# Automotive Technology 5th Edition
# Chapter 37 Engine Assembly & Dynamometer Testing
## Opening Your Class

| KEY ELEMENT | EXAMPLES |
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| **Introduce Content** | This course or class provides complete coverage of the components, operation, design, and troubleshooting. It correlates material to task lists specified by ASE and NATEF and emphasizes a problem-solving approach. Chapter features include Tech Tips, Frequently Asked Questions, Real World Fixes, Videos, Animations, and NATEF Task Sheet references. |
| **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:<br>1. Explain short block preparation and cylinder head preparation.<br>2. Discuss trial assembly and final short block assembly.<br>3. Describe camshaft installation and piston/rod installation.<br>4. Discuss the advantages of performing a trial assembly of the engine.<br>5. List the steps needed to assemble an engine.<br>6. Explain the cylinder head installation procedure.<br>7. Discuss torque-to-yield head bolts.<br>8. Explain valve train assembly and final assembly of an engine.<br>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 5th Edition Chapter Images found on Jim's web site @ www.jameshalderman.com**

**LINK CHP 37: ATE5 Chapter Images**

| ICONS | CH37 Engine Assembly |
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|  | 1. **SLIDE 1 CH37 ENGINE ASM DYNO TESTING**<br>2. **SLIDE 2 EXPLAIN Figure 37-1** uniquely designed W-8 engine installed in some Audi/Volkswagen vehicles. Rebuilding engine would require detailed service information to be sure that all steps are taken for proper assembly. |
|  | **Check for ADDITIONAL VIDEOS & ANIMATIONS @ http://www.jameshalderman.com/**<br>**WEB SITE IS CONSTANTLY UPDATED**<br>**VALVE & SEAT SERVICE**<br>**Videos** |
|  | **"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.<br>4. **SLIDE 4 EXPLAIN Figure 37-3** Studs installed in the block, replacing head bolts.<br>5. **SLIDE 5 EXPLAIN FIGURE 37-4** Main bearing studs installed on V-8 block.<br>6. **SLIDE 6 EXPLAIN FIGURE 37-5** Cadillac Northstar engine being rebuilt.<br>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). |

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|  | **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** |
|  | 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.** |
|  | 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.<br>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.** |

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|  | 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.<br>12. **SLIDE 12 EXPLAIN Figure 37-11** Engine assembly lube is recommended to be used on engine parts during assembly.<br>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.<br>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.<br>15. **SLIDE 15 EXPLAIN Figure 37-14** All oil galleries should be cleaned using soap (detergent), water, and a long oil gallery cleaning brush.<br>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.<br>17. **SLIDE 17 EXPLAIN Figure 37-16** Sealer should be applied to cup plug before being driven into the block. |
|  | **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.<br>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.** |

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|  | **After installing cam bearings, check for alignment of oil holes & oil galleries. This can be done with short piece of stiff wire.**<br>**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.** |
|  | **<u>HANDS-ON TASK:</u> Have students sort used main bearings to find upper, lower, & thrust bearings** |
|  | 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.<br>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.<br>22. **SLIDE 22 EXPLAIN Figure 37-21** Always use the proper driver to install a main seal. Never pound directly on the seal.<br>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. |
|  | **<u>DEMONSTRATION:</u> Show students how to install rope seal.** |
|  | **Make sure the main caps are square with the block before performing the first torque step.** |
|  | 24. **SLIDE 24 EXPLAIN Figure 37-23** Many engine builders prefer to stagger parting lines of a rope-type seal.<br>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. |

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|  | **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)** |
|  | 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.<br>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.** |
|  | 30. **SLIDE 30 EXPLAIN Figure 37-29** notch on a piston should always face toward the front of the engine.<br>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). |

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|  | **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.<br>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.<br>34. **SLIDE 34 EXPLAIN Figure 37-33** gapless ring is made in two pieces that overlap. |
|  | **DEMONSTRATION: Show students how to install piston rings** |
|  | 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.<br>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.<br>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. |

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|  | 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.<br>39. **SLIDE 39 EXPLAIN Figure 37-38** connecting rod side clearance is measured with a feeler gauge. |
|  | **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.<br>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.<br>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. |
|  | **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.** |

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|  | **HANDS-ON TASK Have students install & and torque cylinder head (s).** |
| | 43. **SLIDE 43 EXPLAIN Figure 37-41** Typical cylinder head tightening sequence.<br>44. **SLIDE 44 EXPLAIN Figure 37-42 Examples of cylinder head bolt torquing sequences**<br>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 |
|  | 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.<br>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.<br>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. |

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|  | 50. **SLIDE 50 EXPLAIN Figure 37-48** Both crankshafts have to be timed on this engine and timing belt also drives water pump.<br>51. **SLIDE 51 EXPLAIN Figure 37-49** Some timing chains have plated links that are used to correctly position the chain on the sprockets.<br>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.<br>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). |
|  | **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.<br>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.** |

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|   | **A cylinder leak-down test can be used to find a valve that has not been adjusted correctly (i.e., too tight).**<br><br>**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.<br>**57. SLIDE 57 EXPLAIN Figure 37-55** exhaust manifold gasket is used on some engines. It seals the exhaust manifold to the cylinder head.<br>**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<br>**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.)**<br>**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.**<br>**Installing a vibration damper with a hammer can damage vibration damper. This damage could cause catastrophic failure of damper.**<br><br>**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.<br>**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.<br>**62. SLIDE 62 EXPLAIN Figure 37-60** Oil should be seen flowing to each rocker arm as shown. |

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|  | **HANDS-ON TASK: Have students install water pump.** |
|  | **63. SLIDE 63 EXPLAIN Figure 37-61** Heat tabs can be purchased from engine supply companies |
|  | **When using a chassis dynamometer, drive tires should have the same circumference and inflation. This will help prevent the vehicle from wandering on rollers.** |
|  | **64. SLIDE 64 EXPLAIN Figure 37-62** 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. |
| | **65. SLIDE 65 EXPLAIN Figure 37-63** chassis dynamometer is used to measure torque at the drive wheels. There is a power loss through the drive train so the measured values are about 20% less than when measuring engine output at the flywheel using an engine 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** magnetic pickup being used to monitor engine speed when the vehicle is being tested on a chassis dynamometer. |
| | **67. SLIDE 67 EXPLAIN Figure 37-65** Because horsepower is calculated from measured torque, the horsepower and torque curves should always cross at exactly 5,252 RPM |

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|   | **DEMONSTRATION: Show the standard formula for calculating horsepower: HP = RPM x Torque/5,252**<br>$BHP = \frac{F \times 6.28\,RN}{33{,}000_t} = \frac{FRN}{5252} = \frac{Torque(T) \times RPM}{5252}$<br>$BHP = \frac{Torque(t) \times RPM}{5252}$<br>D distance<br>F dynamometer load in pounds<br>R effective length of the lever (in feet) radius arm of dynamometer<br>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)** |
|  | **68.SLIDES 68-75 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.** |
|  | **HOMEWORK**<br>**Crossword Puzzle (Microsoft Word) (PDF)**<br>**Word Search Puzzle (Microsoft Word) (PDF)** |

Crossword