Among the iconic inventions of our time, few have given us more fun and freedom than the car engine. As Chris Wright notes, its current greening should ensure it many more journeys to come

START ME UP

Imagine the pitch. It is 1884, and Karl Benz sits on one side of the table, a group of industrial executives on the other. "I have invented an engine, which when attached to a chassis will create a new vehicle called the car," he says.

"It will bring you freedom and prestige, will open new horizons to you and your family, and in future will transport you at speeds as high as a hundred miles an hour," he continues. "And all you have to do is fill it with petrol, and maintain it with a little oil."

I see, Herr Benz. And how do you propose to separate these contraptions as they move at such speeds on opposite sides of a road? He smiles: "We thought a painted white line might do the trick."

TIN GOD

"The mechanically propelled vehicle, and most of all the car, is a tin god, and one of our own making," wrote author Jonathan Glancey. "Since its invention, it has been worshipped like no other machine."

Whatever Benz actually said in his first pitch clearly worked. A century and a quarter later, *Discovery Channel Magazine* is standing in a cavernous UMW Toyota assembly plant in Shah Alam, Malaysia, looking at the results of where that pitch has taken us today.

Well-oiled Kawasaki robot arms make jagged, purposeful sweeps as they weld frames together, showers of sparks filling the air. The huge room, like an aircraft hanger, is a cacophony of competing sounds: the bangs and hisses of construction and pneumatics, the constant chimes — like children's toys — of alerts at different points on the assembly line.

Engine blocks wait to be bolted onto transmissions and front suspensions, then hoisted and fixed into car shells on hangers in the air, where sensors ensure the bolts are tightened just the right amount.

PHOTO: JAGUAR LAND ROVER

A LOOK AT THE JAGUAR XF ENGINE, A MARVEL OF ENGINEERING

Every few metres, the shell looks more and more like a car: a headlight here, an exhaust pipe there, until the boxes of parts at one end of the factory have become a sleek, gleaming car at the other, ready for testing. In all, 67,000 Toyotas, from Hiace vans to Innova multi-purpose vehicles and Vios cars, rolled off this line in 2011. On this day alone, 300 will see the light of day.

Organisation Internationale des Constructeurs d'Automobiles, better known as OICA, a global industry body, estimates almost 78 million vehicles, and over 58 million cars, were produced in 2010. China alone contributed 18.2 million vehicles. Benz and his peers started a process that has totally reshaped our world.

While we can pin plenty of negatives on the engine and the car — congestion, pollution, Jeremy Clarkson — it has also given us freedom of movement, ease of everyday life, and the sheer pleasure many take from the craftsmanship and engineering of a good car and its engine. As Glancey notes: "Once its reliability was proven, the car spelt freedom."

UNDER THE BONNET

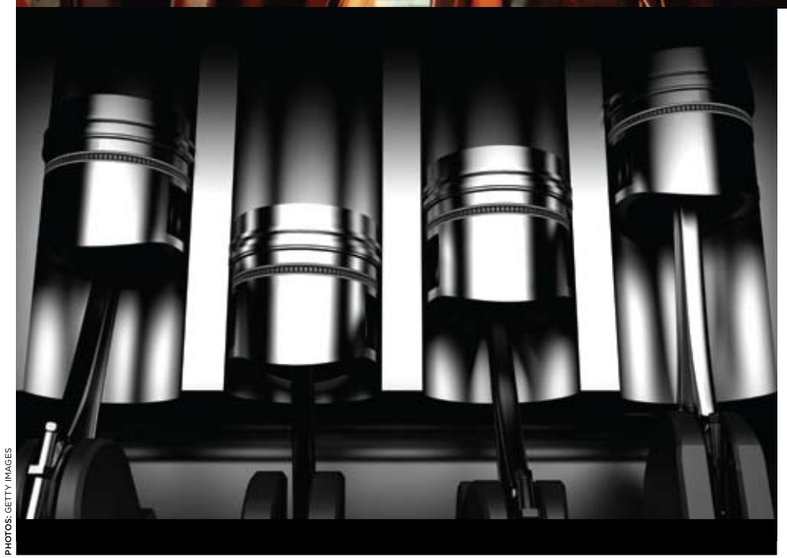
The humble car engine has taken on a complex evolution since its early days, yet the basic principle of the four-stroke engine is much the same as over a century ago. Engines are made up of cylinders, with pistons that move up and down within them. The four strokes refer to what happens within those cylinders.

