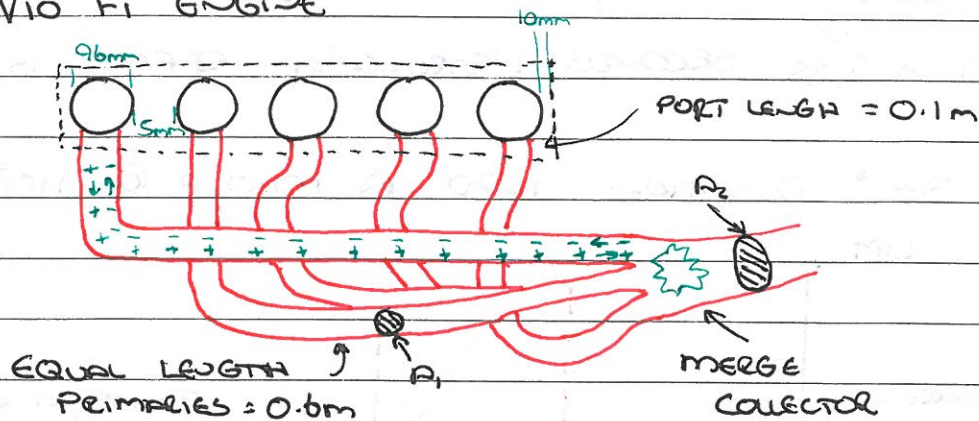


COMBUSTION ENGINE PERFORMANCE

10/03/16

V10 FI ENGINE



$$\text{ENGINE LENGTH} \approx (5 \times 96) + (4 \times 5) + (2 \times 10) = 520 \text{ mm}$$

TOTAL LENGTH FROM VALVE TO MERGE COLLECTOR = 0.7m

IN FI N/A ENGINE EXHAUST TEMP IS AROUND 850°C AT MANIFOLD AND AROUND 600°C AT COLLECTOR.
 $\therefore$ MEAN GAS TEMP = $\frac{850 + 600}{2} = 725^\circ\text{C}$

SPEED OF SOUND $\propto \sqrt{T_{\text{ABS}}}$ $\therefore$ MEAN SPEED OF SOUND IN EXHAUST IS -

$$330 \times \sqrt{\frac{725 + 273}{20 + 273}} = 609 \text{ m/s}$$

RATIO OF ABSOLUTE TEMPS

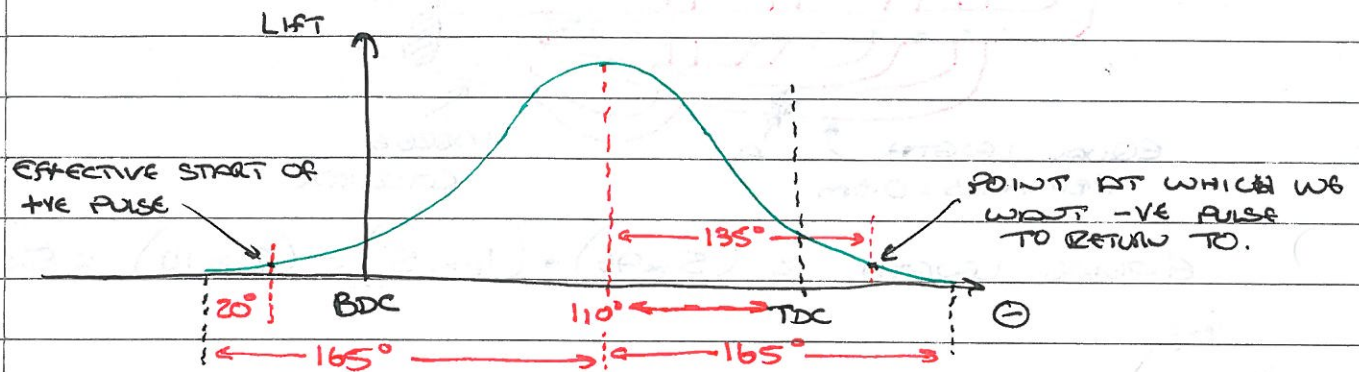
WHEN THE POSITIVE PULSE GETS TO THE COLLECTOR IT SUDDENLY EXPANDS AND LEAVES A NEGATIVE PULSE IN ITS OWN PRIMARY. A LARGER EXPANSION WILL CREATE A STRONGER PULSE.

