

FOURWHEELING ACADEMY

TIRE INFLATION GASES

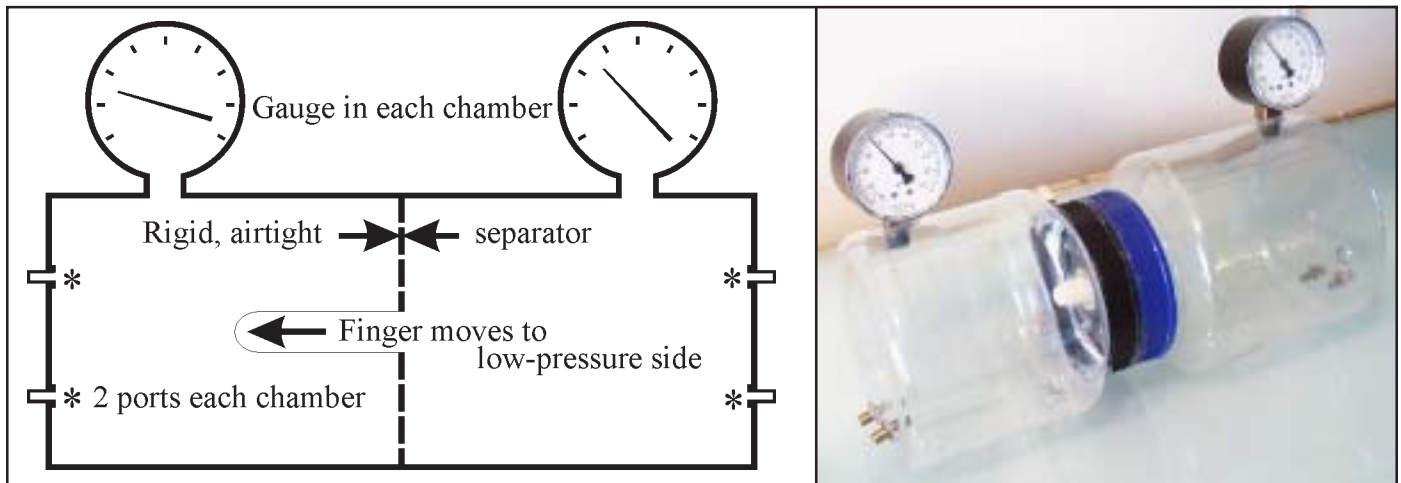


Figure 1 Left is the tire inflation gas test fixture schematic and right is the actual fixture with the pressure indicator “finger” in the neutral position. This means the pressure is the same in both chambers as indicated by the gauges.

By Harry Lewellyn

This article looks at how temperature affects various gases used to inflate tires. Normally, you’d expect the pressure to increase as the tire heats up. Some racers believe pure nitrogen holds a given pressure and does not react to heat buildup. Other folks believe carbon dioxide changes more with temperature than air, and is detrimental to the rubber. Still others think that moist air will rust the steel belts in the tires. I’ll report on air vs. nitrogen vs. carbon dioxide vs. helium temperature/pressure effects. I’ll save the possible detrimental effects of carbon dioxide and moisture for another article.

I will use the word “gas” to include air, nitrogen, carbon dioxide and helium. When I refer to a specific gas, it will be named.

I included helium to compare it to carbon dioxide. CO₂ is 1100% heavier than helium, whereas air is only 1% heavier than pure nitrogen. If weight

(mass) has anything to do with heat and expansion, it will certainly show up when helium and CO₂ are compared.

I know the fur goes up on the back of the necks of some when I make reference to science. For the scientist (physicists and engineers), I’m reinventing the “gas” wheel with what follows. For the skeptic, the test fixture (see Figure 1) should graphically demonstrate, beyond a doubt, how pressure, relative to temperature, is identical for all gases.

BACKGROUND

According to Robert Boyle, (1660), and Gay-Lussac (1802), scientists who extensively studied how gases “work,” the racers’ nitrogen belief just can’t be true. Most conclusive is Gay-Lussac’s studies. He found that all gases expand at the same rate with heat. That is, the coefficient of thermal expansion is very nearly the same for all gases and combinations of gases. In contrast, the coefficient of thermal expansion for other

states of matter (liquids and solids) varies widely! This means nitrogen gas expands at the same rate as does air when heated. If any gas is in a closed, fixed-volume container, like a tire, the pressure will vary with a change in temperature.

