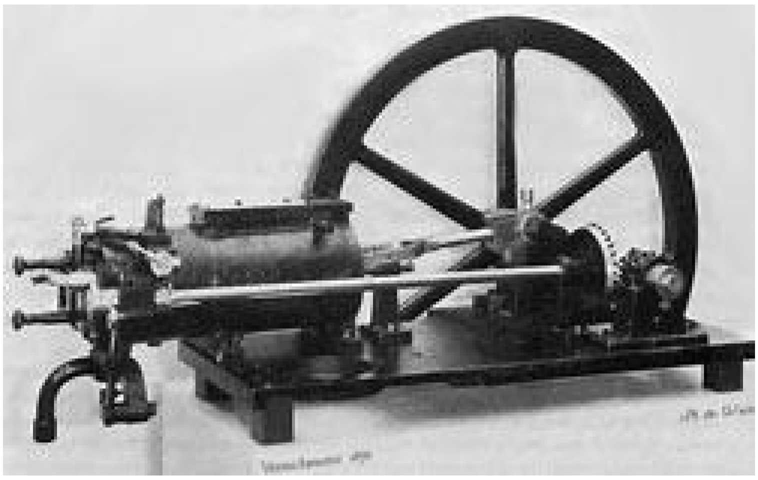
The History and Development of the V8 Engine

Abstract
First developed in 1876 by Nicolaus Otto, the internal combustion engine has revolutionised personal transport since it was first fitted to a three-wheeled automobile ten years later. Obviously it has changed dramatically since then in terms on the technology applied in design and construction, but the basic principles of operation remain the same. Originally a single cylinder design, the number of cylinders has increased in attempts to increase smoothness and power. Several engine layout configurations have been developed, one of which is the V-style engine. So why look at the V8 in particular? First produced in 1914, the V8 engine is a fairly compact layout for large engine sizes (which were needed in order to move heavy vehicles at sufficient speed) and proved to be the most popular engine layout (in terms of sales) in America since it was introduced and has become famous worldwide. One major reason for this is the noise. Although there have been many great sounding engines over the decades, from various cylinder layouts, almost all V8s sound special and are loved by car enthusiasts. This, along with a wide range of capacities (from under 2 litres to over 8 litres in mass produced form), has earned them places in a wide variety of vehicles - initially just in large saloons - but later in sports cars, off road vehicles, powerboats, the occasional aeroplane and even a motorbike. The passion towards the V8 design ensures that it will endure.

Introduction
The idea of an internal combustion engine was first designed in 1680 (although never built) by a Dutch physicist named Christian Huygens. It took until 1807 before attempts were made to construct such an engine and they were met with very limited success. During the 1850s and 60s, more attempts were made, however it wasn't until 1876 that the first fully successfully design was produced. There had been two ideas over the ways for such an engine to operate, using either a 2-stroke or a 4-stroke design. As it happens, both designs were made to work in 1876, the 2-stroke by Sir Dougald Clerk and the 4-stroke by Nicolaus Otto. It was this 4-stroke design, known as the Otto cycle, which became the basis for all modern engines [1a]. Not that it was the only 4-stroke design, however, just 6 years later (in 1882) the Atkinson cycle was devised, which was very similar but with an emphasis on efficiency and low fuel usage. Also the Miller cycle, developed in the 1940s, was different again, also with an aim to increase efficiency (through the use of a supercharger). However both the Atkinson and Miller cycles are basically modified versions of the Otto cycle, which is why it is so highly regarded.

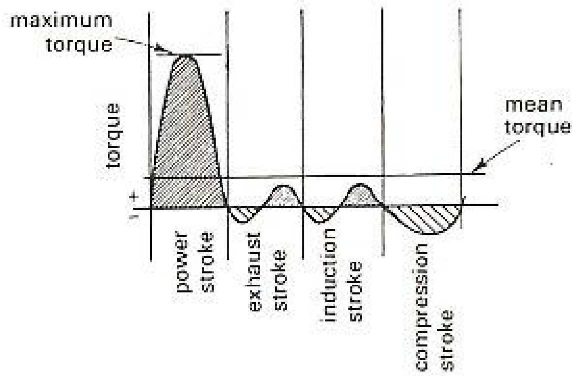


1a. Otto's first four stroke engine

All these types of combustion engine have so far been reciprocating designs, but there are rotary designs also. I won't go into detail on these but they deserve a mention for completeness; the first to be designed was the Wankel engine in 1924 (although it wasn't production ready until 1958), the little known Wolfhart engine (a two stroke engine using ball pistons design in the 1970s designed as a competitor to the Wankel engine, but it never went anywhere), the ball piston engine (a more modern 4-stroke design), and most recently the Quasiturbine engine (patented in 1996 but is still undergoing prototype work). All these designs address issues with previous designs but still have their own strengths and weaknesses.

