Timing The Camshafts On The LT5 Engine

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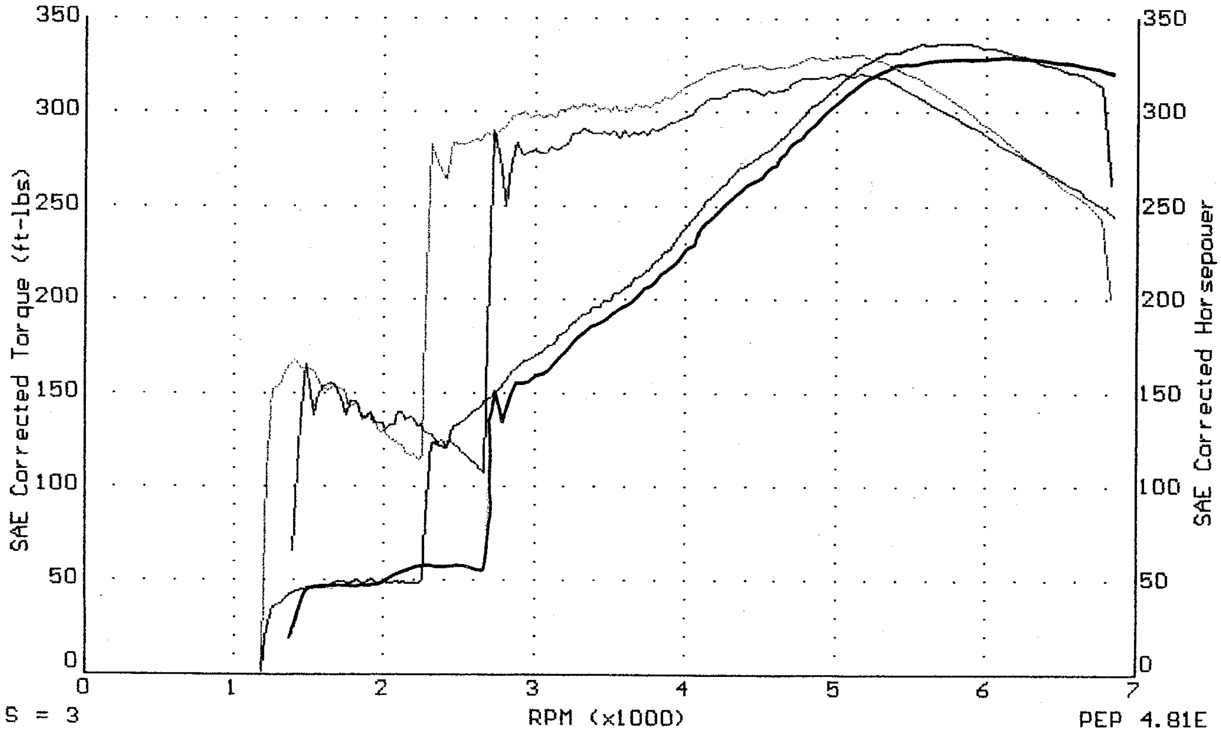
Overview

Accurate camshaft timing is a basic requirement for any healthy engine. This is an especially significant issue for the LT5 because of its extensive camshaft drive system. There are several factors that can contribute to deviations from correct camshaft timing. They are detailed below.

It's best to have the engine on an engine stand when timing the camshafts. The camshaft timing was checked and adjusted on my '93 engine with 33K miles. Preliminary to the check, a baseline measurement was performed on a DynoJet™ chassis dyno. The camshaft timing was found to be out of specification in two ways. The right camshafts were retarded by about four degrees. This would be expected from normal wear as the drive chains stretch and the right upper chain guide wears down. The left intake camshaft was similarly out of specification. Secondly, and somewhat surprisingly, the left exhaust camshaft was found to be positioned correctly. This camshaft was apparently installed four degrees out of phase with respect to the other camshafts when the engine was assembled at the factory. The three camshafts that were out of specification were adjusted to the original engine specification.

The engine was reassembled with no other changes. The DynoJet machine was revisited. As illustrated by the dyno chart, the peak torque increased by about 10 and the peak horsepower increased by about eight. However, the improvement in the area under the curve was the most significant improvement. The torque and horsepower improvements span approximately 4000 RPM. Behind the throttle, in normal street driving, I'm constantly aware of the increased torque. It's interesting to observe how the horsepower curves cross at 6300 RPM. In an engine of this type, retarded camshaft timing will normally favor the power output at the higher engine speeds. For most engines, as the timing chain(s) wear, the output tends to become peaky. Returning to the designed camshaft positioning reduced the power output from 6300 to 7000 RPM. However, this is offset a huge amount, by the increased output from 2500 RPM to 6300 RPM. The average power output, or area under the curve, is much more important in terms of acceleration than the peak power. The average torque increased by 13 and the average horsepower increased by 5. Previous to the adjustment, this engine was usually shifted at 7000 RPM for best acceleration. The ideal shift point has moved to 6800 RPM, which is probably good for the engine in the long run.

At the drag strip, a 10 horsepower increase theoretically equates into about a .1 second improvement for a vehicle with the ZR-1's power to weight ratio. It was not possible to perform an exact comparison between before and after the camshaft timing was adjusted. This is because between my visits to the track, the battery was also relocated to the rear storage compartment. The improvements netted a .2 second reduction in my best time. From 12.79@112 to 12.59@114. I was able to run the best time twice.



