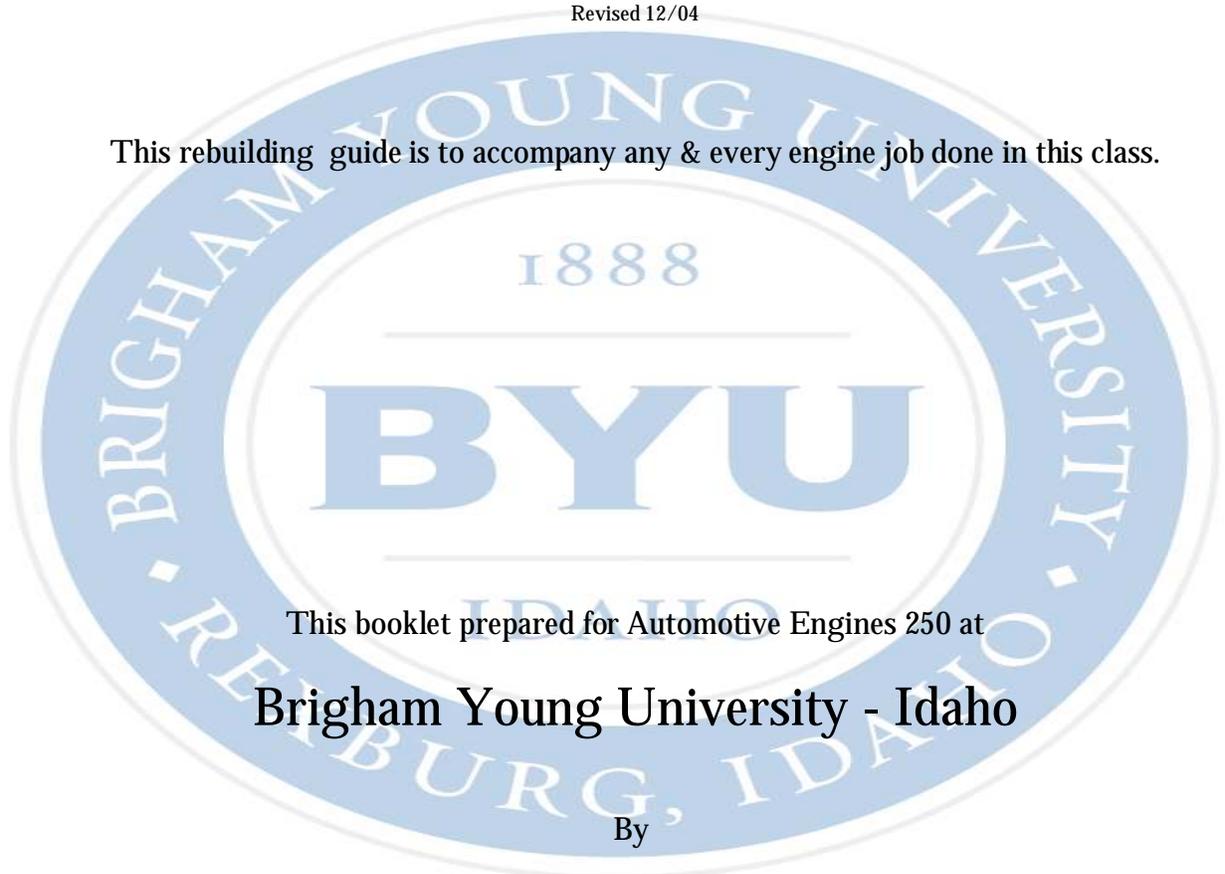


Automotive Engine Rebuilding Guide

Auto 250

Revised 12/04

This rebuilding guide is to accompany any & every engine job done in this class.



This booklet prepared for Automotive Engines 250 at

Brigham Young University - Idaho

By

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Engine Make _____ Engine Size _____ # of Cylinders _____

Year & Month of Vehicle _____ Model of Vehicle _____

I. General engine specifications:

Bore x Stroke _____ Compression ratio _____

Oil Pressure _____ Coolant Capacity _____

Brake horse power _____ Oil/Crankcase Capacity _____

Spark Plug Gap _____ Distributor Rotation _____ Firing Order _____

II. Block & Crankshaft Specs:

Piston to Cylinder Wall Clearance _____

Piston Ring End Gap or Butt Gap _____ (Compression rings)

Piston Ring Side Clearance _____ (Compression rings)

*Cylinder Taper (Max. Allowable) _____

*Cylinder Out of Round (Max allowed) _____

*Deck & head Warpage max. allowed ____/____

Connecting rod journal Clearance _____

Connecting Rod Journal Size _____

*Connecting Rod Side Clearance _____

*Rod Journal Out of Round (max) _____

*Rod Journal Taper (max) _____

Main Journal Size _____

Main Journal Clearance _____

*Main Journal Taper _____

*Main Journal Out of Round _____

*Saddle Alignment _____

Crankshaft End Play _____

III. Cylinder Heads:

Intake Exhaust

Stem to Guide Clearance _____

Stem Diameter _____

Valve Face Angle _____

Valve Seat Angle _____

*Valve Margin (Min. Allowed) _____

Installed Spring Height _____

Spring Pressure @ Height valve closed _____

Spring Pressure @ Height valve open _____

Spring Free standing Height _____

Valve Lash: Adjustment spec. _____

IV. Torque Specs:

Main Bearings _____

Connecting Rods _____

Cylinder Head Bolts _____

Camshaft Caps (if applicable) _____

Exhaust Manifold _____

Intake Manifold _____

Flywheel Bolts _____

Harmonic balancer bolt _____

Clutch/torque converter bolts _____

Rocker Arms/Shaft _____

(If applicable)

Look-up and print all engine 1) SPECIFICATIONS and 2) BULLETINS from PROSIS program.