Engine Configurations

The first application of the internal combustion engine was personal transport. Automobiles were reasonably large, heavy and slow. The early stages of development for engines were fuelled by the quest for power (and therefore speed). The simple way to do this is to increase the internal volume of the engine, however the downside is that while larger pistons give more torque, they also rev more slowly, and since power is a function of torque multiplied by speed, this has its drawbacks. Also early engines were very lumpy, the first engine designed by Otto turned at 250rpm, with the 4-stroke design this means just over 2 ignitions per second, or one ignition for every 720° the crankshaft turns [(2a)]. The easy way to cure this, and the previous problem, is to use multiple cylinders connected to the same crankshaft, and to ignite the cylinders at different times. So with for example 8 cylinders in the engine, that's nearly 17 ignitions per second or one ignition every 90°. Also engines began to rev much higher early on in their development; it wasn't long before engines could turn at multiple thousand rpm – so that's multiple hundreds of ignitions per second, the smoothness issue solved, and one step towards creating more powerful engines.



2a. Torque output during 4-stroke cycle

This brings up the question of how to put all these cylinders together in the cylinder block. The simplest solution is to put them all inline with one another, and while this is a fine solution for engines with a low number of cylinders, it doesn't take many cylinders before engines become quite long. For the huge vehicles built in the early 20th Century this wasn't too much of a problem, and "straight eight" engines were not uncommon. As cars became smaller and more popular, a neater solution to packaging the engine was required. The Boxer engine was an alternative configuration, where the cylinders are split into two banks and lay flat, horizontally opposed. This creates a low but wide engine which has never proved overly popular among motor manufacturers (increased cost also being a reason), although they do balance perfectly as the movement of each piston is exactly counted by the corresponding piston in the other bank. A compromise then is the V style engine (due it to resembling the letter "V" when viewed end on), where the banks of cylinders are at an angle less than 180° apart - 120° or less is usual. This style of engine is narrower than a flat engine but still lower than an inline engine, and is a very compact way to package a reasonable number of cylinders. These three engine layouts are by far the most popular, however other layouts have been tried, they include:

- Monosoupape engines, developed by Blazer in 1899, this is a radial design of engine where all the pistons faced outward in a circle from a common crankshaft. Very high numbers of cylinders were common (14 to 24). This type of engine was primarily used in aircraft. Its main benefits were that it was a short engine and, due to the way it was mounted, did not require a flywheel, which made it lighter than other engines of the time.
- "In-line vee" style engines use a staggered layout, essentially a V style engine where the angle between the banks is so narrow (~15°) that cylinders from opposing banks are not aligned (the Volkswagen VR6 is the only production example). This style of engine is longer than a V engine but shorter than an inline engine.
- W style engines come in three varieties:
    - 2 bank designs a basically a V style engine with two separate crankshafts
    - 3 bank designs are the classic style of W engines, where a V style engine has two banks of cylinders connected to a single crankshaft, a W has three. It resembles a three pronged fork more than the letter W.
    - 4 bank designs are like two V style engines with a common crankshaft but with small angles between banks to keep the width down. Only Volkswagen has produced an engine such as this and they made it from two VR6 engines. It is a very compact design for high numbers of cylinders.
- H style engines are basically two flat engines on top of one another (picture the letter H on its side), then geared together at one end. This makes them very compact but gives them a high centre of gravity and low power-to-weight.
- U style engines were an early attempt at cost saving (through part sharing with other straight engines) where two inline engines are joined together by gears, but engines suffered from a low power-to-weight and unnecessary complexity.

The number of cylinders in an engine, the cylinder layout, how well the engine is balanced, the exhaust, along with probably everything else in the engine, all help determine the noise of an engine. However most engines can be easily identified as to their cylinder configuration, as a V6 has a very different sound to a flat six or to a V10, for example. That said, the V8 configuration is particularly distinguishable again, why this is I'm not sure, all I know is that I like it.

