# Marine Engines

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# Electric Outboard Motor and General Electric LM2500

# Electric Outboard Motor

**Electric Outboard Motors** are an increasingly popular and environmentally friendly option for boat propulsion. Most electric outboard engines are equipped with 0.5 to 4 KW DC electric motors, operated at 12 to 48 volts DC. These systems have the propeller fixed directly to the electric motor which is mounted in the lower unit under water. This setup limits the power output. Recently developed outboard motors like the Aquawatt or Parsun are powered with an AC or DC electric motor in the power head like a conventional petrol engine. With this setup a motor can produce 10 KW output or more and is able to replace a petrol engine of 15-20 HP.

### *Power Supply*

The advantage of electric boat propulsion systems are the low maintenance costs, the limited noise and emission free operation. The only disadvantage are the batteries, which in case of lead acid technology, limit the range of operation due to their high weight (38 watt hours / kilogram) and limited capacity when quickly discharged (60% at 1 hour). Newer battery technologies like lithium systems (e.g. LiFePO4 or Lithium polymer) offer up to seven times the performance of a lead acid battery. Charging the batteries with a photovoltaic solar system can make the whole system fully independent of any external energy source. If this is not sufficient for longer trips, the system can be equipped with a range extender, like a small gasoline or diesel generator which recharges the batteries.

### *Costs*

Due to the still small quantities of electric boat engines produced, two to three times the cost of a four stroke petrol engine still needs to be invested. On the other hand, the operation costs are lower. Taking the rising energy costs due to future shortage of oil into consideration, electric boat motors will be the financially more interesting way of marine propulsion in a few years time. A 2 horsepower electric outboard motor including a lead acid battery can be purchased from USD 750.00 (2010) which is already competitive to a 2.5 HP petrol engine.

### *Large Vessels*

As there is no technical limit to the size of an electric motor, even large vessels can be equipped with electric engines. The limitation is the power supply to the motors, which can be solved with newer battery technology and the use of hybrid systems. The first electric boat has been operating in 1834 for the zar of Russia and a lot of suppliers prove, that electric boating is a serious alternative, especially to replace 2 - stroke outboard engines.

# General Electric LM2500

## LM2500

An LM2500 on USS Ford (FFG-54)

| | |
|---|---|
| **Type** | Gas turbine |
| **National origin** | United States |
| **Manufacturer** | General Electric |
| **First run** | 1960s |
| **Developed from** | General Electric CF6 |

The **General Electric LM2500** is an industrial and marine gas turbine produced by GE Aviation. The LM2500 is a derivative of the General Electric CF6 aircraft engine.

Current versions of the LM2500 deliver 33,600 shaft horsepower (25.1 MW) with a thermal efficiency of 37 percent at ISO conditions. It has been used in various applications such as in U.S. Navy warships (as well as those belonging to other navies), hydrofoils, hovercraft and fast ferries. As of 2004, more than one thousand LM2500 gas turbines have been in service for more than 29 international navies.

### *Design and development*

A heavy lift lowers the main propulsion module into the hull of USS Bunker Hill (CG-52) during construction at Ingalls Shipbuilding. The module consists of two General Electric LM2500 gas turbine engines and a Westinghouse gear reduction unit.

The LM2500 was first used in US Navy warships in the *Spruance* class of destroyers and the related *Kidd* class, which were constructed from 1970. In this configuration it was rated to 21,500 shp (16,000 kW). This configuration was subsequently used into the 1980s in the *Oliver Hazard Perry* class frigates, and *Ticonderoga* class cruisers. It was also used by one of People Republic of China's Type 052 Luhu Class Missile Destroyer (Harbin 112) acquired before the embargo.

The LM2500 was uprated to 26,500 shp (19,800 kW) for the *Arleigh Burke* class destroyers, which were initiated in the 1980s and started to see service in the early 1990s, and the T-AOE-6 class of fast combat tanker.

In 2001 the LM2500 ( 20 MW ) was installed in a sound-proof capsule in the SA Navy Valour class (Meko A-200 SAN) frigates as part of a CODAG propulsion system with two MTU 16V 1163 TB93 Propulsion Diesels.

The current generation was uprated in the late 1990s to over 30,000 shp (22,000 kW).

Many of the military LM2500 installations place the engine inside a metal container of the same dimensions as a standard 40-foot (12 m) intermodal shipping container - 8 feet (2.4 m) wide, 8.5 feet (2.6 m) tall, and 40 feet (12 m) long. The containerized LM2500s may be designed for easy removal from their ships if the air intake ducting is shaped appropriately.

The LM2500+ is an evolution of the LM2500, delivering up to 40,200 shp (30,000 kW) or 28.6 MW of electric energy when combined with an electrical generator. Two of such turbo-generators have been installed in the superstructure near the funnel of *Queen Mary 2*, the world's largest transatlantic ocean liner, for additional electric energy when the ship's four diesel-generators are working at maximum capacity or fail. Celebrity Cruises uses two LM2500+ engines in their *Millennium*-class ships in a COGAS cycle.

The LM2500 is license-built in Japan by Ishikawajima-Harima and in Italy by Avio.

The LM2500/LM2500+ can often be found as turbine part of CODAG or CODOG propulsion systems or in pairs as powerplants for COGAG systems.

## *Applications*

- Arleigh Burke class destroyer
- Independence class littoral combat ship
- Kidd class destroyer
- Oliver Hazard Perry class frigate
- Spruance class destroyer
- Shivalik class frigate
- Ticonderoga class cruiser
- Type 052 destroyer
- Valour class frigate
- Sachsen class frigate
- Brandenburg class frigate
- Bremen class frigate
- FREMM multipurpose frigate
- Horizon class frigate
- Halifax class frigate
- Anzac class frigate

- Sa'ar 5 class corvette

## Chapter- 2

# General Electric LM500, General Electric LM6000 and Mercury KG-7Q Super 10 Hurricane

## General Electric LM500

| LM500 | |
|---|---|
| **Type** | Gas turbine |
| **National origin** | United States |
| **Manufacturer** | General Electric |
| **Developed from** | General Electric TF34 |

The **General Electric LM500** is an industrial and marine gas turbine produced by GE Aviation. The LM500 is a derivative of the General Electric TF34 aircraft engine.

Current versions of the LM500 deliver 6,000 shaft horsepower (4.47 MW) with a thermal efficiency of 31 percent at ISO conditions. It has been used in various applications such as in the Stanflex 300 series of patrol boats, and in fast ferries.

### *Applications*

- Stanflex 300

# General Electric LM6000

**LM6000**

LM6000 GTG in an electrical power plant application

| | |
|---|---|
| **Type** | Gas turbine |
| **National origin** | United States |
| **Manufacturer** | General Electric |
| **Developed from** | General Electric LM6000 |

The **General Electric LM6000** is a turboshaft gas turbine. The LM6000 is derived from the CF6-80C2 aircraft turbofan. It has additions and modifications designed to make it more suitable for marine propulsion, industrial power generation, and marine power generation use. These include an expanded turbine section to convert thrust into shaft power, supports and struts for mounting on a steel or concrete deck, and reworked controls packages for power generation. It has found wide use including peaking power plants, fast ferries and high speed cargo ship applications.

## *Design and development*

The LM6000 provides 54,610 shaft horsepower (40,700 kW) from either end of the low-pressure rotor system, which rotates at 3,600 rpm. This twin spool design with the low pressure turbine operating at 60 Hz, a common electrical frequency, eliminates the need for a conventional power turbine. Its high efficiency and installation flexibility make it ideal also for a wide variety of utility power generation and industrial applications, especially peaker and cogeneration plants. When LM6000 power generation units are installed on a 50 Hz power grid, they require a gearbox between the turbine and the generator.

GE has several option packages for industrial LM6000s, including *SPRINT* (SPRay INTercooling), water injection (widely known as "NOx water"), and Spray Mist

Evaporative Cooling (SMEC). The SPRINT and SMEC options are designed to increase efficiency and power of the turbine, and the water injection is for reducing emissions. The SMEC system is a water fogger system that sprays a fine mist of water into the inlet air before the air filters. This system is high maintenance and may be replaced by chillers in newer units. The SPRINT system injects demineralized water into the engine either upstream of the low pressure compressor or between the low pressure and high pressure compressors. The water injection system injects water into the primary or secondary fuel nozzle inputs, usually on natural gas fired engines.

The GE LM6000 PC is rated to provide more than 43 MW with a thermal efficiency of around 42% LHV at ISO conditions. With options, this can be increased to around 50MW rated power.

# Mercury KG-7Q Super 10 Hurricane

**Mercury KG-7Q Super 10 Hurricane** is an outboard motor built by Kiekhaefer Mercury during the years of 1950 through 1952.


1951 KG-7Q

## *History and development*

In 1950 Mercury engineers came out with the Super 10 Hurricane, Model KG-7. This motor was based on previous models KE-7 Lightning and KF-7 Super 10. Upgrades included redesigned connecting rods, upgraded aluminum clamp and swivel brackets, a new high RPM magneto, improved porting, an 8 Reed valve cage (as opposed to KE-7 and KF-7's 4) and larger crankcase opening. Hurricane was also advertised at 10 hp*, way below the actual horsepower developed, Mercury noted this asterisk by stating that horsepower varies with rpm; really the Hurricane could deliver up to 18 hp. Shortly after the introduction of the Hurricane, Mercury came up with their first performance gear case with the capability of mating to a standard driveshaft housing of a KG-7 or similar green top engine of the time. This was named "Quicksilver" and promised an extra 20 to 30% increase in top speed. Essentially, it boasted a significantly slimmer pointed gear case that housed an integrated rubber rotex water pump and forward only 1:1 gears along with the necessary bearings. After a few months of use, Mercury found that the average race boat's transom would not elevate the standard driveshaft housing and quicksilver gear case high enough for peak performance. Rectifying this problem, Mercury developed the Quicksilver driveshaft housing. This new driveshaft housing was three inches shorter which in turn lowered the motor's center of gravity on the boat which helped turning ability, reduced the strain on the boat's transom and motor's clamp brackets, and decreased underwater drag while increasing top speed as less gearcase was below the boat. In addition the motor had a sort-of cut down lower anti-cavitation plate, protruding forward upper anti-cavitation plate (spray plate), a stronger rear-mounted steering bar design, and finally, an exhaust opening above the water surface that reduced exhaust back pressure while increasing noise levels when the boat was on plane. When the dealer installed the quicksilver driveshaft housing and gear case (packaged at $82.25) he had authorization to hand stamp a small "Q" behind the serial numbers on the tag and block. Some did, some did not – and so, the "Stamped Q" came to be. 1951 saw the first production race-ready outboard models; KG-4Q, KG7-Q, and KG-9Q. These motors were pulled off the production line at random, given the quicksilver gear case, driveshaft housing, and "Q" stamp behind the tag serial number and block serial number. These KG-7Qs worked fine on runabouts but were too long for hydroplanes – and the racers made this known to Mercury. So thus was born the 2" shorter "H" driveshaft housing in 1952. Right before Mercury released this "H" driveshaft housing, they still had several "Q" length driveshaft housings, so they introduced a factory KG-7Q which had a green silk screened Q behind the serial number on the tag and a factory stamped "Q" on the block. These motors are very rare; they fall into in the serial range of 532404-532963.

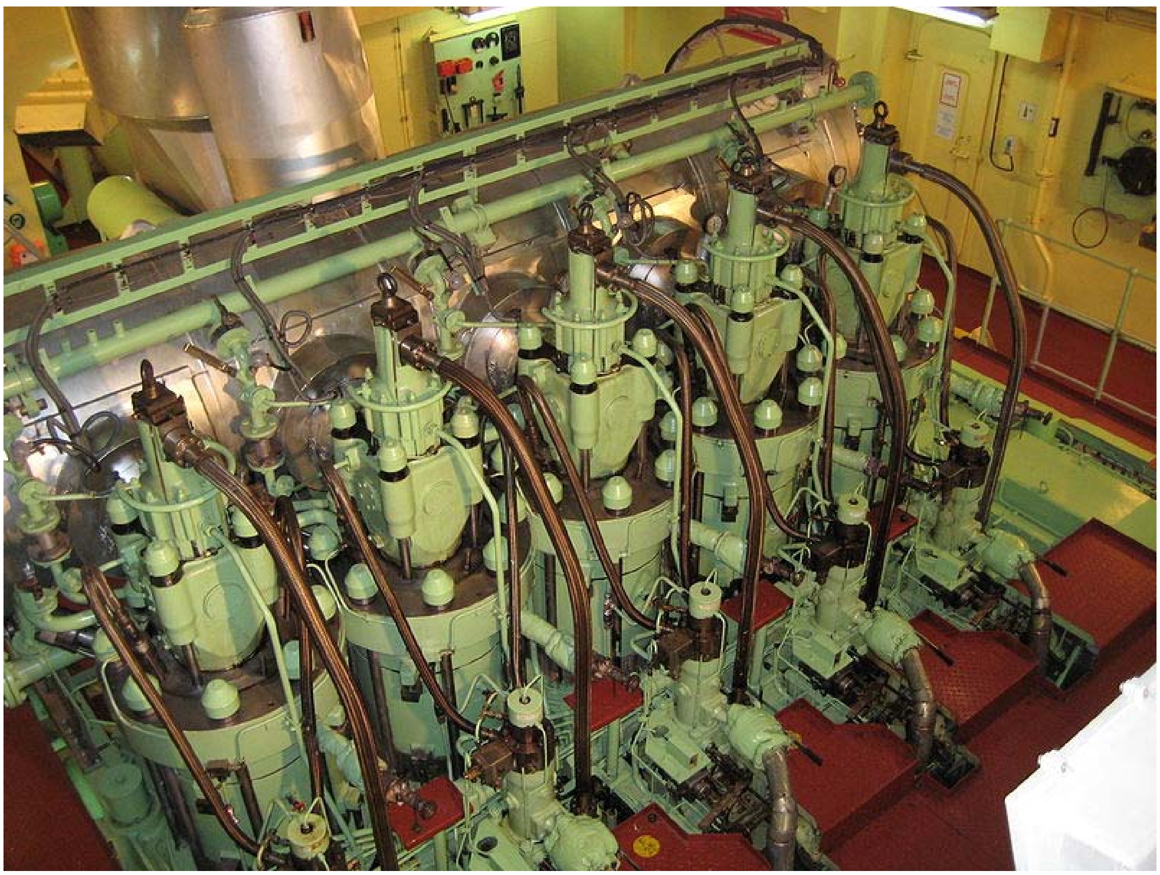
## *Continued interest*

Today many Mercury KG-7Q Super 10 Hurricane's have survived the years, many are still raced at local Antique Outboard Motor Club, Inc. (AOMCI) Events. In demand and also rare; today a KG-7Q will go for the price of a brand new 10 hp motor.

Chapter- 3

# Inboard Motor and Oswald Engine

## Inboard motor



The MAN B&W 5S50MC 5-cylinder, 2-stroke, low-speed marine diesel engine. This particular engine is found aboard a 29000 tonne chemical carrier.

An **inboard motor** is a marine propulsion system for boats. As opposed to an outboard motor where an engine is mounted outside of the hull of the craft, an *inboard motor* is an engine enclosed within the hull of the boat, usually connected to a propulsion screw by a driveshaft.

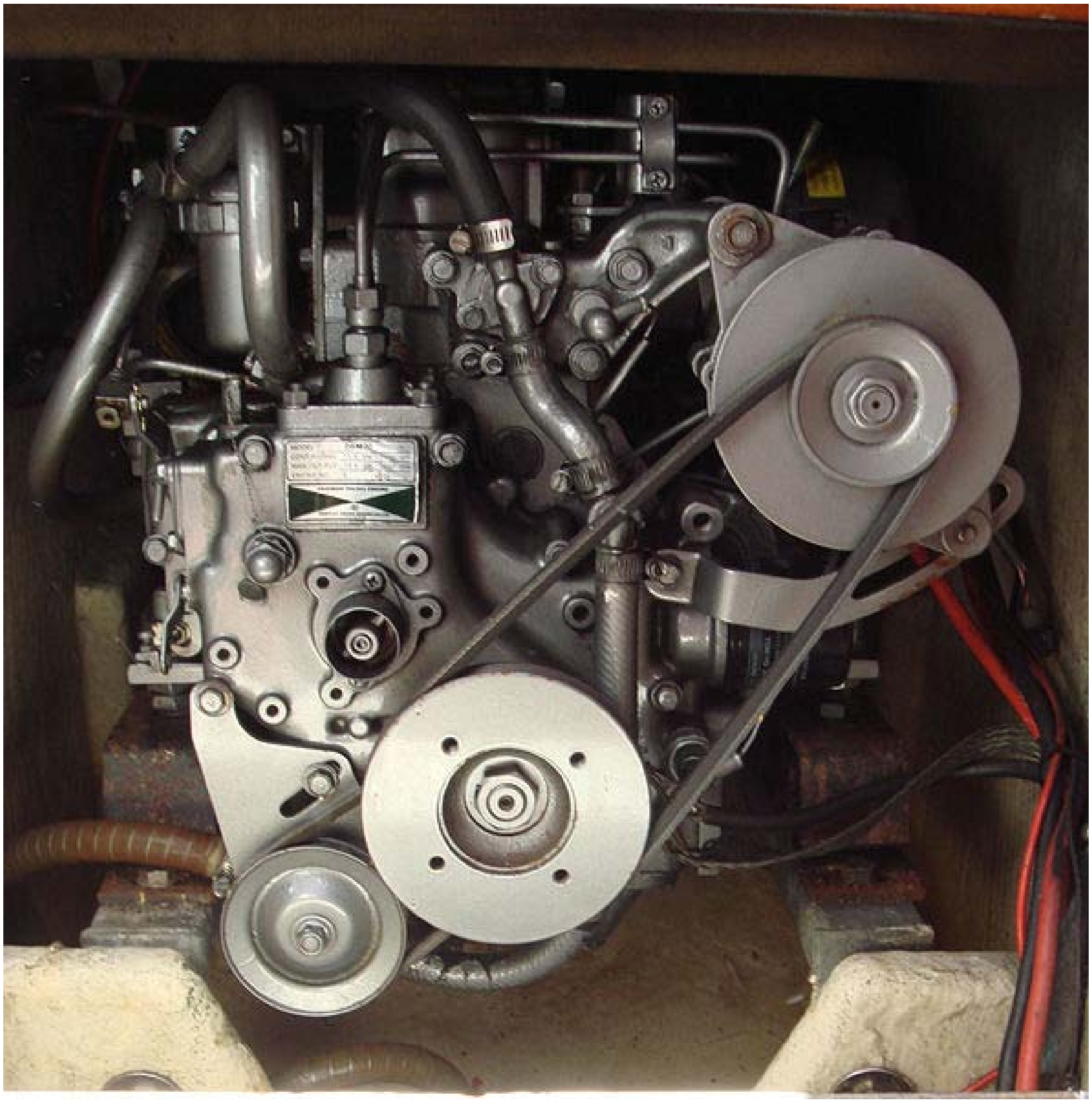
## *History*

Cat diesels in rescueboat of Eire

The first inboard were steam engines going back to 1805 and the Clermont and the Charlotte Dundas. Harbour tugs, and small steam launches had inboard steam engines. In the 1880s the naphtha engine made its appearance and a few boat engines appeared. They were dangerous and difficult to run.

The gas engine pioneer Gottlieb Daimler and Maybach built a four-cycle boat engine and tested it in 1887 on the Neckar River. Sintz in America built several commercially available engines from 1893. About 1895 the inboard oil engine emerged for small boats. From this hundreds of small boat engine manufactures set up shop: Bolinder, Gray Marine Engine, Kermath, Union Iron Works, Caille, Palmer, Red Wing, St. Lawrence, and Buda; Sulzer, B and W, Gardner, and Ailsa Craig to mention a few. Two cycle engines were popular for many years, however, the parallel development of the auto engine, with their many cylinders, became a natural transposition. Chrysler, Ford, Packard, and Hudson also made marine engines.

### *Sizes*



A Yanmar 2GM20 inboard marine diesel engine, installed in a sailboat.

Inboard motors may be of several types, suitable for the size of craft they are fitted to. Boats can use one cylinder to v12 engines, depending if they are used for racing or trolling.

