Where the Rubber Meets the Road ……. *Part II* Camshafts and Valvetrain

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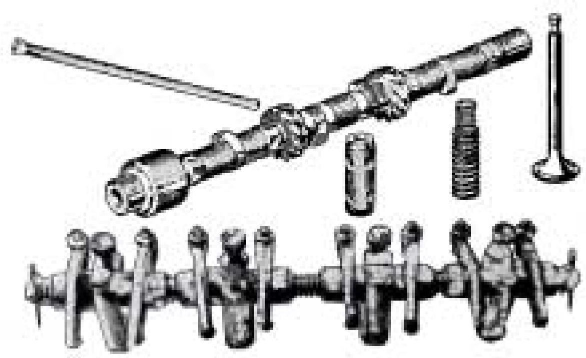
"If the Cylinder Head is the engines Heart and Soul, Then the Camshaft is its Personality."



Valvetrain Components

This month we will cover: Camshafts, Cam Timing, and Valvetrain. In this article we will cover:

- Basic camshaft design.
- Engine characteristics that effect camshaft design
- Build Three (3) engines, using four (4) different camshafts; from stock 1250cc to a highly tuned 1466cc street engine, to determine what cam best suits the engine requirements. Simulate each engine on a computer using Performance Trends Engine Analyzer V3.0, engine simulation software.
- Review the remaining components in the valvetrain.

Basic Camshaft Design

- What is a camshaft?
- Coming to terms - A CAM Glossary
- What does the AAA3096 Camshaft look like when delineated on a graph

What is a camshaft?

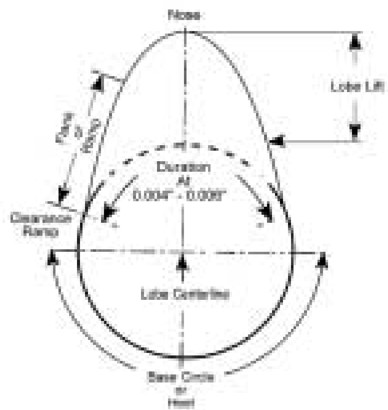
The Camshaft and its associated valvetrain components can be mysterious and confusing. Understanding camshaft and valve train technology can be the most challenging to understand. It can also be the most rewarding in terms of power increases as you begin to grasp how changing these pieces can affect your engine.

I like to think of the camshaft as the conductor of the orchestra. A camshaft can bring all of the variables of the engine's design into order. On the other hand, if the wrong cam is selected for a particular engine combination, it can result in lost power and driveability. The focus of this article is on MG-T series cars that are regularly driven on the street. The operating range is from 1,500 rpm to 5,000 rpm.

For best performance, the cam must be matched not only to the engine's displacement and rpm band, but also to its head's airflow characteristics, bore-to-stroke relationship, induction system, exhaust system and compression ratio. Even the engine's rod-to-stroke ratio plays a part. But the bottom line is how much cylinder pressure the cam allows the engine to make at a given rpm.

Lift, duration and timing of events are the three major considerations used in camshaft design. The size, shape and position of the cam lobes determine how high, how long and when the valves open and close. Selecting the best combination of lift and duration amounts to a compromise between low-speed torque and high-speed horsepower.

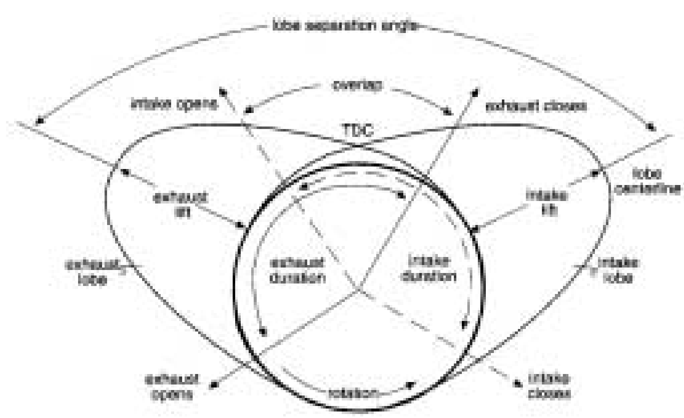
Coming to terms - A CAM Glossary



Cam Lobe

A cam lobe is more complex than it may appear. Its shape determines the operating characteristics of the engine. For a better understanding of the terms used to describe a camshaft I have compiled a glossary of terms. (sources: Jim Resnick, Cole Quinnell Camshafts & Valvetrain 2/99, Bill Jenkins SA Design 1986,Stockel, Stockel and Johnson ,Goodheart Willcox 1996)