The V8

The first time an engine was built in the V8 configuration was 1914, although it was until Ford introduced a V8 into its range of cars in 1932 that it began to get popular. By the 1950s V8s were increasing popular in America, with the height of their popularity being during the 1970s before the oil crisis (at this point in time most cars on sale in America could be bought with a V8 under the bonnet), which also led the demise of the Big Block V8 (due to it's thirst), but V8s remain the preferred choice for most customers. V8-ism hit the UK too once Rover bought the rights to an unsuccessful Buick engine in 1965 (it was deemed to small for the American market), although it didn't enjoy the long term success that V8s did in America.

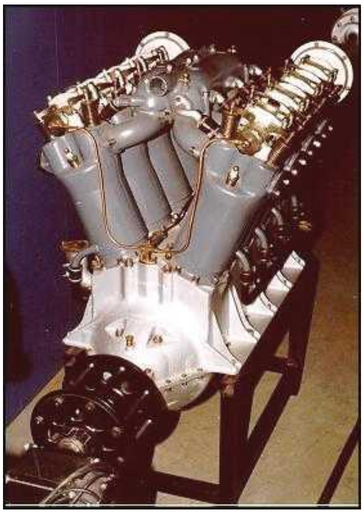
V8 engines are still popular in racing though, in fact there are many racing series that are V8 only, such as IRL, ChampCar, NASCAR (all American), plus many single-make race series such as the Ferrari 360 Challenge or TVR Tuscan Challenge (on the European side of things). Even Formula One is supposed to be using V8 engines next season.

The V8 engine must have been made in the largest range of capacities of any engine configuration, the smallest ever V8 being just 1500cc (the FWMW Conventry Climax engine), although this was only ever produced in small numbers and used in some Lotus racing cars. The smallest mass produced engine was 1990cc and the largest 500cid (that's 8194cc in European measurements).

Engine Balancing

With the exception of the flat configuration, engines do not balance without some effort. The angle between the banks affects how they balance, which is why the vast majority of V8 engines have their cylinder banks 90° as this is when best balanced is achieved, but there have been some exceptions:

- TVR Speed Eight uses 75 degrees, also has one of the best power-to-weight ratios for any road going normally aspirated engine, although is beaten by the (newer) Radical
- Radical RPA V8 uses 72 degrees to keep the engine compact, and is basically two bike engines as found in the Suzuki Hayabua sports bike
- Ford Yamaha V8 uses 60 degrees as it was based on the Ford Duratec V6, the engine is now used in some Volvos
- Once heard of 45 degrees in a WWI era plane (Hispano-Suiza) [3a]

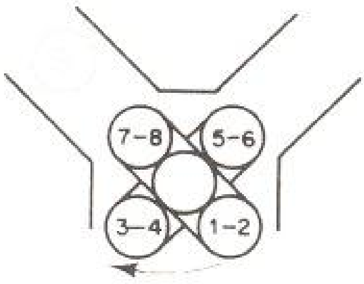


3a. A V8 engine with a 45° angle between banks

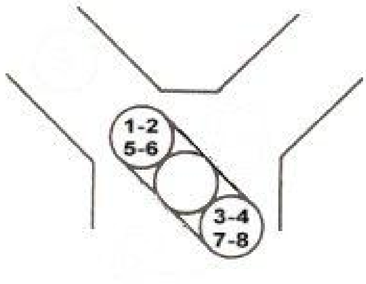
V8s generate no vibration in either vertical or transverse directions, or between the banks. However, depending on which style of crankshaft is used, they may suffer from end-to-end or second order vibration. Unlike other engine configurations, there are two possible layouts that can be used for the crankshaft, these being cross-plane [3b] or flat-plane [3c].

Cross-plane V8s suffer from end-to-end vibration which is cured by using extra-heavy counterweights on every cylinder. Each counterweight is heavy enough to balance the weight of the crank throw, con-rod and the piston of that cylinder, thus vibration is eliminated and you have a very smooth engine. The downside is that these counterweights increase the weight of the engine, increase the rotational inertia and also raise the height and centre of gravity for the engine. This makes engines less responsive, drops the upper rev limit and therefore top-end power, which is why in performance applications flat-plane cranks are favoured.

Flat-plane V8s do not suffer from this end-to-end vibration because of the way the pistons are located. However there is a second order vibration, which means flat-plane V8s run less smoothly, hence the preference for cross-plane V8s where performance is non-critical.



