Automotive Technology 6th Edition
Chapter 37 Engine Assembly & Dynamometer Testing
Opening Your Class

KEY ELEMENT	EXAMPLES
Introduce Content	This Automotive Technology 6th text provides complete coverage of automotive components, operation, design, and troubleshooting. It correlates material to task lists specified by ASE and ASEEducation (NATEF) and emphasizes a problem-solving approach. Chapter features include Tech Tips, Frequently Asked Questions, Case Studies, Videos, Animations, and ASEEducation (NATEF) Task Sheets.
Motivate Learners	Explain how the knowledge of how something works translates into the ability to use that knowledge to figure why the engine does not work correctly and how this saves diagnosis time, which translates into more money.
State the learning objectives for the chapter or course you are about to cover and explain this is what they should be able to do as a result of attending this session or class.	Explain the chapter learning objectives to the students as listed: 1. Explain short block preparation and cylinder head preparation. 2. Discuss trial assembly and final short block assembly. 3. Describe camshaft installation and piston/rod installation. 4. Discuss the advantages of performing a trial assembly of the engine. 5. List the steps needed to assemble an engine. 6. Explain the cylinder head installation procedure. 7. Discuss torque-to-yield head bolts. 8. Explain valve train assembly and final assembly of an engine. 9. Explain dynamometer testing.
Establish the Mood or Climate	Provide a ***WELCOME,*** Avoid put downs and bad jokes.
Complete Essentials	Restrooms, breaks, registration, tests, etc.
Clarify and Establish Knowledge Base	Do a round robin of the class by going around the room and having each student give their backgrounds, years of experience, family, hobbies, career goals, or anything they want to share.

NOTE: This lesson plan is based on the 6th Edition Chapter Images found on Jim's web site @
www.jameshalderman.com

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http://www.jameshalderman.com/automotive_principles.html
NOTE: You can use Chapter Images or possibly Power Point files:

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	1. **SLIDE 1 CH37 ENGINE ASM DYNO TESTING** 2. **SLIDE 2 EXPLAIN FIGURE 37–1** A Ford 1.0 liter 3-cylinder engine is different than many small engines and may require detailed service information for proper assembly. **Check for ADDITIONAL VIDEOS & ANIMATIONS @ http://www.jameshalderman.com/** **WEB SITE IS CONSTANTLY UPDATED** **http://www.jameshalderman.com/automotive_principles.html** **DOWNLOAD** **Crossword Puzzle (Microsoft Word) (PDF)** **Word Search Puzzle (Microsoft Word) (PDF** **ENGINE ASSEMBLY** **"Tolerance stacking" is one concern that needs to be checked during trial assembly. One example of this is in valve guide. If the guide is at the smallest specified diameter and valve stem is at the largest specified diameter, they may not fit. They are both within specification, but valve may not fit in guide.** **DISCUSSION: Have students discuss why it is so important to keep engines clean when assembling.** **(Answer: One example is valve stem clearance. Valve stem clearance is only 0.0015" to 0.003." It would not take a very large piece of dust or lint to stop oil flow.)** **DEMONSTRATION: Have a block prepared to show students various levels of bore prep** 3. **SLIDE 3 EXPLAIN Figure 37-2** Deburring all sharp edges is an important step to achieve proper engine assembly. 4. **SLIDE 4 EXPLAIN Figure 37-3** Studs installed in the block, replacing head bolts. 5. **SLIDE 5 EXPLAIN FIGURE 37-4** Main bearing studs installed on V-8 block. 6. **SLIDE 6 EXPLAIN FIGURE 37-5** Cadillac Northstar