*Means this spec is typically hard to find and the instructor will give it to you in class.

V. Torque Sequences/Diagrams:

1. Head Bolt Torquing Pattern

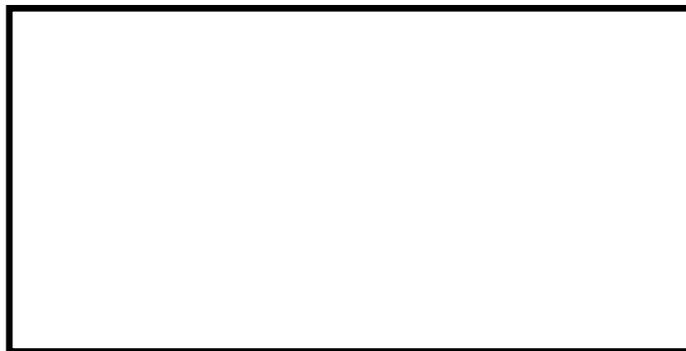


Cylinder Head Bolt Pattern

(Draw bolt heads with their #)

2. Timing Marks: Draw how the camshaft, crankshaft, balance shaft, etc. are (1) arranged (2) where each timing mark is located with #1 piston at TDC.

3. Intake Manifold Torque Pattern:



Draw torque pattern with bolt #

Engine Project Guide

Name _____ Engine _____

I. BEFORE rebuilding an engine, first analyze/test engine condition, if its not “seized”.

Engine Tests Before Repairs	1	2	3	4	5	6	7	8
Compression Test Results								
Cylinder Leak Test Results								

A. Remove engine from vehicle.

NOTE: Be certain to label or mark hoses & connections ! You may even wish to use small plastic bags to group manifold bolts together, water pump bolts, etc. Take pictures, mark or label everything you possibly can. You’ll be glad you did.

II. Disassembly:

A. Mount the engine on a stand to perform the following:

1. Remove the fuel system, intake and exhaust manifolds.
2. Remove the oil pan, rocker covers, accessories, etc.
3. Mark the direction that components were originally mounted to the engine.
4. Position crankshaft in TDC #1 compression stroke.
5. Mark the position of the distributor's housing and the rotor before removing it.
Make GOOD marks !!! Distributor pump on diesel applications!!
6. Remove front cover, timing chain/belt, etc. Note how the marks on the cam, crankshaft balance shaft, etc. line up.
7. Draw how these gears/sprockets are arranged on page 2 of this booklet.

_____ 1st Instructor check point

8. When removing the cylinder heads loosen the head bolts reverse of tightening sequence.
9. Note the direction that the cylinder head gaskets were originally installed.
** NEVER use a torque wrench to loosen bolts. Only use one tighten or torque bolts.
10. Remove the oil pan at this time as well.
11. This is a good time to get the casting numbers of the following components.

Engine Block casting# _____ Cylinder Head casting# _____

Connecting Rod casting# _____ Crankshaft casting # _____

Measure or mark the following components:

B. Warpage	Right Bank	Left Bank	
Cylinder heads			

Cylinder block deck							
Piston to Deck height clearance...Dial caliper	(Measure only 1 - 2 cyl.)						
Connecting Rod side clearance....feeler gauge							
Number each connecting rod...if they're not numbered							

___ Instructor check point

C. Piston Removal

1. Number the connecting rod caps, rods and main bearing caps using number stamps.
2. Now remove the connecting rod nuts/bolts. Protect the crankshaft journals using rubber hose pieces on the rod bolts.
3. Keep all rod caps and rods paired together
4. Next, measure crankshaft end play....dial indicator or feeler gauge.

Crankshaft End-play	Specification: _____	Reading: _____
---------------------	----------------------	----------------

D. Main Bearing caps:

1. Remove the main bearing caps. Note the direction they face. Also, keep them in order number them if they are not numbered already. (Number stamps)
2. Tape the woodruff key to the crankshaft OR remove it and store it so it won't get lost
3. Remove the crankshaft from the block
4. Remove only the center THREE engine bearings from the block. Put the crankshaft back into the block and with a dial indicator, measure for crankshaft run-out.

Reading: _____

5. Remove the Cam bearings...careful not to scratch the cam bearing bores. Also note and draw a picture of where the oil holes line up to the block. IMPORTANT!