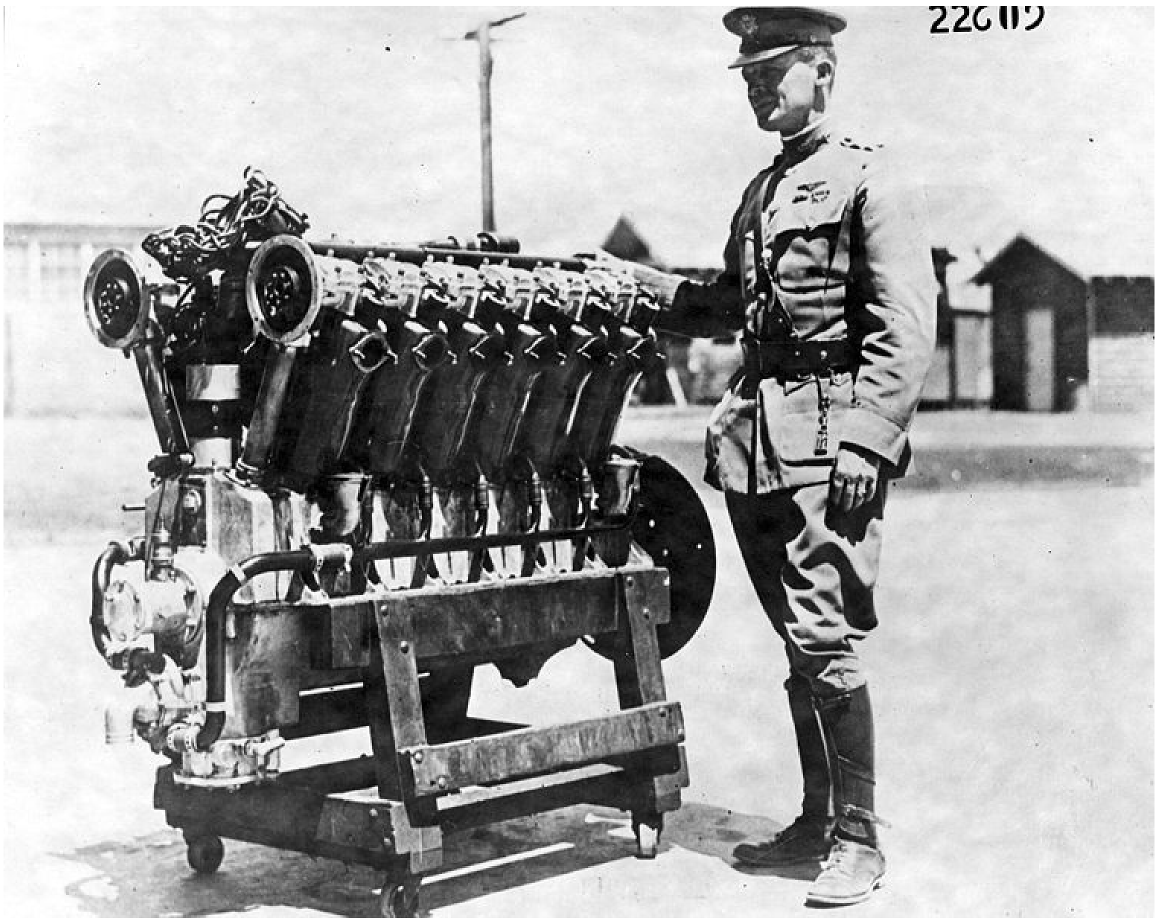
### Small craft

For pleasure craft, such as sailboats and speedboats, both diesel and gasoline engines are used. Many inboard motors are derivatives of automobile engines, known as marine automobile engines. The advent of the stern drive propulsion leg improved design so that auto engines could easily power boats.

### Large craft

For larger craft, including ships (where outboard propulsion would in any case not be suitable) the propulsion system may include many types, such as diesel, gas turbine, or even fossil-fuel or nuclear-generated steam. Some early models used coal for steam-driven ships.

### *Cooling*




Major Henry H. Arnold with the first Liberty engine. Aircraft engines were later used in boats. Hap Arnold went on to command all US Airforces in WWII.

Some inboard motors are freshwater cooled, while others have a raw water cooling system where water from the lake, river or sea is pumped by the engine to cool it.

However, as seawater is corrosive, and can damage engine blocks and cylinder heads, some seagoing craft have engines which are indirectly cooled via a heat exchanger. Other engines, notably small single and twin cylinder diesels specifically designed for marine use, use raw seawater for cooling and zinc sacrificial anodes are employed protect the internal metal castings.

# Oswald Engine

The **Oswald Engine** was a gasoline powered internal combustion marine engine manufactured in San Francisco. They were available in two cylinder and four cylinder models. With a magneto and spark plug ignition. Oswald was a small company on Turk Street, San Francisco then later in South San Francisco, Oswald built engines for a short period of time in the early 1900s. The last known Oswald Engine was found in an engine parts warehouse in South San Francisco. The magneto on this example was made by Robert Bosch and was dated from 1914.

## *Dealership*

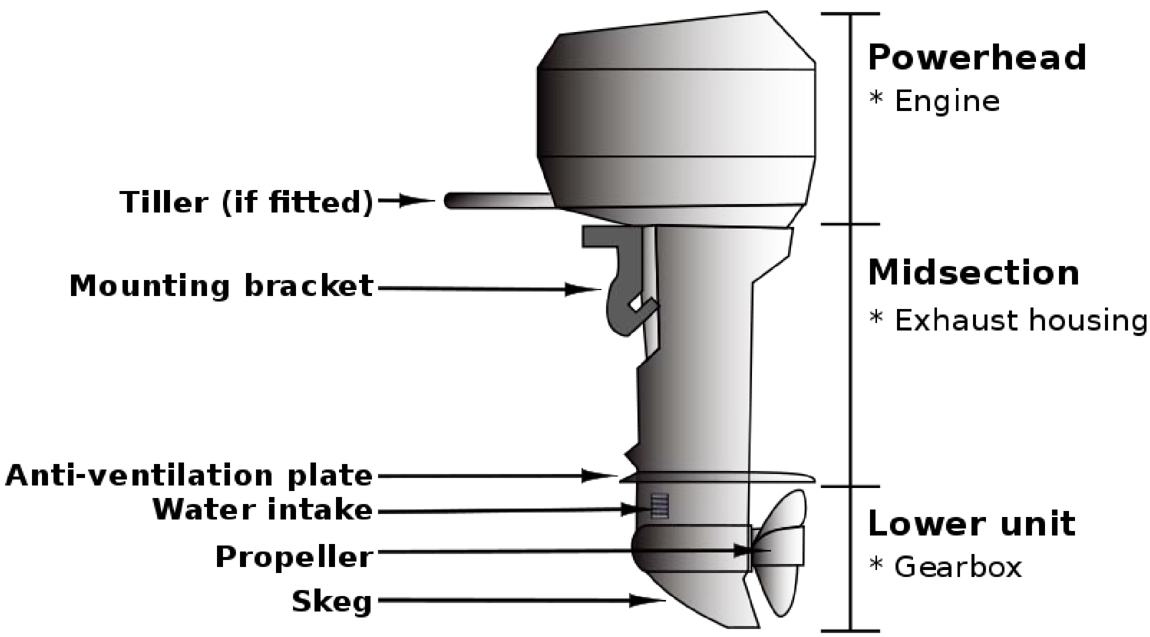
The engine venture was apparently short lived, and Mr. Oswald became a dealer for R A Lister and Company and later Lister-Petter diesel power plants, as Diesel engines grew in popularity and the era for gasoline inboards for the west coast fishing fleet in San Francisco and Monterey Bay faded.

## *Lighting plant*

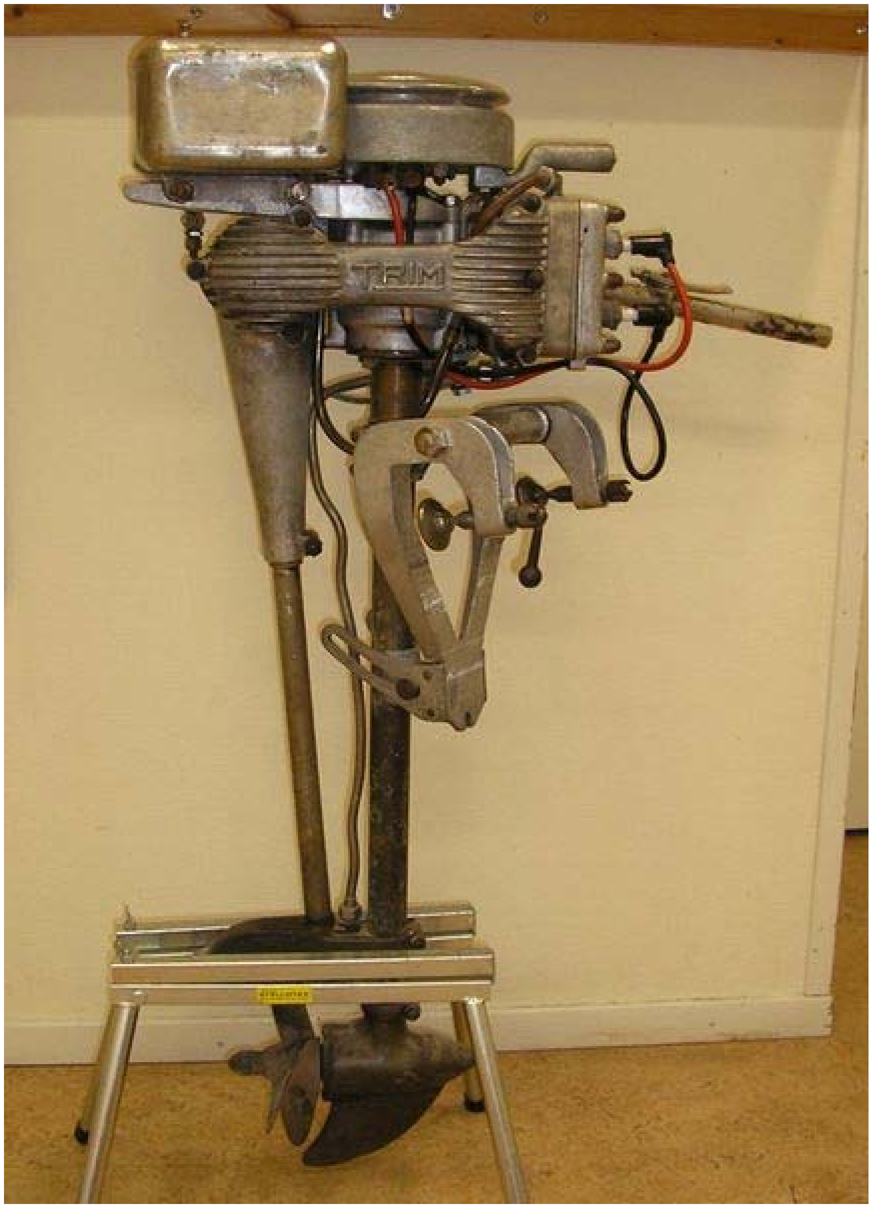
Oswald later produced portable diesel powered lighting plants popular during the Vietnam War and was a distributor and service center for diesel engines serving Northern California, and government contracts with customers including the Coast Guard.

## Chapter- 4

# Outboard Motor




Basic parts of an outboard motor




Bolinder's two cylinder *Trim* outboard engine.


A Mercury Marine 50 HP outboard engine, circa 1970's

1979 Evinrude 70 HP outboard, cowling and air silencer removed, exposing its shift/throttle/spark advance linkages, flywheel, and three carburetors

Rotor of the impeller pump (cooling system) of an outboard motor


A motorboat with an outboard motor attached to it

An **outboard motor** is a propulsion system for boats, consisting of a self-contained unit that includes engine, gearbox and propeller or jet drive, designed to be affixed to the outside of the transom and are the most common motorized method of propelling small watercraft. As well as providing propulsion, outboards provide steering control, as they are designed to pivot over their mountings and thus control the direction of thrust. The skeg also acts as a rudder when the engine is not running. Compared to inboard motors, outboard motors can be easily removed for storage or repairs.

When boats are out of service or being drawn through shallow waters, outboard motors can be tilted up (tilt forward over the transom mounts) to elevate the propeller and lower unit out of the water to avoid accumulation of seaweed, underwater hazards such as rocks, and to clear road hazards while trailering.

## *General uses*

### Portable

Small outboard motors, up to 15 horsepower or so are easily portable. They are affixed to the boat via clamps, and thus easily moved from boat to boat. These motors typically use a manual pull start system, with throttle and gearshift controls mounted on the body of the motor, and a tiller for steering. The smallest of these weigh as little as 12 kilograms

(26 lb), have integral fuel tanks, and provide sufficient power to move a small dinghy at around 8 knots (15 km/h; 9.2 mph) This type of motor is typically used:

- to power small craft such as jon boats, dinghies, canoes, etc.
- to provide auxiliary power for sailboats,
- for trolling aboard larger craft, as small outboards are typically more efficient at trolling speeds. In this application, the motor is frequently installed on the transom alongside and connected to the primary outboard to enable helm steering.

### Large Outboards

Large outboards are usually bolted to the transom (or to a bracket bolted to the transom), and are linked to controls at the helm. These range from 2- 3- and 4-cylinder models generating 15 to 135 horsepower suitable for hulls up to 17 feet (5.2 m) in length, to powerful V-6 and V-8 cylinder blocks rated up to 350 hp (260 kW)., with sufficient power to be used on boats of 18 feet (5.5 m) or longer.

### Electric-Powered

Commonly referred to as "trolling motors" or "electric outboard motors" , electric outboards are used

- on very small craft or on small lakes where gasoline motors are prohibited,
- as a secondary means of propulsion on larger craft, and
- as repositioning thrusters while fishing for bass and other freshwater species,

and any other application where their quietness, and ease of operation and zero emissions outweigh the speed and range deficiencies.

### Diesel

Diesel outboards are also available but their weight and cost make them rare.

### Pump-jet

Pump-jet propulsion is available as an option on most outboard motors. Although less efficient than an open propeller, they are particularly useful in applications where the ability to operate in very shallow water is important. They also eliminate the laceration dangers of an open propeller.

## *History and developments*

The outboard motor, as a portable propulsion system for boats that would otherwise be powered manually by oars, was made possible by the experimentations of Cameron Waterman, a young Yale Engineering student. The Waterman outboard engine appears to be the first real gasoline-powered outboard offered for sale. It was four stroke. Between

1903 and his patent in 1905 he successfully created the outboard. Starting with two dozen built in 1907, the company went on to make thousands of the units in the next 5 years. The inboard boat motor firm of Caille Motor Company of Detroit were instrumental in making the cylinder and engines. Kiekhaefer eventually bought out Cameron Waterman and used magazine ads with references to the Waterman.

The creation of the first practical and marketable outboard motor is often miscredited to Norwegian-American inventor Ole Evinrude in 1909. Between 1909 and 1912 Evinrude made thousands of his outboards and the three horse units were sold around the world. His Evinrude Outboard Co. was spun off to other owners, and he went onto success with ELTO. The 1920s were the first highwater mark for the outboard with Evinrude, Johnson, ELTO, Atwater Lockwood and dozens of other makers in the field.

Historically, a majority of outboards have been two-stroke powerheads fitted with a carburetor due to the design's inherent simplicity, reliability, low cost and light weight. Drawbacks include increased pollution, due to the high volume of unburned gasoline in their exhaust, and louder noise.

In the 1990s US and European exhaust emissions regulations led to the proliferation of four-stroke outboards. Though fewer in number, four-stroke outboards have always been available. For example Honda Marine has been marketing small four-stroke outboards since the early 70s. Other brands have been produced for over a 100 years, but again in fewer numbers.

Mercury Marine, Mercury Racing, Tohatsu Outboards, Nissan Marine, Honda Marine, Suzuki Marine, and Yamaha Marine, China Oshen-Hyfong marine have all developed new four-stroke engines. Some are carbureted, usually the smaller engines. The balance are electronically fuel-injected. Some models benefit from variable camshaft timing, and multiple valves per cylinder. Mercury Verado four-strokes are unique in that they are supercharged.

Mercury Marine, Mercury Racing, Tohatsu, Yamaha Marine, Nissan and Evinrude each developed computer-controlled Direct-Injected two-stroke engines. Each brand boasts a different method of DI.

Fuel economy on both direct injected and four-stroke outboards measures from a 10 percent to 80 percent improvement, compared with conventional two-strokes. Depending on rpm and load at cruising speeds figure on about a 30 percent mileage improvement.

Outboard motors benefit from the use of a submerged pump to draw water for cooling, obviating the need for radiators and cooling fans, thereby simplifying the design and lowering component weight, however constant usage in seawater is liable to cause corrosion.

For boats which are moored rather than trailered, bronze propellers are unsuitable owing to galvanic effects. It is a surprising fact that quite often sacrificial anodes are found which have been painted over. One can only assume that owners notice that these parts were corroding and thought that the factory forgot to paint them. Severe damage is usually the result.

## *Outboard motor selection*

It is important to select a motor that is a good match for the hull in terms of power and shaft length.

### Power requirements

Overpowering is a dangerous condition and underpowering often results in a boat that is incapable of performing in the role for which it was acquired. Boats built in the U.S. have a *Coast Guard Rating Plate* which specifies the maximum recommended horsepower for the hull. A motor with less than 75% of the maximum will most likely result in unsatisfactory performance.

### Shaft length

Outboard motor shaft lengths are standardized to fit 15-inch, 20-inch and 25-inch transoms. If the shaft is too long it will extend farther into the water than necessary creating drag, which will impair performance and fuel economy. If the shaft is too short, the motor will be prone to ventilation. Even worse, if the water intake ports on the lower unit are not sufficiently submerged, engine overheating is likely, which can result in severe damages.

## *Operational issues*

### Motor mounting height

Motor height on the transom is an important factor in achieving optimal performance. The motor should be as high as possible without ventilating or loss of water pressure. This minimizes the effect of hydrodynamic drag while underway, allowing for greater speed. Generally, the antiventilation plate should be about the same height as, or up to two inches higher than, the keel, with the motor in neutral trim.

### Trim

Trim is the angle of the motor in relation to the hull, as illustrated below. The ideal trim angle is the one in which the boat rides level, with most of the hull on the surface instead of plowing through the water.


If the motor is trimmed out too far, the bow will ride too high in the water. With too little trim, the bow rides too low. The optimal trim setting will vary depending on many factors including speed, hull design, weight and balance, and conditions on the water (wind and waves). Many large outboards are equipped with *power trim*, an electric motor on the mounting bracket, with a switch at the helm that enables the operator to adjust the trim angle on the fly. In this case, the motor should be trimmed fully in to start, and trimmed out (with an eye on the tachometer) as the boat gains momentum, until it reaches the point just before ventilation begins or further trim adjustment results in an RPM increase with no increase in speed. Motors not equipped with power trim are manually adjustable using a pin called a topper tilt lock.

### Ventilation

Ventilation is a phenomenon that occurs when surface air or exhaust gas (in the case of motors equipped with through-hub exhaust) is drawn into the spinning propeller blades. With the propeller pushing mostly air instead of water, the load on the engine is greatly reduced, causing the engine to race and the prop to spin fast enough to result in cavitation, at which point little thrust is generated at all. The condition continues until the prop slows enough for the air bubbles to rise to the surface. The primary causes of ventilation are: motor mounted too high, motor trimmed out excessively, damage to the antiventilation plate, damage to propeller, foreign object lodged in the diffuser ring.

### Cavitation

Cavitation as it relates to outboard motors is often the result of a foreign object such as marine vegetation caught on the lower unit interrupting the flow of water into the propeller blades.

### Preventive Maintenance

- Lower unit gear lubricant—change annually.
    - Inspect the old oil for metal fragments and if found, disassemble gearbox for inspection and repair.
    - Inspect old oil for evidence of water intrusion and if found, replace seals at propshaft, drive shaft and shift rod.

- Water pump impeller -- replace every two years (annually in a salt water environment).
    - Inspect pump housing, and replace if scored or damaged.
    - Inspect old impeller for missing pieces and if found, remove thermostat housing and water jacket cover if necessary, to recover the liberated material.
- Powerhead—annual inspection
    - Inspect engine wiring for corrosion, burned/chafed/missing insulation. Check all connections for tightness.
    - Inspect fuel lines for signs of aging.
    - Inspect spark plugs and replace when necessary.
    - Check all fasteners for tightness, torque to manufacturer specification if necessary.
    - Clean and inspect throttle, shift, spark advance linkages, lubricate according to manufacturer recommendations.
    - Starter motor (if equipped) -- apply two drops of light oil to the bendix gear threads.
    - Test overtemp warning horn or light (if equipped).

## *Manufacturers*

- British Anzani
- Aquawatt Electric Outboard Motor
- British Seagull
- Briggs & Stratton
- China Parsun Marine
- Evinrude/Johnson, a division of Bombardier Recreational Products
- Hidea
- Honda
- Honda Marine
- Mercury/Mariner
- McCulloch
- Nissan Marine
- Oshen-Hyfong Marine
- Parsun Marine
- Selva Marine
- Suzuki
- Tohatsu
- Ul'yanovsk Motor Plant
- West Bend
- Yamaha Motor Corporation
- Yanmar Diesel Power

**Chapter- 5**

# Rolls-Royce Marine Trent and Trolling Motor

## Rolls-Royce Marine Trent

The **Rolls-Royce MT** (Marine Turbine) is a marine gas turbine based on Rolls-Royce Trent 800 aero engine. The current model is the **Rolls-Royce MT30**

The MT30 retains 80% commonality with the Trent 800, the most successful engine for the Boeing 777. The maximum power rating is 36MW and minimum efficient power 25MW.

Rolls-Royce announced the MT30 programming on September 11, 2001. The first run of the engine was on September 6, 2002. In early 2003 the MT30 was selected to power the Royal Navy future aircraft carriers (CVFs) and the demonstrator of the US Navy's DD(X) multimillion destroyer. In June 2004 Lockheed Martin awarded the engine contract to the MT30 for its Littoral combat ship design.

### *Applications*

- Royal Navy *Queen Elizabeth* class aircraft carriers
- US Navy DDG1000 Zumwalt class destroyer
- Lockheed Martin Freedom class littoral combat ships
- French Navy *PA2* aircraft carriers

# Trolling motor

A 12 volt electric trolling motor mounted on a 8 foot inflatable boat

A **trolling motor** is a marine propulsion system consisting of a self-contained unit that includes an electric motor, propeller and controls, and is affixed to an angler's boat, either at the bow or stern. A gasoline-powered outboard used in trolling, if it is not the vessel's primary source of propulsion, may also be referred to as a *trolling motor.* Trolling motors are often lifted from the water to reduce drag when the boat's primary engine is in operation.

## *Uses*

- Trolling for game fish; a motor used for this purpose is usually a secondary means of propulsion, and mounted on the transom alongside the primary outboard motor or on a bracket made for the purpose.
- Auxiliary power for precision maneuvering of the boat, to enable the angler to cast his bait to where the fish are located; trolling motors designed for this application are typically mounted in the bow.

- Primary source of propulsion for smaller water craft, such as canoes and kayaks, and on lakes where the use of a gasoline-powered engine is prohibited; usually transom-mounted.

## History

Before 1934 - A PORTABLE ELECTRIC PROPELLER FOR BOATS. Article in Scientific American 1895-09-21. "Briefly described, it consists of a movable tube which is hinged at the stern of the boat, much as an oar is used in sculling. The tube contains a flexible shaft formed of three coils of phosphor bronz. This tube extends down and out into the water, where it carries a propeller, and at the inboard end an electric Motor is attached, which is itself driven by batteries." Invented and sold by the Electric Boat company.