As measured on DYNOJET'S MODEL 248C DYNAMOMETER

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DYNORUN.006          63.6 °F   29.20 - 0.33   in.Hg.   0 ft.   CF=1.00   RPM/MPH=56
    Max TORQUE =   330.8   Max POWER = 336.8

DYNORUN.003          60.1 °F   29.30-0.42 in.Hg.   0 ft.   CF=1.00   RPM/MPH=56
    Max TORQUE = 321.0   Max POWER = 328.9
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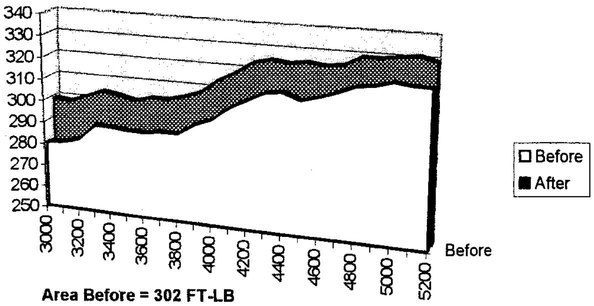
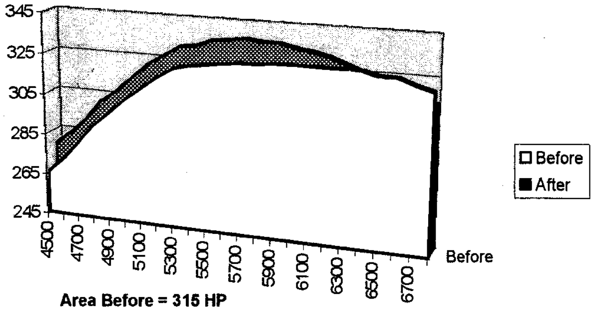
Change in the Area Under the Curve for Torque



Area Before = 302 FT-LB
Area After = 315 FT-LB

Change in the Area Under the Curve for Horsepower

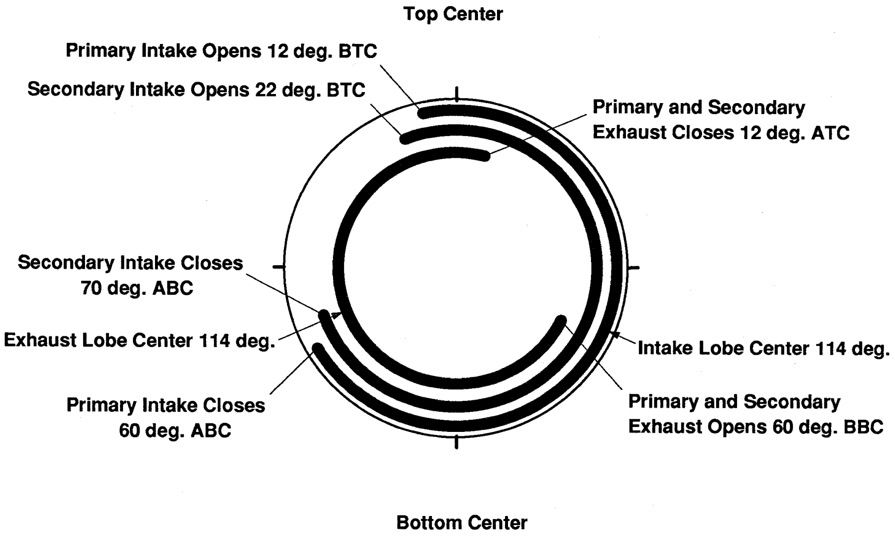


Area Before = 315 HP
Area After = 320 HP

A Detailed Description of How to Check and Adjust the Camshaft Timing on the LT5 Engine

The Corvette service manual is the primary guide for disassembly, adjustment and reassembly of the engine. This procedure provides supplemental information that is either not available in the factory documentation or may be helpful in addition to it. For example, the camshaft timing specifications:

Camshaft Event Timing '90 - '92 LT5



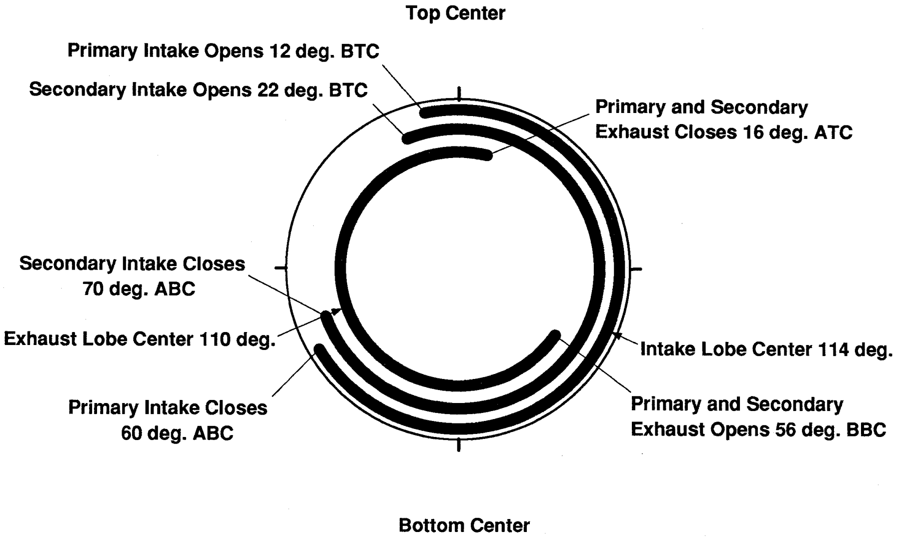
Durations:
- Primary Intake. 252 Degrees.
- Secondary Intake. 272 Degrees.
- Primary and Secondary Exhaust. 252 Degrees.

The Lift at All Lobes is .390 Inch.