- Base Circle or heel - Lowest point of the cam lobe in relation to lift; the closed valve position occurs at this position of the cam lobe. All valve lash settings are made when the each lobe has the base circle (or "heel") against the lifter. When a camshaft is being ground, the base circle is the actual part of the lobe that is ground to form lift at the lobe.
- Basic RPM - The rpm range in which the engine makes the best power.
- Cam Centerline - Cam phasing in relation to the crankshaft; where the centerline of the intake or exhaust lobe is in relation to the No.1 cylinder's piston given in degrees of crank rotation after Top Dead Center (TDC). When degreeing a cam, you must know this figure to install it properly. When you do advance or retard the camshaft centerline (when degreeing a cam), you affect both the intake and exhaust lobes; these are not individually adjustable.
- Degreeing a cam - Setting the camshaft's phase (or position) in the engine in relation to crank position. XPAG cam AAA5776 is ground 0 straight up, AAA3096 0 straight up, AEG 122 4 deg. advanced, Crane 340-010 4 deg. advanced. The cams that are ground with some advance make up for timing chain stretch. If the installer places the cam ahead in relation to crank/piston timing, it has been advanced; if it is moved back from straight up, it has been retarded. Advancing a cam moves the power band to a higher rpm range. Retarding a cam does the opposite.
- Dual Pattern - When the intake and exhaust lobes do not have the same duration and lift, i.e. Crane 340-010.Cams are often ground this way to aid poor exhaust ports and exhaust systems.
- Duration - Time (in degrees of crankshaft rotation) that the valve is open during its tappet lift. The four cams studied in this article are measured at seat-to-seat or 0.004"-0.006" lift. This is also referred to as advertised duration.
- Lobe separation angle - Actual spacing of cam lobe centerlines (in degrees) for a common cylinder; ground into a camshaft - not changeable; largely responsible for the idle quality of an engine. Narrow separation angles (102-108 deg.) seal a cylinder for a longer period of time but also give a rough idle quality, while larger angles (109-114deg.) generally give a smoother idle.

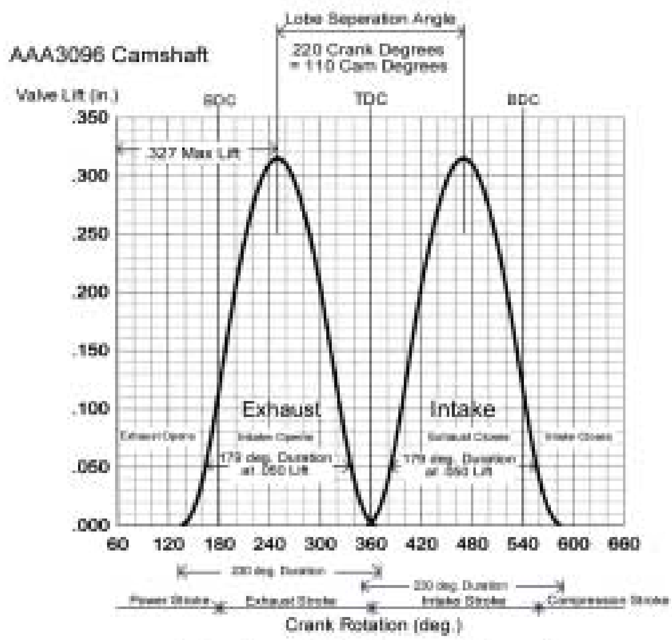


Lobe Separation Angle Characteristics

Condition	Narrow Separation Angle	Wide Separation Angle
Intake Event	Starts & Ends Earlier	Starts & Ends Later
Exhaust Event	Starts & Ends Later	Starts & Ends Earlier
Valves Closed Simultaneously	Increased Time	Decreased Time
Overlap	Increased	Decreased
Low Speed Cyl. Pressure	Higher	Lower
High Speed Cyl. Pressure	Lower	Higher
Detonation	Higher Potential	Lower Potential
Manifold Vacuum	Lower	Higher