The electric trolling motor was invented by O.G.Schmidt in 1934 in Fargo, North Dakota, when he took a starter motor from a Model A Ford, added a flexible shaft, and a propeller. Because his manufacturing company was near the Minnesota/North Dakota border, he decided to call the new company MinnKota. The company still is a major manufacturer of trolling motors.

Several other trolling motor manufacturers have appeared over the last few decades, including Motor Guide and Rhodan Marine Systems. Motor Guide introduced the Pin Point system using sonar to follow bottom countours. Minn Kota and Rhodan Marine Systems recently introduced wireless trolling motors with integrated GPS systems. The Rhodan GPS Anchor has been demonstrated at trade shows to precisely hold a boat's position within a couple feet in wind and current acting as a virtual anchor.

## *Design*

### Electric Trolling Motors

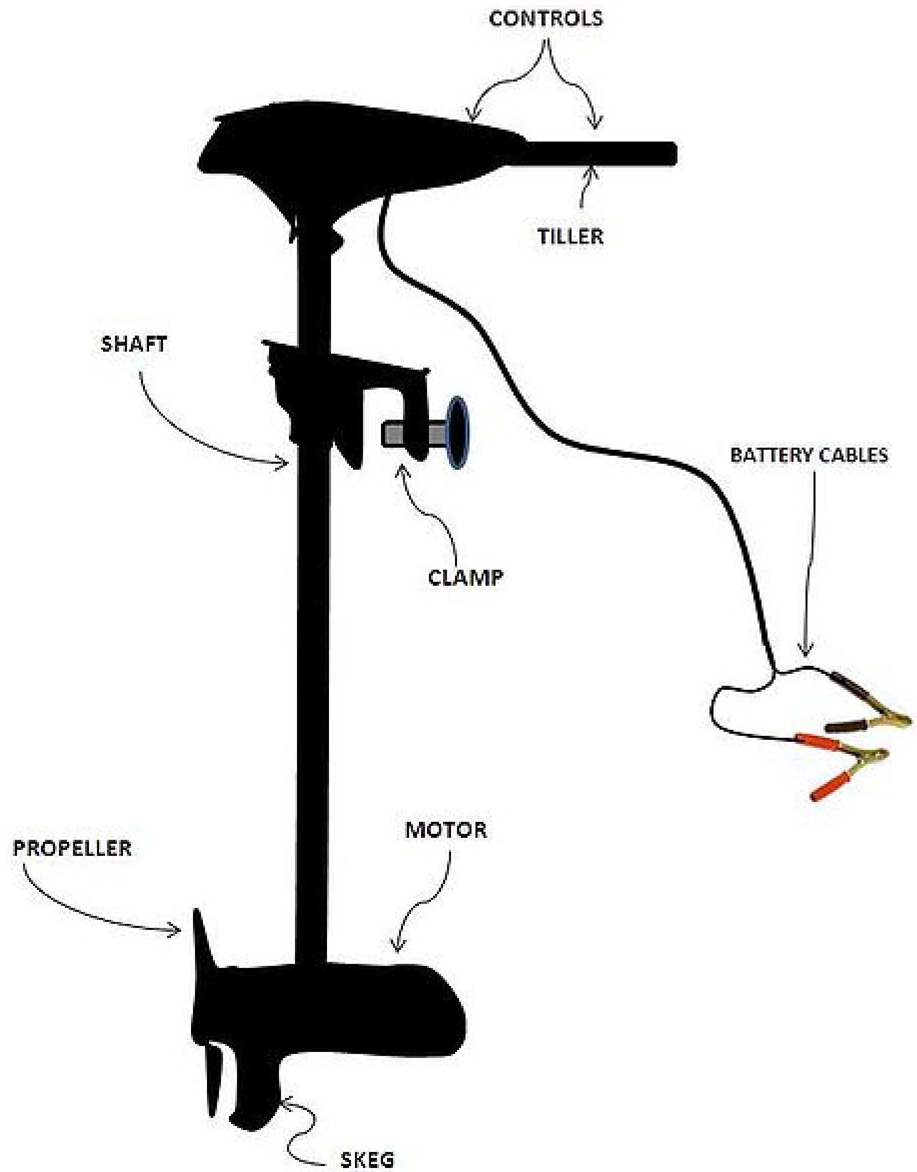



Diagram of a hand-controlled trolling motor.

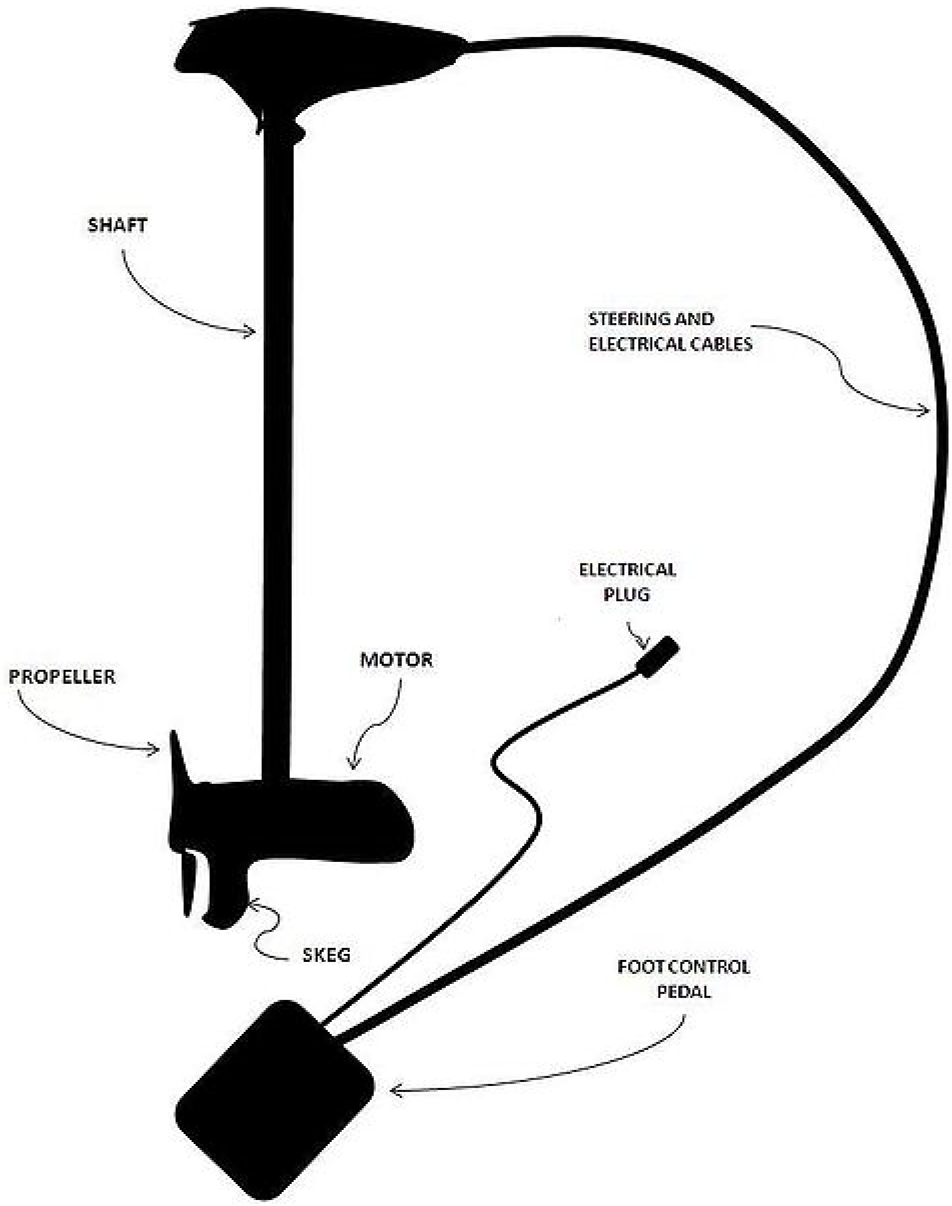



Diagram of a foot-controlled trolling motor.

- Modern electric trolling motors are designed around a 12-volt, 24-volt or 36-volt brushed DC electric motor, to take advantage of the availability of 12-volt deep cycle batteries.
- The motor itself is sealed inside a watertight compartment at the end of the shaft. It is submerged during operation, which prevents overheating.
- The propeller is fitted directly on to the propshaft.
- Hand-control: tiller for steering, with speed control either built in to the tiller or a control knob on top of the unit. Hand controlled trolling motors are attached to the boat with a clamp.
- Foot-control: on/off and speed controls are foot-operated, and built into a pedal that also controls the steering mechanism. Steering may be via electronically

controlled servo motors, or in early-model (and late-model low-end units), a push-pull cable. Foot controlled trolling motors require a specialized mounting bracket that bolts horizontally to the deck.

- Wireless remote: available on high-end late-model trolling motors. Servo-controlled steering and speed control both respond to a wireless device, either in a foot pedal or a key-fob transmitter (similar to an automotive remote keyless system).


Foot controlled trolling motor mount in the deployed position.


Foot controlled trolling motor mount in the stowed position.

## Gasoline-powered Trolling Motors

- Small outboard motors are frequently used as trolling motors on boats with much larger engines that do not operate as efficiently or quietly at trolling speeds. These typically are designed with a manual pull start system, throttle and gearshift controls mounted on the body of the motor, and a tiller for steering, but in a trolling application, will be connected to the steering mechanism at the helm.

**Chapter- 6**

# Rolls-Royce Meteor, Universal Atomic 4 and Rolls-Royce WR-21

## Rolls-Royce Meteor

The **Rolls-Royce Meteor** (also sometimes known as the **Rover Meteor**) was a British tank engine of the Second World War.

It was developed from the Rolls-Royce Merlin aero-engine by W. A. Robotham and his chassis design and development division at Belper, as they were not involved in aero-engine work. With the aid of engineers from Leyland, who were engaged in tank work, he considered RR's two V12s. The Kestrel, while having more power than the existing "Liberty" or Meadows engines, did not provide the desirable 20 bhp per ton required, so the Merlin III was used.

Despite his lack of experience in tank design or warfare, Robotham was made Chief Engineer of Tank Design and joined the Tank Board. He was involved in the Cruiser Mk VIII Challenger tank. The Tank Division at Belper was involved with the overall design of four versions of the Cromwell tank, using a standard set of components.

### *Design and development*

For tank use the Merlin had its supercharger, reduction gear, and other equipment removed from its camshaft, greatly simplifying its construction. It had cast (not forged) pistons. and was de-rated to approximately 600 bhp (447 kW), running on lower-octane pool petrol instead of high-octane aviation fuel. In addition, because weight saving was not so important for a tank engine, some of the Merlin's more expensive light-alloy components were replaced with cheaper, steel components in the Meteor X version. It was also envisaged that the Meteor would use some components rejected on quality grounds for the Merlin, i.e., Merlin scrap. In 1943 an acute shortage of blocks was met by dismantling surplus older marks of Merlins.

Unlike previous British tank engines, such as the American Liberty L-12 of 340 bhp (250 kW) licence-built by Nuffield that was used in the Crusader, the engine was very lightly stressed and reliable, while doubling the power available. Previously British tanks had been regarded as underpowered and unreliable, and the Meteor is considered to be the engine that for the first time gave British tanks ample, reliable power. Initially it was used in the Cromwell tank, which was a further development of the cruiser line and would replace the Crusader tank.

But in 1941 Leyland, who had an order for 1,200 Meteor engines, were still advocating their own diesel tank engine, although it would deliver only 350 hp (260 kW), as they were concerned with the problems of sufficient cooling. Meadows produced some Meteors, but the small factory of 2,000 men was producing 40 different types of engine. So Meteor production was to be by Rover (Tyseley) and Morris (Coventry).

The first Merlin prepared for tank use was trialled in a modified Crusader in September 1941 at Aldershot.

## *Use*

The Meteor was used in the following vehicles:

- Cromwell
- Comet
- Centurion
- Tortoise experimental assault tank.
- Conqueror post war heavy tank

- A Mk II version of the Valiant tank, to use a two-thirds-size (V8) version of the engine called the "Meteorite" was suggested but not proceeded with.

## *Production*

When Leyland withdrew their support, Robotham took the problem to Ernest Hives. Hives took the problem to the Ministry of Supply, telling Lord Beaverbrook that he already had his hands full making Merlin aero engines, and Rolls-Royce would want £1 million to their credit and 'no interference' to make tank engines, Beaverbrook telegrammed back:

OHMS Ministry of Supply to W. Hives Nightingale Road Rolls-Royce Derby

The British Government has given you an open credit of one million pounds. This is a certificate of character and reputation without precedent or equal. Beaverbrook

An order for 1,000 engines followed. The Meteor was initially produced by Rolls-Royce. Rolls-Royce were also aiding the development of production jet engines at Rover, but progress there was slow, and Rover were becoming disillusioned. Hives struck a deal in

December 1942 with Spencer Wilks of Rover to trade W.2B/23 production at Barnoldswick for the Rolls-Royce tank engine factory in Nottingham and production of the Meteor, to become officially effective on 1 April 1943. Rover took over the Meteor in January 1944, and in 1946 the British Government made Rover responsible for research and development of large military engines. In this role Rover continued the development and production of the Meteor Mk IVb and various derivatives, including the Meteorite V8 and the M120 V12. Rover ceased this activity in 1964, having produced approximately 9,000 engines, and Rolls-Royce again became responsible for the manufacture of spare parts to support fielded engines. Future engines for British tanks were manufactured by Rolls-Royce engine divisions, which were acquired by Perkins UK and then Caterpillar US.

# Universal Atomic 4

The **Universal Atomic 4** is a four cylinder, 64.46 cubic inch, 30 horsepower (22 kW) gas engine produced by the Universal Motor Company between 1947 and 1984 for use as auxiliary power on sailboats. Over 40,000 of the engines were produced during that time, with an estimated 20,000 still in use today. This "workhorse" engine dominated the expanding sailboat market starting in the 1960s, and between the years of 1965 and 1975 they were installed on up to 80% of new sailboats in the 25-40 foot (7.6-12 meter) range. Their longevity and reliability is proven by the fact that thousands of sailors still depend on the engine, even multiple decades after the Universal Motor Company ceased production.

## *History and Lineage*

The Atomic 4 is descended from an earlier Universal Motor Company design called the Utility Four, which was used extensively in World War II by the United States Navy and allies to power the lifeboats for the ships, barges, and tankers of many navies and merchant marine fleets. The Utility Four was replaced by the Atomic 4 in 1947.

## *Specifications*

| | | |
|---|---|---|
| **Engine Type** | Four Cylinder, Vertical, 4 Cycle, L-Head | |
| **Bore** | 2 9/16" x 3 1/8" | |
| **Displacement** | 64.46 Cubic Inches | |
| **Compression Ratio** | 6.3:1 | |
| **Engine Rotation** | Counter-clockwise from flywheel end | |
| **Firing Order** | 1-2-4-3 (no. 1 on flywheel end) | |
| **Reduction Gear Ratio** | 2.04:1 | or direct 1:1 drive |

| | |
|---|---|
| **Maximum Operating Angle** | ~15 degrees |
| **Fuel** | unleaded gasoline |
| **Lubrication Oil** | SAE 30 |

| @ RPM | 600 | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 |
|---|---|---|---|---|---|---|---|
| Brake Horsepower: | 5 | 7.3 | 11.9 | 16.2 | 20 | 25 | 30 |

# Rolls-Royce WR-21


The WR-21 powers Royal Navy Type 45 destroyers.

The **Rolls-Royce WR-21** is an advanced marine gas turbine engine, designed to power the latest naval surface combatants of the partner nations, and currently fitted to the Type 45 destroyer of the Royal Navy. Developed under a US Navy contract, with support from the UK and France the WR-21 was designed and manufactured by an international consortium which includes Rolls-Royce, Northrop Grumman and DCN.

## *Characteristics*

The WR-21 is the first aeroderivative gas turbine to incorporate compressor intercooling and exhaust heat recuperation (ICR) technologies that deliver low specific fuel consumption across the engine's operating range. It offers a reduction in fuel burn of 30% across the typical ship operating profile.

- The intercooler cools air entering the high pressure compressor, reducing the amount of energy required to compress the air.
- The recuperator preheats the combustion air by recovering waste energy from the exhaust, improving cycle efficiency and reducing fuel consumption.

WR-21 development draws heavily on the technology of the successful Rolls-Royce RB211 and Trent families of gas turbines.

## *Applications*

It is a candidate power plant for propulsion of cruise ships and other large commercial vessels, where fuel efficiency and its small size mean improved operational flexibility and significant lifetime cost reductions to operators.

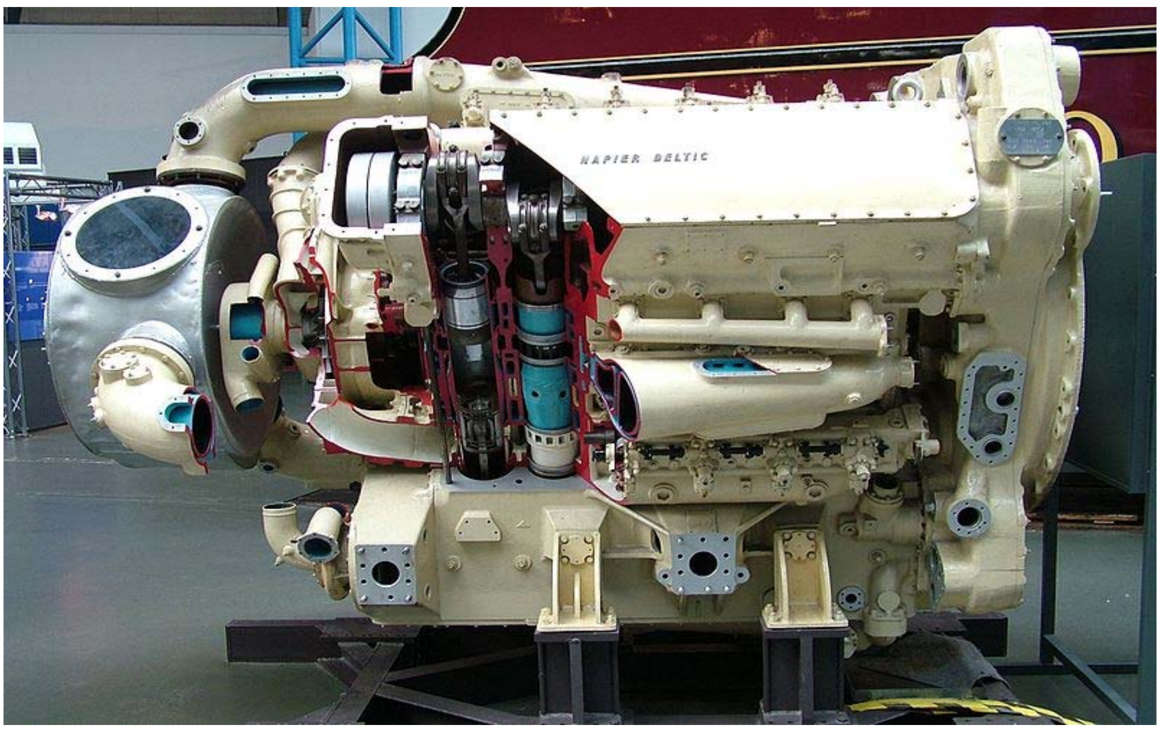
The only current use of the WR-21 is in the Type 45 destroyer.

## *Specifications*

- Rated power 25.2 MW
- Specific fuel consumption ~190 g/kWh
- Main module wet weight 45 974 kg
- Triple-spool design
- Six-stage IP compressor
- Intercooler
- Six-stage HP compressor
- Exhaust heat recuperator
- Nine radial combustors
- Single-stage HP turbine (8100 rev/min)
- Single-stage IP turbine (6200 rev/min)
- Five-stage power turbine (3600 rev/min = 60 Hz)

## Chapter- 7

# Napier Deltic




Napier Deltic engine at the National Railway Museum, York, UK

The **Napier Deltic** engine was a British opposed-piston valveless, two-stroke diesel engine used in marine and locomotive applications, designed and produced by Napier & Son. The cylinders were divided in three blocks in a triangular arrangement, the blocks forming sides with crankcases located in each apex of the triangle.

The term Deltic (meaning in the form of the Greek letter Delta) is used to refer to both the *Deltic E.130* opposed-piston high-speed diesel engine and the locomotives produced by English Electric using these engines, including their demonstrator locomotive named *DELTIC* and the production version for British Railways, who designated these as (TOPS) Class 55.

A single half-sized, turbocharged Deltic power unit also featured in the English Electric-built Type 2 locomotive, designated as the Class 23. Both locomotive and engine became better known as the "Baby Deltic".

## *History and design*

The Deltic story began in 1943 when the British Admiralty set up a committee to develop a high-power, lightweight diesel engine for Motor Torpedo Boats. Hitherto in the Royal Navy, such boats had been driven by petrol engines but this fuel is highly flammable, making them vulnerable to fire, and at a disadvantage compared with the German diesel-powered E-boats.

Until this time, diesel engines had poor power-to-weight ratio and low speed. Before the war, Napier had been working on an aviation diesel design known as the Culverin after licensing versions of the Junkers Jumo 204. The Culverin was an opposed-piston two-stroke design. Instead of each cylinder having a single piston and being closed at one end with a cylinder head, the Jumo-based design used an elongated cylinder containing two pistons moving in opposite directions towards the centre. This negates the need for a heavy cylinder head, as the opposing piston filled this role. On the downside, the layout required separate crankshafts on either end of the engine, and some form of gearing to take off power and combine it back into a single shaft. The primary advantage of the design was that it led to a rather "flat" engine, intended to be buried in the wings of large aircraft.

