

LAB - Engine Rebuild

NAMES:

Engine Rebuilding is a required part of Level I Mechanics at GESS. Students may elect to rebuild their own engine at their own cost, or they may rebuild an engine belonging to or provided by the school at no charge.

UNDERSTAND AND ACCEPT THE FOLLOWING RISKS:

YOUR ENGINE:

- Many times it is not cost-effective to rebuild a very worn engine. You must make the call. Proper testing can help you decide before the engine is disassembled.
- Once an engine is taken apart, money must be spent on replacement gaskets and rings (at a minimum) to make it run again.
- There is no warranty whatsoever on engines rebuilt at the school. The school will not be held liable for anything that happens to your engine while at, or after leaving the school.
- It is in your best interest to complete the rebuilding of the engine faithfully and accurately.

SCHOOL ENGINE:

- Each group leaving an engine unassembled at the end of the course will have each student charged \$100 per hour per for me to reassemble the engine.
- Each group intentionally losing parts or intentionally assembling the engine incorrectly will have each student charged \$100 per hour for me to replace parts and/or reassemble the engine.
- This will also include travel time and additional costs for parts lost or destroyed during the student's involvement with the engine.

I would rather not charge you – But I would rather spend time with my family instead of reassembling your engine.

READ AND FOLLOW EVERY STEP IN THIS BOOKLET!
IF YOU ARE UNSURE ABOUT ANYTHING – ASK!
I REALLY ENJOY TEACHING YOU ABOUT ENGINES

Your engine is:

(Year)

(Make)

(Model)

(Engine)

LAB - Engine Rebuild

Students: 1. _____
2. _____
3. _____

Date: _____
Block: _____

FOLLOW THE INSTRUCTIONS

NO PARTS FROM THIS ENGINE SHALL BE THROWN OUT WITHOUT THE INSTRUCTOR'S APPROVAL

ENGINE IDENTIFICATION

Record ALL Block Casting Numbers & Identification on your engine:

SPECIFICATIONS

Find the following specifications You might not find ALL, but most are CRITICAL:

"Front Crank Pulley" is sometimes called "Vibration Damper" or "Harmonic balancer"

Not all engines have adjustable "Valve Lash," but instead have a "process" or a "torque"

Torque Specifications (*units!!!!*)

Intake Manifold bolts: _____
Exhaust Manifold bolts: _____
Flywheel/Flexplate bolts: _____
Cylinder Head bolts: _____
Connecting Rod bolts: _____
Main Bearing Cap bolts: _____
Front Crank Pulley Bolt: _____
Camshaft Sprocket bolt: _____
Rocker Arm (if applicable): _____

Valves and Valvetrain

Valve stem diameter: _____
Valve stem-guide clearance: I: _____ E: _____
Valve lash (Rocker clearance) I: _____ E: _____
Valve Lash Adjustment Procedure: _____

Pistons and Rings

Piston-to-bore clearance: _____
Piston ring end gap(s): Top: _____
2nd: _____

Crankshaft and Connecting Rods

Main bearing journal diameter: _____
Main bearing journal clearance: _____
Rod bearing journal diameter: _____
Rod bearing journal clearance: _____

SKETCH a diagram for setting **CAMSHAFT TIMING (ALIGNMENT)** on this engine (you will wish you drew this better later on):

STOP!!

INSTRUCTOR'S INITIALS:

PREPARATION

DO YOU WANT SUCCESS?

DO YOU WANT EASY?

NOTE:

- | | |
|--------------------------------------|---|
| 1. There is a way things come apart | 5. Use the service manual (NOT the owner's manual) |
| 2. There is a way things go together | 6. Everything has a purpose - there ain't nothing "random" in an engine |
| 3. You need to be very organized | 7. "It's just nuts and bolts" |
| 4. Take pictures | |

AVOID THE WRATH OF YOUR INSTRUCTOR

NOTE:

1. NO PARTS from this engine shall be THROWN OUT!
2. NOTHING on this engine shall be DESTROYED!
1. ASK FOR HELP – They pay me to help you *(if you don't ask, they still pay me)*

GET:

1. Containers for parts storage
2. Masking tape and Pen/Felt for labelling
3. Digital Camera for taking pictures of assemblies



You are ready to start

STOP!!

INSTRUCTOR'S INITIALS:

REMOVE THE CYLINDER HEAD

READ ME



OHV

Label and remove the pushrods & lifters – they must be kept IN ORDER

NOTE!

Some OHV engines set their LIFTER PRE-LOAD by pushrod lengths!

YOU MUST KEEP THE PUSH-RODS IN ORDER AND KNOW EXACTLY WHERE THEY CAME FROM!!

Remove the lifters from the block – otherwise they will fall out onto the floor later.

I'm totally going to make fun of you when I hear your lifters clatter on the floor.

See page 9

NO PARTS FROM THIS ENGINE SHALL BE THROWN OUT WITHOUT INSTRUCTOR'S APPROVAL

- **FOLLOW** the service manual procedure to remove the cylinder head from the engine.
 - **EVERY ENGINE IS DIFFERENT** – I cannot make this lab follow EVERY engine.
 - **ASK** if you are unsure.



KEEP EVERYTHING IN ORDER – KNOW WHERE EACH INDIVIDUAL PART CAME FROM!

- **ALL ENGINES** – You WILL be removing:
 - THE VALVE COVERS
 - THE INTAKE MANIFOLD
 - THE EXHAUST MANIFOLD(S)
- **SOME ENGINES** – You MIGHT be removing:
 - THE ALTERNATOR
 - THE DISTRIBUTOR
 - PUSHRODS
- **OVER HEAD CAM (OHC) ENGINES** – You **MUST** remove:
 - **IF BELT:** THE FRONT PULLEY, TIMING BELT COVER, AND TIMING BELT
 - See page 14 if you have to remove a Harmonic Balancer
 - **IF CHAIN:** CAMSHAFT SPROCKET
 - NOTE any missing or damaged HEAD ALIGNMENT DOWELS/PINS
 - LABEL EVERYTHING; THREAD FASTENERS BACK INTO THEIR HOLES

TAKE PICTURES!

You won't remember how it goes back together months from now!

You won't know what you **SHOULD HAVE** taken a picture of until you're putting it back together!

- ***NOW REMOVE THE HEAD BOLTS AND REMOVE THE HEAD(S)***

STOP!!

INSTRUCTOR'S INITIALS:

DISASSEMBLE THE CYLINDER HEAD

IF THIS IS ONE OF THE SHOP ENGINES, JUST DO ONE(1) CYINDER HEAD.

IF THIS IS YOUR ENGINE, DO BOTH

WEAR EYE PROTECTION

WEAR EYE PROTECTION

WEAR EYE PROTECTION

WEAR EYE PROTECTION

DO I NEED TO PUNCH YOU IN THE FACE?

