CAMSHAFTS BY ELGIN

Much information has been recorded about the four stroke internal combustion engine and yet only a small percentage of people really understand how it works and fewer people know how to modify an engine to suit their needs.

I will try to simplify this very complex subject by discussing some basic principles that may be overlooked by the average person.

It is very important to understand which way the piston is traveling and where the valves are during the four strokes.

We have four strokes to consider. The valve timing events, relative to piston placement, are the only thing easy to adjust/change. The camshaft that opens and closes the valves makes one complete 360deg revolution while the crankshaft which moves the piston up and down the cylinder rotates twice (720deg). Camshaft timing is usually talked about in crankshaft degrees relative to piston placement in the cylinder. We know that the piston is at the top (Top Dead Center) of the cylinder twice and at the bottom (Bottom Dead Center) twice.

The First Stroke starting at the TDC position the piston starts moving down the cylinder (intake stroke), picks up speed, and must slow down when it reaches the bottom. As the piston is moving down the cylinder the intake valve is opening. Some air and gas mixture is beginning to flow into the cylinder but the greatest gulp comes when the pressure differential is the greatest. That occurs when the piston reaches maximum velocity. The things that govern piston velocity (Velocity=Rate of change of position, in relation to time) are the stroke, rod length and piston pin off-set. You must be wondering why I'm talking about piston velocity during the first (intake) stroke. FACT ONE: Volumetric efficiency is directly related to piston velocity! We have at least 200 miles of air above the engine waiting to fill the cylinder with 14.7psi @ sea level.

As the piston reaches BDC the intake valve is almost closed. The intake valve finally closes after BDC when the piston is on the way back up the cylinder. You might guess correctly now that the piston does not move very fast at TDC or BDC. As the piston starts the second (compression) stroke it must compress the air and fuel to a high enough pressure and temperature that the spark plug ignites the mixture. We hope to have a CONTROLLED BURN (an "explosion" = detonation) to move the piston back down for the third (power) stroke. In most instances the expanding gasses are at a low pressure by the time the crankshaft is at 90deg after TDC (ATDC) so we can safely open the exhaust valve before BDC (BBDC). When we begin the fourth (exhaust) stroke the exhaust valve is opening at a fairly rapid rate, the piston is going up and if the exhaust valve is not open a lot by the time the piston reaches maximum velocity there will be resistance in the cylinder caused by exhaust gas pressure. This is known as pumping losses. As the piston is reaching the top of the cylinder, the end of the fourth stroke, you will see the exhaust valve is almost closed but, low and behold, the intake valve is just beginning to rise off its seat! At TDC at the end of the exhaust stroke both the intake and exhaust valve are open just a little. This end of the exhaust stroke is also called the OVERLAP PERIOD.

Commonly during the overlap period you will find that at TDC exhaust stroke both valves will be open an equal amount and that is called SPLIT OVERLAP. On standard engines the valves are only open together for 15-30deg of crankshaft rotation. In a race engine that uses higher engine speeds, 5000-7000RPM, you will find the overlap period to be in the neighborhood of 60-100deg (will also mean more duration)! With this much overlap the low speed running is very poor and a lot of the intake charge goes right out the exhaust pipe.

Let us review the four strokes again and add some timing events to calculate total valve duration. Let us use a good street cam timing of 268deg duration with 108deg camshaft lobe centers. Lobe centers=the center line of the exhaust lobe to the center line of the intake lobe in camshaft degrees. As we have discussed, at the end of the fourth stroke both valves were open and the next stroke is the intake stroke. With the 268deg cam the intake valve began to open at 26deg before TDC. We now have the piston going down the cylinder with the valve reaching full lift at 108deg (lobe center) ATDC and the intake valve is still open when the piston reaches BDC. The crankshaft has rotated 180deg from TDC to BDC. The intake valve opened 26 deg. BTDC. Now we have 26 deg.+180 deg.=206deg. of crank rotation. We started with a 268 deg. camshaft so that tells us when the intake valve will close. 268 deg. less the 206 deg. that we have already counted = 62 deg. The intake valve will close 62 deg. after bottom dead center (ABDC). The second stroke is the compression stroke but the intake valve is still closing! FACT TWO: The engine does not have any compression until the intake valve is fully closed! Now we compress the air fuel mixture and ignite it at the proper time in order to maximize the push down on stroke number three. Remember I said that most of the cylinder pressure is gone by 90 deg. ATDC? Now with our 268 deg. cam the exhaust valve will begin to open 62 deg. BBDC and we'll have 180 deg. of crankshaft rotation on the exhaust stroke. 62 deg.-180 deg. = 242 deg. of crank rotation. At TDC at the end of the exhaust stroke the intake valve just begins to open again and the exhaust valve is almost closed. When does it close? We already had 242 deg. of rotation and the cam has 268 deg. 268-242=26 deg. The exhaust valve closes 26 deg. ATDC. With the intake opening at 26 deg. BTDC and the exhaust closing 26 deg. ATDC we have a total of 52 deg. overlap.

