

TWO-STROKE OIL PREMIX RATIOS

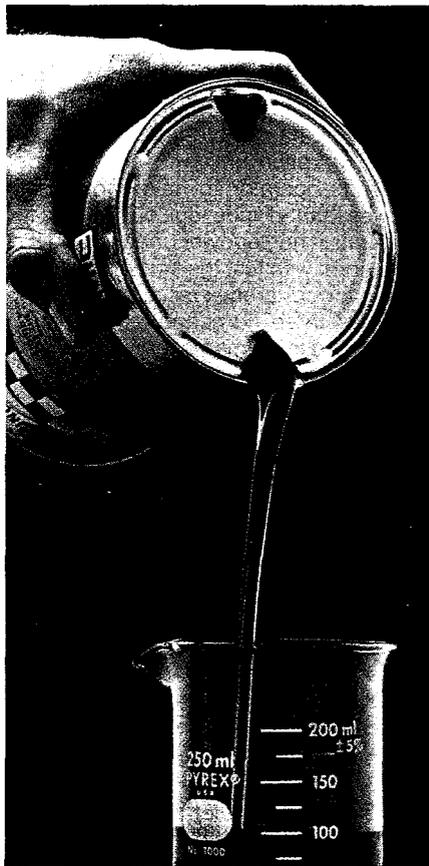
● ZEN PHILOSOPHY SAYS "LESS IS MORE," and we'd agree that probably is true of sermons, rhubarb tonic and irreversibly platonic relationships. However, we do have doubts about the efficacy of Zen in the art of motorcycle maintenance, particularly when it involves applying the less-is-more precept to two-stroke engine lubrication. This places us among motorcycling's heretics: majority opinion insists that oil is the enemy of two-stroke performance and advises adding the stuff to fuel with an eye-dropper. We've heard riders boast of running engines on a 50:1 fuel/oil mixture and becoming downcast, even envious, when told that others have found a new oil that works at an 80:1 mix ratio. All these people seem utterly convinced that in premix-lubricated two-stroke engines, less oil does yield more horsepower and will also reduce the ring-sticking tendency so prevalent in the type.

We've watched this high mix-ratio trend develop and have regarded it, like all things trendy, with cautious pessimism. Despite all the glowing reports and enthusiastic endorsements, we've been unable to find any satisfactory answer to a fundamental question we keep asking: Why would any engine, a collection of busy, fretful moving parts, work better with lubrication reduced? All our experience with two-strokes indicated the opposite to be true; these engines seem to run harder and happier for us when we pour a lot of oil through them. The hardest kind of experience has shown us what happens when lubrication fails: pistons cease pumping, wheels stop turning, enduro riders become enduro walkers, and road racers consider themselves lucky if they survive a sudden engine seizure able to walk at all.

So we haven't been greatly impressed with the notion of scanty lubrication for two-stroke engines. However, it's hard to halt a trend with nothing but the subjective evidence provided by experience. We needed hard numbers and solid facts which would either confirm the conclusions drawn from experience or—horrid prospect—oblige us to admit we've been wrong. Our problem was that it's a world easier to speculate about the results of oil testing than to devise and conduct a satisfactory test program. Simply making up sample batches of premix at varied

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**IS LESS, MORE?
IS MORE, LESS?
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IS LESS, LESS?**



By Gordon Jennings

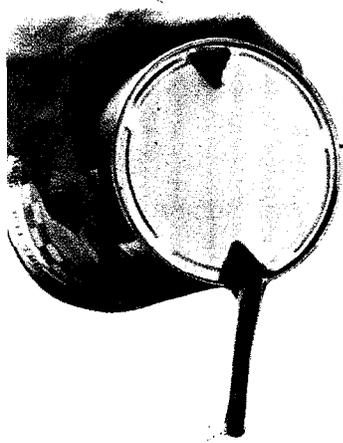
fuel/oil ratios and trying them in five-minute dynamometer runs did not seem to be a procedure that would settle anything. We suspected that oil migrates through premix-lubricated engines rather slowly, which meant running long enough to stabilize our test engine at an oil content level normal to each premix ratio. Brief test periods, we thought, might blur any power differences that otherwise might emerge. Further, it was almost certain that short-duration dynamometer runs would tell us nothing about the rela-

tionship between premix ratio and piston cleanliness, and this aspect could not be ignored. If there were short-term power gains with more oil in the engine's fuel, and these became losses due to ring sticking after 15 minutes of running, then less would indeed be more: *sustained* performance is what counts.

