds one gets from axle ratios in the mid-to-high threes and tires typical of many street high-performance cars, assume runout more than .005 inch may cause a vibration.

The vibration environment was something to consider. We had a street-driven vehicle that was fairly quiet inside and had no other significant vibration problems. It had very low-compliance, Global West "Del-A-Lum" rear-lower control arm bushings, and an Energy Suspension polyurethane transmission mount. Both transmit driveline vibration more efficiently than stock parts. The car is a station wagon having some large, near-flat surfaces that amplify or resonate some types of vibration. The combination of a low axle ratio and an overdrive transmission results in high driveshaft speeds. We had a long, large-diameter shaft—a lot of mass spinning at high rpm. All these factors combined to make this a worst case scenario as far as a platform to create vibrations and transmit them to the interior.