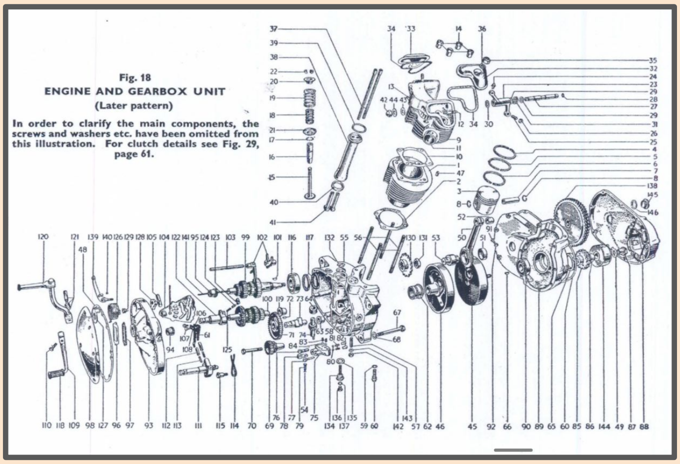
Top End Engine Team



Tasman Moskowitz and Mary Christian McCoy

FRS 106 - Spring ‘23

Before Picture: February 6th, 2023

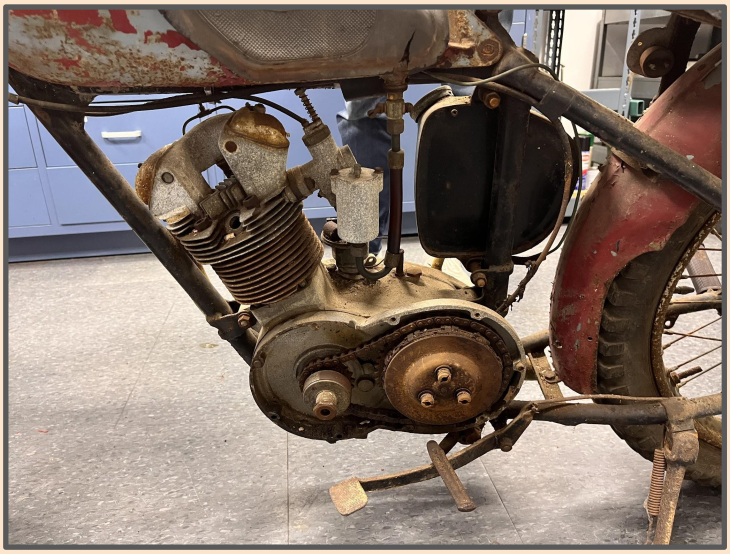
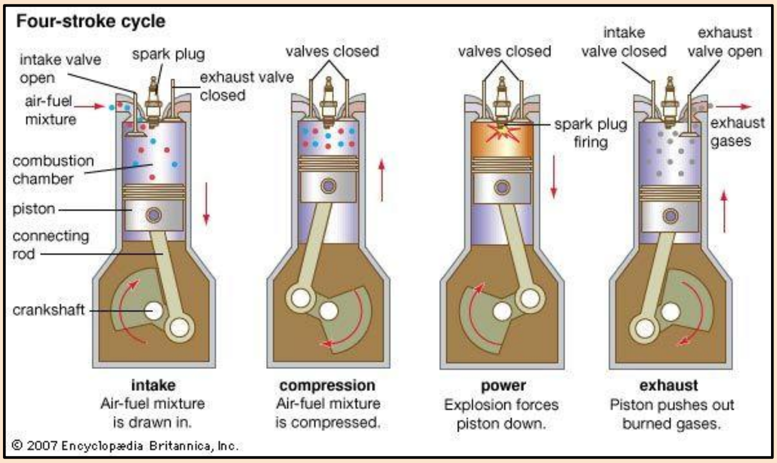