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	engine being rebuilt. 7. **SLIDE 7 EXPLAIN Figure 37-6** thread chaser (top) is the preferred tool to clean threaded holes because it cleans without removing metal compared to a tap (bottom).
	**EXPLAIN TECH TIP: *Be Aware of BMW Engine Procedures*** **If rebuilding a BMW engine, check service information carefully because most BMW engines require that threaded inserts be installed in all head bolt threads. Performing this operation can increase the cost and time needed. Always follow all recommended service procedures on the engine being serviced. • SEE FIGURE 37–5.**
	**DISCUSS CHART 37-1 The surface finish of the block and cylinder head depends on the type of gasket being used.**
	DEMONSTRATION: Show students difference between thread chaser and tap.
	HANDS-ON TASK: Have students use both thread chasers and taps to clean threads. Students should compare threaded holes cleaned with the a chaser to those cleaned with a tap.
	HANDS-ON TASK: Have students use a straightedge & feeler gauge to check for flatness
	**EXPLAIN TECH TIP: *Keep the Engine Covered*** **Using a large plastic trash bag is an excellent way to keep the engine clean when storing it between work sessions. • SEE FIGURE 37–7.**
	8. **SLIDE 8 EXPLAIN Figure 37-7** Using a plastic trash bag is an excellent way to keep the engine clean during all stages of assembly.
	DISCUSSION: Have students discuss how clearances may change when non-stock parts are used. An example might be a "stroker" crankshaft. One clearance students may overlook is that between connecting rods & camshaft. This often overlooked area can cause catastrophic failure.

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	9. **SLIDE 9 EXPLAIN Figure 37-8** trial assembly showed that some grinding of the block will be needed to provide clearance for the counterweight of the crankshaft. Also, notice that the engine has been equipped with studs for the four-bolt main bearing caps. 10. **SLIDE 10 EXPLAIN Figure 37-9** typical high-performance aftermarket rocker arm which is equipped with needle roller bearings at the valve stem end and caged needle bearing at the pivot shaft end to reduce friction, which increases engine horsepower and improves fuel economy. **When assembling an engine, never stop midway through a step. Always complete step you are on before taking a break or going home.** **When installing oil gallery plugs, be sure to check that the plug doesn't interfere with an intersecting gallery. This could starve part of the engine of oil.**
	**DISCUSS CASE STUDY: *Valve Springs Can Vary*** **A technician was building a small block Chevrolet V-8 and found that many of the valve springs did not have the same tension. Using a valve spring tester, the technician visited a local parts store and measured all of the valve springs that the store had in stock. The technician selected and purchased the 16 valve springs that were within specification and within a very narrow range of tension. Although having all valve springs equal may or may not affect engine operation, the technician was pleased that all of the valve springs were equal.** **Summary:** **Complaint—A technician discovered that valve springs did not all have the same tension.** **Cause—Due to manufacturing tolerances, valve springs can vary in tension.** **Correction—The technician tested all available springs and selected those that were the most equal in tension.**
	**EXPLAIN TECH TIP: *Fogging Oil and Assembly Lube*** **When assembling an engine, the parts should be coated with a light oil film to keep them from**

rusting. This type of oil is commonly referred to as fogging oil and is available in spray cans. • SEE FIGURE 37–10. During engine assembly, the internal parts should be lubricated. While engine oil or grease could be used, most experts recommend the use of a specific lubricant designed for engine assembly. This lubricant, designed to remain on the parts and not drip or run, is called assembly lube. • SEE FIGURE 37–11.

11. **SLIDE 11 EXPLAIN Figure 37-10** Fogging oil is used to cover bare metal parts when the engine is being stored to prevent corrosion.
12. **SLIDE 12 EXPLAIN Figure 37-11** Engine assembly lube is recommended to be used on engine parts during assembly.
13. **SLIDE 13 EXPLAIN Figure 37-12** angle gauge being used to check the angle between the cylinder heads on this small block Chevrolet V-8 engine.
14. **SLIDE 14 EXPLAIN Figure 37-13** best way to thoroughly clean cylinders is to use soap (detergent), water & large washing brush. This method floats machining particles out of block and washes them away.
15. **SLIDE 15 EXPLAIN Figure 37-14** All oil galleries should be cleaned using soap (detergent), water, and a long oil gallery cleaning brush.
16. **SLIDE 16 EXPLAIN Figure 37-15** This engine uses many cup plugs to block off coolant and oil passages as well as a large plug over the end of the camshaft bore.
17. **SLIDE 17 EXPLAIN Figure 37-16** Sealer should be applied to cup plug before being driven into the block.

DISCUSS FREQUENTLY ASKED QUESTION:

What Causes Premature Bearing Failure?

According to a major manufacturer of engine bearings, major causes of premature (shortly after installation) bearing failure include the following: Dirt (45%)

- **Misassembly (13%)**
- **Misalignment (13%)**
- **Lack of lubrication (11%)**
- **Overloading or lugging (10%)**

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- **Corrosion (4%)**
- **Other (4%)**

Many cases of premature bearing failure may result from a combination of several of these items. Therefore, to help prevent bearing failure, keep everything as clean as possible.