THE -VE PULSE SHOULD RETURN FINALLY WHEN THE PISTON IS BETWEEN TDC AND EXHAUST VALVE CLOSING TO MINIMISE FLOW REVERSAL. THE TIME FOR THE -VE SUCTON TO RETURN TO VALVE

$$= n \times \frac{2L}{609} \text{ SECONDS} = n \times \frac{2 \times 0.7}{609} \text{ SECONDS}$$

$\therefore T = n \times \frac{1}{435} \text{ SECONDS}$. STRONGEST EFFECT IS 1ST HARMONIC

WITH 330° DURATION AND A M.O.P @ 110° BTDC



$$\text{M.O.P} \rightarrow \text{START OF +VE PULSE} = 165^\circ - 20^\circ = 145^\circ$$

$$\text{M.O.P} \rightarrow \text{T.D.C} = 110^\circ$$

$$\text{M.O.P} \rightarrow \text{CLOSE} = 165^\circ$$

$$\text{M.O.P} \rightarrow \text{MID POINT (TDC} \rightarrow \text{CLOSE)} = \frac{110 + 165}{2} = 137.5^\circ$$

$$\text{START OF PULSE} \rightarrow \text{DESIRED RETURN} = 145^\circ + 137.5^\circ = 282.5^\circ$$

$$T \text{ FOR CRANK TO TURN} = \frac{282.5}{360} \times \frac{60}{\text{RPM}} = n \times \frac{1}{435}$$

$$\text{FOR BEST TUNING RPM} = \frac{282.5}{360} \times \frac{60}{n} \times 435$$

$$n_1 = 20, 481 \text{ RPM}$$

$$n_2 = 10, 240 \text{ RPM}$$

$$n_3 = 6, 827 \text{ RPM}$$

$$n_4 = 5, 120 \text{ RPM}$$

$$n_5 = 4, 096 \text{ RPM}$$

$$\text{IF DURATION IS } 300^\circ, \text{ THEN RPM} = \frac{260}{360} \times \frac{60}{n} \times 435$$

$$n_1 = 18,850 \text{ rpm}$$

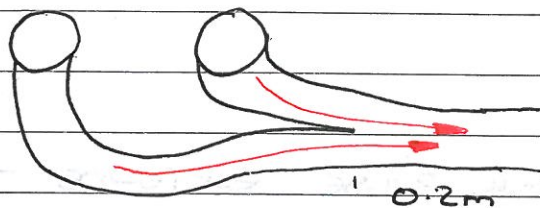
$$n_2 = 9,425 \text{ rpm}$$

$$n_3 = 6,283 \text{ rpm}$$

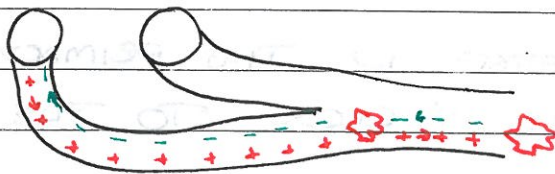
$$n_4 = 4,712 \text{ rpm}$$

$$n_5 = 3,770 \text{ rpm}$$

THE SHAPE OF THE MERGE COLLECTOR IS IMPORTANT, TRY TO MERGE TOGETHER IN A SMOOTH WAY FOR GOOD FLOW CHARACTERISTICS AND VENTURI EFFECT.



SUPPOSE THAT LENGTH FROM COLLECTOR TO THE END IS 0.2m



THE PULSE CONTINUES TO THE TAIL PIPE THEN HAS ANOTHER SUDDEN EXPANSION, LEAVING

ANOTHER -VE PULSE TO TRAVEL BACK.

