Building a Competition Engine, or Maybe Not!

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Over the past few years I have responded to a number of questions from enthusiasts about modifications to the Austin-Healey engine. It seems that either the engine that was inherited from a previous owner is running poorly and is in need of a rebuild, or the engine has been previously modified unsuccessfully and runs poorly. As a result, a lot of us are constantly "thinking about rebuilding the engine and ‘hopping it up’ along the way". Well, like all things mechanical and especially Healey-related, the solution must take into consideration a number of factors. The following are some of the answers that I have given to questions asked. These answers are directed at the six-cylinder engine, but the principles are the same for the fours.

"I have my engine out of the car. How can I get the most performance with the simplest (*read: "cheapes*t*"*) modifications?"

This is the number one asked question and it leads to a Pandora’s box of counter-questions. How much are you willing to spend? What type of driving will you be doing? Are you trying to stay concours? How solid is your frame, the engine mounts, the gearbox, the overdrive and the rear axle? And this is just the beginning. As the layers of the onion are peeled back to reveal the thought process for modifying the engine, new sub-questions always arise.

As you can see, there is not a single simple answer, but there are some guidelines.

The first recommendation (not a change) is to "blueprint and balance" the engine. This should be done by a quality machine shop. It means that all of the engine parts are checked for the proper specified clearances and dimensions. Then, all of the moving pats are weighed and balanced. Each set of pistons and connecting rods will weigh the same. The rotating parts, as a unit, are all balanced together. This will allow your engine to rev higher and more freely. There will be less wear on the parts. This is *very* important, especially if a new cam is being considered.

The first change that I suggest is to the compression ratio of the engine. The BJ8 engine has a compression ratio of 9:1. Older models have even lower compression. Higher compression means higher horsepower. The tradeoff is having to use higher octane gasoline. The useful compression ratio is also limited by the design of the combustion chamber. For example, some modern Jags have compression ratios over 12:1 but can still run on pump gas. They have very efficient designs. Healeys are not afforded that luxury. The reason for the use of low compression in the original engine design is that immediately following WWII, the worldwide quality of gas was quite suspect. Nowadays we have very uniform gas quality that will support higher compression ratios. I recommend between 10:1 and 10.5:1 as a reasonable ratio.

The next change that I always recommend is a change to a BJ8 camshaft grind (more on cams later). If your cam is in good condition, it can be reground to the later model specifications. There are many sources for having a cam reground. If your cam is toast, you might as well buy the later model grind since it will be the same price. How much will you gain in horsepower? If you compare the factory published power ratings, the increase is 10-15 horsepower.

The next most efficient use of your time and money is made by concentrating on the breathing qualities of the engine. This means work on the head. Think of the intake and exhaust system of the engine as a drainpipe. If you have a clog in the pipe, the water cannot drain efficiently. The engine works the same way. If the air/fuel cannot get into the combustion chamber and the exhaust is restricted on the way out, the engine will not function efficiently.

The Austin-Healey head is like a big clog in a drain. Clean it out! You need to port and polish the intake and exhaust ports, match the intake and exhaust manifolds along with their respective gaskets to the head and unshroud the valves. If you have the time and patience, this can be done at home with a Dremel® tool or other similar grinder. *You want cheap? Do it yourself!* There are books available at specialty book shops, or available for checkout at your local library that will explain how to do it. As you are working on the head, imagine water flowing through the openings. Where would it swirl? What can you do to make the path easier for the water?

Still nervous about tackling the job yourself? Find the best racing engine shop in your area and pay them to do it right. Talk to local racers, either circuit or drag racers, to see what shop has a good reputation for producing fast cars. (Remember, how much do you want to spend?) It is all labor cost to rework the head, so figure three or four hours minimum at $$ per hour for shop labor.

Do you really have the $$$ to spend? Go for an aluminum head. There are several aftermarket suppliers. The heads can be purchased in various stages of finish. A raw head is the least expensive but then it needs to be ported and polished, etc. Why an aluminum head? The modern casting is strong and is a cleaner, less restrictive casting than the original iron head.

How much will you gain? Depending on the limits of your cam and how bad your head was before you started, 5 to 50 horsepower. That's a big range but it really depends on what else you are doing to the engine.

The next step that I would recommend involves lightening the drive train components. This step is not aimed so much at power as it is at responsiveness. The reduction of centrifugal inertial weight allows the engine to spin up faster and slow down faster. Anything that moves is a target for weight reduction. If it goes around, the closer to the outer edge of the circle that the weight is reduced, the more effective the change. Imagine that you added twenty pounds of weight to the outer rim of your bicycle. It would be a lot more difficult to first start up riding the bike and would be much harder to stop. The same is true with the engine except that the effect is magnified by 6,000 rpm instead of 2 or 3 rpm on a bicycle!