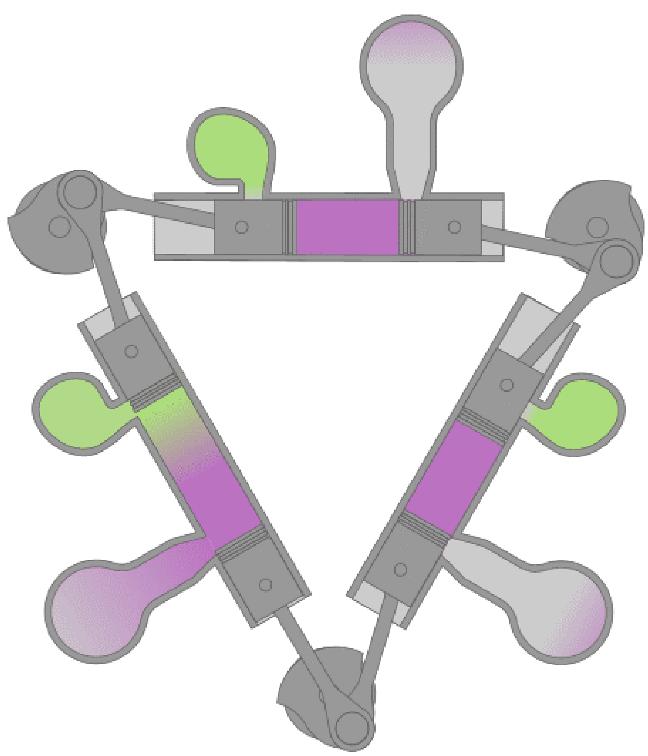


Diagram of Deltic engine layout

Note: The bottom left input and output ports are shown incorrectly as reversed

The Admiralty required a much more powerful engine, and knew about Junkers' designs for multi-crankshaft engines of triangular- and diamond-form. The Admiralty felt these would be a reasonable starting point for the larger design it required. The result was a triangle, the cylinder banks forming the sides, and tipped by three crankshafts, one at each apex. The crankshafts were connected with phasing gears to drive one output shaft. In this arrangement, there were six banks of pistons driving three crankshafts, the same as three separate V-engines of the same overall size. Various models of Deltic engine could be produced with varying numbers of cylinders, though nine and eighteen cylinders were the most common, having three and six cylinders per bank respectively. In 1946, the Admiralty placed a contract with the English Electric Company, parent of Napier, to develop this engine.

One feature of the engine was the way the crankshaft-phasing was arranged to allow for exhaust port lead and inlet port lag. These engines are called 'uniflow' designs because the flow of gas into and out of the cylinder is one way, assisted by mild supercharging to improve cylinder exhaust scavenging. The inlet/outlet port order is In/Out/In/Out/In/Out going around the triangular ring (i.e. the inlet and outlet manifold arrangements have $C_3$ rotational symmetry).

Earlier attempts at designing such an engine failed because of the difficulty in arranging the pistons to move in the correct manner, for all three cylinders in one delta, and this was the problem which caused Junkers Motorenbau to leave behind work on the delta-form while continuing to prototype of a diamond-form four-crankshaft 24-cylinder Junkers Jumo 223. Mr. N. Penwarden of the Admiralty Engineering Laboratory solved this problem by suggesting that one crankshaft needed to revolve anti-clockwise to achieve the correct piston-phasing, so Napier designers produced the necessary gearing in order that one of them rotated in the opposite direction to the other two.

In an opposed-piston design with no inlet or exhaust valves, and no ability to vary the port positions, the Deltic design arranged each crankshaft to connect two adjacent pistons operating in different cylinders in the same plane, using "fork and blade" connecting rods, the latter an 'inlet' piston used to open and close the inlet port, and the former an 'exhaust' piston in the adjacent cylinder to open and close the exhaust port.

Crankshaft connecting-rod journals were arranged so that each cylinder's exhaust piston 'led' its inlet piston by 20 degrees of crankshaft rotation. This allowed the exhaust port to be opened well before the inlet port, and allowed the inlet port to be closed after the exhaust port, which led to both good scavenging of exhaust gas, and good volumetric efficiency for the fresh air charge. It also led to Deltics' even, buzzing exhaust note, with a charge ignition every 20 degrees of crankshaft revolution, and a lack of torsional vibration, ideal for use in mine-hunting vessels.

Although the engine was cylinder-ported and required no poppet valves, it did still have camshafts, with each bank having a separate camshaft, driven at crankshaft speed. This was used solely to drive the fuel injection pumps, each cylinder having its own injector and pump, driven by its own cam lobe.

## *Uses*

### Naval service


The Deltic-powered Hunt class Mine Countermeasures Vessel HMS *Ledbury*

Development began in 1947 and the first Deltic unit was produced in 1950. By January 1952 six engines were available, enough for full development and endurance trials. S212, a captured ex-German E-Boat powered by three Mercedes-Benz diesel engines, was selected for these trials, since its power units were of approximately equal power to the new 18-cylinder Deltic engines. Two of the three Mercedes-Benz engines were replaced with Napier Deltics, the compactness of the Deltic being graphically illustrated: they were half the size of the original engines. The Deltic weighed one fifth of its contemporaries of equivalent power.

Proving successful, Deltic diesel engines became a common powerplant in small and fast naval craft. The Royal Navy used them first in the Dark class fast attack craft. Subsequently they were used in a number of other smaller attack craft. The low magnetic signature lent itself to use in mine countermeasures vessels and the Deltic was selected to power the Ton class minesweeper. The Deltic engine is still in service in the Hunt class. These versions are de-rated to reduce engine stress.

Deltic diesels served in MTBs and PT Boats built for other navies. Particularly notable was the Norwegian *Tjeld* or *Nasty* class, which was also sold to Germany, Greece, and the United States Navy. *Nasty* class boats served in the Vietnam War, largely for covert operations.

Smaller nine-cylinder *Deltic 9* engines were used as marine engines, notably by minesweepers. The Ton class vessels were powered by a pair of Deltic 18s and used an additional Deltic 9 for power generation for their magnetic influence sweep. The Hunt class used three Deltic 9s, two for propulsion and again one for power generation, but this time with a hydraulic pump integrated as well to power bow-thrusters for slow-speed manœuvring.

### Railway use

The 'Deltic' engines were used in two types of British rail locomotive: classes 55 and 23, built in the 1960s—both earned the *nom-de-plume* or nickname from the type of engines—"Deltics" and "Baby Deltics" respectively.

The Class 55 used two deltic engines: mechanically-blown 18-cylinder engines, the Class 23 used a single less powerful nine-cylinder turbocharged T9-29 Deltic of 1,100 hp (820 kW).

### Reliability in service

While the Deltic engine was successful and very powerful for its size and weight, it was a highly-strung unit, requiring careful maintenance. This led to a policy of unit replacement rather than repair in situ. Deltic engines were easily removed after breakdown, generally being sent back to the manufacturer for repair, although after initial contracts expired both the Royal Navy and British Railways set up their own workshops for overhauls.

## *Turbo-compound Deltic*

The *E.185* or *Compound Deltic* turbo-compound variant was planned and a single protoype was built in 1956 and tested in 1957. This capitalised on Napier's experience with both the *Nomad* and their increasing involvement with gas turbines. It used the Deltic as the gas generator inside a gas turbine, with both a twelve-stage axial compressor and a three stage gas turbine. Unlike the Nomad, this turbine was not mechanically coupled to the crankshaft but merely drove the compressor. It was hoped to produce 6,000 horsepower, with fuel economy and power-to-weight ratio "second to none". Predictions by the engineers closely connected with it were that connecting rod failure would be the limit on this power, failing at around 5,300 bhp. On test it actually produced 5,600 bhp, before throwing a connecting rod through the crankcase just as predicted.

Naval interest had waned by 1958 in favour of the pure gas turbine, despite its heavier fuel consumption, and no further development was carried out.

**Chapter- 8**

# Wärtsilä-Sulzer RTA96-C and Yanmar 2GM20

## Wärtsilä-Sulzer RTA96-C

The **Wärtsilä RT-flex96C** is a two-stroke turbocharged low-speed diesel engine designed by the Finnish manufacturer Wärtsilä. It is currently considered the largest reciprocating engine in the world, designed for large container ships, running on heavy fuel oil. It stands at 13.5 metres (44 ft) high, is 27.3 m (90 ft) long, and weighs over 2300 tonnes in its largest 14-cylinder version — producing 109,000 brake horsepower (80,08 MW).

The 14-cylinder version was put into service in September 2006 aboard the Emma Mærsk. The design is based on the older RTA96C engine, but revolutionary common rail technology has done away with the traditional camshaft, chain gear, fuel pumps and hydraulic actuators. The result is better performance at low revolutions per minute (rpm), lower fuel consumption, and lower harmful emissions.

The engine has crosshead bearings so that the always vertical piston rod allows a tight seal under the piston. One of the reasons that the large two-stroke diesels use this design is so that the lubrication in the combustion area is separated from the crank case oil, which stays clean from combustion products. The upper portion is lubricated by continuous injection of consumable lubricant which is formulated to stand up to high temperatures and high sulfur. Another reason is to reduce sideways forces on the piston, keeping diametral cylinder liner wear in the order of only about 0.03 mm per 1000 hours.

The descending piston is used to compress incoming combustion air for the adjacent cylinders which also serves to cushion the piston as it approaches bottom dead centre (BDC) to remove some load from the bearings.

25 engines are in service, and 86 are on order.

## Technical data (as of 2008)

engine configuration
: turbocharged two-stroke diesel straight engine, 6 to 14 cylinders

cylinder bore
: 960 mm

piston stroke
: 2500 mm

engine displacement
: 1820 litres per cylinder

engine speed
: 92–102 revolutions per minute

torque
: 7,603,850 newton metres (5,608,310 ft·lbf) @ 102 rpm

mean effective pressure
: 1.96 MPa @ full load, 1.37 MPa @ maximum efficiency (85% load)

mean piston speed
: 8.5 metre per second

specific fuel consumption
: 171 g/(kW·h) (126 g/(bhp·h), approx. 3.80 litres per second) @ full load; 163 g/(kW·h) (120 g/(bhp·h)) @ maximum efficiency

power
: up to 5720 kW per cylinder, 34320 to 80080;kW (46 680 to 108 920 bhp) altogether

power density
: 29.6 to 34.8 kW per tonne, 2300 tonnes for the 14 cylinder version

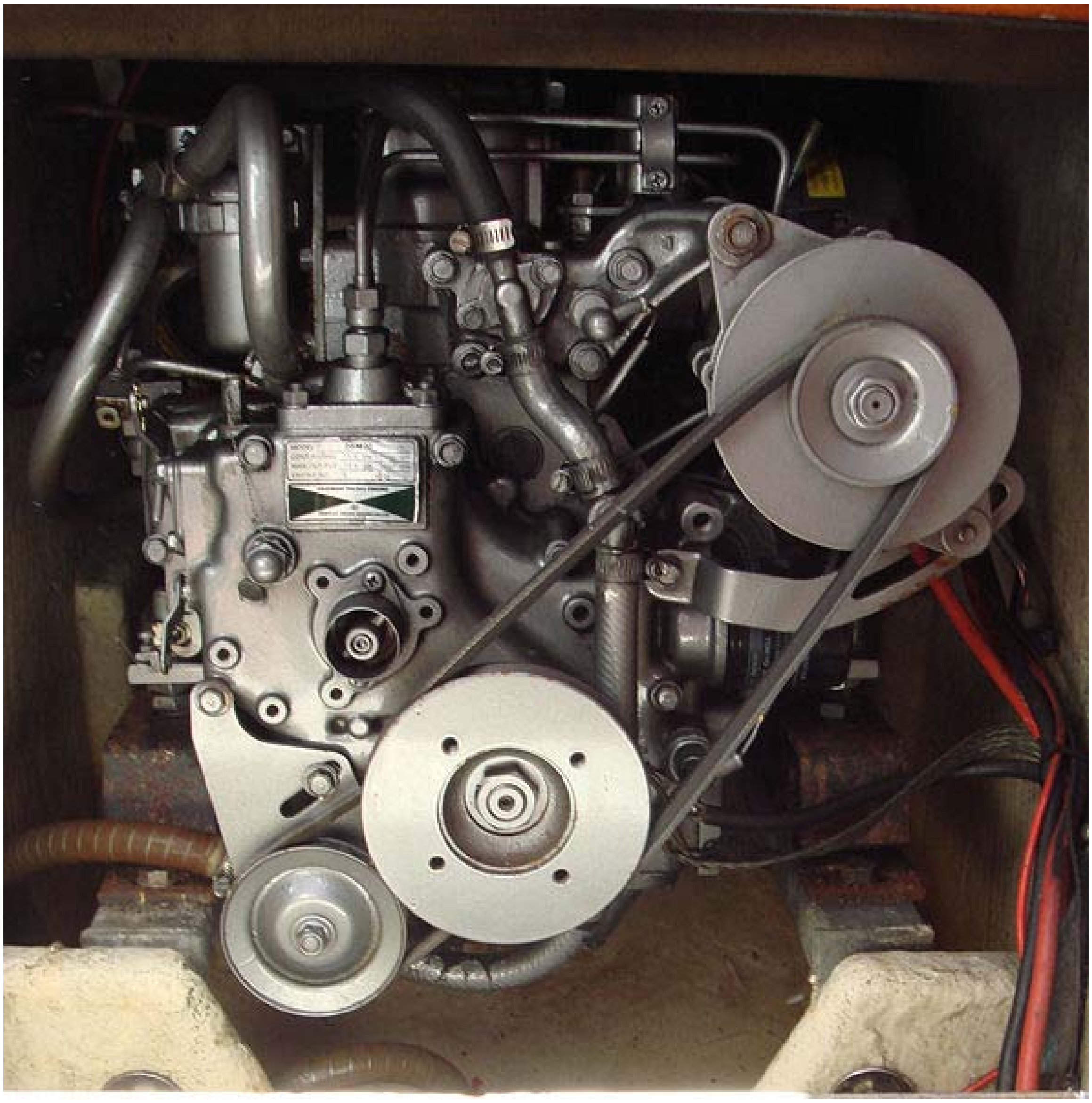
amount of fuel injected in a single cycle of single piston
: ~160 g @ full load

crankshaft weight
: 300 tons

## Efficiency

An equal MAN engine in terms of stroke, rated speed, power and technology is the 14-cylinder K98ME7 (87 220 kW) that has a minimum SFOC-rating of 164 g/kWh at partial load.

# Yanmar 2GM20



A Yanmar 2GM20 marine diesel engine, installed in a sailboat. The center pulley is the crankshaft, the lower left one the seawater pump, the upper right one the alternator.

The **Yanmar 2GM20** is an inboard marine diesel engine manufactured by the Japanese company Yanmar Co. Ltd.. It is used in a wide range of sailboats and motorboats.

## *Specifications*

It is a four-stroke, vertical, water cooled diesel engine. It is built around two cylinders (hence the "2" in 2GM20) of 75mm in length and 72mm in stroke, adding up to 0.635

liters in displacement: each cylinder is roughly the size and volume of a 300ml soft-drink can. The compression system uses a proprietary swirl-type pre-combustion chamber.

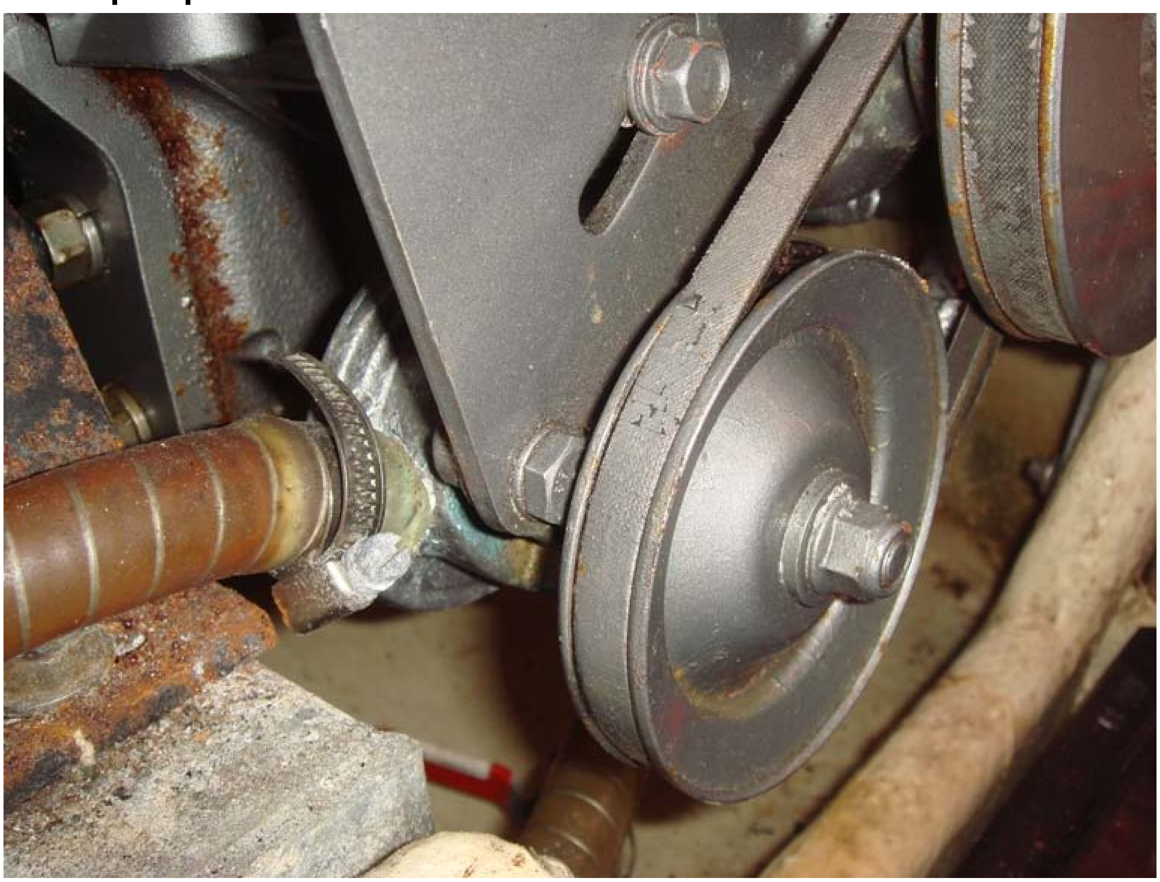
The continuous rating output at the crankshaft is 11.8 kW, and 3400 revolutions per minute (rpm). The maximum output at crankshaft is 13.4 kW, and 3600 rpm.

The engine delivers roughly 20 horsepower (hence the "20" in 2GM20), for a weight of about 114 kg.

The engine is equipped with a starting motor (D.C. 12V, 1 kW), and an alternator to provide electricity and charge onboard batteries (12V, 55A).

The engine is typically activated by a key and a starting motor switch. Upon turning the key and pressing the starting motor switch, the oil pressure alarm will ring for about a second until the engine starts to run. The exit of cooling water from the exhaust into the sea (typically at the aft of the boat) should be checked at that time. After a few minutes, the hot cooling water alarm will sound if the cooling water does not get through the engine (as when the seawater cock has remained closed -most likely case- or if something is clogging the seawater tubing).

### Water pump



Yanmar 2GM20 seawater pump. Cooling seawater enters from the tube on the left.

The 2GM20 series uses either a seawater cooling system, or a freshwater cooling system (specified by the letter F). Seawater is pumped into the engine through a seawater pump (impeller type). In the engines equipped with a seawater cooling system, seawater is used to cool the internals of the engine directly. The engines equipped with a freshwater cooling system have an additional heat exchanger, where heat transfer occurs between the seawater and internal freshwater.

The impeller of the seawater pump can suffer from wear and tear, especially when run dry for some period of time, in which case it has to be replaced to avoid loss in the flow of cooling seawater, a potential source of engine overheating.

The seawater pump is rotated by a short belt linked to the crankshaft.

## Fuel filter

Yanmar 2GM20 fuel filter.

An inline fuel filter is easily accessible from the front part of the engine. The filter allows to retain dust particles and separate water from diesel (as water is heavier than diesel, it will settle at the bottom of the filter), just before the diesel fuel enters the highly sensitive high-pressure fuel pump. Water inside diesel fuel can lead to rusting of the internals of the engine, as well as lubrication problems. The filter is made of a metallic mesh.

When the engine has to be bled because air has penetrated into the pipes (usually after running out of diesel), it will usually be necessary to bleed the diesel filter: the top vent is unscrewed so as to let excess air escape, while diesel fuel is pumped into the fuel filter with the manual fuel lift pump (just behind the yellow dipstick). The vent can be screwed shut when diesel fuel starts to gush out of it.