See **GAS/p3**

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MORE ON M/TRs

By Harry Lewellyn

Jimmy Nylund (past tech editor for Petersons) gave me a call re last month's article on MT/Rs. He offered some insights, info and advice.

For whatever it's worth, he claims the MT/Rs that were first used in competition had a different tread compound than those currently available off the shelf. He called it a "cheater" compound – softer than normal rubber that significantly improves traction.

He also correctly pointed out I may have misled you re load range rating and

plys. I said, "...you need light truck (LT) or load range C... 3-ply sidewalls..."

Neither LT nor the load range guarantee the number of plys. I based my statement on the "average" size 4X tire with a typical load range of B or C.

Larger, higher load range tires (E, F, G) may have fewer plys, but still be just as strong, maybe stronger. I've never used them. In summary, a specific load range rating does not set the number of plys.

We wandered on to talk about weights and the tire moving on the wheel with extreme use. To keep track of this,

I typically use nail polish to mark the valve stem and weight locations, which eventually wears off. He uses his Dremel® tool to harmlessly notch the rubber at the various locations. That won't come off!

I've moved and knocked weights off the wheels by accident, but he cures that with GOOP®. He glues the weight to the wheel and claims it keeps them in place most of the time. He and I both are great fans of GOOP®.



By Ed Hooper and Harry Lewellyn

MOON PHASES

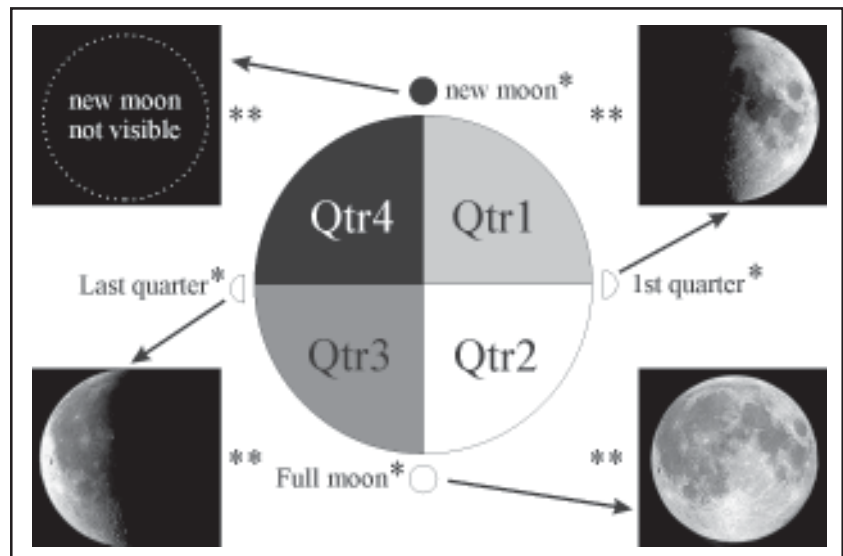
Last issue (March-April, p. 5), we wanted to know why a calendar shows a fully filled circle for the full and new moon, but shows a half-filled circle for the first and last quarters. Why isn't it a quarter circle.

First, no one caught my graphic mistake. I swapped the full moon and last quarter symbols.

Uwe Luettringhaus got the answer. It has to do with the phases of the moon. The symbols show the very end of each phase (see right).

At the new moon, we see nothing, hence the black circle. At the first quarter, we see a half-moon with the (sun) illuminated side to the west. At the end of the second quarter, we see the full moon. At the end of the next (third) quarter, we see a half moon facing east.

I'm still confused as to why the third quarter is called the "last quarter" on a calendar. According to Ed, it's officially the third quarter per "Discovering the Universe" by William J. Kaufmann III, W. H. Freeman and Co., pages 21 and 22.



*Phases of the moon * = as represented on a calendar. ** = as you see it in the sky. Go to http://aa.usno.navy.mil/faq/docs/moon_phases.html for the complete story and neat pictures.*

Ecological WHEELING ADVENTURES

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Copy Editor: Bill Kane
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ECO4WD is committed to passive appreciation of Mother Nature and ecological backcountry travel on unpaved roads.