Firstly, a mixture of fuel and air goes into the cylinder; second, it is compressed as the piston goes up. Thirdly, the compression

A GLOBAL INDUSTRY BODY ESTIMATES ALMOST 78 MILLION VEHICLES, AND OVER 58 MILLION CARS, WERE PRODUCED IN 2010

and the spark plug ignite the fuel, creating energy which pushes the piston down, and is transmitted through a crankshaft to turn the wheels. Fourthly, what is left is then removed, as exhaust. Right now, millions of car engines around the world are completing those four strokes over and over again, many times per second.

Looking at the motorwagen, considered the first commercial car (Benz built it in 1885, patented it in '86 and made the first public sale in 1888), you might think it has little in common with the streamlined, high-powered cars of today. It had huge, spoked wheels like a penny-farthing bicycle, and no cover for the driver, whose position was more like on a stagecoach.



PHOTOS: GETTY IMAGES

ABOVE: THESE DAYS, ROBOTICS AND MACHINERY HAVE TAKEN OVER MANY OF THE JOBS THAT HENRY FORD AND OTHERS USED TO PAY PEOPLE TO DO
LEFT: THE CYLINDERS IN A CONVENTIONAL FOUR-STROKE ENGINE AT WORK

REINVENTION

Over the years, some have dabbled with alternatives to the four-stroke system. The main example is the rotary engine, designed by Felix Wankel. The principle was that the four-stroke system of converting up-down motion in the cylinders into circular motion in the crankshaft was too complex. So why not just create circular motion out of the engine? Rotary engines have many admirers, despite concerns about fuel economy. Mazda is probably the brand most closely associated with them.

But look at the important bit — the engine — and you'd be surprised. There is a radiator to cool the engine, an accelerator to control it, a spark plug to ignite it, and a clutch. Other familiar innovations swiftly followed: Benz's rival and later partner, Daimler, put out a car called the 35HP in 1901, which put the driver behind the engine instead of above it, with a four-cylinder engine like you might find in most standard cars today, under a bonnet (or hood), on a pressed-steel chassis. If the name 35HP doesn't ring a bell, maybe you know of it by its other name, inspired by the daughter of a big buyer of Daimler's new cars. Her name was Mercedes.

It is extraordinary how quickly the car and its engine evolved — and the Shah Alam plant, with its sophistication and demanding production targets, is not new either. In fact, plants like this started almost exactly a century ago, when Henry Ford introduced a moving assembly line for his iconic and transformative Model T Ford.

By 1914, Ford was producing a thousand of these cars a day; two million rolled off the lines in 1924 alone, twice as many cars as the Shah Alam plant has produced in its lifetime. The 15 million Model Ts that were made remained a record total for a single car, until Volkswagen broke it with the Beetle in the 1970s.

We have a lot else to thank the Model T for, especially under the bonnet. Ford believed in keeping things simple, both for production, and for durability on America's bumpy roads of the time. The T's sturdy engine would be a role model for years to come, with innovations like a removable one-piece cylinder head, that made the car easy to service, and a new cooling system.

He did not get every innovation right, though. Ford decided there was no need for a fuel pump, since gravity could push the petrol into the carburetor — the part supplying fuel and air into the engine, until Mercedes pioneered the now-ubiquitous fuel injection system in its 300SL in the 1950s. One consequence of Ford's decision was, if there wasn't much fuel in the tank, you had to reverse up hills.

Look at a Model T engine today, and it is remarkably recognisable. The biggest difference is the starting handle somebody had to twist, to get moving. Otherwise, it is a familiar-looking apparatus: spark plugs, exhaust ports, cylinder block with four cylinders in a line, camshafts, crankshaft, transmission. One thing that you probably wouldn't recognise though, is the pedal set-up. There was a left-hand pedal, which you had to press fully to engage first gear, halfway to get neutral, and release fully to get top gear; there was a middle pedal for reverse, and a right-hand pedal for a transmission brake, with a hand control lever for the back brakes. For today's motorists, it would take some driving.