TIME FOR LONGER LENGTH -VE. PULSE TO RETURN

$$= n \times \frac{2L}{60\pi} = n \times \frac{2 \times 0.9}{60\pi} \text{ seconds}$$

$$n_1 = 2.9 \times 10^{-3} \text{ s}$$

$$n_2 = 5.9 \times 10^{-3} \text{ s}$$

$$n_3 = 8.9 \times 10^{-3} \text{ s}$$

$$n_4 = 0.012 \text{ s}$$

$$n_5 = 0.015 \text{ s}$$

FOR BEST TUNING FOR LONGER LENGTH

$$\frac{282.5}{360} \times \frac{60}{\text{Rpm}} = \frac{n \times 2 \times 0.9}{609}$$

$$\therefore \text{Rpm} = \frac{282.5}{360} \times \frac{60}{n \times 2 \times 0.9} \times 609$$

$$n_1 = 15,700 \text{ Rpm}$$

$$n_2 = 7,964 \text{ Rpm}$$

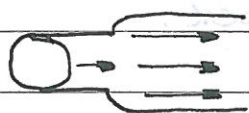
$$n_3 = 5,309 \text{ Rpm}$$

$$n_4 = 3,982 \text{ Rpm}$$

$$n_5 = 3,185 \text{ Rpm}$$

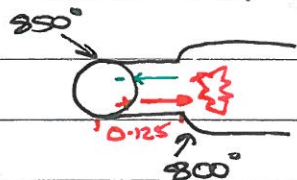
THE SECOND LONGER PULSE EXTENDS THE POWER BAND TO THE LOWER RPM RANGE.

F₁ EXHAUSTS USE A STEP IN THE PRIMARIES, THIS PROVIDES AN EXPANSION V. CLOSE TO THE EXHAUST VALVE.



THIS STEP PROVIDES AN EARLY RETURN PULSE JUST BEFORE BDC TO REDUCE -VE WORK AS THE PISTON

MOVES UP.



$$T_{\text{EMP AT PORT}} \approx 850^{\circ}\text{C}$$

$$T_{\text{EMP AT STEP}} \approx 800^{\circ}\text{C}$$

$$\therefore T_{\text{AV}} = \frac{850 + 800}{2} = 825^{\circ}\text{C}$$

IF PORT LENGTH = 0.1m

$$\therefore L_T = 0.225\text{m} \quad (\text{AS PORT TO STEP} = 0.125\text{m})$$

AVERAGE TEMP IS MUCH HOTTER SO THE SPEED OF SOUND = $330 \times \sqrt{\frac{825 + 273}{20 + 273}} = 639 \text{ m/s}$

$$\text{Time} = n \times 2 \times \frac{0.225}{639}$$

$$n_1 = 7 \times 10^{-4} \text{ s}$$

$$n_2 = 1.4 \times 10^{-3} \text{ s}$$

$$n_3 = 2.1 \times 10^{-3} \text{ s}$$

$$n_4 = 2.8 \times 10^{-3} \text{ s}$$

$$n_5 = 3.5 \times 10^{-3} \text{ s}$$

AT 19,000 RPM, Time for 1° CRANK ROTATION =

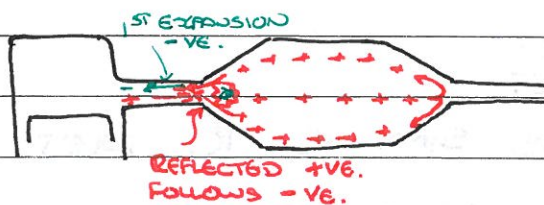
$$\frac{1}{360} \times \frac{60}{19000} \text{ SECONDS} = 8.8 \times 10^{-6} \text{ SECONDS}$$

IN THE TIME FOR THE SUCTION PULSE TO RETURN THE CRANK HAS TURNED =

$$\frac{7 \times 10^{-4}}{8.8 \times 10^{-6}} = 79.5^\circ$$

IF EXHAUST VALVE OPENS AROUND $80-90^\circ$ BBDC USE THE STEP TO REDUCE THE CYL. P AT BBDC SO PISTON DOESN'T HAVE TO FIGHT ITS WAY UP. USE STEP TO REDUCE -VE WORK.

