Timing The Camshafts on the LT-5 Engine

by Marc Haibeck

Overview:

Accurate camshaft timing is a basic requirement for any healthy engine. This is an especially significant issue for the LT-5 because of its extensive camshaft drive system. There are several factors that can contribute to deviations from correct camshaft timing. They are detailed in the next section. Due to the significant potential for timing deviation, I feel that checking the timing is a fundamental element in the process of tuning the LT-5 engine.

Measurement of the camshaft positioning requires significant effort. A major step in the process is obtaining access to the camshafts. Another significant problem is the difficulty with reading the timing from a timing wheel. Because of this, measurement of the timing commonly involves removal of the engine. But, the work can be performed with the engine in the car if these two issues can be resolved. Accessing the camshafts does not present any insurmountable problems. However, it can be tedious. If you are comfortable with working on tightly packaged equipment, it's only a moderately difficult project. The second problem can be eliminated with a compact video camera and a monitor.

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™ machine. All necessary parts and sealants were acquired.

In order to gain access to the camshafts, the plenum and power brake booster were removed, as were most of the accessories on the front of the engine. The camshaft timing was found 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's specifications.

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 8. 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 in the 700 RPM after the 6300 RPM point, but this is offset a huge amount, by the increased output in the 4000 RPM that precedes the 6300 RPM point. 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 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.

Revisions to the Camshaft Timing Procedure
January 2010

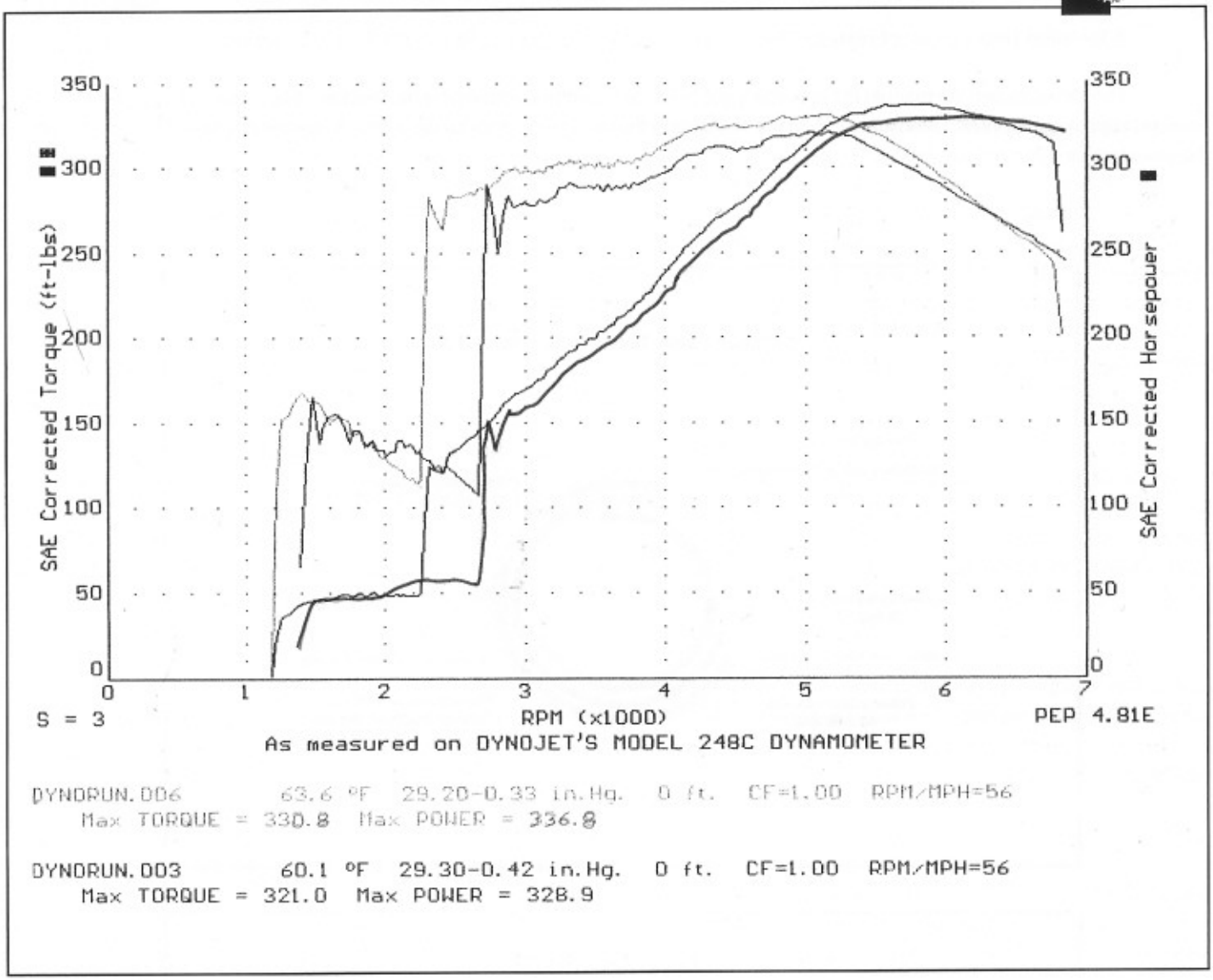
The procedure was published in August of 1998. Some things have changed since then. Apply the following updates to the procedure.

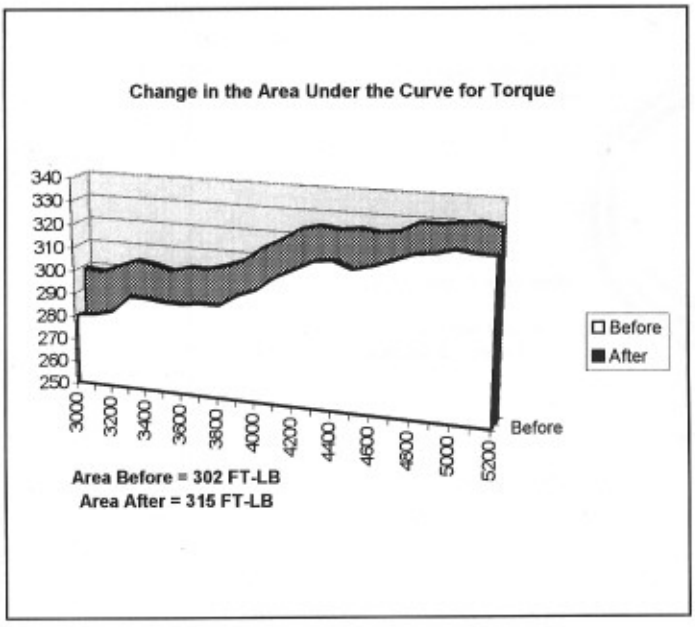
- LT-5 should read LT5.
- It's better in the long run to remove the engine from the car for camshaft timing.
- All of the gaskets and o-rings are available from www.jerrysgaskets.com
- The camshaft cover bolt sealing washers are available from www.jerrysgaskets.com
- Loctite 518 can be used in place of Permabond A136.
- The camshaft sprocket bolts are available from Haibeck Automotive. Go the Products section of our site.

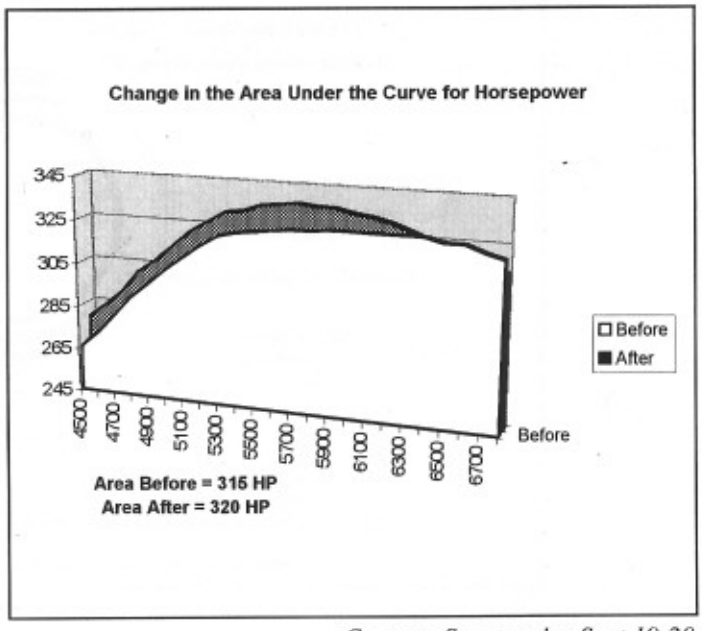
The camshafts need to be located fully in the cam bearings during cam timing. The factory installed camshaft hold down caps are intended to locate the camshafts for the factory method of cam timing with the camshaft alignment pins. The factory camshaft hold down caps have about .010" bearing clearance. That allows the camshafts to float in the bearings during the cam timing process that is described in the article. This will negatively effect the accuracy of the adjustments as described in the article.

