How a Model A Breathes And How to Help It - Part 1

BY HOWARD ECKSTEIN

Ford wanted the Model A to be a 40 horsepower car so the company could compete in the marketplace of the day. It was necessary to bring all of the engineering challenges of the New Ford to a culmination of compromises that would work together to achieve that goal.

The engineers who worked out your car's intake and exhaust systems were probably versed in wave theory and maybe even had a background in music. Fluency in those two disciplines could have contributed to their success.

So let's get down to the principles of how manifold & exhaust design and valve timing affect the engine's ability to breathe which translates into torque and horsepower.

Principle 1: The Difference Between Torque and Horsepower

The ability of an engine to exert force in a rotational direction is called torque. The degree of torque produced by the engine is all about how efficiently air and fuel can be fed into the cylinders, and how easily the exhaust can be removed.

Due in part to its long stroke and camshaft configuration, the Model A engine produces the most torque around 1000 RPM. As the engine speeds up, it becomes harder for it to draw in enough air and the torque output drops.

Horsepower rises with torque and reaches its peak at higher RPMs. At the point where the torque and horsepower curves cross over each other is where the engine is running at its most efficient speed. On the power graph for the Model A, we see that the torque and horsepower curves crossover at about 1430 RPM. See **Fig. 1**.

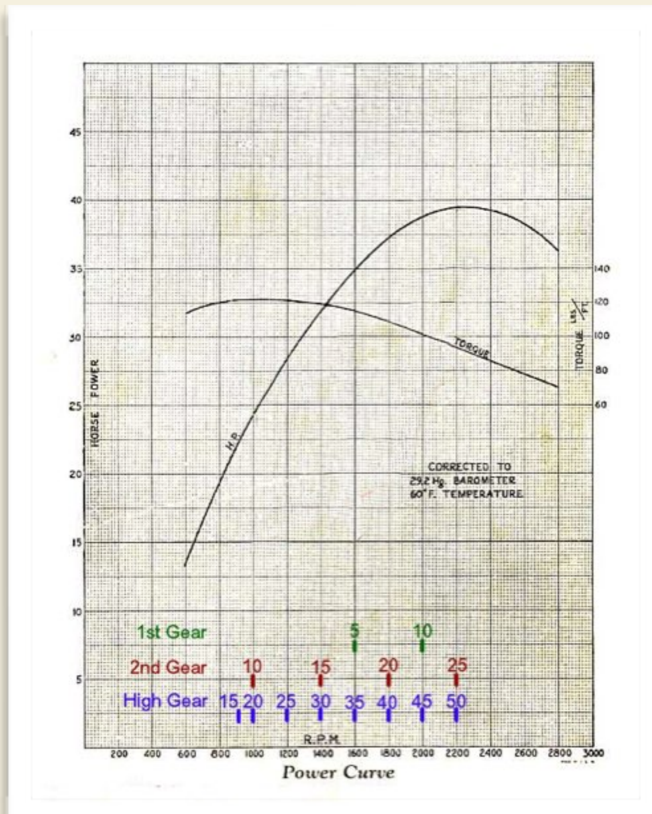

Figure 1

Torque's role in performance is to move the car from a stop to a rolling condition. It's the leverage that breaks the inertia of a one-ton Model A that is happily sitting at rest at a stoplight. There isn't much horsepower at the lower RPMs, but torque is highest there.

You can feel the torque of your engine when you encounter a hill at 30 MPH. You approach at half-throttle and soon the car starts to slow down. You react and open the throttle whereupon you can hear and feel the engine work harder to maintain 30 MPH as you climb. The RPM of the engine doesn't change, but the torque demand does.

When your engine can no longer provide sufficient torque to maintain the speed, you downshift to second gear and begin to climb again. This is because the 53% ratio of second gear nearly doubles engine torque at the rear wheels.

Horsepower's role in performance is to accelerate the car once it has begun moving. The greater the horsepower output, the faster the car will cover a certain distance.

Principle 2 The Inertia of Flowing Air

Air has mass and obeys all the laws of motion. If air is drawn into an open pipe, it will keep moving even if the end of the pipe is suddenly closed. When that happens, the trapped air will bunch up at the closed end and then bounce back to the opposite end. This is because of the inertia of the air mass due to the energy used to get it moving in the first place. The inertia of a column of moving air in a pipe creates a compression wave which plays a role in the resulting torque and horsepower produced by the engine.