Now we can start discussing duration, lift, lobe centers, compression and cylinder head flow.

Let us now take the four timing events and put them in order of importance. The least important is the exhaust valve opening. It could open anywhere from 50 to 90 degrees before bottom dead center (bbdc). If it opens late, close to the bottom, you'll take advantage of the expansion, *power,* stroke and it would be easier to pass a smog test but you'll pay for it with pumping loss by not having enough time to let the cylinder blow-down. You must let the residual gas start out the exhaust valve early enough so that the piston will not have to work so hard to push the gas out. Opening the valve earlier will give the engine a longer blow-down period and that will reduce pumping losses. For a low speed engine, say up to 4000 rpm, the cam can open the valve later.

The next least important timing point is the exhaust closing. If it closes early, say around 15 degrees after top dead center (ATDC), you will have a short valve overlap period. Less overlap is required to pass the smog test but it does not help power at higher engine speeds. Closing the exhaust valve later, in the vicinity of 40 degrees ATDC, there will be a longer valve overlap period and a lot more intake charge dilution that will make low speed operation poor. Some compromise must be made as to how much overlap one needs to use. Many factors need to be considered like idle quality, low speed throttle response, fuel economy, port sizes, and combustion chamber design just to name a few.

The next least important timing event is the intake valve opening. Early opening allows for a greater valve overlap period and adds to the poor low speed use. For the high performance enthusiast, low engine speed could mean 3000 RPM! I would not consider that as a typical street engine. If you're not concerned about passing the smog test then early intake valve opening will help the power output of the engine. Earlier valve opening will have the valve open further when the piston reaches maximum velocity and that increases the volumetric efficiency (V.E.).

I must stop now and ask you a question about your engine. If the stock 1275cc BMC head does not flow much air above .350" valve lift and it is possible to have the intake valve open that much by the time that the piston reaches maximum velocity WHY IS IT THAT MOST PEOPLE WANT AT LEAST .500" VALVE LIFT??

Now the last timing event is the most important and the most critical THE CLOSING OF THE INTAKE VALVE. The closing of the intake valve is the governor of the RPM range and the governor of the effective compression ratio! If the intake valve closes early, about 50 degrees after bottom dead center (ABDC) then it will limit how much air/fuel mixture could enter the cylinder. Early closing makes the low speed very nice but it does limit power output as well as RPM. Another problem with early intake valve closing that most people do not consider is that if you have a high compression engine, say 10:1 or higher, you will have more pumping loss trying to compress the mixture. You might even have head gasket and or piston failure! Now if you close the intake valve later the cylinder will have more time to take in more air/fuel and the RPM will move up. That seems simple enough doesn't it? The later that the intake valve closes the higher the RPM and therefore the more power, maybe! If the valve closes past 75 degrees (ABDC) you could lose most of the low speed torque and if your STATIC compression is only 8:1 the engine will not be able to reach its horsepower potential. Now you might have a better understanding why the intake valve closing is the most important timing event.

Now to get onto another topic. It is very important to know the following in order to make a proper camshaft selection. What will be the RPM range that the engine must perform in? 1000- 4000, 2000-5000, 3000-6000, 4000-7000, 5000-8000 RPM?? What size is the engine? What is the bore and stroke? How long is the center to center distance on the connection rod? How much piston pin offset is there? What is the static compression ratio? In the cylinder head what is the maximum cubic feet per minute (CFM) air flow in the intake track with the manifold and carb installed? At what valve lift does the air flow level out on both the intake and exhaust valve? What is the percentage of the air flow of the exhaust vs. the intake? What are the valve sizes? What are the lengths and sizes of the intake and exhaust systems?

Once you have this data then a logical cam choice can be made. Sometimes the engine combinations are wrong for the expected RPM range that is desired.

How can a layperson look in a catalog and make a correct choice? The parts supplier must have the proper information in order to help the customer choose the proper camshaft.

Let us now look at the cam listings that are provided in this catalog. You will notice that of the six cams that are listed each one has the exhaust duration greater than the intake duration. The reason for this is when the standard 1275cc cylinder head and two other modified heads were flow tested the results showed that the exhaust flow was not up to par. In order to have the correct intake to exhaust balance a dual pattern cam must be used. If the engine is to be used for serious competition then it is necessary to install larger intake and exhaust valves and do the grinding and polishing with the aid of a steady state flow bench. When the cylinder head is prepared in this manner it is then advisable to use a single pattern camshaft.