Thanks to the Society of Automotive Engineers, we didn't have to launch into our oil tests totally blind. We obtained one SAE paper that reported the results of tests performed to determine the behavior of oil in crankcase-scavenged engines, and this paper provided information invaluable in planning test-run duration. The paper's authors switched a running engine, very briefly, to a supply of premix with oil containing a radioisotope, tritium, then continued to run the engine on an untagged premix. Radioactive oil began to appear in the exhaust gases almost immediately, reached maximum concentration within two minutes, and only after a half-hour of 2500-rpm running did it dwindle to a last-traces level. Therefore, we could anticipate running our own test engine for at least 30 minutes just to get the oil content stabilized.

Another SAE paper provided direction when we were attempting to decide upon test severity. Experience, of a disheartening sort, had shown that it's entirely too easy to produce piston seizures in air-cooled two-stroke engines merely in routine dynamometer running. We've discovered that it's necessary to use a thermocouple washer to register spark plug temperature and to avoid exceeding plug-washer temperatures of 425 to 450 degrees F. This second SAE paper was a great encouragement because it outlined an accelerated, severe oil test procedure in which the cylinder head temperatures mentioned were very well aligned with our own appreciation of the disaster threshold for two-stroke engines. What the paper's authors said, in brief, was that it's possible to learn a lot about an engine's lubricated condition without getting involved in hundred-hour tests. Lengthy testing is required when you're attempting to differentiate between closely matched oils or nearly equal premix ratios; we were interested only in the two-level testing of a broad concept: would more of a suitable reference oil cause an engine to produce

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more power or less, and would ring sticking be reduced or made worse?

The choice of test engines was based on practical considerations, foremost among them reliability. We didn't want some mechanical failure to abort a test. And we wanted to use a 250cc single-cylinder engine because that's a representative size—and because a single presented the fewest problems in terms of top-end dismantling. The plan was to run a new piston in each series of tests so we'd have no confusion over which premix ratio created the most varnish and/or carbon deposits around the top of the piston and the ring grooves. Finally, we had to consider the possibility of a seizure severe enough to damage the cylinder bore, something that would require a cylinder replacement.



20:1 Our baseline premix ratio produced 26.9 bhp and the light coating of piston varnish seen here.

This final consideration brought us to the Suzuki PE250: the manufacturing process used in making its cylinders yields a superior part, with fairly precise alignment of ports and port windows, and little variation between individual cylinders. Changing cylinders between tests would compromise the overall results and was to be avoided if possible, but Suzuki's nearly-identical cylinders would allow us to continue testing. Finally, we opted for the PE250 because we know it's very reliable, and while not as vigorous as a motocrosser powerplant, the engine does work up more than enough power to give its oil something to resist.

We chose Castrol 40R as our reference oil, knowing that this choice would be

widely criticized. Castrol "R" is a castor-base lubricant, bean oil, and if you ask racing's sharpest tuners about it, they'll tell you it's the worst stuff in the world—except for everything else. Talk to the Castrol people, and they'll give you a dozen reasons for using their petroleum- or synthetic-base two-stroke oils instead of the castor bean juice, before admitting castor provides last-ditch-stand lubrication that the other, less difficult oils can't quite match. Bean oil *is* horrible stuff, and treacherous (more on this later), but it will do the job under the most severe conditions, and that's precisely what we had planned for our oil tests. Besides, it has a marked tendency to cook into varnish and sludge on pistons; consequently, castor would very quickly give us a good indication of a particular premix ratio's influence on cleanliness.

Cycle's routine dynamometer work is done at Webco, but for our oil testing we elected to use Jerry Branch's facilities. Jerry's dyno has an old-fashioned water-brake absorption unit with controls that require its operator to have more arms and eyes than a Hindu idol, but it is fine for comparative horsepower checks, and it is surrounded with just the sort of hardware needed for our premix tests. Jerry's dyno room has three hurricane-force cooling blowers and instrumentation to meter everything from fuel flow to exhaust gas temperature. The only thing it lacks is a television set, which we soon learned was needed to relieve the boredom of waiting while the engine lunged against the dynamometer load for the required hours.