HANDS-ON TASK: Have students clean oil galleries and install gallery plugs.

18. **SLIDE 18 EXPLAIN Figure 37-17** Screw-type puller being used to install a new cam bearing. Most cam bearings are crush fit. The full round bearing is forced into the cam bearing bore. Most vehicle manufacturers specify that the cam bearings be installed "dry" without lubrication to help prevent them from spinning, which would cause the bearing to block the oil feed hole.
19. **SLIDE 19 EXPLAIN Figure 37-18** Typical main bearing set. Note that the upper halves are grooved for better oil flow and the lower halves are plain for better load support. This bearing set uses the center main bearing for thrust control. Notice that the upper bearing set has the holes for oil, whereas the lower set does not.

When installing cam bearings with a bearing driver and a hammer, never let driver bounce on the bearing. Keep hand pressure on driver.

After installing cam bearings, check for alignment of oil holes & oil galleries. This can be done with short piece of stiff wire.
Marking the oil hole in the cam bearing & oil gallery with a felt marker can make cam bearing installation easier.
Bearing shells should snap into the block and caps. If they not, check for the correct part number on the bearings.

HANDS-ON TASK: Have students sort used main bearings to find upper, lower, & thrust bearings

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	20. **SLIDE 20 EXPLAIN Figure 37-19** width of plastic gauging strip determines oil clearance of main bearing Alternate method of determining oil clearance includes careful measurement of crankshaft journal and bearings after they are installed and main housing bore caps are torqued to specifications. 21. **SLIDE 21 EXPLAIN Figure 37-20** Lip-type rear main bearing seal in place in the rear main bearing cap. The lip should always be pointing toward inside of engine. 22. **SLIDE 22 EXPLAIN Figure 37-21** Always use the proper driver to install a main seal. Never pound directly on the seal. 23. **SLIDE 23 EXPLAIN Figure 37-22** rear seal for this engine mounts to a retainer plate. The retainer is then bolted to the engine block. **EXPLAIN TECH TIP:** ***"One to Three"*** **When engine technicians are talking about clearances and specifications, the unit of measure most often used is thousandths of an inch (0.001 inch). So, a clearance expressed as "one to three" would actually be a clearance of 0.001 to 0.003 inch. The same applies to parts of a thousandth of an inch. Specification of 0.0005 to 0.0015 inch would be spoken of as simply being "one-half to one and one-half." The unit of a thousandth of an inch is assumed, and this method of speaking reduces errors and misunderstandings.** **NOTE: Most engine clearance specifications fall within one to three thousandths of an inch. The written specification could be a misprint. Therefore, if the specification does not fall within this general range, double-check the clearance value using a different source.** **DEMONSTRATION: Show students how to install rope seal.** **Make sure the main caps are square with the block before performing the first torque step.**

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	24. **SLIDE 24 EXPLAIN Figure 37-23** Many engine builders prefer to stagger parting lines of a rope-type seal. 25. **SLIDE 25 EXPLAIN Figure 37-24** dial indicator is being used to check the crankshaft end play, known as thrust bearing clearance. Always follow the manufacturer's recommended testing procedures. **HANDS-ON TASK: Have students' measure crankshaft end play using a dial indicator.** 26. **SLIDE 26 EXPLAIN Figure 37-25** thrust bearing insert being installed before the crankshaft is installed. **DISCUSSION: Have students discuss why the pre-lubrication requirements are different for flat tappets versus roller tappets. (Answer: The roller lifter has less friction. Therefore it doesn't need the zinc additives)**
	**EXPLAIN TECH TIP: *Use a Long Bolt to Hold the Camshaft* To help install a camshaft without harming the cam bearings, install a long bolt into one of the end threaded holes in the camshaft. Then tilt the engine vertically so that gravity causes the camshaft to fall straight down while holding onto the camshaft using the long bolt. • SEE FIGURE 37–26.** 27. **SLIDE 27 EXPLAIN Figure 37-26** Installing a camshaft is easier if engine is vertical so gravity can help, and reduces possibility of damaging bearings.
	**EXPLAIN TECH TIP *Two Choices If Using Flat-Bottom Lifters: An old or rebuilt engine that uses flat-bottom lifters must use one of two lubricants.*** 1. **Oils that contain at least 0.15% or 1,500 parts per million (ppm) of zinc in the form of ZDDP. Oils that contain this much zinc are designed for off-road use only and in a vehicle that does not have a catalytic converter, such as racing oils. If the vehicle is equipped with a catalytic converter, replace the**

camshaft and lifters with roller type, so that newer oils with lower levels of zinc can be used.