MH 3-97

Measurement Points Are Just Off of the Base Circle. The Total Duration is Shown.

Camshaft Event Timing '93 - '95 LT5



Durations:
- Primary Intake. 252 Degrees.
- Secondary Intake. 272 Degrees.
- Primary and Secondary Exhaust. 252 Degrees.

The Lift at All Lobes is .390 Inch.

MH 3-97

Measurement Points Are Just Off of the Base Circle. The Total Duration is Shown.

’90-’92 Event timing specifications at .050” lift.

Intake Primary Duration	Center Line	Pri. I Opens	Pri. I Closes
214	114	7 ATC	41 ABC
Intake Secondary Duration	Center Line	Sec. I Opens	Sec. I Closes
228	114	TDC	48 ABC
Exhaust Duration	Center Line	Opens	Closes
214	114	41 BBC	7 BTC

’93-’95 Event timing specifications at .050” lift.

Intake Primary Duration	Center Line	Pri. I Opens	Pri. I Closes
214	114	7 ATC	41 ABC
Intake Secondary Duration	Center Line	Sec. I Opens	Sec. I Closes
228	114	TDC	48 ABC
Exhaust Duration	Center Line	Opens	Closes
214	110	37 BBC	3 BTC

Causes for Incorrect Camshaft Positioning

There are basically four. First; The chains stretch as they wear. Second; Normal wear of the right upper chain guide. On the right side, there is a guide on the tension side of the chain path. This is because the space for the alternator intrudes into the path of the chain. Normally, the chain links wear into the guides. As this happens, the camshaft positions can retard. Contrary to what the service manual states, it is best to keep normally worn guides in service. When the guide wears to the point where the rollers come into contact with it, the wear rate will diminish and stabilize. I learned this from Graham Behan of Lingenfelter Performance Engineering. Third; The factory lock pin method for positioning the camshafts and crankshaft during production, is subject to variation depending on how accurately the alignment points are machined into the camshafts, crankshaft, cylinder heads and the block. The vernier disks were improved for the ’93 - ’95 engines. The ’90 - ’92 disks have one flat for engagement with the camshaft. The ’93 – ’95 disks have two flats that reduce the rotational clearance with the snout of the cam. The timing variation due to the fit of the disks improved from about 4 to 2 degrees. Fourth; Inaccuracy associated with the production method of setting the camshafts. Human error is possible. On this engine, factor three or four was probably responsible for mispositioning the left exhaust camshaft four degrees out of phase with respect to the other camshafts.

Performing Precise Custom Camshaft Positioning

The camshafts can be precisely set to any desired position with a dial indicator. I consulted with Graham Behan as to what the options might be with respect to custom timing. My engine was stock internally. At the time the engine used the stock exhaust system and the factory service EPROM for calibration. Graham explained that Lotus experimented with about every conceivable combination of camshaft positioning. The factory timing specifications for a stock engine are the net result of all of that experience and knowledge. I was also concerned about getting a poor trade off between an increase in peak power and loss of area under the curve. Since I primarily use my ZR-1 on the street, I was interested in retaining good low speed torque. For this, the stock ’93 – ’95 timing is ideal.

The ongoing process of timing chain wear needs to be considered. Used chains that are in good condition are preferred because they are stable with respect to wear. New chains are subject to accelerated initial wear as they break-in. To compensate for the ongoing normal wear, the camshafts were set one degree advanced so that they would wear in, not out, as additional wear occurs. Thus the intake camshafts were set to 114 - 1 = 113 degrees. And the exhausts were set to 110 + 1 = 111. As the chains continue to wear, the positions will drift toward the ideal settings of intake 114 and exhaust 110 degrees.

Getting Setup for Measuring the Camshaft Positions
Prepare the camshafts for installation. We clean the sprocket bolt holes with an 11x1.5 mm tap. We remove glaze if present, on the sprocket and the camshaft snout face with 80 grit abrasive paper. The camshaft must be thoroughly degreased so that the thread locker for the sprocket bolt can be as effective as possible. The hex plug on the end of the camshaft should be removed for thorough cleaning. Application of heat on the end of the cam will facilitate removal of the plug without damage to the plug. The hex drive is 3/16". The plug has a 1/8" NPT threads. Always use a new sprocket bolt. Reuse of the original torque to yield bolt could lead to the sprocket slipping on the camshaft. We use Loctite 266 thread locker rather than the GM specified 262 (300 degrees F maximum) because the 266 has a 450 degrees F maximum temperature specification.