- Lift - Distance the valve is closed to the peak lift when fully open.
- Mechanical (solid lifter) cam - a cam using lifters with only a radiuses contact face in which the pushrod end sits. This is the type of cam used in the XPAG engine.
- Nose - Full-lift portion of the cam lobe where the lifter is pushed open at maximum distance.
- Overlap - The amount of time in crankshaft degrees that the intake and exhaust valves are open simultaneously.
- Ramps - Portions of the cam lobes that lift or settle the lifter from the base circle of the cam; does not include nose. They have different rates of lift in velocity and degrees of crank rotation. Symmetrical cams have individual lobes with the same opening and closing ramp rates while asymmetrical cams have different opening and closing rates on the same lobe.
- Profile - The actual shape of an individual cam lobe. There are hundreds of possible profiles within a lobe shape with the exact same lift opening and closing points.
- Valve Lift - Calculated by multiplying cam lift by the engine's rocker arm ratio. Valve lift for the AAA3096 cam is 0.327 in. The rocker arm ratio is approximately 1.5:1.
- Valve Timing - The timing of valve events, which are the points at which the intake and exhaust valves open and close (in crankshaft degrees) are also extremely critical in determining not only the engine's power, but also its power curve.

What does the AAA3096 Camshaft look like when delineated on a graph?



Valve Motion Chart

To better understand how changes in lift, duration and lobe separation angle affect our XPAG engine, we need to get a better understanding when the valves open and why. The Valve Motion Chart plots the amount of lift at the cam timed in relation to degrees of crankshaft rotation. Before the piston reaches Bottom Dead Center (BDC) on the power stroke, the exhaust valve begins to open. That allows the exhaust gases to begin exiting the cylinder under their own pressure, reducing the engine's effort to discharge the gases on the upward stroke of the piston. As the piston approaches Top Dead Center (TDC), the intake valve begins to open before the exhaust valve is closed. Although it's hard to see in the graph, there is some overlap in the AAA3096 Cam. The overlap allows the exiting exhaust gases to help draw in the intake charge. As the piston begins the intake stroke, the exhaust valve closes, and the downward motion of the piston begins drawing in the rest of the incoming air/fuel mixture. The intake valve remains open for a short time after the piston begins the compression stroke to take advantage of the momentum generated by the column of air/fuel mixture. Also, remember that the valves don't flow much when they are opening or closing at a low lift period. Later in this article when I cover the Valves I will discuss how we can gain additional flow by just following the factory recommendations.

Engine characteristics that affect camshaft design

As I stated earlier, the camshaft is the conductor of the orchestra. Well, there are a lot of players in this system. The Cylinder head is where most of the power is made. Therefore its ability to breathe efficiently is very important. Our goal is to fill the cylinders with as much air and fuel as we can. Airflow through the cylinder head is directly controlled by the height of the valve's lift. Up to a point, the higher the valve lifts the greater flow. In general terms, higher valve lift helps generate torque and horsepower.

The speed at which the piston moves away from TDC is an important factor in determining the cams profile. The high rod-to-stroke ratio (1.98:1) causes the piston to accelerate away from TDC at a slower rate than most engines.

Build three (3) engines, using four (4) different camshafts

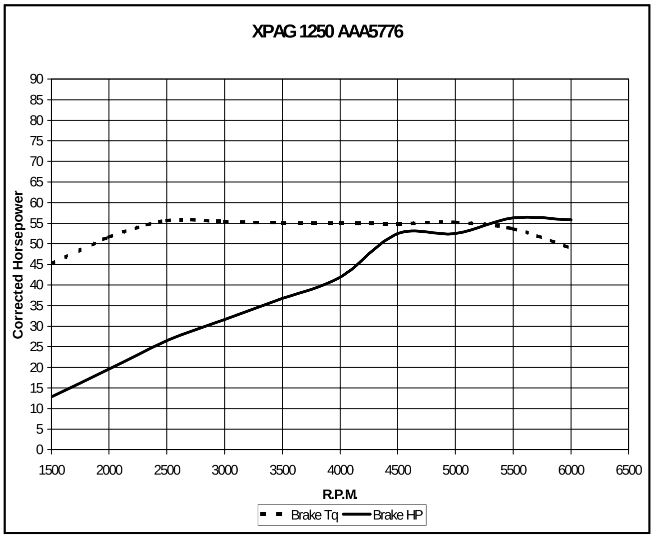
Believe me, this is where the fun starts. Although this is a simulation, I believe that the information contained in this analysis is consistent and fairly accurate. The Performance Trends Engine Analyzer is stated to be accurate to ±7%. The program allows the user to input engine specifications, including but not limited to; Bore, Stroke, # of cylinders, connecting rod length. **Cylinder head data** includes valve diameter, average port diameter, and port volume in cc's, port length, flow, efficiency, and compression ratio. **Intake manifold data** includes design, runner diameter, runner length, flow efficiency, intake heat, and CFM rating for the carburetors. **Exhaust system data** includes design primary diameter, primary length flow efficiency collector length exhaust system CFM rating. **Cam/Valve train data** includes rating lift (i.e. seat-to- seat 0.004-0.006, .040, .050 inches) centerline, advertised duration, intake timing, max lobe lift, rocker arm ratio. **Test conditions:** I used standard dyno (60deg. 29.92). Coolant temperature: 180 degrees. Fuel specifications: 96 Octane. Additionally, I measured Intake and exhaust ports on a stock cylinder head, Intake manifold volume on a stock 1-1/4 and an XPEG 1-1/2-inch manifold. These are probably the most important specifications, but there were numerous others that were also used.