WEAR EYE PROTECTION

WEAR EYE PROTECTION

WEAR EYE PROTECTION

WEAR EYE PROTECTION

THE VALVE SPRING WILL PUNCH YOU IN THE FACE!

WEAR EYE PROTECTION

WEAR EYE PROTECTION

WEAR EYE PROTECTION

WEAR EYE PROTECTION

NO PARTS FROM THIS ENGINE SHALL BE THROWN OUT WITHOUT INSTRUCTOR'S APPROVAL

- **DISASSEMBLE** the cylinder head according to the SERVICE MANUAL

EVERY ALUMINUM HEAD USES STEEL SHIMS UNDER THE VALVE SPRINGS DO NOT LOSE THEM!!!

ALL VALVES ARE ASSEMBLED WITH RETAINERS AND KEEPERS - DO NOT LOSE THEM!!!

READ THE STEPS IN THE MANUAL!

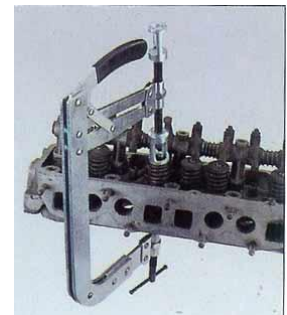
- **KEEP TRACK** of EACH valve, spring, retainer, keeper, rocker arm, push rod, etc. as appropriate
- **HAVE I** yelled at other kids already for not doing this? Convince me right now that you can read!
- **KNOW EXACTLY** where they came from. **KEEP THEM IN ORDER!**
- **WIRE-WHEEL** the carbon off the valves and mark their locations on them with a felt
- **LABEL** each part location – **KNOW** where everything goes!

OHV ENGINES: REMOVE the LIFTERS from the block, label their EXACT location! DO NOT LOSE THEM!

- **CLEAN** the cylinder head(s) and parts in the **SOLVENT TANK**. Clean again with the **Pressure Washer**, then blow dry with compressed air and spray with **WD40 AS SOON AS POSSIBLE!**
- Head must be **WHITE-GLOVE CLEAN**
- **THREAD FASTENERS BACK INTO THEIR HOLES SO THEY ARE NOT LOST**



Mr. Wellwood's Demo



STOP!!

INSTRUCTOR'S INITIALS:

INSPECTING THE CYLINDER HEAD

DESCRIBE the visual condition of ALL the valve stems, valve faces, valve tips, and rocker arms (if equipped). You are looking for any damage or excessive wear on any moving contact surface:

DESCRIBE the visual condition of ALL the valve retainers, valve springs, keepers. You are looking for any damage - these parts don't usually wear:

Pick your **WORST** looking intake valve, and your **WORST** looking exhaust valve

Using a **MICROMETER**, measure and record the smallest diameter of each valve stem (look for the most wear)



Copy Valve Stem Spec here:



Circle

Your Intake Valve Stem Smallest Diameter: _____

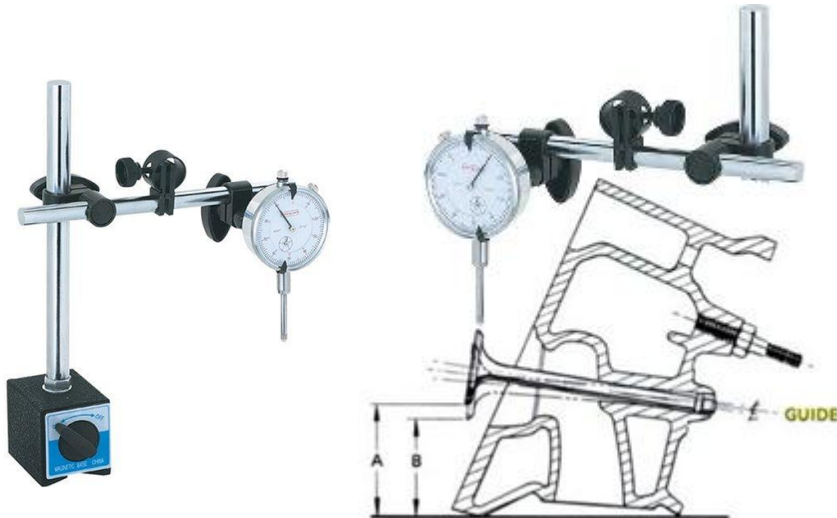
Your Exhaust Valve Stem Smallest Diameter: _____

Copy Valve Guide Clearance spec here:



Circle

ATTACH a **DIAL INDICATOR** with a **MAGNETIC BASE** to your cylinder head and measure and record the valve guide clearance of these two valves sitting in **THIER** guides about a baby finger thickness (sticking out only as far as the wear shows on the stem):



Your Intake Valve Guide Largest Clearance: _____

Your Exhaust Valve Guide Largest Clearance: _____

GET A BONUS MARK!

A more accurate method:

Set a telescoping gauge to the diameter of the valve guide and measure the gauge with a Micrometer.



Subtract the diameter of the Valve Stem

That's your clearance!



MrW's Demo

Typical oil clearances in a motor are about the thickness of a human hair – that's not much!!

STOP!!

INSTRUCTOR'S INITIALS:

INSPECTING THE CYLINDER HEAD

INSPECT AND KEEP IN ORDER:

OHC

"Over Head
Cam"

Camshaft is
IN the HEAD,
not the
engine
block.

- **OHC ONLY:** Remove & inspect Camshaft, Rocker-Arms/Cam-Followers/Spring-Buckets
 - Lobes should be smooth, sharp edges, consistent shape between lobes.
 - Worn camshafts can be re-ground and installed with new or re-ground cam followers
 - Wear/Damage found:



OHV

"Over Head
Valve"

Camshaft is
IN the
BLOCK, not
the cylinder
head.

- **OHC ONLY:** Inspect Timing Chain/Belt/Gears/Tensioner
 - Timing chains and belts are usually replaced in a rebuild. Gears usually last forever.
 - Inspect the "looseness" of the chain. Idler and Tensioner pulleys should spin freely
 - Wear/Damage found:



Cylinder Head Demo

When you're
buying a
vehicle,
"new Head-
gasket" or
"new
radiator"
usually
means
"over-
heated"

Over-heated
engines are
usually
NEVER the
same again

- **OHV AND OHC:** Warpage
 - Usually means overheating. Warped heads must be machined flat. ANY warpage is bad.

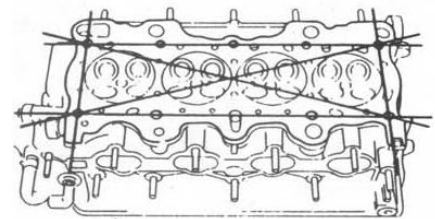
Use a **STRAIGHT EDGE**
and **FEELER GAUGES**

Check:

- Outside edges of the head surface
- Center of head surface
- Diagonally

Largest feeler gauge size: _____

Circle:



STOP!!

