Basics

INSTRUMENTS

By Gordon Jennings

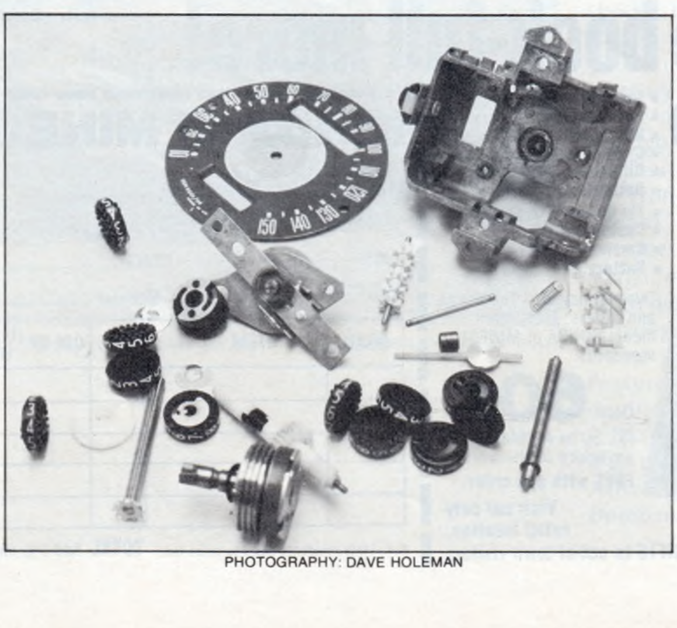
• Motorcycling has its genuine artists: gifted men who can squeeze a tire, touch a crankcase, listen to the whisper and jangle of moving parts, and simply *sense* many of the mechanism's vital signs; riders who can feel the wind, watch the pavement blurring underneath, and just *know* their speed. But real artistry is rare, and at its best still is subjective, imprecise. How hot is hot; how fast is fast? We often need that kind of information expressed in hard numbers, and for numbers we must turn to that category of devices called instrument—and make sure that they actually are more trustworthy than our fallible human senses.

One instrument common to all touring motorcycles is the speedometer, which in most instances cannot be trusted at all. Our regular road test procedure includes a check for speedometer error, of which there usually is plenty even when everything else is lacking. People who ride at the current energy-crisis speed limit often are heard to complain that everyone else is charging past at least 10 mph over the legal maximum. Maybe, but not likely, when you consider that the average motorcycle speedometer is about 4-mph optimistic at an indicated 60 mph. So, when your bike's speedo needle is trembling right at the legal mark you're probably thudding along at no more than 51 mph and that's one reason why others on the road seem to be such outrageous scofflaws. Make further adjustments for the typical driver's habit of bending the speed regulations right to their elastic limits, toss in the psychological enhancement of the speed of any object whizzing past one's elbow, and you have a good explanation for the law-abiding riders' complaints.

Heaven forbid we should lead people to sin against the law; we must warn the reader that he must not arbitrarily add four or five mph to his bike's indicated speed, assuming that true speed would then be at the legal maximum. A few motorcycles (particularly those from England) do have accurate speedometers, and it is best that you do not learn from your local friendly police that your bike is one of the few. You can save yourself the embarrassment, and the fine, by checking the instrument's accuracy. All you need is a stopwatch and a stretch of road with mile-markers.

Here's the speedo-check procedure: you time yourself between mile markers while holding a steady indicated speed; then divide the time, in seconds, into 3600 to get your true speed in miles per hour. You should repeat this procedure at perhaps three different speeds. Speedometer error usually is a fairly constant percentage of indicated speed, but isn't in every instance. Above all, *do not* try to use your bike's odometer as a substitute for the measured distances, because the average odometer, no less than the speedo itself, definitely speaks with forked tongue.