Suzuki had loaned us a new PE250 for our oil testing, and we began this project with an hour of break-in running during which engine speed and load were cycled up and down to approximate the recommendations given by the owner's manual. This running was done on a 20:1 premix ratio, per Suzuki's recommendations, with Castrol 40R carefully blended with 98 octane premium-grade fuel (the latter was obtained, in bulk, from a single source so that a shift in fuel quality would not bias test results). With the break-in completed, a full-throttle power test was made—adjusting the dynamometer's load until the highest torque reading showed on its scale and then noting engine speed. What we had was 25.9 brake horsepower at 7000 rpm, about what we'd expected of the stock PE250 engine. Unfortunately, this brief full-throttle blast had sent the spark plug washer temperature soaring up into the 435 degree F. twilight zone very rapidly. Subsequent examination of the spark plug indicated there was a bit too much timing advance, which we then set about correcting. After a couple of tries we got the ignition timing more nearly optimized (retarded four degrees

from the standard setting) and made two more power runs—both of which showed the engine output had been raised to 26.9 bhp at 7000 rpm.

With the above horsepower baseline established the endurance testing (for us and the Suzuki) was begun. We somewhat arbitrarily decided to run the engine at 5500 rpm, and throttle and load were jiggled to bring plug temperatures into the 390–400 degree F. range. The load re-



30:1 Reducing the fuel's oil content caused heavy scuffing, more varnish and a 12 percent power loss.

quired to hold the above readings was equal to a modest 8.8 bhp, or a third of maximum output. Our reason for choosing a 5500-rpm engine speed was that it made testing relatively painless work. At that speed, we found, the throttle and load settings did not require constant adjustment and the engine seemed happy. Also, we wanted to see whether this condition would be stable in the still relatively new engine: if it became necessary to increase the load to hold the speed and plug temperature readings constant, then we'd have to assume that an hour of break-in running wasn't adequate. In fact, there was no shift in settings or readings during the test phase just described. The Suzuki droned on, and on, and on, as though it would continue forever; we let it continue for a half-hour.

Earlier we'd decided to run for 30 minutes with plug-washer and cylinder-head



15:1 Adding oil reduced varnishing and raised the output 3.7 bhp over that obtained on 30:1 premix

CYCLE

temperatures well into the danger zone, and with the moderate-duty phase completed we began the severe-duty testing. There was no question of trying a half-hour run at 7000 rpm and full throttle; neither the PE250 nor any of its cousins will operate at maximum output for more than 15 seconds without melting a piston. But we quickly found that the engine would hold 6000 rpm and a dynamometer load equal to 9.6 bhp without requiring too much coaxing at the controls, and this combination brought the plug temperature up into the 410–420 degree F. bracket—which experience has shown to be a severe test of a two-stroke engine's lubrication. With that plug-washer temperature, cylinder head readings (taken with a thermocouple under the blind plug that closes the head's compression-release hole) were in the order of 385–390 degrees F. We could not measure piston temperature but presumed it to be high enough, at the engine load, to tell us something about the lubrication.

And so it went, for another half-hour, without any indication of distress from the engine. Then, the severe-duty phase completed, the engine was throttled back to bring its plug-washer temperature down to 350 degrees F., held there for two

entire cycle of break-in, moderate-duty and severe-duty running was repeated . . . after a lot of fiddling with carburetor jets. When you feed an engine 20:1 premix, only 95 per cent of the fluid passing through the carburetor is fuel; five per cent is oil, which does not burn. In switching to a 30:1 premix, we dropped the oil content to 3.3 per cent and changed the fluid's viscosity in the bargain, which meant the engine's air/fuel ratio would be changed unless corrective measures were taken. We took those measures, flowing premix through main-jets into the dark of one night and almost to the lunchbreak of the following day, until we had achieved fuel-flow parity between the 20:1 and 30:1 gasoline/oil mixtures.