Photo Credit: Paige Walworth

Four-Stroke Engine Overview



- Cycle is complete after two revolutions of the crankshaft
- Power stroke provides the crankshaft with the angular momentum for other 3 strokes
- Air-fuel mixture travels in from the carburetor into head
- Ideal Gas Law

  $PV = nRT$

- Chemical potential energy to mechanical work

Balanced Chemical Equation for Combustion: $2C_8H_{18} + 25O_2 \longrightarrow 16CO_2 + 18H_2O$ + Heat

- During the intake stroke of a 4-stroke engine, the piston moves from top dead center to bottom dead center. This downward motion creates a vacuum meaning that there is lower air pressure on the inside the combustion chamber than outside, so when the intake valve opens the air-fuel mixture is sucked into the combustion chamber
- During the compression stroke, piston moves from BDC to TDC and both valves are closed. The air-fuel mixture is compressed and the spark plug fires
- The compressed air fuel mixture ignites and this combustion forces the piston back down to BDC. Burning the octane and oxygen mixture is exothermic, so chemical potential energy is transferred into thermal energy. According to the ideal gas law, temperature is proportional to volume, so as the temperature of the gasses inside the combustion chamber increases, then the gas will expand. This pushes the piston back to BDC, providing a torque that rotates the crankshaft and the angular momentum needed for the next 3 strokes of the cycle. This stroke propels the vehicle forward.
- During the exhaust stroke, the piston moves back upwards, pushing the water and carbon dioxide produced during combustion and other gasses out of the open exhaust valve

Valve Timing

- As the cam turns, the pushrods move and push on the rockers. The rockers then push on the valve spring and move the valves.

- The stiffness of the valve spring controls how fast the valves close and determines rpm

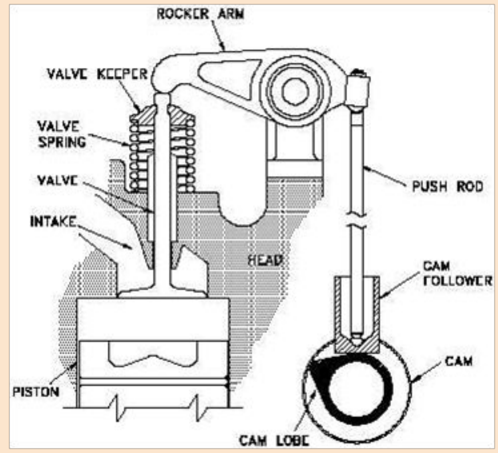


Photo Credit: Spring 2011's '63 Tiger Cub Top Engine Page

The cam rotates within the bottom half and pushes the push rods into the rocker arm which "hand demonstration" one arm of the rocker pushes down on the valve spring which moves the valve down and then when the cam rotates again, the valve moves back. This controlshow fast the valves are able to open and close, which is in part controlled by the springs and their stiffness.

Key Terms from Class

Engine Knocking:

- A knocking sound of metal hitting metal within the engine
- May be caused by an incorrect air-fuel ratio or fuel may be igniting at the wrong time in the combustion cycle

Compression Ratio:

- the ratio of the maximum to minimum volume in the cylinder of an internal combustion engine
- 7:1 for our motorcycle
- In general, the higher the combustion ratio, the more power output from the engine

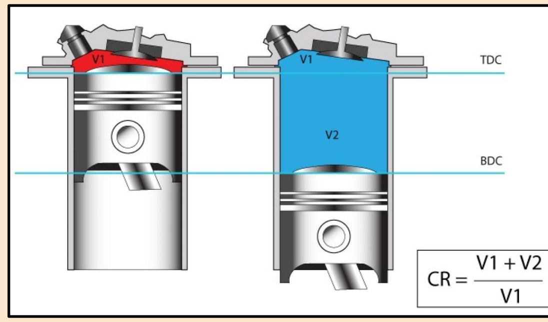
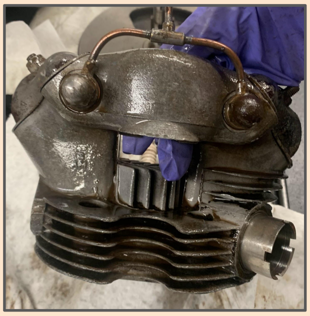


