March/April 2017 | V4 N2

PERFORMANCE TECHNICIAN

VACUUM PUMPS AND POWER OIL PUMPS PART TWO

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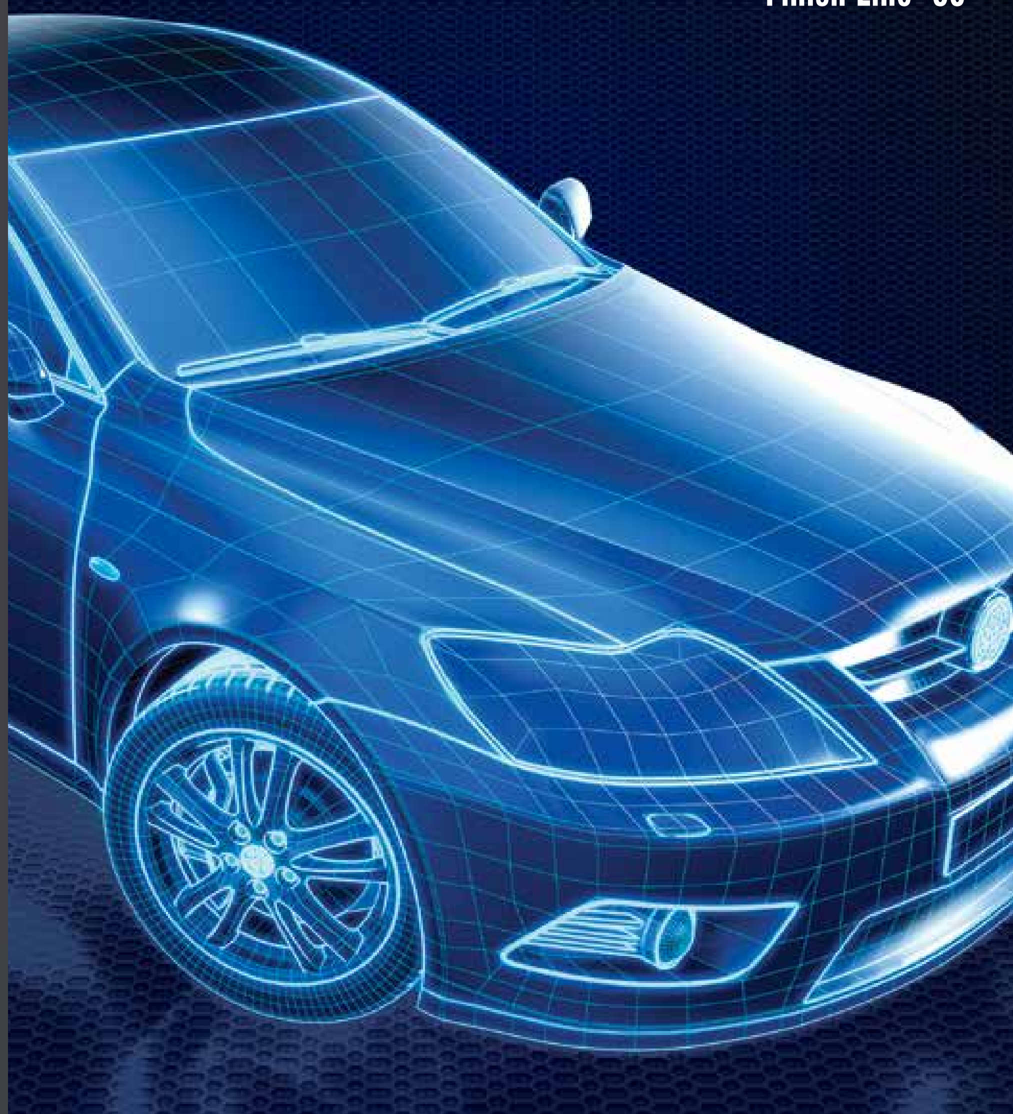
FEATURES

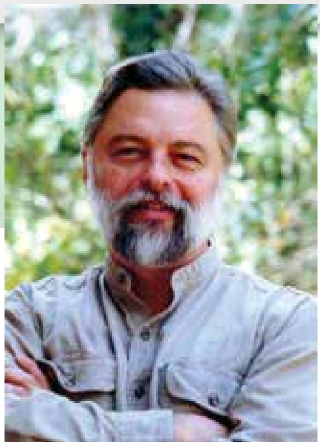
DEPARTMENTS



STARTING LINE

EARTH DAY NOTWITHSTANDING, THE SPORT DIDN'T DIE

-Robert Freudenberger



-Bob Freudenberger

Many years ago when I was an associate editor on the ***Motor's Manuals***, I got an offer to take over ***Speed Shop Magazine***. It had about 120,000 readers and was distributed through — you guessed it — speed shops. High-performance tech and drag racing were the topics, and even though I was a kid at the time there didn't seem to be anybody else available with writing/editorial skills in the New York area who had a clue about automotive technology or any form of high performance, whereas I'd just been working as a line mechanic at a Ford dealership, and running an L-Stock car at my local NHRA strip, Raceway Park in Englishtown, NJ.

I'll never know how the parent company, St. Regis Publications, got into the deal, but its owner, Lee Solomon, a brilliant man who'd been a New York Times reporter and always reminded me of an older Paul Newman, had about 35 different magazines (and lived in a two-floor apartment on Park Avenue — print publishing was a rich business in the days before the Internet), and somebody convinced him that such a publication had potential for advertising revenue.

Although it didn't pay very well, it was ideal for me because I loved drag racing and could keep my own hours, thus avoiding the commuter traffic in and out of Manhattan. I also got to attend various big meets on my press credentials with all expenses paid. I particularly remember the Spring Nationals in Ohio, where I met Linda Vaughn, "Miss Hurst," who was beautiful and sweet and drove me around in her golf cart to get my pictures. My magazine connection gave me the entrée to talk to big names such as Don Garlits, the inventor of the mid-engine dragster (today, he's the proprietor of the Museum of Drag Racing in Ocala, Florida), Grumpy Jenkins, and many others.

It also gave me plenty of opportunities to practice photography, a skill I learned from a couple of old Kodak books. I actually sprang for a Yashica DL1000 SLR with its Pentax screw-mount lens at something like $120 in those days, and the magazine bought me a Sun zoom that went to 210 mm. Back then, I shot with Tri-Ex black & white. Digital photography wasn't even imaginable at the time.

One day, Mr. Solomon asked me to meet with him at his home office — we were having a financial crisis with the magazine.

Speed shops were going out of business at an alarming rate, and SS had about $160,000 in bad debts — almost a million bucks in today's money. He had me do the math on advertising versus expenses with a pencil (no calculators yet), and it looked bad. He asked me if I thought "going out on the road" to sell ads would save us.

Besides basic honesty, Mr. Solomon had become a mentor and friend, so I had to tell him the truth as I saw it even though it was going to cost me my job. This was just a few years after the environmental movement had really gotten rolling with new regulations and Earth Day celebrations, and young people were becoming more interested in eliminating all forms of pollution than in the building of hot cars. It seemed to me that you'd have to be blind not to see that this trend was going to continue to seriously erode the speed shop business, hence the foundation of the magazine, and that's exactly what I told him. I even went so far as to call SS a "dinosaur."

My first cover photo!

So, Mr. Solomon quietly closed the magazine and ate his loss. He continued to pay me for a couple of months and gave me all the freelance work he could on his other publications — even layout of a cookbook! — so I was able to get by until I was hired as the executive technical editor of ***Motor Service*** and ***Service Station Management*** in Chicago. Thanks, Lee, wherever you are.

As logical and candid as I'd tried to be in my assessment of ***Speed Shop's*** future, looking at it today I think I may have given Mr. Solomon faulty advice. The number of speed shops did indeed decline, but perhaps we could have put the magazine's distribution on a different basis and kept it alive because the high-performance business sure didn't die. Motorsports are flourishing, and the annual SEMA Show in Las Vegas just keeps growing and growing in spite of environmentalism, regulations, looming electric cars, and complex engine management systems. I guess I just didn't get how tenaciously car enthusiasts would hang onto their hobby. ■

TECHNICAL MINUTE
VACUUM PUMPS AND POWER

-Greg McConiga

One racers' trick is the use of a vacuum pump plumbed into the crankcase to lower crankcase pressure. There are a myriad of positive benefits and gains, some obvious, some not so obvious, and there are certainly a couple of precautions that you need to be aware of if you decide to use one on your application, so let's take a look at them and how they might fit your program.

