

Evaluating engine operation and pinpointing specific problems requires a comprehensive testing routine. Here's how to do it.

There's nothing more basic than the fact that an engine is just a big air pump. It draws in air by creating a low-pressure area in the intake manifold and cylinders, compresses the air, mixes in a little gasoline, lights a fire, generates heat and pressure and finally pumps out the spent exhaust. Our preoccupation today with things electronic sometimes makes us overlook old-fashioned mechanical symptoms of problems and the mechanical test equipment used to troubleshoot them. Vacuum gauges are often in this category, but the insight that a vacuum gauge can provide is as valuable today as it was 30, 40 or 50 years ago.

Remember that engine vacuum is just air pressure lower than atmospheric pressure. The starting point to evaluate engine vacuum is the intake manifold. When you connect a gauge to a tap on the intake, you're measuring manifold vacuum. Note that vacuum will vary in different areas of the engine, such as above or below the throttle valve and right at the intake and exhaust ports.

Vacuum drawn from an opening ahead of the throttle is called ported vacuum. Throttle opening affects ported vacuum opposite to the way it affects manifold vacuum. For example, at closed throttle, manifold vacuum is at its peak. But there is no significant vacuum at a port ahead of the throttle plate when the throttle is closed. Vacuum appears at such a port only when the throttle opens.

It's important to remember that manifold vacuum is used to power vehicle systems that need a steady supply of low-pressure air under all engine operating conditions. These systems include power brake boosters, a/c vacuum motors and some emissions controls.

Ported vacuum is used to control vehicle systems in relation to engine load. These include old-fashioned distributor vacuum advance diaphragms and carburetor assist devices. They also include many emissions control devices and transmission shift points. Under some engine load conditions, ported vacuum may equal manifold vacuum, but it can never exceed it.

Get Out the Gauge

Most vacuum gauges are graduated in inches of mercury (in.-Hg) and millimeters of mercury (mm-Hg). Some also show the modern metric scale of kilopascals (kPa). For comparison, 1 in.-Hg equals 25.4mm-Hg, or about 3.4 kPa. For this review, we'll stick to in.-Hg, or simply inches of vacuum.

Because engine vacuum is based on comparison with atmospheric pressure, it varies with altitude just as atmospheric (barometric) pressure does. The following table shows that as altitude increases, vacuum decreases about 1 inch for every 1000 feet above sea level.

Inches of Altitude Vacuum

Sea level-1000 ft. 18-22

1000-2000 ft. 17-21

2000-3000 ft. 16-20

3000-4000 ft. 15-19

4000-5000 ft. 14-18

5000-6000 ft. 13-17

Normal manifold vacuum at idle for an engine in good condition is about 18 to 22 in.-Hg.

Manufacturers used to publish vacuum specs in service manuals, but this isn't as common as it was years ago. Still, the physics of internal combustion haven't changed in a hundred years, so the guidelines given here are a good starting point for vacuum gauge troubleshooting. Your best analysis based on vacuum readings will come from your own experience, however. As you use a vacuum gauge on different engines, you'll learn what's typical for one model compared to another. Some engines have reputations as low-vacuum motors; others are unusually higher than average. Experience is your best teacher.

Cranking Vacuum & Speed Tests

You can get a quick basic appraisal of engine condition by connecting a vacuum gauge to the manifold

and a tachometer to the ignition to check vacuum and rpm at cranking speed. Warm up the engine first, then shut it down and connect your test equipment. Close the throttle and disable the ignition, or use a remote starter so the engine won't start. Crank the engine for 10 to 15 seconds and observe the vacuum and tach readings.

Note that different engines produce different cranking vacuum readings. Some carmakers publish specifications; others don't. Again, experience will be your best guide. What you're looking for, most importantly, is steady vacuum and cranking speed.