2. Use a newer oil and an additive such as:

a. GM engine oil supplement (EOS) (Part #1052367 or #88862586)

b. Comp Cams® camshaft break-in oil additive (Part #159)

c. Crane Cams® Moly Paste (#99002-1)

d. Crane Cams® Super Lube oil additive (Part #99003-1)

e. Lumati Assembly lube (Part #99010)

f. M ell-Lube camshaft tube oil additive (Part # M-10012)

g. Other available additives designed to protect the camshaft:

(• SEE FIGURE 37–27.)

28. **SLIDE 28 EXPLAIN Figure 37-27** commercial additive designed to protect a flat bottom lifter camshaft used in older vehicles when using newer oils that do not have enough ZDDP to protect the camshaft and lifters.

DEMONSTRATION: Show students how to lube and install camshaft.

DEMONSTRATION: Show students how to adjust ring gap.

HANDS-ON TASK Have students' measure ring gap on an assigned engine

29. **SLIDE 29 EXPLAIN Figure 37-28 f**eeler gauge is used to check piston ring gap

DEMONSTRATION: Show students how to measure a connecting rod "big end" using inside micrometer.

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	30. **SLIDE 30 EXPLAIN Figure 37-29** notch on a piston should always face toward the front of the engine. 31. **SLIDE 31 EXPLAIN Figure 37-30** On V-type engines that use paired rod journals, side of the rod with the large chamfer should face toward the crank throw (outward). **DISCUSS CHART 37-2 approximate ring gap based on the size of the bore in inches.** **Always check service information for the exact specifications for engine being assembled.** **HANDS-ON TASK Have students prep pistons for installation.** **DEMONSTRATION: Show students how to use a piston ring compressor.** **Pushing the piston in with a hammer handle is easier on the rings than tapping it in.** **On an engine with two rods per crank throw, be sure to install both rods on a given throw before torqueing them. This helps prevent rods from binding on crank.** 32. **SLIDE 32 EXPLAIN Figure 37-31** inside micrometer can be used to measure the inside diameter of the big end of the connecting rod with the bearings installed. This dimension subtracted from the rod journal diameter is equal to the bearing clearance. 33. **SLIDE 33 EXPLAIN Figure 37-32** One method of piston ring installation showing location of ring gaps. Always follow OEM recommended method for the location of ring gaps and for ring gap spacing. 34. **SLIDE 34 EXPLAIN Figure 37-33** gapless ring is made in two pieces that overlap. **DEMONSTRATION: Show students how to install piston rings**

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	35. SLIDE 35 EXPLAIN Figure 37-34 This style of ring compressor uses a ratchet to contract the spring band and compress the rings into their grooves. **36. SLIDE 36 EXPLAIN Figure 37-35** This pliers-like tool is used to close the metal band around the piston to compress the rings. An assortment of bands is available to service different size pistons. **37. SLIDE 37 EXPLAIN Figure 37-36** When threaded onto the rod bolts, these guides not only help align the rod but also protect the threads and holds the bearing shell in place. The soft ends also will not damage the crankshaft journals. **38. SLIDE 38 EXPLAIN Figure 37-37** Installing a piston using a ring compressor to hold the rings into the ring grooves of the piston and then using a hammer handle to drive the piston into the bore. Connecting rod bolt protectors have been installed to help prevent possible damage to the crankshaft during piston installation. **39. SLIDE 39 EXPLAIN Figure 37-38** connecting rod side clearance is measured with a feeler gauge.
	**EXPLAIN TECH TIP *Tightening Tip for Rod Bearings*** **Even though the bearing clearances are checked, it is still a good idea to check and record the torque required to rotate the crankshaft with all piston rings dragging on the cylinder walls. The retaining nuts on one bearing should be torqued, and then the torque that is required to rotate crankshaft should be rechecked and recorded. Follow the same procedure on all rod bearings. If tightening any one of the rod bearing caps causes a large increase in the torque required to rotate the crankshaft, immediately stop the tightening process. Determine the cause of increased rotating torque using the same method as used on the main bearings. Rotate the crankshaft for several revolutions to ensure that the assembly is turning freely and that there are no tight spots. The rotating torque of the crankshaft with all connecting rod cap bolts fully torqued should be as follows:** • **4-cylinder engine: 20 lb-ft maximum (88 N-m)**