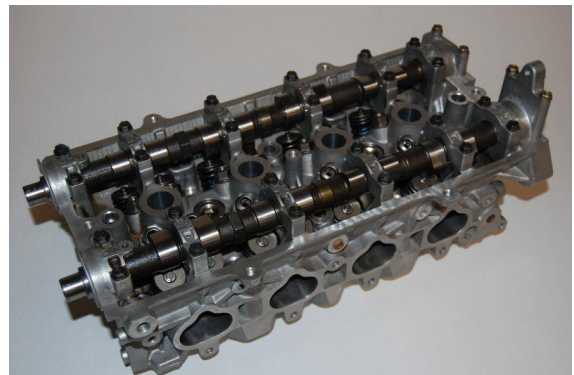
INSTRUCTOR'S INITIALS:

REASSEMBLY

- Valve seats and faces can be lapped, re-ground, or merely re-assembled depending on what you have found.

What rebuilding does this cylinder head need to have done? **BE DETAILED:**

- MACHINE the cylinder head as needed.
- THOROUGHLY clean the cylinder head, and all its components.
- Cylinder Head must be WHITE GLOVE clean prior to assembly. You do not want crud inside your nice new engine when you're done. CLEAN!!!
- Reassemble the cylinder head according to the service manual.
- Use new valve seals if this is your engine, and then show this sentence to your instructor for a bonus.
- Don't forget any spring shims
- **USE OIL ON EVERY MOVING SURFACE!**
- **NEVER re-assemble anything "dry"**



You want
CLEAN.

You should
be able to
lick the
engine and
taste only
metal, not
oil or grease

(Oil and
Grease taste
nasty! Ask
me how I
know)

STOP!!

INSTRUCTOR'S INITIALS:

ENGINE BLOCK

DO NOT TAKE ANYTHING APART YET **DISPLACEMENT**

We taught
you BEDMAS
for a reason

And MATH

And you do
know what
 π is, right?

Measure the BORE: _____

Measure the STROKE: _____

Using ($\pi r^2 h n$):

$$\pi \times (\text{BORE} \div 2)^2 \times (\text{STROKE}) \times (\text{\#CYINDERS})$$

What is the displacement of this engine?

25.4mm per inch _____
1000cc per liter
16.39 cc per cubic inch



INSPECTION

- **SKETCH** the top of a piston
 - Include any VALVE RELIEFS (these are pie-shaped cut outs in the top of the piston to allow the valves to open further)
 - Include the **NOTCH** (points to the *front* of the engine – Front is where the pulleys are)

Piston Top Sketch

←←←←← Front of motor

- Pistons **MUST** be reassembled a certain way (the pin is not actually centered – it is offset to reduce "*piston slap*" sound)
- Rotate the engine on the stand to remove the oil pan*
- Report ANY missing parts, fasteners, bearings, components you see inside the engine:

DO NOT REMOVE –ANY- PISTONS YET

STOP!!

INSTRUCTOR'S INITIALS:



DON'T be
like the kid
who drew
this
correctly,
AND STILL
MANAGED
TO PUT ALL
THEIR
PISTONS IN
BACK-
WARDS!!!



*This is
where I hear
all your
lifters fall
onto the
floor, and I
come and
make fun of
you

See page 4

PREPARATION FOR DISASSEMBLY

DO NOT REMOVE ANYTHING YET!

THERE IS A WAY TO NOT DESTROY THIS CRANKSHAFT; 3 THINGS YOU NEED TO KNOW:

Rods & caps
MUST be
numbered

NOT ALL
MAKERS
NUMBER
THEIR RODS
FROM THE
FACTORY!!!
(I'm looking
at YOU,
Chevy...)

1. THE CONNECTING RODS MUST BE NUMBER STAMPED BY CYLINDER ORDER

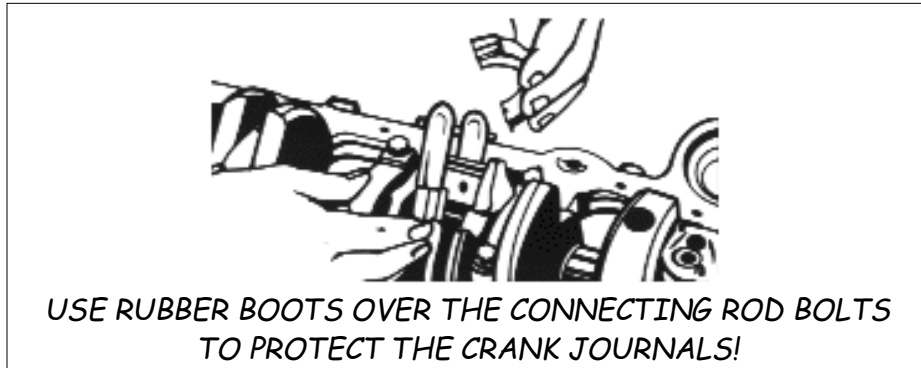
Connecting Rods and Main Bearings are so precisely machined, if the caps get mixed up or put on backwards, the engine will not even turn!!!!



DO NOT REMOVE ANYTHING YET!

2. THE HARD CONNECTING ROD BOLT THREADS CAN DAMAGE THE SOFT IRON OF THE CRANKSHAFT JOURNAL - RUBBER BOOTS ARE SLIPPED OVER THE THREADS

Rubber
boots on the
hardened
threads to
protect the
crankshaft
journals



DO NOT REMOVE ANYTHING YET!

3. THE CRANKSHAFT NEEDS TO BE ROTATED TO REMOVE PISTONS, THEREFORE, ONLY REMOVE PISTONS ONE AT A TIME

DO NOT REMOVE ANYTHING YET!

NOW RECITE THESE 3 THINGS BACK TO YOUR INSTRUCTOR

STOP!!

INSTRUCTOR'S INITIALS:

ROD BEARING CLEARANCE

ROD BEARINGS
Have to do with the CONNECTING RODS

MAIN BEARINGS
are what support the CRANK-SHAFT and allow its ROTATION

!
FRAC-TURED ROD CAPS?
(a rough, NOT machined mating surface)

CLAMP THEM TOGETHER BACKWARDS ONCE AND THEY ARE JUNK

!
CHECK the QR CODE for a DEMO!

PLASTIGAUGE® - ONE OF THE SEVEN WONDERS OF THE UNIVERSE

We can measure the **CONNECTING ROD Oil** clearance really easily using Plastigage®



Image: www.veritec-competition.com



- **Plastigage®** is used to measure the **Connecting Rod** Bearing clearances by being squished inside the bearing clearance. How wide it squishes tells us how tight the clearance is.

- Most crankshaft bearing clearances are around 0.001" to 0.0015"



Plastigage Demo

- REMOVE a Connecting Rod Cap and lay the Plastigage® on a main bearing journal (recommended: all).