3b. Cross-plane crank



3c. Flat-plane crank

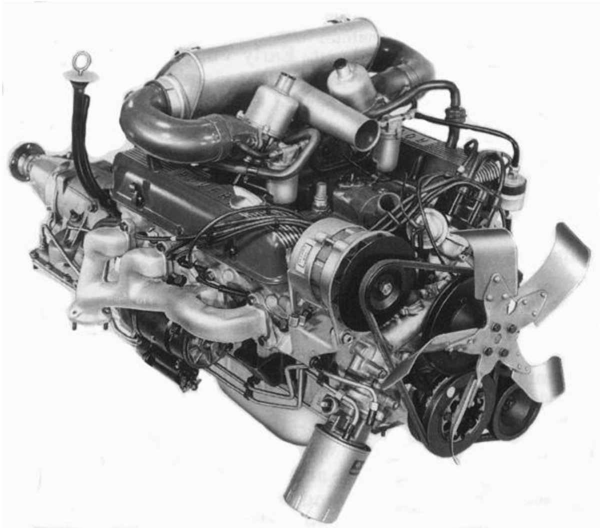
The style of crankshaft used also greatly affects the sound of a V8 engine, while the more usual cross-plane crank gives the classic deep, woolly rumble that V8 are so well known for, whereas flat-plane cranks make the engine sound more like two inline fours screaming at once. The sound is usually still recognisable as a V8, just more subtly so. One exception is the Lotus Esprit V8; the car that was well known for having a V8 but sounding like a "four banger".

Valves

Engine arrangement:
Side-valve engines, also known as L-heads due to combustion chamber resembling an upside down letter "L", were the first arrangement of the pistons, valves and such in the cylinder block. In this style of engine the intake and exhausts valves are placed alongside the cylinder mounted in the bottom of a side chamber. The first production V8 to use this system (and therefore also the first production V8) was the Ford Flat-head introduced in 1932.

The next engine arrangement came with the introduction of overhead valves (OHV), also known as pushrod engines. While this system had been invented by Auto Union (now Audi) in 1899, it was 50 years until the first production V8 engine was to use it; this being the Oldsmobile Rocket V8, but other companies soon followed suit; Lincoln in 1952, Ford with the Y-Block in 1954 and Chevrolet with the (to-be) legendary Small-Black, also that year. The OHV system worked by mounting the valves in the top of the cylinder head directly above the piston, operated by the camshaft in the sump via rods and valve lifters. This system involved lots of moving parts and also creates lag between the cam's activation of the valve and the valve's movement.

The next step in the evolution of the V8 engine came with the overhead camshaft (OHC) design, first trialled in 1908, it is similar to the OHV system but with much reduced moving parts by moving the camshaft from the sump to on top of the engine (therefore requiring one camshaft per bank of cylinders, so two camshafts are involved in an OHC V8), just above the valves, which it moves though use of rocker arms. The main advantage to this system over pushrod engines is speed; the engine can run faster so more power can be gained from the engine. The first V8 engine to use this system was the Rover V8 [5a]. Although it had been a pushrod engine when Rover bought the rights to produce the engine off Buick, Rover converted it to use overhead cams before they put it into production in 1965. It wasn't until 1991 that the American market got its first OHC V8 with the Ford MOD. In 2004 the Ford MOD went from having 16 valves to 24, through the use of three valves per cylinder (two intakes and one exhaust) instead of the usual two. Engines with 4 valves per cylinder were tried with the OHC system but it was extremely difficult to get enough lobes on a single crankshaft to operate them all properly.



5a. Rover V8 with single overhead cams

The solution to this was simple; use double overhead cams. That way the lobes can be spread out more and fitting them all in isn't a problem. Hence engines are only fitted with the DOHC system when used with multi-valve configurations (i.e. 3 or more valves per cylinder). The DOHC system was first used in a racecar in 1913, although it took until 1925 before it reached a production vehicle. The first production V8 to feature the DOHC system was made by Pegaso in the 1950s, however only around 100 were made, DOHC V8s didn't reach the mainstream until the Ford MOD was altered to use this design in 1993. Since then all newly designed V8s have switched to DOHC, such as Ford's Yamaha V8 and Jaguar's AJ-V8, both in 1996, and the Radical RPA V8 designed in 2004 although that's yet to go into production (as such). To avoid confusion, the old single overhead cam system is now usually abbreviated to SOHC.