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	• 6-cylinder engine: 25 lb-ft maximum (110 N-m) • 8-cylinder engine: 30 lb-ft maximum (132 N-m) **SEARCH INTERNET: Have students search Internet to find upgraded head gaskets to fix pattern failures.** **Water or solvent from the cleaning process can cause the same cracking as described in Tech Tip "Watch Out for Wet and Dry Holes." This can be a problem on LS1 Chevrolets.** **DEMONSTRATION: Using a stiff wire or welding rod, show students how to determine "wet" and "dry" head bolt holes.** 40. **SLIDE 40 EXPLAIN Figure 37-39 (a)** Valve clearance allows the metal parts to expand and maintain proper operation, both when the engine is cold and at normal operating temperature. Adjustment is achieved by turning the adjusting screw. 41. **SLIDE 41 EXPLAIN Figure 37-39 (b)** Valve clearance allows the metal parts to expand and maintain proper operation, both when the engine is cold and at normal operating temperature. Adjustment is achieved by changing thickness of adjusting shim. 42. **SLIDE 42 EXPLAIN Figure 37-40** Some overhead camshaft engines use valve lash adjusting shims to adjust valve lash. Special tool is usually required to compress the valve spring so that a magnet can remove the shim. **EXPLAIN TECH TIP *Watch Out for Wet and Dry Holes:* Many engines, such as the small block Chevrolet V-8, use head bolts that extend through the top deck of the block and end in a coolant passage. These bolt holes are called wet holes. When installing head bolts into holes that end up in the coolant passage, always use sealer on the threads of the head bolt. Some engines have head bolts that are "wet," whereas others are "dry" because they end in solid cast-iron material. Dry hole bolts do not require sealant, but they still require some oil on the threads of the bolts for lubrication. Do not put oil into a dry hole because the bolt may bottom out in the oil. The liquid oil**

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	cannot compress, so the force of the bolt being tightened is transferred to the block by hydraulic force, which can crack the block. **NOTE: Apply oil to a shop cloth and rotate bolt in cloth to lubricate threads. This procedure lubricates threads without applying too much oil.** **DEMONSTRATION: Show students how to shim an OHC valve train to adjust valve lash (clearance)** **Using sealant or adhesives on a head gasket could cause gasket failure. Cylinder heads and blocks expand at different rates. The head gasket must allow this movement without being damaged.** **HANDS-ON TASK Have students install & and torque cylinder head (s).**
	**EXPLAIN TECH TIP: *Piece Of Paper Demonstration*** **Some students and beginning technicians forget the correct order to tighten head bolts or other fasteners of a component. Try the following DEMO:** • **Place a single sheet of paper on a table.** • **Place both hands on paper in center and then move your hands outward.** • **Nothing should have happened and the paper should have not moved.** • **Now place your hands on paper at the ends and move them toward the center.** • **The paper wrinkles as the hands move toward the center.** **This demonstration shows that the forces are moved away toward the ends of the cylinder head if the fasteners are tightened from the inside toward the outside. However, if the cylinder head bolts were tightened incorrectly, the head would likely crack due to the forces exerted during tightening.**
	**EXPLAIN TECH TIP *Always "Exercise" New Bolts*** **New bolts and studs are manufactured by rolling the threads and heat treating. Due to this operation, the threads usually have some rough**

areas, which affect the clamping force on the gasket. Many engine building experts recommend that all new bolts be installed in the engine using a new or used gasket and torqued to specifications at least five times, except for torque to-yield bolts. This process burnishes the ramps of the threads and makes the fastener provide a more even clamping force. Using the recommended lubricant, the bolts should be torqued and removed and then torqued again.