Reducing engine crankcase pressure improves external leak control, helps with ring sealing by increasing pressure drop across the ring pack and venting the area between the top and second ring more efficiently, improves crankcase pumping losses, has a positive effect on windage and oil contamination, and increases horsepower by aiding ring seal at higher rpm while allowing for thinner, lighter, lower-drag ring packages.

A lot of folks think that all of the horsepower gains made are just from running low tension ring packs and improving ring seal, but I think a good case can be made for the idea that if the piston normally "sees" a pressure of 100 psi on the top and a pressure of 14.7 or a touch more due to blowby on the bottom, then the total pressure drop across the piston is 85.3 psi.

Now, if we drop the crankcase pressure by 20 in. Hg, that's about 10 pounds per square inch, and the pressure drop across the piston is now 95.3 psi. Since torque is simply cylinder pressure times the stroke (or lever), engine torque has to rise — and horsepower rises as well by as much as 50-60 horsepower on some applications! Where, exactly, the power increases come from is open to discussion, but the dynamometer and the race track don't lie. Vacuum pump-equipped engines consistently produce more power on the dyno and lower ETs and higher mph at the track.

RACING-ONLY SOLUTION

Reducing engine crankcase pressures and providing positive crankcase ventilation isn't a new idea. It's been around on street cars since the advent of the positive crankcase ventilation (PCV) system first launched in the early sixties, and with the Pan-Evac system that was used by many racers as far back as the early seventies that I can recall, and they may have been around before that. The first time I remember seeing it in person was on Grumpy Jenkins's Vega out East at Cecil County or Atco when it was still a body in white (Navy uniform), but I seem to remember reading somewhere that Hedman Headers was an early leader in Pan-Evac.

The purpose of the PCV system isn't really for performance. It replaced the old road draft tubes of the fifties and before that swept the crankcase by passing air over a taper-cut tube as the vehicle rolled down the road. The problem with that was it provided very minimal air flow through the crankcase, and if the oil breather was restricted or there was any significant amount of blow-by the system was simply overwhelmed. The result was dirty oil and sludge, often to the point where one of the recommended services became pulling the pan off and cleaning it periodically.

Because the system was passive and open to the atmosphere, the hot, noxious vapors poured out of the tube and contributed to photochemical smog, that nasty reddish haze that hung like a dome over the big cities in the bad old days. The PCV system is a metered vacuum leak attached to a valve cover designed for best operation during part throttle, and it works to keep crankcases much cleaner, and reduces HC pollution of the atmosphere by recycling blowby from the crankcase back into the intake for more-complete burning. Of course, under high load conditions, the PCV stops working altogether as engine vacuum drops to near zero.

A side benefit to running any sort of crankcase vacuum system is a reduction or elimination of engine oil leaks. Even PCV-equipped street cars often remain drip free for many years if the system is kept clean and operational. While under ideal conditions, the PCV system might make a few inches of vacuum in the crankcase at high manifold vacuum levels, racers quickly figured out that they needed a different approach to maintain pan evacuation under load.

The Pan-Evac system taps the exhaust system with a taper-cut tube long enough to reach into the exhaust collector and "sense" exhaust gas velocity and a check valve to maintain one-way flow. The exhaust gas velocity created a low pressure signal and when plumbed into the valve covers provided a very slight negative pressure in the crankcase. The downside to the design is that since the system is passive, it only creates a negative pressure of roughly one to two inches of vacuum on most engines, and that's when some smart racer started using a belt-driven emissions air pump to mechanically pull a vacuum.

The issue with these converted systems was service life because those pumps weren't meant to handle crankcase vapors and oil mist. Now, there are dedicated pumps made that are repairable and made from materials compatible with crankcase vapor.

BELT OR ELECTRIC?

There are two options when it comes to engine vacuum pumps, mechanical belt-driven if you have room to mount it, and electric motor-driven if real estate is scarce and you need a remote option. The belt-driven pumps are available with different sized pulleys to limit drive pump speeds to around 6,000 rpm maximum and/or somewhere between 55-75% of engine speed. Again, this is an area where reading the directions is helpful.

Wire stiffened hose or braided stainless hose rated for vacuum can be used to plumb the pump suction to the engine and the pump discharge to the combination catch can and breather. Belts may be either standard Vee-type or Gilmer, depending on your application. The obvious advantage to the Gilmer drive is that it's positive, and if the rate of acceleration for your engine is violent enough a Vee belt might slip or fail as it tries to overcome the inertia of the pump.

Vacuum pumps are rated by SCFM air flow and are available in different sizes and configurations. The drive can be a standard Vee-belt, a Gilmer-type square-tooth, or a High-Torque-Drive belt, and different drive and driven pulleys are available to increase or decrease pump speed. Most pump builders recommend that you limit pump speeds to something under 6,000 pm at the pump. If you were wondering about the term "Gilmer" belt, it refers to one of the earliest makers of toothed belts, the L.H. Gilmer Co., which was acquired by Uniroyal in 1940 and later absorbed by Gates Rubber. It refers to a square- or trapezoidal-shaped toothed drive belt like those used on some of the earliest timing belt applications. Today, most toothed belts use a curvilinear-tooth or rounded-tooth, which has more contact surface area and is capable of transmitting more torque, hence the High-Torque Drive moniker. Virtually all of the racing timing belt systems I've seen use the rounded-tooth design, and to the best of my knowledge so do all the late model street engines out there that still use a rubber timing belt to drive their cams. Today, "Gilmer" is an archaic term, but still often used and understood to be the earlier square-tooth design by most people who frequently use that type of belt.

IT'S A CAUTIONARY TALE

The amount of engine vacuum you shoot for will depend on your oil pump type (wet sump or dry) and your performance goals. Most engine builders and vacuum pump suppliers recommend an upper limit of 15-16 in. Hg of vacuum for a wet sump Engine, and 20-22 in. Hg for a dry sump. Adjustable vacuum breaks are used to set the upper limit, and you'll have to experiment to know what works best for your build. There can be too much vacuum in the crankcase, as we shall see next.

Some builders have postulated that the oil mist that lubes walls and pins falls out of suspension more quickly with too much vacuum, which they believe leads to lubrication and cooling shortfalls on the cylinder walls and pins.

I find it hard to believe that given the operating rpm of a typical racing engine and the voluminous amount of oil thrown off each rod pair through the side clearance that running high vacuum contributes much at all to any sort of pin or piston skirt lubrication issues… but I've been wrong before. A case MIGHT be made for the oil dropping out of

Racing engine vacuum pumps require a bit of oil passing through them for lubrication. The earliest attempts at using smog air pumps as engine vacuum pumps failed in part because they were never designed to pull vacuum and only produced a usable vacuum when driven at speeds high enough to cause failure, and they weren't designed to handle the oil that got ingested during operation. Racing pumps need to have a bit of oil flow to keep them alive and use the oil vapors and mist pulled through them for internal lubrication, but that requires a catch can with a breather system on it, which becomes one more thing you have to remember to check and do in between runs. Forgetting to drain your catch cans and oiling the track down will not win friends and influence people!