If the cranking speed is steady (about 200 rpm) and vacuum also is steady (around 5 inches), the engine most likely is in good mechanical condition. If rpm and vacuum are uneven, the cylinders aren't pumping equally. The engine probably has leakage past the valves, rings or head gasket. If the vacuum reading is pretty steady but cranking speed is not, you're probably looking at a damaged flywheel ring gear or starter. If the cranking speed is normal or high but vacuum is low and slightly uneven, the engine probably has low compression or retarded valve timing. A jumped timing chain or belt is a common cause here.

The cranking vacuum test also can provide a quick test for PCV restrictions. Perform the test and note the average vacuum reading. Then pinch the hose to the PCV valve closed with your pliers and repeat the test. If the PCV system is clear, vacuum should increase. If it doesn't, check the PCV system closer for restrictions.

What Idle Tests Can Reveal

You can zero in on several basic mechanical problems by taking a quick look at manifold vacuum. Warm the engine to normal temperature-get it really warm-and connect your vacuum gauge. Make sure you connect to a manifold vacuum tap and not to ported vacuum. Connecting a tachometer also is a good idea.

Just to be sure that the evaporative emissions system doesn't interfere with vacuum testing, disconnect and plug the canister purge hose and its manifold port. If you're testing an OBD II car, check for evap-related DTCs when you finish testing to be sure none set.

Run the engine at idle, low cruise (1800 to 2200 rpm) and high cruise (2500 to 3000 rpm). Note the vacuum readings, and any fluctuations, at each speed. Next, hold engine speed steady at about 2500 rpm for 15 seconds and read the gauge. Now release the throttle and watch the gauge as the speed drops. The vacuum reading should jump as the throttle closes, then drop back to its normal idle reading. If vacuum doesn't increase at least a couple of inches when you release the throttle, you may be looking at worn rings, cylinders or valves.

Idle vacuum for most engines is about 18 to 22 in.-Hg, but some may produce only 15 to 17 inches at idle. (Remember what we said about experience.) If vacuum is steady and within these ranges, the engine and fuel and ignition systems are operating normally.

If vacuum is steady at idle but lower than normal, the ignition or valve timing may be retarded. Low compression, an intake leak or tight valves also can cause low vacuum at idle.

If the vacuum reading fluctuates within the normal range-the gauge needle bounces around a lot-uneven compression (broken rings or leaking valves or head gasket in one or two cylinders) is a likely culprit. An uneven air/fuel mix, erratic ignition timing, a misfire, misadjusted valves or a manifold leak near one or two cylinders also are possible causes.

If vacuum drops intermittently at idle, one or more valves may be sticking open or dragging. Higher-than-normal vacuum at idle is a common clue to overly advanced ignition timing, while low vacuum can indicate retarded timing.

Low vacuum also can be an immediate clue to a plugged exhaust. To check further, run the engine at about 2500 rpm for about 15 seconds. If vacuum drops during this period and does not increase when you close the throttle, you're almost certainly looking at a restricted exhaust.

Vacuum Fluctuations & Power Balance

Several of the guidelines in this article have distinguished between steady vacuum gauge readings and fluctuating readings, where the gauge needle bounces up and down erratically. This may seem secondary-almost inconsequential-but it's an important distinction. A steady but abnormal vacuum reading indicates a problem common to all cylinders. Things like incorrect ignition timing or an old, tired, high-mileage engine affect vacuum equally for all cylinders. A bouncing needle, however, usually indicates that the problem is localized to one or just a few cylinders. Here's where power balance testing enters the picture.

Compression testing on many late-model engines is flatly impractical from a labor standpoint for a quick engine evaluation. That's especially true on some of the weird vans for which removing and reinstalling spark plugs is a two-hour job. It's relatively quick and easy, however, to connect a vacuum gauge to the manifold and your engine analyzer to the ignition system.

If your initial vacuum tests produce gauge fluctuations, you have a definite indication that the problem is limited to just one or a few cylinders. In these instances, a power balance test can help you pinpoint those cylinders and the condition they're in. Does the engine need a valve job (fluctuating vacuum) or a complete engine exchange due to universally worn rings and cylinders (steadily low vacuum)?

Combine modern power balance testing with traditional vacuum analysis and you'll have the answer.