A TWO STROKES EXPANSION CHAMBER WORKS A LITTLE DIFFERENTLY -

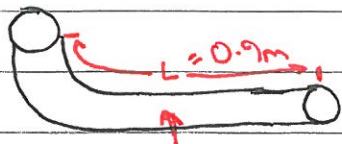


AS THE GASES LEAVE THE CYLINDER A +VE PULSE IS CREATED AND ONCE THE EXPANSION CHAMBER IS REACHED

A -VE. PULSE IS SENT BACK TO THE CYLINDER. THE +VE PULSE CONTINUES TO THE OTHER END OF THE EXPANSION CHAMBER WHERE IT REFLECTS AS A +VE BACK TOWARDS THE CYLINDER. TIME THIS +VE PULSE

TO REACH THE CYL. TO STOP THE FRESH AIR/FUEL MIX COMING OUT OF EXHAUST PORT WHEN BOTH INLET + EXHAUST PORTS ARE OPEN.

$$3L \text{ VIO} \approx 300 \text{ cc/CYL}$$



MEAN GAS TEMP
 $\approx 725^\circ\text{C} = 998 \text{ K}$

THE DIAMETER OF THE EXHAUST ONLY HAS A MINOR EFFECT ON THE TUNED EXHAUST LENGTHS.

IT HAS THE EFFECT OF SMALL

END CORRECTIONS $\frac{D}{3}$ E.G. IF $D = 4 \text{ cm}$, THE EFFECTIVE LENGTH BECOMES $L = 90 + \frac{4}{3} = 91.3 \text{ cm}$.

IF CYL. DISP = 300 cc THEN THE PRIMARY NEEDS TO BE ABLE TO CONTAIN THE SAME AMOUNT OF GAS. TO AVOID CONGESTION AT THE COLLECTOR WITH THE OTHER CYLINDERS, YOU NEED TO MAKE THE PRIMARY VOLUME BIG ENOUGH TO HOLD A CYLINDER WORTH OF EXHAUST GASES.

INLET 300 cc COMES IN AT 293 K BUT EXHAUST IS AT 998 K SO IS FAR LESS DENSE.

$$P.V = m.R.T$$

$$\text{DENSITY} = \rho = \frac{m}{V} = \frac{P}{RT}$$

ASSUMING EXHAUST P IS SIMILAR TO INLET P -

$$\rho \propto \frac{1}{T}$$

↓ RATIO OF ABSOLUTE TEMPS.

$$\frac{\text{DENSITY INLET}}{\text{DENSITY EXHAUST}} = \frac{998}{293} = 3.4$$

$$\text{VOL OF PRIMARY + PORT} = 90 \times \frac{\pi \phi^2}{4} \quad (\text{if } \phi \text{ is cm})$$

$$\text{VOL MUST BE } 300 \text{ cc} \times 3.4 = 1020 \text{ cc}$$

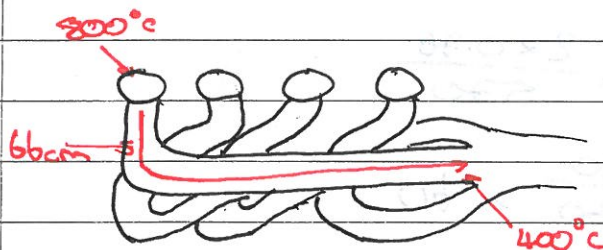
$$\therefore 1020 = 90 \times \frac{\pi \phi^2}{4}$$