43. **SLIDE 43 EXPLAIN Figure 37-41** Typical cylinder head tightening sequence.
44. **SLIDE 44 EXPLAIN Figure 37-42 Examples of cylinder head bolt torquing sequences**

DISCUSS FREQUENTLY ASKED QUESTION: *Why Do Both Head Gaskets Have "Front" Marked?* A common question asked by beginning technicians is how to install head gaskets on a V-6 engine that is mounted transversely (sideways) in vehicle. The technician usually notices that "front" is marked on one gasket, and, therefore, installs that gasket on the block, on top of forward-facing cylinder bank. Then, the technician notices that the other gasket is also marked with "front." How could both be marked "front"? There must be some mistake. Mistake is in terminology used. In the case of head gaskets, "front" means toward accessory drive belt end of engine and not on the cylinder bank toward front of vehicle. • SEE FIGURE 37–43.

45. **SLIDE 45 EXPLAIN Figure 37-43** Typical head gasket markings. The front means that the gasket should be at the accessory drive belt end of the block

EXPLAIN TECH TIP *Creep Up on Torque Value*
Do not jerk or rapidly rotate a torque wrench. For best results and more even torque, slowly apply force to the torque wrench until it reaches the

preset value or the designated torque. Jerking or rapidly moving the torque wrench often cause the torque to be uneven and not accurate.

46. **SLIDE 46 EXPLAIN Figure 37-44** Due to variations in clamping force with turning force (torque) of head bolts, some engines are specifying the torque-to-yield procedure. The first step is to torque the bolts by an even amount called the initial torque. Final clamping load is achieved by turning the bolt a specified number of degrees. Bolt stretch provides the proper clamping force.
47. **SLIDE 47 EXPLAIN Figure 37-45** To ensure consistent clamp force (load), many OEMs recommending torque-angle method of tightening head bolts. The method specifies tightening fasteners to a low-torque setting and giving an additional angle of rotation. Difference in clamping force is much smaller than it would be if just torque wrench with dirty threads used

DEMONSTRATION: Show difference between standard and torque-to-yield head bolts.

HANDS-ON TASK Have students install cylinder head that uses torque-to-yield head bolts

DISCUSSION: Have students discuss why torque-to-yield head bolts must be replaced every time they are removed.

48. **SLIDE 48 EXPLAIN Figure 37-46** Torque angle can be measured using a special adaptor.
49. **SLIDE 49 EXPLAIN Figure 37-47** An electronic torque wrench showing the number of degrees of rotation. These very accurate and expensive torque wrenches can be programmed to display torque or number of degrees of rotation.
50. **SLIDE 50 EXPLAIN Figure 37-48** Both crankshafts have to be timed on this engine and timing belt also drives water pump.
51. **SLIDE 51 EXPLAIN Figure 37-49** Some timing chains have plated links that are used to correctly position the chain on the sprockets.
52. **SLIDE 52 EXPLAIN Figure 37-50** special tool may be needed to bleed air from the hydraulic lash adjusters

(HLA) through the bleed hole. These lash adjusters are part of the valve end of the rocker arms in this example.

53. **SLIDE 53 EXPLAIN Figure 37-51** Timing chain and gears can be installed after the crankshaft and camshaft have been installed and the timing marks are aligned with cylinder 1 at top dead center (TDC).

EXPLAIN TECH TIP: *Soak the Timing Chain* Many experts recommend that a new timing chain be soaked in engine oil prior to engine assembly to help ensure full lubrication at engine start-up. The timing chain is one of the last places in the engine to get lubrication when the engine first starts. This procedure may even extend the life of the chain.

EXPLAIN TECH TIP: Watch Out for Different Length Pushrods: The very popular General Motors family of engines, including 2.8 liter, 3.1 liter, 3.4 liter, and 3.5 liter, each use different pushrod lengths for intake and exhaust valves. If the wrong pushrods are used, two things can occur.

1. **The pushrod(s) can be bent.**
2. **The engine runs rough because the longer pushrod prevents the valve from closing all the way. Always check service information for the exact location of the pushrods.**

DISCUSSION: Have students discuss advantages and disadvantages of different types of cam drive systems. (Examples: gear to gear, belt, chain.)

DEMONSTRATION: Show students how to time a camshaft and install a timing chain on a cam-in-block engine.

HANDS-ON TASK: Have students line up cam drive components on a bench mockup. The gears, sprockets, guides, and other components can be attached to a piece of plywood.

54. **SLIDE 54 EXPLAIN Figure 37-52** With the lifter resting on the base circle of the cam, zero lash is achieved by tightening the rocker arm lock nut until the pushrod no longer rotates freely.
55. **SLIDE 55 EXPLAIN Figure 37-53** Most adjustable valves use a nut to keep the adjustment from changing.