The first engine is a stock 1250cc. It uses 1-1/4 inch H2 SU's rated at 110 CFM each. The second engine is what many people are running today; a 1326cc Stage II with a compression ratio of 9:1. It uses 1-1/2 H4 carburetors rated at 133 CFM each, and the TF1500 intake manifold. The third engine is a 1466cc Stage IVA as defined in the book "The XPAG Engine Data Service Supertuning by: W.K.F. Wood, edited by Jerry Austin 11/98.

The four camshafts used include; AAA5776, AAA3096, AEG122, Crane 340-010 also known as (Moss Motors "3/4" Cam). Valve timing is measured seat-to-seat. Although the engine simulator provides comprehensive information on each engine and a five-page report, this much information is beyond the scope of this article. I exported the Horsepower and Torque data into an Excel spread sheet and plotted charts for each combination.

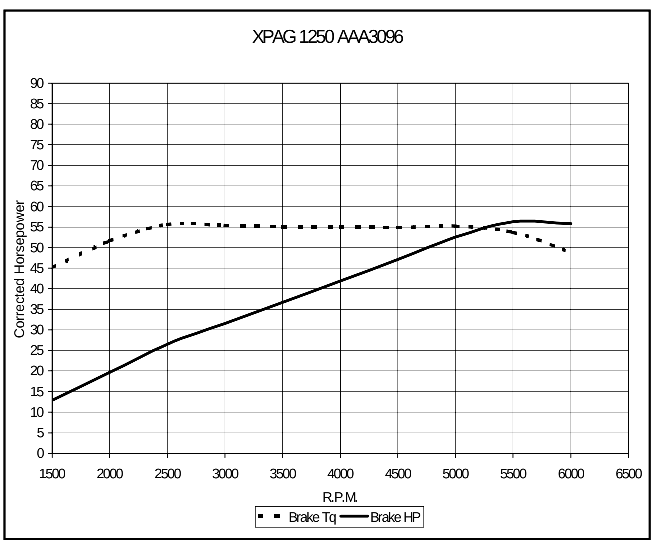
Stock XPAG 1250

AAA5776 "Early" Camshaft



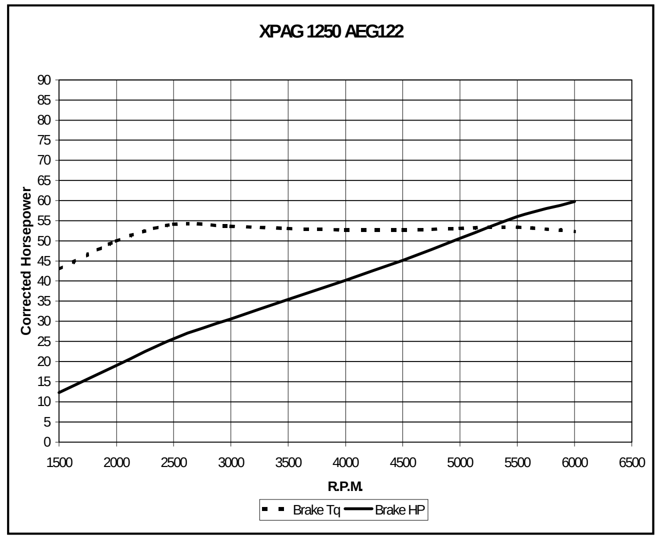
Peak Torque is 54.3 @ 2500 rpm, Average Torque 52.1. Horsepower @ 5500 RPM 56.4 Average Horsepower is 37.7. The Volumetric Efficiency at peak Torque is 67.7. BSFC at @ 3500 rpm is .554 A good BSFC is in the range of .40 - .45 for gas. The lower the BSFC, the more efficient the engine is at converting fuel into horsepower.