--	--	--	--	--

6. Remove freeze & gallery plugs. The engine block should be totally disassembled.
7. With the instructor, identify *how oil flows through the engine*. Show where the oil flows from the oil pump, to the filter, through gallery passages, to the cylinder head, rockers, etc. *This is a good exercise if you want to understand engine lubrication.
8. Bake the block in the OVEN (600 degrees F) over night.
-Then put it in the HOT TANK the next day. Soak it for 1 - 3 days.
9. After "hot tanking" the block, put it in the green part spray washer OR use the steam cleaner to finish cleaning the block.
*Spray the block with WD - 40 *immediately*. WD-40 dispels water and prevent RUST.
10. Wipe the block somewhat dry with a towel and check for cracks with the MAGNA-FLUX. Magna-Flux the:
 1. cylinders &
 2. freeze plug bore areas.

___ Instructor check point

III. Measurements: Perform the following measurements to determine necessary repairs.

A. Cylinder Block Measurements	1	2	3	4	5	6	7	8
Compression Ring Side Clearance Top Ring								
Spec _____ Second Ring								
Compression Ring End Gap.....Feeler Ga.								
Cylinder TaperCylinder Bore Ga.								
Cylinder Out of Round....Cylinder Bore Ga.								
Cylinder Size....Actual Size (Micrometer w/ bore gauge)								
Piston Size....Actual Size (Micrometer)								
B. Piston to Cylinder wall Clearance (Subtract cylinder dia. from piston dia.)								
Main Bearing Saddle Alignment	1	2	3	4	5			
Main Bearing Bore Out of Round & Taper Torque main caps... Use Cyl. Bore gauge								

Look for any scratched, gouges, etc. in each lifter bore. Record below any problem bores

Lifter Bore Condition																		
-----------------------	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

___ Instructor check point

C. Crankshaft Condition (Micrometer)	1	2	3	4	5			
Main Journal Size...Compare to Spec. _____								
Crankshaft Run-out....bend ? _____ (This was done earlier)								
Main Journal Out of Round (Micrometer)								
Main Journal Taper								
Inspect Thrust Surfaces of the Crankshaft								
Rod Journal Measurements	1	2	3	4	5	6	7	8
Rod Journal Size ...compare spec.								

Rod Journal Out of Round								
Rod Journal Taper								

D. Balance Shaft Journal Measure	1	2	3
Journal Diameter			
Journal Taper/Out of Round			

E. Pistons & Rods	1	2	3	4	5	6	7	8
Condition of Piston, Lands, skirt, boss area, ring grooves, etc.								
Connecting Rod condition ? Check for Bent or Twisted rods								
Connect. Rod Bore Out of Round Remove bearings, torque caps.								
Mark "Front" of Connecting Rod in relation to piston direction !!								
Press the rods from pistons (See instructor before pressing)								

1. The condition of the block should be able to be determined at this time.
What machining operations are necessary?

2. What repairs or work needs to be done to the pistons & rods? _____

3. What needs to be done to the crankshaft? _____

****Send the block, crankshaft & rods out to be machined as needed.***

_____ Instructor check point

F. Measure both the intake and exhaust manifolds at this time for warp:

1. Maximum exhaust manifold warpage .008 = depending on length

2. Maximum manifold warpage allowed: .005 = depending on length

Manifold WARPAGES	Intake:	Exhaust:	
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1. What needs to be done with the manifolds? _____

Measuring Continued: Inspect the valve train

1. Disassemble the camshaft, lifter and rocker assemblies at this time.
2. DO NOT remove the valves from the cylinder head at this time.

G. Camshaft					
Camshaft Run-out (V-blocks w/dial indicator)					
Camshaft Saddle Alignment (OHC..use straight edge)					
Cam Journal Size	1	2	3	4	5
Cam Journal Out of Round					
Cam Journal Taper					

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Cam lobe high																
Lobe base/low																

3. What needs to be done with the camshaft ? _____

____ Instructor check point

IV. CYLINDER HEAD (s):

A. Inspect the rocker arms, any replacement needed? _____

Look where valve stem tip contacts the rocker, where pushrod contacts the rocker and at the fulcrum area (where the rocker pivots...any scratches?)

	1	2	3	4	5	6	7	8
Rocker Condition ?								

C. Lifters Condition ?														
------------------------	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Look for wear especially on the bottom side of lifer...convex where, scratches, etc.

____ Instructor check point

D. Measure "Spring Installed Height" before disassembling the valves. Use a steel ruler.

	1	2	3	4	5	6	7	8
Spring installed Height								

E. Next remove the valve springs/keepers and:

1. Measure valve "Stem Height".
2. Use a digital caliper or the "Valve Stem Height Gauge" to do this. Record below.
3. Measure the other valve related items at this time as well = record below.
 - a. when measuring the stems for wear, measure in 4 different places
 - b. Quite often, the valve springs are replaced
 - c. Stem height is a critical measurement on valve trains/engines that don't have adjustable valve lash. Especially OHC "bucket lifter" systems.