The ECO4WD newsletter is published every other month. Subscriptions are \$14 for six issues. January through September features the Coyote's technical articles. The 40-page November-December *Bonus Issue* is the only issue that contains advertising. Contact ECO4WD for advertising rates or to receive a free *Bonus Issue*. Bulk copies are also available. For *Newsletter Reprints* on selected topics and back issue orders, see page 10. Back issues are \$3.00 each.

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GAS, from page 1

TEST FIXTURE

Figure 1 (left side) is the design schematic for the test fixture. On the right is the actual apparatus used for the tests. It compares gas expansion/contraction, literally, side-by-side.

In essence, it's two chambers, joined at the middle, with a very sensitive membrane in between. The flexible membrane is the finger from a latex glove and the chambers are peanut jars. I suppose you'll have to take my word for it, for the size difference in the jars makes no difference whatsoever. Except as noted below, we're looking at pressure, not volume. The effect of temperature on gas pressure is independent of volume.

Two pressure gauges (one Swiss made, Noshok, bellows-type, 0-5 PSI gauge in each chamber) independently read the pressures in the chambers.

Two ports per chamber made it such that I could simultaneously introduce and exhaust a gas into/from a chamber. The ports are hose-connect tire valve stems that take a standard tire valve core. Cores were used as needed. In essence, I wanted to make sure I could empty a chamber of the original gas, while introducing another gas. Simply filling the chamber through one port wouldn't do that. Two ports ensured a relatively pure gas inside the chamber each time it was changed.

The heart of the test fixture is the flexible, "fickle finger of fate." Picture if you held it to your lips and blew, it would inflate away from your face, and with a suck, it would move into your mouth. This means the finger will always move toward/into the chamber with the least pressure. Most importantly, if the finger does not move (actually, regardless of position), there is no pressure change between the chamber gases. So, if the gas in one chamber, say nitrogen, doesn't expand with heat, and the other chamber's gas does, the finger will so indicate.

A "point and shoot" IR (infrared) thermometer was used to measure chamber temperature. With this, I could make some brief calculations to compare observed pressure change with temperature change. These tracked as anticipated.

FIXTURE CHECKOUT

I first tested to see how easily the finger moved while in the test fixture. I attached a hose to one of the ports (no

core) and used my lungs. All other ports were closed with valve cores. The finger would change from side to side with blow and suck. Finger creep (slight movement) could be seen with next to no pressure (one needlewidth, ~0.01-PSI) indicated on either gauge.

On one occasion, while carrying the cold fixture into the house, I noticed the

chambers, I tested for leaks. The slightest leak of any sort would invalidate the tests.

To help reveal leaks, although the actual tests would be performed at a lower pressure, I raised the pressure to 2 PSI in both chambers. The finger was then adjusted to the neutral position and everything kept at a constant temperature. This would test for external leaks and could indicate chamber-to-chamber leaks. I also introduced a pressure difference (finger displaced toward the low-pressure chamber) to positively test for chamber-to-chamber leaks. I observed each condition for 24 hours. All leaks were eventually plugged.

After chamber-to-chamber and external pressure integrity was confirmed, I purposefully raised the pressure in one chamber until the finger moved into the low-pressure side, then observed. This was then reversed, chamber-wise testing for chamber-to-chamber differences. I found none.

With the slow cooling of night and the warmth of day, I expected to see the fixture finger and gauges remain in a set state, that is, finger neutral or displaced, and no chamber pressure difference. I anticipated the chamber pressure would raise and lower with temperature, but no pressure difference should develop if the historic scientists were correct. The results showed both chambers heated and cooled at the same rate.

Next, differential temperature effects were observed. With the finger in the neutral position, one chamber was heated with a hair dryer or surrounded by ice. This would temporarily expand or contract the gas within that chamber, and the finger should be affected accordingly. It was.

All pre-tests were performed with air only. After considerable patching, the test fixture was made leak proof and it was shown there were no side-to-side leaks or differences. The fixture performed as desired.

TECHNICAL CONSIDERATIONS

This subsection is complicated, but I feel I must address as many of the subtleties as I can think of to convince the skeptics that I've done my homework. If my words leave you glazed, you won't miss anything by skipping to the next subhead.

See GAS/p7



Figure 2 The top two photos show the finger in the neutral position. The bottom photo shows the finger extended (lower pressure in this chamber).

finger move. Further investigation proved body heat (my hands on one end) had expanded the gas in that end enough to move the finger. That little finger is one very sensitive pressure difference indicator (see Figure 2)!