To properly hold the cams in the bearings it is necessary to use camshaft hold down caps. These are tight clearance bearing caps. They are used to hold the camshafts tightly in the bearings as the cam cover would.

The caps are available from Jeal Enterprises. Contact Bill Kirchhofer at 502-608-1273 (KY) for information about purchasing the camshaft hold down caps.

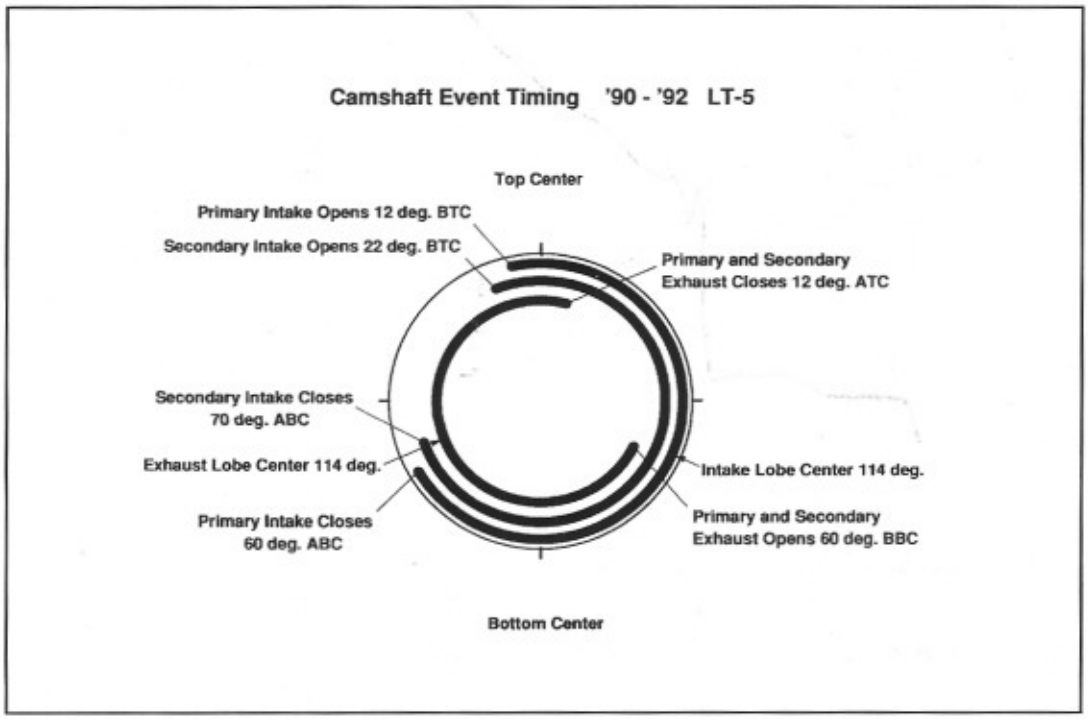

SAE Corrected Torque (ft-lbs)
SAE Corrected Horsepower
RPM (x1000)
S = 3
PEP 4.81E
As measured on DYNOJET'S MODEL 248C DYNAMOMETER
DYNORUN.DD6 63.6 °F 29.20-0.33 in.Hg. 0 ft. CF=1.00 RPM/MPH=56
Max TORQUE = 330.8 Max POWER = 336.8
DYNORUN.DD3 60.1 °F 29.30-0.42 in.Hg. 0 ft. CF=1.00 RPM/MPH=56
Max TORQUE = 321.0 Max POWER = 328.9

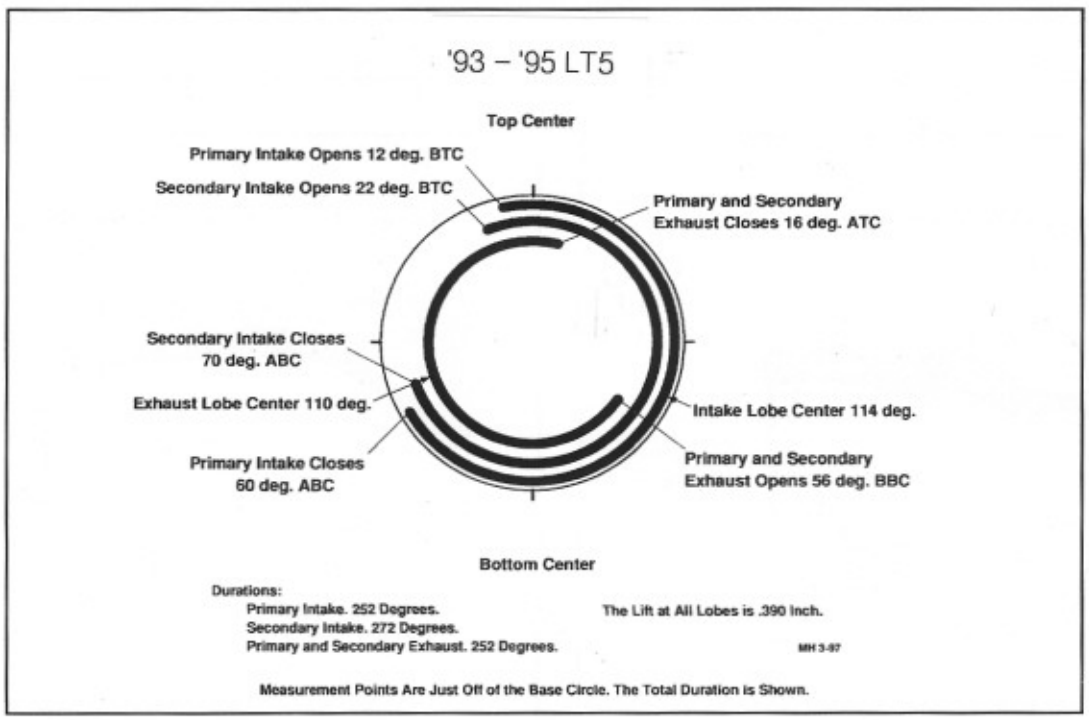

Change in the Area Under the Curve for Torque
Before
After
Area Before = 302 FT-LB
Area After = 315 FT-LB


Change in the Area Under the Curve for Horsepower
Before
After
Area Before = 315 HP
Area After = 320 HP

A Detailed Description of How to Check and Adjust the Camshaft Timing on the LT-5 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:





Causes for Incorrect Camshaft Positioning

There are basically four. First, the chains stretch as they wear. In the case of this engine, assuming that they were timed fairly accurately when the engine was built, this allowed the camshafts to retard about four degrees. 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 guide. As this happens, the camshaft positions can retard. In spite of what the service manual states, it is best to keep this worn guide 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. 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 mis-positioning the left exhaust camshaft four degrees out of phase with respect to the other camshafts.