	1		2		3		4		5		6		7		8	
F. Valves Chart	In	E														
Stem height at this time																
Guide hole Size																
Stem Dia. ...wear																
Valve head "Tulip"?																
Stem/guide Clearance																
Seat Condition ?																
Spring Squareness																
Free height																
Spring Tension																
Have the <i>guides</i> SERVICED, Grind your VALVES and then grind the valve SEATS.																
<i>Margin after grinding *</i>																
<i>Stem height after grind*</i>																

<i>Seat width after grind</i>																	
-----------------------------------	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

G. What needs to be done to the Cylinder head (s), valves, springs, keepers, etc.? _____

____ Instructor check point

H. With the cylinder heads completely disassembled:

1. Magna-flux the combustion chambers, look for cracks between valve seats & spark plug holes. _____
2. Inspect cylinder head surface, threaded bolt holes, etc. _____

I. You should also inspect the following:

1. Spark Plug Thread areas _____
2. Timing chain/belt sprockets for wear _____
3. Valve keepers (replace these generally) _____

* You now have enough information to send out the head(s) for machining.

** It is quite common that the heads will need new guides, resurfacing where the head gasket goes and maybe some valve seat repair.

Send the head(s) and manifolds out to be machined as needed.

____ Instructor check point

* While your block or heads are off to the machine shop, soak/wash/clean all pans, covers, tumble/ buff or clean bolts, etc. This will speed up the reassembly process.

This concludes engine disassembly, inspection and recommendations for needed machine work.

Shopping List

*All bearings, gaskets, lifters, camshaft, Rings, and pistons come in a rebuild kit.

**The following is a list of possible components that may need replacing or servicing.

I. Engine parts:

- _____ Piston & Rings
- _____ Connecting rod Bolts
- _____ Connecting Rod (s) replace
- _____ Connecting Rod Recondition
- _____ Polish Crankshaft
- _____ Crankshaft Grind
- _____ Cylinder Head Work:
 - _____ Guides _____
 - _____ Valves _____

 - _____ Springs _____

 - _____ Keepers _____
 - _____ Surface cylinder head
 - _____ Other: _____
 - _____ Shims (VSI) _____
 - _____ Block Work _____
 - _____ Valve stem seals

II. Cooling System:

- _____ Water Pump
- _____ Thermostat & Gasket
- _____ Radiator cap
- _____ Hose Clamps _____
- _____ Radiator hoses
- _____ Heater hoses
- _____ Anti-freeze...# of gals. _____
- _____ Fan Clutch
- _____ Radiator service/replace _____
- Belts:

III. Fuel System:

- _____ Fuel pump
- _____ Fuel lines
- _____ Fuel Filter
- _____ Other _____

IV. Misc.

- Motor Oil _____
- _____ Oil filter

- _____ Air filter
- _____ PAINT....color _____
- _____ Battery Cables
- _____ Motor Mounts
- _____ Power Steering hoses
- _____ Power Steering Fluid _____
- _____ Gear Oil _____
- _____ Clutch replacement set
- _____ Surface Flywheel/replace Flex plate
- _____ Clutch bolts/crankshaft bolts

- _____ Loc-tite
- _____ Torque Converter...pump seal
- _____ Auto Trans Fluid _____

- _____ Oxy Sensor

V. Ignition System

- _____ Spark plugs

____ Alternator
____ Power Steering
____ Air Cond.
____ Smog/AIR pump
____ Other _____

____ Ignition wires
____ Dist. Cap & Rotor
____ Other _____

BYU-Idaho Automotive Engine Assembly Guide

*It would be an EXTREMELY good idea to photocopy from a repair manual or print the engine section from Mitchell / Motor (All Data) at this time. Also, print a copy of the PROSIS engine specs and bulletins for your engine project.

I. HEAD & VALVES

1. You may choose to do your CYLINDER HEAD WORK while your block is off being machined. Before you grind faces and seats measure “valve stem height” unless your are certain that is has already been done. PAGE 8

2. Before grinding your valves inspect for: (1) margin thickness, (2)for valve stem wear and (3) bent stems etc.
 - A. Grind your valves
 1. Typically, “butt” grind the valve stems if they need it.
 2. Bevel grind (chamfer) the tips...just enough to remove the mushroom.
 3. Grind the face of each valve if they appear to have enough margin.
Grind just enough to remove all pits and recessions.

3. Last of all service/grind the seats. Don’t grind the seats until the guides have been serviced.

4. After grinding both the seats and faces check “valve stem height” again. See page 8.

5. Grind the stem tips if the valve stem measurement is too high.
*this is extremely important if your rocker arms are *not adjustable* OR if you are working on an OHC engine with “*bucket*” lifters.

____ Instructor check point

6. Are you replacing the valve springs? ____ yes ____no.
Are you replacing the valve keepers? ____yes ____no.

7. WASH the head and camshaft. with hot soapy water before assembling the head (OHC).

A. Lubricate your valve stems and install your valve guide seals. Use a protector for installing the guide seals and shown in the video in class. There may be one provided in your engine kit...see the instructor. Now assemble your valve springs and retainers. Assemble ONE valve & spring assembly. Measure the valve spring installed height. Have the instructor check your work.