Since my experiments involved the fixture sitting overnight to stabilize the temperature of, and the gas within the

FOURWHEELING ACADEMY

ANTI-SWAY BAR BUSHINGS



Figure 1 Factory rubber bushings deteriorate with exposure to the elements and stress.



Figure 2 Rubber bushing deterioration leads to washer failure.

By Harry Lewellyn

There are many tricks to make your 4X's suspension just right. The type of suspension (solid axle or independent), springs (leaf, coil, torsion bar) and shocks all play into the equation, but regardless, you must eventually couple the suspension to the frame. This is where suspension bushings come into play.

BUSHINGS DEFINED

The bushings are the fat, supple grommets that make this connection. They "flexibly" couple two very rigid elements (suspension and frame) and thus take tremendous abuse. Through every bump and turn, they are flexed and stressed beyond belief. OEM engineers do their best to achieve perfection, but the bean counters eventually get into the act at the corporate "bottom line." Their influence typically trades potential perfection for the compromised performance and short life of rubber bushings.

BUSHING DETERIORATION

Figures 1 and 2 show what time and use have done to factory rubber bushings and metal washers on Jenna's Toyota. Automotive chemicals like gas and oil, road salt, plus the atmosphere (primarily oxygen in the form of ozone) take their

toll on the rubber bushings' exterior. This breakdown eats away at the rubber and leads to deep surface cracks.

Weakened by deterioration, the malleable inside eventually succumbs to the stress of black diamond roughies. The rubber, now less substantial than originally manufactured, is stressed beyond its limits. This leads to more force on metal-to-metal contacts, and ultimately, deformation. The distorted washers (above) show what stress does when rubber has been pushed too far.

Wear and tear on the outside and inside of the bushing leads to mushy handling and poor steering response. Eventually, worn bushings must be replaced. Consider polyurethane.

WHY POLYURETHANE?

The advantages of polyurethane over rubber are numerous. Starting on the outside, polyurethane does not rot or deteriorate. It does not break down like rubber.

Durometer is the scale used to measure the hardness of materials that are softer than metal. Rubber has a hardness of approximately 45A to 65A durometer in its free state. But when compressed into a shell for use as a bushing (also known as pre-load), it will increase and can vary. Also, when rubber



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Figure 3 Energy Suspension bushings, hardware and lubricant ready to install.

breaks down, the preload changes. This affects handling and performance.

The durometer of polyurethane can be “tuned” to the application. For example, if you have two different materials of the same durometer, one can be made more abrasion-resistant or can have higher rebound qualities. Energy Suspension’s automotive-specific polyurethane material varies from approximately 70A to 95A. But more significantly, it does not change because it does not break down. It retains its shape and durability over the life of the bushing (5 to 10 times longer than the life of rubber bushings).

Rubber bushings also see more and different stresses than their polyurethane counterparts. In some bushings, the rubber is bonded to a metal shell at the outside and a metal sleeve on the inside. As the rubber bushing does its job, stress twists the rubber and strains the bond.

Energy Suspension does not bond polyurethane to metal, so the bushing freely rotates thus eliminating this added stress. This also allows the suspension to travel through its whole range of movement without binding. As 4-wheelers, we need this when the going gets tough! Rubber bushings start to bind up at only seven degrees of rotation. This

either limits the suspension travel, stresses or damages the rubber bushing or both. This is where aftermarket products come into play.



Energy Suspension has been in the polyurethane component and bushing business (aftermarket and selected OEM) for more than 20 years. Over this time, through testing, it has made great strides in suspension bushing design, material properties and manufacturing processes. This primarily centers on the material used in the bushings, but manufacturing methods and product design also play a major role. Energy Suspension uses nothing but the latest in computer controlled mold building technology and robotic manufacturing. It also makes body mounts, bump stops, shock boots, tie rod and ball joint boots, shock reservoir isolators, and motor and transmission mounts and inserts.

According to founder and president, Don Bunker, “We are proud to offer our customers the finest performance polyurethane suspension components available in the marketplace today.”

HYPER-FLEX

As much of an art as it is a science, Energy Suspension calls its polyurethane “Hyper-Flex.” American-made in-house through and through, you know Energy Suspension has immediate, complete control over materials, manufacturing and quality.