Why all the speedometer and odometer error? We're not sure, because both are marvels of simplicity and should not require super-precise manufacturing to provide reliability. The speedo's cable drives a circular magnet inside the instrument and the spinning of the magnet produces an eddy-current drag on an enveloping aluminum drum. The drum is prevented from turning freely with the magnet by a spiral-wound counterbalance spring. A shaft extending out through the instrument face carries the speedometer needle, which assumes a position of equilibrium between the torque induced by the spinning magnet and the counterbalancing influence of the spiral spring to give a reading in miles per hour. Manufacturing tolerances obviously will introduce some variations in the strengths of individual magnets and springs, and these factors would account for some instrument error. However, the errors we find are too consistently in favor of motorcycle makers' performance claims to be entirely honest



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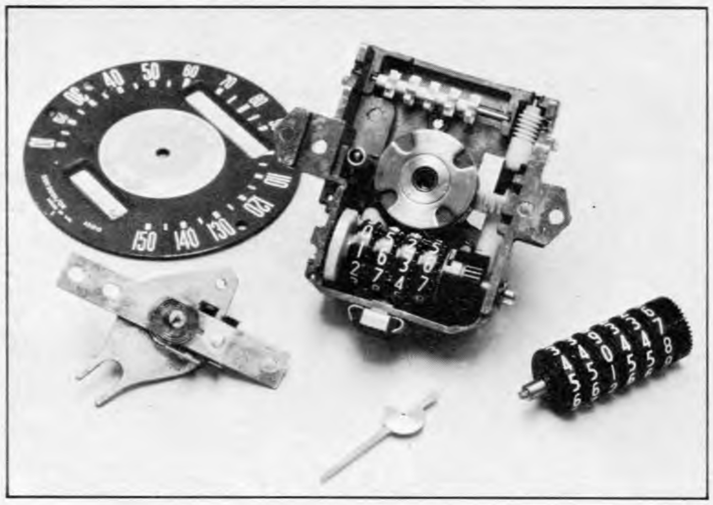
mistakes. If speedometers can be made to a nearly-constant 4-mph "fudge factor" then it should be possible to at least close the gap slightly between indicated and true speed.

There is even less justification for the odometer errors we have found. The odometer is totally gear driven, and will respond to the number of turns of the wheel to which it is linked with absolute fidelity. When the "tenths" drum in the odometer makes a complete revolution it trips the adjacent numbered drum one notch, then when the latter has moved around ten notches it trips the next drum a notch—and so on. Accuracy depends on providing gearing appropriate to the rolling circumference of the speedo-driving wheel. Differences in tire inflation pressure can produce small errors in odometer readings, but here again we have mistakes consistently in favor of the manufacturers' claims: an odometer that errs 10-percent higher than the miles actually covered will encourage the owner to believe he's getting fuel economy and distance between tuneups 10-percent better than really is the case. You can check for odometer error using those same mile markers you need for the speedometer, and you probably will have to revise some of those mileage figures you've been bragging about. If the error is 5-percent or less you can lay it to a little honest sloppiness; more, and it's probably flim-flam.

Viewed from the standpoint of law, tachometer error is much less important than those little white lies told by your bike's speedometer, and most nonracing motorcycles very likely do not need a tach at all. But if you're dealing with an engine that's sensitive to over-revving and/or has a narrow power band, the tachometer is a vitally important instrument. Don't worry about full-range accuracy, as that probably is unattainable; the important thing is that the tach should give precise information when the engine is at its redline, and even that may be beyond the instrument's capabilities. The tachometer's main problem is that it tends to lag behind rising engine speed when a bike is accelerating rapidly in first and second gears. This lag seems to be inherent in the mechanically driven tach, which is identical internally with the speedometer, due to the inertia of its aluminum drum and attached needle.