_____ Instructor check point

B. Check all valve “ spring installed heights”. This ensure proper spring tension.

	1		2		3		4		5		6		7		8	
	I n	E	I n	E	In	E	In	E	In	E	In	E	I n	E	I n	E
Spec. _____																

_____ Instructor check point

B. Stem height should have been taken care before spring installed height.

C. With water, brake spray...anything that is liquid... see if the valve face and seat actually hold a seal/fluid for at least 30 seconds. Do this with the head upside down.

_____ IMPORTANT Instructor check point

**** Cylinder head(s) should be completely assembled at this time.
Set them aside until you're ready to install them**

Did you:

1. Lubricate all valve stems ?
2. Install all valve guide seals ?
3. Measure valve stem height correctly ?
4. Measure valve spring installed height correctly ? (within .030 of spec.)
5. Check to see if the valve seat to face contact area can hold a seal/fluid ?
6. Before any of the above procedures, did you wash the head, camshaft, etc.?
7. Did you use new keepers ? (unless it was determined that the old ones could be reused)

II. BLOCK PREPARATION

1. Inspect the block for cleanliness, packaging/installation instructions, etc.
Once the engine components have returned from the machine shop:
 - a. CHASE all the threaded holes on the block. Especially the cylinder head bolt holes.
 - b. Oil pan bolts, water pump bolt holes should at least have a bolt “run through” them.
 - c. DO NOT chase any Oil gallery or Water jacket holes....these are PIPE THREAD.
These threads are tapered and have a different thread pitch than do bolt threads !
 - d. Emery cloth/sand all freeze plug bores. Do this before washing your engine block.
 - e. Clean/buff the deck surface at this time so it will be clean for a good head gasket seal.
2. Give your *block, rods and crankshaft* a “bubble bath”. Run a brush through ALL the oil holes. Don’t wash your block until you’ve finished honing, chasing the threads for cylinder head bolts, etc.
 - a. When washing, use plenty of hot water, scrub every possible passage, bore, and surface that will come in contact with oil, a bearing or a gasket.
3. After washing your block, IMMEDIATELY spray down the cylinders, lifter bores and main bearing saddles with WD-40 or Diesel (penetrating fluid, anything). Then blow it completely dry. This way the cast iron won’t rust.
 - a. Wipe all bearing, cylinder bores and head/deck surfaces with an oily towel until the towel comes out white OR no more “gray” shows up on the towel. The “gray” indicates there is still some grit or machine filings left.

_____ Instructor check point

4. Typically the camshaft bearings are installed first (V-type engines)
You may have to remove the engine from the engine stand for this procedure.
** Lubricate and install the camshaft once the bearings are in. This is to see if the cam will rotate freely.
5. Next install the rear freeze and oil galley plugs.
 - a. Use some brake cleaner to clean out the freeze plug bores. This is so the sealer can do its job. Use "Gasket Eliminator" or Aviation Form A Gasket (a non-hardening type of sealer).
6. Now put your engine on an engine stand.
 - a. Finish installing all plugs...oil and freeze type.

- b. If a freeze plug bore is “nicked” or gouged, you may have to use JB Weld to fill in the damaged area.
- c. Let the instructor inspect... ensure that ALL plugs are in place.

____IMPORTANT Instructor check point

III. CRANKSHAFT INSTALLATION

1. Now that the crankshaft has been washed, lightly wipe all the journals with an oily CLEAN towel. “Mic” the crankshaft journals if the crankshaft was “ground” just to compare to bearing size. Sometimes machine shops make mistakes... double check to see if the crank was ground .010" under and make sure the bearings are .010" under size (example).

Micrometer Readings	1	2	3	4	5	6	7	8
Connecting Rods								
Mains								

2. With CLEAN HANDS insert the upper main bearings into the engine block.
 - a. Typically, the main bearing halves that are installed in the block are the ones with a groove down the middle of the bearing.
 - b. Apply assembly lube to these upper bearing halves, journal side of bearing only.
 - c. Don't forget to lubricate the thrust bearing surface too.
 - d. Pay attention to the bearing locating lug and where you position it.

NOTE: handle the bearings by their sides. Try not to touch the bearing surface at all.

____Instructor check point

3. Lay the crankshaft into place being careful of the thrust bearing surface.
4. Insert the lower main bearings into the bearing caps (CLEAN HANDS).
 - a. Plastigage/measure all the main bearings at this time.
 - b. With an oily towel, wipe some OIL onto the main bearing cap bolt threads. Do not install these bolts “dry”.
 - c. You need to know what the actual bearing to journal clearance is. This effects oil pressure !
 - d. Main bearing bolt torque Spec. ? _____
 - e. When torquing these bolts, do it in two increments (75% of torque and then 100%)

	1	2	3	4	5
Main Bearing Clearances ?					

5. After plastigaging,
 - a. Try to determine the best time when to install the rear main seal. Get some tips from the instructor on how to properly “seal” around it.
 - b. Reinstall the main bearing caps. Note the locating lug/bearing tab direction.
 - c. Don’t forget to lubricate the lower bearing halves with some assembly lube.
6. Install all the bearing caps and turn the bolts down into place with a ratchet by hand. Tighten the thrust bearing cap to about 5 - 10 ft. lbs. (just snug). Align the thrust bearing using two pry bars Or the hammer method. Now torque the thrust bearing cap to 50% of final torque and then to 100%. This step aligns the *thrust bearing’s surface*.