STOP: DO YOU HAVE "FRACTURED" CAPS??

- Install and torque the Rod Cap to spec (DO NOT ROTATE THE CRANKSHAFT)

- Remove the Cap and compare the squish to the stripes on the wrapper - measure the bearing clearance:

DO NOT rotate the crankshaft or you will smear the Plastigage

Measured Clearance:

Copy Rod Bearing Clearance spec here:



Circle

- Scratch the Plastigage® off the bearing and the journal with your thumbnail.

Excessive rod bearing clearance can cause "knocking" sounds from inside the motor. Also, the oil can escape more easily, resulting in low oil pressure, and flooding the piston rings with extra oil.

LOSE a BONUS MARK if you just measured the MAIN BEARINGS

STOP!!

INSTRUCTOR'S INITIALS:

MAIN BEARING CLEARANCE

MAIN BEARINGS are what support the **CRANK-SHAFT** and allow its **ROTATION**

ROD BEARINGS Have to do with the **CONNECTING RODS**

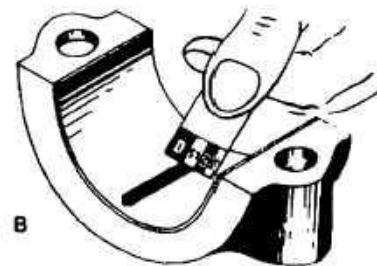
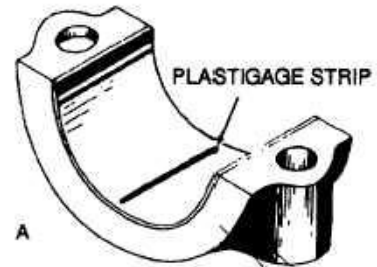
CHECK the QR CODE for a DEMO!



Plastigage Demo

We can measure the **MAIN BEARING** Oil clearance really easily using Plastigage®

- **Plastigage®** is used to measure the **Main Bearing** clearances by being squished inside the bearing clearance. How wide it squishes tells us how tight the clearance is.



- Most crankshaft bearing clearances are around 0.001 to 0.0015"
- Lay the Plastigage® on a main bearing journal (recommended: all).
- Install and torque the main cap to spec.
- Remove the main cap and compare the squish to the stripes on the wrapper - measure the bearing clearance:

DO NOT rotate the crankshaft or you will smear the Plastigage

Measured Clearance:

Copy Main Bearing spec here:



Circle

- Scratch the Plastigage® off the bearing and the journal with your thumbnail.

Excessive main bearing clearance can cause "rumbling" sounds from inside the motor. Also, the oil can escape more easily, resulting in low oil pressure, and flooding the piston rings with extra oil.

LOSE another **BONUS MARK** if you didn't pay attention on the last page, and went ahead and measured the **MAIN BEARINGS** just now. I will make fun of you.

STOP!!

INSTRUCTOR'S INITIALS:

THRUST BEARINGS!

STILL DO NOT REMOVE -ANYTHING- YET!

There are special **Thrust Bearings** that restrain the crankshaft from moving fore/aft. **Where are they** in your engine?

	INSTRUCTOR'S INITIALS:	
--	------------------------	--

NOW: REMOVE PISTONS (ONE AT A TIME, USE RUBBER BOOTS, DANG IT!)

DO NOT REMOVE THE CRANKSHAFT YET

DO NOT BEAT, BANG, DAMAGE or RISK DAMAGING ANY PART OF THIS ENGINE – EVERYTHING COMES APART EASILY – JUST ASK FOR HELP

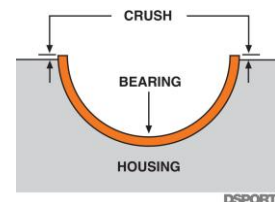
- **LABEL** each piston, bearing, oil pump part, etc. as appropriate.
- **WIRE-WHEEL** the tops of the pistons **ONLY (NOT the sides)**.
- **LABEL** each part location, and ask the guy in charge of this class for a magical extra mark
- **CLEAN** parts in solvent tank, clean with soap and water, then blow dry with compressed air **AS SOON AS POSSIBLE**, and spray with WD40 to keep from flash-rusting



THREAD FASTENERS BACK INTO THEIR HOLES SO THEY ARE NOT LOST

Bearings are kept in their location by **CRUSH** – they are slightly larger than the bearing journal housing, so when they are assembled, they become a **PRESSED** fit.

Bearing shells also have one more special way to locate them in their bores. Have a close look! What is it? How are they aligned with each other?



Thrust bearings are **CRITICAL!** **DO NOT LOSE THEM!**



DO YOU HAVE FRACTURED ROD CAPS?

(a rough, NOT machined mating surface)

CLAMP THEM TOGETHER BACKWARDS ONCE AND THEY ARE JUNK



PAY ATTENTION TO HOW BEARINGS ARE INSTALLED

ASSEMBLE THEM PROPERLY!

CRUSH: If you over-rev your engine, you risk stretching bolts, reducing CRUSH, and SPINNING the bearing – ruining the crankshaft rod.

STOP!!

INSTRUCTOR'S INITIALS:

TIMING CHAINS/SPROCKETS and GEARS

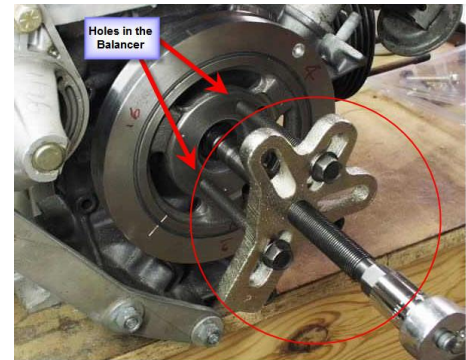
Remove the **front pulleys** (if any). You may have one on a water pump, you will likely have one on the crankshaft.

Harmonic Balancers are an important part for the life of a crankshaft. It absorbs vibrations, preventing the crankshaft from cracking.

It has a heavy cast iron ring that is glued to a rubber band around a cast iron hub. The rubber allows vibrations to be absorbed or "countered" by the heavy outer ring.



You CANNOT use a pulley puller that grabs the outside of the pulley – it will pull the outer ring off, **RUINING** it.



USE A HARMONIC BALANCER REMOVER

DO NOT USE AN IMPACT WITH THIS PULLER!!!!

If your engine is OHC, you may have already done this



MrW's
PULLER
DEMO

Remove the Timing Cover

INSPECT the Timing Chain/Gear/Sprockets: Should not be excessively loose or sloppy. Teeth should look solid and complete. As the teeth and chain wears, the chain may "jump" and change the cam timing - resulting in a loss of power or damage

WATCH THE 3-SECOND VIDEO CLIPS!!!

By comparison, how is your Timing Chain and Sprockets?