An Opportunity to Perform Precise Custom Camshaft Positioning

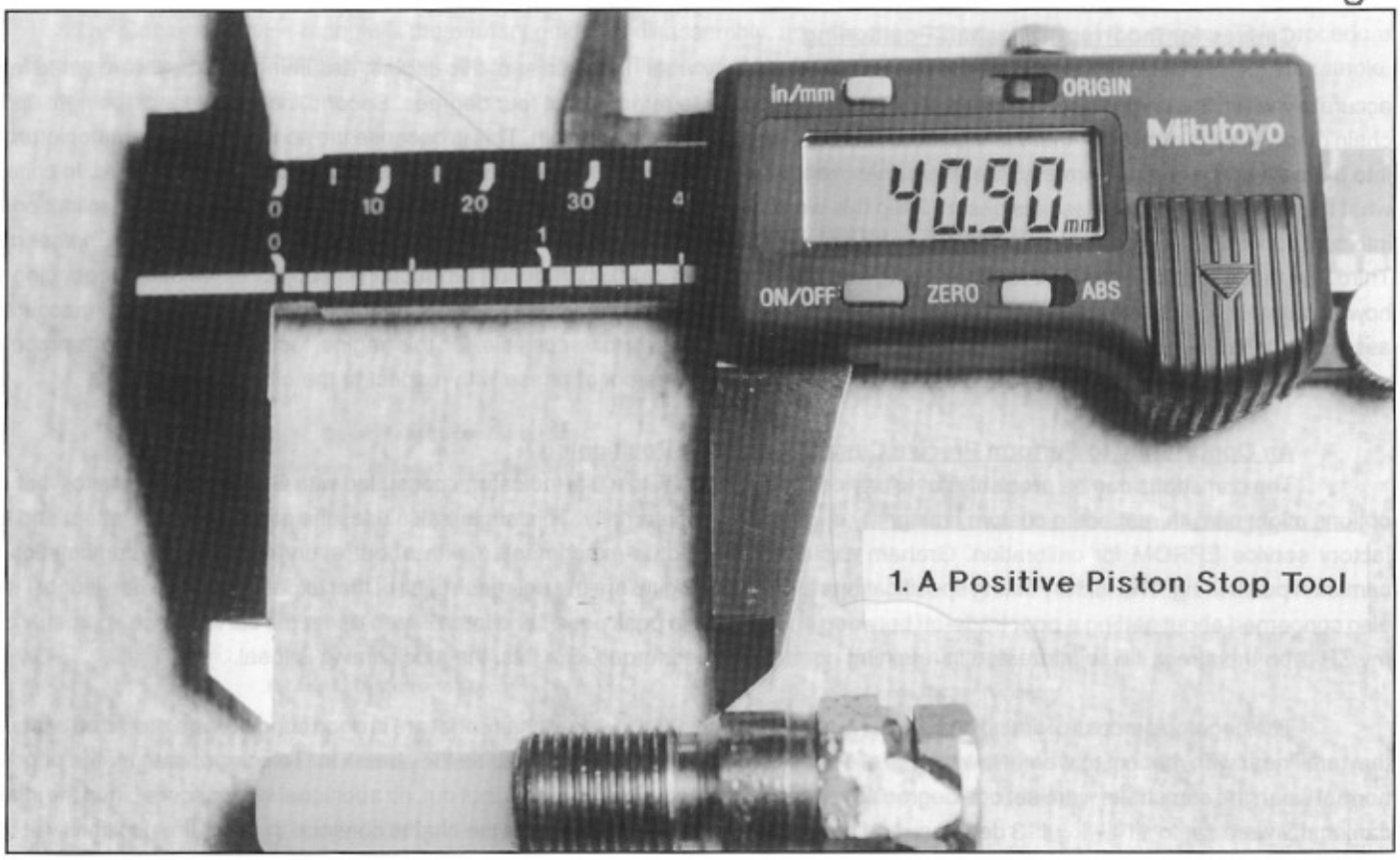
The camshafts can be precisely set to any desired position with a dial indicator. I consulted with Graham Behan as to what my options might be with respect to custom timing. My engine is stock internally. This engine also uses the stock exhaust system and the factory service EPROM for calibration. Graham 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 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 linear 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 to 110 + 1 = 111. As the chains continue to wear, the positions will drift toward the ideal settings of 114 and 110 degrees.

Getting Setup for Measuring the Camshaft Positions

The first step is to establish a **Top Dead Center** reference point. This simple process becomes challenging when it is to be done with the engine in the car. The difficulty is the severely restricted access to the front of the crankshaft. The crankshaft can be turned with a fine tooth ratchet and a 21 mm or 13/16-inch socket. Sleeve a pipe over the ratchet to create an approximately 18-inch handle. In order to move the ratchet freely, the accessory drive belt and the plenum need to be removed.

The use of a positive stop device is the preferred way to locate the Number One piston for TDC. I believe that the positive stop is more accurate than a dial gauge in this situation. An example of a positive stop tool is shown in Picture 1. This tool was constructed from a spark plug body and a plastic 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.



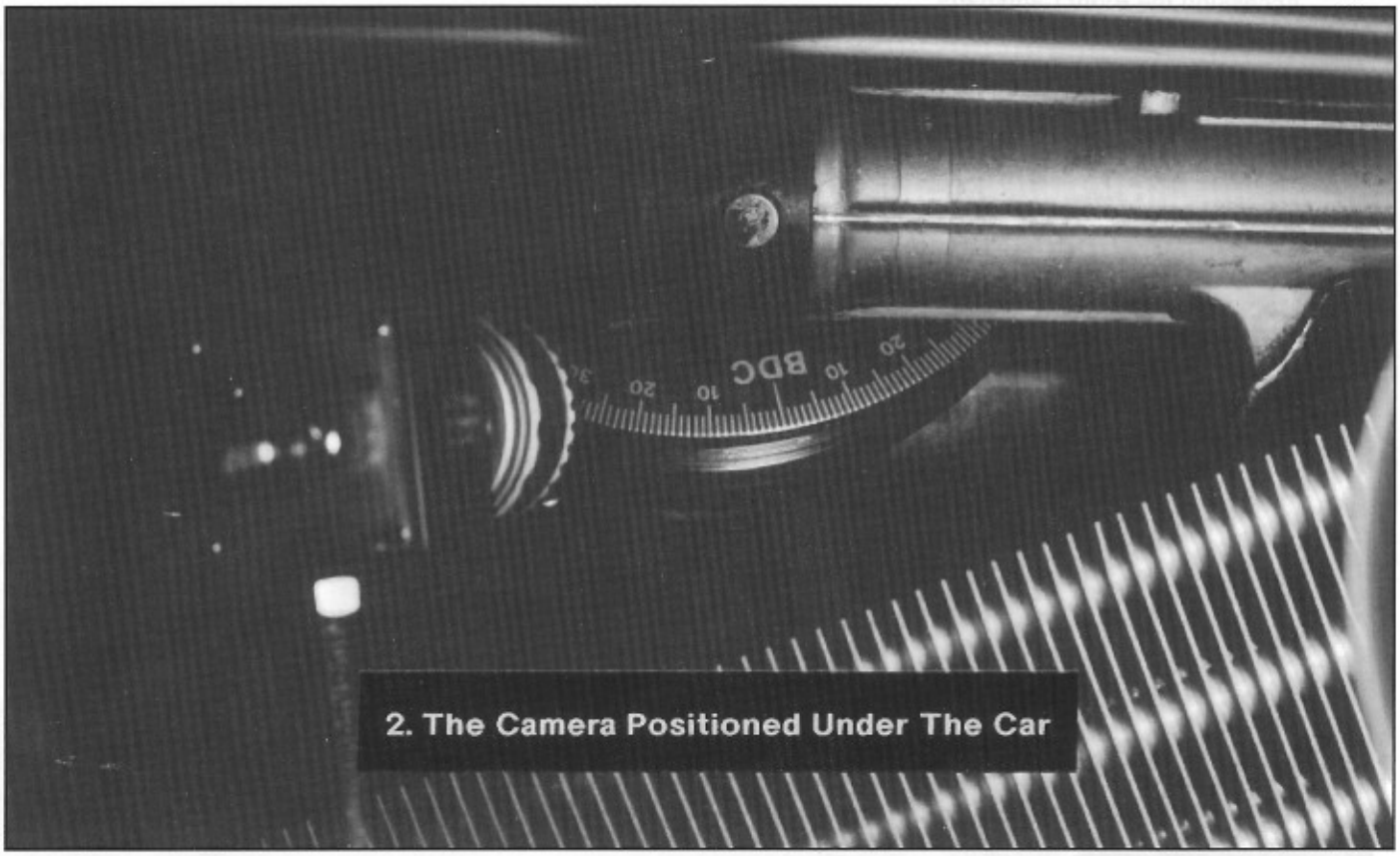
1. A Positive Piston Stop Tool

To improve access to the crankshaft pulley, drop the power steering cooler to the left side. Fabricate a pointer with a heavy wire. Attach it to the engine's lower right oil pump cover bolt. Rock the engine back and forth against the piston stop. Mark the stop points on the crankshaft pulley. Then find 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.