Energy Suspension fine-tunes the durometer of each bushing depending on the application. Hyper-Flex is also freeze resistant, which keeps the handling consistent in cold or hot weather.

INSPECTION

A “bell-like” rattle sounded a worn bushing alarm in my case. The problem with wear, over time, is that you unconsciously adapt to the handling degradation. It would have been more prudent for me to have made an occasional visual inspection. That’s easy.

Experience shows the leading edge of a bushing takes more abuse than the backside. The outer wall of your shocks (leading vs. following) reveals just what’s going on under there! The entire bushing is exposed to the elements, but the leading edge takes more of a continual pounding from rocks and gravel than the

See **BUSHINGS/p6**

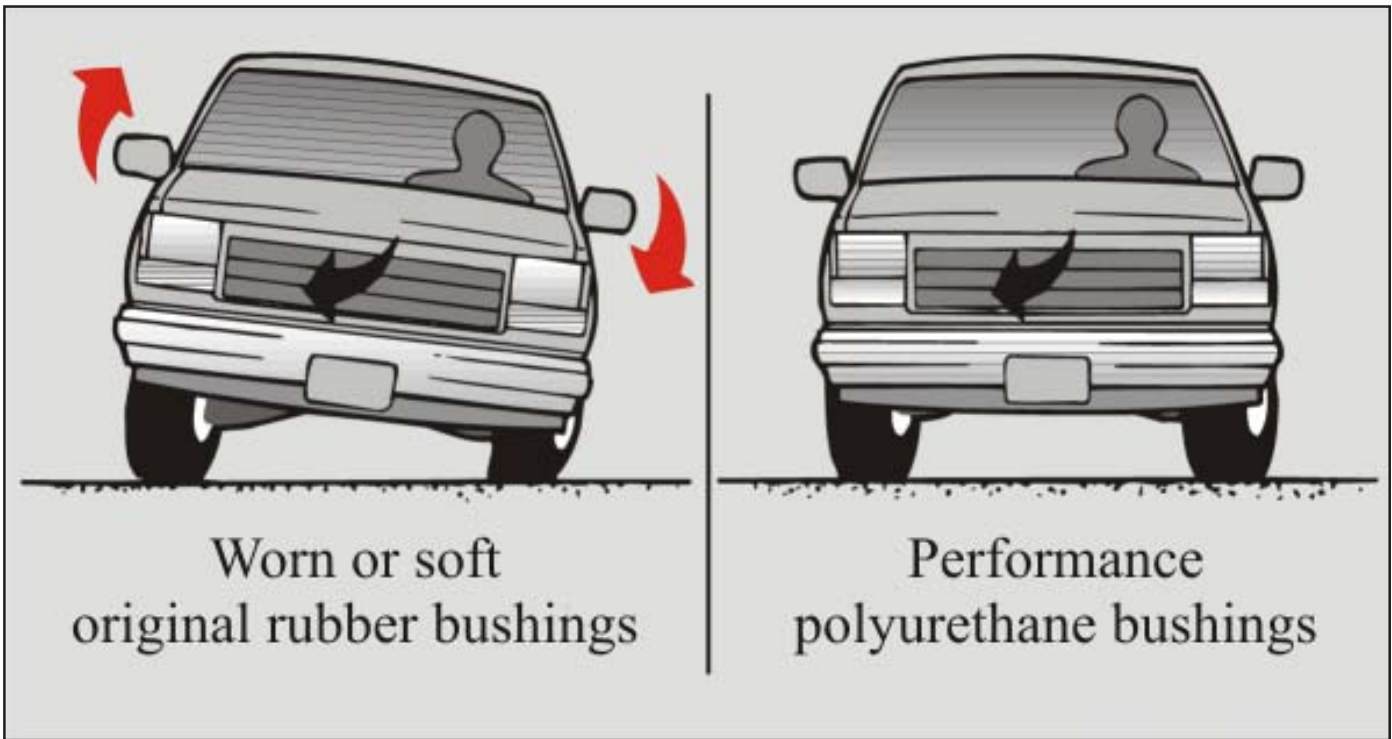


Figure 4 Anti-sway bar action: rubber versus polyurethane bushings (drawing courtesy of Energy Suspension).

BUSHINGS, from page 5

backside. Start by looking at the leading edge.