BIGGER WAS BETTER

The passing years bought more innovations, typically from America and Germany. After Benz and Daimler started working together, their company added superchargers — a forerunner to today's turbos, boosting engine performance by forcing air into the right places — as early as 1922. By then, Cadillac had dumped its starting handles, fitting self-starters to all cars.

Cadillac epitomised America's early drive towards big, bigger and bigger still. Ordinary cars today have four-to-six cylinders, or in the smaller cars like the Tata Nano, just two. A V8 engine boasts eight cylinders — higher performance given more cylinders fire for each revolution of the crankshaft — and is considered the preserve of the performance car enthusiast. In the early days, V8s were almost the norm.

Cadillac introduced the first mass-produced V8 engine in 1915. By 1930, the company had launched the fabulous V12 and V16 engines, which still look impressive today. The V16, in particular, is an absolute beast. Other American brands soon followed suit, and the Chevrolet small-block V8 engine, introduced into Corvettes in 1955, became a standard that sold millions. "With a V8 transplant, the Corvette became a venerable US institution," notes *The Car Book*, a definitive history of car development.

But the Cadillacs and Chevvies of the world would fall foul of changing times. By the 1960s, emission standards appeared, as the sheer scale of the pollution by car engines became clearer. Manufacturers started scaling back their engines, and by the oil crisis in the 1970s, smaller was becoming better. Save those big engines for professional racers.

Take Volkswagen (VW). Most often associated with the reliable but unsexy Beetle or Polo, or the zippy but small Golf, one of VW's most important engines was designed by Ferdinand Porsche. *Volks wagen* means people's car, and Porsche had been instructed by Adolf Hitler to build an engine worthy of the name: affordable, durable and productive. His innovation was to build an engine cooled by air, not water, saving the radiator or water pump.

Its innovative horizontally-opposed cylinder layout would later show up in "dream-machine" Porsche models, while variations of the engine were built for