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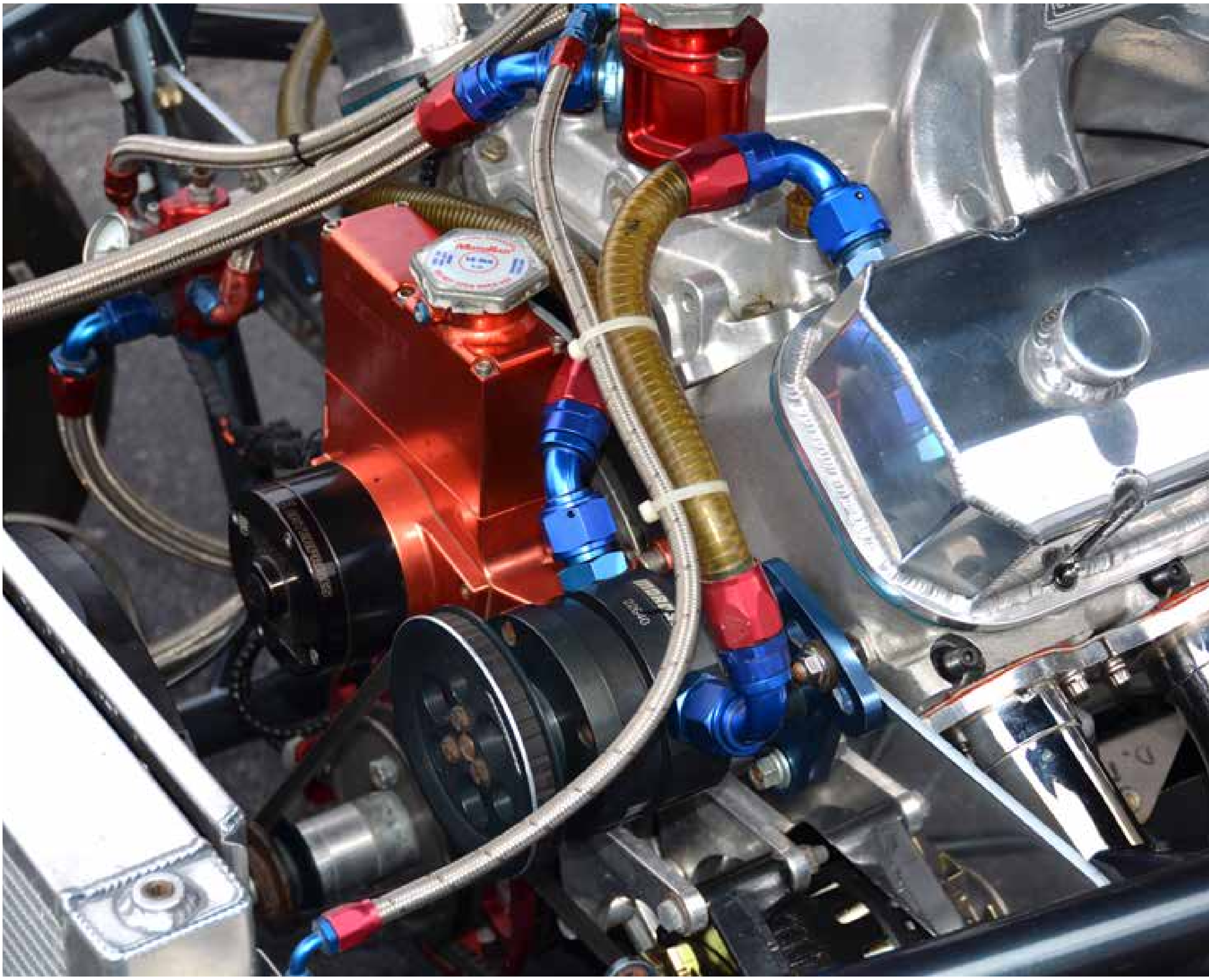
windage more quickly, thus lessening the oil available to the bores given that part of the effect of removing air is a potential increase in oil movement (all objects fall at the same rate in a vacuum regardless of surface area), and that combined with a vacuum-induced increase in the density of the oil made possible by removing the air and leaving it mostly oil could have an effect I can't envision. BUT that same removal of air and lowering of pressure would also result in a more dense oil droplet with theoretically longer droplet travel once it's pitched off the crank — the outgoing travel away from the spinning crankshaft would be just as energetic if it departs up toward the bore as it would be if it were thrown back to the pan in a lower pressure atmosphere — so I'm left wondering if the high vacuum caused the issue, or if the higher accompanying engine speeds allowed by increased crankcase depression required a more robust pin or a coated pin, or a change in clearance to prevent failures and we just blamed the high vacuum levels. I guess in my mind, the oil is flying out of that rod pair all the way around the rotation plane and while we have kick-outs and screens below to strip away the oil as it rotates into the pan on the upper end, it's still free to be thrown upward and outward onto the bore, skirt, and pin. Maybe someone can explain to me what I don't know about this…

All this cogitating doesn't change the fact that there were reported pin and piston issues when engine vacuum pumps were first used, but in my mind it's more likely that those early problems were attributable to the higher engine speeds made possible by the pump and the fact that in those first versions the builders hadn't adjusted their techniques to account for the higher engine speeds that were attained. Provisions can be made in the form of piston oilers (via a manifold built into the oil pan near the pan rail) used to spray oil up under the piston onto the pin, walls, and bottom of the piston head if you are a subscriber to the theory that high vacuums create oil shortages around the pins and bores.

PRESSURE AGAIN

On most engines there will be an oil pressure drop when the vacuum pump is installed. Why? Because we're back to the idea of pressure drop across a fixed orifice. Volume supplied and the leak rate of that volume out of a fixed dimension sets the pressure. If you pull a 20 in. Hg vacuum with the pump, then you increase the pressure drop across the bearing clearance by roughly 10 psi — the oil is "pulled" from the bearing and the volume through the bearing increases which "acts" or "looks like" a larger clearance, and anyone who's built an engine with larger clearances knows what that means to oil pressure.

You're also messing around with the differential pressure that moves the oil from the pan into the suction of the pump. If you run deep vacuum in the pan, you run the risk of having less pressure in the pan than what is generated at the suction of the pump, and if that occurs the scavenging or pickup flow stalls. 16 in. Hg of vacuum on a wet sump engine is pretty close to the practical limit because that leaves a positive pressure in the pan of about six psi, which becomes the suction head available to



In most cases, mounting is simple and straightforward, although using terms like that when building a racing engine is inherently dangerous. Brackets, drive mandrels, and pulleys are available and usually you can mount the pump and align the belts without too much effort. If you're running a blower, cam-driven fuel pump or other space-robbing components on the front of the engine can be spaced off the block and the pump-mounted facing rearward because the pumps can be driven in either direction. Just remember that the inlet and outlet often swap positions if run in reverse rotation — always refer to the literature supplied with the pump and read it completely before beginning your installation. In fact, I've learned through hard experience that you should do that with every single racing engine component — read it ALL first, then start mocking-up and building if you want to save yourself some time and pain. The hoses to the engine must be rated for vacuum. In this application, they use a wire-supported clear hose, but most stainless-steel braided hoses and most press-on or socketless hoses are also rated for some degree of vacuum. If you refer to your hose supplier's catalog, you'll see both a pressure and vacuum rating for the type and size of hose available. Again, read carefully — typically, the larger the hose inside diameter, the lower the vacuum it can handle. It's all about wall strength and inside surface area.

move the oil into the negative pressure of the oil pickup.

There may also be an effect caused by the fact that you are now reading what should be an absolute pressure with an atmospheric gauge. An absolute pressure gauge reads 14.7 psi at rest in open atmosphere and zero at a perfect vacuum, whereas the typical atmospheric gauge reads zero psi at rest. In my previous life, I worked with gauges marked as PSIA or PSIG, which indicated "absolute" or "gauge," which is atmospheric. A PSIG gauge assumes that the pressure reading is taken from something near 14.7 psi as the starting point. If you think about it, the total pressure drop is really pretty much the same. Just remember that pressure is the result of volume and the restriction that that volume is moves through; the same volume through a smaller hole will show more pressure on a gauge attached to the pump. Anything

Location of the vacuum port should be high up and forward to minimize oil carry out from the engine, and the driver's side valve cover is a good choice. If you think about the dynamic forces present on a race car, either a drag or track, the oil will be shoved back or to the outside, and locating the suction of the pump high and forward keeps the suction out of most of the wet flow. You can size the catch can for your application, using a larger tank with better oil separation and multiple breathers if track rules allow a pump on a duration racing engine. Something to remember about running engine vacuum: The better the mechanical sealing, the lower the unnecessary flow created by pulling outside air through the gaskets and seals. High flow rates might cause a lot of oil carry-out and what would be preferable is to make sure the engine is tightly sealed mechanically during the build so that the only flow you have to manage is whatever blowby flow is produced by the engine. If you have access to an evaporative emissions system smoke machine, it's a great tool to use to check and verify your engine sealing efforts before dropping the engine in the car.