What components do you lighten? Start with the flywheel. Have a competent machine shop do the job. As I remember, the OEM flywheel weighs in at about 26 pounds. Three to five pounds can be removed without degrading the strength of the flywheel. There are several shops that specialize in Healey flywheels. Some claim that they can remove 10 pounds or so. Want more and have the $$ to spend? Go to an aluminum or composite (part steel, part alloy) flywheel. You can get the weight down to as little as ten pounds or so. However, there is a trade off here. Sure the engine spins up faster, but that also means that the torque from inertia has been *substantially* reduced. You will not have all that flywheel weight to help start off the car from a dead stop in city traffic when you let out the clutch or to keep the car traveling smoothly along the highway. Ever noticed that an F-1 car or NASCAR racer revs the engine to about 8,000 before he drops the clutch to leave the pits? Even so, they stall the engine a lot. It's not because they are bad drivers. Their cars have tiny flywheels and little low-end torque. This is an exaggerated example but suggests the tradeoff that will be made.

The lesson here is to be judicious about removing flywheel weight if you want your car to not be a challenge to drive in town (remember that it is important to determine what type of driving will you be doing).

The other end of the scale here is to go to the alloy flywheel, 7.5 inch clutch, twin disk small pressure plate and remove some of the counterweight mass on the crankshaft. Then lighten the connecting rods, pistons, valves and camshaft components. How much do you want to spend? And are you only going to race the car at a steady 6500 to 7500 rpm?

Okay, those are the big five. What about concours? The experts will have to answer that one but my understanding is that if you cannot see it, it does not count against you.

(Generally true, but bear in mind that the car must idle normally and not produce excessive noise. – Ed.)

"I bought a 'X' camshaft that I am planning to install. How many horsepower will I have?"

My answer is usually, "You bought *a what!?!*" Followed up by, "Did you plan out the engine first?" The answer that I have always received so far is, "No." Usually with a qualifying phrase such as, "but the previous owner/mechanic/salesman/club member (pick one) said that it would be really fast." You can see where I am going with this. The same questions apply as before. Everything has to work together or you are wasting money and effort. Installing a cam that is "hotter" than a factory cam may not do anything if it is not matched up with the rest of the engine components.

The camshaft is the brain of the combustion operation. It sets the timing for when the valves open and close and drives the distributor for sending the spark. Car manufacturers spend millions of dollars trying to find the perfect cam for a given engine and car. If you are going to change the cam, it should be done because you are planning to use the car differently from its original intended use. Once again, there are a number of tradeoffs. Too much cam will result in an engine that runs very poorly at low end. Not enough cam will result in an engine that runs out of power at the top end.

There are three design elements to the cam: Lift, duration and timing.

Lift is the amount that the cam causes the valve to open, measured from complete closure to complete opening. It can be measured either at the cam or at the valve; the numbers will be different because of the rocker arm ratio. The BJ8 engine cam has .368 inches of lift (at the valve, not at the cam).

Duration is the measurement, in degrees, of the amount of time that the valve remains open during one camshaft revolution. The duration can be the same for both the intake and exhaust valves (as in the BJ8) or can be designed to be different (as in the tri-carb). This measurement is taken either "seat to seat" (i.e., when the valve is completely closed) or at .005 of opening (i.e., when the valve is .005 off of the seat). The BJ8 cam has a duration of 252 degrees for both intake and exhaust valves, seat to seat.

Timing is the measurement of when, during the camshaft revolution, the intake or exhaust valve begins to open or finishes closing. Typically, the intake valve will begin to open at a certain number of degrees before top dead center (BTDC) of the camshaft and will close at a certain number of degrees after bottom dead center (ABDC). The exhaust valve will open a certain number of degrees before bottom dead center (BBDC) and will close a certain number of degrees after top dead center (ATDC).

BJ8 cam specs are:

Intake opens: 16º BTDC

closes: 56º ABDC

Exhaust opens: 51º BBDC

closes: 21º ATDC

Four other terms that are used in connection with camshafts are ramp speed, overlap, lobe centerline and initial advance.

- The ramp speed refers to the shape of the camshaft lobe. It determines how fast the valve opens when leaving the seat.

- Overlap refers to the time during the cam rotation when both the intake and exhaust valves are simultaneously open.

- The lobe centerline refers to the angular location in degrees of the centerline of either the intake or exhaust lobe on the camshaft when the camshaft is at TDC. The lobe centerlines can be the same for both intake and exhaust or they can be offset. The BJ8 cam is offset by 35 degrees. The intake centerline is 110º; the exhaust centerline is 75º. The difference between the lobe centerlines is referred to as lobe separation.

- The initial advance refers to the relationship between the crankshaft driving sprocket and the camshaft driven sprocket. The two can be lined up so that TDC on the crank is the same as TDC on the cam or the cam can be retarded or advanced. This adjustment will change the placement of peak horsepower and torque in the rev curve. Advancing the cam generally causes the peak horsepower to occur at a lower rev point but will also lower overall horsepower.