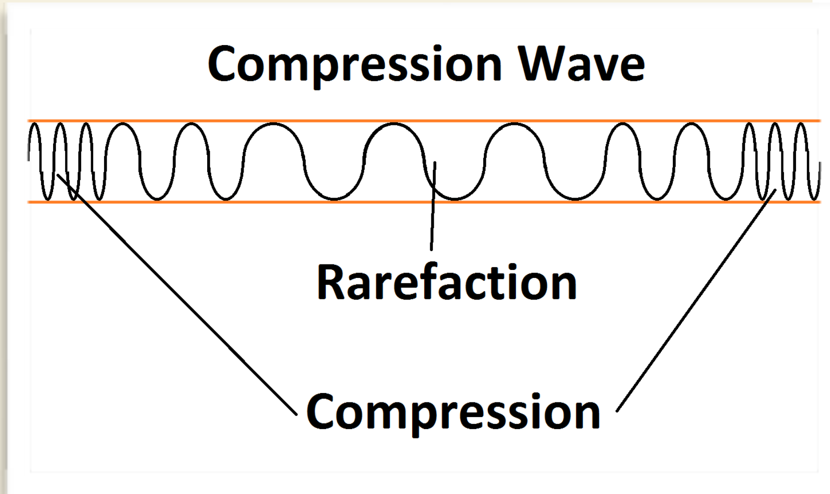

Figure 2

Principle 3: Compression Waves

Compression waves move at the speed of sound; about 13,500 inches per second. In **Fig. 2**, we see a compression wave in an open pipe. The bunched up waves at each end are high pressure and the wide waves in the center are low pressure; called rarefaction.

Principle 4: Resonance

One thing about waves is that they like order. In a pipe, a compression wave will conform itself to the length of the pipe where possible. This conformance is called resonance. Where the frequency is way off for the length of the pipe, resonance can't be achieved and the result is noise.

To visualize resonance in action, let's consider an organ pipe. As moving air passes through the pipe, a disturbance near the entrance causes the air to vibrate as it passes through. This vibration occurs at a frequency matched to the length of the pipe. The vibration results in a compression wave which wants to be at its fullest energy pulses right at the ends of the pipe.

Each musical note is defined by a specific frequency. For example, the note known as "Middle C" has a frequency of 261.626 cycles per second and the wavelength or pitch is 51.24 inches.

If a pipe in the organ is 51.24 inches long, the vibrating air moving in it will resonate at that frequency and pitch whereupon you will hear a middle C being played.

If the pipe is not the exact length, the wave will either be stretched or compressed, thus changing the pitch and the resulting note is either flat or sharp. The organ tuner climbs up in the box and adjusts the little sleeve on the top of the pipe to change the overall length which corrects the sound. The next time you're in a building with a pipe organ, look for the tuning sleeves on the top ends of the pipes. See **Fig. 3**.

By cutting the pipe exactly in half, the new frequency will be 523.252 cycles per second and the sound will still be a C, but one octave higher in pitch.

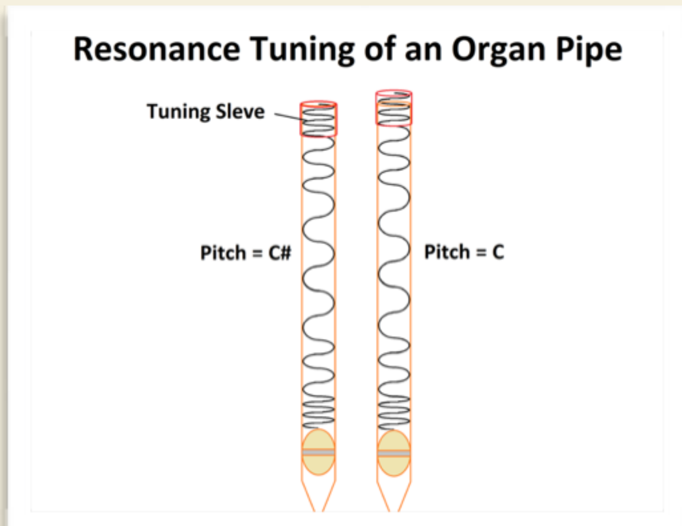

Figure 3

Principle 5: Tuning of the Intake and Exhaust

Just as an organ pipe can be tuned by controlling its length, so also can the intake and exhaust be tuned to get the most amount of air into the cylinders and thus increase the torque and horsepower that the engine can produce.