Besides bad handling, cracks and voids are one of three replacement indicators. The other takes a little experience and evaluation.

Like a beer belly sagging over a belt, do the bushings seem to be bulging over the washers? Are the washers more or less parallel to each other, equidistant around and over the bushings and centered in the receiving holes? Do all of the washer-to-bushing “fits” seem the same? If one shows a quarter inch gap between a pair of washers and all the rest are twice that, the skinny guy is dying, but don’t stop at just replacing one. It’s important to replace all or none. One good guy and three questionable hombres may lead to irregular handling. Replace ‘em all!

EASY VS. HARD

Some bushings are relatively easy to replace and others require specialized knowledge, skill, equipment and wheel realignment. Shock and sway (stabilizer) bar bushings fall into the former category while shackles, control arms and strut

bushings are more difficult. This article treats sway bar bushing replacement (see Figure 3, page 5).

SWAY BAR FUNCTION

The stabilizer (anti-sway) bar reduces body lean on highway-speed curves. It’s like a crosswise torsion bar with a lever at each end. These are connected to the suspension via end links (defined below). As a turn compresses the suspension on the outside of the vehicle, some of this “down force” is transferred to the inside via the sway bar. It attempts to keep the body level in a turn (see Figure 4).

BUSHING REPLACEMENT

Typically, a pair of cap screws at each of two U-brackets (and bushings) holds the central portion of the sway bar to each side of the frame. End or drop links (vertical extensions at each end) connect to the suspension. If the body and suspension are level, there’s virtually no stress on any of this, thus making it pretty straightforward to remove and replace the bushings.

The Energy Suspension instructions were clear and to the point. You have to grease certain surfaces, and make sure each bushing and washers are in the correct order and centered over the receiving holes. Note there is a right-side-up for the washers, too.

I was also impressed with Energy Suspension’s use of zinc-plated hardware, grade 5 bolts and nylock nuts. With this, it’s unlikely that anything is going to rust, break or come loose.

REPLACE WORN BUSHINGS

Besides being completely worn out, as mine were, there are three reasons to replace soft rubber OEM bushings: performance, durability and appearance. Suspension bushings make a difference both on and off highway. Inspect and replace as necessary. Jenna’s Toyota felt like a new car after replacing just the sway bar bushings. Try it. It’s easier than you think!



GAS, from page 3

As long as the finger is not stretched, air pressure is the only force acting on the position of the finger besides gravity and latex “memory.”

To test the effects of gravity, with the test fixture horizontal (as pictured in Figure 1, right side), I inflated both chambers to the same pressure where the finger was in a crumpled flat, neutral position (see Figure 3). The test fixture was then flipped 180° (gauges down) and also turned upright (90°) in both directions. The flattened finger moved (hung down) with the 180° flip and slightly moved when turned upright, either direction. As best I could, I reinstated the blow and suck test to see if I could feel or measure any significant difference between the various positions. I couldn't. Further, I knew I could set the finger's neutral position to midway (not hanging out either side as in Figure 2, center and right). I presumed this would minimize the influence of gravity on finger movement.

“Memory” (force) is that quality of flexible things that makes them want to return to their original form or position. Try to take a regular balloon and make it lie completely flat on a table. Some, if not all, will try to jump back to an irregular or semi-inflated shape.

The finger, when crumpled, would mildly try to jump back into a “ready to inflate” form. Since there was nothing I could do about this, and I could very easily move the finger back and forth between chambers with very slight pressure, I neglected the “memory” factor.

If the finger is stretched by air pressure, the elasticity of the latex now enters into the balance between all of the forces, and thus could influence the tests. In other words, when stretched, the gas pressure within the finger must not only overcome the external gas pressure (force) to move, but it must also stretch the rubber to expand. This takes force. You feel this when you try to inflate a balloon. It straightens out easily, then you must blow harder to continue inflating it. To eliminate this, I avoided finger stretch while testing. I felt “limp only” movement would not be influenced by the “stretch” force factor.

As a side point, with stretch, I watched a pressure difference develop between the gauges, which verified the “stretch” force factor. This may explain why the apparently infallible differential pressure rule seems not to apply to tire

pressure measurement as reported in several past articles. These reported the effects of altitude on tire pressure measurement and the footprint.

