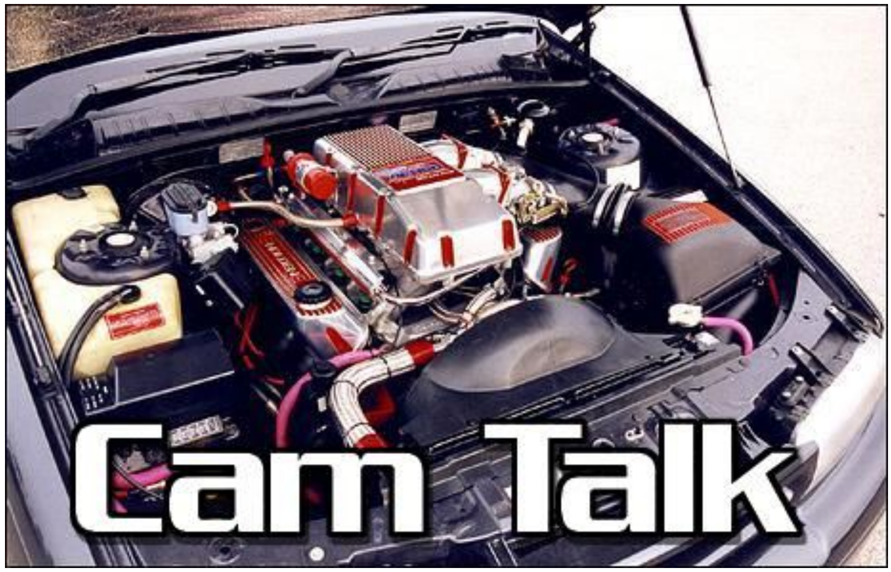


Cam Talk

A quick overview of the engine's mechanical brain

Courtesy of COMP Cams

In an effort to simplify what actually happens inside a 4-stroke internal combustion engine, let's take a walk inside a typical engine. We'll discuss valve events, piston position, overlap and centrelines. Although we don't have enough room to explain cam design in great detail, we will clear up several of the most often misunderstood terms. We hope to give you a more clear understanding of what actually occurs in the operation of a four-stroke engine. We'll graphically illustrate the relationship between all parts of the engine and to try to help you understand how the camshaft affects the power of the engine.

We begin with the piston all the way to the top of the cylinder with both valves closed. Just a few degrees ago the spark plug fired the explosion and the expansion of the gases forced the piston toward the bottom of the cylinder. This event which pushes the crankshaft is referred to as the "power stroke" . Each stroke lasts half a crankshaft revolution. Since the camshaft turns at half the speed of the crankshaft, the power stroke only sees one-quarter of a turn of the cam.

As we move closer to the bottom of the cylinder, just before the piston reaches the bottom, the exhaust valve begins to open. By this time the charge has been burned and the cylinder pressure begins to push the burnt mixture into the exhaust port where it exits the engine. After the piston passes bottom-dead-centre, it begins to rise. Now we have begun the exhaust stroke. This forces the remainder of the gasses out of the cylinder to make room for new air and gas. While the piston is moving toward the top of the cylinder, the exhaust valve quickly opens, goes through maximum lift and begins to close.

At this point a quite unique occurrence begins to take place. Just before the piston reaches the top of the cylinder, the intake valve is not fully closed. The exhaust stroke of the piston has pushed out just about all of the burnt mixture and as the piston approaches the top, the intake valve begins to slowly open. Here begins a siphon or "scavenge" effect in the chamber.