Let's take a look at the engineering involved in the Model A intake manifold. The curved shape of its top was not made to be an aesthetic design feature, but is the way the proper length was achieved to get good performance at cruising speed.

As the column of air is drawn through the carburetor by the vacuum created in the cylinders, the inertia of the air in the manifold wants to keep the air mass moving even though it encounters a suddenly closed intake valve. The air runs into the blockage and bunches up until its energy bounces back all the way down the "pipe" of the manifold and carburetor.

In **Fig. 4**, the red lines represent the compression wave in the intake manifold. They are bunched up at the

Figure 4

valve ports and at the end of the carburetor.

The distance from the open end of the carburetor to any intake valve is about 20 inches. The distance from the valves in the 1-2 intake port through the top of the manifold to the valves in the 3-4 port is also about 20 inches. The branch-off point where the riser meets the curved cross-over is about 10 inches from the open end of the carburetor, which would be the equivalent of an octave. See **Fig. 5**.

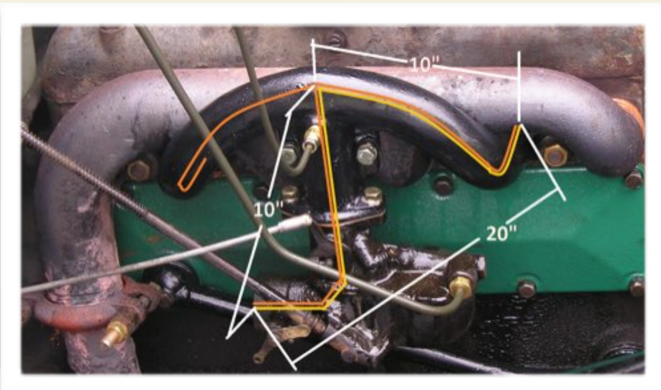

Figure 5

Principle 6: Intake Manifold Harmonics

Let's look at a bit of arithmetic to see why 20 inches was chosen for the Model A intake manifold. If this makes your eyes glaze over, that's OK; some readers like this stuff.

1. The pressure wave of air reverberates in the manifold at the speed of sound which is about 13,500 inches per second.
2. The model A engine runs about 1800 RPM at 40 miles per hour.
3. 1800 RPM ÷ 60 seconds per minute = 30 revolutions of the crankshaft per second (RPS).
4. The crankshaft turns 720° for each full revolution of the camshaft.
5. The intake valve is open for a period of 236° of crankshaft rotation.
6. Subtracting 236° from 720° leaves the intake valve closed for 484° of crankshaft rotation.
7. 30 RPS x 360° = 10,800° rotation of the crankshaft per second.
8. 484° ÷ 10,800° per second = .0448 seconds that the intake valve is closed at 1800 RPM.
9. 13,500 inches per second x .0448 seconds = 604 inches. This is the wavelength and the distance the pressure wave moves each second.
10. The 604 inches is divided by 2 because the pressure wave travels both directions in the manifold. This leaves a distance of 302 inches a single pressure wave would move in the manifold at 40 MPH.

If we divide 302 inches by 20 inches, the result is 15. This means the pressure wave bounces back and forth 14 times to find the intake valve still closed. But on the 15th cycle, it arrives just in time to find the valve open and rushes in to fill the cylinder.

This resonance supercharging not only works at 40 miles per hour. At about 32 MPH, the engine is running at1500 RPM and the pressure wave reverberates 18 times.

Principle 7: Scavenging Effect of the Exhaust System

The exhaust system, on the other hand, is designed to be the right length to present a negative pressure at the exhaust port when the valve opens. Since the Model A exhaust manifold is in a line where the pulses of each cylinder travel down the same pipe, the distances the pulses travel are not equal. Nevertheless, the inertia of the moving air through the tailpipe does draw exhaust from the cylinder even after the piston has reached top dead center.

Just like the organ pipe, the exhaust pipe is calculated to be a specific overall length. There are four major sections of the Model A exhaust pipes and muffler.

1. The length of the inlet pipe from the manifold to the front bell of the muffler.
2. The shape and dimensions of the tapered muffler.
3. The location of the baffles in the muffler.
4. The length of the tailpipe.