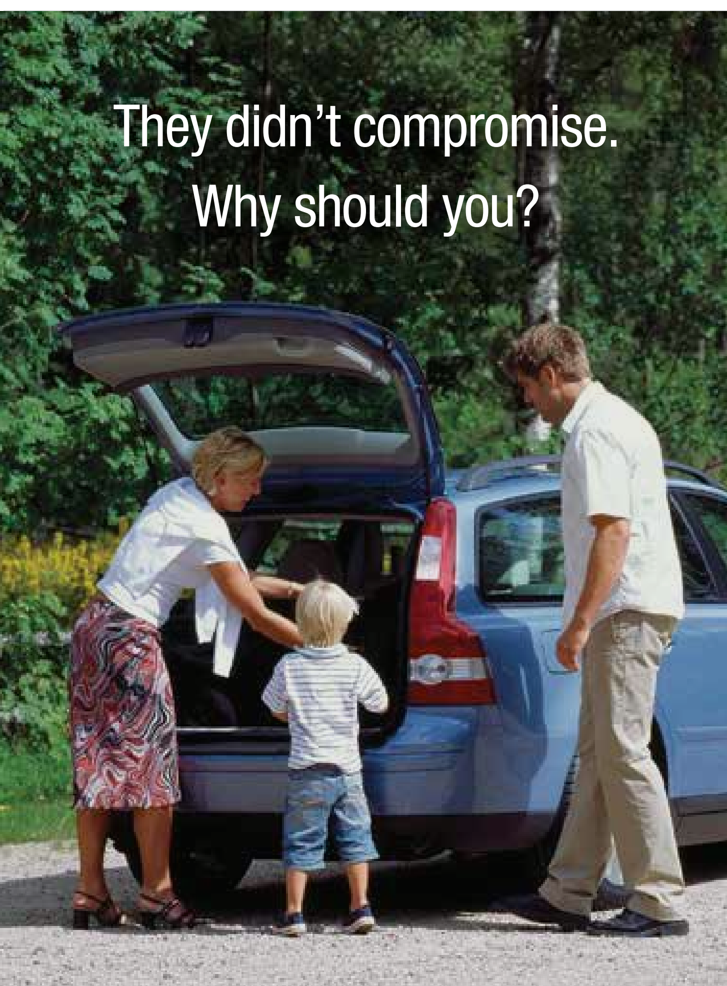
that increases or decreases the flow rate through and out of the bearing clearance will have an effect on pressure readings.

THERE ARE LIMITS

Because a vacuum pump is capable of pulling much more vacuum than the engine would like, it's important to design the system with a vacuum break in place. The same companies that make vacuum pumps also make fully-adjustable vacuum breaks in different configurations and threaded male sizes. As a starting point, most builders will recommend limiting the vacuum on a wet sump engine to something around 16 in. Hg and 22 in. Hg on a dry sump, although there are some racers running as much vacuum as they can get on wet sump applications — as much as 23-24in. Hg has been reported on some applications. How much is right for you application is something you'll have to select for yourself by slowing increasing crankcase vacuum while monitoring your pressure gauge for signs of suction side flow reduction, which often shows up as oil pressure gauge fluctuations.

FINALLY

Vacuum has to be managed because there are physical limits to how much is safe to run. Vacuum breaks or vacuum regulators are used to set the maximum vacuum at levels that don't create suction head pressure problems for the oil pump. Safe levels are in the 12-16 in. Hg for a wet sump engine, and in the 18-22 in. Hg range for a dry sump engine, but again, this is all subject to testing and validation



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for your application. If you get a wildly-fluctuating oil pressure, you're running too much vacuum for the oil pump to handle. Oil pressure is expected to drop by roughly your engine vacuum in inches of mercury divided by two, so if you normally run 70 psi and you introduce a twenty-inch vacuum in the crankcase, twenty divided by two is 10 and your oil pressure should be about 60 psi, but it must be steady on the gauge or else you'll need to reduce engine vacuum. At the end of the day, it will be your engine bearing wear that will tell you everything you need to know about your oil delivery system, so look at it often, keep records at the end of each season, and keep the bearings in order as part of your regular PM program as a means of monitoring engine health. ■

Vacuum has to be managed because there are physical limits to how much is safe to run. Vacuum breaks or vacuum regulators are used to set the maximum vacuum at levels that don't create suction head pressure problems for the oil pump. Safe levels are in the 12-16 in. Hg for a wet-sump engine, and in the 18-22 in. Hg range for a dry-sump engine, but, again, this is all subject to testing and validation for your application. If you get a wildly-fluctuating oil pressure, you're running too much vacuum for the oil pump to handle. Oil pressure is expected to drop by roughly your engine vacuum in inches of mercury divided by two, so if you normally run 70 psi and you introduce a twenty-inch vacuum in the crankcase, twenty divided by two is 10 and your oil pressure should be about 60 psi now, but it must be steady on the gauge or else you'll need to reduce engine vacuum. At the end of the day, it will be your engine bearing wear that will tell the tale.

The "Big Four" in racing engine vacuum pumps:

http://www.gzmotorsports.com/vacuum-pump-guide.html

http://www.starvacuumpumps.com/about/

http://www.moroso.com/

http://shop.aerospacecomponents.com/vacuumpumpsandaccessories.aspx

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OIL PUMP SYSTEMS, DRIVES, AND PANS, PART 2: THE SUBTLETIES OF WET VS. DRY SUMP ENGINE OILING

-Greg McConiga

Windage, clearances, load, and the advantages of dry sumps

In the last issue we began this discussion with the traditional wet-sump engine oiling system and looked at some of the challenges involved in making it work reliably in high-performance engines and in applications where the forces exerted on the vehicle were sufficient to cause the oil in the sump to move away from the pickup.

Installing a dry sump system can be an exercise in patience. All of the dry sump builders and suppliers are good about offering technical help and installation advice with the sale, which is a good thing because as-supplied it resembles nothing if not a jigsaw puzzle with the box top that should show the completed puzzle missing. On the bench or engine stand everything looks real easy, but once you factor in the chassis, headers, steering shaft and gear, and suspension, things tighten up dramatically. Don't be surprised if you find yourself spending a day or two just finagling hoses, fittings, and mounts to get to a field-workable solution... I say "field workable" because the design has to be simple enough to repair in the pits should a leak develop, or some other repair show up that requires removing parts of the dry sump to accomplish. A best -practice is to tack weld bushings and spacers to brackets when you can so they won't disappear

WHEN YOU NEED TO GO DRY

As power levels and G-forces increase, even the best wet-sump pans equipped with all the tricks such as custom-built high tech pumps, dams, diverters, and swinging pickups are challenged to keep an adequate volume of oil and suction head pressure supplied at the oil pickup. Erratic oil control on the suction side under violent operating conditions can result in severely aerated oil or low oil volumes being supplied to the engine bearings with predictable results.

In any engine, volume is king (two gallons a minute at idle up to 12 gallons a minute or more at full operating speed), and the pressure we all observe and monitor is the result of the right volume shoved into and through the correct bearing clearances while using the proper viscosity for your particular application. You needs as much pan depth as can safely be run to provide the capacity and pan volume needed to keep the pickup fully covered under one to three inches of oil (or more) without running the pan into the track – and you need engine oil clearances consistent with your application.

in the grass during repairs, for example.