Therefore, to adjust the valves, the nut has to be loosened and the screw rotated until the proper valve clearance is achieved. Then screw should be held while tightening lock nut to keep adjustment from changing. Double-check valve clearance after tightening the nut.

When adjusting hydraulic lifters, as outlined on page 406, be sure to do Step 3 right after Step 2 is performed. If students take a break after Step 2, pushrod will spin due to lifter bleed-down. If they repeat Step 2, the adjustment will be too tight.
A cylinder leak-down test can be used to find a valve that has not been adjusted correctly (i.e., too tight).

56. **SLIDE 56 EXPLAIN Figure 37-54** This intake manifold gasket includes end seals and a full shield cover for the valley to keep hot engine oil from heating the intake manifold.
57. **SLIDE 57 EXPLAIN Figure 37-55** exhaust manifold gasket is used on some engines. It seals the exhaust manifold to the cylinder head.
58. **SLIDE 58 EXPLAIN Figure 37-56** A 1/8 to 3/16 inch (3 to 5 mm) bead of RTV silicon on a parting surface with silicon going around the bolt hole
59. **SLIDE 59 EXPLAIN Figure 37-57** A beam-type torque wrench being used to tighten the oil pump pickup assembly to factory specification.

DISCUSSION: Have students discuss what happens if manifold bolts are too long. (Answer: gasket will not be compressed. This will cause the gasket to fail.)
Exhaust manifold gaskets can be installed more easily by loosely installing end bolts in the manifold. Next, cut end bolts holes open in gasket. Now gasket can be slid into place between head & exhaust manifold.
Installing a vibration damper with a hammer can damage vibration damper. This damage could cause catastrophic failure of damper.

EXPLAIN TECH TIP: *Check the Oil Pump Pickup to Oil Pan Clearance:* Whenever installing the oil pan

on a rebuilt engine, it is wise to check clearance between the oil pump pickup and the bottom of the oil pan. This distance should be 3/16 to 3/8 inch (5 to 9 mm). To check the clearance, two methods can be used.

METHOD 1 With engine upside down and oil pump and pickup installed, measure distance from oil pan rail to top (actually the bottom) of oil pump pickup. Then measure distance from oil pan rail to bottom of oil pan and subtract two measurements to get clearance.

METHOD 2 Place about 1/2 inch (13 mm) of modeling clay on pickup of oil pump. Then, temporarily install oil pan with a gasket. Press down on oil pan to compress modeling clay. Remove oil pan and measure thickness of clay. This thickness is oil pan to oil pump pickup clearance. • SEE FIGURE 37–58.

60. **SLIDE 60 EXPLAIN Figure 37-58** Using clay to determine the oil pan to oil pickup clearance, which should be about 1/4 in.

61. **SLIDE 61 EXPLAIN Figure 37-59** Using a hammer to straighten the gasket rail surface of the oil pan before installing a new gasket. When the retaining bolts are tightened, some distortion of sheet metal covers occurs. If the area around the bolt holes is not straightened, leaks can occur with the new gasket.

DISCUSS FREQUENTLY ASKED QUESTION: *What Is "Torque Paint"?* Whenever a major fastener is tightened to the proper torque at the assembly plant, a dab of paint is applied to the head of the fastener to indicate that it was properly torqued. This is part of the quality control procedure used to help ensure that all fasteners are properly tightened to factory specification. • SEE FIGURE 37–60.

62. **SLIDE 62 EXPLAIN FIGURE 37–60** Torque paint applied to the head of the fastener indicates that it has been properly torqued to factory specification.