Now, with that background, we come back to the question of what cam grind to use. With more cam (meaning more lift and longer duration), more horsepower can be generated. But with more cam, proportionally more torque does not necessarily follow. Further, both the horsepower and torque peaks will move to a higher rpm level with more cam, usually about 500 rpm for each 8 to 10 degrees additional duration. The factory designed an engine with a lot of drive train inertial mass and a fat torque peak at low rpm. It was designed for the American market where we are used to low revving V-8s with lots of torque. If the cam is changed to one with more lift and duration, the torque peak will move up the rpm scale. Horsepower will increase but will likely not be noticed prior to 4,000 rpm. Low-end torque will be noticeably reduced. The driving characteristics of the car will be changed.

Combined with the choice of cam must be a review of the carburetion system. In order to get more horsepower you must burn more gas and air. Thus, you must be able to either deliver more gas or use the gas that you are delivering more efficiently if you are adding more cam.

If you are planning to use the same carburetor setup as came with the car, do not plan on increasing the cam much. By cleaning up the head and matching the intake and exhaust ports and gaskets, you can create some air/fuel delivery efficiencies that will allow for slightly more cam. I have seen the following aftermarket cams offered in the past (by duration): 260, 268, 272, 286, 290, 300 and 315. The lifts of these cams varied from a low of .368 (same as a BJ8) to a high of .515.

Another note, any cam with a lift of over .450 or so needs to be *carefully* checked for clearance as it opens when installed. You may have to pocket the block for exhaust valve clearance. Remember, lift at the valve is different from lift at the cam. The lift at the cam has to be multiplied by the rocker arm ratio (OEM is 1.5). For example, a cam with a lift of .315 at the cam will have .4725 at the valve using stock rockers. That lift could cause interference problems. When you discuss a cam with your cam grinder make sure you are both referring to the same lift.

What horsepower will you have must be answered in conjunction with an entire engine intake/exhaust plan.

"I have a BN6/BN7/BJ7/BJ8 (pick one) and am putting on triple Webers. What will my horsepower be?"

Putting three SU HD8s or triple Webers on the manifold is not the end-all answer to horsepower. They will not match up with just any new cam. Depending on what type of manifold you install (individual runners or log type common plenum) triple Webers may require a full race cam to be properly utilized (duration of at least 300º). You need to have some idea of the flow rate of your head and intake, and then match that to the cam and carburetion. Over-carburetion will result in poor drivability at low rpms. In addition, it is difficult to jet too large a carburetor. Jetting it correctly for high rpms will cause an improper mix for low rpms and vice versa.

Under-carburetion is also a problem. You will not have a proper match to your new cam.

Your small carbs are set for a cam with a low rpm torque and horsepower curve, but your cam is expecting bigger volume of air/fuel mix at high rpms than you are able to deliver. The result is a car with less performance than before you changed the cam. You have the wrong cam for low end and not enough carb to fulfill your upper end expectations.

Carburetion, like all of the factors mentioned here, is a compromise choice. In order to get more fuel and air to the engine at peak rpm, the carburetors that you choose must have large throats. Guess what, according to the Bernoulli Theorem, large throats have slower air speed than smaller throats for the same volume of air passing through. What does that matter? It means that at low engine speeds (low air volume), a large throat carburetor is much less efficient than a small one. The faster the airflow through the throat, the better the venturi works and the better atomized the fuel/air mix is and therefore the better the burn efficiency in the combustion chamber. This principle is referred to as volumetric efficiency and is the reasoning behind triple carburetors with progressive linkage. Use one small throat at low speeds and open up more throats at high speed. Unfortunately, the Healey is not set up with progressive linkage. They had enough trouble with just standard unified opening of the carbs. Even triple carbs by themselves are not the final answer.

Triple SU HS4 carbs provide better efficiency and drivability at city speeds than triple HD6 s or HD8 s or Webers because they have smaller throats and better volumetric efficiency. But the triple HS4 s run out of steam as the engine revs up. They cannot deliver enough fuel/air to the engine. They are choking on their throat size. Back to engine breathing again.

Conclusion

So, what is the answer? The answer is more questions. How are you going to drive your car? What kind of characteristics are acceptable to you? How much is in your budget to spend? Those are the questions and they are ones to which only you know the answers.

If you do plan to install more cam, make sure the engine is ready for the necessary increased fuel/air mixture flow, then match your carburetion to the amount of flow that your engine can accept and choose a cam that works within that set of criteria.

Post Script

After I finished writing the first part of this article, I decided that I left the first question hanging. So, I am going out on a limb (and putting on my flame-retardant suit) to give my opinion on how I would build a street driving budget/performance engine. I would spend most of the money on preparing the head, flow, flow, flow, flow and more flow. I would choose a cam with about 260 (268 if you like higher rev driving) degrees of duration with lift for both the intake and exhaust (at the seat) of .425, or more if your engine layout permits it. I would choose three HD6 s mounted on a log plenum and would spend some time setting them to match the cam. Probably re-jetting them and changing the dampening and pump jet characteristics. This would likely be trial and error and very time consuming. I might also try to make the linkage slightly progressive as a later project.

My answer for a race engine would be completely different. Okay, flame away. I'm ready.

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