Photo Credit: AutoProtips.com

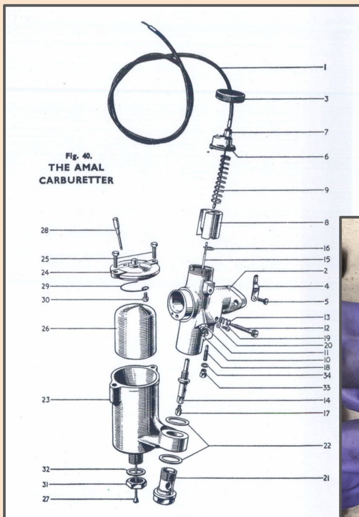
Our Parts

Engine Head



Carburetor

Barrel

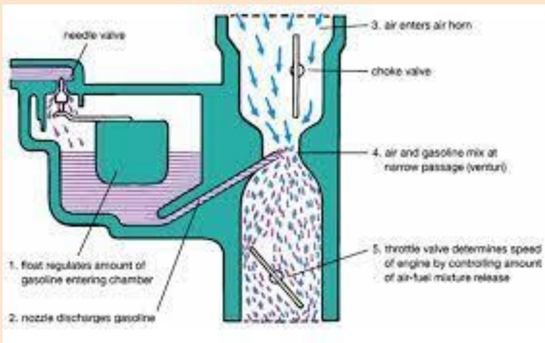


Carburetor

- This is where <u>fuel and air mix</u> through the use of jets.
  - Throttle - Controls speed by adjusting air and fuel
- Float controls amount of fuel let in.
- Pilot jet works till about 20% throttle.
- Main jet works at 80% throttle and above.
- Needle jet works between 20% and 80% throttle.

First, we're going to focus on our premonobloc Amal Carburetor. The carb is where fuel and air mix together through the jets. The float controls the amount of fuel let in by creating a vacuum that pulls in fuel. Each jet has its own purpose. The pilot jet pulls in the fuel/air mixture at low levels of throttle and is assisted by either a fuel or air adjusting screw (point out) which helps maintain the ratio of air to fuel. Then we have the main jet pulls in fuel at higher levels of throttle (point out) Then the needle jet works during mid-levels of throttle. It move the throttle valve to adjust the amount of fuel in and out. Then the slide is controls how much air comes into the carburetor. We used a thin copper wire to map out the carburetor.

Science of our Carburetor: How does it work?



* This model does not perfectly match our carburetor
http://ecoursesonline.iasri.res.in/mod/page/view.php?id=677

Bernoulli's Principle states that an increase in the speed of a fluid occurs simultaneously with a decrease in static pressure.

- The venturi of a carburetor is a tube with decreasing cross sectional area
- When air flows through the narrowing tube, its velocity increases
- The static pressure in the tube decreases which creates a vacuum drawing in fuel
- $\Delta P \propto \Delta v^2$

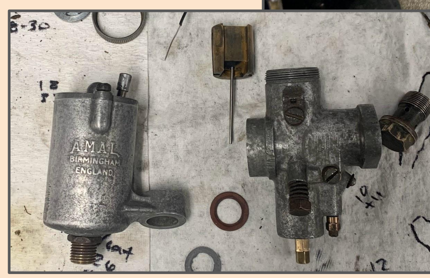
When air moves through the tapering venturi tube, it moves faster and the resulting change in pressure is proportional to the change in velocity squared. This lower pressure creates a vacuum that draws fuel through the jets.