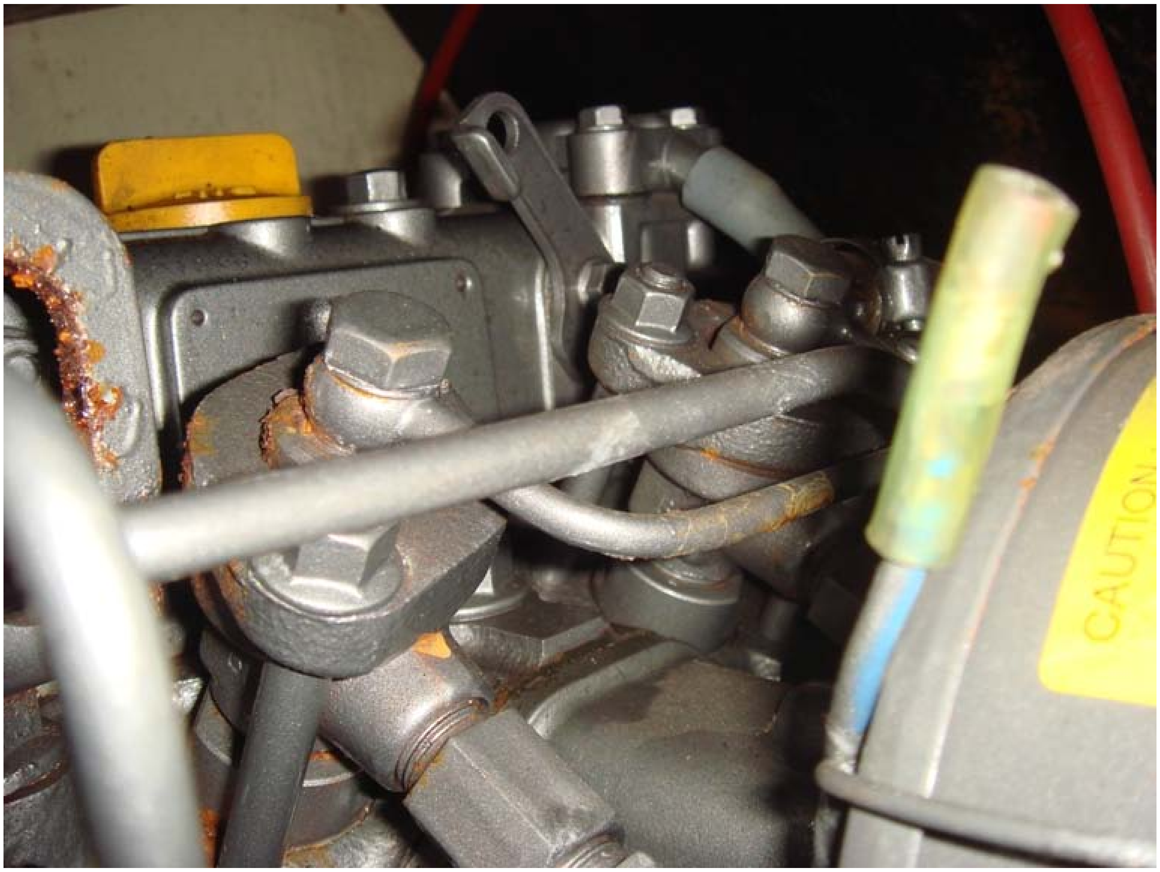
A primary fuel filter is usually installed upstream of the engine, so as to filter out the larger particles, and filter a larger quantity of water that might be present in the fuel.

Every time a filter is disassembled or changed, it will be necessary to bleed it so as to remove excess air, again by opening the top vent so as to let diesel chase all the air (diesel fills up the filter either through gravity -usually the case for the primary filter- or with the help of the fuel lift pump -usually the case for the engine fuel filter-) and diesel starts to gush out. The vent should then be screwed shut.

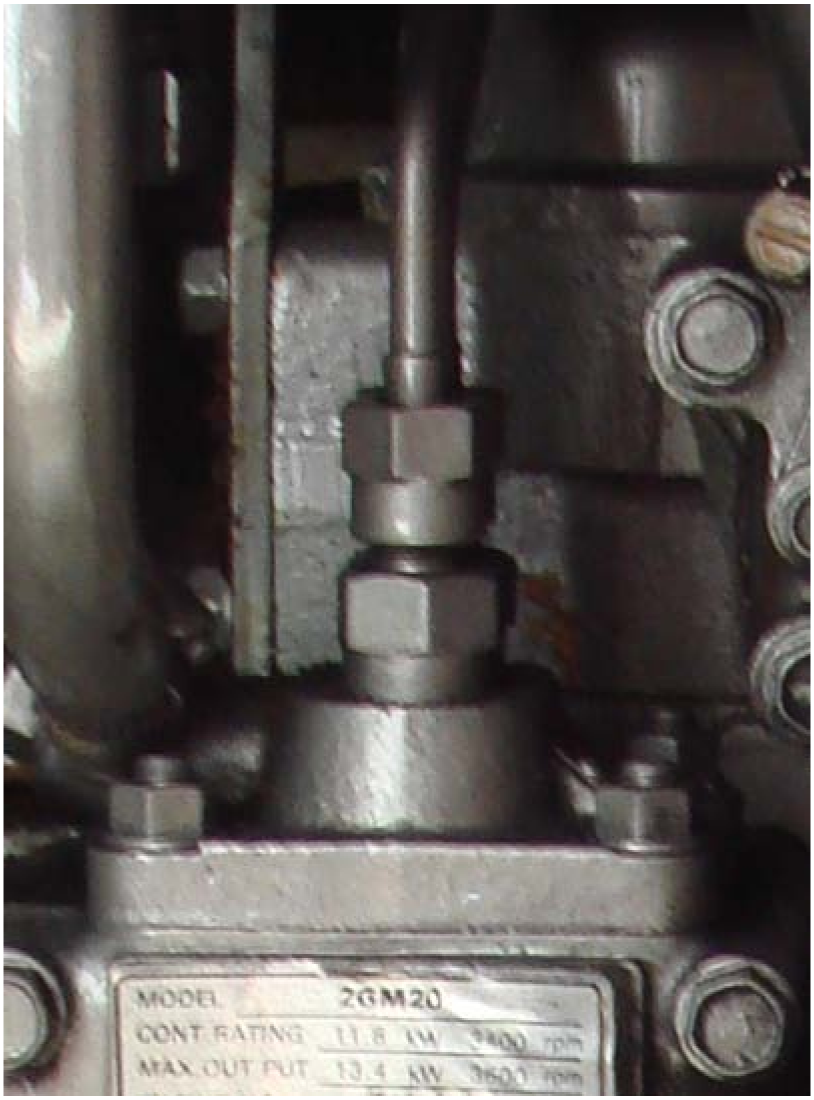
## *New models*

The 2GM20 and 3GM30 (three cylinder) series have now been superseded in the Yanmar catalog by new lightweight and modernized engines, the 2YM15, 3YM20 and 3YM30. These new engines also feature simplified maintenance of the seawater pump and other services points, as they are now located on the front part of the engine. These new engines also meet new Tier II emission standards introduced in the EU and the US in 2006.

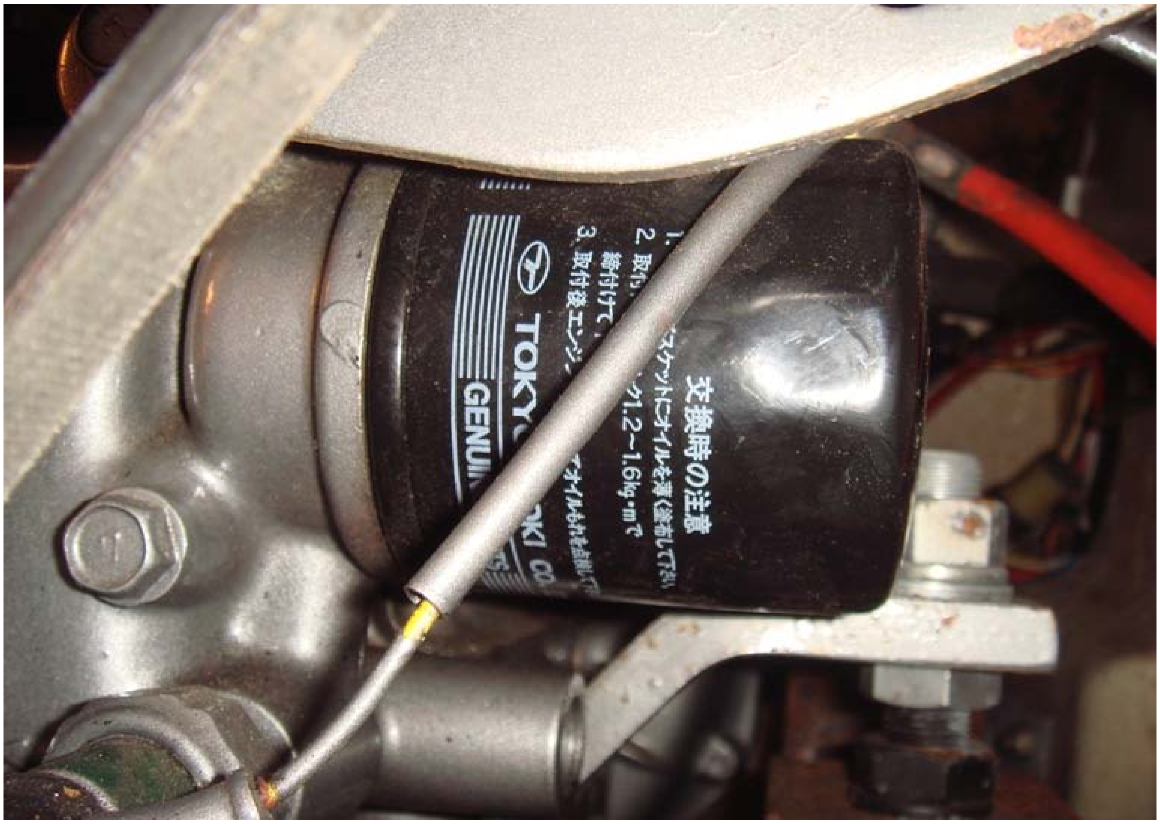
### *Parts*




Yanmar 2GM20 injectors.




Yanmar 2GM20 high pressure fuel pump.




Yanmar 2GM20 oil filter.

Yanmar 2GM20 dipstick (yellow) and fuel lift pump (top).

Yanmar 2GM20 cooling seawater cock (in closed position).

### *Versions*

- Yanmar 2GM20: Marine main engine (for export), seawater cooling, model codes: 128271 (S, N, G).
- Yanmar 2GM20-B: Marine main engine (domestic use), seawater cooling, model codes: 128271 (A, B, C).
- Yanmar 2GM20C: Saildrive engine, seawater cooling, model code: 128271 E.
- Yanmar 2GM20F: Marine main engine (for export), freshwater cooling, model codes: 128291 (S, N, G) Pdf.
- Yanmar 2GM20FC: Saildrive engine, freshwater cooling.
- Yanmar 2GM20FV: Marine main engine, freshwater cooling, equipped with compact V-drive marine gear KM3V.Pdf
- Yanmar 2GM20FVE

## Chapter- 9

# List of Volkswagen Group Diesel Engines

**List of Volkswagen Group Diesel engines**. The compression-ignition diesel engines listed below are currently used by various marques of automobiles and commercial vehicles of the German automotive concern, Volkswagen Group, and also in Volkswagen Marine and Volkswagen Industrial Motor applications. All listed engines operate on the four-stroke cycle, and unless stated otherwise, use a wet sump lubrication system, and are water cooled.

Since the Volkswagen Group is European, official internal combustion engine performance ratings are published using the International System of Units (commonly abbreviated "SI"), a modern form of the metric system of figures. Motor vehicle engines will have been tested by a Deutsches Institut für Normung (DIN) accredited testing facility, to either the original *80/1269/EEC*, or the later *1999/99/EC* standards. The standard initial measuring unit for establishing the rated motive power output is the kilowatt (kW); and in their official literature, the power rating may be published in either the kW, or the 'Pferdestärke' (PS, which is sometimes incorrectly referred to as 'metric horsepower'), or both, and may also include conversions to imperial units such as the horsepower (hp) or brake horsepower (bhp). (Conversions: one PS ≈ 735.5 watts (W), ≈ 0.98632 hp (SAE)). In case of conflict, the metric power figure of kilowatts (kW) will be stated as the primary figure of reference. For the turning force generated by the engine, the Newton metre (Nm) will be the reference figure of torque. Furthermore, in accordance with European automotive traditions, engines shall be listed in the following *ascending* order of preference:

1. Number of cylinders,
2. Engine displacement (in litres),
3. Engine configuration, and
4. Rated motive power output (in kilowatts).

As with the discontinued Volkswagen Group Diesel engines, whilst the Volkswagen Golf may have started the Diesel craze in Europe, every Diesel engine in each generation of the Volkswagen Golf has been offered in Industrial applications, and has since had impressive field results on par with a Isuzu, Kubota, or Yanmar Industrial Diesel engine in industrial applications, and has been as much of a workhorse as the latter Japanese choices.

The Diesel engines which Volkswagen Group previously manufactured and installed are in the ***list of discontinued Volkswagen Group diesel engines*** article.

## *Three and four cylinder EA111 diesels*

The **EA111** series of internal combustion engines was introduced in the mid 1970s in the Audi 50, and shortly after in the original Volkswagen Polo. It is a series of water cooled inline three- and inline four-cylinder petrol and Diesel engines, in a variety of displacement sizes. This overhead camshaft engine features a crossflow cylinder head design, and directly-driven auxiliary units. The exhaust side is in driving direction, closest to the front of the vehicle.

## *Three cylinder diesels*

### 1.2 R3 12v TDI 55kW BlueMotion

identification
: parts code prefix: ???, ID code: ???

engine configuration & engine displacement
: inline three cylinder (R3/I3) Turbocharged Direct Injection (TDI) turbodiesel; 1,199 cubic centimetres (73.2 cu in), bore x stroke: 79.5 by 80.5 millimetres (3.13 in × 3.17 in), stroke ratio: 0.99:1 - 'square engine', 399.6 cc per cylinder

cylinder block & crankcase
: ????

cylinder head & valvetrain
: cast aluminium alloy; four valves per cylinder, 12 valves total, double overhead camshaft (DOHC)

aspiration
: turbocharger, intercooler, water-cooled exhaust gas recirculation

fuel system & engine management
: common rail (CR) Diesel direct injection with 8-nozzle piezo element injectors, pressure up to 1,850 bars (26,830 psi)

DIN-rated motive power & torque output
: 55 kilowatts (75 PS; 74 bhp) @ 4,200 rpm; 180 newton metres (133 ft·lbf) @ 2,000 rpm

applications
: 2008 Volkswagen Polo Mk5 BlueMotion, forthcoming VW up!

### 1.4 R3 TDI PD 51-66kW

identification
: parts code prefix: 045

engine configuration & engine displacement

inline three cylinder (R3/I3) Turbocharged Direct Injection (TDI) turbodiesel; 1,422 cubic centimetres (86.8 cu in), bore x stroke: 79.5 by 95.5 millimetres (3.13 in × 3.76 in), stroke ratio: 0.83:1 - undersquare/long-stroke, 474.1 cc per cylinder, compression ratio: 18.0:1 to 19.5:1

cylinder block & crankcase

grey cast iron with bed-plate frame; inner and outer two-part oil sump; die-forged steel cross-plane crankshaft with 120 degree crankpins with four main bearings, simplex roller chain driven balance shaft; Mahle pistons; water:oil cooler

cylinder head & valvetrain

cast aluminium alloy, non-crossflow; two valves per cylinder, 6 valves total, each with two concentric valve springs, bucket tappets with manually adjustable rocker arms for valve clearance; timing belt-driven single overhead camshaft (SOHC)

aspiration

Bosch hot-film air mass meter, cast alloy Siemens-VDO throttle body with electronically controlled 'drive by wire' throttle butterfly valve, cast aluminium alloy intake manifold; Garrett variable turbine geometry (not all models) turbocharger incorporated in exhaust manifold, 2.3 bars (33.4 psi) absolute boost; side-mounted intercooler (SMIC)

fuel system & engine management

low pressure fuel lift pump, underfloor fuel cooler; Pumpe Düse (PD) high pressure direct injection (with three camshaft pressurised solenoid operated combustion chamber sited Unit Injectors), Bosch EDC15P+ electronic engine control unit

exhaust system

cooled exhaust gas recirculation, oxidising catalytic converter, EU4 compliance

dimensions

127 kilograms (280 lb)

DIN-rated motive power & torque outputs, ID codes

51 kilowatts (69 PS; 68 bhp) @ 4,000 rpm; 155 newton metres (114 ft·lbf) @ 1,600-2,800 rpm — (BNM:- Polo: 04/05-, Ibiza & Cordoba: 05/05-, Fabia: 10/05-, Roomster: 07/06-), (BWB:- Polo: 05/06-)

55 kilowatts (75 PS; 74 bhp) @ 4,000 rpm; 195 newton metres (144 ft·lbf) @ 2,200 rpm — (AMF:- Polo: 10/99-09/01, Arosa: 10/99-05/03, Lupo: 05/99-07/05, A2: 06/00-08/03, Ibiza & Cordoba: 05/05-12/05, Fabia: 04/03-10/05), (BAY:- Polo: 11/03-06/05) (BHC:- A2: 09/03-08/05) (discontinued)

59 kilowatts (80 PS; 79 bhp) @ 4,000 rpm; 195 newton metres (144 ft·lbf) @ 2,200 rpm — (BMS:- Polo BlueMotion: 05/06-, Ibiza & Cordoba: 06/06-, Roomster DPF: 07/06-, Fabia DPF/GreenLine: 01/07-) (BNV:- Polo: 04/05-05/08, Ibiza & Cordoba: 05/05-, Fabia: 10/05-, Roomster: 05/06-)

66 kilowatts (90 PS; 89 bhp) @ 4,000 rpm; 230 newton metres (170 ft·lbf) @ 1,900-2,300 rpm — (ATL:- Polo: 01/00-04/00, A2: 11/03-08/05) (discontinued)

applications

Audi A2, Volkswagen Polo Mk4F, Volkswagen Lupo, Volkswagen Fox (51 kW), SEAT Arosa, SEAT Ibiza, SEAT Córdoba, Škoda Fabia, Škoda Roomster

## *Four cylinder diesels*

### EA827 diesels

The following are all part of the **EA827** engine series, with a cylinder spacing between centres of 88 millimetres (3.46 in).

### 1.6 R4 16v TDI CR 55-85kW

identification

parts code prefix: ???

engine configuration & engine displacement

inline four cylinder (R4/I4) Turbocharged Direct Injection (TDI) turbodiesel; 1,598 cubic centimetres (97.5 cu in); bore x stroke: 79.5 by 80.5 millimetres (3.13 in × 3.17 in), stroke ratio: 0.99:1 - 'square engine', 399.5 cc per cylinder

cylinder block & crankcase

grey cast iron; five main bearings, die-forged steel crankshaft

cylinder head & valvetrain

cast aluminium alloy; four valves per cylinder, 16 valves total, double overhead camshaft (DOHC)

aspiration

turbocharger, intercooler, water-cooled exhaust gas recirculation (EGR)

fuel system & engine management

common rail (CR) direct injection (DI) with eight-nozzle output piezo element injectors, rail pressure up to 1,600 bars (23,210 psi), European EU5 emissions standard

DIN-rated motive power & torque outputs, ID codes

55 kilowatts (75 PS; 74 bhp) @ 4,000 rpm; 195 newton metres (144 ft·lbf) @ 1,500-2,500 rpm — CAYA (Polo only)

66 kilowatts (90 PS; 89 bhp) @ 4,200 rpm; 230 newton metres (170 ft·lbf) @ 1,500-2,500 rpm — CAYB

77 kilowatts (105 PS; 103 bhp) @ 4,400 rpm; 250 newton metres (184 ft·lbf) @ 1,500-2,500 rpm — CAYC

85 kilowatts (116 PS; 114 bhp) @ 4,400 rpm; 250 newton metres (184 ft·lbf) @ 2,000-2,500 rpm — ????

applications

SEAT Ibiza Mk4, SEAT Ibiza Mk5, SEAT León Mk2, SEAT Altea, SEAT Altea XL, Škoda Octavia Mk2, Volkswagen Polo Mk5, Volkswagen Golf Mk6, Volkswagen Golf Plus, Volkswagen Golf Variant, Audi A1

### 1.9 R4 D 44-50kW

identification

parts code prefix: 028

engine configuration & engine displacement

inline-four engine (R4/I4); 1,896 cubic centimetres (115.7 cu in), bore x stroke: 79.5 by 95.5 millimetres (3.13 in × 3.76 in), stroke ratio: 0.83:1 - undersquare/long-stroke, 474.1 cc per cylinder, compression ratio: 22.0:1 - 22.5:1

cylinder block & crankcase
    grey cast iron; five main bearings, die-forged steel crankshaft
cylinder head & valvetrain
    cast aluminium alloy; two valves per cylinder, 8 valves total, timing belt-driven single overhead camshaft (SOHC)
aspiration
    cast aluminium alloy intake manifold, cast iron exhaust manifold
fuel system
    timing belt-driven Lucas AEF mechanical distributor injection pump, indirect fuel injection into whirl chamber
EWG-rated motive power & torque output, ID codes, application
    44 kilowatts (60 PS; 59 bhp) — **ARD**: Volkswagen Industrial Motor (01/02->)
    48 kilowatts (65 PS; 64 bhp) — **28B, ADG**: Volkswagen Industrial Motor (28B: 01/90-03/94, ADG: 04/94->)
DIN-rated motive power & torque output, ID codes
    47 kilowatts (64 PS; 63 bhp) @ 4,300 rpm; 124 N·m (91 ft·lbf) @ 2,500-3,200 rpm — **1Y, AEF** (discontinued)
    50 kilowatts (68 PS; 67 bhp) @ 4,400 rpm; 127 N·m (94 ft·lbf) @ 2,200-2,600 rpm — **1Y** (discontinued)
applications
    Audi 80 (1Y: 08/89-12/91), SEAT Ibiza Mk2 (1Y: 02/93-06/99), SEAT Cordoba (1Y: 09/93-06/99), SEAT Toledo (1Y: 05/91-03/99), SEAT Inca (1Y: 11/95-06/03), Škoda Felicia (AEF: 10/95-08/01), Volkswagen Golf, Volkswagen Passat B3 (1Y: 05/89-09/93), Volkswagen Polo 6N (1994–2001).