REMOVE the timing chain



GOOD

BAD



STOP!!

INSTRUCTOR'S INITIALS:

REMOVING THE CRANKSHAFT

- You may now CAREFULLY remove the crankshaft, and disassemble the rest of the engine block (*It's HEAVY*)
- ***INSPECT EACH JOURNAL AND FIND OUT HOW YOU DAMAGED THE SURFACES WITH THE ROD BOLT THREADS, YOU MONSTER!***
- ***IF THIS IS YOUR ENGINE:*** Wrap all the crankshaft journals with masking tape to protect them from any accidental damage



STORE CRANKSHAFT STANDING UPRIGHT

- Crankshafts should be stored standing on end, or suspended by their crank bolt or flywheel flange. They can warp just by gravity if they are laying on their side.



Continue...



Removal

OHV: THE CAMSHAFT (OHC CAN SKIP THIS)

You should have already removed your lifters.

Dig them out now, we need to look at them

NOTE: When I rebuild these motors, I have a WEE TINY hone to clean up the lifter bores and make it EASIER to rotate as the cam tries to lift it.

If you have an Over Head Cam Engine (OHC), you already did this (skip it)

NOTICE: Old school OHV engines have FLAT TAPPET cams. Modern engines use a ROLLER LIFTER to reduce friction. We're going to look at the Flat Tappet design for now:

FLAT TAPPET LIFTER BORES are NOT actually centered over their cam lobe. If you look closely, you will notice that they are slightly offset! This helps make the lifter WANT to rotate as the cam tries to lift it – *rotating friction is always better than sliding friction.*

FLAT TAPPET LIFTERS are also slightly **CONVEX** on the bottom (crowned, they have a slight curve). This also makes them WANT to rotate as the cam tries to lift it – *rotating friction is always better than sliding friction.*



CHANGE YOUR OIL!

IF YOU DO NOT CHANGE YOUR OIL ON A REGULAR BASIS, THE LIFTERS (among other things) GET GUMMED UP, AND DO NOT WANT TO ROTATE, BECOMING A SLIDING FRICTION!

THIS EATS THE CAM AND EATS THE LIFTERS!

and then... where did all that metal go?? Everywhere – and metal shavings are NOT a good lubricant

INSPECT YOUR LIFTERS:

Are your lifter bottoms CROWNED (junk), FLAT (junk), or CONVEX (good)?

Camshaft: Should have smooth lobes and bearing surfaces. Flat-Tappet cam lobes are angled slightly. This also makes them WANT to rotate as the cam tries to lift it – *rotating friction is always better than sliding friction.* You should see evidence of contact along one side of the lobe. As the lobes and the lifters wear out, that contact will get wider and wider and then start eating the lobe (Image below: see how the wear over the nose is getting significantly wide and covers a lot of the ramp?)

INSPECT YOUR CAM LOBES:

Do the lobes have EDGE Wear, or is the nose wear getting WIDE? Is there a lobe (or more) where the wear is significant or the lobe is smaller?



STOP!!

INSTRUCTOR'S INITIALS:

ENGINE BLOCK INSPECTION, MEASUREMENT and DIAGNOSIS

The TOP of the cylinder bore is usually the most worn, due to

1. High heat
2. Limited oil
3. The thrust of the piston.

1. USE a TELESCOPING GAUGE and a MICROMETER, measure and record the TOP of the MOST worn cylinder just below the RIDGE

The BOTTOM of the cylinder bore is usually the least worn due to:

1. Lots of oil
2. Very little heat
3. Very little thrust of the piston.

2. USE a TELESCOPING GAUGE and a MICROMETER, measure and record the BOTTOM of the cylinder

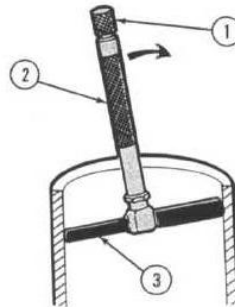
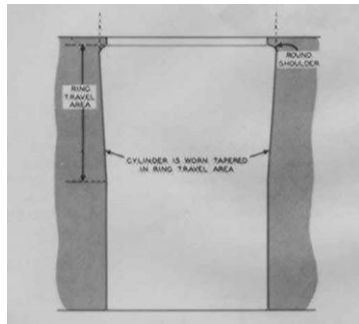
- Rings seal best with a perfect cylinder
- Taper within spec can be honed and the old pistons reused with new rings.
- An excessively worn cylinder must be re-bored and over-size pistons fitted.

3. SUBTRACT the BOTTOM of the cylinder from the TOP of the cylinder is to find the TAPER/out-of-round.

You can merely hone and "re-ring" a worn cylinder up to a point, but too much cylinder taper makes the rings flex every time they move, making them wear out quickly.

Don't expect your engine to stay "fresh" very long.

With enough taper, it's wiser to get the block bored out and oversize pistons installed.



Measuring with a telescoping gauge is pretty tricky. Ask for a free demo from your instructor!

1. _____ - 2. _____ = 3. _____
(TOP) (BOTTOM) (Total Taper)

STOP!!

INSTRUCTOR'S INITIALS:

PISTONS

EXCESSIVE
Piston-to-
Cylinder
Wall
clearance
results in
"Piston Slap"
which
sounds a bit
like a the
clatter of a
Diesel

Inspect the piston for physical damage: detonation damage (looks like a pick-axe went medieval), scoring, scratches, cracks, missing parts, carbon buildup, holes, melting, overbore markings, etc. Describe what you found:

Using a MICROMETER, measure the diameter of the piston from your WORST cylinder.

MATH MOMENT: Piston Clearance is usually about 0.0015" PER INCH OF BORE



Measure at pin height, 90° to the piston pin, and record:

1. _____ (CYLINDER TOP)	-	2. _____ (PISTON AT SKIRT)	=	3. _____ (ACTUAL CLEARANCE)	How is it? 😊 😞 Circle
1. _____ (CYLINDER TOP)	X	0.0015"	=	3. _____ (DESIRED CLEARANCE)	

STOP!!

INSTRUCTOR'S INITIALS:

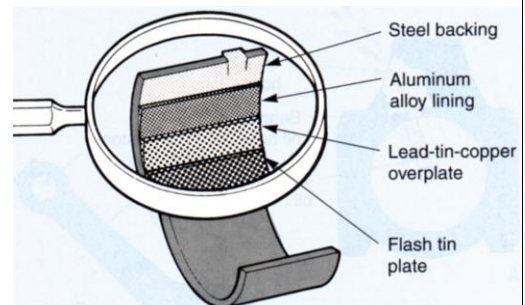
BEARING SHELLS:

New bearings are a light silver/gray colour.

Worn bearings will start showing the layers underneath.