There's nothing you can do about tachometer lag, apart from showing restraint in your style of riding; it is possible to cope with error. A few shops around the country specialize in speedometer and tachometer calibration, but they may find themselves stymied by the rather odd tach drive ratios employed in Japanese-made motorcycles. Besides, professional calibration work is expensive and hairline accuracy isn't necessary except in the tachometers used on racing bikes (where it can make the difference between winning and breaking an engine). All the sporting street rider needs to know (if only to satisfy his curiosity) is the relative accuracy of his bike's tach, and we have a no-expense method whereby he may accomplish that much.

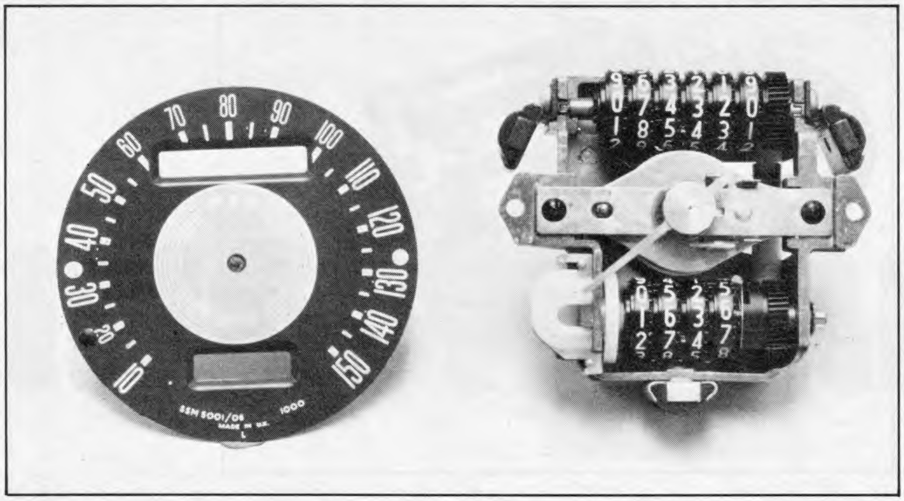


To check your bike's tachometer for truthfulness you need to know its overall gear ratios and the amount of speedometer error present. The method involves calculating what the tach reading should be at some true road speed and then checking to see if the instrument agrees. You begin by finding the rear wheel's rolling circumference. Sit on the bike, to load the tire, and get a friend to make chalk marks on the tire and the road. Then roll the bike ahead until its rear wheel has made one turn and the chalk reference line is again down against the pavement. Measure between the starting point and the new position of your reference line to get the number of feet your bike travels for each rear wheel revolution, a figure you must divide into 5280 to arrive at the number of wheel revolutions per mile. Multiply wheel revs/mile by the overall gear ratio and you have engine revs/mile, which is then multiplied by the bike's true speed—expressed in miles per minute—to obtain engine speed in rpm.

Let's apply The Method to a hypothetical motorcycle: we make the marks on tire and pavement, measure between them, and find that the bike moves ahead 78-inches, or 6.5-feet, for each wheel revolution. We then divide the 6.5-feet into 5280 (number of feet in a mile) and come up with 812 wheel revs/mile. Assuming that the overall gear ratio is 5:1, we would then multiply 812 by 5.0 and get 4060 engine revs/mile. The easiest testing speed is a true 60 mph, because that's exactly one mile per minute and at that speed our hypothetical bike's tach should be reading 4060 rpm. We know from experience that calculated engine speed is extremely accurate when done carefully, so if your bike's tachometer doesn't agree with your calculations do not be too quick to assume the difference is a matter of arithmetic mistakes. Chances are the error is in the tach and not in the numbers.

Industrial and some aircraft tachometers bear added resemblance to speedometers in having what amounts to an odometer, only with numbers reflecting engine-hours instead of miles. In fact, the gauge will be marked "engine hours" but what it tells you is not service time; it's the total number of revolutions turned by the engine. This system has shortcomings, as the figure on the instrument face does not take into accounting factors such as load, or the rate at which the crank turns were accumulated. Still, it is better than mileage as a standard of service intervals. Engine-hour recording tachometers are not available for motorcycles but you probably could convert a speedometer/odometer to serve the purpose. We're not entirely sure what purpose that might serve; it would be fun to try, and you might discover that fuel consumption, for example, relates more closely to "engine hours" than to miles traveled.