ENGINE EVOLUTION

1861
ALPHONSE BEAU DE ROCAS INTRODUCES IDEA OF A FOUR-STROKE ENGINE

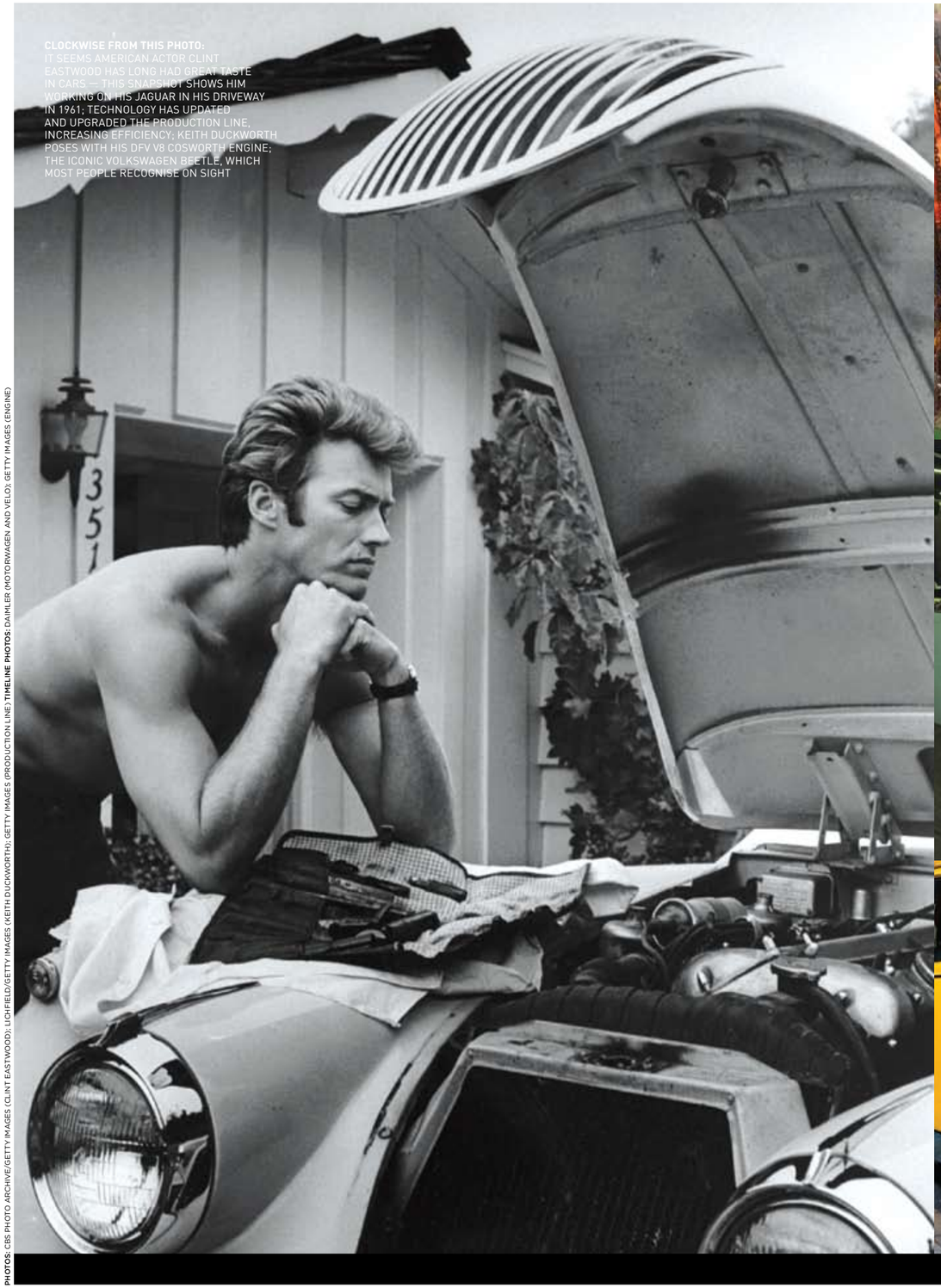
1876
NIKOLAUS OTTO BUILDS FOUR-STROKE ENGINES

1885
KARL BENZ PUTS A FOUR-STROKE ENGINE INTO A VEHICLE TO MAKE THE MOTORWAGEN, PATENTING IT IN 1886 AND SELLING ONE FOR PUBLIC SALE IN 1888. THIS IS USUALLY SEEN AS THE FIRST CAR

1894
BENZ'S VELO IS THE WORLD'S FIRST LARGE-SCALE PRODUCTION CAR

1913
HENRY FORD INTRODUCES THE MOVING ASSEMBLY LINE. THE MODEL T FORD SHIFTS 1,000 MODELS PER DAY THE FOLLOWING YEAR

CLOCKWISE FROM THIS PHOTO: IT SEEMS AMERICAN ACTOR CLINT EASTWOOD HAS LONG HAD GREAT TASTE IN CARS — THIS SNAPSHOT SHOWS HIM WORKING ON HIS JAGUAR IN HIS DRIVEWAY IN 1961; TECHNOLOGY HAS UPDATED AND UPGRADED THE PRODUCTION LINE, INCREASING EFFICIENCY; KEITH DUCKWORTH POSES WITH HIS DFV V8 COSWORTH ENGINE; THE ICONIC VOLKSWAGEN BEETLE, WHICH MOST PEOPLE RECOGNISE ON SIGHT



PHOTOS: CBS PHOTO ARCHIVE/GETTY IMAGES (CLINT EASTWOOD); LICHFIELD/GETTY IMAGES (KEITH DUCKWORTH); GETTY IMAGES (PRODUCTION LINE) **TIMELINE PHOTOS:** DAIMLER (MOTORWAGEN AND VELO); GETTY IMAGES (ENGINE)

almost 70 years. It would also power, from the rear of the car, the VW Beetle, which sold over 21 million cars. To date, no single car model has sold more.