Worn bearings allow oil to leak out (engine loses oil pressure), the leaky oil over-splashes the cylinders (increases oil consumption), and increases noise (large clearance with less oil to absorb shock). Point out this sentence as you explain how worn bearings affect an engine to your long-suffering instructor for a bonus.

Describe how all the bearings (including the thrust bearings) look:



CRANKSHAFT JOURNALS

JOURNALS are the MACHINED BEARING SURFACE of the crankshaft

I am VERY FUSSY about taking good care of these!!

MAIN JOURNALS

Using a micrometer, measure your WORST Main Bearing Journal Diameter:

Copy Main Journal spec here:



Circle



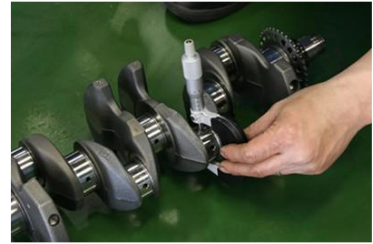
ROD JOURNALS

Using a micrometer, measure your

Copy Rod Journal spec here:



Circle



WORST Rod Bearing Journal Diameter:

This sentence to your instructor for a bonus you will show.

OIL PUMP – THE LIFE BLOOD OF YOUR ENGINE

A new oil pump is cheap.

I prefer to buy "High Volume" oil pumps – these are better when feeding oil coolers and turbo-chargers. They also maintain better pressure at low speeds

I usually "port" oil pumps and oil passages for more flow

Oil pumps can be found inside the crankcase, outside the engine block, inside the timing cover or wherever the manufacturer saw fit.

Where is (was) your oil pump physically located on the engine?

How is your oil pump driven (what makes the guts rotate so it will pump?)?

DISASSEMBLE THE OIL PUMP (use an **Impact Driver** and a **Hammer** if the fasteners do not come undone easily - **DO NOT STRIP THE FASTENERS**).

Inspect and Describe the wear and/or damage inside the oil pump (look at every moving surface for scratches, gouges or other damage – anything not perfectly smooth and shiny):

STOP!!

INSTRUCTOR'S INITIALS:

PISTON RINGS – YOU NEED TO BE GENTLE!!!

NO, SERIOUSLY: YOU NEED TO BE GENTLE HERE! (FREE DEMO!)

CAREFULLY remove the TOP COMPRESSION RINGS on your WORST cylinder with PISTON RING PLIERS - NOT YOUR FINGERS!!!

Piston Rings are VERY fragile – spread them ONLY enough or they WILL break – and you *cannot* buy "just one."

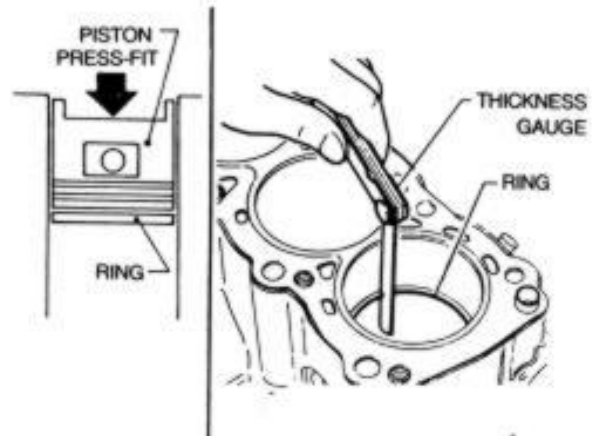
Note WHICH ring came from WHICH groove, and WHICH way was UP. This is very important for the engine to seal.



YOU MAY REMOVE THE TWO OIL SCRAPER RINGS AND THEIR SEPARATOR WITH YOUR FINGERS

Place a COMPRESSION RING in a cylinder, and push it to the bottom of the cylinder using the head of the empty piston (you are pushing the head of the piston upside down back into the cylinder)

Use feeler gauges to measure the piston ring gaps (you might have to stack some and add them:



Top: _____

Second: _____

Copy ring gap spec here:

TOP: _____

SECOND: _____



Circle

Excessive ring gap will allow compression pressure to escape into the crankcase (called "blow by"), and draw oil into the cylinder on intake (oil sucked in during intake will burn blue in the exhaust)

***RING GAP RULE-OF-THUMB: 0.004" per INCH of Cylinder Bore
for naturally aspirated engines***

**LOTS of
COLD-
STARTS and
SHORT
TRIPS are
where an
engine
burns
EXTRA
FUEL**

**EXTRA
FUEL
washes the
oil off the
cylinder,
making the
rings and
cylinders
WEAR OUT
FAST!**

**EXTRA
FUEL
getting into
the oil,
THINS the
oil, which
LUBRI-
CATES LESS,
accelerat-
ing wear!**

You want:

**TURBO?
BLOWER?
NITROUS?**

**You MUST
run larger
ring gaps!**

**Ask me
why!**

STOP!!

INSTRUCTOR'S INITIALS:

AUTOPSY – CSI AUTOMOTIVE

TELL ME ABOUT:

POWER

NOISES

FUEL
CONSUMPTION

OIL
CONSUMPTION

OVERHEATING

HOW WAS IT
RUNNING
BEFORE IT DIED

WHAT KILLED
IT?

Based on all the information you've gathered, describe SPECIFICALLY how this engine was running before it died, and what specifically killed it. Be as detailed yet as POINT FORM as possible. Give me *EVIDENCE*:

- 50 Perfectly and thoroughly detailed, no stone unturned, The Force is with you!
- 40 Very good and reasonable, some contributing causes mentioned
- 30 Basic description only; root cause identified; I tried leading you to more ideas but didn't win
- 20 Marginal evidence of analysis and I'm going to give you a strange look
- 10 You're giving me lame reasons, and I'm merely going to shrug and walk away from you
- 0 Are you actually enrolled in this course?

STOP!!

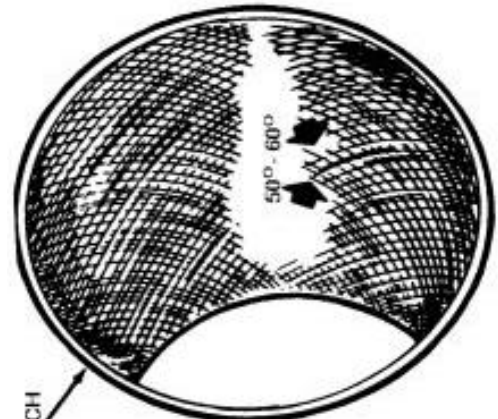
INSTRUCTOR'S MARK:

/50

CYLINDER HONING & THREAD CLEANING

CYLINDER HONING

1. Rings and cylinders "wear in" together.
2. New rings will not seal against a polished cylinder.
3. Honing the cylinder produces a cylinder wall finish that lets new rings "wear in" properly.



If merely doing a re-ring, or assembling a "dead" engine, hone the cylinders as shown by your instructor. You must have a 60° crosshatch pattern (30° above horizontal).

