How do you make your Model T go so fast?

Part three: Volumetric

By Tom Carnegie

Henry Ford said that the top speed of Model T Fords was 45 miles per hour. A lot of them now days are hard pressed to achieve that speed. Sometimes after someone has taken a ride in my car, they will ask me: "How do you make your T go so fast?" My stock, off-the-cuff reply is that there are only two things to make a T go fast - compression and aspiration. This is essentially true, but is an oversimplification. There are really THREE things! The three things are: 1. Mechanical efficiency 2. Thermodynamic efficiency and 3. Volumetric efficiency. Last newsletter we talked about thermodynamic efficiency. This time we will talk about volumetric efficiency.

I think that obtaining maximum volumetric efficiency may be somewhat akin to voodoo. It is hard to know exactly what might improve it or why. What improves volumetric efficiency at one RPM range may hurt it in another. Rules of thumb that hold true for most engines might not correlate or even apply to the model T motor. It seems that since volumetric efficiency is simply a matter of pumping as much fuel mixture into the combustion chamber at any given speed, that it would be a simple matter to rotate your motor with an external power source, and note the compression at various rpm's. Then you could manipulate the various parameters until you achieved the desired results. Unfortunately this method may give you a starting point, but it doesn't take into consideration some very important variables such as heat, combustion and scavenging. We will talk more about this later. For now, let's talk about the parameters referred to above.

Some of the parameters, such as carburetor air flow and porting, are not adjustable within the confines of the Montana 500. With the intake manifold you have several choices. Examples are the early dogleg aluminum manifold, the later non-dogleg aluminum manifold, the cast iron manifold that is shaped like the aluminum manifold, and the typical 1917 through 1926 style cast iron manifold. Of these, the non-dogleg aluminum type flows the most air. This is according to studies done by Chaffin's. Of course in the Montana 500 we have to contend with the restrictor plate which surely limits the efficacy of the high flow manifold. In fact, some people contend that because of the restrictor plate, it may be better to run with a smaller manifold. We will go into this in more detail later. Once the fuel mixture makes it past the manifolds and the ports, it encounters the intake valve.

An important parameter is when the intake valve opens in relation to the piston position. Intuitively, one may think that the best time to open the intake valve may be when the piston is at top dead center. This is essentially true, but as with most volumetric issues there is more to the story. There are at least two schools of thought on this issue. I'll talk about the second school later. One school says that it may be good to open the intake valve slightly after TDC. The model T motor has two cylinders sharing each intake port. Number two cylinder fires immediately after number one, and number three fires right after number four. Since these two pairs of cylinders share intake ports, cylinders number two and three get starved slightly because the manifold leg that feeds these cylinders doesn't have time to refill before the next cylinder needs a charge. I believe that it is not just a matter of getting less air-fuel mixture as if the throttle is slightly closed. It is also a matter of the air not being able to absorb the same amount of fuel as the previous charge. You can see evidence of this by observing your spark plugs. Number one and four sparkplugs are almost always blacker than two and three. By opening the intake valve later the theory goes, each cylinder gets an equal charge. If the charge is slightly smaller than could be obtained otherwise, this is supposedly offset by the fact that you get better combustion if all the cylinders have the same air fuel mixture, and the engine runs better with four more equal explosions. Steve Coniff has done some experiments along these lines and found that the exhaust temperature also is more consistent between the four cylinders when the intake valve is opened later. Opening the intake valve slightly later is somewhat less efficient than opening it at TDC, but not as much as you might think. This is because the movement of the piston past TDC is not totally wasted. As the piston moves past TDC it begins building a vacuum in the cylinder. What changes is the amount of time available to fill the cylinder, which could be a problem, as we'll discuss later. Going hand in glove with the intake opening timing is the exhaust closing timing. Let's follow the cycles through to the time that the exhaust valve closes.

After the fuel mixture is drawn in it is compressed then exploded. The explosion drives the piston down and then the piston comes up and drives out the spent gasses. Using the same logic as above, you might think that the very best time to close the exhaust valve would be when the piston is at top dead center. This is exactly where the stock T cam is supposed to close the exhaust valve. Usually on high-speed engines the exhaust valve is closed sometime after TDC. This is to allow more time for the exhaust gasses to escape. This begs the question of how can the exhaust gasses continue to escape as the piston is heading down? Wouldn't it tend to try to suck the spent gasses back into the cylinder? The answer in a word is "no". The chief reason for this is that the gasses in the exhaust system have mass, and since they have mass, they have momentum. This momentum tends to continue to pull the gasses out of the cylinder even after the piston has stopped pumping. This brings up another important subject. Scavenging.

For illustration's sake, imagine the air-fuel mixture that is drawn into the cylinder to be clear, and the spent exhaust gasses to be black. The piston goes down and draws in a charge of clear mixture. It is compressed then exploded, and then the black exhaust is pumped out. When the piston is clear to the top, you still have a combustion chamber full of black exhaust. When the next clear charge is drawn in, it is going to mix with this black exhaust which will weaken it. There is a way to slightly overcome this problem. The method is to make the exhaust gasses pull a fresh charge into the combustion chamber. Holding the intake and the exhaust open at the same time does this. This is the first school of thought mentioned above.