Neither speedometers, tachometers nor their drives are likely to give trouble. Back when the reduction gearing was in add-on housings there were some problems, especially when people tried to shoot grease into them with a high-pressure lube gun and discovered that the seals and gaskets (and sometimes the housing itself) were not strong enough to hold the load. But now that tach drives have become built-in engine components, and speedo drives gears commonly are part of motorcycle's front wheel hub assemblies (sharing the same supply of lubricant), failures are extremely rare. Indeed, the only problems most people experience are those they bring on themselves, and these usually arise from a severe kinking of the instrument drive cable. We've witnessed speedo and tach drive cables routed so they were certain to get pinched between the lower fork bridge and the steering stop, and seen then where they had to get kinked if the forks compressed even halfway. These drive cables also get used as lifting straps by people trying to pull their bikes out of mud holes, and cables are snagged on everything from tree branches to spectators. All of these things pull kinks into the cables and their sheaths, and that's very nearly the cause of cable failure.



When a cable has been kinked the best thing you can do is to replace it, but if the new part isn't available or you're short of money a repair is possible. The job requires that you remove the cable from its sheath and then make separate fixes. The cable, when kinked, must be pulled straight and the damaged section silver-soldered into a solid bar—which may then be filed or hammered until it has the same shape and diameter as the rest of the cable, albeit a little stiffer. The cable sheath can be coaxed straight, but the plastic covering that makes it water- and dust-proof will keep you from using heat. If all else fails you can force a short length of steel or copper tubing over the kinked spot to hold it straight, and if for any reason you have repeated problems with kinking try winding spring wire over the sheath ferrules and the first couple of inches of sheath—which is where most of the kinks develop.

We could avoid *all* difficulties with tach/speedo drive cables if electrical instruments could be made a practical proposition. There are non-mechanical instruments of this sort that provide extremely accurate readings, but the good ones seem to be horrendously expensive. Certainly the electronic tachometers of the type used on some 750 Ducatis, for instance, leave much to be desired. They waver and waggle, and when not doing that alternate between fits of sulkiness and moments of sly whimsy. We can't claim experience with all electronic tachometers; the ones we've tried have not been very good. The electrically-driven tachs used in tuneup work and the like do work fairly well. Maybe it's all the vibration and jolting of operation on a motorcycle that makes them misbehave.

It may be significant that the electronic tachometers with 90-degree needle-travel have the best reputation for accuracy, and it strikes us that the reason is they can't be read closely enough for anyone to know when they're wrong. The mechanical tachs usually have needles that sweep an arc of about 270-degrees, within a face diameter averaging something near 3 inches. Cut an arc like that into 1000-rpm or 10-mph increments and the readings don't become too badly crowded even when 12,000 rpm and 120 mph maxima are provided. Do the same on a 90-degree arc, compressing the markings by a factor of three, and you really can't tell what the instrument is trying to say unless you get your nose against the glass.

An important fact to consider relative to reading instruments is that when you're out in the real world of turns and traffic you don't actually read them at all. There may be times, tootling along an Interstate highway, that allow a long, studied glance at the tach and speedo; but the occasions upon which the tachometer, especially, should be watched sharply are those requiring maximum attention to the road. Racing provides an extreme example of this conflict of interests: riders have to watch the track, or crash; they have to watch the tach, or risk breaking an engine. And racing provides an answer: racers turn the tachometer so that when the critical number is reached, the needle is pointing straight up. Do that, and you don't even need numbers on the dial.

Now that the development of light-emitting diodes has brought direct digital readouts to everything from computers to alarm clocks, some one of the motorcycle manufacturers is sure to come up with the stunning idea of digital speedos and tachometers. These will be dazzlers in advertising copy and in the dealers' showrooms; they aren't going to work worth a hoot. Why? Because most of the instrument reading you do when you're riding is a quick scan and most people can scan-read the position of a needle much faster than their vision can register numbers. Also, you can watch the swing of an indicator needle and anticipate when a critical reading will be reached, which is very difficult with digital displays.