Part 2 continued next month

How a Model A Breathes And How to Help It - Part 2

BY HOWARD ECKSTEIN

All of these sections are engineered to reflect the compression waves back up the pipe as we saw with the intake manifold. Properly tuned, the exhaust components correspond to the same engine RPMs the intake system is designed for. This facilitates breathing during valve overlap, which we will discuss here shortly.

Principle 8: Valve Timing

Careful engineering of the shape and position of the camshaft lobes in reference to degrees of rotation of the crankshaft is essential for getting the desired performance from the engine. Whether for a family grocery hauler, a Formula 1 race car, or a Model A, each engine is designed to produce peak performance within a certain range of speed. The timing of the valves in relationship to the position of the crankshaft plays an important role in each of these applications.

Principle 9 Valve Overlap

Now that we have pressure waves for the intake and exhaust tuned nicely, let's take advantage of them. Each stroke of a 4-stroke engine, such as that used in the Model A, occupies 180° of crankshaft rotation. That's true for the pistons. But the valves march to the beat of their own drummer; and that drummer is the camshaft.

Fig. 6 graphs the 720° of crankshaft revolution. The four strokes are shown as follows:

1. The inner blue circle represents the 236° during which the intake valve is open.
2. The outer green arc represents the 180° of the compression stroke which begins at bottom dead center.
3. The purple arc shows the 180° of the firing or power stroke that begins at top dead center.
4. The red circle represents the 236° period where the exhaust valve is open.

To get the full benefit of the inertia of air, whether exhaust or fresh fuel-charged intake, the engineers have designed into the valve timing a period of valve overlap where the exhaust valve is just closing and the intake valve is just opening. In a Model A engine, both valves are slightly open at the same time for 12° of crankshaft rotation.

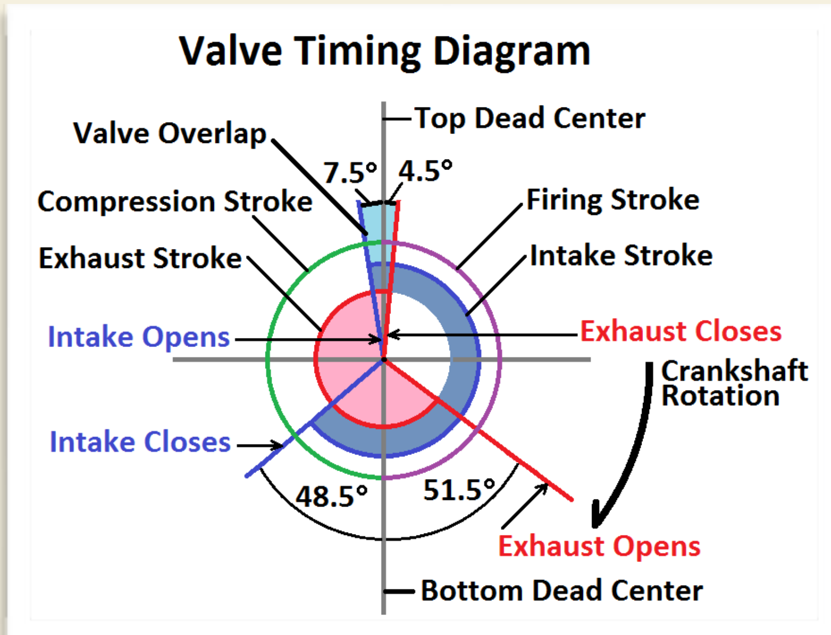

Figure 6

With both valves open for that instant, the inertia of the exhaust gas leaving through the tailpipe combined with the rarefaction part of the exhaust system's compression wave at the exhaust valve actually helps to draw in the fresh fuel-loaded air just entering past the intake valve. Once the exhaust valve is completely closed, the descending piston creates the negative pressure that continues to draw the new air into the cylinder while the intake valve is open.

Now here's the crazy part: The Model A intake valve remains open for 48.5° *after* the piston is starting on its way back up for the compression stroke! This is to take advantage of the inertia of the air still packing itself into the cylinder.

In addition, the exhaust valve opens 51.5° *before* the firing stroke reaches bottom dead center. This is to start the scavenging of the exhaust from the cylinder.