A funny thing happened during the break-in period of the 30:1 premix test: at almost precisely the half-hour mark, which is the time the SAE paper said was required for a complete oil exchange, we noticed that engine output sagged slightly. The break-in runs included quick power checks at 5500 rpm and holding a 350-degree F. plug-washer temperature, and we found that the dyno load corresponding to these readings was a trifle lower. We became very curious about the difference in maximum power, if any, but

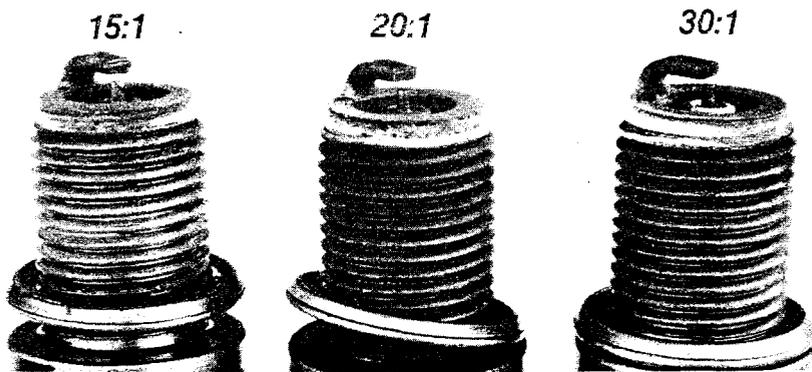
word on the 30:1 premix ratio: a drop to 23.6 bhp, for an overall power loss of 3.3 bhp or 12.2 per cent. Also, on the second of these power checks, engine output sagged perceptibly, so we were not surprised to find that the piston was marked by scuffing. The piston didn't seize, but it obviously had been at the ragged edge of seizure. Further, it was very much dirtier than the one we'd run on 20:1 premix. So on both counts, power and cleanness, less was less.

After the 30:1 testing had been completed and we had taken the PE250's top end apart for a new piston and rings, we had a difficult decision to make. Not only had the piston been scuffed, the cylinder bore had suffered, and we were forced to consider switching to a new cylinder. That option finally was discarded, because even though the testing to follow—scheduled for a 15:1 premix ratio—would surely give results made a bit worse by the poor condition of the cylinder bore, we knew that a new cylinder could not be substituted without raising a chorus of "Ah Ha's" from the less-is-more adherents. We did ultimately scrub the worst of the rough spots out of the wounded bore with emery paper and, with time running out (others were waiting to use Branch's dyno facility), slammed it all back together with a new piston and resumed running.

Again, we changed the carburetion to maintain the original effective air/fuel mixture. The 15:1 premix, which has a 6.7 per cent oil content, is appreciably more viscous than 20:1 or 30:1 premix and required raising the jet needle one notch to get the part-throttle mixture right as well as a main-jet adjustment. And again we did an hour of break-in before attempting a full-throttle power check, and we could almost hear the engine heave a sigh of relief as its oil supply began to increase. Then came the pre-endurance power check, and we were pleased to get 26.6 bhp at our 7000-rpm checking speed out of this somewhat unhealthy engine. It was

down 0.3 bhp from its best performance on 20:1 premix, and we just didn't know if that was a function of the scored cylinder, or if Suzuki's mix-ratio recommendation simply was in all ways best for the PE250. Anyway, we continued to run, proceeding through the moderate-duty and severe-duty phases, and finished the test program with a final power check with the 15:1 premix. To our astonishment, the hour of running had improved the suffering engine's health, and it then gave us the highest power reading we obtained in the course of this project: 27.3 bhp at 7000 rpm, an output only 0.4-horsepower higher than the Suzuki's best effort on 20:1 premix, but no less than 3.7 bhp above the performance on 30:1 premix.

(Continued on page 112)



None of these plugs fouled; the one used in testing 15:1 premix did acquire a heavy coat of deposits.

minutes, and two more 7000-rpm power checks made. Again, after all the teetering on the edge of thermal disaster, the PE250 gave us the same 26.9 bhp, and we hadn't even changed the spark plug. Suzuki's manual says the PE250 should be run on a 20:1 mixture of gasoline and castor oil, and there was nothing in the results of this first test to suggest otherwise. The plug was reasonably clean after two hours of continuous running, and when we removed the piston it too was clean—despite the presence of "death ash" on the underside of its crown, which is a certain sign of dangerously high piston temperatures.