Restoration

- Almost all parts went into sonic cleaner, and then a wire brush was used to clean most of the brass parts
- Aluminum surface —> oxidized in the presence of air to have a coat of aluminum oxide on the surface
- Sandpaper, Scotch Brite, and brushes were used to remove oxidation from the outside

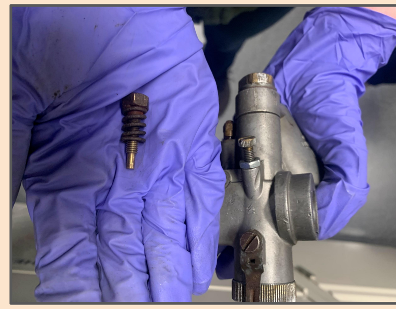
Before →

After
↓



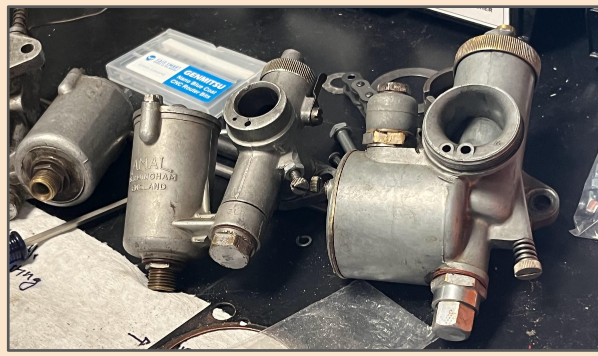
Almost of the carburetor at some point went into the sonic cleaner. Some of the screws that and brass implements were cleaned with the dremel in order to remove rust and clean the threads. One of the main obstacles was (read middle tick), but (Read final tick) and also was used to help loosen the air valve assembly

Our Carburetor v.s. Others



Throttle Adjusting Screw (Part #10)

- Springs and a nut are both used to maintain the screw’s position



Monobloc Carburetor

- Later carburetors will get rid of the two part carburetor and switch to a one part carburetor.

One complication, we had is that we could not identify this screw. That was because some motorcycles used a nut instead of a spring in order to maintain how far the screw goes into the carburetor. A bolt or screw is stretched when a nut is tightened which holds it under tension the same way that a spring would. The spring/nut is added to maintain tension in the screw regardless of vibration or thermal expansion. In the later carburetors, in order to reduce costs the two part carburetor was moved towards a one part carburetor but it did not remove the problem of the float being to one side of the carburetter, so still on certain turns it would be difficult for the mixture to get into the other part of the carburetor.

Head

- Home of the valves and spark plug.
- Combustion chamber.
  - Spark plug starts the combustion that starts the motorcycle.
  - Valves let the air/fuel mixture in and let out the exhaust gases.
- Fun Fact: We had a wasp's nest in here

The next part is the head. Its important parts are its valves and spark plugs. The spark plug starts the combustion that starts the motorcycle. The valves, as mentioned before in the discussion of the four stroke engine, let the air/fuel mixture in on the intake side, and let out the gases on the exhaust side.

Disassembly

- Utilized the jam nut technique in order to help free the rocker from the head.

- Used a spring compressor tool in order to push the valve spring down to remove the keepers.

The main difficulty in taking apart the head was removing the insides. First, the rocker was being blocked from leaving by the rocker cover stud. In order to remove it, we had to use the jam nut technique. We took two nuts and screwed them down until they were tight. Then we loosened the bottom one which couldn't unscrew itself, it moved the screw instead. Then once we removed the bolt for the rocker covers, we could get the rocker out. Then, in order to get the spring out we used a spring valve compressor tool in order to squeeze the springs down until the keepers popped out.

Restoration

- Rust shows that materials are beginning to decay

- “Rust begets rust” - Prof. Littman

- Sandblasted, emory paper

- We used WD-40 in order to remove rusty bolts that were stuck.