AAA3096 also known as the "Late" Camshaft.



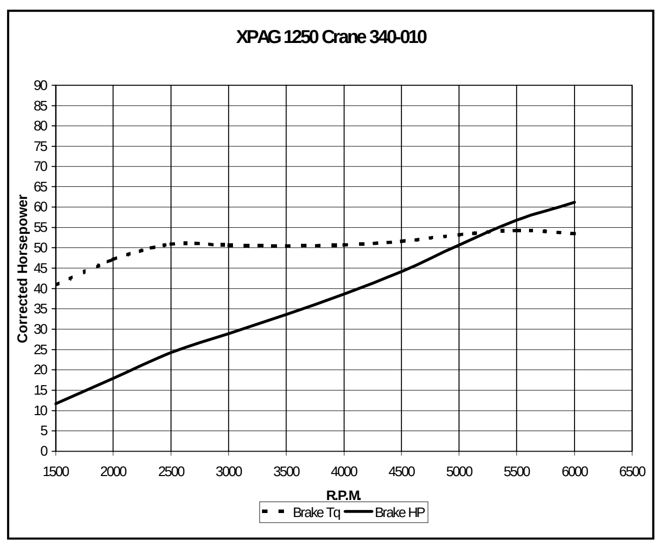
Peak Torque is 55.6 @ 2500 rpm, Average Torque 53.0. Horsepower @ 5500 RPM 56.3 Average Horsepower is 38.1. The Volumetric Efficiency at peak Torque is 66.5. BSFC at @ 3500 rpm is .542.

AEG122 "3/4 Race Factory Cam"



Peak Torque is 54.1 @ 2500 rpm. Average Torque 51.8. Horsepower @ 5500 RPM 56.0. Average Horsepower is 37.5. The Volumetric Efficiency at peak Torque is 65.5. BSFC at @ 3500 rpm is .555.

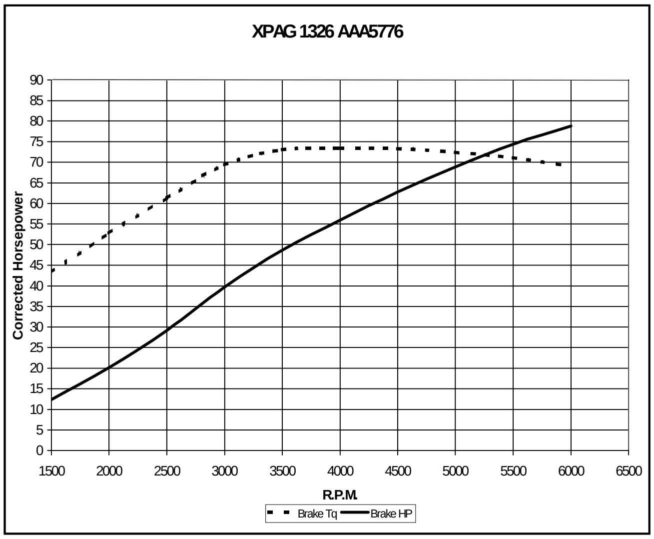
Crane 340-010 (Moss Motor "3/4")



Peak Torque is 54.3 @ 5500 rpm, Average Torque 50.3. Horsepower @ 5500 RPM 56.8 Average Horsepower is 36.8. The Volumetric Efficiency at peak Torque is 71.6. BSFC at @ 3500 rpm is .576.