____Instructor check point

7. Now tighten the remaining main bearing caps. Torque these bearing caps to 50% of the final torque. Torque the center cap FIRST! Then work from the center cap out to the outer two caps last.
8. Now that the crankshaft is all in place, with a hammer, “tap” each main bearing cap bolt head a couple of times. Now retorque them to their final spec. again. (Do not loosen them...simply set the torque wrench to 100% of torque) Taping them with a hammer can sometimes relieve some stress. SEE the INSTRUCTOR if you have questions.
9. Now check the rotating torque of the crankshaft with a “dial” torque wrench.
It should measure 5 ft. lbs. or less.

Rotating torque reading: _____

10. Measure crankshaft “end-play” Spec _____ Actual reading _____

____Instructor check point

IV. PISTON & ROD INSTALLATION

1. Connecting rods:
 - A. If the rods were reconditioned, measure all the connecting rod bores WITHOUT the bearings in place. Be certain to torque the caps in place then using a dial bore gauge to measure the rod bores. (.0007" tolerance)
You are simply double checking the machines shops work. We have to know that all the bores are the same diameter or size. (Machine shops can make mistakes)
 - B. If the rods were not reconditioned, skip this step.

Rod bore measurements	1	2	3	4	5	6	7	8
Check out of round & Taper	/	/	/	/	/	/	/	/

2. Fitting Pistons:
 - a. Measure each PISTON with a micrometer and write, on the top of the piston, with a marker exactly what its diameter is. (To four decimal places)
 - b. With the dial bore gage determine which cylinder(s) are the biggest and smallest so that

the larger piston(s) will be installed to the larger bore(s), smaller pistons will be installed to the smaller bores, etc.

3. Write the cylinder number onto the piston once you've decided which bore it will go into.
4. With the help of the instructor, install your connecting rods onto to the pistons using the rod heater, if they are the "press-in" style of connecting rod.
 - NOTE 1: try to match the number on the connecting rod with the number on the piston.
 - NOTE 2: Correctly orient the connecting rod to the piston (how were they facing when you pressed them apart..... see page 6).
5. Lubricate the piston pins after they have been installed with 30 wt oil.

____Instructor check point

6. Piston Rings:
 - A. Measure the "ring end-gap" of 3 of the "top grove" and 3 of the "second groove" compression rings. Compare to spec. Perform this measurement three inches or so from the top of the cylinder. (You're trying to determine if you were sold the correct rings)

Spec. _____ Top rings _____/_____/_____ 2nd rings:_____/_____/_____
 - B. Next install piston rings.
 1. Install the oil control ring assembly first. First install the "expander" and then SPIRAL on the two oil "rails".
 2. Next install the two compression rings. DO NOT spiral these rings on. Use ring pliers when installing compression rings onto the pistons!!
**Follow any instructions as given from the package the rings came in. Make sure that the right ring get puts into the right groove & that each ring is right side up !!!
 - C. Check ring groove to ring clearance! Do this to ALL piston rings. Use a feeler gauge. What's most important is that none of the rings " bind" in their respective groove. They should be 100% free in their groove. Spec. _____
7. Wipe all of the cylinder bores with oil in preparation of piston installation. This is a final cleaning as well as lubricating procedure. (I know you did this earlier...do it AGAIN !)

____Instructor check point

- With the instructor.... do the next three steps.... #8, #9 and #10. Also, when installing pistons, completely install one piston assembly and then rotate the crank, install the next piston, rotate crank, etc. This is the *correct procedure* to follow when installing pistons.
8. With #1 piston insert the upper connecting rod bearing (CLEAN HANDS). Lubricate the bearing and place protective boots over the rod bolts
 9. Dip the piston & ring assembly in oil so that the rings are well lubricated.
 - a. Mount the piston and rod assembly in a soft vice.
 - b. See that the oil & compression ring end spacings are properly spaced.

- c. Now compress the rings using a piston ring compressor.
10. Piston installation:
- Position the crankshaft's connecting rod journal at BDC before "knocking" the piston down inside its bore.
 - Hold (or even tap with a hammer) the ring compressor down against the deck surface *before* striking the piston head with a hammer handle. Tap the piston "IN"
 - Once the piston is in it's bore you should be able to push the piston down further, to position the rod around the crankshaft journal, by hand.
 - DO NOT put #1 piston into #3 cylinder or #2 into # 8 cylinder, etc. Keep everything matched according to number !!
11. You are now ready to Plastigage the bearing's oil clearance.
- After measuring the bearing clearance, lubricate the lower bearing half & reinstall the connecting rod cap. Bearing to journal clearance are must be correct, if not see the instructor. Record your plastigage readings below. You need to know what the actual bearing to journal clearance is. This effects oil pressure !
 - Make certain that the rod bearing cap is installed in the RIGHT DIRECTION !! (bearing lugs are located on same side of rod bore)
Serious problems can result if you don't pay attention during this process.
 - After plastigaging the rod journals use just DROP of blue "Loc-tite" on the threads of the connecting rod bolts. Torque the two rod cap nuts to 50% of their final torque and then torque them to 100% of their torque value. (Loc-Tite cures in about 5 min)

