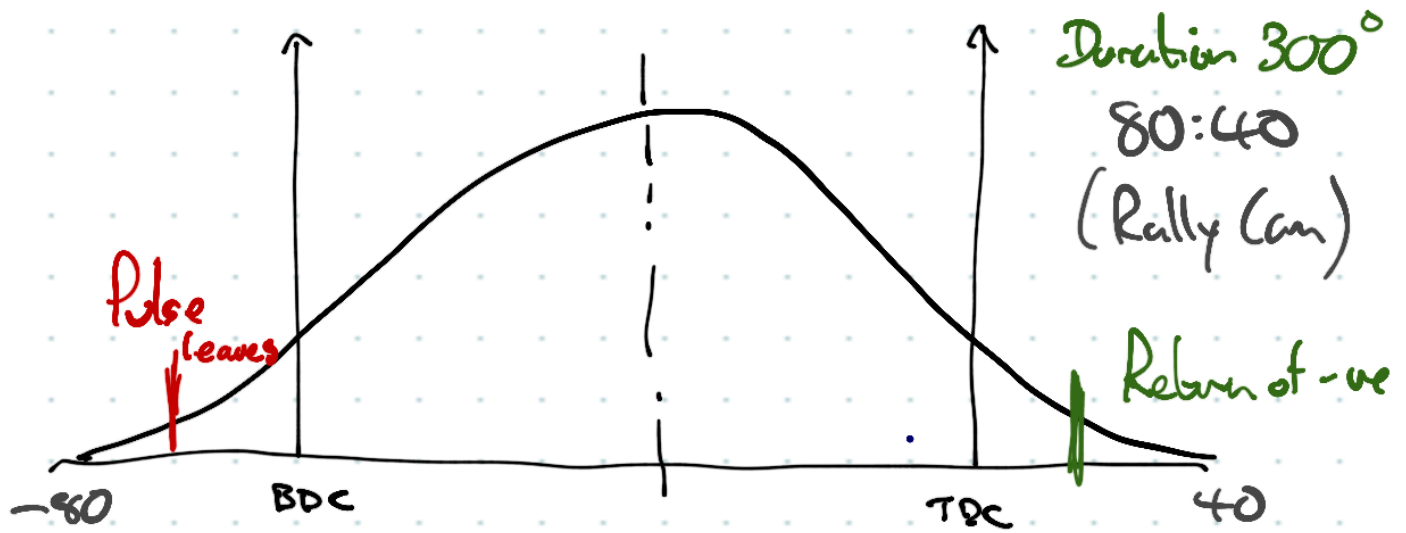
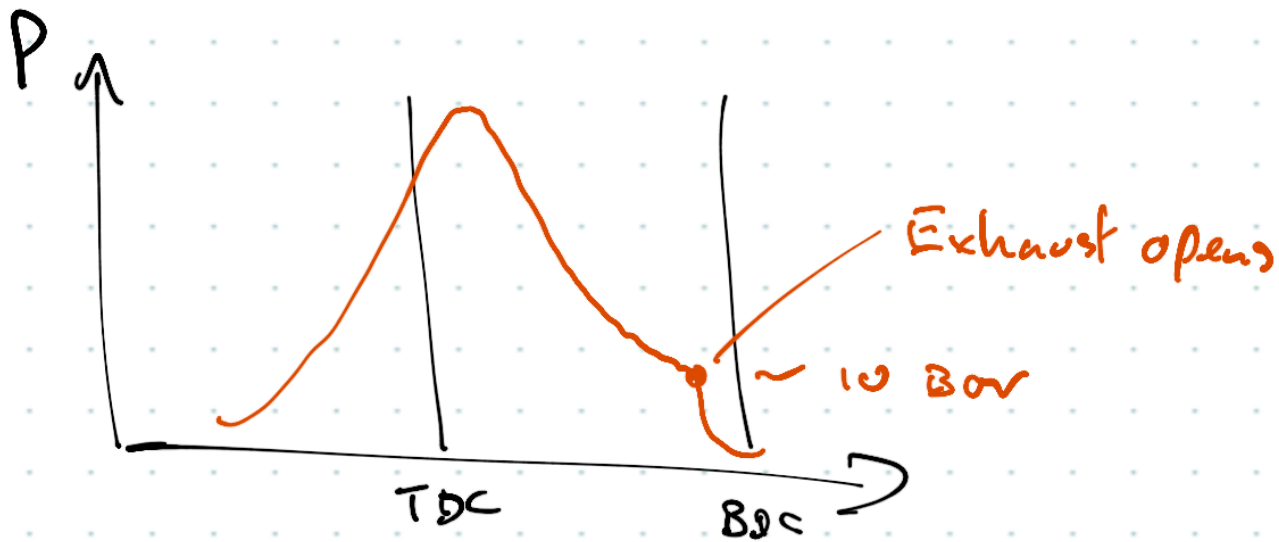
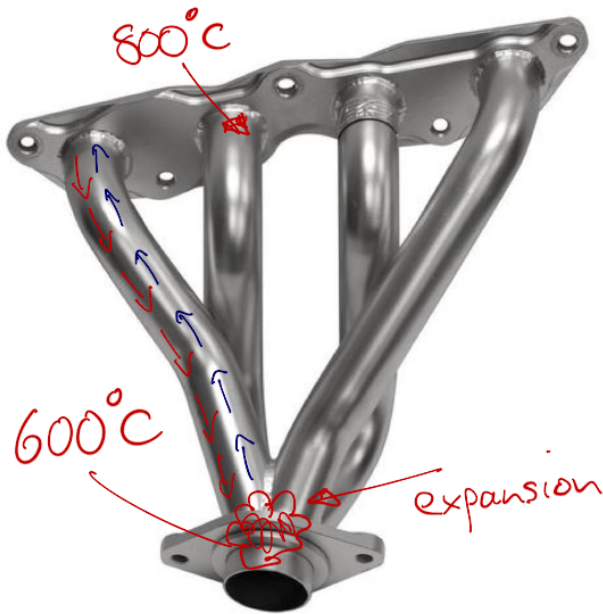