DO NOT HIT THE
CRANK WEBBING
WITH THE
HONING TOOL

USE LIGHT OIL
FOR HONING



- A proper honing pattern is a result of how fast you **SPIN** the hone and how fast you **STROKE** the hone. Somewhere in there is balance. Try it!
- **CHASE** all threaded holes in the block and head(s) with the appropriate tap.



***CLEAN threads = ACCURATE torque readings
when assembling (CRITICAL!)***

STOP!!

INSTRUCTOR'S INITIALS:

--



How-To

ENGINE CLEANING

YOU SHOULD BE ABLE TO EAT OFF OF IT

- Scrape off ALL the oil and grease using scrapers, flat screwdrivers, and wire brushes
- Use brand-name Oven Cleaner to soak and remove heavy carbon deposits
- Use degreasers (like solvent, Simple Green, or others) to clean right down to bare steel.
- Rinse thoroughly and blow dry with compressed air. The engine must be WHITE-GLOVE clean.
- You think it's clean? Think again. Get your instructor to check all the nooks and crannies in the engine block. You'd be surprised.



PROTECT THE ENGINE

THIS STEP IS CRITICAL: BARE METAL RUSTS QUICKLY!!!

- SPRAY **WD40** ON THE CYLINDER WALLS AND ALL MACHINED SURFACES ("**WD**" means "**WATER DISPLACEMENT**")
- PROTECT THE CLEAN ENGINE BLOCK AND HEADS IN CLEAN PLASTIC GARBAGE BAGS TO KEEP DUST AND GARBAGE OUT OF THE ENGINE



STOP!!

INSTRUCTOR'S INITIALS:

CAMSHAFT (OHV) and CRANKSHAFT

Everything
assembled is
OILED

If it MOVES
it is OILED

Cam lobes
like a Molyb-
denum
Disulphide
grease to
survive
break-in



How-To

- If this is a cam-in-block V engine, oil and insert the camshaft at this time (it's much harder to do so once the crankshaft is in).
 - *YOUR engine? New cam bearings are a good idea*
 - *New "Flat-Tappet" cams need a "Break-In" lube or it will be wiped flat in the first 20 minutes*
- Insert the main bearing shells **DRY** (no oil)
- **PUT OIL ON THE BEARING SURFACE and GREASE ON THE SEAL SURFACE** and then gently set the cleaned crankshaft into the block

PAY ATTENTION HERE

- ***MAIN BEARING CAPS*** have been machined to ***ONLY*** fit ***THAT*** engine in ***THAT*** location, pointing in ***THAT*** direction, ***ONLY***.
--- ANYTHING ELSE IS WRONG ---
- Install all the main bearing caps **ONE AT A TIME** and **WITH OIL** and **IN THE RIGHT LOCATION** and **IN THE RIGHT DIRECTION**
 - *It is **good practice** to install one main bearings cap and see if the crankshaft still turns, then move to the next one. **You want to know THE INSTANT there is ONE problem!***
 - *It is **good practice** to torque the mains in **stages***

*If the **THRUST BEARING** is **ONE PIECE** with a **MAIN BEARING**, you must **SET IT** by loosening the cap bolts, and smack the crankshaft*

- *If this is **YOUR OWN** engine, consider checking things with Plastigage.*

Does the crankshaft STILL ROTATE? No? You SCREWED UP. FIX IT!

STOP!!

INSTRUCTOR'S INITIALS:

PISTONS

Everything assembled is OILED!



Install

DO NOT
BREAK
RINGS

DO NOT
BREAK
PISTONS

DO NOT
BREAK
PISTON RING
LANDS

DO NOT
DAMAGE
THE CRANK

DEMOS ARE
FREE, AND
I'M HAPPY
TO DO THEM



DO YOU
HAVE "FRAC-
TURED" ROD

CAPS?
CLAMP
THEM
TOGETHER
BACK-
WARDS
ONCE AND
THEY ARE

JUNK

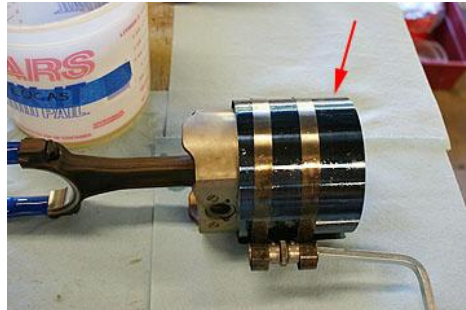


INSTALL THE PISTONS ONE AT A TIME – USE RUBBER BOOTS!!!

- **ALIGN THE PISTON RING END GAPS** around the piston as shown (typical)
 - *Your engine service manual may suggest something different - follow your manual*
- Oil the piston and rings:

IF IT MOVES – IT IS OILED – NEVER ASSEMBLE DRY

- Use a **PISTON RING COMPRESSOR** to compress the rings onto the piston
Square Key faces UP



- **RUBBER BOOTS** on the rod bolts to protect the crank!
- Use a hammer to **TAP** around the outside of the **RING COMPRESSOR** to make sure it sits **FLAT** against the **DECK** of the block
- Use the hammer handle to **TAP** the head of the piston into the cylinder, **GUIDING** the rod to the crankshaft

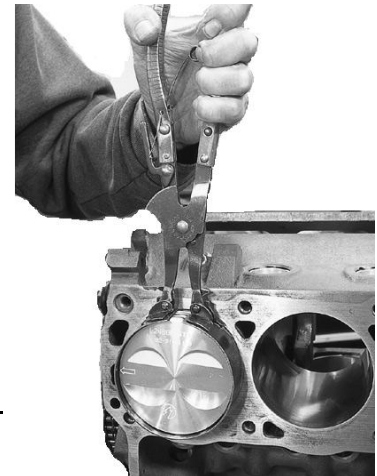
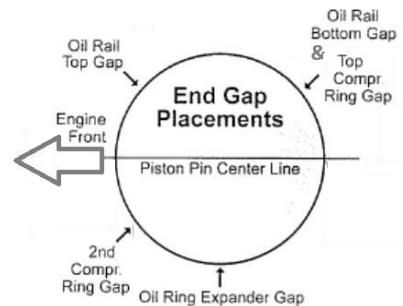
IF THE PISTON DOES NOT GO IN EASILY,

FOR HEAVEN'S SAKE STOP!!!!

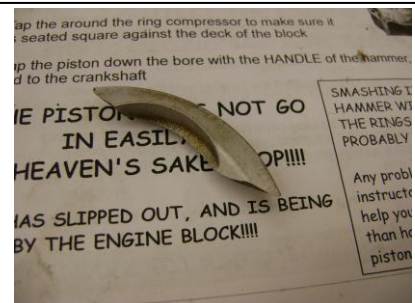
Likely....

A RING HAS SLIPPED OUT, AND IS BEING HELD UP BY THE ENGINE BLOCK!!!!