Small car innovation has continued. The British Mini sold over five million, with an engine "transversely placed", or wedged in sideways. Meantime, India's Tata Nano uses only two cylinders, which keeps fuel use down, and just one overhead camshaft, which is the bit that opens and closes an engine's inlet and exhaust valves (two are more common). And of course, less moving parts means less things that can break down.

THE RIGHT STUFF

While small is nice, the relentless pursuit of perfection was in the performance car market. To enthusiasts, designers of great engines are celebrities every bit as important as racing drivers. One example of such a celebrity is Keith Duckworth, who designed the legendary DFV V8 Cosworth engine, powering Lotus to 12 Formula One driver's titles from the 1960s to the early 1970s.

Italians revere Giuseppe Busso, whose engines for Ferrari and Alfa Romeo took both to success on the track and in salesrooms. Others laud the British team behind the Jaguar XK straight-six engine, a beautiful, light machine that would power numerous Jaguars, from the E-types *(see page 56)* to professional racers and ordinary saloons.

CADILLAC EPITOMISED AMERICA'S EARLY DRIVE TOWARDS BIG, BIGGER, AND BIGGER STILL, WITH ITS V12 AND V16 ENGINES

But what makes a high-performance engine roar with that velvety, urgent growl? Take a look inside one of the greatest-ever high-performance engines: the Porsche flat-six, powering the epic 911 car. It has six cylinders and, like that VW engine, positions them flat, not in line, to keeping the centre of gravity low.

The Porshe 911 engine is far wider and lower than most others, aiding road-handling. Another difference is the sophisticated induction system, which changed the way air inlet tracts are set up as the speed rises, and forced more air into the cylinders.

In later, water-cooled 911 engines, Porsche used four valves per cylinder, helping the engine to "breathe" and handle its airflow. And the sound? Probably the single most influential element is a multi-blade fan, drawing cooling air over the cylinder heads.

In other top cars, the distinctions are primarily about power. The Lamborghini Countach uses a V12 engine, which was first designed by another iconic Italian, Giotto Bizzarrini, in the 1960s, and is still produced today.
In the Ferrari F40, the engine has eight cylinders, but incorporates twin turbochargers in addition to two gizmos called intercoolers, which help to extract extra juice from the engine.

Not that these vehicles are easy to drive — just intense. "The absence of power steering or anti-lock braking systems provided further proof that this sublime example of automotive engineering really was aimed at those able to drive at the extremes," notes *The Car Book*.

THE FERRARI ENZO IS SAID TO THE MOST POPULAR SUPERCAR EVER BUILT. ONLY 400 UNITS WERE PRODUCED

ENGINE EVOLUTION

1930
A PERIOD OF BIGGER-AND-BETTER INNOVATION PEAKS WITH CADILLAC'S V12 AND V16 MODELS

1936
PRODUCTION BEGINS OF VOLKSWAGEN'S FLAT-FOUR ENGINE, COOLED BY AIR RATHER THAN WATER; THIS WILL POWER THE BEETLE, THE BIGGEST-SELLING CAR MODEL IN HISTORY

1950
CHEVROLET INTRODUCES AUTOMATIC TRANSMISSION IN THEIR CARS

1955
CHEVROLET'S SMALL-BLOCK V8 ENGINE BECOMES ONE OF THE MOST SUCCESSFUL ENGINES EVER

1963
THE PORSCHE 911 IS LAUNCHED; ITS FLAT-SIX ENGINE IS ONE OF THE MOST REVERED HIGH-PERFORMANCE ENGINES EVER MADE

1997
TOYOTA PRIUS BECOMES THE WORLD'S FIRST MASS-PRODUCED HYBRID

2009
TATA LAUNCHES THE NANO, THE WORLD'S CHEAPEST CAR, DRIVEN BY A TWO-CYLINDER ENGINE WHOSE 624CC CAPACITY IS SMALLER THAN BENZ'S MOTORWAGEN OVER A CENTURY EARLIER, THOUGH A FAIR BIT FASTER

PHOTOS: CORBIS (MAIN); **TIMELINE PHOTO:** PORSCHE (ENGINE)

ENGINE GODFATHER?