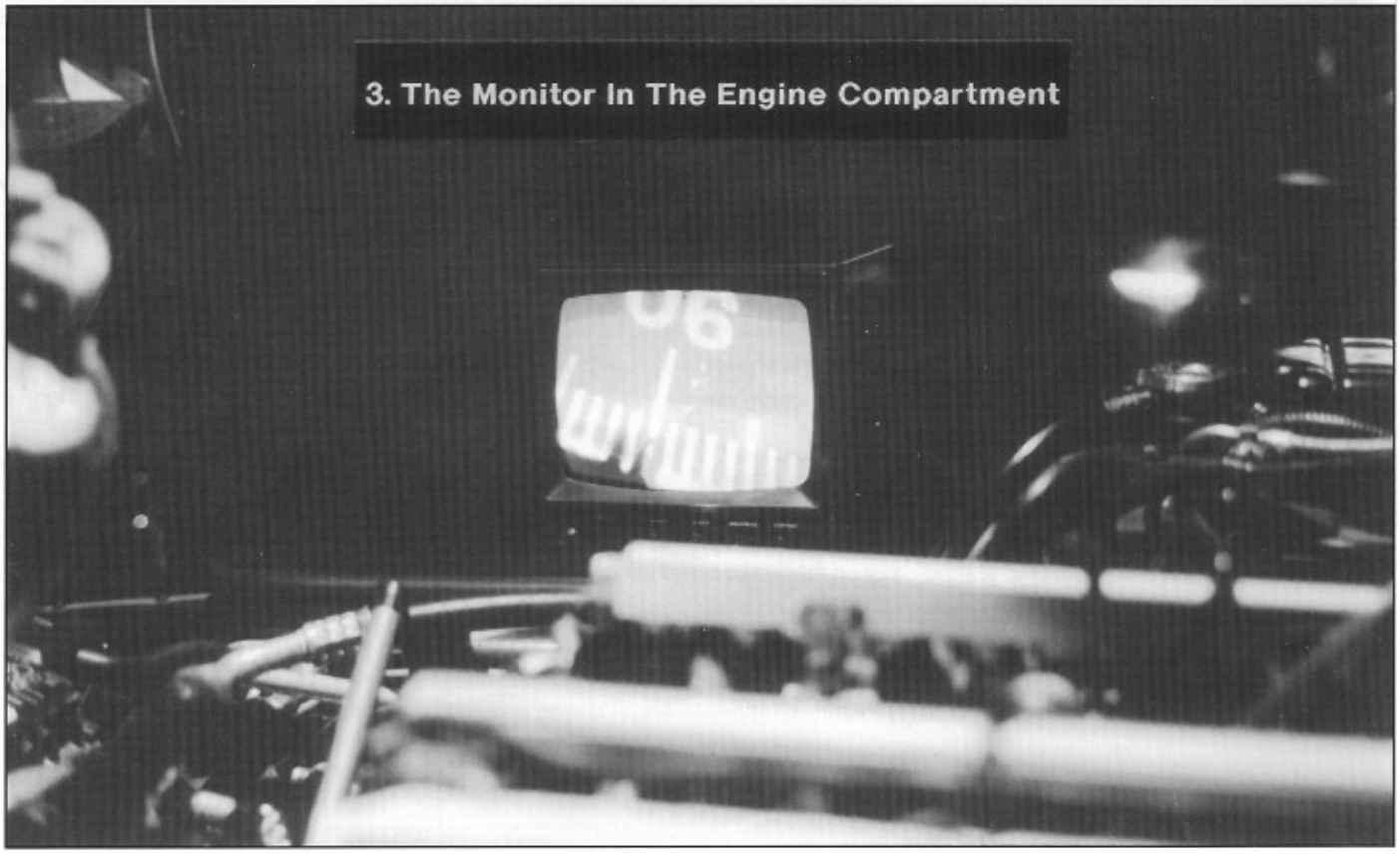
When the engine is turned by hand, it might make some really disturbing snapping sounds. It sounds terrible but is of no consequence. This occurs because without oil pressure, the chains are not tensioned. The noise is from the camshafts as they jump over the lobe centers due to the slack in the chains.

Using A Camera as A Tireless Helper

The timing wheel is most easily read from under the car. To avoid inconvenience and to enhance accuracy in reading the crankshaft position, a camera is a tremendous aid. A compact CCD camera can be utilized with a small monitor. The display can be placed in the same line of sight as the dial gage. This makes timing measurements effortless and highly accurate. The camera and display setups are shown in Pictures 2 and 3.



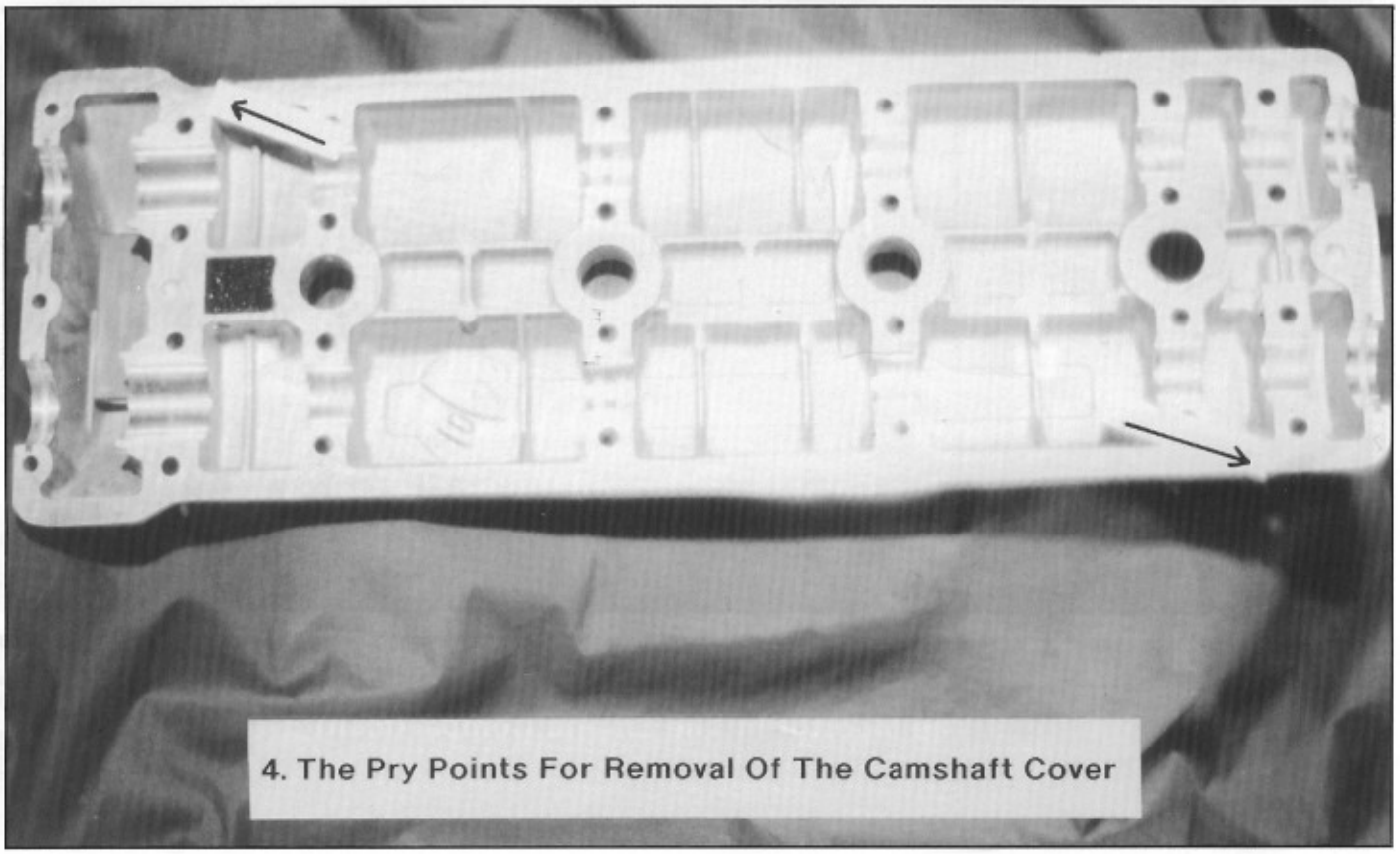
2. The Camera Positioned Under The Car



3. The Monitor In The Engine Compartment

Accessing the Right Camshafts

Remove the coolant outlet manifold. Loosen the bolt that holds the crankcase vent tube to the injector housing. Remove the five screws that hold the removable panel at the top of the air conditioner evaporator housing. Note that the screw that goes into the bulkhead has a different pitch than the others. Some of the camshaft cover bolts may be very tight, so use a top quality Torx™ tool to remove them. The tight bolts are held by oxide buildup between the bolt threads and the cylinder head. To aid with removal, the camshaft covers have convenient pry points machined into two of the corners. The locations are shown in Picture 4. To provide access to the camshaft sprocket bolts, remove the alternator, the accessory belt tensioner, and the oil filter/regulator assembly.