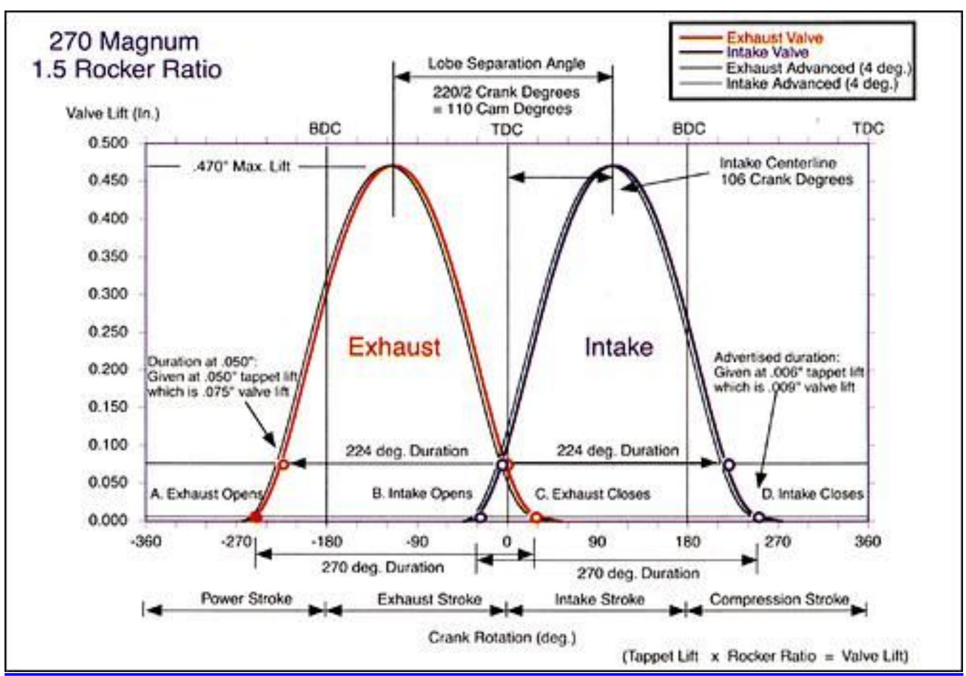
The rush of gasses into the exhaust port will draw in the start of the intake charge. This is how the engine flushes out all of the spent fuel. Some of the new gas actually escapes into the exhaust. Once the piston passes through top-dead-centre and starts back down, the intake charge is pulled in quickly so the exhaust valve must close at precisely the right point, after the top, in order to keep any burnt gas from re-entering. This area around top-dead-centre with both valves open is referred to as "overlap". This is one of the most critical moments in the cycle and all points must be positioned correctly with the top-dead-centre of the piston. We'll take a more in-depth look later.

We have now passed through overlap. The exhaust valve has closed just after the piston started down and the intake valve is opening very quickly. This is called the intake stroke, where the engine "breathes" and fills itself with another charge of the air/gas mixture. The intake valve reaches its maximum lift at some defined point (usually about 106 degrees) after top-dead-centre. This is called the intake centreline, which refers to where the cam has been installed in the engine in relation to the crankshaft. This is commonly called degreeing.

The piston goes all the way to the bottom and as it starts up, the intake valve is rushing towards the seat. The closing point of the intake valve will determine where the cylinder actually begins to build pressure, as we are now into the compression stroke.

When the mixture has all been taken in and the valves are now both closed, the piston begins to rise, compressing the mixture. This is where the engine builds power. Just prior to the piston reaching the top of the cylinder, the spark plug fires and we are ready to start again.

The engine cycle we have just observed is typical of all 4-stroke engines. There are several topics we have not yet discussed, such as lift, duration, opening and closing points and lobe separation angle. The valve timing section and diagram in this catalog will help you get a more complete understanding of the process.



Most cams are rated by duration at some defined lift point. As slowly as the valve opens and closes at the very beginning and end of its cycle, it would be impossible to find exactly where it begins to moves. In the example given, the rated duration is measured at 0.006" tappet lift. In our plot we use valve lift, so we must multiply by the rocker arm ratio to find this lift. For example, 0.006" x 1.5 = 0.009". Instead of the original 0.006" tappet lift, we now use 0.009" valve lift. These opening and closing points are circled so you can see them. If you count the number of degrees between these points you will arrive at the advertised duration, in this case 270 degrees of the crankshaft rotation. In this illustration, this is the same for both the intake and the exhaust lobes, thus making this a single pattern cam. Some cam manufacturers rate their cams at 0.050" lift. If we multiply this by the rocker arm ratio, we get 0.075". We can mark the diagram and read the duration at 0.050" lift - this cam shows around 224 degrees, standard for this 270H cam.

Lift is easy to determine - simply read from the axis going up. This is the lift at the valve as we said earlier. Sometimes you will hear it referred to as "lobe lift". This means the lift at the lobe or the valve lift divided by the rocker arm ratio. In this case, it would be 0.470" divided by 1.5 or 0.313" lobe lift. Lift is simply a straightforward measurement of the rise of the valve or lifter.

Earlier we touched on opening and closing points - now we'll look at them in depth.

As you see above, the valve begins to slowly rise, picking up speed as it approaches the top. It does the same when closing. It comes down quickly, before slowing to a gentle stop. It's kind of like driving your car. If you were to go from 100 to 0 km/h in a fraction of a second, you can imagine what that would do to your car - not to mention your body. It would be much too severe for you or the car to endure. The same is true for engines and valve trains.