Connecting Rod Bolt/Nut torque specification: _____

Rod Journal Clearances Plastigage each journal	1	2	3	4	5	6	7	8
	/	/	/	/	/	/	/	/

 IMPORTANT Instructor check point

12. After the first piston has be completely installed, rotate the crankshaft to get a feel of how "free" the crank turns. At the same time, position a crankshaft rod journal at BDC in preparation for the next piston to be installed.
13. Install the next piston (s) exactly how the first one was installed. Rotate the crank between each piston installation. Note, as each additional piston installed, the crankshaft will become a little harder to rotate. It should never get so difficult that it will not rotate.
When all pistons have been installed, measure the amount of torque it takes to rotate the crankshaft. It should measuree somewhere between 20 - 30 ft. lbs. This spec. includes 4, 6, or 8 cylinder applications.

Measured rotating torque: _____

14. When all the pistons have been installed leave the crankshaft in TDC #1 position. This will

save time for timing chain/belt and distributor installation.

____ Instructor check point

15. With all the pistons installed, it is time to lubricate and install the camshaft if the engine is “push-rod” type.
 - a. Name the main ingredient in camshaft lube. _____
 - b. Lubricate each lobe 100%. Lubricate the journals too.
 - c. With the cam installed see if the cam rotates freely... no binding.

V. VALVE TIMING SET-UP

1. Now install the timing gear & chain/timing belt. If it is a chain, soak it in oil for 15 min. before you install it. Let the instructor INSPECT the TIMING MARKS to ensure they are aligned properly. Blue "Loc-tite" the cam sprocket bolts.
2. Prime and install the oil pump (as shown in the video).

____ Instructor check points

VI. CYLINDER HEAD INSTALLATION

1. Its now time for cylinder head installation. Head and deck surface cleanliness is a MUST. Use some “Brake Clean” to clean the oil or other contaminants off the head & deck surfaces. In order for head gaskets to seal they have to have a clean, oil free, flat, surface.
 - a. Check or orient the new head gasket on a clean, oil free surface.
 - b. There may be a “Top” or “Front” stamped on the gasket. You could inspect the old gasket to see how they were originally installed.
 - c. Ensure the alignment dowels are on the block. These hold the head gasket in place.
 - d. QUESTION: are your head bolts clean and ready for installation ??
 - e. Determine if it matters which head goes on which bank. The only reason it usually matters has to do with bolting on accessories (Power steering, alternators, etc.)
This may save you time...

____ Instructor check point

2. Install the head gaskets “dry”(usually). Once the gaskets are in place, set the cylinder head onto the deck. Be sure the dowels & dowel holes line up! Generally, no sealer is to be used. See if the instructions that came with the head gasket states differently.
** On V-8's the there is one thing to consider when deciding which head goes on which side coolant temp sensor location AND brackets for accessories.
3. Lightly oil the head bolts threads, with an oily towel, if the bolts are going into a “dry” hole. If they are going into the water jacket (wet hole) use Blue or Red “Loc-tite” on the threads to

seal coolant from migrating up the head bolt threads.

4. Follow manufacturers instructions for Torquing cylinder head bolts. You must follow the *torque sequence/pattern*. Also, the head bolts should be torque in three-four increments, unless the manufacturer has specific instructions. Use new head bolts when the manufacturer suggests it or if the bolts are of a torque to yield type, replace them.

Torque Spec: _____

Draw a picture of the torque pattern:

5. After torquing the cylinder head bolts, move on the timing belt/chain installation if the engine is of OHC design. Refer to a repair manual for instructions and placement of the marks on gears and timing chains, etc. Let the instructor inspect timing components/alignment.

____Instructor check point

VII. MANIFOLDS, Pre-lubrication and PANS /COVERS

1. With the cylinder head, camshaft, timing belt/chain in place you are now ready to install the push-rods, rocker arms etc. Use some engine assembly lube to lubricate any pivot point where the push-rods contact the lifters and the rockers. Also where the rockers pivot on their fulcrum.

____Instructor check point

2. When you're certain that the intake manifold is clean and the gaskets all match-up, all bolts have been cleaned, get the instructor to inspect your set-up and give you few tips for installing an intake manifold gasket. These gaskets are typically installed dry. If the intake gasket is a "valley pan" type of gasket, some "Copper Coat" could be used.

**Sometimes the intake gasket comes with some black silicone for the water jacket passage.

____Instructor check point

3. Before installing the oil pan or valve covers, "*PRE-LUBE*" the engine with the pressure tank or by spinning the distributor oil pump drive shaft. This will:
 - a. Pre-lubricate the engine
 - b. If any oil gallery plugs were left out, you'll now discover which one(s).
 - c. This will test to see IF the crankshaft, lifers, rockers, camshaft bearings, etc. are all getting oil.

NOTE: install an oil filter before pre-lubing. Also, on Chev SB you'll need to install the distributor in order to maintain proper pre-lube oil pressure.