Arguments abound about whether Benz, whose motorwagen was built in 1885, and who patented a two-stroke internal combustion engine in 1879, was the true father of the automobile. Other candidates include Gottlieb Daimler, who made the first four-wheeled petrol-engined vehicle to hit 16 kilometres per hour in 1886. Or Nikolaus Otto, who worked with Daimler and built four-stroke engines in 1876. Likewise, a French engineer named Alphonse Beau de Rocas originated the idea of a four-stroke engine in 1861.

ABOVE: THE SCUDERIA FERRARI DURING A PIT STOP AT THE F1 CHAMPIONSHIPS 2011 ITALIAN GRAND PRIX

Seeking extremes? Enter Formula One, which you probably know as F1. As anyone who has ever been present at a race will know, a bunch of F1 engines in action

NOT THAT TOP CARS ARE EASY TO DRIVE, LACKING POWER STEERING AND ANTI-LOCK BRAKING SYSTEMS — JUST INTENSE

sounds more like a swarm of livid bees trapped in your inner ear, than the silk-smooth rumble of a Jaguar.

In some respects, F1 engines are not all that different to ordinary ones: four-stroke, 2.4-litre V8s are the current F1 standard. From 2014, those will replaced with turbocharged 1.6-litre V6s, which may be smaller than what's powering your car.

The difference lies in the speed at which F1 engines work — up to 18,000 revolutions per minute, about three times a usual road car, with the same sized engine. So the speed is all about the engine turning faster. Plus, instead of metal valve springs in normal cars, F1 engines use pneumatic springs and pressurised air. And as you'd expect, the engines are built with the lightest materials possible.

GOING GREEN

Engine innovation today is chiefly environmental, and nowhere is that more clear than with the hybrid engine. Two Japanese manufacturers have led the charge: Toyota, whose Prius is probably the best-known hybrid in the world, and Honda. The Prius, which has been on sale since 1997, was the first mass-produced hybrid, selling two million by 2010. In its 2011 annual report, Toyota says it will introduce around 10 new hybrid models by 2015, including plug-in hybrids, electric vehicles and fuel cell vehicles.

But what is a hybrid engine, and how is it greener than a regular engine? A hybrid engine combines an internal combustion engine with an electric motor. When appropriate, the car shifts to electricity, reducing fuel consumption and emissions.

There are two kinds of hybrids, a series (where an engine generates electric power and is connected to the wheels) and a parallel (when both engine and motor can power the wheels). The Honda Insight uses the parallel model, and in the Prius's case the two models are combined.

There is probably no greater imperative in engine design today than greening. Just look at how quickly unleaded fuel has become the norm, almost worldwide. However, the jury is still out as to whether hybrids are the best way to reduce emissions and improve economy. The Tata Nano, for example, has instead gone for a small but powerful non-hybrid engine which has been designed for fuel efficiency. This, matched with as light a body as possible, produced a vehicle that is said to have the lowest carbon dioxide emissions of any cars in India. And Tata Motors is hardly the only one taking this route.

But make no mistake: wherever the engine goes next on its long and winding road, it is going to have to be greener. Yet as Jonathan Glancey, author of *The Car: A History of the Automobile* and writer for the *Guardian*, reminds us, love or hate its dirty habits, it remains difficult to imagine many new roads without the car: "Today we find it almost impossible to live without it. We fuss over it. Talk about it proudly in pubs. We build it little houses to live in. It is truly part and parcel of our lives." ●

WHAT ELSE CAN IT DO?

Two-strokes and four-strokes don't just work on motorbikes and cars, but have widespread application. The world's largest engine of this kind is made by the Finnish group Wärtsilä. It's a two-stroke, turbocharged, low-speed diesel engine, found on container ships. One version (below), which operates the Emma Maersk, one of the largest container ships in the world, has 14 cylinders, weighs 2,300 tonnes and measures 13.5 metres high by 27.3 metres long. At the other end, internal combustion engines are widely used in lawnmowers, particularly rotary models.