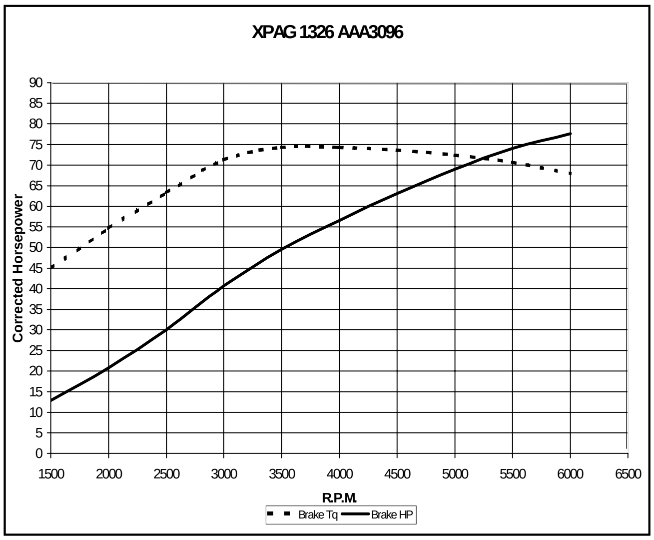
Tuned Stage II XPAG 1326

AAA5776 "Early" Camshaft



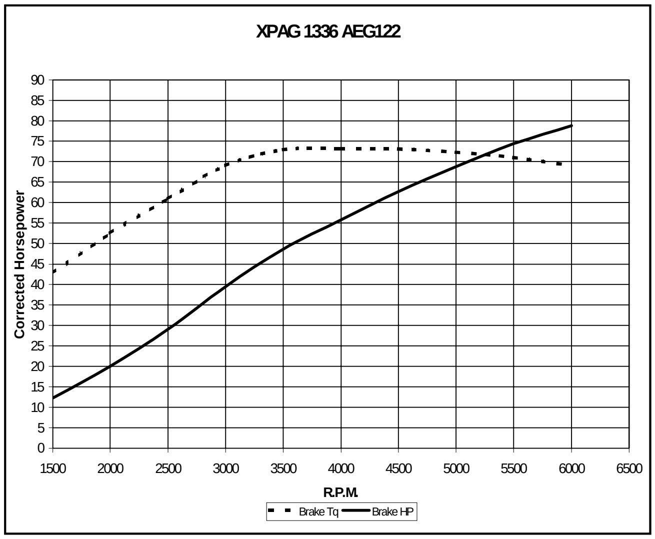
Peak Torque is 73.4 @ 4000 rpm, Average Torque 65.9. Horsepower @ 5500 RPM 74.4 Average Horsepower is 49.1. The Volumetric Efficiency at peak Torque is 78.5. BSFC at @ 3500 rpm is .512.

AAA3096 also known as the "Late" Camshaft.



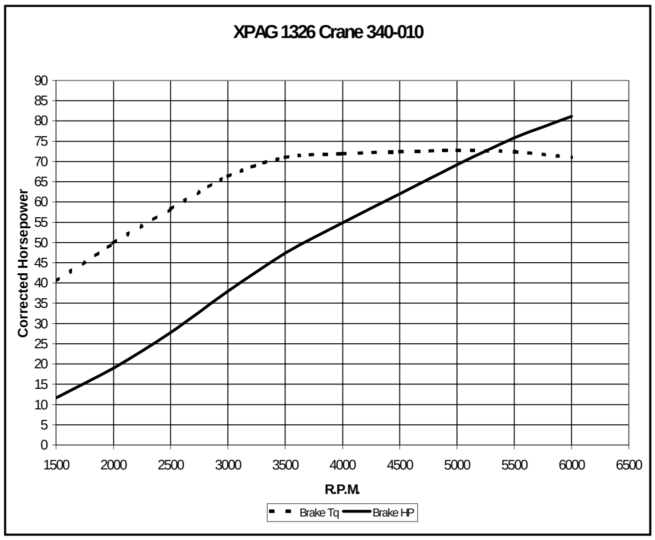
Peak Torque is 74.3 @ 3500-4000 rpm, Average Torque 66.7. Horsepower @ 5500 RPM 74.0. Average Horsepower is 49.4. The Volumetric Efficiency at peak Torque is 79.0. BSFC at @ 3500 rpm is .507.

AEG122 "3/4 Race Factory Cam"



Peak Torque is 73.2 @ 4000 rpm. Average Torque 65.7. Horsepower @ 5500 RPM 74.4. Average Horsepower is 49.0. The Volumetric Efficiency at peak Torque is 78.4. BSFC at @ 3500 rpm is .511.