Some things can't be changed, like the pump relationship to the crankshaft because that's where you're getting your driving power for the pump. The pump can be mounted on the left or the right, and even if an oil pan isn't readily available for a right hand mount (and for some applications it isn't), you can always have a pan made for your application for a little more money. It's a good practice to mount the crankshaft drive parts to the crank nose followed by the pump to the block and get the pump drives aligned, the belt installed and adjusted, and once all the spacers and bracketry are worked out it's time to buy about a hundred AN fittings from 180 to straight (only a slight exaggeration because you either misplaced them or lent them to your buddies and never got any back in return), and start part two — the fun of trying to figure out how to connect every scavenging port on the pump to those on the pan and where the pressure line has to run to get oil back into the engine to feed the galleries. On most racing blocks, there are two or three places to plumb in: on the back bell housing skirt near the top of the block, at the oil filter mounting pad, and in some cases a provision is made above or near the oil filter pad for access. If access is tight at the oil filter mounting pad, look around for another point you can plumb into. The last lines to worry about are the scavenge discharge to the oil tank and the suction from the tank to the pressure section. Since the scavenge sections have a common manifold inside the pump, you can move the scavenge discharge line along the top of the pump body by removing section plugs and installing a fitting into the location with

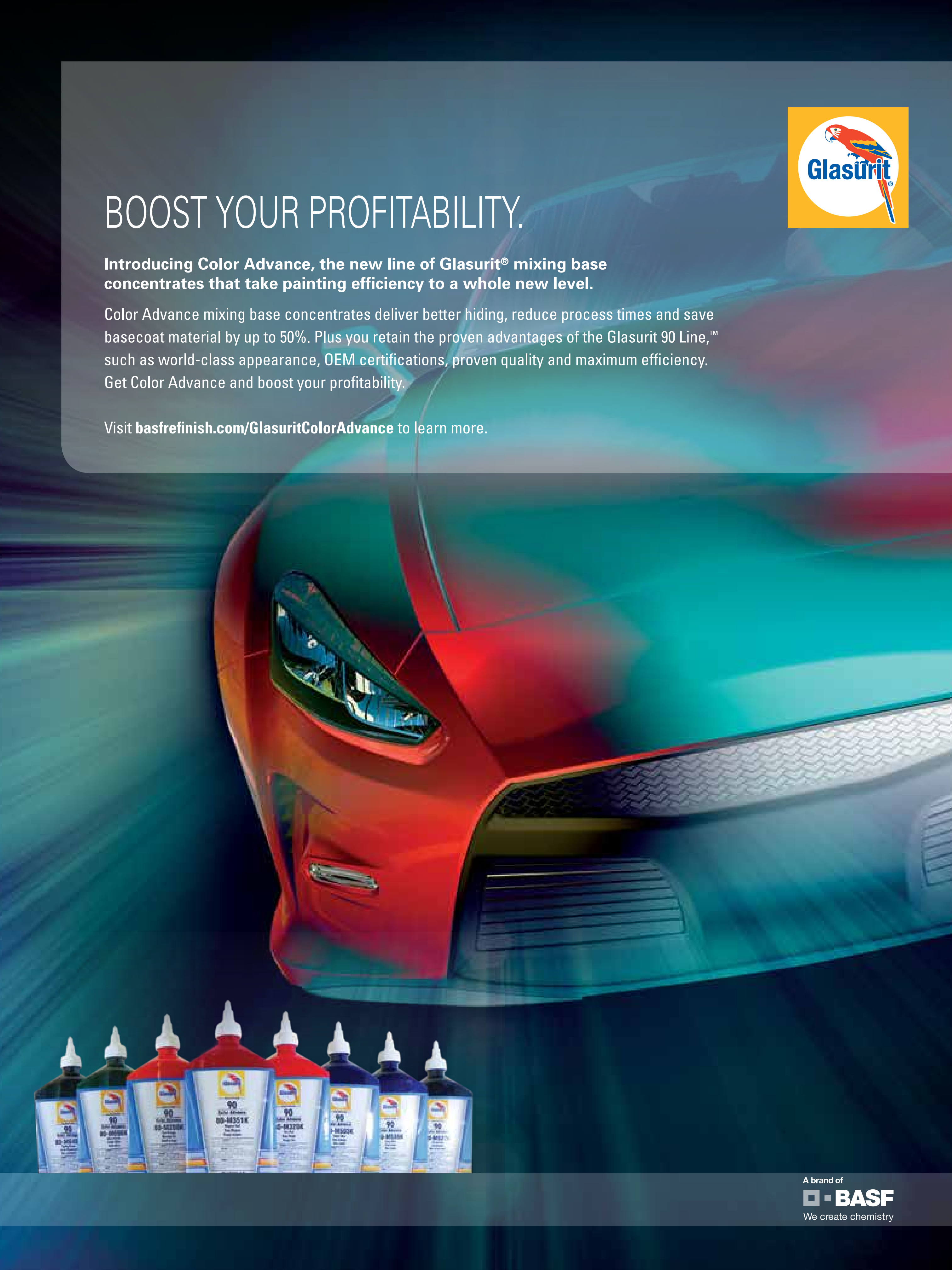
the best access, or move the section with the fitting if you must. If at all possible, keep the scavenge discharge as far to the rear of the pump as you can. The suction into the pressure section is on the bottom of the pump, so it's often more accessible. Take a look at any one of the pump photos and you'll see it. Now that you see all the bits needed, you can understand why a dry sump system is expensive and why getting it all installed and routed the first time can test your patience!

TINY SPACES AND LUBE THICKNESS

Clearance start from .00007 in. to .0015 in. for a daily street driver to .006 in. (or a bit more!) for a Top Fuel, and as the clearances open up the viscosity of your motor oil must increase. There are exceptions to viscosity following clearances and there's some power to be made by running lighter oils, but that's something only recommended for someone with a very comprehensive engine building and monitoring program.

For commuter vehicles, you might run a 0W-20 multi-grade in a factory-built engine with main and rod bearing clearances on the order of .0007-.002 in. For a carbureted racing engine or performance street engine, it might be anything between 10W30 and 20W50 at .0025-.0035 in. For blown alcohol, you would expect to see something along the lines of a straight 50W at .0035-.005 in. clearances, and for a Top Fuel car, you might be at a straight 70W with clearances at .006-.0075 in. Monitor your bearing condition and your oil pressure gauge to determine what combination is needed to keep the little monster alive. What's important to note is that as the power levels escalate the clearances increase to allow a safety margin for the distortion and bending forces that grow with torque and rpm because no matter how good the parts are there are physical limits and sooner or later you'll overrun part strength and need the extra clearance to compensate for that.

More clearance means more volume demand in gallons per minute, as delivered by the oil pump, and more volume means more windage and a faster emptying of the pan, which means you need more pan volume. It's like a row of dominoes set up on end: Once the first falls, they all fall in sequence.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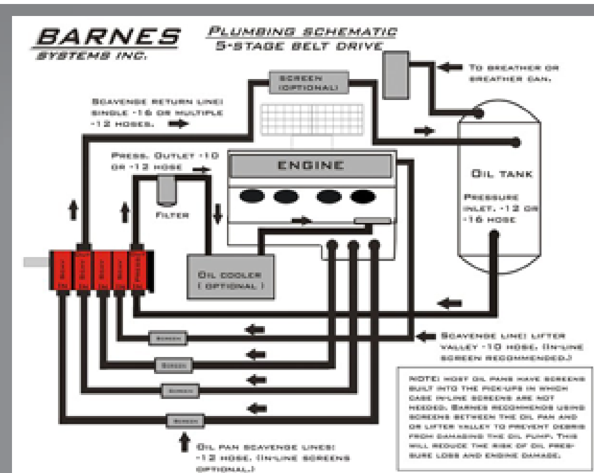
There is almost no way that I've found to have these hoses made up off site. It's such a cut-and-try process you just have to figure them out as you go. You will become expert at hose makeup if you start running a dry sump. Unless you love the sight of your own blood, you shouldn't even think about making up hoses without the tool kits from Koul Tools that we've featured before. You're either going to buy Band-Aids by the truckload, or these tools — your choice (the tools are cheaper and less painful).