Exhaust pulse tuning



the pulse leaves valve $\approx 20^\circ$ after opening

How does this all work?



the pulse leaves at about 20° after opening and travels at speed of sound towards the collector.

the pulse collapses

resulting in a -ve pulse which travels back to the valve. A -ve pulse between TDC and valve closing will help Scavenge the cylinder clearance volume.

We need to consider temperatures :

$$T_{AV} = \frac{600 + 800}{2} = \underline{700^{\circ}\text{C}}$$

Speed of sound $\propto \sqrt{T_{ABS}}$

Absolute temp

The time for +ve pulse to leave and return as a -ve pulse, N times:

$$T = N \cdot \frac{2L}{330} \quad \leftarrow \text{Speed of Sound}$$

So we need the new speed of sound.

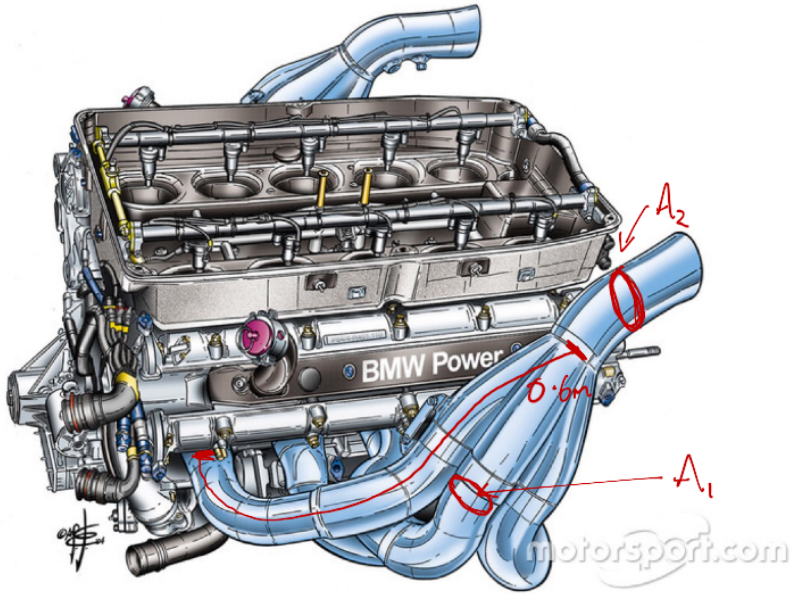
$$\text{Speed at } 700^{\circ}\text{C} = \sqrt{\frac{700+273}{20+273}} = 1.82$$