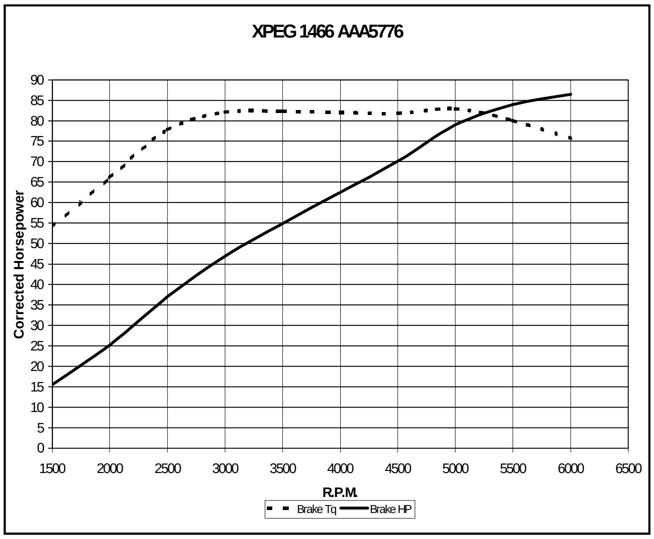
Crane 340-010 (Moss Motor "3/4")



Peak Torque is 72.7 @ 5000 rpm, Average Torque 64.6. Horsepower @ 5500 RPM 75.8. Average Horsepower is 48.6. The Volumetric Efficiency at peak Torque is 81.7. BSFC at @ 3500 rpm is .528.

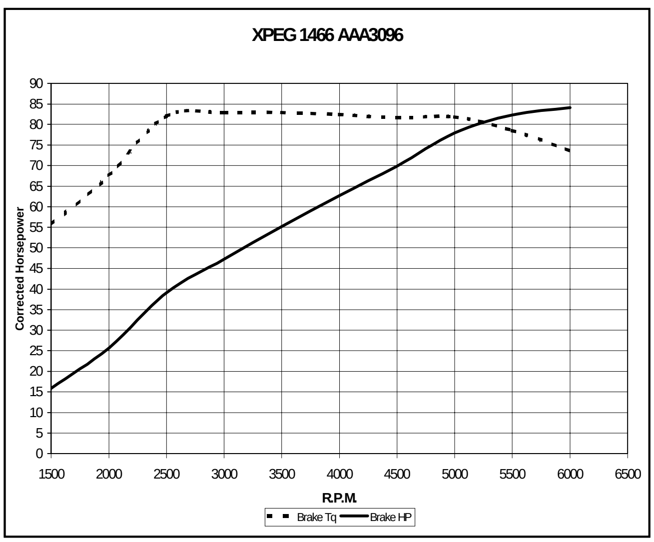
Tuned Stage IVA XPAG 1466

AAA5776 "Early" Camshaft



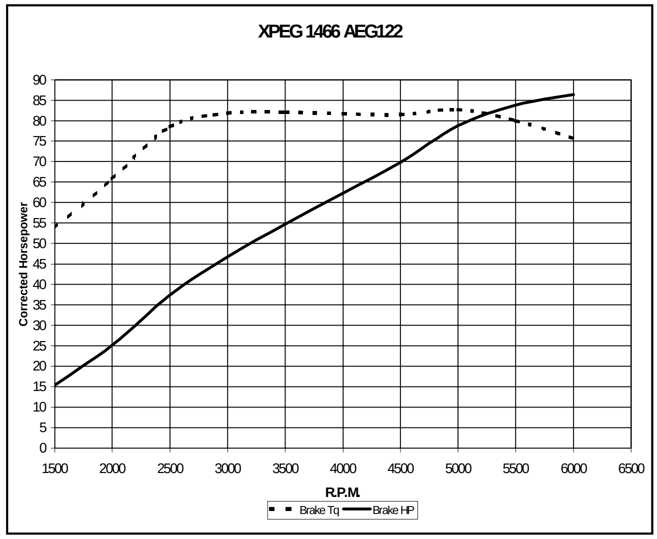
Peak Torque is 82.9 @ 5000 rpm, Average Torque 76.5. Horsepower @ 5500 RPM 83.9 Average Horsepower is 56.2. The Volumetric Efficiency at peak Torque is 82.6. BSFC at @ 3500 rpm is .502.

AAA3096 also known as the "Late" Camshaft.