Principle 10 The Problem with Backpressure

Alas, here comes the downside to all of this. Due to the friction of air moving through the pipes, the construction of the muffler, the changes of direction the air must take and the effort required to push the exhaust out through the tailpipe, there is a certain amount of backpressure in the system.

The resonance used to ram a charge into the cylinders and to withdraw exhaust only works at certain RPMs and closely corresponds to the torque and horsepower curve crossover. At this point, we expect backpressure to be low. Where this resonance is not in alignment, backpressure is greater.

Is Your Model A Lacking Power?

Sometimes we wonder why our Model A engines seem to be less powerful than we remember. Some of it can be traced to increased backpressure which robs power. An old muffler full of soot and rust, or a reproduction muffler that isn't made to Ford specifications, can work against us.

Fig. 7 shows four different after-market mufflers. The top picture is of the Aires Muffler, which the manufacturer has built to original Ford specifications. By not following the original dimensions, the lengths of the other samples are incorrect and the tuning is lost. This image is used by permission from Aires.

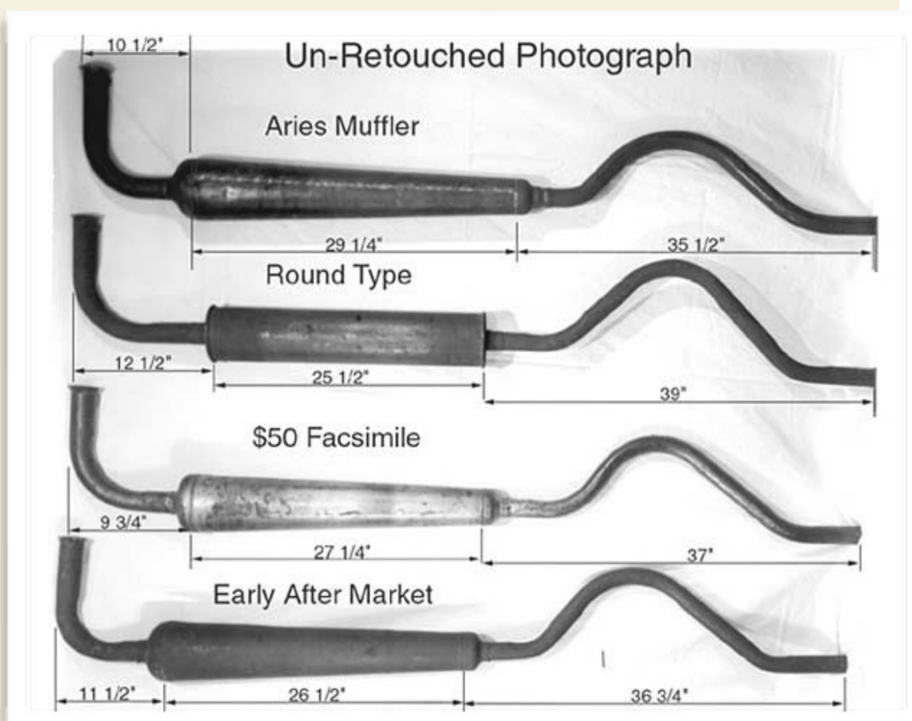

Figure 7

In addition to backpressure, performance loss can also be traced to faulty timing. Keep in mind that there are two kinds of timing: ignition and valve timing.

Improper Valve Timing

Valve timing can be retarded due to wear of the cam gear, which in turn will retard ignition timing. Incorrect gap at the tappets will also affect valve timing. The amount of drift in valve timing may develop over many years and seem very small in degrees of rotation, but be assured that in this case, little things mean a lot.

If valve timing is retarded due to a worn cam gear, the intake valves open later than they should and less air is pulled into the cylinders. Moreover, the exhaust valves close too late, allowing some of the inert exhaust gasses to be drawn back into the cylinders, further weakening the energy produced during the power strokes. Late ignition timing exacerbates the whole thing, resulting in lackluster performance as your Model A chugs its way up a hill.

The spring in the timing case cover which presses the thrust plunger against the front of the camshaft may be weak, allowing the camshaft to float back and forth during acceleration and deceleration. This dynamically changes valve and ignition timing due to the helical cut of the timing gears.

Valve timing is also dependent upon the integrity of the cam lobes. If they have worn down over years of use, the overall valve dwell time is shortened and the valves do not open as far as they should.