If we look at part #CAM006 you will see that it was designed for a special

application. Usually the cylinder head was slightly modified and the compression ratio is on the high side for regular street driving. If a stock or near stock style camshaft is used the power would fall off early in the RPM range and the engine would have a pinging or detonation problem. In order to solve this problem the intake valve must close later and the other timing points need to be increased. This will compromise the idle and the torque under 2500 RPM but watch out after 3000 RPM!

We have covered a variety of topics related to the workings of the four stroke internal combustion engine. We discussed a little about volumetric efficiency (VE) and how it is related to piston velocity, cylinder pressures that determine normal or abnormal combustion, pumping losses that occur on the compression stroke as well as the exhaust stroke, overlap period, lobe centers and how to figure out the duration of the camshaft in crankshaft degrees. We went deeper into the four strokes by listing the order of importance of each stroke and how it affected engine performance. We talked about compression ratio versus intake valve closing, what RPM range one might choose for their application, some information about cylinder head flow, and finally some ideas about camshaft decisions when the engine data is known.

Let us now go over some more cylinder head information. We will compare a few BMC "A" series heads in different states of tune. A slightly reworked 1098cc head with std valves [A]; a stock 1275cc head with std valves, I=1.400", X=1.155" [B]; a modified 1275cc with larger valves, I=1.444", X=1.215" [C]; and a highly reworked "Longman" head with larger intake valves, I=1.477", but std exhaust valves, X=1.155" [D].

If you look at the ratio of the exhaust valve versus the intake valve you will find that the stock 1275 head has a ratio of 82% (X/I=1.155/1.400 =0.825); the modified 1275 head has a ratio of 84% and the "Longman" head has a ratio of only 78%. I prefer to be in the 80-85% range and the port the head to achieve about 80% exhaust CFM flow compared to intake CFM flow. the [B] head just got into the 70% range at low lift but dropped to 60% above .250" lift. The modified [C] head averaged 72.5% throughout the lift range. The [C] head could use a single pattern cam but all the other heads require a dual pattern cam because of their lower exhaust CFM flow. Some cylinder head shops tell me that they get good results using X/I ratios of 90-95%. That high a ratio will only work when you are stuck with using a standard cam with about 250deg duration or in the full throttle drag race application. For hot street, autocross or roadracing applications 90% will overscavange the cylinder which will waste fuel an lower the torque curve.

When we compare the [A] head to the [B] head we find that they are similar in flow even though the [B] head has larger valves. All of the BMC heads will increase in flow very nicely up to 0.350" lift and the the increase in flow will start to level out. The larger the valve the more CFM is the norm. The BMC head requires a lot of extra time on the flow bench grinding, polishing and blending valves and ports in order to get more air flow above 0.450"lift. The bottom line is that with a good cylinder head the engine will produce more power. Cylinder head [C] has close to 15% more air flow than a stock head and the [D] "Longman" head has about 20% greater flow than stock. If you can get more air into and out of the engine, you get more horsepower at the same time.

When making any engine modification a person has to be realistic about where they want the power range. Longer duration equals more top end power but it will reduce the torque in the lower RPM range. Just about any engine would benefit from a prepared cylinder head, a good exhaust system with a relatively small diameter for street use, and maybe a little larger carb and manifold. As you increase the RPM band you'll need to increase

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compression and add some duration to the cam. The more duration that you add the more compression you need and that combination will increase the upper mid range and top end power. It is very important to keep your combinations balanced; for example, you cannot use a 270deg cam with 8:1 compression, 9.5:1 would be a lot better and conversely you cannot have 10:1 compression and use a cam with 250 or 264deg duration! As soon as the duration is above 264deg the standard exhaust system will restrict the breathing ability of the engine. Sometimes it's difficult to make the idle mechanism work properly in the carb due to the reduced vacuum and extra exhaust back pressure.

You probably have figured out by now that I am not an advocate of extra high lift, unnecessarily long duration or very high compression for any street driven car. I prefer to use maximum velocity on the camshaft design and that enables me to have more duration at 0.050", .100" and .200" lift as compared to "brand X". When you have longer duration at .200" lift and not as high cam lift you will them have a cam lobe with a rounder nose radius which will support higher loading's and therefore last longer than a pointed high lift cam. I learned a long time ago that DWELL on the nose-top portion of the cam lobe is the equal to lift provided that you have the valve open far enough when the piston reaches maximum velocity. On a normally aspirated engine I have NEVER seen power increase by adding more lift than the port can flow.