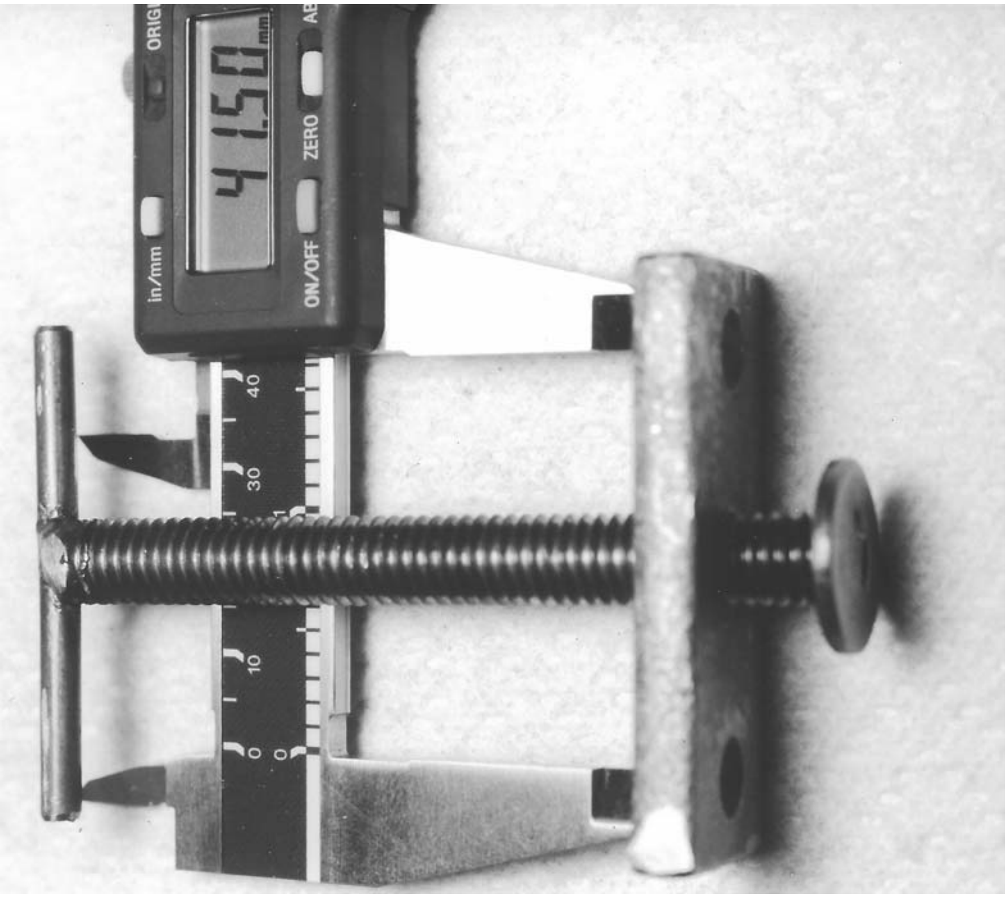
Install the camshafts as described in the service manual. Lay the cams in their neutral positions where minimal pressure is placed on the valves. Don't install the vernier pins. Install the sprocket bolts but don't tighten them, so that the sprockets can free wheel. Install the engine's cam hold-downs. Establish a Top Dead Center reference point. The use of a positive stop device is the best way to locate the number one piston for TDC. Finding the top dead center point eliminates the need for the J38908 crankshaft locator tool to lock the engine at 51 degrees before top center. An example of a positive stop tool is shown below. This tool was constructed from a spark plug body and a nylon rod. Plastic was used in order to avoid marring the top of the piston. Drill a 1/8-inch air vent hole through the length of the tool. Make sure that the tip of the tool is positively retained.

Rotate the engine back and forth against the piston stop. Mark the stop points on the crankshaft pulley. Then mark the center point between the marks. A seven-inch timing wheel will fit the face of the pulley quite nicely. Cut a three-inch hole in the center of the timing wheel to provide access to the bolt for the torsional damper. Attach the timing wheel with double stick tape so that the TDC mark is aligned with the center point that was found. Triple check the position of the timing wheel.

Position the crankshaft at 51 degrees before top dead center. Rotate the camshafts to the installation position. Six millimeter diameter steel rods can be used to locate the camshafts rather than the special pin tools listed in the service manual. Install the manual chain tensioners described below. Tighten the sprocket bolts to about 60 lb. ft. This will hold the sprockets so that they won't slip without the vernier pins. The pins will be installed as each cam is timed.