Warning lights usually are not considered instruments. They are, and their yes-no, some-none readings provide all the information many people require. The warning lights' problem is that they may not be bright enough to give an adequate warning at mid-day, and that they do not tell you trouble is coming—only that it has arrived. We are inclined to believe that a simple warning light is all the instrumentation the modern motorcycle's electrical system needs. Today's alternators, etc., are extremely reliable and when something does go wrong the flickering of a charge indicator light will tell you as much as a flickering ammeter needle. On the other hand, it sometimes is very important to monitor such things as oil temperature and pressure—which at their critical highs and lows respectively are warnings of impending engine damage.

Oil pressure is less important than oil temperature in most motorcycle engines, and vastly more difficult to measure. A simple pressure switch and warning light system is perfectly appropriate when the engine in question has a roller-bearing

(Continued on page 93)

BASICS *Continued from page 38*

crankshaft, because such engines require only a trickle of oil delivered at extremely low pressure. The Kawasaki Z1 engine, for example, will show only 2.8 pounds/square inch with its oil warmed to 140°F. Few of the available oil pressure gauges would respond to such a low-level stimulus; the best of gauges would provide substantially some-none information and you get that from a warning light. Unfortunately, while the majority of motorcycle engines would be satisfactorily served by a pressure light, many do not have them.

And then there are the bikes with oil warning lights that might better have a pressure gauge. Hondas Fours fall into this category, because they have plain-bearing cranks and those main and rod inserts need a lot of oil delivered at high pressure. The workshop manual for CB750s says their pressure-relief valves should be set to provide 57 psi with the oil temperature at 176°F. and engine speed at 4000 rpm. This is fairly typical for plain-bearing motorcycle engines, all of which have relief valves and run oil gallery pressures around 45-65 psi. Of course oil changes its viscosity very considerably with temperature, so the readings you'd get would be high on a cold morning and drop somewhat below specifications on a hot summer day—even with a perfectly healthy engine.

In most instances oil pressure readings really are nothing more than second-hand reflections of oil temperature, so anyone planning to fit a motorcycle with just one extra instrument should go for the thermometer. Or maybe they shouldn't because what they learn may send them off in search of an oil cooler. Don't be too eager to insert a radiator into your bike's oiling system: the oil should be fairly hot, 175-180°F., to prevent fuel and water dilution, and to reduce mechanical losses arising from viscous shear. Engines will run very comfortably with their oil at 200°F. and can survive, for a while, conditions that raise oil temperature to as much as 250°F. The oil itself will accept much higher temperatures, but those tend to reflect scorching-hot bearings, pistons, etc., and may be taken as a signal to slow down and give your engine a chance to cool off a bit. We know of a few motorcycle engines that cannot be made to hold their oil temperatures below 325-350°F. unless either fitted with an oil cooler or used with great restraint by their rider: they survive, but the lower operating temperatures have been established for aircraft and other kinds of engines and one must assume that reliability ultimately must suffer at the higher levels.

You obviously cannot measure the temperatures and pressure given here unless you install the instruments that do the measuring. These instruments may be obtained from various sources, VDO and Stewart-Warner being two that spring instantly to mind. The details of installation you'll have to work out to suit your particular motorcycle. The main point of concern in this is that their sensors be placed so that they actually pick up the desired information. Oil pressure should be taken at some spot in the engine's main gallery; many times there will be restricted orifices limiting oil delivery to the cylinderhead, and readings taken downstream from those orifices will be unrealistically and alarmingly low. The oil temperature sensor should be located in much the same place, though not for the same reasons. If you insert the sensor bulb into the oil sump it will be insulated by a layer of relatively cool oil clinging to its surface and thus read too low. The other extreme is represented by a temperature sensor screwed directly into a cylinderhead, where it would pick up heat from the surrounding metal and read too high. The sensor should be placed where it will be scrubbed by moving oil, and where it can accurately pick up the temperature of the oil itself and not that of some overheated metal casing.