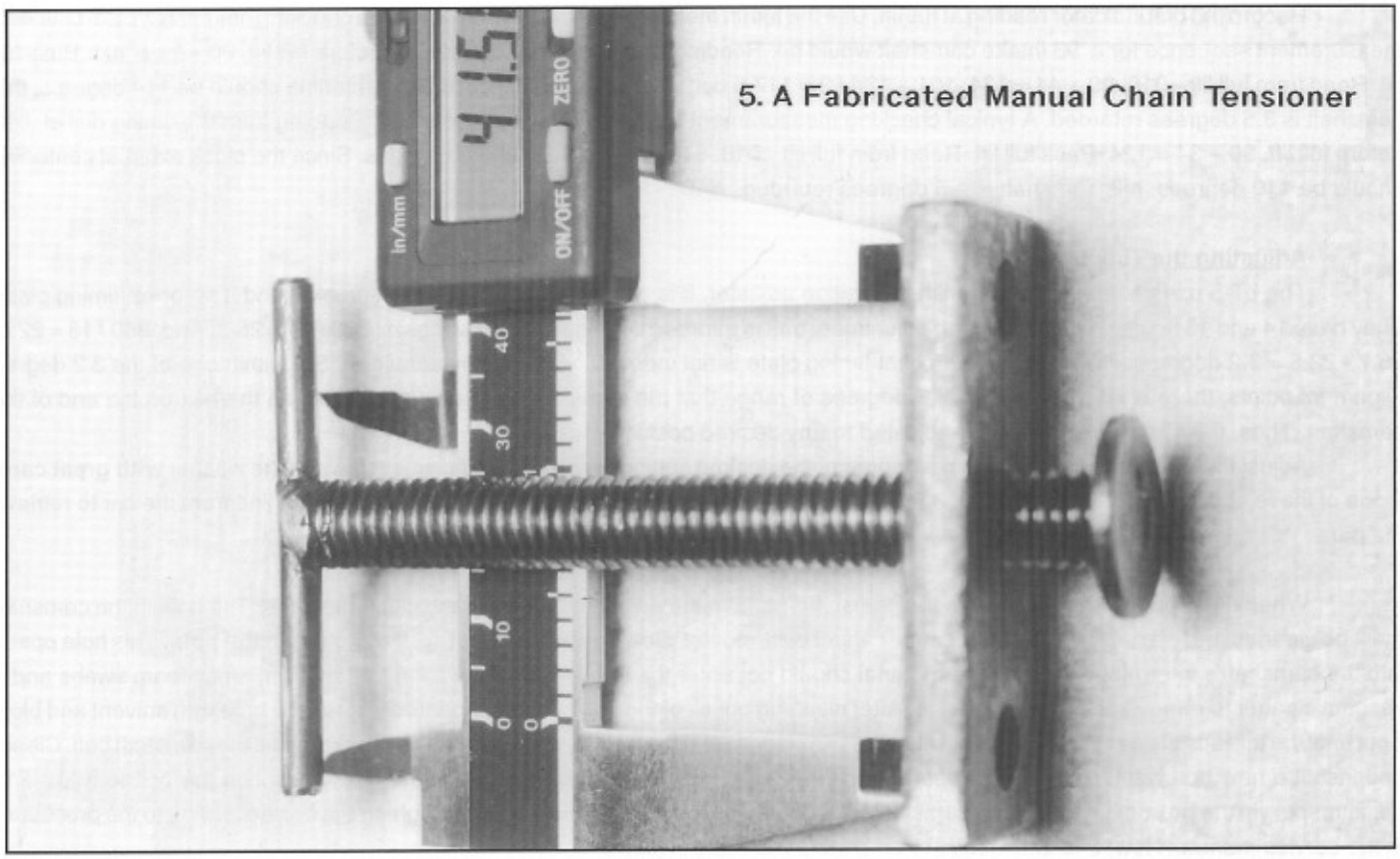
4. The Pry Points For Removal Of The Camshaft Cover

The Manual Timing Chain Tensioner

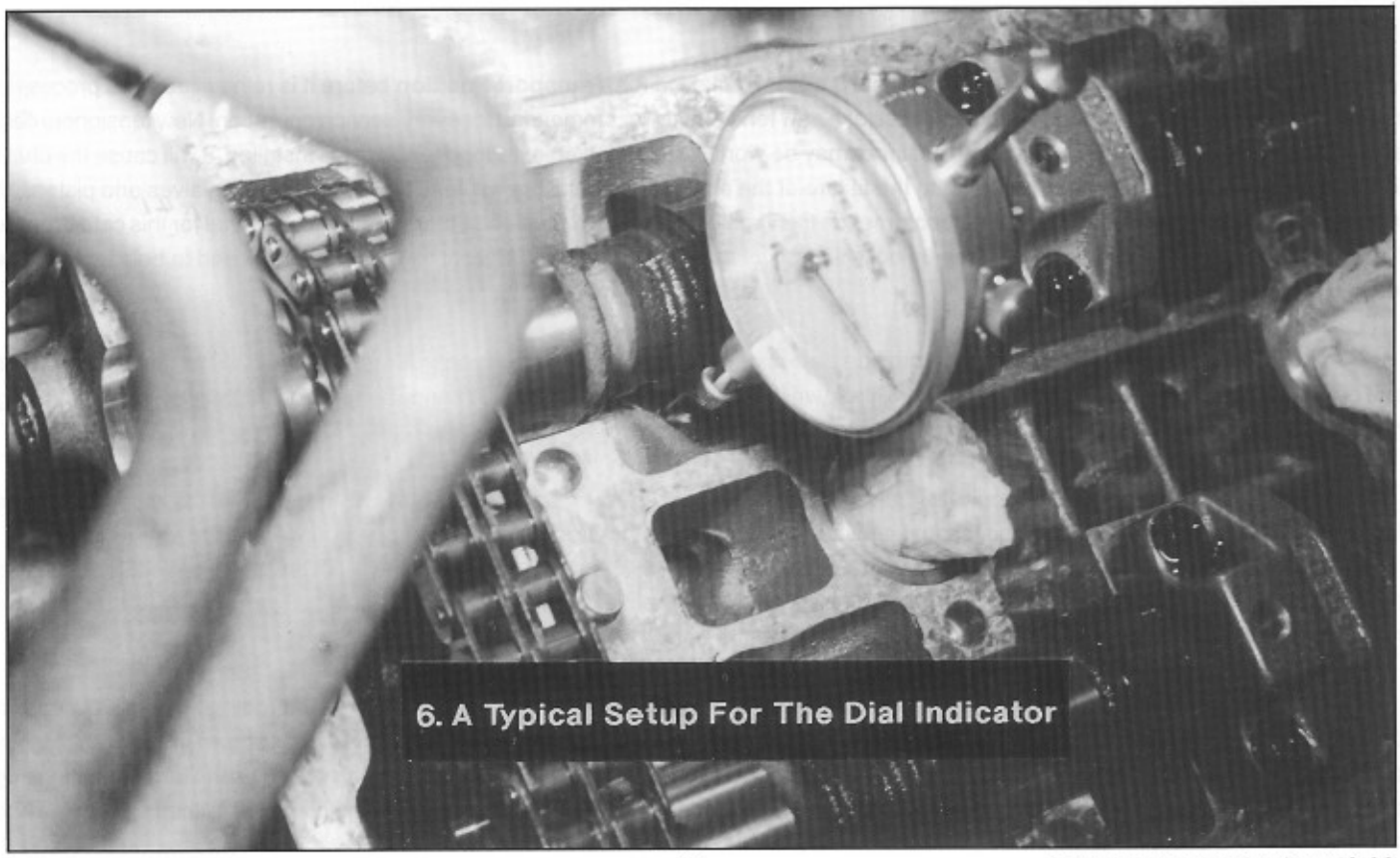
When measuring the timing, a manual tensioner must be used to control the slack in the chain. A manual tensioner can be easily made out of a steel bar and a threaded rod. An example is shown in Picture 5 (opposite page). When removing the hydraulic tensioner, observe which side is up. Mark the top for correct positioning when the tensioner is reinstalled. Insert the manual tensioner. Tighten it finger tight with the small wings.