Aircraft jet engines are also internal combustion, though not four-strokes. They work by pushing hot gas from a combustion process through a nozzle to create acceleration and thrust. Also, gas turbines, which have been used in everything from power plants to buses, turboprop planes to tanks, involve a compressor and a combustion chamber, and are closely related to the car engine.

A MODERN CLASSIC

For as long as cars have existed, they have had the ability to make people, particularly men, go a bit gooey and excitable. But surely no car has ever induced quite such bracing palpitations as the E-Type Jaguar

First launched in 1961 and refined into various models along the way, everything about the E-Type conveys style, grace and class. Just *look* at it. It's like somebody turned a panther into a car, and sounds like one, too.

One man who fell in love with E-Types long ago is Henry Pearman, owner and managing director of Eagle, who has devoted much of his professional life to restoring, rebuilding and generally reviving them. He first got bitten by the E-Type bug after seeing one when he was four or five; then he remembers it turning up in a Cadbury's Milk Tray advertisement in the early 1970s. "There was an E-Type that had to jump across a broken-down bridge," he recalls. "I thought: that's my favourite car ever. One day I'm going to get one."

He would do more than that; he once won a Pirelli marathon in one, across Alpine rally routes, against a field that included F1 legend Stirling Moss. In 1982 he established Eagle in Sussex, England, first to restore E-Types, and since 1991 to undertake an extraordinarily comprehensive handcrafted rebuild to a modern-day standard of quality. This is more than a revamp; building one the Eagle way takes, on average, 4,200 man hours, and the team only produces about three per year.

BBC journalist Quentin Willson has called the resulting Eagle E-Type "probably the best build handmade car in the world," and it reduced Jeremy Clarkson to a jelly-legged lust. "I think this, by a long way, is the most beautiful car I have ever seen," he said after trying one out. "It might actually be the most beautiful thing I have ever seen. This to me is absolute perfection. I will put my hand on my heart and say here and now I have never ever driven a car ever that I have wanted more than this one. I yearn to have it."

So what's so special about the E-Type? "The first thing is the shape, which is the first thing you see," Pearman says. But beyond that is its durability as a symbol of something beautiful. "We've gone through two generations now that stop in awe of it. When you get it into shape, you get lots of looks and people's jaws drop — but as well as that, people cannot believe how modern and easy they are to drive."

That's partly a function of the engine, which was even more ahead of its time than the rest of the E-Type. The XK120 that powered E-Types first appeared in 1948 — the 120 stood for 120 miles per hour, or 193 kilometres per hour, its top speed. "Opening the bonnet to that engine was like looking at the F1 engine of the time," says Pearman. "It had an overhead cam, which was exotic for the time; it was a super-advanced modern engine for 1948." When Eagle seeks to improve it in its restorations, there's surprisingly little that can be done: a slight redesign of the crankshaft, for example, and an electronic rather than a mechanical fuel injection. "It's fundamentally fantastic. With our upgrade of the original E-Type, you're looking at more torque than a Ferrari 430."

The Eagle approach starts with an original car. "We buy it, rescue it from near death, and dismantle it to every last nut, bolt and washer," he says. The team painstakingly remakes all the mechanical components, then mates them to a new body built by Eagle, using modern paint and anti-corrosion techniques ("nobody thought of anti-rust in 1961"). The wiring and electrical parts are also replaced prior to final assembly, but it remains fundamentally what it was. "You'll get an E-Type, but we dial out the weak points: we improve the brakes, the electrics, the cooling system. You only need small things to keep this car with its head held high against anything around today."

It's not cheap; it's a long way from cheap at GBP295,000 — that's around US$450,000. But it proves there remains a constituency of people who have not lost interest in the inner workings of their car, in what makes a beautiful machine go. "Clients who come to us who are based in the city are shocked at how involved they find themselves getting in the process of the restoration," he says. "They thought they'd come once or twice. But they bring their sons and daughters, and really get a buzz out of the experience of learning how it works. It gives such confidence if you have seen a car put together."

Someone once called the E-Type "the most beautiful car ever made". He knew a bit about cars. His name was Enzo Ferrari. ●

PHOTO: CORBIS