I was also concerned with the “piston” effect of the finger moving in and out of the chambers. Picture the finger to be a large piston. As it moves from one chamber into the other, it is compressing the air in the chamber it's moving into and reducing the pressure in the other. It is literally changing the volume of the two chambers. I reasoned although this would definitely play a part in chamber pressure, the finger would still move easily. Finger movement of



Figure 3 *Finger in crumpled flat, neutral position*

any sort would definitely indicate a pressure change, which was exactly what I was investigating: thermal expansion differences between various gases.

To further put my mind at ease, I calculated the volumetric significance of the “finger piston.” At its maximum, prior to stretch, the finger represents only 0.647% of the larger chamber volume and 0.789% of the smaller one. As a result of all the above, I neglected the “piston” factor.

I also wanted to see if specific heat (a “heat capacity” quality of all states of matter) influenced the rate of thermal expansion. In the quick heat and cool tests (explained below), I patiently looked for temporary finger movement. If one gas absorbed heat faster than the other, I expected to see the finger first move away from that gas. Then, as the other gas heated (caught up), the finger would move back. The CO₂ vs. helium would be the best for this test. I detected nothing relative to specific heat.

TEST PROCEDURE

I first filled (at various pressures) one chamber with a specific gas, then balanced the finger to the neutral position by adding or removing the other gas

(usually air) from the opposite side. The test fixture was allowed to temperature stabilize for a few hours, then, as needed, the finger position was reneutralized with the “air” side. This compensated for initial gas temperature differences. Most of the time, there was no need to readjust the pressure.

Next, I let the fixture cool on the patio overnight and observed it in the morning. This would surely equalize the temperature of the entire fixture and the gases within. If one chamber's content expanded (contracted) differently than the other, the finger would show it.

To explore temperature extremes, and speed observation, I would also place the entire fixture in the oven (100°F, pilot light only) and then the refrigerator (40°F). The gauges reported the expected pressure change and the results were the same as the overnight tests.

At the fixture's low test pressure, the temperature/pressure influence was more significant than originally anticipated. The above 60°F difference accounts for a 1.12-PSI change. As a result, I upped the minimum setup pressure (at 70°F) to 1-PSI. This kept the gauges in the plus and not at zero. Zero would have left me wondering what the pressure was.

All of the above was repeated with various gas combinations.

RESULTS

Boyle and Gay-Lussac were correct. Temperature affects all gases in the same way. It's a misconception that different gases react differently to temperature change.

THANKS

Thank you Darren Bradley (Spectrum Gas Products) for supplying the various gases. Darren has killer deals on CO₂ (tank) tire inflation systems.



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2003 Coming Events

EVENT	DATE	REMARKS <small>(See Bonus Issue N/L /p# for more info)</small>
San Felipe Sand Blast (H)	May 16 to 19	LAST CALL! Sand driving and local excursions /p27
Piute Passage (C)	June 7 to 8	Historic California tour /p28
Arrowhead Brunch	June 8	Easy back way into CA's San Bernardino mountains /p28
Hot Spring Mountain	June 21 to 22	Rancho Santiago College class (714) 480-7390
Land of Volcanoes (C/H)	June 21 to 23	Geologic California tour /p29
Hot Spring Mountain (C)	June 28 to 29	Resurrected! 2 skills-improving days at Los Coyotes /p29
Fat Hill Fandango (H)	July 19 to 21	Historic California/Ghost town tour /p30
Rubicon Rendezvous (C)	August 14 to 17	Camping roughie in Tahoe, CA /p30
Monache Meandering (C)	August 16 to 18	Historic California tour /p31
Arrowhead Brunch	September 7	Easy back way into CA's San Bernardino mountains /p28
By God, to Bodie (C/H)	September 13 to 15	Historic California ghost town tour /p31
Golden Leaves & Trails (C/H)	September 20 to 22	Historic California tour /p32
Death Valley II (C)	October 17 to 20	4WD camping mini-vacation /p32
Copper Canyon Mexico (H)	November 7 to 18	See Mexico's Barranca del Cobre up close /p27

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Death Valley I (H)	January 23 to 26	Furnace Creek Ranch-based backcountry tour /p23
Pinion Mountain (C)	February 14 to 15	Roughie, camping, skills trip /p23
Truckhaven (C)	February 28 to 29	Roughie, camping, skills trip /p24
Baja Whales & Rock Art (H)	March 5 to 11	Great intro to Baja — Open to 2WDs /p25