Checking the Camshaft Timing

For the right side, mount the dial indicator on the intake 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. Picture 6 (opposite page) shows a typical setup for the dial indicator.



5. A Fabricated Manual Chain Tensioner



6. A Typical Setup For The Dial Indicator

Record the dial indicator reading at full lift. Use the full lift measurement minus .010 inch as a checking height. A typical checking measurement sequence for a '93 intake camshaft would be: Reading from the timing dial 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. A typical checking measurement for an exhaust lobe would be: Reading from the timing dial at .010 before full lift, 90 + 34 = 124. Pass full lift. Read from full lift -.010. 87. 124 + 87 / 2 = 105.5 degrees. Since the stock exhaust centerline should be 110 degrees, this camshaft is 4.5 degrees retarded.

Adjusting the Timing

The LT-5 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 an excess of 3 degrees of range that the 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.

Adjust the camshaft until it is within a degree of the desired setting. Handle the adjustment pin and the washer **with great care.** If one of these small parts should fall into the timing chain cover area, it will be necessary to remove the engine from the car to retrieve the part.

When all is ready for locking down the camshaft, remove the adjuster assembly and clean the parts. The hole in the camshaft must be cleaned and degreased. The old Loctite™ must be removed. **Don't allow the Loctite™ to go down the hole.** This hole opens into the camshaft's internal oil gallery. The material should not enter the engine's oil circulation system. Use small foam swabs and a vacuum cleaner to remove all of the old Loctite. After cleaning out all of the solid debris, repeatedly spray the hole with solvent and blow it out until the threads are dry. All traces of oil must be removed, so that the new thread locker can effectively hold the camshaft bolt. Clean, and install a new bolt with a couple of drops of Loctite™ 262. Snug the bolt down. Check the timing. Loosen the bolt to make fine adjustments via the hex on the end of the camshaft. Double-check the final positioning. Then tighten the bolt according to the procedure in the service manual. Now, this only needs to be done three more times!

Compressing the Hydraulic Chain Tensioner

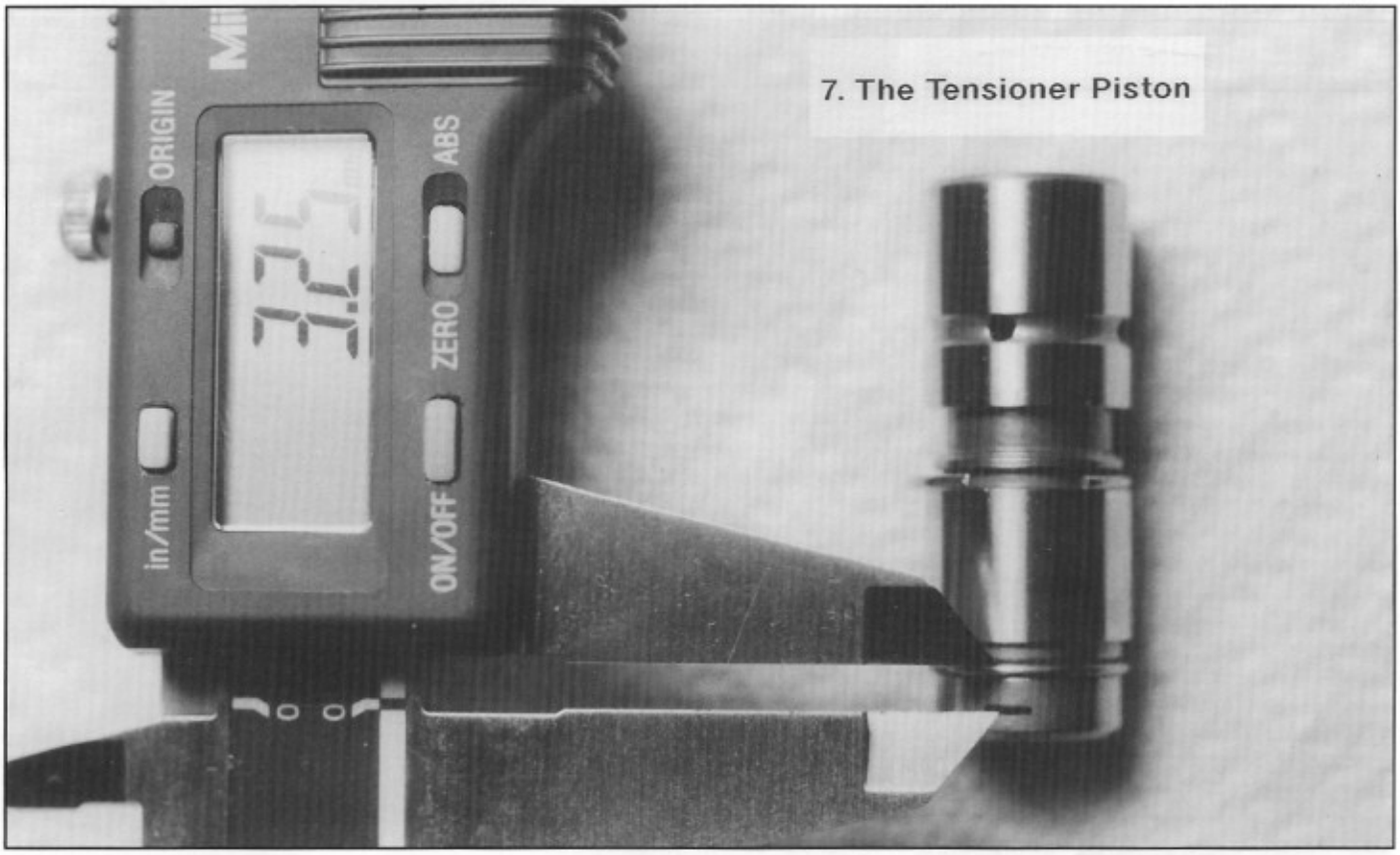
The tensioner must be compressed so that it can be locked in the **Transport Position** before it is reinstalled. This process is not included in the service manual, instead, the use of a new tensioner is recommended for every service operation. New tensioners cost about $150 each. So, compressing a used tensioner may be worth the effort. If an extended tensioner is installed, it will cause the chain to run in a heavily loaded condition, leading to the failure of the chain. A chain failure will result in damage to 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 unit. With some luck, the piston can be withdrawn from the body by pulling on it by hand. The piston is held by the larger retaining ring that can be seen in Picture 7(opposite page).