- Oil was stuck between fins

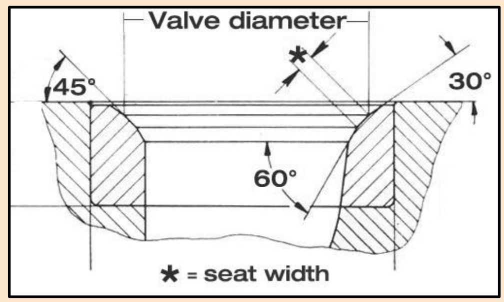
Photo Credit: Theisen’s

- Rust is a form of corrosion
- Once the surface layer of a material rusts then the layers underneath will begin to rust
- WD-40 prevents the formation of rust, because it needs water and oxygen in order to form and WD-40 stands for water displacement formula

Valve Seat Cutting

Cutting Valve Seats: Ensures that the valves come into contact with the head in a way that maximizes the engines performance and reduces wear

- 3 angles
- Allow gasses to pass valves with less turbulence
- Heat is transferred from valves via conduction, and the angles cut determine the SA of the valve in contact with the head



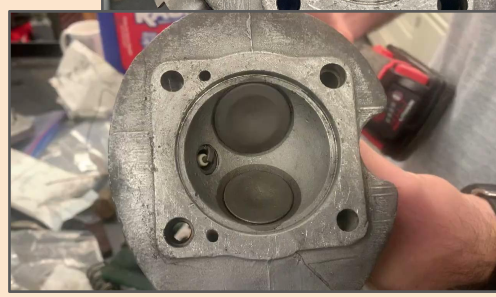
Valve Seat Cutter Photo Credit: Spring 2011's '63 Tiger Cub Top Engine Page
Diagram Credit: John Maher Racing

We used the valve seat cutters to cut down the valve seats.

Lapping

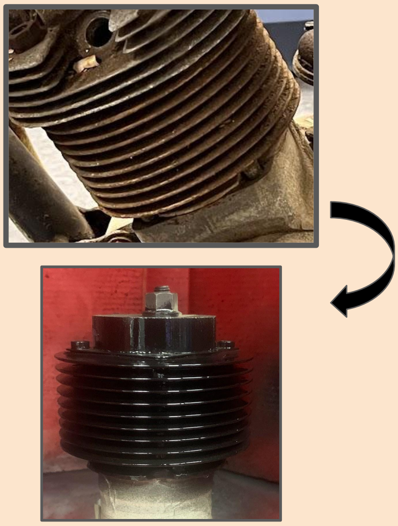
- Used to create a sealing surface between the valve and its seat.

- With a gritty compound, we spun the valve around multiple time in order to make sure the two surfaces meet exactly.



Then we lapped the valves, which means basically we took a gritty compound and rubbed the valve into its seat in order to create a sealing surface. (video) We did this by attaching fuel line hose to the end of the valve and to a screwdriver and then spinning .

Barrel



- Held on to the engine case with four large bolts
- Piston moves up and down inside the barrel
- Sandblasted to remove rust
- Painted black to return to factory appearance, most likely black, because color increases emissivity

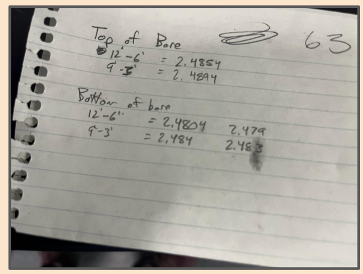
Honing & Boring

Honing: Removes surface layer of metal to remove surface defects and ensure proper piston ring seating

- Used a lathe and paddle hone the MAE shop
- Cutting Fluid: Lard Oil

Boring: Repairs wear and tear due to friction in engine cylinders by widening and tapering it

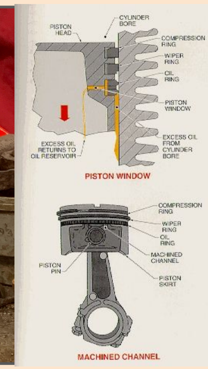
- Used T-gages to determine that the cylinder was egg shaped and needed to be bored
- Prof. Northey bore our cylinder
- Was originally a standard bore of 63 mm