$$\text{Speed at } 700^{\circ}\text{C} = 1.82 \times 330 = 601 \text{ ms}^{-1}$$

We want to exhaust pulse back midway between TDC and closing, $\therefore$ The pulse needs to be back 260° after it left

$$\text{Time for } 260^{\circ} = \frac{260}{360} \times \frac{60}{\text{RPM}} = \frac{N \cdot 2L}{601}$$

BMW V10 F1



$$\text{Port} = \underline{0.1 \text{ m}}$$

$$\text{Primary length} = \underline{0.6 \text{ m}}$$

$$\begin{aligned} &\text{Total length from} \\ &\text{Valve to merge Collector} \\ &= \underline{\underline{0.7 \text{ m}}} \end{aligned}$$

F1 engine (N/A) Exhaust Temp is maybe 850°C @ manifold end and about 600°C at the collector

$$\text{Mean gas temp} = \frac{850 + 600}{2} = \underline{\underline{725^{\circ}\text{C}}}$$

Mean speed of sound in the exhaust

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

Ratio of absolute
temperature

when +ve pulse hits collector
the expansion sends back a -ve

Things to note:

The 'expansion ratio' for
this 5 cylinder bank is $\frac{A_2 + 4A_1}{A_1}$

A larger expansion will create a stronger pulse

The -ve pulse should get back between TDC
and closing to minimise flow reversal

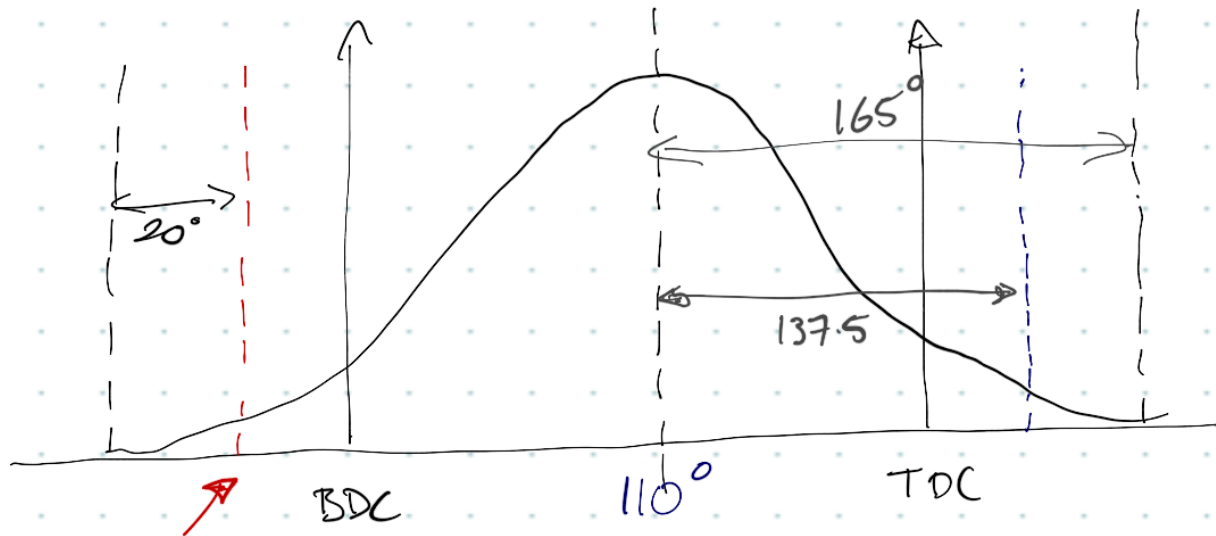
Time for the -ve pulse to return

$$T = N \cdot \frac{2L}{609} \quad \begin{matrix} \swarrow 1 \\ \searrow 0.7 \end{matrix}$$

$$T = \frac{1}{435} = 0.0023 \text{ seconds}$$

So what about the camshaft?

Try a 330° duration cam with MOP at 110° BTDC



effective
start of pulse

$$\text{MOP} \rightarrow \text{start of +ve pulse} = 165^\circ - 20^\circ = 145^\circ$$

$$\text{MOP} \rightarrow \text{TDC} = 110^\circ$$