Head Flow Comparison

Valve Lift	1098cc "A" Head 1.3" Int. CFM	1.14" Ext. CFM	Stock "S" "B" Head 1.4" Int. CFM	1.155" Ext. CFM	Modified "S" "C" Head 1.44" Int. CFM	1.215" Ext. CFM	Longman "D" Head 1.47" Int. CFM	1.155" Ext. CFM
.020	7.5	6.9	7.8	6.3	7.8	6.6	8.2	6.4
.050	18.3	15.1	19.5	14.3	21.2	16.2	21.6	15.2
.100	39.3	32.4	43.0	32.8	43.0	32.8	45.4	32.4
.150	57.6	45.3	53.1	40.4	62.7	43.9	65.8	46.1
.200	74.6	55.9	69.1	49.4	82.0	54.3	88.1	57.7
.250	85.5	60.4	85.5	58.1	94.4	65.2	102.8	65.8
.300	88.8	65.5	93.4	62.4	107.4	73.5	116.7	73.2
.350	96.3	68.0	102.1	66.0	114.2	79.9	128.2	79.1
.400	99.0	72.1	106.8	68.0	116.7	88.6	135.8	88.5
.430	99.5	73.6	109.0	68.0	117.9	92.2	136.5	84.8
.450	99.9	74.5	109.0	67.0	117.5	92.0	136.6	84.0
.500	101.1	75.6	108.0	67.0	116.8	91.5	135.9	83.5

ELGIN CAM SHAFTS

Camshaft No.	Seat to Seat Duration In / Ex	Duration @ .50 cam lift	Cam Lift In / Ex	Valve Lift In / Ex 1.25 rockers	Valve Lift In / Ex 1.5 rockers	Application
CAM001	244/264	198/215	.264/.264	327/327	393/393	Mild Road. Smooth Idle.
CAM002	250/264	208/215	.250/.264	312/327	375/393	One up from Cooper 'S' Spec.
CAM6608	264/264	217/217	.262/.262	327/327	393/393	Max. for smog emmissions
CAM003	264/268	215/222	.264/.289	327/358	393/430	Fast Road Cam.
CAM004	262/268	225/230	.293/.318	366/397	439/477	Fast Road Cam. 9.1:1 compression recommended.
CAM6708	268/268	222/222	.289/.289	361/361	433/433	Mini & 1275. Will work with stock engine.
CAM6707	268/268	230/230	.318/.318	397/397	477/477	Heavy duty springs reqd. Cylinder head porting recommended.
CAM005	268/278	230/240	.318/.321	397/401	477/481	Hot Street. Header recommended. 9.5:1 compression.
CAM7008	280/280	228/228	.263/.263	329/329	395/395	Hot Street. Must have header to idle. 9.5:1 compression, heavy duty valve springs & good cyl.head are required. Adv. cam +2 deg.
CAM7007	280/280	228/228	.278/.278	348/348	417/417	Hot street grind. Same reqs as above.
CAM7107	284/284	235/235	.290/.290	363/393	435/435	Autocross. 9.5:1 compression required.
CAM71506	286/286	242/242	.302/.302	378/378	453/453	Autocross. 10:1 compression required.
CAM7207	288/288	235/235	.290/.290	363/363	435/435	Autocross. 10:1 compression required.
CAM006	288/292	235.254	.293/.321	366/401	439/481	Autocross. 11:1 compression. Pump gas okay.
CAM7505	300/300	250/250	.297/.297	371/371	446/446	Race grind. 11:1 compression reqd.
CAM007	300/300	250/250	.323/.323	404/404	485/485	Race grind. 11:1 compression reqd.
CAM76506	306/306	261/261	.341/.341	426/426	512/512	Full race. 13:1 compression reqd.
CAM7706-32	308/308	255/255	.322/.322	403/403	483/483	Full race.13:1 compres.Power ramge from 4500-7500
CAM7706-34	308/308	263/263	.348/.348	435/435	522/522	Full race. 13:1 compression reqd.
CAM73503	310/310	268/268	.380/.380	475/475	570/570	Max. for a fully prepared 948cc. Dyno tune Race. Works best for 1275 - 1380cc engines.

Elgin Cams is a company that is a direct descendent of such famous California specialists as Isky, Delong, Winfield, etc. etc. Elgin has taken the art of cams into the science of the '90's. Computer designed and handcrafted workmanship guarantee a First Class camshaft. Custom designed cams are a specialty.
Elgin has made cams or sold his design to General Motors, Ford Motor Co., Nissan Corp., Zakespeed International, Porsche Motor Sports, Winston Cup Engine Builders. Elgin has the largest percentage of cams used at SCCA's Runoffs from GT-1 to Formula-V. He also has provided original or new technology for antique and vintage racers.