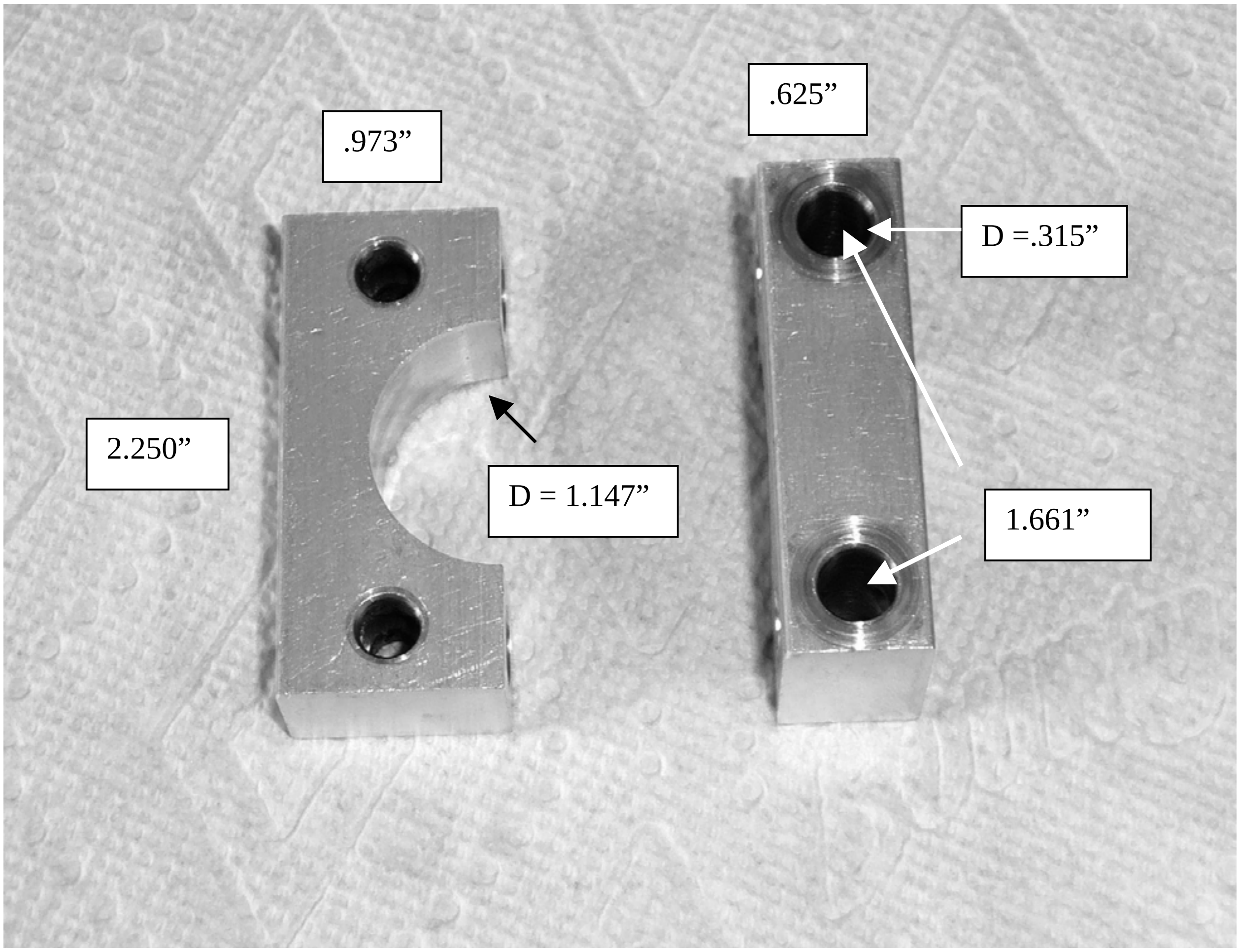
The Manual Timing Chain Tensioner

When measuring the timing, a manual tensioner must be used to control the slack in the chain. The GM tool is J37305. A manual tensioner can be easily made out of a steel bar and a threaded rod. An example is shown below. Install manual tensioners on both banks. Tighten them finger tight with the small wings.



Install Camshaft Hold-Downs

The OE camshaft hold-downs have about .008" camshaft bearing clearance. This is much looser than the camshaft bearing clearance when the camshaft cover is in place. For greater accuracy the camshafts should be held down closer to the normal bearing clearance. The GM tool is J37303. It's easy to have a machinist fabricate camshaft hold-downs. Eight hold-downs are needed. These are the dimensions:

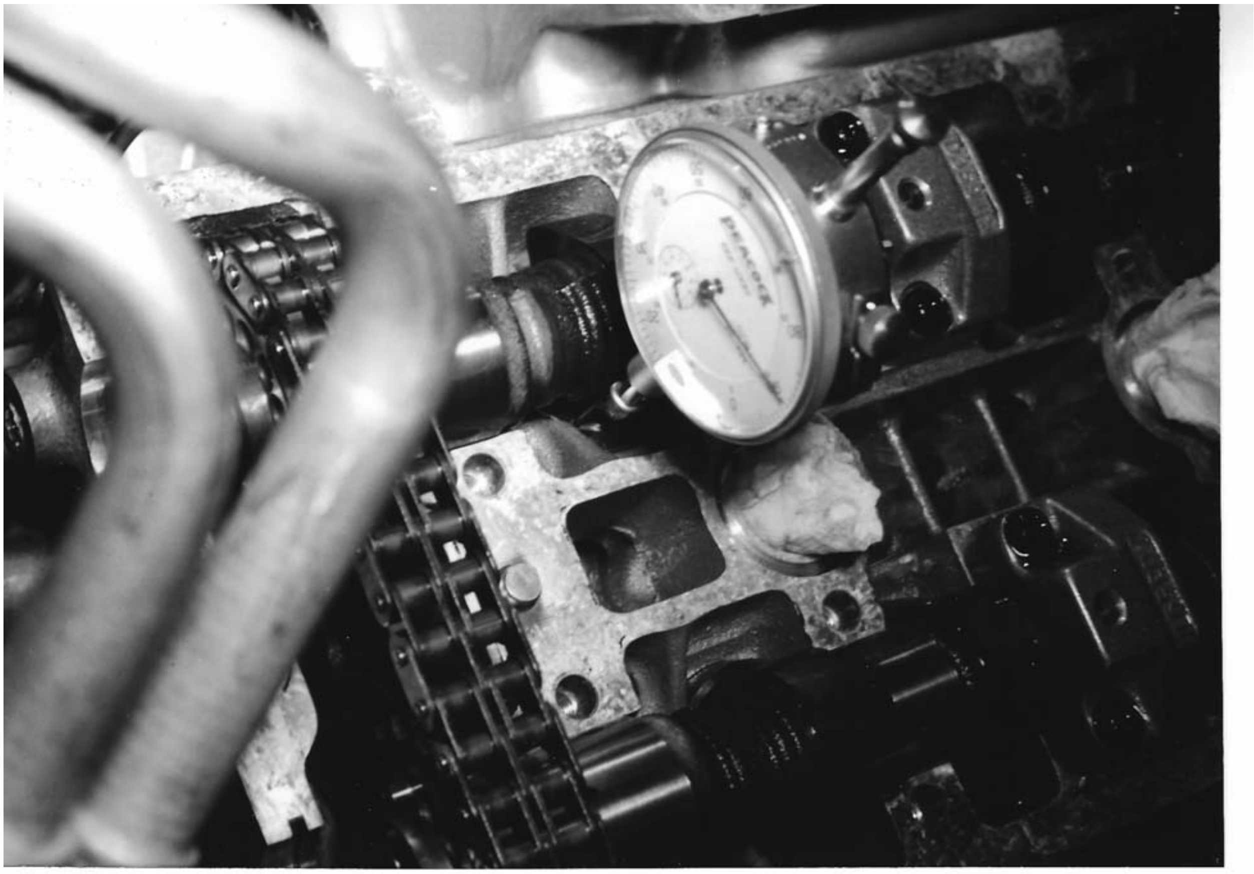


Adjusting the Timing

The LT5 uses a vernier type camshaft position adjuster. It is composed of a camshaft sprocket and a sprocket timing plate. They have 14 and 16 holes. The finest timing adjustment that is afforded by these hole spacings is: 360 / 14 = 25.7. And, 360 / 16 = 22.5. 25.7 – 22.5 = 3.2 degrees. However, the sprocket timing plate is not indexed tightly on the camshaft. So, within one of the 3.2 degree alignment points, there is also more than 3 degrees of range that camshaft can be fine adjusted via the hex on the end of the camshaft. Thus, the camshaft can be fine adjusted to any desired position.

Checking the Camshaft Timing

For the right bank, mount the dial indicator on the exhaust camshaft on cylinder number six. Since cylinder number six is one cycle behind cylinder number one, the timing readings on the timing wheel can be used just as if the measurements were being made on cylinder number one. Use the primary lobe, because it has less duration. Thus it will make larger swings on the dial indicator near TDC. Fabricate a bracket that will mount the dial indicator to a camshaft cover bolt hole. The dial indicator will need an offset tip in order to probe the lifter in its close proximity to the camshaft lobe. The picture shows a typical setup for the dial indicator. It’s shown on cylinder number one.



Record the dial indicator reading at full lift. Use the full lift measurement minus .010 inch as a checking height. A typical checking measurement for an exhaust lobe would be: Reading from the timing dial, before TDC, at .010” before full lift, 90 + 34 = 124 degrees. Pass full lift. Read from full lift -.010”. 87 degrees. 124 + 87 / 2 = 105.5 degrees. Since the exhaust centerline should be 110 degrees, this camshaft is 4.5 degrees retarded.

To increase the exhaust camshaft centerline number, rotate the camshaft clockwise. Carefully hold the camshaft with the hex on the end and simultaneously turn the sprocket bolt loose without turning the camshaft. Adjust the camshaft; .001” on the dial gage equals approximately one degree of camshaft rotation. In the example above turn the camshaft clockwise about .004” to get to 110 degrees. Snug the bolt to about 60 lb. ft. Rotate the camshaft one turn to check the results of the adjustment. I aim for a final position at 111 degrees +/- .5 degree.

A typical checking measurement sequence for an intake camshaft would be: Reading from the timing dial, after TDC, at .010” before full lift, 90 + 11 = 101. Pass full lift. Read from full lift -.010”. 90 + 44 = 134. 101 + 134 / 2 = 117.5 degrees. Since the stock intake centerline should be 114 degrees, this camshaft is 3.5 degrees retarded.

To increase the intake camshaft centerline number rotate the camshaft counter clockwise. In the example above turn the camshaft clockwise about .003” to get to 114 degrees. Snug the bolt to about 60 lb. ft. Rotate the camshaft one turn to check the results of the adjustment. I aim for a final position at 113 degrees +/- .5 degree.

Locking a Camshaft in Position

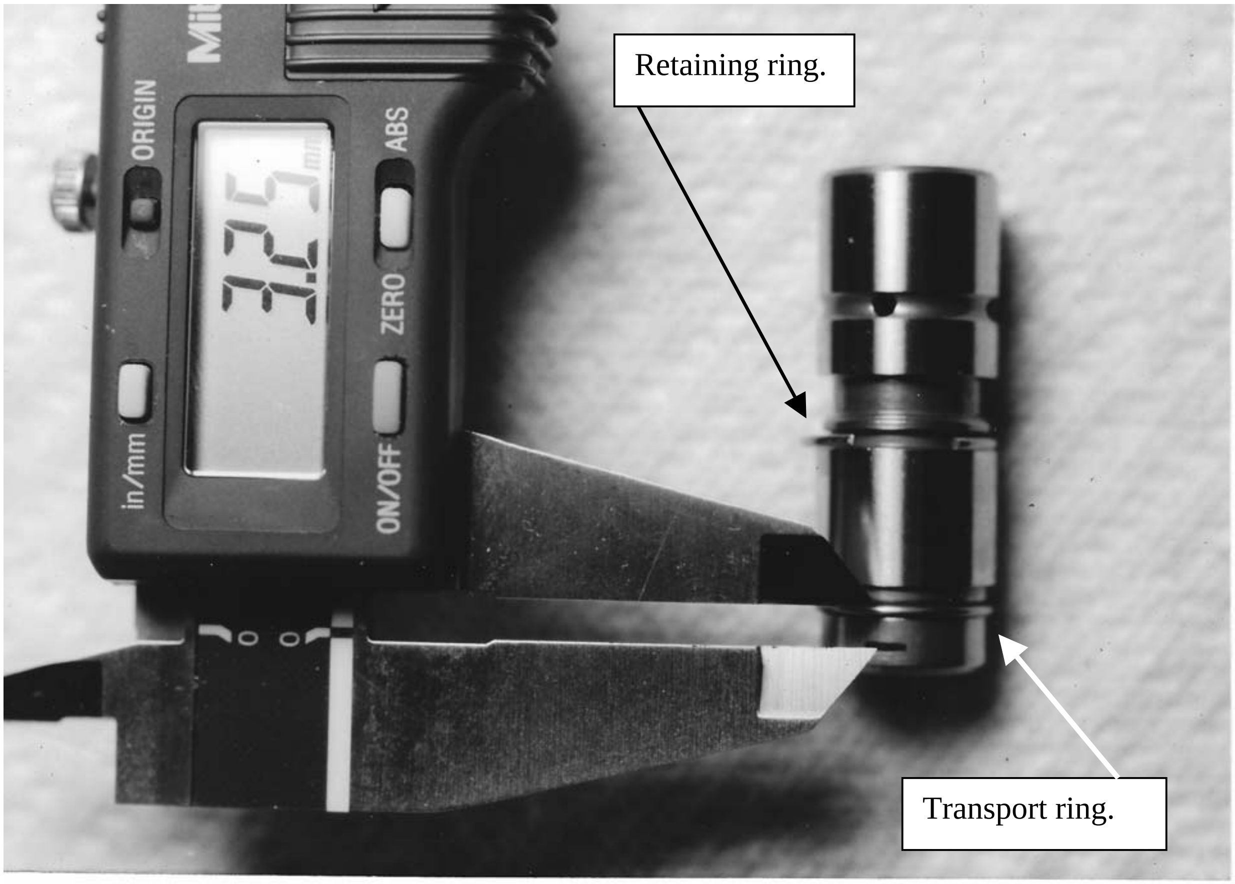
Remove the forward camshaft hold-down. Use a 1” long by ¾” wide strip soft shim .020” thick to lock the cam under the hold-down. A piece of cardboard from an oil filter box works nicely. Place the cardboard shim under the camshaft hold-down and tighten the bolts. This will lock the cam in position while the sprocket bolt is tightened. Use a wrench on the back end of the cam to counter balance the force applied to the sprocket bolt. Use the tightening procedure in the service manual.