It's important to follow the plumbing recommendations of the pump supplier. Line sizes are not optional if you expect to get the best results from your installation. In general, you would like the largest oil tank you can fit into your car and still mount it so that the suction feed fitting at the tank is higher than the suction inlet at the pump pressure section. Larger systems afford you more tank "dwell time" for de-aeration and/or more reserve to make up for loss or consumption. There are size limits of course, not the least of which is weight and the expense of carrying a larger quantity of oil, but bigger is better, within reason. Oil tanks should be filled to about 2/3 full and checked with the engine running to allow sufficient head space for de-aeration. If you're using a remote breather, make sure to mount one large enough so it is at least as high as the oil tank breather fitting and check it between runs for oil carryout. Tanks may or may not have an integral breather welded

in. Screens should be mounted on each scavenge line and a filter mounted between the oil pump pressure section and the engine. If you choose to run a small micron oil filter, you'll need to check it after every racing weekend to monitor engine health, particularly after you freshen up the engine. Once everything seats in and the engine is happy, it may be possible to ease up on the schedule, but keep an eye on that oil pressure for any sign of drop that would indicate a restriction and possible problem.

BEARING LOADS AND BEARING CLEARANCE

There's another point to consider when it comes to clearance that's not directly related to oil pumps, or pressure and volume demands: the load footprint on the bearing. The closer the shaft diameter and the bore diameter into which it fits, the wider the footprint the shaft has on the bearing. Think of it as points of coincidence. If the shaft were 1in. and the bearing four in., the loading area would be very close to a line contact where the two touched because the arc described by the one inch shaft would quickly depart from the arc of the four-in. bore. As the shaft size increases to four in., the footprint widens out as the bore and shaft sizes approach the same dimension until the shaft is at full contact at all points on the circumference. Of course, it won't turn at this point, but in terms of shaft and bearing contact surface area it's as good as it gets.

Normal recommended bearing clearances are .001 in. for every inch of diameter, so a crankpin clearance on a 2.200 in. journal should be .0022 in. — with a half a thousandths taken off for a tight build (assuming you tailor the build to fit the clearance) and a half thousandths added to the dimension for a loose build. So, on the tight side, the bearing clearance should be .0017 in., and for a loose build the clearance should be .0027 in.

These are, of course, general rules and are not cast in stone, but at least they give you a starting point.

Most builder's subscribe to the "looser is better" theory of engine building, and for the most part that works because loose is definitely safer. But, if you're running premium parts, if the crank is stiff, true, properly polished, and machined and you're running a dry sump there may be some power and or durability to be had by closing up the clearances. The only way to know is to start where you're safe and slowly creep up on tighter clearances while periodically inspecting the bearings.

SUCTION HEAD PRESSURE

To continue what we started in the Tech Minute last month (The Physics of Lubrication) we should briefly talk about suction head pressure required and suction head pressure available. A pump moves what it moves because of differential pressure and nothing moves if the pressures are equal on both sides of any pipe, which we have to account for and adjust for on both the suction and discharge side of the oil pump.

Wet sump systems consist of an inlet side and a discharge side, and suction head pressure is what moves the oil through the screen into the pickup and piping and on into the pump. This discussion will be important in both wet and dry sump applications and in our article in this issue concerning the use of a vacuum pump on the engine.

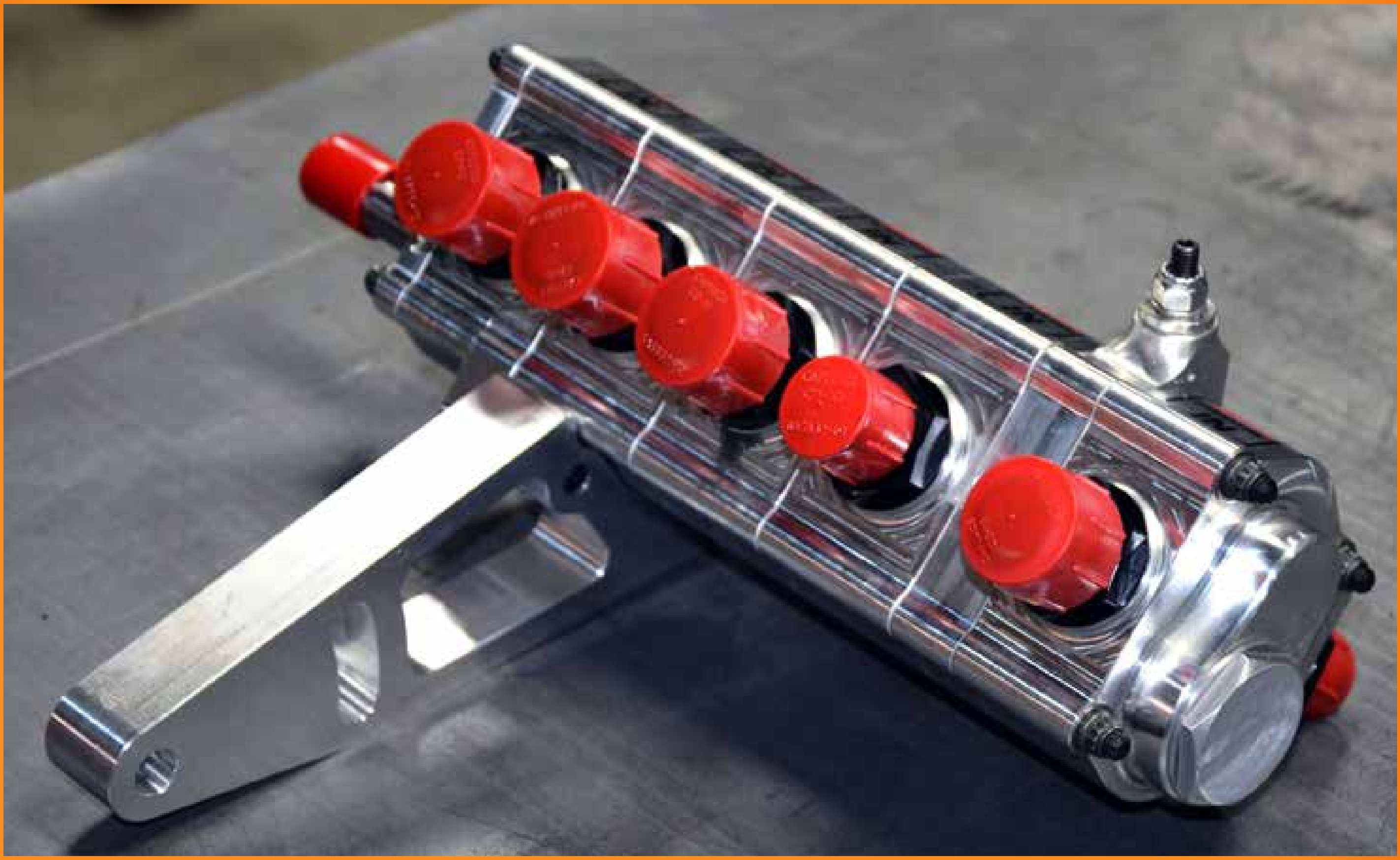
Suction head pressure is the result of the difference in pressure (between crankcase pressures, typically atmospheric pressure, plus the liquid head pressure plus maybe a bit from blow-by) and the low pressure

There's always maintenance on a race car and part of your design should be to make the system as good as you can afford while demanding as little maintenance required as possible. Let's face it, racing consumes a ton of time and money and anything you can do to reduce either is a good thing.

Dry lubricant coatings to reduce friction applied to the twisted rotor elements of this pump extends life and reduces the drive power required to run the pump. A side benefit — you want to call it that — is that anything passing through the pump upsets the coating so it serves as a tell-tale created by the pump. The weight of the fluid column and the air pressure in the crankcase are what cause the oil to move. You will also have some loss to overcome caused by the viscosity of the oil and the friction of the screen and piping, so the lesson to take from this is that there must be a large-enough pickup opening, a reasonable pickup screen wire and hole size, and as big a suction pickup pipe as you can fit.