We recommend using pressure/temperature instruments with electrical sensors, if they are available. There's nothing wrong with the ones having a capillary-tube connection between the sensor and the gauge itself, except that it sometimes is difficult to find a tidy routing for the rather fragile tube. Also, the motorcycle's high level of vibration can cause the tube to fracture. The electric sensors need only a small wire for their connection with the gauge, the wire can be tied in knots without effecting the instrument's functions, and if the wire breaks you won't have a stream of oil squirting you right in the eye.

Vacuum gauges are thought to be exclusively the property of tuneup mechanics and weird old guys who also have a compass mounted on their Rambler's instrument panel. In fact, you can get some worthwhile information out of a gauge connected to register manifold vacuum, and it does relate to *total* tuning—including some engine modifications. Assuming that you haven't changed gearing, then manifold vacuum at a given speed, on a level road and in still air will reflect the success of any tuning changes made. That is to say, if you change the engine's spark advance or jetting and get a little more power then it will take just a little less throttle to hold a given speed and the gauge will show a slightly higher manifold vacuum. The same response will be observed with changes in compression ratio, valves, porting, and anything else that does not too greatly elevate the speed at which an engine makes its power. Conversely, if you find you're getting lower manifold vacuum readings after, say, a change in ignition timing then you may be reasonably sure your hot setup has proven to be only luke-warm.

Two-stroke engines can hardly be said to have any oil pressure or temperature, and all those with water cooling have that instrumented by the makers. But there is one rather specialized gauge that profitably may be applied to two-strokers: the spark plug thermocouple. As it happens, two-stroke engines are both very succeptible to detonation, and very apt to suffer catastrophic piston failure as a consequence of that combustion process irregularity. We have a fair amount of experience with dynamometer testing these engines, and use spark plug gasket temperature as a kind of thermal redline. There are thermocouples you can substitute for the ordinary spark plug gasket, and when the gauge to which the thermocouple is attached says the plug temperature has reached about 450°F. it is time to ease back on the throttle. Our experience is that the temperature will rise relatively slowly until it nears four-fifty; then it will begin climbing very rapidly—probably due to the onset of detonation—and if full throttle is maintained the dynamometer needle will start to fall back toward zero. When that happens you can plan on replacing a piston. Thermocouples and the related hardware are very expensive, so we certainly are not recommending that every two-stroke engined motorcycle should have plug-temperature sensors; the equipment is small and could be mounted on a bike for use in experimental work, where it probably is cheaper than repeated engine rebuilds.

One instrument *every* motorcyclist should have and use is a tire pressure gauge. Sure, there's one connected to the air hose at most service stations, but those are often wildly inaccurate, and quite small changes in tire inflation pressure have a large effect on handling and tire tread life. Manufacturers do a lot of testing to establish correct tire inflation pressures for motorcycles; all their work goes for naught when the customer relies on those service station gauges.

There are other forms of instrumentation, some of which does not involve wiring and cables and dials. At this moment our shop contains one motorcycle with experimental brake discs (aluminum, with a sprayed surface coating) and the operating temperatures of those discs are being monitored with a couple of tiny, heat-sensitive decals. Dots on the decals turn color at 350, 400, 450 and 500-degrees, providing a permanent record of how hot the discs have been. There are other decals for other temperature ranges, and heat-sensitive paints and crayons to accomplish the same thing. Such devices have been coming into use here and there, mostly in racing, and we expect that this kind of technology eventually will trickle down to the shade-tree, private-owner level. It's all part of a growing recognition that motorcycling should be much less art and more science, and that instrumentation really is the distinguishing feature between the two fields. ◉