$$\text{MOP} \rightarrow \text{close} = 165^\circ$$

$$\text{MOP} \rightarrow \text{Midpoint of [TDC - close]} = \frac{110 + 165}{2} = 137.5^\circ$$

$$\begin{aligned} \text{So Start of pulse} \rightarrow \text{desired return point} &= 145 + 137.5 \\ &= \underline{282.5^\circ} \end{aligned}$$

Time for crankshaft to turn

$$T = \frac{282.5}{360} \times \frac{60}{\text{RPM}} = \frac{N}{435}$$

So we get

$$\text{RPM} = \frac{282.5}{360} \times \frac{60}{N} \times 435$$

$$N=1 \rightarrow 20,481$$

$$N=2 \rightarrow 10,240$$

$$N=3 \rightarrow 6,827 \quad \text{RPM}$$

$$N=4 \rightarrow 5,120$$

$$N=5 \rightarrow 4,096$$

If the duration was 300°

$$\text{RPM} = \frac{260}{360} \times \frac{60}{N} \times 435$$

$$N=1 \rightarrow 18,850$$

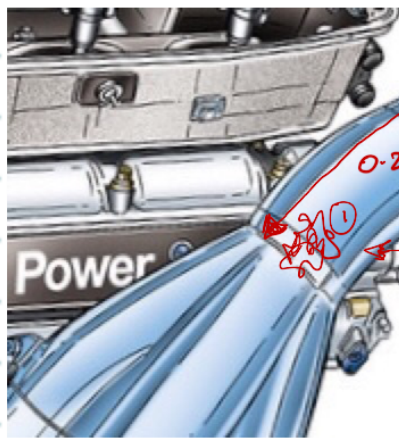
$$N=2 \rightarrow 9,425$$

$$N=3 \rightarrow 6,283 \quad \text{RPM}$$

$$N=4 \rightarrow 4,712$$

$$N=5 \rightarrow 3,770$$

$$\text{Remember } T = \frac{260}{360} \times \frac{60}{\text{RPM}} = \frac{N \cdot 26}{609}$$



Merge collectors are good for good flow
 → Venturi effect

Suppose for the BMW V10, the distance from merge collector → end is 0.2m

So the +ve pulse continues to the tail pipe then sees another expansion, creating another -ve pulse which travels back...

Time for the longer length -ve pulse

$$\text{Pulse to return} = \frac{N \times 2L}{609} = \frac{N \times 2 \times 0.9}{609}$$

for best tuning for longer length

$$\frac{282.5}{360} \times \frac{60}{\text{RPM}} = \frac{N \cdot 2 \cdot 0.9}{609}$$

$$\text{So RPM} = \frac{282.5}{360} \times \frac{60}{2 \times 0.9 \times N} \times 609$$