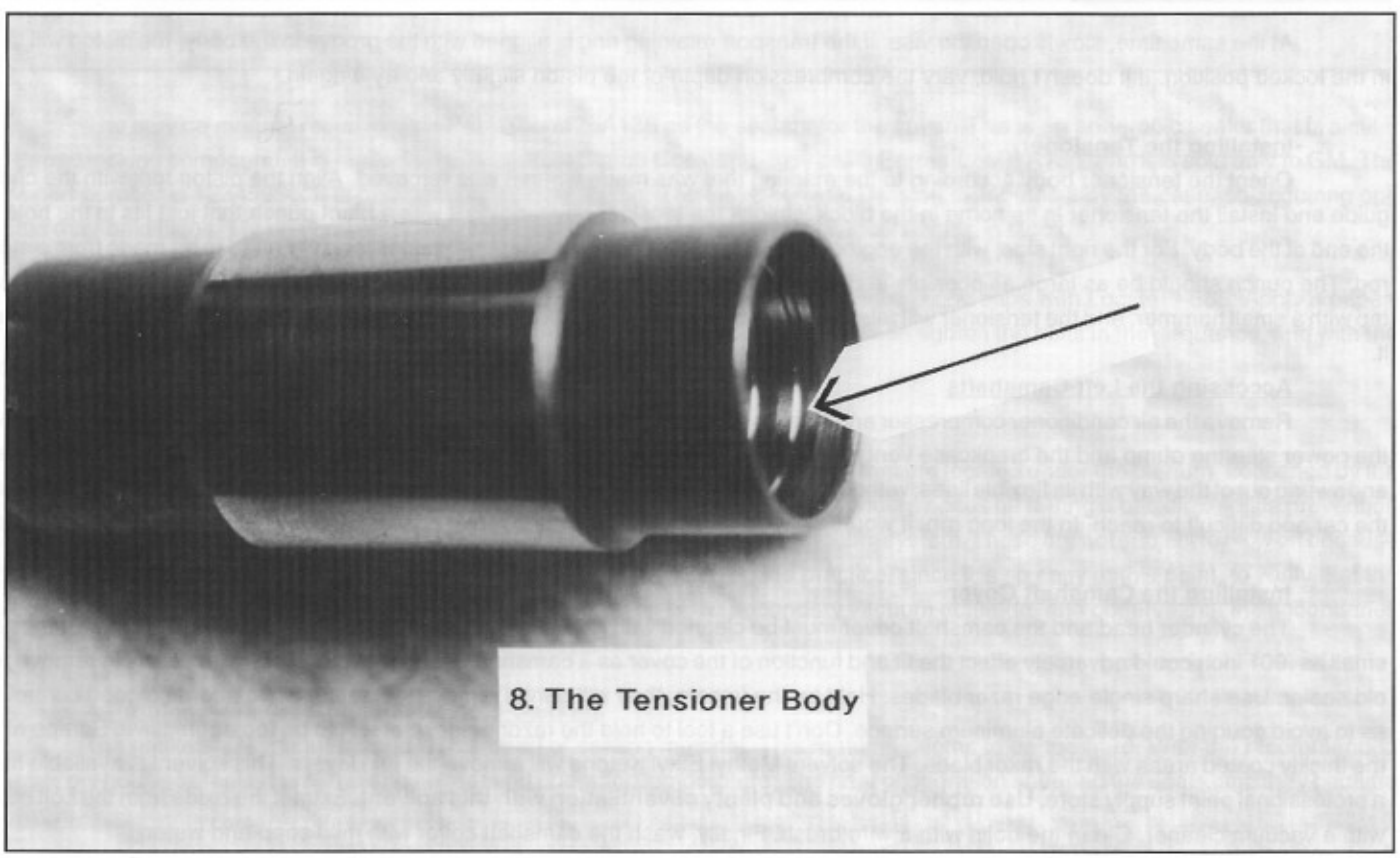
Push down on the piston and pull. It should come out after a few tries. If it can't be withdrawn by hand, strike the assembly, piston first, into the top of the workbench. This should cause it to release. Be prepared for about half of an ounce of oil to emerge.

After removing the piston, clean all of the parts. 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. Picture 7 shows the transport retaining ring. Picture 8 (opposite page) shows the groove in the body.

To facilitate the assembly of the tensioner, measure the distance from the end of the body to the groove. Mark this dimension on the piston as shown in Picture 7. Make sure that the larger retaining ring is in the piston's small groove as shown in Picture 7. 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 grooves in the body. Compress it until the depth mark that was previously marked on the piston is lined up with the end of the body.

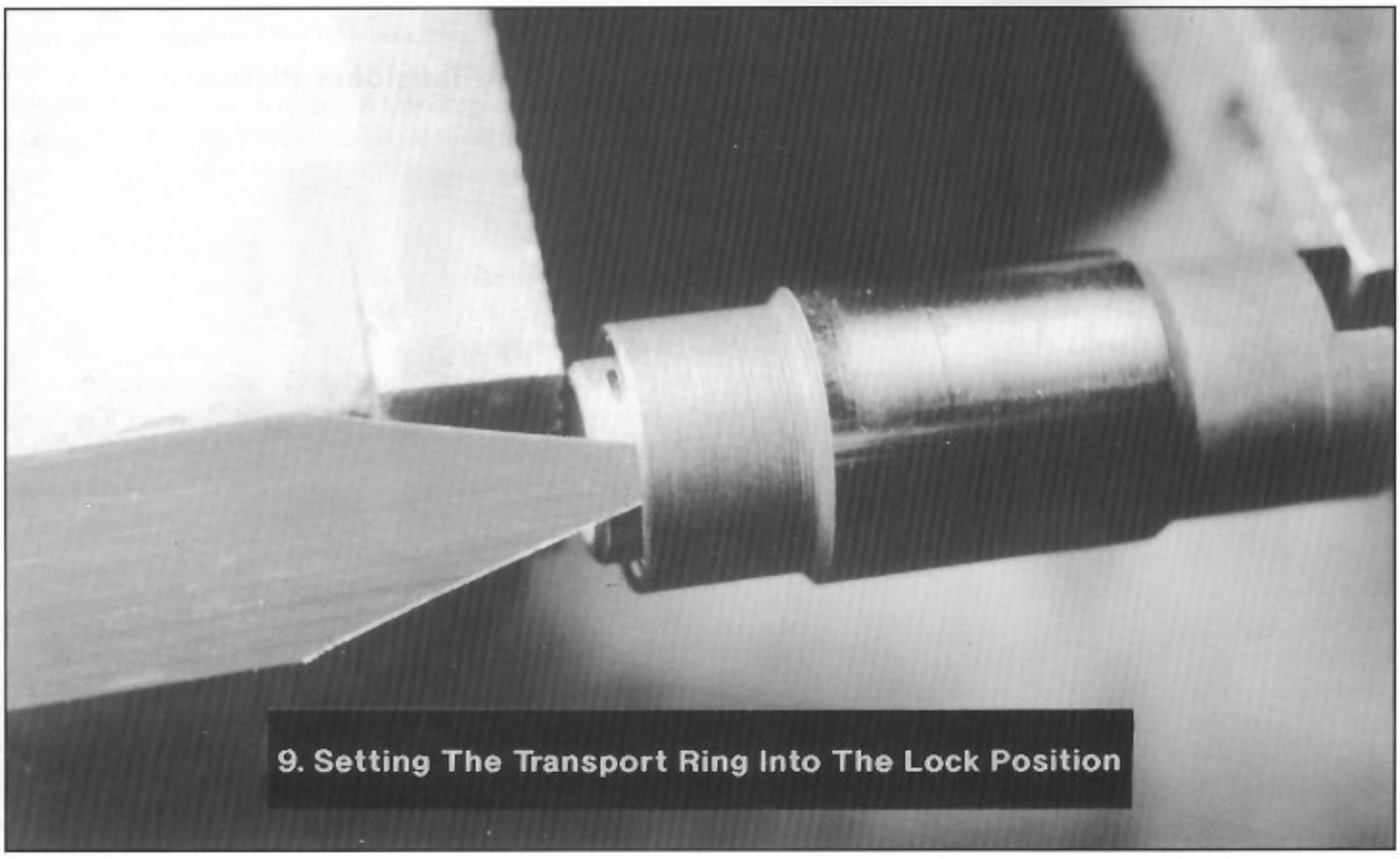


7. The Tensioner Piston



8. The Tensioner Body

Finally, alternately push on opposite sides of the transport retaining ring with a thin pointy tool as shown in Picture 9 (below).



9. Setting The Transport Ring Into The Lock Position

At the same time, slowly open the vise. If the transport retaining ring is aligned with the groove in the body, the piston will stay in the locked position. If it doesn't hold, vary the compression depth of the piston slightly and try it again.

Installing the Tensioner

Orient the tensioner body according to the marking that was made when it was removed. Align the piston fork with the chain guide and install the tensioner in its home in the block. Unlock the tensioner by tapping it with a blunt punch that just fits in the hole in the end of the body. For the right side, with the engine in the car, a short punch about 1 1/4-inches long will need to be made from a steel rod. The punch should be as large as possible in diameter. If it is too small, it could damage the check valve. Give the punch a sharp tap with a small hammer, and the tensioner will release with a satisfying, "pop"! Coat the hex plug with Loctite™ 565 sealant and reinstall it.