Weak valve springs can allow the valves to "float", altering the time they are open; thus robbing power.

What to Do About It?

If you use your Model A for the occasional buzz around the block with the grandkids, leave the engine alone and enjoy the car once in a while. If you tour with the Club, you'll want to be able to keep up with everybody. Tackle the easy things to fix first. Chances are most of these things will need your attention anyway.

Consider changing that muffler which now weighs four times what it did when new. It's likely full of carbon, rust and tar that corrupts the free flow of exhaust; which is somewhat made up for by the rotted-through spots.

Pull the timing cover side plate and inspect the teeth of the cam gear. See **Fig. 8**. A new gear measures

Figure 8

1.255" across the top of the tooth. Put the car in high, release the brake and gently roll it back and forth. If the cam gear moves forward and back when you do this, the plunger and spring in the front cover are defective. It's not hard to change timing gears, and they aren't that expensive.

In **Fig. 9**, the fronts of new timing gears are visible. The specifications for backlash here is .003 to .005 inches between the crank and camshaft timing gears.

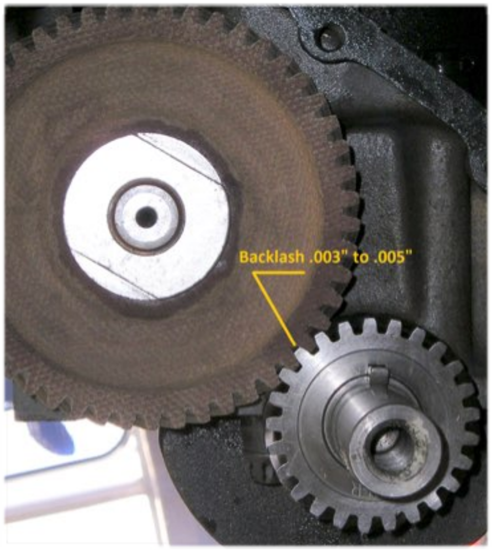

Figure 9

Check your valve to tappet clearances when the engine is cold. See **Fig. 10**. They should be between .011 and .014 inches for both the original intake and exhaust valves. Weak intake valve springs do not affect engine performance nearly as much as exhaust valves floating due to weak springs. As long as you have the valve cover off to check the valve lash, you can replace the springs.

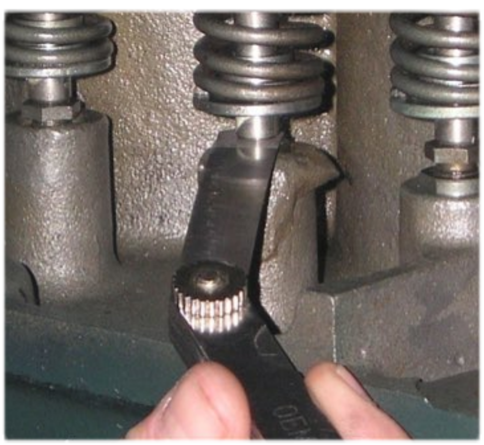
Figure 10

Another thing to check is your ignition timing. If there is excessive backlash in the distributor drive shaft, ignition timing will jump around when you are driving the car. Go to the catalogs and get replacement parts that will bring the tolerances back into range.

All of the above repairs are inexpensive and do not require removing the engine from the car.

If you decide your camshaft needs to be replaced, go the full route and have the engine redone by a reputable rebuilder. Just sticking in a new camshaft may not work well if the cam bearings are worn.

A word about camshafts: A reground Model A camshaft will never perform as well as a new one. This is because the regrinder has to choose whether to restore lift at the expense of duration, or to restore duration at the expense of lift. Most reproduction camshafts on the market today are ground to Model B specifications which require different valve tappets. The original Model A tappets had a base that was 1.117" diameter, whereas the Model B tappet has a base of 1.187" to accommodate the higher lift of the cam lobes. Model B camshafts were used for replacements in service starting back in 1932 on the Model A, so it's fine to use them. They are supposed to increase torque and horsepower a little over the original Model A cam.

Leaky Valves

One way to diagnose a leaky valve is to hold a piece of cardboard over the end of the exhaust pipe at idle. If the valves are good, you'll feel a rhythmic bounce of the cardboard against the pipe with each cylinder's pulse. If there is an intermittent pause in the pulse, that points to ignition troubles.

Continued on page ____