### 1.9 R4 SD 36kW

This is a naturally aspirated (non-turbo) indirect injection version of the 1.9 SDI VP37

identification
    parts code prefix: 028, ID code: 436
engine configuration & engine displacement
    inline-four engine (R4/I4); 1,896 cubic centimetres (115.7 cu in); bore x stroke: 79.5 by 95.5 millimetres (3.13 in × 3.76 in), stroke ratio: 0.83:1 - undersquare/long-stroke, 474.1 cc per cylinder, compression ratio: 23.0:1
cylinder block & crankcase
    grey cast iron; five main bearings, die-forged steel crankshaft
cylinder head & valvetrain
    cast aluminium alloy; two valves per cylinder, 8 valves total, bucket tappets, single overhead camshaft (SOHC)
aspiration
    cast aluminium alloy intake manifold, cast iron exhaust manifold
fuel system & engine management
    Bosch VP (VerteilerPumpe) distributor injection pump, indirect injection into swirl pre-chambers
EWG-rated motive power & torque output

36 kilowatts (49 PS; 48 bhp) @ 3,000 rpm; 121 newton metres (89 ft·lbf) @ 1,800 rpm

application

Volkswagen Industrial Motor

### 1.9 R4 SDI 29-50kW

This is a naturally aspirated (non-turbo) Suction Diesel Injection version of the 1.9 TDI VP37

identification

parts code prefix: ???; ID codes: AEY, AGD, AGP, ASX, ASY, AYQ

engine configuration & engine displacement

inline four cylinder (R4/I4) Suction Diesel Injection (SDI); 1,896 cubic centimetres (115.7 cu in); bore x stroke: 79.5 by 95.5 millimetres (3.13 in × 3.76 in), stroke ratio: 0.83:1 - undersquare/long-stroke, 474.1 cc per cylinder, compression ratio: 19.5:1 - 22.0:1 (44 kW - 19.5:1)

cylinder block & crankcase

grey cast iron; five main bearings, die-forged steel crankshaft

cylinder head & valvetrain

cast aluminium alloy; two valves per cylinder, 8 valves total, bucket tappets, single overhead camshaft (SOHC)

aspiration

cast aluminium alloy intake manifold, cast iron exhaust manifold

fuel system & engine management

Bosch VP37 (VerteilerPumpe) electronic distributor injection pump, direct injection (DI) with five-hole nozzles, Bosch EDC 15V+ electronic engine control unit (ECU)

dimensions

mass: 198 kilograms (437 lb) (dry weight, Marine variants)

EWG-rated motive power & torque outputs, ID codes, application

30 kilowatts (41 PS; 40 bhp) — **BXT** Volkswagen Industrial Motor 430 (05/06->)

44 kilowatts (60 PS; 59 bhp) @ 3,600 rpm; 130 newton metres (96 ft·lbf) @ 2,200 rpm — **AEY** Volkswagen Industrial Motor 444

DIN-rated motive power & torque outputs, ID codes, applications

29 kilowatts (39 PS; 39 bhp) @ 2,600 rpm; 125 newton metres (92 ft·lbf) @ 2,000 rpm — **BGM** Volkswagen Marine 40-4 (02/03->)

33 kilowatts (45 PS; 44 bhp) — **BEQ** Volkswagen Marine (02/02->)

37 kilowatts (50 PS; 50 bhp) @ 3,000 rpm; 125 newton metres (92 ft·lbf) @ 2,000 rpm — **BGL** Volkswagen Marine 50-4 (02/03->)

44 kilowatts (60 PS; 59 bhp) @ 3,600 rpm; 125 newton metres (92 ft·lbf) @ 2,000 rpm — **ANC** Volkswagen Marine 60-4 (02/03->)

47 kilowatts (64 PS; 63 bhp) @ 4,200 rpm; 125 newton metres (92 ft·lbf) @ 1,600-2,800 rpm — **???**

50 kilowatts (68 PS; 67 bhp) @ 4,000 rpm; 133 newton metres (98 ft·lbf) @ 1,800 rpm — **AQM**

applications

VW Polo 6N/6KV (AEY: 12/95-08/99), VW Golf Mk3 & VW Golf Mk4 (AEY: 07/95-02/99), VW Vento (AEY: 07/95-12/97), VW Caddy Mk2 (AEY: 11/95-09/00), Škoda Fabia, SEAT Ibiza Mk2/SEAT Cordoba 6K (AEY: 09/95-06/99), SEAT León Mk1 (1M) (AQM: 06/00-10/03), SEAT Inca (AEY: 11/95-09/00)

## 1.9 R4 TDI 29-81kW

identification

parts code prefix: 038, 064 (Volkswagen Marine)

engine configuration & engine displacement

inline four cylinder (R4/I4) Turbocharged Direct Injection (TDI) turbodiesel; 1,896 cubic centimetres (115.7 cu in); bore x stroke: 79.5 by 95.5 millimetres (3.13 in × 3.76 in), stroke ratio: 0.83:1 - undersquare/long-stroke, 474.1 cc per cylinder, compression ratio: 19.5:1

cylinder block & crankcase

grey cast iron; five main bearings, die-forged steel crankshaft, fracture-split forged steel connecting rods, Mahle or Alcan pistons, simplex roller chain-driven oil pump, cast aluminium alloy baffled oil sump

cylinder head & valvetrain

cast aluminium alloy; two valves per cylinder, 8 valves total, bucket tappets, timing belt-driven single overhead camshaft (SOHC)

aspiration

hot-wire mass air flow (MAF) sensor, cast aluminium alloy intake manifold, Garrett or KKK turbocharger, side-mounted intercooler (SMIC), exhaust gas recirculation (EGR), cast iron exhaust manifold

fuel system & engine management

timing belt-driven Bosch VP37 (VerteilerPumpe) electronic distributor injection pump, direct injection (DI) with five-hole nozzles, Bosch EDC 15V+ electronic engine control unit (Marine variant uses MDC)

dimensions

mass: 200 kilograms (441 lb) (Marine variants, dry weight)

EWG-rated motive power & torque output, ID code, application

60 kilowatts (82 PS; 80 bhp) — **AFD**: Volkswagen Industrial Motor - 480 (04/94-01/02)

DIN-rated motive power & torque outputs, ID codes

29 kilowatts (39 PS; 39 bhp) — **CDX** Volkswagen Marine (10/07->)

55 kilowatts (75 PS; 74 bhp) @ 3,600 rpm; 155 newton metres (114 ft·lbf) @ 2,000 rpm — **CDX** Volkswagen Marine (10/07->)

66 kilowatts (90 PS; 89 bhp) @ 4,000 rpm; 202 newton metres (149 ft·lbf) @ 1,900 rpm — **1Z, AHU**

66 kilowatts (90 PS; 89 bhp) @ 3,750 rpm; 210 newton metres (155 ft·lbf) @ 1,900 rpm — **AGR, AHH, ALE, ALH**

81 kilowatts (110 PS; 109 bhp) @ 4,150 rpm; 235 newton metres (173 ft·lbf) @ 1,900 rpm — **AFN, AHF, ASV, AVG**

applications

Audi 8L A3 (Mk1) (AHU: 09/96-08/00, AHF: 01/97-04/02, ALH: 08/97-06/01, ASV: 09/99-06/01), Audi B4 80 (1Z: 09/91-07/95), Audi Cabriolet (1Z: 07/95-07/96, AHU: 07/96-08/00), Audi B5 A4 (1Z: 01/95-07/96, AFN: 02/96-07/99, AHU: 08/96-06/00, AHH: 04/97-09/01, AVG: 08/99-06/00), Audi C4 A6 (1Z: 07/94-06/96, AHU: 07/96-10/97), Audi C5 A6 (AFN: 04/97-04/01, AVG: 08/99-10/00)

Ford Galaxy Mk1

SEAT Ibiza Mk2 (1Z: 07/96-12/96, AHU: 12/96-06/99, AFN: 03/97-06/99, ASV: 03/99-05/02, AGR: 04/99-05/02, ALH: 10/99-05/02), SEAT Córdoba Mk1 (1Z: 07/96-12/96, AHU: 12/96-06/99, AFN: 03/97-06/99, ASV: 03/99-08/02, AGR: 04/99-08/02, ALH: 10/99-05/01), SEAT León 1M (Mk1) (ASV: 10/99-10/05, AGR/AHF: 11/99-09/02, ALH: 05/00-10/05), SEAT Toledo Mк1-Mk2 (1Z: 04/95-12/96, AHU: 06/96-03/99, AFN: 12/96-03/99, ALH: 03/99-07/04, AGR: 04/99-09/02, AHF: 10/98-09/02, ASV: 10/99-07/04), SEAT Alhambra (1Z: 03/96-07/96, AHU: 07/96-02/00, AFN/AVG: 09/97-02/00)

Škoda Octavia 1U (Mk1) (AGR: 10/96->, AHF: 08/97->, ALH/ASV: 08/00->)

Volkswagen Polo Mk3 Classic / Variant (AHU: 01/97-08/99, ALE: 11/97-08/99, AFN: 06/98-08/99, AGR/ALH/ASV: 10/99-09/01), Volkswagen Golf Mk3 (1Z: 07/93-07/96, AFN: 02/96-08/99, AHU: 07/96-06/00), VW Vento/Jetta Mk3 (1Z: 07/93-07/96, AFN: 02/96-12/97, ALE: 01/97-12/97, AHU: 08/96->), Volkswagen Golf Mk4 (ALE: 05/96-12/01, AHF: 10/97-05/06, AGR/ALH: 10/97->, ASV: 05/00-05/06), VW Bora/Jetta Mk4 (AHF/ALH: 09/98-05/05, AGR: 10/98-05/05, ALH: 11/98->, ASV: 05/00-05/05), Volkswagen New Beetle (ALH: 01/98-06/04), VW Passat B4 (1Z: 10/93-12/96), VW Passat B5 (AFN: 03/96-08/99, AHU: 08/96-08/00, AHH: 05/98-08/00), Volkswagen Sharan (1Z: 09/95-07/96, AHU: 08/96-10/00, AFN: 12/96-07/99), Volkswagen Caddy (1Z: 10/96-03/97, AHU: 10/96-09/00, ALE: 09/97-09/00, ALH: 09/00-06/03)

## 1.9 R4 TDI PD 43-118kW

This ubiquitous engine shares a fundamentally identical bottom end (cylinder block/crankcase, crankshaft) to the earlier 1.9 R4 TDI with its VP37 VerteilerPumpe distributor injection pump. However, an all-new cylinder head is fitted to this "PD" engine, to specifically accommodate its "Pumpe Düse" Unit Injectors.

identification

parts code prefix: 038, 03G

engine configuration & engine displacement

inline four cylinder (R4/I4) Turbocharged Direct Injection (TDI) turbodiesel; 1,896 cubic centimetres (115.7 cu in); bore x stroke: 79.5 by 95.5 millimetres (3.13 in × 3.76 in), stroke ratio: 0.83:1 - undersquare/long-stroke, 474.1 cc per cylinder, compression ratio: 19.0:1

cylinder block & crankcase

grey cast iron; five main bearings, die-forged steel crankshaft, fracture-split forged steel connecting rods, Mahle or Alcan pistons, simplex roller chain-driven oil pump, cast aluminium alloy baffled oil sump cylinder head & valvetrain

cast aluminium alloy; two valves per cylinder, 8 valves total, bucket tappets, timing belt-driven single overhead camshaft (SOHC)

aspiration

hot-wire mass air flow (MAF) sensor, cast aluminium alloy intake manifold, Garrett, KKK or BorgWarner variable turbine geometry turbocharger (VGT), side-mounted intercooler (SMIC), water-cooled exhaust gas recirculation (EGR), cast iron exhaust manifold

fuel system & engine management

Pumpe Düse (PD) direct injection (DI): engine-driven vane-type low pressure fuel lift pump, four camshaft-actuated (via roller rocker arms) high pressure Bosch 1,920 bars (27,850 psi) Unit Injectors with solenoid valve injection nozzles, Bosch EDC 16 or EDC 17 electronic engine control unit (ECU) with altitude compensation

EWG-rated motive power & torque outputs, ID codes, applications

43 kilowatts (58 PS; 58 bhp) — **BEU**: Volkswagen Industrial Motor (11/02->)

53 kilowatts (72 PS; 71 bhp) — **BJC**: Volkswagen Industrial Motor (11/03->)

63 kilowatts (86 PS; 84 bhp) — **AVM**: Volkswagen Industrial Motor (11/00->)

DIN-rated motive power & torque outputs, ID codes, applications

55 kilowatts (75 PS; 74 bhp) @ 4,000 rpm; 210 newton metres (155 ft·lbf) @ 1,900 rpm — **BSU**

Volkswagen Caddy Mk3 (09/05->)

66 kilowatts (90 PS; 89 bhp) @ 4,000 rpm; 210 newton metres (155 ft·lbf) @ 1,800−2,500 rpm — **BRU, BXF, BXJ**

SEAT Ibiza Mk2 (BXJ: 06/08->), SEAT León 1P (Mk2) (BXF: 06/07->), SEAT Altea (BXF: 08/09->), Volkswagen Golf Mk5 (BRU: 05/04-02/06, BXF: 02/06-11/08, BXJ: 11/07-11/08), VW Golf Plus (BXF: 05/07-12/08, BXJ: 11/07-12/08), Volkswagen Touran (BRU: 11/04-02/06, BXF: 02/06->, BXJ: 06/06->)

66 kilowatts (90 PS; 89 bhp) @ 4,000 rpm; 240 newton metres (177 ft·lbf) @ 1,900 rpm — **ANU**

Ford Galaxy, SEAT Alhambra (06/00->), Volkswagen Sharan (03/99->)

74 kilowatts (101 PS; 99 bhp) @ 4,000 rpm; 240 newton metres (177 ft·lbf) @ 1,800–2,400 rpm — **ATD, AXR, BEW, BMT**

Audi 8L A3 (Mk1) (ATD: 01/01-06/03, AXR: 11/01-06/03), SEAT Ibiza Mk3 (ATD: 09/01->, AXR: 05/05-11/09, BMT: 09/06-11/09), SEAT Córdoba Mk2 (ATD: 09/02->, AXR: 05/05->, BMT: 06/06-11/09), SEAT León 1M (Mk1) (AXR: 10/05-06/06), Škoda Fabia 6Y (Mk1) (ATD: 01/00-10/05, AXR: 10/05-12/07), Škoda Roomster (AXR: 03/06-05/06), Škoda Octavia 1U (Mk1) (ATD: 08/00-01/06, AXR: 10/05->), Volkswagen Polo Mk4 (ATD/AXR: 11/01->, BMT: 05/06->), Volkswagen Golf Mk4 (ATD: 02/00-06/06, AXR: 05/01-06/06), VW Bora/Jetta Mk4 (ATD: 05/00-05/06, AXR: 05/01->, BEW: 07/03->), Volkswagen Golf Mk5 (BEW: 08/03->), VW Jetta Mk5 (AXR: 06/07->), Volkswagen New Beetle (ATD: 10/00->, AXR: 06/03->, BEW: 07/03->)

74 kilowatts (101 PS; 99 bhp) @ 4,000 rpm; 250 newton metres (184 ft·lbf) @ 1,900 rpm — **AVB, AVQ**

Audi B6 A4 (AVB: 04/01-05/04), Škoda Superb 3U (Mk1) (AVB: 06/02-10/05), Volkswagen Touran (AVQ: 02/03-05/04), VW Passat B5 (AVB: 02/00-05/05)

77 kilowatts (105 PS; 103 bhp) @ 4,000 rpm; 240 newton metres (177 ft·lbf) @ 1,800 rpm — **BSW**

Škoda Fabia 5J (Mk2) (04/07->), Škoda Roomster (05/06->), Volkswagen New Beetle (07/03->)

77 kilowatts (105 PS; 103 bhp) @ 4,000 rpm; 250 newton metres (184 ft·lbf) @ 1,900 rpm — **BJB, BKC, BLS, BSV, BXE**

Audi 8P A3 (Mk2) (BKC: 06/03-05/06, BLS: 10/05-05/10, BXE: 06/06-05/10), SEAT Ibiza 6J (Mk4) (BLS: 02/08->), SEAT León 1P (Mk2) (BKC: 07/05-02/06, BLS: 11/05->, BXE: 02/06->), SEAT Altea (BJB: 04/04-09/05, BKC: 04/04-05/06, BLS: 10/05->, BXE: 02/06->), SEAT Toledo Mk3 (BJB: 09/04-09/05, BKC: 09/04-02/06, BLS: 10/05-09/09, BXE: 02/06->), Škoda Fabia 5J (Mk2) (BLS: 04/07->), Škoda Roomster (BLS: 11/06->), Škoda Octavia 1Z (Mk2) (BJB: 02/04->, BKC: 05/04-02/06, BXE: 03/06->, BLS: 05/06->), Škoda Superb 3U (Mk1) (BSV: 10/05-05/07, BLS/BXE: 03/08->), VW Vento (BKC: 11/05-02/06, BXE: 03/06->), VW Bora (BXE: 04/06->), Volkswagen Golf Mk5 (BKC: 10/03-07/07, BLS: 06/05->, BXE: 05/07->), VW Jetta Mk5 (BKC: 05/05->, BLS: 08/05->, BXE: 02/06->), VW Golf Plus (BLS: 05/07-12/08, BXE: 05/07-01/09), Volkswagen Touran (BKC: 08/03-02/06, BLS: 06/05->, BXE: 02/06->), VW Passat B6 (BKC: 03/05-02/06, BLS: 06/05-11/08, BXE: 02/06-11/08), Volkswagen Caddy Mk3 (BJB: 02/04->, BLS: 06/05->)

85 kilowatts (116 PS; 114 bhp) @ 4,000 rpm; 250 newton metres (184 ft·lbf) @ 1,900 rpm — **BPZ**

Škoda Superb 3U (Mk1) (01/07-03/08), VW Passat B6 (04/08->)

85 kilowatts (116 PS; 114 bhp) @ 4,000 rpm; 285 newton metres (210 ft·lbf) @ 1,900 rpm — **AJM**

Audi B5 A4) (08/98-09/01), Audi C5 A6 (01/98-04/01), Volkswagen Golf Mk4 (05/99-04/02), VW Bora/Jetta Mk4 (11/98-07/01), VW Passat B5 (01/99-12/99)

85 kilowatts (116 PS; 114 bhp) @ 4,000 rpm; 310 newton metres (229 ft·lbf) @ 1,900 rpm — **ATJ, AUY, BVK**

Audi B5 A4 (ATJ: 01/00-09/01), Ford Galaxy Mk1, SEAT Alhambra (AUY: 06/00->, BVK: 11/05-05/08), Volkswagen Golf Mk4 (AUY: 01/00-07/01), VW Bora/Jetta Mk4 (AUY: 05/00-07/01), VW Passat B5 (ATJ: 01/00-08/00), Volkswagen Sharan (AUY: 04/00->, BVK: 11/05->)

96 kilowatts (131 PS; 129 bhp) @ 4,000 rpm; 285 newton metres (210 ft·lbf) @ 1,750–2,500 rpm — **AWX**

Audi B6 A4 (12/00-06/03), Audi C5 A6 (06/01-01/05), Škoda Superb 3U (Mk1) (12/01-03/08), VW Passat B5 (10/00-05/05)

96 kilowatts (131 PS; 129 bhp) @ 4,000 rpm; 310 newton metres (229 ft·lbf) @ 1,900 rpm — **ASZ, AVF, BLT**

Audi 8L A3 (Mk1) (ASZ: 05/00-06/03), Audi B6 A4 (AVF: 11/00-12/04), Audi C5 A6 (AVF: 06/01-01/05), Ford Galaxy Mk1, SEAT Ibiza Mk3 (ASZ: 11/01->, BLT: 05/05-07/09), SEAT Córdoba Mk2 (ASZ: 10/02->, BLT: 05/05->), SEAT León Mk1 (1M) (ASZ: 05/03-06/06), SEAT Toledo Mk2 (ASZ: 05/03-06/06), SEAT Alhambra (ASZ: 11/02->), Škoda Fabia Mk1 (6Y) (ASZ: 06/03-10/05, BLT: 10/05-04/07), Škoda Octavia 1U (Mk1) (ASZ: 09/02-09/04), Škoda Superb 3U (Mk1) (AVF: 01/04-03/08), Volkswagen Polo Mk4 (ASZ: 11/03->, BLT: 05/04->), Volkswagen Golf Mk4 (ASZ: 04/01-05/06), VW Bora/Jetta Mk4 (ASZ: 04/01-05/05), VW Passat B5 (AVF: 10/00-05/05), Volkswagen Sharan (ASZ: 11/02->)

110 kilowatts (150 PS; 148 bhp) @ 4,000 rpm; 320 newton metres (236 ft·lbf) @ 1,900 rpm — **ARL, BTB**

Ford Galaxy Mk1, SEAT León Mk1 (1M) (ARL: 09/00-12/05), SEAT Toledo Mk2 (ARL: 10/00-07/04), SEAT Alhambra (BTB: 06/05-05/07), Volkswagen Golf Mk4 (ARL: 09/00-05/06), VW Bora/Jetta Mk4 (ARL: 09/00-05/05), Volkswagen Sharan (BTB: 01/05-05/07)

118 kilowatts (160 PS; 158 bhp) @ 3,750 rpm; 330 newton metres (243 ft·lbf) @ 1,900 rpm — **BPX, BUK**

SEAT Ibiza Mk3 (BPX: 03/04->, BUK: 11/05-12/08) (engine exclusively developed by Audi for SEAT Sport)

## 2.0 R4 SDI PD 51-55kW

identification

parts code prefix: ???

engine configuration & engine displacement

inline four cylinder (R4/I4) Suction Diesel Injection (SDI); 1,968 cubic centimetres (120.1 cu in), bore x stroke: 81.0 by 95.5 millimetres (3.19 in × 3.76 in), stroke ratio: 0.85:1 - undersquare/long stroke, 492.1 cc per cylinder, compression ratio: 19.0:1

cylinder block & crankcase

grey cast iron; five main bearings, die-forged steel crankshaft

cylinder head & valvetrain

cast aluminium alloy; two valves per cylinder, 8 valves total, timing belt driven single overhead camshaft (SOHC)

fuel system & engine management

Pumpe Düse (PD) Unit Injector direct injection (DI)

DIN-rated motive power & torque outputs, ID codes

51 kilowatts (69 PS; 68 bhp) @ 4,200 rpm; 140 newton metres (103 ft·lbf) @ 2,200–2,400 rpm — Volkswagen Caddy Mk3: BDJ, BST

55 kilowatts (75 PS; 74 bhp) @ 4,200 rpm; 140 newton metres (103 ft·lbf) @ 2,200–2,400 rpm — Volkswagen Golf Mk5: BDK

## 2.0 R4 TDI PD 47-103kW

identification

parts code prefix: ???

engine configuration & engine displacement

inline four cylinder (R4/I4) Turbocharged Direct Injection (TDI) turbodiesel; 1,968 cubic centimetres (120.1 cu in); bore x stroke: 81.0 by 95.5 millimetres (3.19 in × 3.76 in), stroke ratio: 0.85:1 - undersquare/long-stroke, 492.1 cc per cylinder; compression ratio: 18.5:1

cylinder block & crankcase

grey cast iron; five main bearings, die-forged steel crankshaft, fracture-split forged steel connecting rods

cylinder head & valvetrain

cast aluminium alloy; two valves per cylinder, 8 valves total, timing belt driven single overhead camshaft (SOHC)

aspiration

turbocharger, intercooler

fuel system & engine management

Pumpe Düse (PD) direct injection (DI): engine-driven vane-type low pressure fuel lift pump, four camshaft-actuated (via roller rocker arms) high pressure Bosch 2,200–2,400 bars (31,910–34,810 psi) Unit Injectors with solenoid valve injection nozzles, Bosch EDC 16 or EDC 17 or Siemens VDO SIMOS PPD1 electronic engine control unit (ECU) with altitude compensation, EU4 compliant

exhaust system

diesel particulate filter (DPF) (not on Industrial variants)

EWG-rated motive power & torque outputs, ID codes, applications

47 kilowatts (64 PS; 63 bhp) @ 3,000 rpm; 200 newton metres (148 ft·lbf) @ 1,750 rpm — Volkswagen Industrial Motor - 447 (CBH: 05/07->)

55 kilowatts (75 PS; 74 bhp) — Volkswagen Industrial Motor - 455 (CBJ: 05/07->)

63 kilowatts (86 PS; 84 bhp) @ 3,000 rpm; 250 newton metres (184 ft·lbf) @ 1,750 rpm — Volkswagen Industrial Motor - 463

74 kilowatts (101 PS; 99 bhp) @ 3,000 rpm; 285 newton metres (210 ft·lbf) @ 1,750 rpm — Volkswagen Industrial Motor - 474 (CBK: 01/07->)

DIN-rated motive power & torque outputs, ID codes

100 kilowatts (136 PS; 134 bhp) @ 4,000 rpm; 310 newton metres (229 ft·lbf) @ 1,750-2,500 rpm — ???