I would rather help you with each piston, than have you destroy even one ring. Rings cannot be purchased individually – only as a COMPLETE SET \$\$\$



SMASHING IT WITH A HAMMER WILL DESTROY THE RINGS, AND PROBABLY THE PISTON!!!!



TORQUING

- If this is YOUR OWN ENGINE (not mine), consider using Plastigage® to confirm the rod and main bearing clearances
- Connecting rod bolt torque is CRITICAL
 - Too loose and the nut could come undone, fall off, and grenade the engine
 - Too tight and the bolt could break, losing the cap and grenade the engine.
- Install the oil pump, pickup and shaft (as equipped)



STOP!!

INSTRUCTOR'S INITIALS:

CYLINDER HEADS & CAM TIMING

- Do one last check to make the engine block is complete
- Install the head gasket and cylinder head onto the block **NOTE ANY ALIGNMENT DOWELS!**
- Torque to specs in a **spiral sequence** and in **stages** - NOTE: head bolts that thread into the water jacket require a special sealant on the head bolt threads
- Show this sentence to your instructor for a bonus
- Finish installing the valve train and cam drive
- **SET THE CAM TIMING** exactly as described in the manual (refer to the picture you wish you drew better on p.2)

STOP!!

INSTRUCTOR'S INITIALS:

ADJUSTING VALVES

How do you adjust the valve clearances (Valve Lash) on this engine? (see manual):

- Adjust the valves and **DEMONSTRATE YOUR MAD TYTE VALVE ADJUSTING SKILLZ** to your instructor

Valve lash is often set larger on exhaust than intake – WHY?

SHOW your instructor that the following components are installed correctly:

- | | |
|--------------------------------|-------------------------------------|
| _____ Oil pump pickup | _____ Timing chain and timing marks |
| _____ Oil pump & drive | _____ Valvetrain |
| _____ Main bearing caps | _____ Fuel pump cam (if equipped) |
| _____ Connecting rods and caps | |

STOP!!

INSTRUCTOR'S INITIALS:

HARMONIC BALANCER



MrW's
DEMO
AT INSTALL

Install the timing cover. Rubber seals should be greased so they don't get cut.

Smear a bit of grease on the sealing surface of the Harmonic Balancer so as not to CUT the seal on install.

Install the **HARMONIC BALANCER**:

The **Harmonic Balancer** and/or crankshaft can be damaged by improper installation (**NO HAMMERS!**)

Use the Harmonic balancer Installer to install.

- Place harmonic balancer on end of crankshaft
- Center bolt of installer is threaded BY HAND into the crankshaft
- Bearing and Nut are tightened with a wrench to push into place



NO

HAMMERS!

HAMMERS
ARE FOR
CHUMPS!

FINAL ASSEMBLY

- Install the Oil Pan (straighten any dents)
- Install the manifolds and valve cover(s) and any other accessories removed for disassembly. Paint as required.
- Reinstall any other components removed
- No bolts left behind

SHOW your instructor that the following components are installed **CORRECTLY**:

_____	Oil pan
_____	Timing cover
_____	Timing mark tab
_____	Harmonic balancer
_____	Pulleys
_____	Accessories
_____	Water pump
_____	Intake manifold
_____	Exhaust manifold
_____	Fuel pump (if equipped)
_____	Distributor
_____	Valve cover
_____	Dip stick
_____	Oil filter

STOP!!

INSTRUCTOR'S FINAL INSPECTION:

DISTRIBUTOR TIMING

If your engine came with a distributor, you need to set the SPARK TIMING

The distributor “distributes” the spark to all the cylinders. Its alignment is VITAL to the engine firing up RIGHT AWAY.

*As with everything you’ve learned in this lab, there is a **RIGHT WAY** things are done.*

Check the **SERVICE MANUAL** to see how the Distributor on **your** engine is **INSTALLED**.

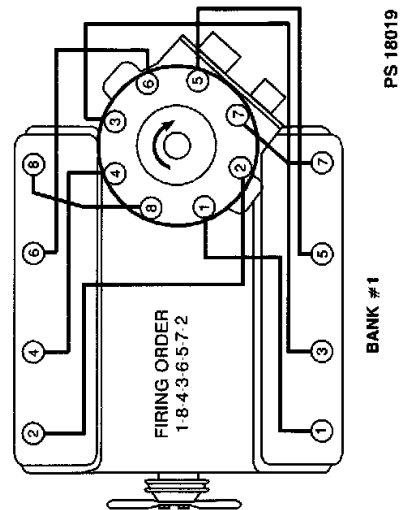
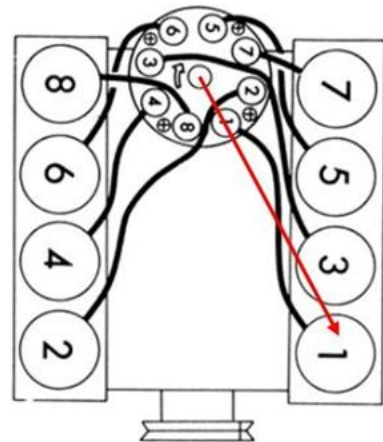
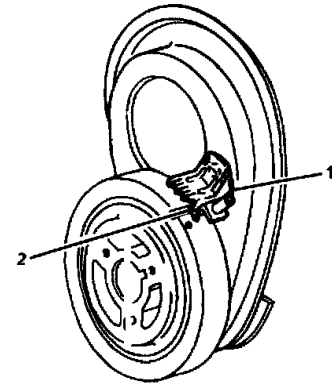
Most of my engines in the shop are Small Block Chevy’s (SBC). This is how it is done:

Set the Crankshaft to **10° Before Top Dead Center** (see the TIMING TAB)

A **SBC** Distributor is properly aligned if...

- **HEI ENGINES:** The VACUUM CANISTER (old HEI ignition) is pointing at **CYLINDER #2**
- **TBI ENGINES:** The DUAL ELECTRICAL CONNECTIONS are pointing at **THE DRIVER**
- The **ROTOR** (inside) is pointing at **CYLINDER #1**
- The **OIL PUMP SHAFT** is lined up
- The **DISTRIBUTOR** sits **ALL THE WAY DOWN**
- The **RELUCTOR** (pointy thing under the rotor) is lined up with the **PICKUP COIL** and **MAGNET** and **ROTOR** is pointing at **TERMINAL #1**

***YOUR ENGINE
MIGHT BE DIFFERENT
>> SET IT RIGHT! <<***



STOP!!

INSTRUCTOR’S FINAL INSPECTION:

Return the engine to its storage place.

Describe FOUR ways you improved in your mechanical ability through this lab:

1.

2.

3.

4.

**YOU MADE
IT!**

How do you
feel?



Circle

Describe any areas of this lab that were unclear to you (this helps me refine the lab for next year):