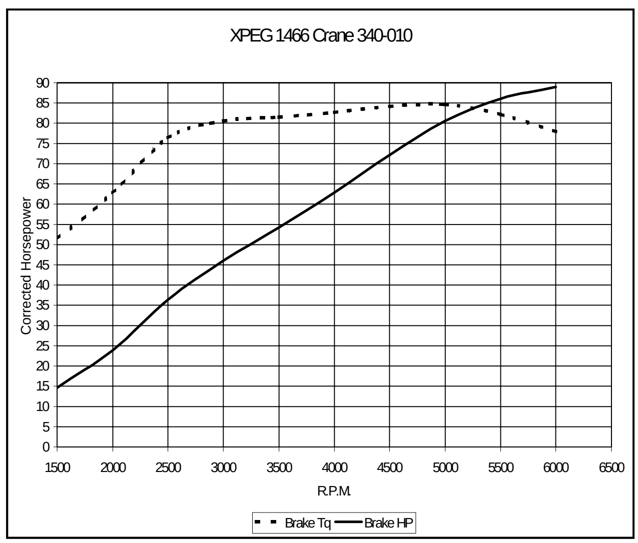
Peak Torque is 82.9 @ 3500 rpm, Average Torque 76.9. Horsepower @ 5500 RPM 82.3. Average Horsepower is 56.0. The Volumetric Efficiency at peak Torque is 77.7. BSFC at @ 3500 rpm is .501.

AEG122 "3/4 Race Factory Cam"



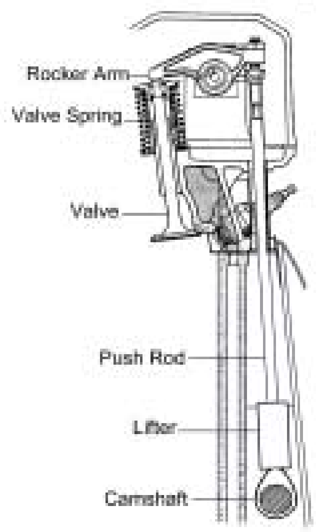
Peak Torque is 82.7 @ 5000 rpm. Average Torque 76.3. Horsepower @ 5500 RPM 83.8. Average Horsepower is 56.0. The Volumetric Efficiency at peak Torque is 82.5. BSFC at @ 3500 rpm is .534.

Crane 340-010 (Moss Motor "3/4")



Peak Torque is 84.7 @ 5000 rpm, Average Torque 76.5. Horsepower @ 5500 RPM 86.1. Average Horsepower is 56.6. The Volumetric Efficiency at peak Torque is 83.4. BSFC at @ 3500 rpm is .511.

Valve Train Assembly



The valve train assembly that is used on the XPAG engine is actually very sophisticated.

The Rocker Arm Assembly

The rocker arm ratio is close to 1.5:1. This means that the lift at the cam is multiplied by 1.5 to achieve the net valve lift. The rocker shaft holds the assembly together. However if it is worn the oil pressure be reduced. If the cylinder head is milled to raise the compression ratio, or the block decked to make it square, shorter push rods will be required. Whatever you do, Do Not use shims under the Rocker brackets. Instead, shorten the push rods to obtain the correct geometry.

Push Rods

When the camshaft is at half of its lift, the rocker arm should be parallel to the cylinder head. By using an adjustable push rod. You can check for the correct length. Using a Dial Indicator on top of the valve spring washer, check the total lift at the valve. Next rotate the engine to one half of the valve lift. Additionally, mark the valve stem with a felt marker and turn the engine over. The rocker will scrape off the marker and you can see the distance that the rocker has traveled across the valve stem. Once you have the adjustable pushrod, you can send it to Smith Brothers to get the new push rods made.

Valve Springs

About a year ago I had a conversation with Skip Kelsey of Shade Tree Motors (925-846-1309), about valve springs. I was getting coil bind when using the Crane cam. He suggested that I use the Brown and Gammons Springs. He sent me an article written by Carl Cederstrand "Bill Phy's Valve spring analysis". I highly recommend these springs.

Valves & Seats

The valves that I received from Moss motors were ground at a 37-degree angle. The factory states the valves should be cut at a 30-degree angle. I know that most people use a 45-degree seat. In an article published in the May issue of Popular Hotrodding, David Vizard presented a paper at the SuperFlow Advanced Engine Technology Conference. David found that at valve lifts up to .150 inch, the 30-degree seat has a 23-percent area advantage over the 45-degree seat. Although David points out that for all out competition this doesn't mean much but for the overwhelming majority of street engines looking for performance, it's a big deal.

Lifters

Stock lifters are heavy and are prone to wear. In a phone conversation with Skip Kelsey, he stated that he no longer manufactures the custom made "Silver Bullets". Bill Phy has also produced custom lifters in the past.

According to Skip, it is best to have your new lifters checked for Rockwell hardness. Skip recommends a Rockwell hardness of 52 or better. Inspect your lifters every 2000-3000 miles.

Well that's it for this month's article. Next month I will be writing about the cylinder head. Until then - Happy Motoring.