- We honed our cylinder before we realized we had to bore it
- The cylinder should have been rehoned after it was bored
-

Piston and Rings

- Since our barrel was bored, we needed a larger piston and new rings
- Piston rings prevent fuel and combustion gasses from leaving combustion chamber and oil from entering it. Also transfer heat to cooling walls
- 3 rings: Two compression rings and one scraper
- Ring gaps should be offset from each other
- Ring gaps will close when the rings undergo thermal expansion

Removing our Piston 2/15/23
&
Photo Credit: University of Windsor

Evolution of the Barrel: Convective Heat Transfer

- We have a round barrel, but the shape of the barrel later changed to a square and then an oval shape
- Based upon Convection heat transfer equation,

$$Q = hA\Delta T$$

$$Q \propto A$$

- The surface area of the fin is proportional to the heat carried away
- Why not add more fins to have greater surface area?

—-> Impedes flow

1964 Tiger Cub
https://www.ebay.co.uk/itm/1665078891

1961 Tiger Cub
https://www.ebay.co.uk/itm/155078891561

More Science: Convective Heat Transfer Calculation

Calculate the heat dissipating off 0.05 m cooling fin attached to our 1954 Triumph Tiger Cub motorcycle engine as it travels at 40 $\frac{km}{h}$. The ambient air temperature is 27°C and the surface temperature of the fin is 236° C.

L = length of fin = 0.05 m $\quad v = 40 \frac{km}{h}$

$$q' = \frac{\text{heat dissipation}}{\text{length}} = \frac{q}{L} = \bar{h} L (T_s - T_\infty) 2$$

($\bar{h}$: constant; 2: there are two sides of the fin)

Units: $\frac{W}{m}$

$$\bar{h} = \frac{\overline{Nu}\, k_f}{L}$$

($\overline{Nu}$: constant; k_f: thermal conductivity)

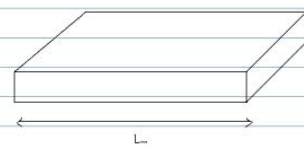
$$\overline{Nu} = f(Re, Pr)$$

(Re: Reynolds constant; Pr: Prandtl number)

$$Re = (v, \nu, L)$$

(v: velocity; ν: viscosity)

* approximate fin as flat plate



from a table:

$k_f = 0.0346 \frac{W}{m\,k}$

$\nu = 27.85 \times 10^{-6} \frac{m^2}{s}$

$Pr = 0.69$

Calculation Continued

We need to know if this is Laminar to look up $\overline{Nu}$ ← unitless

$$Re = \frac{VL}{\nu} = 40 \times 10^3 \frac{m}{hr} \times \frac{1\ hr}{3600\ s} \times 0.05\ m \times \frac{1\ s}{27.85 \times 10^{-6}\ m^2} = 1.995 \times 10^4$$

↳ $< 5 \times 10^5$ so this is Laminar

$$\overline{Nu} = 0.664\ Re^{1/2}\ Pr^{1/3}$$
$$= 0.664\ (1.995 \times 10^4)^{1/2} (0.69)^{1/3} = 82.87$$

$$\bar{h} = \frac{(82.87)(0.0346\ \frac{W}{mK})}{0.05\ m} = 57.35\ \frac{W}{m^2 K}$$

Now we have everything to plug in:

$$q' = \bar{h} L (T_s - T_\infty)$$
$$= 57.35\ \frac{W}{m^2 K} (0.05 m)(236°C - 27°C) 2$$

$$q' = 1198.615\ \frac{W}{m}$$

$$q' = \frac{q}{L} \qquad q = q' L = 1198.615\ \frac{W}{m} (0.05) m = 59.93075\ W$$

60 W

Question Adapted from Nathaniel Nelson's Heat Transfer Notes

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