Bent pushrods, premature cam wear, broken springs and rockers would result. Additionally, all dynamic designs would be lost. With the loss of all dynamic stability, the cam would not run at the desired rpm level and all the parts would collide, causing engine catastrophe. As the valve approaches the seat, you also have to slow it down to keep the valve train from making any loud noises. If you slam the valve down onto the seat, you can expect not only severe noise, but worn and broken parts as well. So it is easy to see that you can only accelerate the valve a certain amount before you get into trouble.

Exploring the timing points diagram further, we first see the exhaust opening point. We have all noticed the different sounds of performance cams, with the distinct 'lope' or rough idle. This occurs when the exhaust valve opens earlier and lets the sound of combustion go out the exhaust pipes. It may still be burning slightly as it passes through the engine, so this sound can be very pronounced.

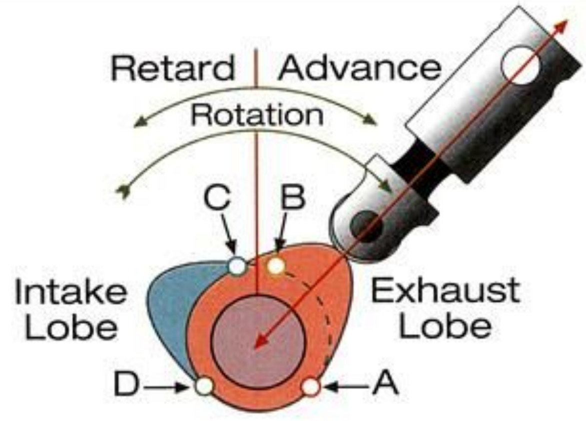
The next point on the graph is the intake opening where overlap begins, which is very critical to vacuum, throttle response, emissions, and especial, fuel economy. The amount of overlap, or the area between the intake opening and the exhaust closing, is one of the most critical points in the engine cycle. If the intake valve opens too early, it will push the new charge into the intake manifold. If it occurs too late, it will lean out the cylinder and greatly hinder the performance of the engine. If the exhaust valve closes early it will trap some of the spent gas in the combustion chamber, if it closes late it will over-scavenge the chamber, taking out too much of the charge. Again, this creates an artificially lean condition. If the overlap phase occurs too early it will create an overly rich condition in the exhaust port which causes a severe dip in fuel economy. So as you can see, the overlap phase is very critical to engine performance.

The last point is the intake closing. This occurs slightly after bottom dead centre and the quicker it closes, the more cylinder pressure the engine will develop. Care must be taken to ensure the valve is open long enough to properly fill the chamber, yet closing it soon enough to yield maximum cylinder pressure. This is a very tricky point in the cycle of the camshaft.

The last subject we will discuss is the difference between intake centreline and lobe separation angle.

These two terms are often confused. Although they have similar names, they are very different, controlling different engine events. Lobe separation angle is the number of degrees separating the peak lift point of the intake and exhaust lobe. Lobe separation cannot be changed after the cam's initial grind, unless you are dealing with a twin cam engine. On the other hand, intake centreline is the position of the centreline (or peak lift point) of the intake lobe in relation to top-dead-centre of the piston, this can be changed when "degreeing" the camshaft (or in engines with variable cam timing). The above diagram shows a normal 270 degree cam. It has a lobe separation of 110 degrees. We show it installed in the engine 4 degrees advanced or at 106 degree intake centreline.

The black curves on the diagram show the same camshaft installed an additional four degrees advanced, or at 102 degree intake centreline. You can see how much earlier overlap is taking place and how the intake is open a great deal before the piston starts downward. This is usually a way to increase bottom end power. However, as illustrated, much of the charge has been pushed out of the engine, making it less efficient. Each cam has a recommended intake centreline installation point.



A. Exhaust Valve Opens - Power Stroke
B. Intake Valve Opens - Exhaust Stroke
C. Exhaust Valve Closes - Intake Stroke
D. Intake Valve Closes - Compression Stroke

This diagram shows the same cam from a different perspective. It shows a view from the end of the cam with all of the opening and closing points marked. This makes it easier to understand all of these points and how they relate to the actual lobes. As you can see, all of the points are in the same order as in the diagram we showed you above. Notice that here the advance value is not marked anywhere. This is because advance and retard are relative to the pin or keyway on the front of each particular camshaft. Because the camshaft turns clockwise, hence, turning the cam will advance it relative to the piston. As stated earlier, lobe separation is the fixed angle between the centrelines of the two lobes.

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