$$\therefore \frac{1020}{90} = \frac{\pi \phi^2}{4}$$

$$\therefore 4 \times 11.3 = \pi \times \phi^2$$

$$\therefore \sqrt{\frac{45.3}{\pi}} = 3.8 \text{ cm} = \text{inner } \phi$$

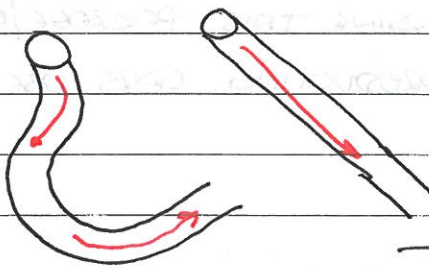
PEUGEOT 205 GTI



10cm PORT LENGTH

TOTAL LENGTH = 76 cm

ASSUME EACH PIPE HAS
AVERAGE GAS T OF $\frac{1}{2} (800 + 400)$
= 600°C



BOTH ARE 76 cm AND 800°C AT
THE PORT. THE CURVED PIPE TRANSFERS
MORE HEAT TO THE OUTSIDE WALL
 $\therefore$ HAS A SLOWER SPEED OF SOUND.

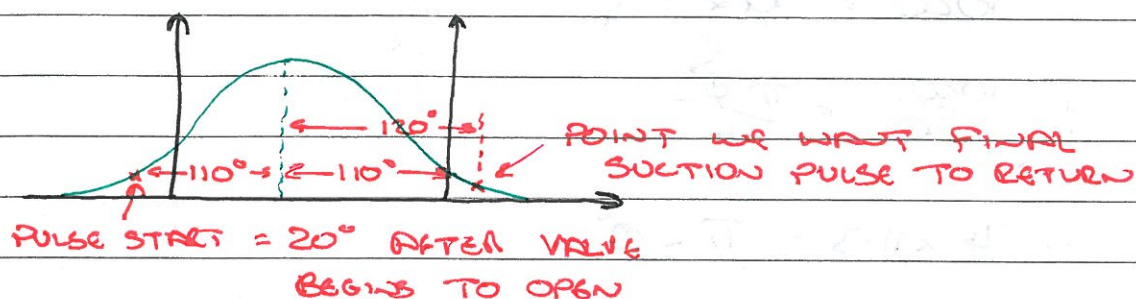
PULSES TAKE LONGER TO TRAVEL ALONG THE
BENT PIPE SO IT BEHAVES LIKE A LONGER PIPE.
THE CURVED PIPE HAS MORE FLOW RESISTANCE ALSO.

ASSUME ALL PIPES ARE EQUAL LENGTH WITH
SAME T.M. OF 600°C .

$$\text{MEAN SPEED OF SOUND} = 330 \times \sqrt{\frac{600 + 273}{20 + 273}} = 570 \text{ m/s}$$

T FOR -VE PULSE TO RETURN = $(0.76 \times 2) / 570 = 0.00265$
 FOR 1ST HARMONIC

ASSUME DURATION = 260° , M.O.P = 110° BTDC



$\Theta T = 110^\circ + 120^\circ = 230^\circ$ OF CRANK ROTATION
 TIME TO ROTATE 230° @ = $(230/360) \times (\frac{60}{\text{RPM}})$ SECONDS
 FOR BEST TUNING T MUST EQUAL = $n \cdot \frac{2 \times 0.76}{570}$ SECONDS

$$\therefore \frac{230}{360} \times \frac{60}{\text{RPM}} = n \times \frac{2 \times 0.76}{570}$$

$$\therefore \text{RPM} = \frac{570}{n \times 2 \times 0.76} \times \frac{230}{360} \times 60$$

$n_1 = 14,375$ RPM $\leftarrow$ NOT USING THIS, PACKAGE/WEIGHT.

$n_2 = 7,187$ RPM $\leftarrow$ MOST PRODUCTION CARS USE n_2 - n_5

$n_3 = 4,791$ RPM

$n_4 = 3,593$ RPM

$n_5 = 2,875$ RPM

VOLUMETRIC EFFICIENCY