103 kilowatts (140 PS; 138 bhp) @ 4,000 rpm; 320 newton metres (236 ft·lbf) @ 1,800 rpm — ???

applications

Volkswagen Golf Mk5, VW Jetta Mk5, Volkswagen Touran, Volkswagen Tiguan, VW Passat B6, Audi 8P A3, Audi B7 A4, Audi B8 A4, Audi C6 A6, SEAT Leon, SEAT Altea and XL, SEAT Toledo, Škoda Octavia, Volkswagen Industrial Motor, Chrysler Sebring, Chrysler Sebring (convertible), Dodge Avenger, Dodge Caliber, Jeep Compass, Mitsubishi Lancer, Mitsubishi Grandis, Mitsubishi Outlander

### 2.0 R4 16v TDI PD 103-125kW

This Pumpe Düse (PD) TDI engine was introduced to replace the older higher-powered versions of the 1.9 TDI. It is the first four-cylinder 16-valve double overhead camshaft (DOHC) Turbocharged Direct Injection (TDI) engine made by Volkswagen Group.

identification

parts code prefix: 038

engine configuration & engine displacement

inline four cylinder (R4/I4) Turbocharged Direct Injection (TDI) turbodiesel; 1,968 cubic centimetres (120.1 cu in); bore x stroke: 81.0 by 95.5 millimetres (3.19 in × 3.76 in), stroke ratio: 0.85:1 - undersquare/long-stroke, 492.1 cc per cylinder; compression ratio: 18.5:1

cylinder block & crankcase

grey cast iron; five main bearings, die-forged steel crankshaft, fracture-split forged steel connecting rods, cast aluminium alloy oil sump

cylinder head & valvetrain

cast aluminium alloy; four valves per cylinder, 16 valves total, timing belt-driven double overhead camshaft (DOHC)

aspiration

hot-film air mass meter, Garrett turbocharger integrated into cast iron exhaust manifold, sandwiched central front-mounted intercooler (FMIC)

fuel system & engine management

Pumpe Düse (PD) direct injection (DI): engine-driven vane-type low pressure fuel lift pump, four camshaft-actuated (via roller rocker arms) high pressure Bosch 2,200–2,400 bars (31,910–34,810 psi) Unit Injectors with piezo valve injection nozzles, Bosch EDC 16 or EDC 17 or Siemens VDO SIMOS PPD1 electronic engine control unit (ECU) with altitude compensation, EU4 compliant

exhaust system

water-cooled exhaust gas recirculation (EGR), diesel particulate filter (DPF)

DIN-rated motive power & torque outputs, ID codes

103 kilowatts (140 PS; 138 bhp) — **BKD**, **BKP**

125 kilowatts (170 PS; 168 bhp) @ 4,200 rpm; 350 newton metres (258 ft·lbf) @ 1,800-2,500 rpm — **BMN**

applications

Audi 8P A3, Audi B7 A4, Audi B8 A4, Audi C6 A6, SEAT León Mk2, Škoda Octavia (BKD: 11/08->), Škoda Superb (BKD: 01/09->), Volkswagen Golf Mk5, Volkswagen Golf Mk6, VW Jetta Mk5, Volkswagen Touran, VW Passat B6

## 2.0 R4 16v TDI CR 81-132kW

identification

parts code prefix: 03L, ID codes: CAGA, CAGC, CAHA, CBAA, CBAB, CBBB, CBDB, CBDC, CEGA, CFCA, CJAA

engine configuration & engine displacement

inline four cylinder (R4/I4) Turbocharged Direct Injection (TDI) turbodiesel; 1,968 cubic centimetres (120.1 cu in); bore x stroke: 81.0 by 95.5 millimetres (3.19 in × 3.76 in), stroke ratio: 0.85:1 - undersquare/long-stroke, 492.1 cc per cylinder, compression ratio: 18:1 (103 kW), 16.5:1 (125 kW)

cylinder block & crankcase

grey cast iron; five main bearings, die-forged steel crankshaft, fracture-split forged steel connecting rods, two counter-rotating gear-driven balance shafts turning at half crankshaft speed, Alcan or Federal-Mogul pistons, cast aluminium alloy oil sump

cylinder head & valvetrain

cast aluminium alloy; four valves per cylinder, 16 valves total, low-friction roller finger cam followers with automatic hydraulic valve clearance compensation, timing belt and gear-driven (relay method: belt drives exhaust camshaft from front of engine, inlet camshaft is driven at rear of engine by gear from exhaust camshaft) double overhead camshaft (DOHC)

aspiration

hot-film air mass meter, electronically regulated variable geometry turbocharger integrated into cast iron exhaust manifold, central front-mounted intercooler (FMIC)

aspiration (147 kW)

twin registered turbochargers with different diameters

fuel system & engine management

low-pressure fuel tank mounted fuel lift pump with underfloor electric fuel relay pump, timing belt-driven high pressure injection pump delivering up to 1,850-bar (26,830 psi) pressure for the common rail (CR) fuel rail, direct injection (DI) with eight-nozzle output piezo fuel injectors; Bosch EDC 17 electronic engine control unit (ECU)

exhaust system

water-cooled exhaust gas recirculation (EGR), catalytic converter, diesel particulate filter (DPF)

DIN-rated motive power & torque outputs, ID codes, applications

81 kilowatts (110 PS; 109 bhp) @ 4,200 rpm; 250 newton metres (184 ft·lbf) @ 1,500–2,500 rpm — CBDC

88 kilowatts (120 PS; 118 bhp) @ 4,000 rpm; 290 newton metres (214 ft·lbf) @ 1,750-2,500 rpm — CAGC SEAT Exeo (09/09->)

103 kilowatts (140 PS; 138 bhp) @ 3,750-4,150 rpm; 320 newton metres (236 ft·lbf) @ 1,750-2,800 rpm — CBAA, CBAB, CBDB, CJAA

105 kilowatts (143 PS; 141 bhp) @ 4,200 rpm; 320 newton metres (236 ft·lbf) @ 1,750-2,500 rpm — Audi B8 A4, Audi Q5, SEAT Exeo (CAGA: 12/08->)

125 kilowatts (170 PS; 168 bhp) @ 4,200 rpm; 350 newton metres (258 ft·lbf) @ 1,750-2,500 rpm — CBBB Audi TT 2.0 TDI quattro, Audi 8P A3; CEGA; SEAT Exeo (CAHA: 02/09->)

132 kilowatts (179 PS; 177 bhp) @ 4,000 rpm; 400 newton metres (295 ft·lbf) @ 1,500-2,000 rpm — CFCA Volkswagen Transporter (T5) GP biturbo

applications

Audi TT Mk2 2.0 TDI quattro (CBBB: 06/08-05/10), Audi 8P A3 (CBBB: 07/08->), Audi B8 A4, Audi Q5, SEAT Leon Mk2 (1P), SEAT Altea, SEAT Toledo Mk3 (5P), SEAT Exeo, Škoda Octavia Mk2 (1Z) (125 kW), Škoda Superb Mk2 (3T) (125 kW), Škoda Yeti (81/103/125 kW), Volkswagen Golf Mk6, VW Jetta Mk5 TDI CleanDiesel (103 kW), Volkswagen Tiguan, Volkswagen Passat CC, Volkswagen Transporter (T5)

## *Five cylinder diesels*

### 2.5 R5 SDI 40-55kW

identification

parts code prefix: ???

engine configuration & engine displacement

inline five cylinder (R5) Suction Diesel Injection (SDI); 2,461 cubic centimetres (150.2 cu in); bore x stroke: 81.0 by 95.5 millimetres (3.19 in × 3.76 in), stroke ratio: 0.85:1 - undersquare/long-stroke, 492.1 cc per cylinder, compression ratio: 19.0:1

cylinder block & crankcase

grey cast iron; six main bearings, die-forged steel crossplane crankshaft, 'bowl in piston' combustion chamber

cylinder head & valvetrain

cast aluminium alloy; two valves per cylinder, 10 valves total, hydraulic bucket tappets with automatic valve clearance compensation, timing belt-driven single overhead camshaft (SOHC), swirl-inducing intake ports

aspiration

cast aluminium alloy intake manifold, cast iron exhaust manifold (water cooled in Marine applications)

fuel system & engine management

rubber toothed belt-driven Bosch VP37 (German: *VerteilerPumpe*) electronic distributor injection pump, two-stage direct injection (DI) with five-hole injector nozzles; Bosch MDC Marine Diesel Control electronic engine control unit

mass

245 kilograms (540 lb) (Marine versions: dry weight, with DMF, all ancillaries and cooling system)

DIN-rated (Marine to ISO 8178-4) motive power & torque outputs, applications, ID codes

40 kilowatts (54 PS; 54 bhp) @ 2,500 rpm (16.3 kW/L); 155 newton metres (114 ft·lbf) @ 2,250 rpm — Volkswagen Marine SDI 55-5 (BCT: 02/02-on)
55 kilowatts (75 PS; 74 bhp) @ 3,600 rpm (22.3 kW/L); 155 newton metres (114 ft·lbf) @ 2,250 rpm — Volkswagen Marine SDI 75-5 (ANF: 02/02-on)
55 kilowatts (75 PS; 74 bhp) (22.3 kW/L); 160 newton metres (118 ft·lbf) @ 2,250 rpm — Volkswagen LT (LT28 & LT35) (AGX: 05/96-04/01)

### 2.5 R5 TDI 65-121kW

This 2.5 litre 'row' five engine (R5), wholly designed and developed by Audi, was the first Turbocharged Direct Injection (TDI) diesel engine in 1989, initially used in the Audi 100. This engine was also used in some Volvo Cars models in the 1990s.

identification

parts code prefix: ???, ID codes: AAT, ACV, AEL, AHY, ANG, ANH, ANJ, AXG, BBR, BCU, BCV, BTW, Volvo D5252T

engine configuration & engine displacement
: inline five cylinder (R5) Turbocharged Direct Injection (TDI) turbodiesel; 2,461 cubic centimetres (150.2 cu in); bore x stroke: 81.0 by 95.5 millimetres (3.19 in × 3.76 in), stroke ratio: 0.85:1 - undersquare/long-stroke, 492.1 cc per cylinder, compression ratio: 19.0:1

cylinder block & crankcase
: grey cast iron; six main bearings, die-forged steel crossplane crankshaft, 'bowl in piston' combustion chamber

cylinder head & valvetrain
: cast aluminium alloy; two valves per cylinder, 10 valves total, hydraulic bucket tappets with automatic valve clearance compensation, timing belt-driven single overhead camshaft (SOHC), swirl-inducing intake ports

aspiration
: cast aluminium alloy intake manifold, cast iron exhaust manifold (water cooled in Marine applications), Garrett Variable Turbine Geometry (VTG) variable-vane turbocharger (water cooled in Marine applications), sea-water intercooler on Marine 108 kW and above

fuel system & engine management
: rubber toothed belt-driven Bosch VP37 (German: *VerteilerPumpe*) electronic distributor injection pump, two-stage direct injection (DI) with five-hole injector nozzles, Bosch MDC Marine Diesel Control electronic engine control unit

mass
: Marine variants: 255–265 kilograms (562–584 lb) (dry weight, with DMF, all ancillaries and cooling system)

EWG-rated motive power & torque outputs, application, ID code
: 80 kilowatts (109 PS; 107 bhp) (32.5 kW/L) — Volkswagen Industrial Motor (BBR: 07/92->)

DIN-rated motive power & torque outputs, applications, ID codes
: 65 kilowatts (88 PS; 87 bhp) (26.4 kW/L); 195 newton metres (144 ft·lbf) @ 1,900 rpm — Volkswagen Transporter (T4)
: 74 kilowatts (101 PS; 99 bhp) @ 2,600 rpm (30.1 kW/L); 275 newton metres (203 ft·lbf) @ 2,500 rpm — Volkswagen Marine TDI 100-5 (BCU: 02/02->)
: 75 kilowatts (102 PS; 101 bhp) (30.5 kW/L); 250 newton metres (184 ft·lbf) @ 1,900 rpm — Volkswagen Transporter (T4)
: 80 kilowatts (109 PS; 107 bhp) (32.5 kW/L); 280 newton metres (207 ft·lbf) @ 1,900 rpm — Volkswagen LT
: 85 kilowatts (116 PS; 114 bhp) (34.5 kW/L); 265 newton metres (195 ft·lbf) @ 1,900 rpm — Audi C3 100, Audi C4 100
: 88 kilowatts (120 PS; 118 bhp) @ 3,250 rpm (35.8 kW/l); 275 newton metres (203 ft·lbf) @ 2,500 rpm — Volkswagen Marine TDI 120-5 (ANG: 02/02->)
: 103 kilowatts (140 PS; 138 bhp) (41.9 kW/L); 290 newton metres (214 ft·lbf) @ 1,900 rpm — 1994 Audi C4 100, Audi C4 A6, Volvo 850, Volvo S70, Volvo V70, early Volvo S80s
: 108 kilowatts (147 PS; 145 bhp) @ 4,000 rpm (43.9 kW/L); 310 newton metres (229 ft·lbf) @ 1,900 rpm — Volkswagen Marine TDI 150-5D (BCV: 02/02->)

111 kilowatts (151 PS; 149 bhp) (45.1 kW/L); 295 newton metres (218 ft·lbf) @ 1,900 rpm — Volkswagen Transporter (T4)
111 kilowatts (151 PS; 149 bhp) @ 3,500 rpm (45.1 kW/L); 310 newton metres (229 ft·lbf) @ 1,700-3,100 rpm — Volkswagen Marine TDI 140-5 (???: ??/??->)
111 kilowatts (151 PS; 149 bhp) @ 4,000 rpm (45.1 kW/L); 310 newton metres (229 ft·lbf) @ 2,500 rpm — Volkswagen Marine TDI 150-5 (ANH: 02/02->)
121 kilowatts (165 PS; 162 bhp) @ 4,000 rpm (49.2 kW/L); 310 newton metres (229 ft·lbf) @ 2,500 rpm — Volkswagen Marine TDI 165-5 (BTW: 04/05-on)

## 2.5 R5 TDI CR 65-120kW

identification
: parts code prefix: ???, ID codes: ???

engine configuration & engine displacement
: inline five cylinder (R5) Turbocharged Direct Injection (TDI) turbodiesel; 2,461 cubic centimetres (150.2 cu in); bore x stroke: 81.0 by 95.5 millimetres (3.19 in × 3.76 in), stroke ratio: 0.85:1 - undersquare/long-stroke, 492.1 cc per cylinder, compression ratio: 18.0:1

cylinder block & crankcase
: grey cast iron GG350; six main bearings, die-forged steel crossplane crankshaft, 'bowl in piston' combustion chamber

cylinder head & valvetrain
: cast aluminium alloy; two valves per cylinder, 10 valves total, hydraulic bucket tappets with automatic valve clearance compensation, timing belt-driven single overhead camshaft (SOHC), swirl-inducing intake ports

aspiration
: turbocharger, intercooler; 80 kW and higher: Variable Turbine Geometry (VTG) variable-vane turbocharger

fuel system & engine management
: common rail (CR) direct injection pump, pressure up to 1,600 bar; Bosch EDC16 electronic engine control unit (ECU)

exhaust system
: diesel particulate filter (DPF)

DIN-rated motive power & torque outputs
: 65 kilowatts (88 PS; 87 bhp) @ 3,500 rpm; 220 newton metres (162 ft·lbf) @ 2,000 rpm
: 80 kilowatts (109 PS; 107 bhp) @ 3,500 rpm; 280 newton metres (207 ft·lbf) @ 2,000 rpm
: 100 kilowatts (136 PS; 134 bhp) @ 3,500 rpm; 320 newton metres (236 ft·lbf) @ 2,000 rpm
: 120 kilowatts (163 PS; 161 bhp) @ 3,500 rpm; 350 newton metres (258 ft·lbf) @ 2,000 rpm

application
: Volkswagen Crafter

## 2.5 R5 TDI PD 96-128kW

identification

parts code prefix: AXD, ID codes: AXE

engine configuration & engine displacement

inline five cylinder (R5) Turbocharged Direct Injection (TDI) turbodiesel; 2,461 cubic centimetres (150.2 cu in); bore x stroke: 81.0 by 95.5 millimetres (3.19 in × 3.76 in), stroke ratio: 0.85:1 - undersquare/long-stroke, 492.1 cc per cylinder, compression ratio: 18.0:1

cylinder block & crankcase

aluminum alloy; six main bearings, die-forged steel 5-throw crankshaft, 'bowl in piston' combustion chamber

cylinder head & valvetrain

cast aluminum alloy; two valves per cylinder, 10 valves total, hydraulic bucket tappets with automatic valve clearance compensation, gear-driven single overhead camshaft (SOHC), swirl-inducing intake ports

aspiration

Variable Turbine Geometry (VTG) variable-vane turbocharger, intercooler

fuel system & engine management

camshaft-actuated Bosch Pumpe Düse Unit Injector direct injection

DIN-rated motive power & torque outputs

96 kilowatts (131 PS; 129 bhp) — Volkswagen Transporter (T5)

128 kilowatts (174 PS; 172 bhp) @ 3,500 rpm; 400 newton metres (295 ft·lbf) @ 2,000 rpm

applications

Volkswagen Touareg, Volkswagen Transporter (T5)

### 8.9 EU4 169-228kW (Scania)

engine configuration & engine displacement

inline five cylinder, turbodiesel; 8.9 litres (543 cu in)

aspiration

turbocharger, intercooler

fuel system & engine management

Scania PDE (German: *Pumpe-Düse-Einspritzung*) high-pressure Unit Injector direct injection system, exhaust gas recirculation, Euro4 compliant

DIN-rated motive power & torque outputs

169 kilowatts (230 PS; 227 bhp) @ 1,800 rpm; 1,050 newton metres (774 ft·lbf) @ 1,100-1,500 rpm

198 kilowatts (269 PS; 266 bhp) @ 1,800 rpm; 1,150 newton metres (848 ft·lbf) @ 1,100-1,450 rpm

228 kilowatts (310 PS; 306 bhp) @ 1,800 rpm; 1,550 newton metres (1,143 ft·lbf) @ 1,100-1,350 rpm

applications

Scania trucks

### 9.3 EU5 169-235kW (Scania)

engine configuration & engine displacement

inline five cylinder, turbodiesel; 9.3 litres (568 cu in)

aspiration

Variable Turbine Geometry (VTG) variable-vane turbocharger, intercooler

fuel system & engine management

Cummins / Scania XPI extra-high-pressure common rail direct injection, exhaust gas recirculation, diesel particulate filter, Euro5 compliant

DIN-rated motive power & torque outputs

169 kilowatts (230 PS; 227 bhp) @ 1,900 rpm; 1,050 newton metres (774 ft·lbf) @ 1,000-1,500 rpm

206 kilowatts (280 PS; 276 bhp) @ 1,900 rpm; 1,400 newton metres (1,033 ft·lbf) @ 1,000-1,350 rpm

235 kilowatts (320 PS; 315 bhp) @ 1,900 rpm; 1,600 newton metres (1,180 ft·lbf) @ 1,100-1,200 rpm

applications

Scania trucks

## *Six cylinder diesels*

### 2.7 V6 TDI CR 120-140kW

This is a stroke-reduced version of the 3.0 V6 TDI CR

identification

parts code prefix: ???

engine configuration & engine displacement

90° V6 engine, Turbocharged Direct Injection (TDI) turbodiesel; 2,698 cubic centimetres (164.6 cu in), bore x stroke: 83.0 by 83.1 millimetres (3.27 in × 3.27 in), stroke ratio: 1.00:1 - 'square engine', 449.6 cc per cylinder

cylinder block & crankcase

compacted vermicular graphite cast iron (GJV/CGI); four main bearings, oil cooler

cylinder heads & valvetrain

cast aluminium alloy; ??????

aspiration

single variable-geometry turbine (VGT) turbocharger

fuel system & engine management

common rail (CR) direct diesel injection, separate high-pressure pump and rail for each bank of cylinders, maximum injection pressure of 1,600 bars (23,210 psi), piezo injectors, up to five injections per piston cycle

DIN-rated motive power & torque outputs, applications, ID codes

120 kilowatts (163 PS; 161 bhp) — Audi A4 (BSG: 11/05-06/08, CAM: 11/07-05/08, CGK: 06/08->), Audi A5 (CAM: 09/07-05/08, CGK: 05/08->), Audi A6 (BSG: 01/05-10/08, CAN: 10/08->)

132 kilowatts (179 PS; 177 bhp) @ 3,300-4,250 rpm; 380 newton metres (280 ft·lbf) @ 1,400-3,300 rpm — Audi A4 (BPP: 01/06-03/09), Audi A6 (BPP: 11/04-10/08)

140 kilowatts (190 PS; 188 bhp) — Audi A4 (CAM: 11/07-05/08, CGK: 06/08->), Audi A5 (CAM: 07/07-05/08, CGK: 05/08->), Audi A6 (CAN: 10/08->)

**3.0 V6 24v TDI CR 150-195kW**


Volkswagen Marine 3.0 litre V6 TDI 265-6 marine engine. This is a marine-modified version of the 3.0 V6 24v TDI CR automobile engine.