We installed a fresh piston in the PE250, with new rings, and a batch of 30:1 premix carefully prepared. And the

we resisted the temptation to depart from the test procedure we'd set for ourselves and waited until the one-hour break-in period was finished before giving the engine a full-throttle blast. And when we did, the engine produced 24.5 bhp at 7000 rpm, which was almost 10 per cent below the power obtained from 20:1 premix. This appeared to be clear evidence that in the relationship between premix oil content and horsepower, less is less.

The post-break-in power run was followed with the same 30-minute moderate-duty and severe-duty periods, as in the 20:1 premix testing, and finished off with the same two-minute cool-down (to a 50-degree F. plug temperature). Then came the final power check, two maximum-effort blasts at 7000 rpm, and the final

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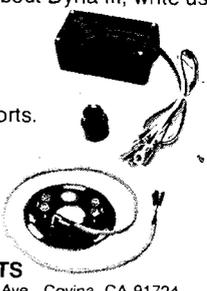
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The horsepower difference we found between runs on 30:1 and 15:1 premix is, we think, conclusive evidence against the entire less-is-more theory. There always is experimental error to be reckoned with in this kind of testing, but when you find a 3.7-bhp difference, when you have *Sample B* giving a result 15.7 per cent better than that of *Sample A*, then there simply isn't a lot of room for argument.

We did everything we could to avoid producing a bias in favor of our pre-test position: we found an ignition setting the engine liked and left it alone; we went to great lengths to erase air/fuel mixture differences when running the three premix samples; we used the NGK B8EV spark plug recommended by Suzuki in all testing, and the same plug stayed in the engine for the entire duration of each sample test—from the beginning of break-in right through the last power check; we measured the pistons used in the test to make sure they were all precisely the same size; and we followed the same procedures for all the tests, monitoring plug, head and exhaust temperatures to be very sure all conditions but lubrication remained the same. Maybe, with all the work we did, the only sure thing is that the PE250 engine we tested, running on a mixture of premium-grade gasoline and Castrol 40R oil, did make appreciably more power when the premix's oil content was raised from 3.3 to 6.7 per cent and all other things were kept equal. Maybe that's all we can say we've proved—but we can say that much with the assurance that comes from hard facts.

Only a little less firmly-factual was the pattern of cleanness that developed in our oil testing, and what we're pretty sure we found is going to blow your minds. There was no evidence of ring-sticking with any of the premix samples tested, but we think that would have occurred if we'd extended the severe-duty testing from 30 minutes to a couple of hours. Why do we think that? Because one of the premix samples left a lot of varnish on its piston. Which one? Surprisingly (for anyone who'd never seen it happen before), it was the 30:1 premix with the lowest oil content. The cleanest piston, by a slight and thus disputable margin, was the poor, abraded devil that ran last, in a scored cylinder, on the 15:1 premix. Judging from this piston's skirt, which was covered with vertical scratches, we hadn't been sufficiently careful in washing out grit from the emery paper. Still, it had given us the best horsepower and did seem to be slightly cleaner than the piston from the 20:1 premix testing; both were much less varnished than our 30:1 piston. So it appears that piston cleanness actually *improves* as the percentage of oil in premix is increased, at least in the 15:1 to 30:1 mix-ratio range. Our results might have been more clear had we been more careful in

that cylinder clean-up, but we think the basic relationship between oil volume and piston cleanness was reasonably well defined by our test program.

Our oil testing kept Branch's dynamometer facility tied up for a week and devoured more man-hours than the Thirty-Years War, and the results can be given in a single, brief sentence: "Engine output and piston cleanness improves as premix oil content is increased." We've already presented the necessary qualifiers to that statement, and though it may be a touch wobbly at the knees the statement stands. We think what we have here is a fundamental truth, and anyone who would change our minds will have to do at least as much hard investigative work as we have done. Personal opinion and conclusions drawn from random experience were what we had before we made the investment in mixing fluids, twirling wrenches and, above all, in enduring the infernally noisy purgatory of Branch's engine-test cell. Anyone who would prove us wrong will have to make the same investment and come up with something a lot more solid than an opinion voiced by the service manager of Bud's Cycle Center in Meadow-Muffin, Iowa.