Multi-valve engines:
While having one valve for the intake and one for the exhaust may sound perfectly reasonable, multi-valve engines increase efficiency, and therefore both the power output and fuel economy of an engine. To improve engine breathing you can increase the size of the intake and exhaust valves, however you can only make them so big before they won't fit into the cylinder head. By using multiple smaller valves, more area can be covered between them, hence the benefits. Engines with 3 valves per cylinder were first tried in 1912; in this case one large exhaust valve is used with two smaller intake valves. 4 valves per cylinder engines were tried once 1910, though this must have been very complicated as the DOHC system had not yet been invented. The first road going application of 4 valves per cylinder was in 1931.

Is there a limit to the gains? The first engine to be made with 5 valves per cylinder was in 1991, however this obviously forces the use of smaller valves, and the total area occupied by 5 valves is the same as 4. There would appear to be no gains then from using 5 valves per cylinder (3 intakes and 2 exhausts), and only the disadvantage of increased cost and complexity. However, in this case the 5th valve can be added in the centre of the other valves, and through opening this valve slightly later than the other intake valves, a swirling affect can be produced which should the flow of the air/fuel mixture. It is not certain if the gains are worth the extra cost, or in fact are noticeable at all, as although Ferrari were proud to advertise the fact that the Ferrari F355 (and later 360) used 5 valves per cylinder (and therefore had created the first 40v V8), their Formula One team switched back from 5v engines back to 4v engines.

Variable valve timing is a modern development which dynamically adjusts valve lift and overlap with rpm to maximise the power-band of the engine. Without variable valve timing engines can only be optimised to work at a very narrow range of engine speeds.

Head shapes

The shape of the top of the cylinder head (in which the valves are mounted in OHV and later styles of engines) has changed during the development of the engine. Originally flat (which was fine for side-valve engines), in 1950 Chrysler introduced a V8 with Hemispherical head (popularly known as the 'Hemi'), where the top of the cylinder head was machine into a perfect half dome. This had the benefit of giving the lowest surface-to-volume ratio, thus making them very efficient, and also increasing the surface area in which to mount the valves, so creating room for larger valves to be used and therefore more power can be gained. However hemispherical heads were expensive to make, complex, heavy and extremely wide, plus the surface-to-volume ratio considered hugely important.

In 1955 Chrysler introduced the 'A', another V8 however this time featuring poly-spherical heads (or 'Semi-Hemi'). Poly-spherical heads are flatter than a hemi but still domed and don't suffer as from as many problems as true hemispherical heads do. Chrysler's next V8 introduced in 1958, the 'B' (for big block), used wedge shaped heads, where the intake valve stem angle is of a low inclination (~20°, though it varies a lot) and the exhaust valve stems use much higher angles (~70°). Ford also adopted wedge heads with the MEL in the same year, and Chrysler also made its LA engine in 1964 using wedge heads as well (the Dodge Viper's legendary V10 engine was based on the LA).

Other Improvements

Engines originally used a carburettor to suck air in from outside then engine and mix it with the fuel. Fuel injection was first used in 1952 as an improvement over carburetion, its early benefits being efficiency and fuel economy, later with the advent of electronic fuel injection in 1975 also helped improved power. Direct injection is the latest version of this technology, where the fuel is directly injected into the cylinder, leaving only the air to come in via the intake valve.

Forced induction has been another route taken to increase power and efficiency. Supercharging (originally known as blowing) basically involves bolting a fan onto the front of the engine that forces air into the cylinders, enable more fuel to be combusted, and therefore more power can be obtained without increasing the engine size. Superchargers however are driven by the engine itself, so while this means they are always working they consume energy themselves. Turbo-charging has become the preferred method of forced induction because it uses the exhausts gasses (otherwise wasted energy) to turn a fan, which then forces air back into the engine. The first (publicly sold) turbocharged engine was in 1962 as fitted to the Turbo Jetfire, which also happened to be a V8. Bentley are also well known for their Turbo V8s.

One of the most recent developments in engines is through the use of advanced materials in the construction. Making the head and later the block from aluminium instead of cast iron allowed weight savings (and therefore less rotational inertia), now use of thermo-set plastics has improved things further.

Mercedes has applied the Twin Spark technique to some of their V8 engines. This is where two spark plugs per cylinder are used in an aim to increase combustion efficiency.

Conclusion

There have been many improvements to the internal combustion engine over the past century, engines are now smaller, more efficient, more powerful, produce less emissions and are more reliable. The V8 configuration remains a popular choice, as a compact layout for powerful saloons and sports cars, while modern restrictions means the sound is now somewhat muted, the classic sound remains, which is the main appeal from the consumer end.

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Word Count: 3498 words