4. Now you're ready for all the pans. Make sure all the gaskets match-up.
 - a. Ensure that all bolts are present CLEAN.
 - b. Peen or flatten the bolt holes areas on the oil pan and valve covers if necessary.

5. You may wish to paint the engine at this time. Typically, you should have to paint aluminum components... they won't rust. Wipe/clean the block and other areas where you want the paint to stick with a towel and brake-clean.

VIII. Misc. Assembly tips:

1. The remaining reassembly procedures may not follow any particular order or because of the various engine designs. Here is a list of several things you need to consider:
 - A. Install the exhaust manifold (s)...no sealers are to be used on these gaskets.
 1. The silver side of gasket goes "out" or towards the manifold.
 2. Make certain that the exhaust manifolds are clean and "flat" ! (.005 warp max.)
 3. Good technicians use "Anti- Seize" on exhaust manifold bolts.

 - B. Install distributor with the engine at TDC #1 compression stroke.

 - C. Check the condition of the Harmonic balancer...replace if questionable. Examine the oil seal surface area of the harmonic balancer. I may need a "speedy sleeve".

2. Consider the following when assembling the accessories onto the engine.

-Install water pump(Not a Rebuilt unit)	-New fuel pump
-New spark plugs (Not Auto-lite...)	-Camshaft
-New motor mounts	-Lifters
-Torque converter, front pump seal	-Power steering hoses
-New oil sending unit	-New ignition wires
-Have the radiator serviced	-New hoses and hose clamps
-New drive belts	

3. When installing the flywheel/flex plate do NOT use a air gun to tighten the bolts...this can distort the rear main seal's surface. Also, use some sealer or loc-tite on these bolts...oil leakage may result if you do not do this.

4. On Ford Small Blocks, don't forget the sheet metal dust cover. It goes ON before the flywheel does. Many students have found this piece after the engine has been installed in the vehicle.

5. Examine the starter ring teeth.... and also the clutch, throw-out bearing, pilot bearing, etc. = do any of these things need replacing ?

- C. Run engine at a high idle again for approx. 15 minutes _____
- D. Shut down the engine and check:
 - 1. Motor oil _____
 - 2. Power steering _____
 - 3. belt tensions _____
 - 4. Look for leaks of any kind under and above engine _____

IV. Start engine up again and test:

- A. Battery charging voltage _____volts
- B. Ignition Total Timing at 2,500 RPM _____degrees
- C. Test drive the vehicle with the instructor
 - 1. Watch engine temperature, oil pressure, noises, etc. _____

Instructor's signature _____

Final inspection

- 1. Double check for leaks... look under and around everywhere.
- 2. Check the tightness of all hose clamps !
- 3. On a test drive, did you "break-in" the rings ?
- 4. Double checked ignition timing. _____degrees
- 5. Total ignition timing. _____ reading ? (Should be 40 + degrees)
- 6. Any lifter or valve train "ticking" noises ?
- 7. Any Trouble Codes in the PCM's memory ? _____ (yes or no) _____
- 8. Charging system voltage _____volts AND amperage _____ (VAT-40)
- 9. Check all Fluids AGAIN !
- 10. Tire pressures _____ psi
- 11. Brake linings Front _____ Rear _____
- 12. Drive-line bolts / CV boots
- 13. All under car fluid levels = transfer case, differentials, etc.
- 14. 2nd oil change completed ?
- 15. Customer Car Care sheet with mileage recorded on the dash of the vehicle ?

- 16. Vacuum, clean vehicle up
- 17. All lights, windshield wipers, etc.
- 18. _____
- 19. _____

Final Instructor's signature _____

Distributor Installation & Quiz (Extra Credit)

Name _____

Team # _____

Objective: Student will learn how to install an ignition distributor and adjust timing

I. List in sequential order, from the steps listed below, the procedures to install an ignition distributor for a gasoline powered four cycle engine.

- _____ Determine the direction of distributor rotation (CW or CCW) then drop the distributor into place. Remember, the drive gear has helical teeth.
- _____ Align the timing marks of the harmonic balancer & the timing pointer.
- _____ Find TDC Compression of #1 cylinder. To do this crank ("bump") the engine over a little at a time until compression is felt.
- _____ Remove the spark plug of #1 cylinder
- _____ Start the engine and set ignition timing with a timing light with the engine at IDLE and WARM.
- _____ When possible, align the pick-up coil teeth/pole piece with the reluctor teeth.
- _____ Install the distributor cap and rotor
- _____ Connect all the ignition cables (spark plug wires) to the distributor cap. Once again, determine the direction of distributor shaft rotation (CW or CCW).

II. Additional information:

- A. What is the firing order for this engine? _____

B. What is the timing specification for this engine ? _____

C. What is the engine idle RPM (curb idle) speed specification for this engine? _____

D. Important. What steps or procedures are to be followed when adjusting ignition timing for this engine?

-For example, do you have to disconnect any wires or hoses ? _____

-If so, what wire or hose(s) ? _____

-Is the engine supposed to be warm when making adjustment? _____

III. Install the distributor on this vehicle and make the engine RUN. Also properly set ignition timing.

Instructor's Signature