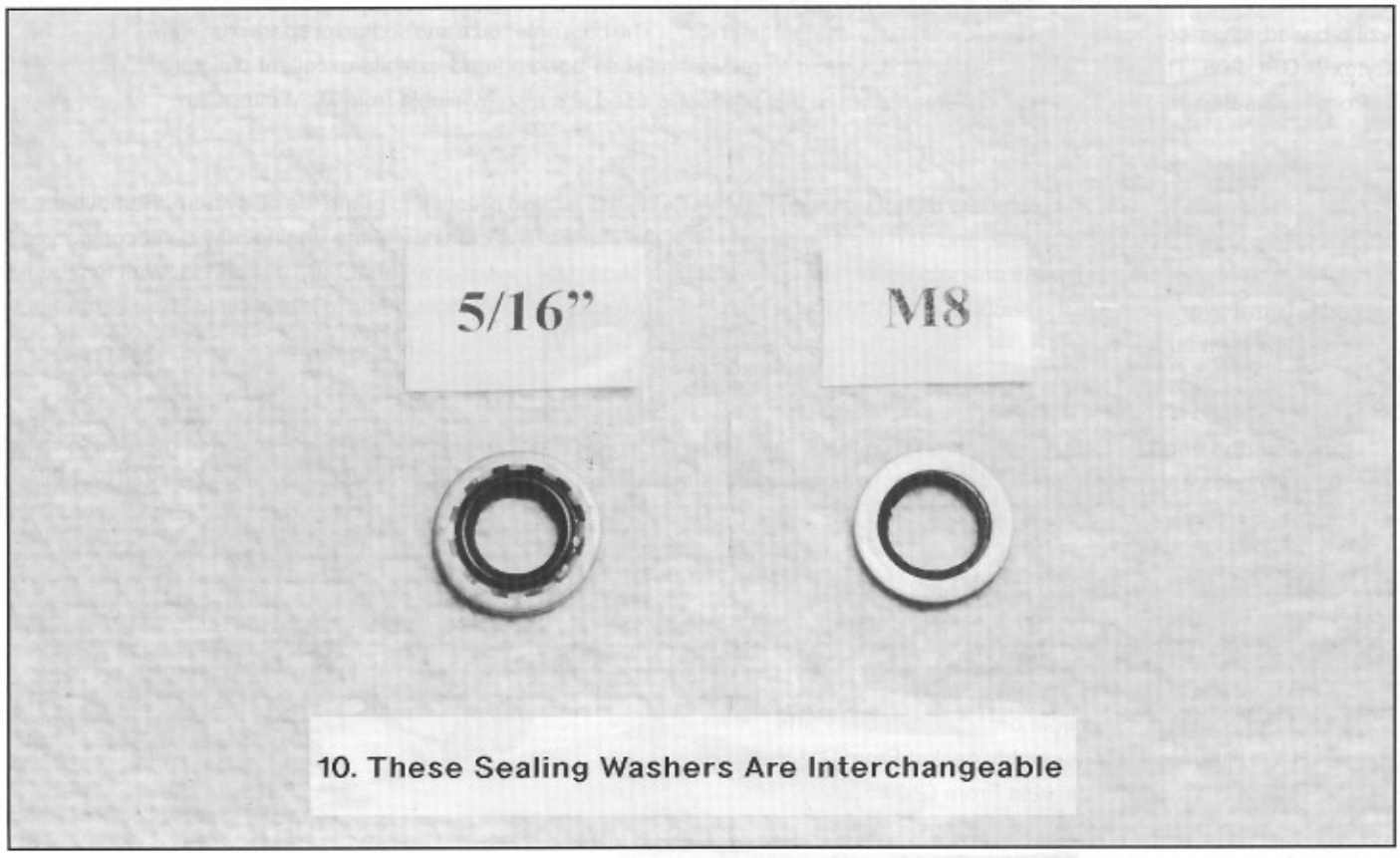
Accessing the Left Camshafts

Remove the air conditioner compressor and suspend it with the attached hoses forward, and out of the way with a rope. Remove the power steering pump and the crankcase vent tube. Remove the power brake booster. The master brake cylinder can be removed and swung out of the way with its flexible lines, without opening the hydraulic system. The fasteners for the power brake booster are inside the car and difficult to reach. In the long run, it would be wise to remove the seat to make access easier. Remove the camshaft cover.

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. 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 present a dilemma. The washers that are supplied by GM Parts cost over a $100 a set. These metric washers don't seem to be readily available as a hardware item in the USA. [redacted]



10. These Sealing Washers Are Interchangeable

The service manual recommends Permabond™ A136 as the sealant for the cover. This is an anaerobic sealer that is similar to thread locking compound. It is made by the American Starch Company; they call it Perma-Loc™ A136, and it is sold only to GM. The GM part number is 12345980; it is packaged in a 50 ml. bottle. The GM Chemical Division distributes it by the case, so acquiring one bottle may be difficult. My dealer was able to locate another dealer that had individual bottles in stock.

Place the o-rings for the spark plug access holes on the cylinder head. Coat the end caps with Loctite™ 565. 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.

Installing the Plenum

This is a great opportunity to improve the attachment of the vacuum hoses that are located under the plenum. Loosened by the oil that normally migrates into the plenum, the LT-5 is notorious for blowing small vacuum hoses off during a backfire. A little prevention can really pay off here. It is not necessary to clamp the hoses for the secondary vacuum system. These are not subject to blow off because they are buffered by the secondary vacuum canister. It would also be a good practice, since it is so easy at this point, to verify that the secondary throttles are opening properly. Apply vacuum to each of the secondary vacuum actuators and observe that the secondaries open and close smoothly and completely.

A Problem with the Coolant Manifold Gaskets

The gaskets are manufactured with a bead of sealing material. This material seems to be too hard. With the recommended torque, my housings leaked until the engine reached operating temperature. The heat of operation softened the seals, and they became effective.

Installing the Spark Plugs

If used spark plugs or new spark plugs that are not prepared with anti-seize are installed, anti-seize should be applied. The ideal anti-seize material will not contain silica or lead. These compounds can contaminate, respectively, the oxygen sensors or the catalysts. A zinc-based, silver-colored anti-seize is available from McMaster-Carr. The best anti-seize and sealer for spark plug wire boots is DuPont Krytox™ GPL 206. This product is specifically designed to prevent silicone bonding and exhibits excellent dielectric characteristics. DuPont claims that cold engines can idle cleaner when this product is used. It's also available from McMaster-Carr.

Preparing For Start-up

Since the timing chain tensioners do not contain oil at this point, it is a good practice to prime the oil system. Remove the fuel injector fuses. Open the throttle a little, and turn the engine over with the starter. The cranking of the engine may be accompanied by the alarming sound of the camshafts snapping over center. The engine should be turned over for about 10 seconds. Wait for about 20 seconds. Turn it over again. On the second or third 10-second run, the oil pressure gauge should jump to the first tick. The nasty snapping sound should then subside.

Start-up

After the engine starts, it will probably be accompanied by a lot of lifter noise. Surprisingly, the lifter noise goes on for a long time. It finally goes away completely as the engine approaches normal operating temperature at idle. The oil filter should be replaced after about 25 miles.

Parts and Supplies Summary List

2 Plenum gaskets From GM Parts
2 Fuel line o-rings From GM Parts
8 Spark plug access hole o-rings From GM Parts
1 Oil filter/regulator assembly gasket From GM Parts
2 Coolant manifold gaskets From GM Parts
4 Camshaft bolts From GM Parts
48 Sealing washers [redacted]
1 50 ML bottle of Permabond™ A136 From GM Parts, PN 12345980
1 10 ML bottle of Loctite™ 262 red thread locker From a local source
1 50 ML tube of Loctite™ 565 sealer with Teflon™ From a local source. AKA PST 565
1 8 OZ. STL Corp. Saf-T-Eze™ zinc base anti-seize From McMaster-Carr, PN ~~10195K31~~ 10105K41
1 2 OZ. DuPont Krytox™ GPL 206 fluorinated grease From McMaster-Carr, PN ~~10105K11~~ 10195K31
Small black cable ties From a local source
Methyl Ethyl Ketone Solvent From a paint supplier
Foam swabs, 3/16-inch. From a local source

McMaster-Carr (phone number) 630-834-9600

Special Tool List

7 inch timing wheel From a local source
Dial gauge From a local source
Piston stop Easily fabricated
Manual timing chain tensioner Easily fabricated

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