(C) = Camping trip

(H) = Hotel-based trip



= Schedule subject to change

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TRAIL TIP

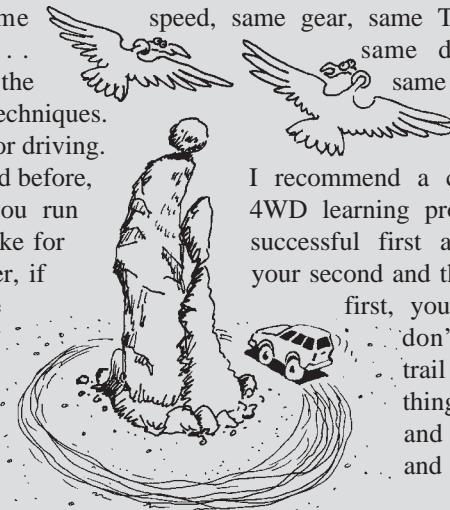
CHANGE SOMETHING

So obvious, it's often overlooked. Page 126 of SHIFTING Into 4WD offers this:

I have this bucket of red paint. I paint the fence. Oops, I wanted blue! Let's do it again. I grab the same bucket and paint away. Darn, it's still red. Several redos later and the fence is still red. How come?

You gotta change something to change something. If you think that's too simple to mention, you should see what I repeatedly see. Same hill, same track, same speed, same gear, same T-case range, same tire pressure . . . same disappointing failure! You'll get the same results if you repeat the same techniques. This is as true for life as it is for driving.

As I've preached before, you walk before you run does not always make for that's OK. However, if are identical to the crawl. When you you want, on the change somewhat to change comes with time



I recommend a crawl before 4WD learning process. That successful first attempts, but your second and third attempts first, you're stuck in don't get what trail or in life, thing! Knowing and how much and practice.

I don't think he knows he's driving in a circle!

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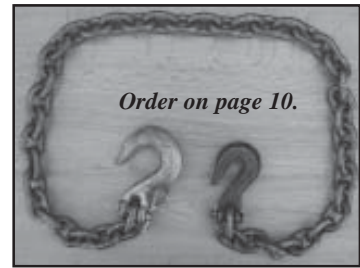
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You are free, but you can't connect...*



The Coyote Chain is your solution!

Attach the **slide hook** (left) directly to the 4X frame or use it as a choker to cinch up on anything, including the downed tree blocking your trail.

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Don't travel the backcountry without one!

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PERMANENT REPAIR: Road heat vulcanizes the plug through a patented repair process. It will not flow under heat or pressure. You make the repair once and it conforms to the shape of the puncture and outlasts the tire.

SIMPLICITY: The first 100% self-vulcanizing rubber-fibre material, *Safety Seal* uses no messy cement. With the patented insert tool, tires can be plugged in minutes, *on the car*, with little effort.

SAFETY SEAL is made from the same ingredients as the tire itself. It is 21 plies of high-grade synthetic fiber completely embedded in a super-sealing vulcanizeable rubber composition. Each yarn is individually coated and then twisted into a durable plug.

Kit comes with a durable 8" x 12" x 3" plastic case, pictorial instructions and 60 plugs.

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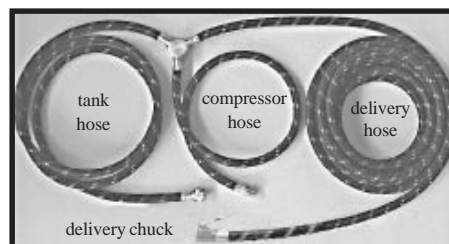
Coyote AIR ROBBER

UNLIMITED AIR: With an AR, you have air with or without a compressor.

SIMPLE TO USE: Connect the AR's screw-on valve stem chuck to any inflated tire. Use the custom lock chuck at the other end to air up.

INNOVATIVE DESIGN: Connect a compressor to the valve stem at the end of the 3-way manifold and you continuously replenish the source-tire while you fill the others.

QUALITY CONSTRUCTION: The AR is 22-feet long, has brass fittings, including a screw-on chuck, a valve stem and a clever lock chuck. **Order on page 10.**



**TRUCK AIR CAN'T BE
MATCHED FOR THE PRICE!**



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