Without differential pressure, the oil stalls in the suction feed line and none moves through the pump — it actually ends up vaporizing and cavitating to the point where no liquid movement occurs. The exact amount of suction head pressure required in an engine isn't well documented, at least not that I'm able to find. Engineering manuals suggest that you'll need at least 3 psi, but I don't think I'd be comfortable with any less than six pounds per square inch of suction head available on a wet sump and four pounds on a dry sump engine.

on engine health and performance when you rebuild it every season. The pump is really pretty simple to service and repair. The pumping elements are keyed on the drive shaft and the driven element spins on a plain shaft on twisted lobe designs. On a gerotor type, the outer ring spins in the housing and the four-lobe driven element is keyed to the drive shaft. The draw rods that hold the pump together have a specific torque value, and you'll need a precision inch-pound torque wrench to tighten them periodically through the season. The pumping elements are located by dowels



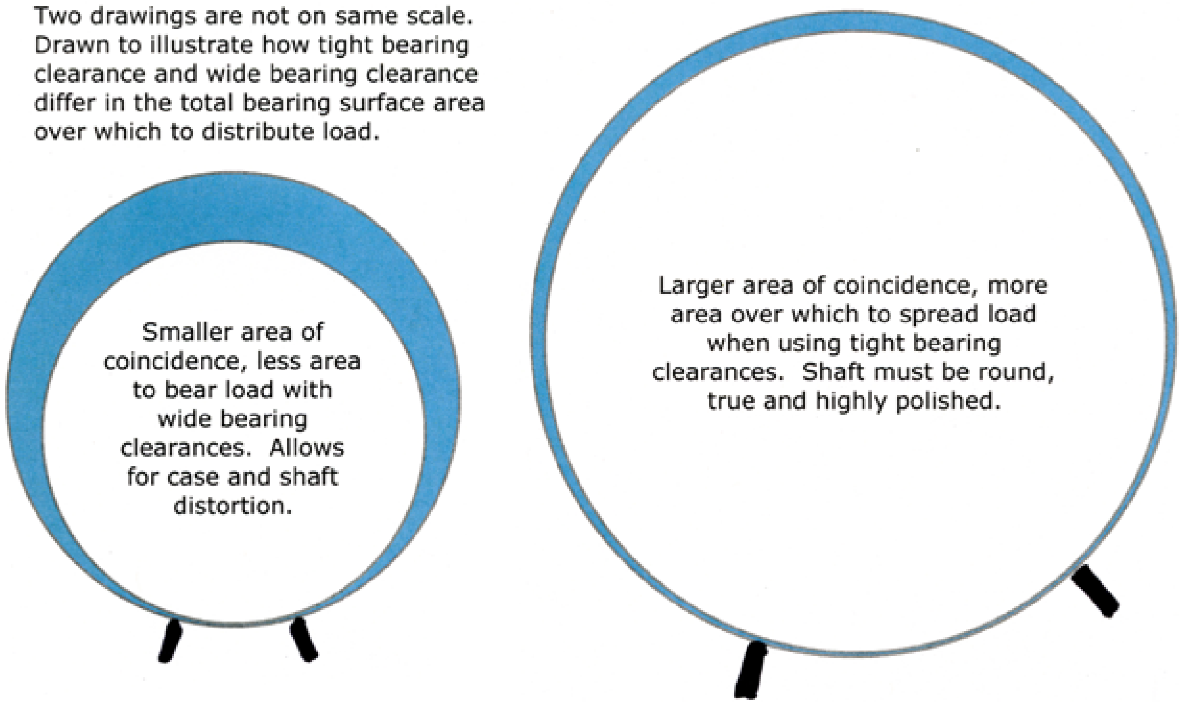
and sealed by O-rings; as long as you're careful, the O-rings can be reused several times. Most of the maintenance involved is inspection; you need to get it apart and see what has been through the pumping elements and replace those elements that are damaged. Bearing material is generally not a problem, but anything like a needle from a lifter or roller rocker or the tail end of a valve spring that breaks off and migrates to the pan can make it through the screens if it's small enough and into the scavenging pumping elements, clobbering them on the way through. The aluminum twisted rotor design is better at digesting garbage and passing it than the gerotor type with the steel elements, which can lock up and snap the belt under the right circumstances.

FUN LIKE THIS COSTS MONEY

Dry sump oil pumps, pans, lines and tanks are a major investment on any racing engine. Costs are typically in the $3,500 to $5,000 range for a complete system as installed, depending on the manufacturer, number of stages, tank size and design, lines, drive mandrels, pulleys, belts, and brackets. While this seems expensive, it's important to remember that this is the system that keeps all those viciously destructive parts from sawing the block in two as they try to escape.

Dry sump systems fix a lot of the oil control, Cavitation, and windage and aeration problems by pulling the oil from the pan through any one of up to seven or eight

Something I was going to mention during the first segment on wet sump pumps was a little quirk of stock oil pump pickups. I've found that a lot of guys never knew about this, and when they attempted to use stock parts on a high-performance street build it got them in trouble. I pried the cover off of this older big block Chevy oil pump pickup to show you how they used to address the issue of cold oil pumping and possible screen plugging. Under that half cover there's a hole in the screen and the screen bows up uncovering it if the engine oil is really cold and viscous, or the screen is plugged with sludge. You can see the problem: anything can pass through that hole if that happens. Back when this was all we had for our performance builds, it was a pretty common practice to pry the cover off carefully, solder a penny over the hole and re-crimp the cover back onto the pickup. Racers today don't know how good they have it with all the high-quality parts out there! Sure, they're expensive, but the "good old days" weren't really all that good!



During the course of this whole discussion, we've covered a lot of ground relating directly to oil pumps, pump volume, pressure, and oil viscosity and how they all interact. One of the points to keep in mind is that if you were able to have perfectly rigid components you could (at least in theory) close up bearing clearance, use a much lighter-weight oil, reduce pumping losses associated with the pump and oil, and free up power, all the while improving the load pattern on the bearing. I drew this up just as an illustration. It's not to scale and certainly not "professionally done" by any stretch, but it should make the point. A round shaft and a round bore must have two different arcs if they are to have clearance between them, and the wider the bearing clearance the more extreme the difference in those arcs, and the smaller the pressure footprint made on the bearing and the higher the loading in pounds per square inch on the bearing. At extremely high cylinder pressures and high power levels, you'd like as large a bearing footprint as possible to reduce the localized load forces. The whole thing is a compromise: increase clearance to make up for distortion and bend, increase viscosity to make up for the clearance, volume demand increases and pressure drops, oil pump power requirements go up, more pumping loss, more friction and more heat from friction, and bearing load in pounds per square inch increases. It's like a Zen riddle — at times it appears there's just no right answer. The trend is moving toward lighter oils and tighter clearances, particularly on street applications, mostly in response to the fuel economy standards that are forcing everyone to reduce losses everywhere they can. Lighter weight oils are also showing up in a lot of racing applications as part strength and quality improves. I would expect that this trend will continue over the next several generations of racing engines, so keep an open mind and read as much as you can on the topic as the technology reveals itself (the leaders in this movement are pretty tight-lipped about exactly what they're doing, so it'll take a few years before we mere mortals are allowed to know what's going on behind the curtain).

sections of scavenging. Because oil caught up in the reciprocating parts has mass and viscosity, it creates a horsepower-robbing drag as it's strung out between the rotating members and stationary members sharing the space under the pan. Think of the oil as a hundred tiny little hands reaching out trying to grab hold of the walls of the bay, the skirt of the block, and the walls of the oil pan as it swings past, riding the crank and rods. Scrapers, screens, baffles and diverters that strip and control the oil along with the rapid evacuation of oil from the pan by multiple scavenging sections reduces the amount of oil captured and held by the crankshaft and therefore dramatically reduces the frictional loading presented by the oil.

Frictional losses occur everywhere in an engine — gas flows, oil flows, rubbing components, drive components, rings, chains and pistons — if two of anything move opposite one another, there's going to be a friction, friction loading, and a frictional heating component involved. The first thing a dry sump does for you is provide you with superior control and rapid evacuation of the oil from the pan. The second thing it does is provide you with a massive volume of oil over which to spread both temperature and contamination, and as a very important side effect, it provides a means to strip the air from the oil before it's reintroduced into the engine by using elements in the oil tank designed to separate the air from the oil and by providing more dwell time for the air to separate.