Compressing the Hydraulic Chain Tensioner

The tensioner must be compressed so that it can be locked in the Transport Position before it is reinstalled. This procedure is not provided in the service manual, instead, the use of a new tensioner is recommended for every service operation. New tensioners cost about $270 each. So, compressing a used tensioner is worth the effort. If an extended tensioner is installed, it will cause the chain to run in a heavily loaded condition, leading to breaking the sprocket snout off the cam. This will result in contact between the valves and pistons. It is interesting to note that even though GM recommends the installation of a new tensioner, there is still the potential for this catastrophe. It is possible for a new tensioner to become unlocked in shipping. Product Service Publication 676109 was issued to help technicians identify a dangerous, extended tensioner.

Graham Behan was kind enough to provide advice on how to compress a tensioner. Start by removing the hex plug from the end of the housing.

Place the forked end of the tensioner assembly horizontally in a vise. Pull out on the piston until a slot near the top of the piston is uncovered. Then use a large screwdriver to carefully pop the piston out. Be prepared for about one quarter of an ounce of oil to emerge. When unlocked, the larger retaining ring that can be seen in the picture stops the piston.

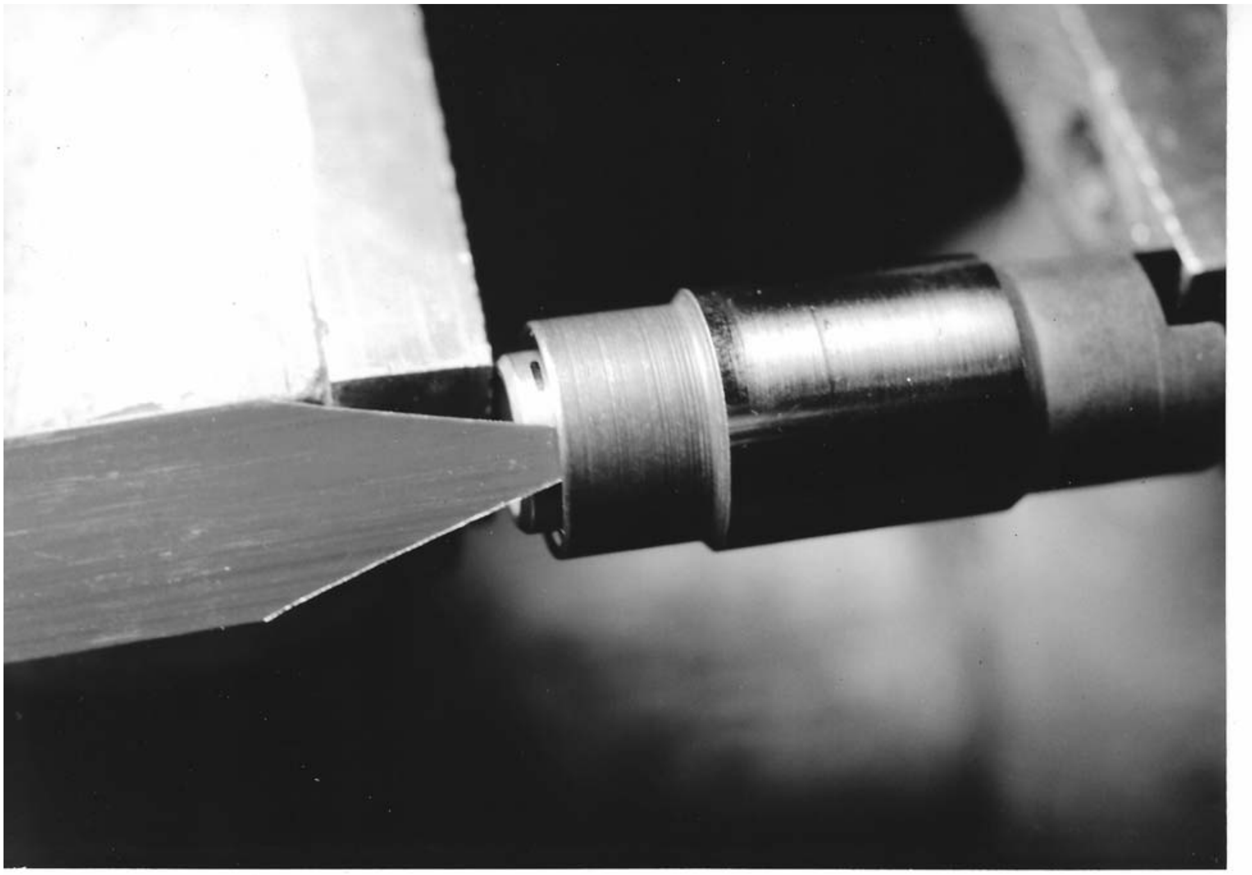


After removing the piston, clean all of the parts. The right and left tensioner springs are not the same. The shorter spring is for the right tensioner.