$$n=1 \rightarrow 15,700$$

$$n=2 \rightarrow 7,964$$

$$n=3 \rightarrow 5,309$$

$$n=4 \rightarrow 3,982$$

$$n=5 \rightarrow 3,185$$

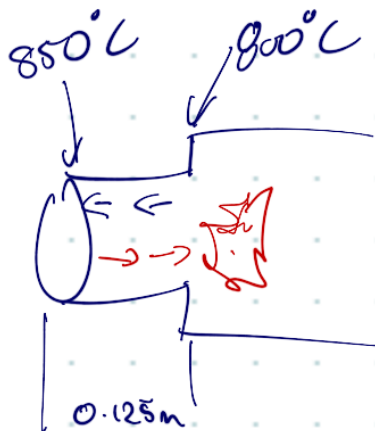
The second (longer) pulse extends the power band to the lower range of RPM

Sometimes we see a 'Step' in the primary...



- Boundary layer on the surface

One possible explanation is that the step prevents flow reversal of low velocity air close to the boundary



The step also provides an expansion very close to the exhaust valve

This we call an 'early return pulse'.

This pulse comes back just before BDC.

which can reduce -ve work as the piston starts to move back up.

So assume a 0.1 m part length -- So

$$L_T = 0.225 \quad (0.1 + 0.125)$$

It's very hot at this point $T = \frac{800 + 850}{2}$

$$T = 825^\circ\text{C}$$

So our speed of sound is

$$v = 330 \times \sqrt{\frac{825 + 273}{20 + 273}}$$

$$v = \underline{639 \text{ m/s}}$$

So

$$T = \frac{2N \times 0.225}{639} =$$

$$\begin{aligned}
 n=1 &\rightarrow 7 \times 10^{-4} \text{ s} \\
 n=2 &\rightarrow 1.4 \times 10^{-3} \text{ s} \\
 n=3 &\rightarrow 2.1 \times 10^{-3} \text{ s} \\
 n=4 &\rightarrow 2.8 \times 10^{-3} \text{ s} \\
 n=5 &\rightarrow 3.5 \times 10^{-3} \text{ s}
 \end{aligned}$$

at 19,000 RPM

Time / °

$$\frac{1}{360} \times \frac{60}{19,000} = 8.8 \times 10^{-6} \text{ s}$$

In the time for the suction pulse the crank has turned

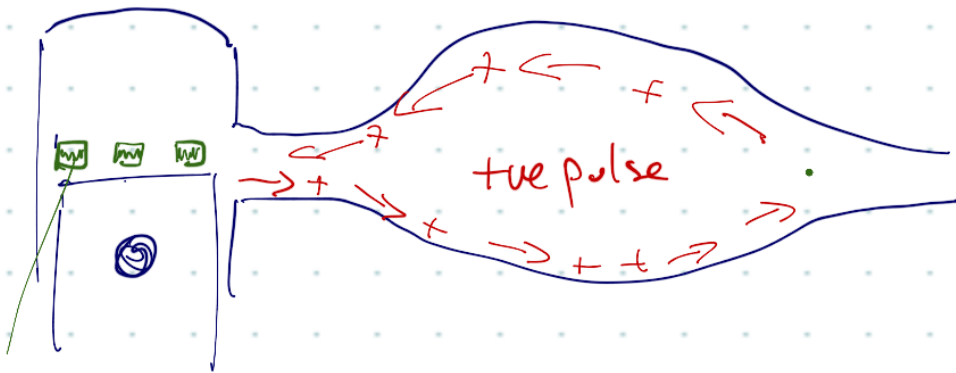
$$\frac{7 \times 10^{-4}}{8.8 \times 10^{-6}} = 79.5^\circ$$

The exhaust valve at 80-90° B.BDC
 So the step would reduce cylinder pressure
 @ BDC so the piston has less pressure to
 fight against on the way up



Reduce -ve work

2 Stroke



Transfer (inlet part) for the two stroke, we create a reflected +ve pulse to try and stop the air/fuel mixture coming into the exhaust when both inlet and exhaust ports are open.