This is the sequence of events in this scenario: Intake opens, charge is drawn into cylinder. Charge is compressed then exploded. Piston goes down then back up. The piston drives out exhaust gasses. Some time before TDC the intake valve begins to open. The momentum of the exhaust gasses begins to pull a new charge into the cylinder even before the piston starts to go down. This is the principle of scavenging. Unfortunately, this effect only works at high speeds. At low speeds the exhaust will not have sufficient momentum and will tend to pressurize the intake manifold. This is not a good thing. This is what causes "cammed up" motors to lope at low speeds. Next we'll talk about the intake valve closing.

We have discussed how the intake valve opens near TDC. Intuitively one might think that the best time to close the intake valve would be when the piston is at BDC. This is not the case. One may think that as soon as the piston begins to move up, it would pressurize the cylinder. This is true, but until the pressure in the cylinder is greater than the atmospheric pressure, the air-fuel mixture will continue to flow. There is another reason for holding the valve open even longer. As with exhaust gasses, intake gasses have mass, therefore, momentum. Once they have begun to move they tend to want to keep moving. If we close the intake valve after BDC it will give the intake charge extra time to fill the combustion chamber. This is true especially at high speeds. The Roof-Laurel cam closes the intake at 55 degrees after BDC. The stock Ford timing is 51 degrees after BDC, which is four degrees sooner. Again, like most things involving the camshaft there is a compromise. If the intake is closed too late it can cause a rough idle. If it is closed way too late it can cause poor performance overall. The piston is moving relatively slowly near BDC, but at a point in time it will tend to pressurize the intake manifold, which as we said before is not a good thing. This may be a good time to mention air velocity. There are two aspects of inertia. Mass and speed. A small object with high speed may have as much inertia as a larger object with low speed. How this applies to volumetric efficiency is that you can increase the velocity of a column of air by forcing it through a smaller tube. Higher velocity could give the air more inertia to pack the combustion chamber. Again, there is a trade off. Smaller pipes mean more restriction. My feeling on this is that restriction trumps velocity. Therefore I use the big intake manifold. Some people disagree with me on this point. As of this time I have not done any empirical tests on this, so I don't know which way is best for sure. The last event is the exhaust valve opening.

The force on the piston after combustion rises very rapidly, then begins to fall rather steadily as the piston is driven down. After the crankshaft has gone 90 degrees the rod begins to lose its leverage. Also the pressure of the explosion steadily weakens as the volume of the chamber gets bigger and the heat is absorbed into the system. In actual fact though, there is still pressure being exerted on the piston all the way to BDC. Again, using our intuition we might think that it is best to keep the exhaust valve closed until BDC in order to capture all of the available power. Again, that would be wrong. If we wait until BDC the piston will have to come up against considerable pressure. This takes quite a bit of energy. It is actually profitable from a power standpoint to open the exhaust valve sometime before BDC and let the exhaust gasses discharge of their own accord. This is known as pre-release. The exhaust opening timing on the Roof-Laurel cam is 55 degrees before BDC. The stock Ford timing s 38 degrees before BDC. As you can see there is a lot more pre-release with the Roof-Laurel cam. Pre-release tends to be most useful at high engine speeds.

As with the induction system, there are volumetric considerations with the exhaust system. For some reason, back pressure tends to increase torque at slow engine speeds, even in a motor with no valve overlap. I really don't know why this happens as no one has been able to explain it to me, but I have experienced it first hand. Most of the books that you read on the subject of the exhaust system will say that for best top end, you should have as little back pressure as possible. The Montana 500 rules demand at least 36 inches of 1 ½" pipe. It seems to me that this would be the system with the least back pressure. But, this doesn't take into account scavenging. In order to have good scavenging we need a system that allows the exhaust to build inertia. The optimum for this would be a long straight tube of constant diameter. In addition to inertia scavenging, there is also a different form of scavenging that we haven't talked about yet. This is wave scavenging. Let me present a musical example that might help illustrate this. A trombone has a slide that moves in and out through seven positions that effectively make the horn longer or shorter. If you were to hand a beginner a trombone and get him to hoot a note with the slide in first (the shortest) position, he would more than likely play an F. This is because F is a harmonic of the resonant tone (B flat) of the horn. If you were to try to play an E in first position you would find it very difficult, although it is quite easy to play an E in second position. The same sort of thing happens with the exhaust system of a motor, that is when the exhaust pipe is the exact right length the exhaust gasses will be more inclined to discharge. In order to maximize this effect though, the exhaust pipe lengths of all four cylinders must be the same. This is done with headers. Headers are not allowed on the Montana 500. What we effectively have with a stock model T is a diffrent length for the exhaust system on each cylinder. To continue our trombone analogy, this would be like four trombone players trying to hit the same notes with their slides in four different positions. It would not be a pleasant sound. Because of this, I don't think tuning the exhaust on a T is practical. If anyone disagrees I'm all ears.

The model T isn't exactly a high-speed motor. Someone once told me that a Model T was all bottom end. In other words, rules of thumb that normally applied to other motors such as "retard the cam for more top end, advance it for more low end torque" don't apply to the Model T. The question is "should you optimize the T motor to do what it does well better, or should you try to get it to improve what it doesn't do well?" I honestly don't know the answer to this question. What I am personally striving for is to make a Model T work as well as half of a flathead Ford V-8 motor. A flathead Ford V-8 has nearly the same size valves as a Model T and much smaller pistons, yet puts out 45 horsepower per four cylinders. How does it do this? Two things really, one it has higher compression, but two, it breathes much, much better. So, I guess the way to get a model T to really put out is to increase compression and aspiration.

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