Lock the tensioner in the compressed, or Transport Position, by engaging the small retaining ring that is found on the end of the piston, into the groove in the body of the tensioner. The picture above shows the transport retaining ring. The picture below shows the groove in the body that engages with the transport locking ring.

The transport ring groove.

To compress the tensioner, first make sure that the larger retaining ring is in the piston's small groove as shown in the picture of the tensioner piston. Lightly oil the piston and place it back in the body. Use a vise to compress the assembly. It will make a clicking sound as the large retaining ring passes the lower stop grooves in the body. Compress it until the piston bottoms. The transport ring will be located 3.5 mm down into the tensioner body. Finally, push down on the transport retaining ring with a thin pointy tool as shown in the picture below. This expands the ring into the groove in the tensioner body.



At the same time, slowly open the vise. If the expanded transport retaining ring is aligned with the groove in the body, the piston will lock in the compressed (transport) position.

Installing the Tensioner

Align the piston fork with the chain guide and install the tensioner in its home in the block. Slip the tensioner holder over the tensioner with the hole in the barrel facing up. Unlock the tensioner by tapping it with a blunt punch that just fits in the hole in the end of the body. The punch should be as large as possible in diameter. If it is too small, it could damage the check valve. Make a mark on the punch to indicate the depth of the insertion. Give the punch a sharp tap with a small hammer, and the tensioner will release with a satisfying, “kick”! Verify the release by observing that the mark on the punch is about ¼” further out. Coat the hex plug with Loctite 565 sealant and reinstall it.

Installing the Camshaft Cover

The cylinder head and the camshaft cover must be cleaned with great care to avoid nicking the fine surface finish. Bumps as small as .001 inch could adversely effect the fit and function of the cover as a camshaft bearing. Avoid using heavy tools to remove the old sealer. Use sharp single edge razor blades. Held by the fingers, they will gently remove the sealer while affording good control so as to avoid gouging the delicate aluminum surface. Don’t use a tool to hold the razor blade, that would be too aggressive. A wide flat X-acto knife blade also works well. Scrape all of the thickly coated areas with the razor blade. The solvent Methyl Ethyl Ketone will remove the thin layers. This solvent is available from a professional paint supply store. Use rubber gloves and plenty of ventilation with this solvent. Extract the oxide from the bolt holes with a vacuum cleaner. Clean the bolts with a wire brush. Finally wash the camshaft cover with mild soap and water. The sealing washers are available from Jerry’s Gaskets.

The service manual recommends Permabond™ A136 as the sealant for the cover. This is an anaerobic sealer that is similar to thread locking compound. The American Starch Company originally made it, they called it Perma-Loc™ A136, and it was sold only to GM. The GM part number is 12345980; it is packaged in a 50-ML bottle. It is no longer available from GM. Today it is called Permabond A136 and it is available from Jerry's Gaskets.

Place the o-rings for the spark plug access holes on the cylinder head. We coat the end caps with silicone gasket sealer. Apply a paper-thin coat of Permabond A136 to all of the mating surfaces of the camshaft cover. Then tighten the bolts in the sequence, and with the torque listed in the service manual. Check that the engine still rotates freely.

Startup

After the engine starts, it will probably be accompanied by a lot of lifter noise. Surprisingly, the lifter noise can go on for a long time. It usually goes away completely as the engine approaches normal operating temperature at idle. If tappet noise persists it should go away after letting the engine cool down.

Parts and Supplies Summary List

2	Plenum gaskets.	From Jerry's Gaskets.
2	Fuel line o-rings.	From Jerry's Gaskets.
8	Spark plug access hole o-rings.	From Jerry's Gaskets.
1	Oil filter/regulator assembly gasket.	From Jerry's Gaskets.
2	Coolant manifold gaskets.	From Jerry's Gaskets.
4	Camshaft bolts.	From Haibeck Automotive or Jerry's Gaskets.
48	Sealing washers.	From Jerry's Gaskets.
1	50 ML bottle of Permabond™ A136.	From Jerry's Gaskets.
1	10 ML bottle of Loctite™ 262 red thread locker.	From a local source.
	or	
1	10 ML bottle of Loctite™ 266 red thread locker.	From McMaster-Carr, PN 91458A570.
1	50 ML tube of Loctite™ 565 sealer with Teflon™.	From a local source. AKA PST 565.
		Methyl Ethyl Ketone Solvent.
		From a paint supplier.

McMaster-Carr: 630-833-0300 www.mcmaster.com

Special Tool List

7 inch timing wheel.	From a local source.
Dial gage.	From a local source.
Piston stop.	Easily fabricated.
Manual timing chain tensioner. J 37305	Easily fabricated.
Camshaft hold-down. Quantity 8. J 37303	Easily fabricated.

Thank you to Graham Behan at Lingenfelter Performance Engineering, for his valuable advice.