Of course, the oil testing we did was a narrow-spectrum effort, with narrow goals and narrow results. We know it leaves questions hanging in the air, and two of these are worth our consideration: first, what would have been the result if we'd conducted our tests with something other than a castor-based oil; and second, how did the whole less-is-more trend get started if the concept had no merit? Answers to both questions are to be found by studying the history of the specialized oils developed for two-stroke outboard-marine and chain-saw engines, and in those units the requirement for oils is not so much centered on lubricity as freedom from spark plug fouling.

Oil, of almost any sort, does tend to cause the formation of fouling deposits on spark plugs, which in turn creates cold-start problems and misfiring and a whole host of posterior pains. That's a fact, as you probably are aware, and it also is a fact that the plug we used in testing 30:1 premix is a lot cleaner than the one from the 20:1 test, etc. It's a fact, too, that people who operate outboard and chain-saw engines generally don't know anything about any kind of engine; for the bass fishermen stranded in the middle of a lake, fouled plugs might as well be a broken crankshaft. High mix-ratio oils, like the 100:1 stuff compounded by McCulloch back in the early 1960s, were invented to keep plugs clean and the bass fisherman happy.

Today's high mix-ratio oils, like those developed years ago, use a base stock—which may be refined petroleum or synthetic in origin—heavily fortified with additives that improve lubricity and promote

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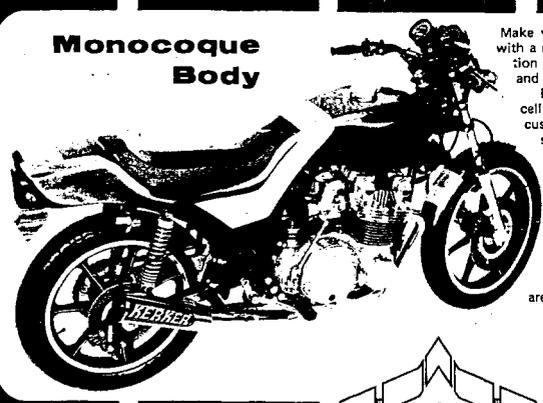
cleanness. The additives can be anything from a petroleum substance called "bright stock" to polymeric chemical compounds. And they can do anything from a wonderfully effective job to bringing about an almost immediate disaster. The best of them are very nearly as good as castor in terms of hard-grunts lubricity and are vastly superior when engine cleanness is taken into consideration. Also, most (but not all) of the petroleum and synthetic based "additive package" lubricants do not have castor oil's dangerously short shelf-life. Mix castor with gasoline and/or leave it exposed to air, and its lubricating qualities quickly degrade; you can use today's batch of castor/gas premix for tomorrow's racing but it's no good for the next weekend. Old castor premix will coat spark plugs with black, tar-like deposits, and its lubricating quality isn't worth zilch, which is why the Castrol people would really rather have you use their less-touchy, easier-to-live-with, and entirely-adequate conventional additive-package oils.

Why didn't we use one of the non-castor, additive oils? Actually, for what we planned that wasn't possible, because we wanted to try different mix ratios, and doing that with additive-package oils is just asking for trouble. These oils' additive contents presume that the user will follow the directions on the can. If the makers' plan for a 50:1 premix ratio, they may use bright-stock to provide scuff resistance, but they won't include much of it in the additive package because it's very dirty, and they'll toss in an extra dash of a detergent chemical to keep the bright-stock from collecting like so much black glue. Now after all that juggling of additives they may have a terrific oil, but it won't be anything we can use in testing premix ratios. If we mix it at 20:1 instead of their 50:1, we'll be pouring more than twice as much bright-stock over our test engine's piston as is healthy, and the doubled amount of detergent chemical may not help, because some of those actually become a dirtying agent above certain levels of concentration. Finally, we couldn't be sure that an additive-package oil would be the same from one bottle to the next, even if all had the same brand-name. We know that these oils' additive contents do get changed without any announcement being made. Some of the additives are expensive, some are in short supply, and changes do occur.

For the reasons just given, we were obliged to do our testing using castor oil, which we admit is horrible stuff in every way but two: it does the job when oils depending on a chemist's slight-of-hand won't, and it let us shoot a couple of big holes in less-is-more Miracle-Oil trendiness. Less, in the context of premix lubrication, isn't more; it's less, just as logic always insisted. ©

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