AERATED?

One of the more serious side effects of windage is aeration because air-filled, frothy oil won't support high bearing loads

One of the concerns about running high engine vacuum levels has to do with piston pin failures, believed by many to be induced by a loss of sufficient lubrication to the pin area. The pin lube system is passive — oil that is cleaned off the walls by the oil control ring is channeled into oil feed holes that terminate in the pin bore. Slots and grooves divert the oil around the pin providing sufficient oil to keep the pin alive. On the top of the rod, a hole is drilled that directs oil into the rod end bushing and the whole thing relies on splash. There are many opinions about this, and

I've got one, too. I think the early problems were more attributable to the increased engine speeds that a vacuum pump makes possible combined with possibly a disruption of oil pump flow on the suction side because we lowered the suction head available more than we should have. One thing that helps pin life in any event is the use of a diamond-like coating (DLC), which reduces pin oiling requirements. Given the substantial power gains that running an engine vacuum pump provides, it's an option that warrants serious investigation. The gains are impressive on the dyno and they translate into lower ETs and more mph at the track. Just start out at a safe level and carefully track engine oil pressure for fluctuation while monitoring bearing wear to determine what's best for your application.

consistently. The reason oil works as it does is two-fold. First, because it's non-compressible and acts like a solid in the bearing-shaft interface, and, second, because at the molecular level it acts like tiny ball bearings that roll easily against their neighbors. Air IS compressible and has no support at the molecular level, so mixing oil and air and pushing it into a bearing will lead to high rates of bearing wear and failure.

Other advantages include a very low pan profile for ground clearance, adjustable oil pump volume through the use of different pulley ratios, externally adjustable oil pressure, expandability should the need arise (a longer drive shaft, added sections, and longer tension rods are all that's needed to add a section), and the fact that most dry sumps pull a partial vacuum in the crankcase, which increases horsepower (see the vacuum pump story for more on this). Another nice feature is that with a dry sump it's relatively easy to pre-heat the oil using in-tank heaters, and it's easy to prime the engine before each startup by slipping the belt and using a drill on the drive end of the pump. The more power you make and the closer you are to the edge the more important bringing the oil up to temperature is and the more important it is to prime the engine every time it's sat for longer than a day. Oil works best when warm, and some oils drain from the bearings of a hot engine quickly. Heating the oil and priming the engine is just common sense if you have that capability.

Installation of a dry sump system can be an exercise in cut-and-try engineering, particularly if you're retrofitting a system onto an older race car. The tank, breather, lines, and pump and brackets all have to be mounted and fit to the engine and to the chassis, and that can often be a real challenge. The best advice I can give you is shop, talk to fellow racers for recommendations, be patient, and read, read, read all the paperwork and instructions and technical literature you can find online before committing to a supplier. There are a hundred variations on brackets, tanks, mounts, and drive systems, so doing a bit of research before purchase can save you countless hours of fabricating, cutting, and welding later. I've included a source guide for you below that will help you get started. While it's not comprehensive, it'll give you a good idea of what's out there. ■

SOURCES

http://barnessystems.com/

http://www.daileyengineering.com/

http://petersonfluidsys.com/

http://www.aviaid.com/

https://drysump.com/index.htm (ARE Systems)

http://www.moroso.com/

http://www.racelinepumps.com/

http://www.stefs.com/stefsindex.htm

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WANDERING FULMINATIONS ON HIGH-PERFORMANCE

LEARN; ADJUST; RESET; REPEAT.

Do you realize how many really smart people there are out there working to make you dumber each day? Not in the literal sense, of course, but here are engineers, practitioners, machinists, and racers toiling away continuously in their respective specialties, all standing on the shoulders of their predecessors, finding more power in more ways than anyone could have imagined when I first started fixing cars. You are just one when there are hundreds out there working to make what you thought you knew yesterday obsolete.

The surprising part is the rate of change now. Computers are designing computers and computer software, which has resulted in relieving much of the tedium and saving time in construction or execution. The result is a sped-up supply chain and the compression of "concept to customer" life cycles. All of life, from the cell phone to the laptop to our cars, has become a monument to technology, and it's all a target moving so fast it would take a Patriot missile to lock onto it. In a previous life I was involved in what was at the time a very high-tech engineering lifestyle, and I freely admit that it was a lifetime ago and that all the hard-earned skills in physics, mathematics, and chemistry are mostly lost in the sands of time. I'm what you'd call a recovering engineer. Still, even with that understanding of how things are designed, prototyped, built, and manufactured, I'm simply stunned by how fast knowledge is gathered, sifted, and disseminated in the world today (although some of that "knowledge" has little value!). You can ask Mr. Google a question and you always get an answer — and sometimes it's even the right answer!

Knowledge has a shelf life, and it's getting shorter by the year. I'll read something I wrote or read a year ago and think, "Man, did I get that wrong," or, "Well, that's not true anymore." What is current just scoots out from under you or changes each and every day!

Getting older is dangerous anyway. I got my Medicare card this year… I'm officially a geezer now. You know the definition of geezer? Not alive… not dead… somewhere in between! (I need a T-shirt like that). Getting older is dangerous because you have a tendency to get stuck in your stuff. You grab onto what I call "the old man's attitude." You've all seen it: "Been there, done that, got the T-shirt…" Or, "I used to walk 20 miles to school in snow up to my brisket, uphill both ways..."

Certainly, there are good reasons to do things the same way, to lock onto those successful strategies that make up the basics of our trade. You should absolutely check your gear, make sure your measuring equipment isn't worn or out of calibration, spend time double-checking every nut and bolt and every stitch of your safety gear.

But more important than that, you've got to stay fresh, study, read, and stretch if you hope to grow. I've often said that some of the dumbest people I've ever met were those who viewed their college experience as "the end" and never picked up another book in their life. They got the sheepskin and called it good. They know what they know and they don't know what they don't know and they don't know they don't know it. They see their education as something to get over, get done, and get past so that they can lean back on it and take it easy. Silly them — all that piece of paper gave them was the key to the door of what must become a lifetime of learning if you hope to make anything out of yourself or have any impact on the lives of others!

In the trades, there has to be both book learning and applied learning, and one thing we don't teach (that we should) is that your mind has to be right to do this — or anything — and do it well. "Your mind controls your actions and your actions control your environment" should be drilled into the impressionable skulls of every trade student beginning on Day One.

I think every mechanic should spend three years on a racing team. It teaches finesse, a can-do, will-do, I'll-figure-it-out attitude. Racing makes no allowance for a victim mentality or mindset and it damn sure rewards innovation and punishes complacency. It's you against the elements, the track, and your opponent. It's life or death writ small and no amount of technological thumb sucking or excuse making will make a loss into a win. Forget to tighten something? Linkage fell off? Didn't turn on the bottle for the nitrous or the shifter? Too bad. That's why it's called "racing" and not "winning."

Racing teaches you that there really are only winners and losers and that — guess what kiddies — not everyone gets a trophy in the real world. Racing teaches you to find a creative way to solve a problem while holding true to the letter and spirit of the rules for your particular brand of fuel-burning addiction. Racing teaches you to adapt, improvise and overcome, and it forces you to either learn or lose. It teaches a young racer patience, money management, and anger management. It speeds them up where speed is useful and slows them down when attention to detail is not just nice, but necessary.

Racing teaches you to congratulate your opponents gracefully when they win and tell them "that was a good race" without pretense or arrogance when you win. Racing teaches you to admit your mistakes with humility because all of your mistakes — or most of them at least — will be public.

Admitting mistakes is the key element to growth. If you never admit your mistakes, you'll never grow because when presented with the same circumstances you'll take the same action and produce the same failed result, which means that your trajectory — or your win/loss record — never changes. And the only way to learn through all of this is to admit what you don't know, understand that the pace of progress is increasing, and that no one — and I mean no one — has all the answers. If you're doing it right, you've got no answers; just more questions! ■

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