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	HANDS-ON TASK: Have students install water pump.
	63. SLIDE 63 EXPLAIN FIGURE 37–61 Oil should be seen flowing to each rocker arm as shown.
	**DISCUSS CASE STUDY: *"Oops"*** **After overhauling a big block Ford V-8 engine, the technician used an electric drill to rotate the oil pump with a pressure gauge connected to the oil pressure sending unit hole. When electric drill was turned on, oil pressure would start to increase (to about 10 PSI), then drop to zero. In addition, oil was very aerated (full of air). Replacing the oil pump did not solve the problem. After hours of troubleshooting and disassembly, it was discovered that an *oil gallery plug had been left out underneath the intake manifold*. The oil pump was working correctly and pumped oil throughout the engine and out of the end of the unplugged oil gallery. It did not take long for oil pan to empty and oil pump began drawing in air which aerated oil, which caused the oil pressure to drop. Installing gallery plug solved the problem.** **NOTE: Many OHC engines use an oil passage check valve in block near deck. The purpose of this valve is to hold oil in the cylinder head around the camshaft and lifters when the engine is stopped. Failure to reinstall this check valve can cause the valve train to be noisy after engine start-up.** **Summary:** **Complaint—Newly overhauled engine lost oil pressure shortly after start up.** **Cause—An oil gallery plug was found to be missing.** **Correction—The missing plug was installed and after reassembly, the engine oil pressure was normal.** **When using a chassis dynamometer, drive tires should have the same circumference and inflation. This will help prevent the vehicle from wandering on rollers.**

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	**EXPLAIN TECH TIP: *Install Heat Tabs:* The wise engine builder should install a heat tab to the back of the cylinder head(s). A heat tab uses a special heat-sensitive metal in the center of a mild steel disc. If the temperature of the cylinder head exceeds 250°F (121°C), the center of the tab melts and flows out, indicating that engine overheated. • SEE FIGURE 37–62.** **64. SLIDE 64 EXPLAIN FIGURE 37–62** Heat tabs can be purchased from engine supply companies. **65. SLIDE 65 EXPLAIN FIGURE 37–63** A dynamometer measures engine torque by applying a resistive force to the engine and measuring the force applied. Water is being used as the resistive load on this dynamometer.
	**SAFETY When tying a vehicle down on a chassis dynamometer, remember that straps stretch. This stretch could cause strap hooks to damage gas tanks, brake lines, & other parts.** **A quick way to tell whether atmospheric conditions are better or worse than standard conditions is to look at the correction factor (displayed on dynamometer computer monitor). If correction value is > 1, atmospheric conditions are worse than standard.**
	**SAFETY Never turn your back to a vehicle/engine on dynamometer. Engines and drivelines can explode when subjected to dynamometer loads.** **66. SLIDE 66 EXPLAIN FIGURE 37–64** A chassis dynamometer is used to measure torque at the drive wheels. There is a power loss through drive train, so the measured values are about 20% less than when measuring engine output at the flywheel, using an engine dynamometer. **67. SLIDE 67 EXPLAIN Figure 37-65** magnetic pickup being used to monitor engine speed when the vehicle is being tested on a chassis dynamometer.
	**EXPLAIN TECH TIP: *Look at the Crossing Point*** **All dynamometers measure torque of an engine, then calculate the horsepower. Horsepower is torque multiplied by engine speed (RPM) divided by**

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5,252 (a constant). Therefore, all graphs should show that the two curves for horsepower and torque should be the same at 5,252 RPM. • SEE FIGURE 37–66.

68. **SLIDE 68 EXPLAIN Figure 37-66** Because horsepower is calculated from measured torque, the horsepower and torque curves should always cross at exactly 5,252 RPM

DEMONSTRATION: Show the standard formula for calculating horsepower:
HP = RPM x Torque/5,252

$$BHP = \frac{F \times 6.28\,RN}{33{,}000_t} = \frac{FRN}{5252} = \frac{Torque(T) \times RPM}{5252}$$

$$BHP = \frac{Torque(t) \times RPM}{5252}$$

D distance
F dynamometer load in pounds
R effective length of the lever (in feet) radius arm of dynamometer
N engine speed in rpm

DISCUSSION: Have students discuss why horsepower and torque are equal at 5,252 RPM. (Answer: Have students enter 5,252 as RPM and they will see that RPM and constant 5,252 cancel out. This leaves HP _ Torque)

EXPLAIN TECH TIP: *Compare Dyno Results from the Same Dyno Only:* There are too many variables between dynamometers to allow a fair comparison when testing an engine. If changes are made to the engine, try to use the same dynamometer and use the same correction factors. Using another dynamometer can result in readings that may not be equivalent when testing on the original tester.

69.SLIDES 69-76 EXPLAIN PLASTIGAGE PROCEDURE

SEARCH INTERNET: Have students search the Internet for retrofit lip seal replacement for an engine originally equipped with a rope seal. Have them share their findings with the class.