This common rail V6 turbodiesel was developed by Audi, and first installed in the Audi D3 A8 in 2004. Subsequently made available for all longitudinal engined Audis, along with the same engine orientation in Volkswagen Passenger Cars 'premium' models and Volkswagen Marine applications.

identification

parts code prefix: 059

engine configuration & engine displacement

90° V6 engine, Turbocharged Direct Injection (TDI) turbodiesel; 2,967 cubic centimetres (181.1 cu in); bore x stroke: 83.0 by 91.4 millimetres (3.27 in × 3.60 in), stroke ratio: 0.91:1 - undersquare/long-stroke, 494.5 cc per cylinder, compression ratio 17.0:1

cylinder block & crankcase

compacted vermicular graphite cast iron (GJV/CGI) with UV laser-honed exposed bores; cast bed-plate reinforcing lower bearing frame incorporating four main bearings each affixed with four bolts, balance shaft, die-forged steel crossplane crankshaft with offset crankpins to create an even firing order, simplex roller chain-driven contra-rotating balance shaft mounted within the 'vee', diagonal fracture-split connecting rods, oil-channel cooled pistons with 'bowl in piston' combustion chamber, two-part oil sump with multi-chamber baffled insert, chain-driven ancillaries, oil filter module (incorporating cyclonic oil separator and water-to-oil cooler) mounted within the 'vee'

cylinder heads & valvetrain

cast aluminium alloy; four valves per cylinder, 24 valves total, low-friction roller finger cam followers with hydraulic valve clearance compensation, 2x double overhead camshafts (2xDOHC - two overhead camshafts per cylinder bank - 'quad cam') driven by four simplex roller chains and spur gears (hybrid relay method), dual inlet ports, siamesed exhaust ports

aspiration

hot-film air mass meter, two separate cast alloy intake manifolds, one BorgWarner variable geometry turbocharger (VGT) with electric boost control fitted within the Vee (water-cooled on Marine variants), maximum absolute pressure 2.3 bars (33 psi), two parallel side-mounted intercoolers (SMICs), sea-water tube intercooler on Marine variants, two cast iron exhaust manifolds (water-cooled on Marine variants)

fuel system, exhaust system & engine management

common rail (CR) diesel direct injection, initially one later two separate timing belt-driven high-pressure injection pumps and rail for each cylinder bank, rail pressure of 230 to 1,600 bars (3,340 to 23,210 psi), centrally-sited seven-hole piezo injectors, dual pilot injection and up to five main injection pulses per piston cycle; water-cooled exhaust gas recirculation (EGR), catalytic converter and diesel particulate filter (DPF); Bosch EDC16 electronic engine control unit (ECU), Bosch MDC16 CP34 Marine Diesel Control on Marine variants

dimensions

length: 444 mm (17.5 in), mass: 219 kilograms (483 lb) (automotive),
325 kilograms (717 lb) (Marine variants - dry weight, including DMF, cooling system & all anciliaries)

DIN-rated motive power & torque outputs, applications, ID codes

150 kilowatts (204 PS; 201 bhp) @ 3,500 rpm (50.6kW/l, 68.8PS/l); 450 newton metres (332 ft·lbf) @ 1,400 rpm — Audi B7 A4 (BKN: 11/04-03/09)

155 kilowatts (211 PS; 208 bhp) (52.2kW/l, 71.1PS/l) — Audi Q7 (BUN: 03/06-11/07), Volkswagen Touareg (BUN: 04/06-11/07, CAS: 11/07->)

165 kilowatts (224 PS; 221 bhp) @ 4,200 rpm (55.6kW/l, 75.5PS/l); 450 newton metres (332 ft·lbf) @ 2,000 rpm — Audi C6 A6 (BMK: 04/04-05/06), Volkswagen Phaeton (BMK: 05/04-05/07), Volkswagen Touareg (BKS: 11/04-05/08, CATA: 02/09->), Volkswagen Marine TDI 225-6 (BSP: 02/06->)

171 kilowatts (232 PS; 229 bhp) @ 4,000 rpm (57.6kW/l, 78.2PS/l); 500 newton metres (369 ft·lbf) @ 1,750 rpm, 450 newton metres (332 ft·lbf) between 1,400-3,250 rpm — Audi B7 A4 (ASB: 01/06-03/09), Audi C6 A6 (ASB: 05/06-10/08), Audi D3 A8 (ASB: 01/04->), Audi Q7 (BUG: 03/06-05/08), Volkswagen Phaeton (CARA: 06/07-11/08)

176 kilowatts (239 PS; 236 bhp) @ 4,000 rpm (59.3kW/l, 80.6PS/l); 500 newton metres (369 ft·lbf) @ 1,500-3,000 rpm — Audi B7 A4 (CAP: 11/07-05/08), Audi

B8 A4 (CCW: 04/08->, CCL: 11/09->), Audi A5 (CAP: 06/07-05/08, CCW: 03/08->), Audi C6 A6 (CDY: 10/08->), Audi Q5 (CCW: 11/08->), Audi Q7 (CASA: 11/07-05/10, CCMA: 11/08->), Porsche Cayenne (2009->), Volkswagen Phaeton (CARA: 03/07-06/07, CEXA: 06/08-05/10), Volkswagen Touareg (CASA/CASB/CASC: 11/07->)

195 kilowatts (265 PS; 261 bhp) @ 4,200 rpm (65.7kW/l, 89.3PS/l); 550 newton metres (406 ft·lbf) @ 2,000 rpm — Volkswagen Marine TDI 265-6 (CEZA: 12/07->)

## 11.7 DC12/DT12 EU4 250-353kW (Scania)

engine configuration & engine displacement

inline six cylinder, turbodiesel; 11.7 litres (714 cu in)

aspiration

turbocharger, intercooler

fuel system & engine management

Cummins / Scania HPI high-pressure Unit Injector direct injection system, exhaust gas recirculation, Euro4 compliant

DIN-rated motive power & torque outputs

250 kilowatts (340 PS; 335 bhp) @ 1,800 rpm; 1,700 newton metres (1,254 ft·lbf) @ 1,100-1,350 rpm

280 kilowatts (381 PS; 375 bhp) @ 1,800 rpm; 1,900 newton metres (1,401 ft·lbf) @ 1,100-1,350 rpm

309 kilowatts (420 PS; 414 bhp) @ 1,900 rpm; 2,100 newton metres (1,549 ft·lbf) @ 1,100-1,350 rpm

353 kilowatts (480 PS; 473 bhp) @ 1,900 rpm; 2,250 newton metres (1,660 ft·lbf) @ 1,100-1,450 rpm

applications

Scania trucks

## 11.7 DC12 EU5 280-309kW (Scania)

engine configuration & engine displacement

inline six cylinder, turbodiesel; 11.7 litres (714 cu in)

aspiration

turbocharger, intercooler

fuel system & engine management

Cummins / Scania HPI high-pressure Unit Injector direct injection, Scania selective catalytic reduction (SCR) - catalytic converter with AdBlue urea injection, Euro5 compliant

DIN-rated motive power & torque outputs

280 kilowatts (381 PS; 375 bhp) @ 1,800 rpm; 1,900 newton metres (1,401 ft·lbf) @ 1,100-1,400 rpm

309 kilowatts (420 PS; 414 bhp) @ 1,800 rpm; 2,100 newton metres (1,549 ft·lbf) @ 1,000-1,400 rpm

applications

Scania trucks

### 12.7 DC13 EU5 265-353kW (Scania)

engine configuration & engine displacement
 inline six cylinder, turbodiesel; 12.7 litres (775 cu in)
aspiration
 variable-vane geometry turbocharger (VGT), intercooler
fuel system & engine management
 Cummins / Scania XPI extra-high-pressure common rail direct injection, two-way exhaust gas recirculation, Euro5 compliant
DIN-rated motive power & torque outputs
 265 kilowatts (360 PS; 355 bhp) @ 1,900 rpm; 1,850 newton metres (1,364 ft·lbf) @ 1,000-1,300 rpm
 294 kilowatts (400 PS; 394 bhp) @ 1,900 rpm; 2,100 newton metres (1,549 ft·lbf) @ 1,000-1,300 rpm
 324 kilowatts (441 PS; 434 bhp) @ 1,900 rpm; 2,300 newton metres (1,696 ft·lbf) @ 1,000-1,300 rpm
 353 kilowatts (480 PS; 473 bhp) @ 1,900 rpm; 2,500 newton metres (1,844 ft·lbf) @ 1,000-1,300 rpm
applications
 Scania trucks

## *Eight cylinder diesels*

### 4.2 V8 TDI CR 235-257kW

This Audi engine is an entirely redeveloped and bored-out evolution of the superseded 4.0 V8 TDI CR, now with 90 millimetres (3.54 in) cylinder spacing between bore centres, and again with roller chain drive for the overhead camshafts and ancillaries. Just like its 4.0 V8 TDI predecessor, this all-new 4.2 V8 TDI retains the mantle of the worlds highest power output car with a diesel V8. This engine is manufacturered at Győr, Hungary by AUDI AG subsidiary Audi Hungaria Motor Kft.

identification
 parts code prefix: 057.C
engine configuration & engine displacement
 90° V8 engine, Turbocharged Direct Injection (TDI) turbodiesel; 4,134 cubic centimetres (252.3 cu in); bore x stroke: 83.0 by 95.5 millimetres (3.27 in × 3.76 in), stroke ratio: 0.87:1 - undersquare/long-stroke, 516.7 cc per cylinder, 90 millimetres (3.54 in) cylinder spacing, compression ratio: 16.5:1, water-cooled alternator
cylinder block & crankcase
 compacted vermicular graphite cast iron (GJV/CGI), 62 kilograms (137 lb); UV laser-honed exposed bore; cast reinforcing bed-plate lower frame incorporating five main bearings (each 'bearing' affixed by four bolts), die-forged chrome molybdenum alloy steel crossplane crankshaft with first and second order forces and moments avoided, three-part oil sump consisting of cast alloy upper section, a middle baffle section and pressed steel lower section, diagonally fracture-split

connecting rods, cast aluminium alloy Kolbenschmidt pistons (Mahle on CCFA), simplex roller chain-driven ancillaries, oil filter module (incorporating oil separator and water-to-oil cooler) mounted within the 'vee' (externally mounted on Marine variants)

cylinder heads & valvetrain

cast aluminium alloy; four valves per cylinder, 32 valves total, operated by low-friction roller finger cam followers with automatic hydraulic valve clearance compensation, 2x double overhead camshafts (2xDOHC - two overhead camshafts per cylinder bank - 'quad cam') - the inlets driven in a relay method at the rear (flywheel) end of the engine by four simplex roller chains and the exhausts driven from the inlets by automatic slack adjusting spur gears at the front end, two unequal-length swirl-inducing switchable inlet ports, siamesed unequal-length exhaust ports

aspiration - automotive

two air filters, two hot-film air mass meters, 'biturbo': two water-cooled turbochargers with electrically direct-actuated Variable Turbine Geometry (VTG) vanes (one turbo per cylinder bank) operating up to 226,000 rpm with a maximum electrically regulated boost of 2.5 bars (36 psi), two side-mounted air-to-air fan-assisted (not on Q7) intercoolers (SMICs), two separate cast alloy intake manifolds interconnected by a "feedthrough" system to equalise the pressure in the two cylinder banks, two-position variable swirl flaps integrated into the intake tract

aspiration - Marine

air filter with hot-film air mass meter, one water-cooled turbocharger with electric boost pressure control mounted within the vee, sea-water tube intercooler, two separate cast alloy intake manifolds interconnected by a "feedthrough" system to equalise the pressure in the two cylinder banks, two-position variable swirl flaps integrated into the intake tract

fuel system & engine management

common rail (CR) direct diesel injection: electric low-pressure fuel lift pump, one timing belt-driven 1,600 bars (23,210 psi) injection pump, two common rail fuel rails (one per cylinder bank), piezo-electric operated fuel injectors with eight-hole nozzles for homogenous fuel delivery, single and double pilot injection, up to four main injection actuations per piston cycle; Bosch EDC16 CP electronic engine control unit (ECU), Bosch MDC Marine Diesel Control on Marine variant

exhaust system

two air-gap insulated fan-branch alloy steel exhaust manifolds, two close-coupled maintenance-free oxidizing catalytic converters, two silicon carbide diesel particulate filters, Euro4 emissions standard compliant

dimensions

length: 520 millimetres (20.5 in), mass: 255–257 kilograms (562–567 lb) (automotive - 15 kilograms (33 lb) lighter than its 4.0 V8 TDI predecessor, 4 kilograms (9 lb) lighter than the all-aluminium alloy Mercedes-Benz 4.0 V8 CDI diesel engine), 368 kilograms (811 lb) (Marine variant: dry weight, including DMF, cooling system & all anciliaries)

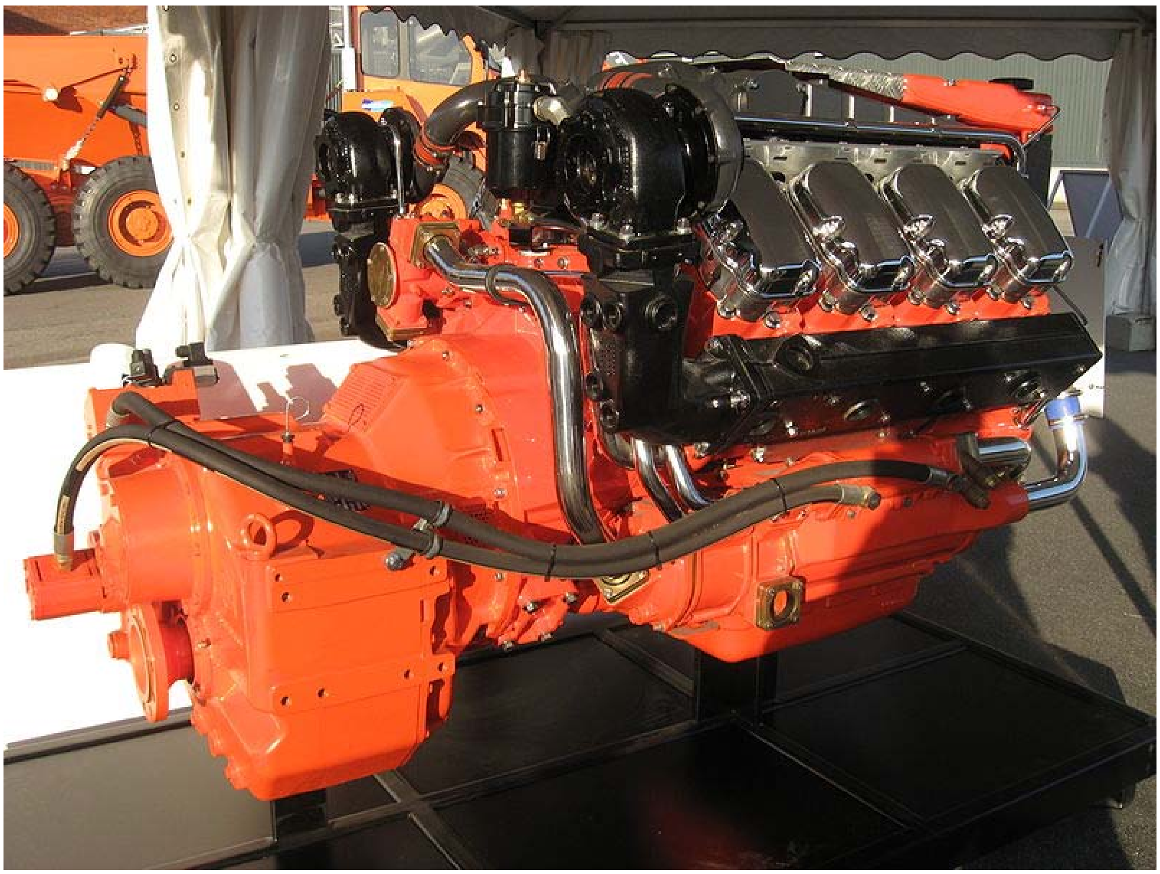
DIN-rated motive power & torque outputs, ID codes

**BMC:** 235 kilowatts (320 PS; 315 bhp)
**BVN:** 240 kilowatts (326 PS; 322 bhp) @ 3,750 rpm; 650 newton metres (479 ft·lbf) @ 1,600-3,500 rpm
**BTR:** 240 kilowatts (326 PS; 322 bhp) @ 3,750 rpm; 760 newton metres (561 ft·lbf) @ 1,800-2,500 rpm
**CCFA:** 250 kilowatts (340 PS; 335 bhp)
**CEM:** 257 kilowatts (349 PS; 345 bhp) @ 4,200 rpm; 800 newton metres (590 ft·lbf) @ 1,900 rpm

applications

Audi D3 A8 4.2 TDI quattro (BMC: 01/05-06/05, BVN: 07/05->), Audi Q7 4.2 TDI (BTR: 03/07-06/09, CCFA: 06/09->), Volkswagen Marine TDI 350-8 (CEM: 02/09->)

## 15.6 V8 DC16 368-456kW (Scania)



Scania V8 16 litre marine engine with reverse.

engine configuration & engine displacement

90° V8 engine, turbodiesel; 15,607 cubic centimetres (952.4 cu in); bore x stroke: 127.0 by 154.0 millimetres (5.00 in × 6.06 in), stroke ratio: 0.82:1 - undersquare/long-stroke, 1,950.8 cc per cylinder

aspiration

turbocharger, intercooler

fuel system & engine management

Scania PDE high pressure Unit Injector system, Scania selective catalytic reduction (SCR) - catalytic converter with AdBlue urea injection

DIN-rated motive power & torque outputs - Euro4

368 kilowatts (500 PS; 493 bhp) @ 1,900 rpm; 2,400 newton metres (1,770 ft·lbf) @ 1,100-1,400 rpm

412 kilowatts (560 PS; 553 bhp) @ 1,900 rpm; 2,700 newton metres (1,991 ft·lbf) @ 1,100-1,400 rpm

456 kilowatts (620 PS; 612 bhp) @ 1,900 rpm; 3,000 newton metres (2,213 ft·lbf) @ 1,100-1,400 rpm

DIN-rated motive power & torque outputs - Euro5

368 kilowatts (500 PS; 493 bhp) @ 1,800 rpm; 2,500 newton metres (1,844 ft·lbf) @ 1,000-1,350 rpm

412 kilowatts (560 PS; 553 bhp) @ 1,900 rpm; 2,700 newton metres (1,991 ft·lbf) @ 1,000-1,400 rpm

456 kilowatts (620 PS; 612 bhp) @ 1,900 rpm; 3,000 newton metres (2,213 ft·lbf) @ 1,000-1,400 rpm

applications

Scania trucks

## *Ten cylinder diesels*

### 4.9/5.0 V10 TDI PD 230-258kW

This '4.9' or '5.0' badged V10 TDI diesel engine is only used in Volkswagen Passenger Cars 'premium' models. At its launch in the Volkswagen Phaeton, it became the most powerful diesel engined car in the world. A heavily modified dry sump version was used in an LMP1 Lola sports car to compete in the 2004 Le Mans under a Caterpillar badge.

identification

parts code prefix: 07Z

engine configuration & engine displacement

90° V10 engine, Turbocharged Direct Injection (TDI) turbodiesel; 4,921 cubic centimetres (300.3 cu in), bore x stroke: 81.0 by 95.5 millimetres (3.19 in × 3.76 in), stroke ratio: 0.85:1 - undersquare/long-stroke, 492.1 cc per cylinder, 88 millimetres (3.46 in) cylinder spacing, compression ratio: 18.0:1, water-cooled alternator

cylinder block & crankcase

low-pressure die-cast aluminium alloy (AlSi8Cu3); bolted-on grey cast iron bearing tunnel and crank carrier with six main bearings, die-forged steel cross-plane crankshaft with 18 degree crankpin offset to achieve a 72 degree even firing order, contra-rotating balance shaft, diagonally cracked forged connecting rods, two-part cast aluminium alloy baffled oil sump

cylinder heads & valvetrain

cast aluminium alloy; two valves per cylinder, 20 valves total, each with two concentric valve springs and bucket tappets, 2x gear-driven single overhead camshaft (2xSOHC - one overhead camshaft per cylinder bank) utilising a separate cassette-type 'motor control module'

aspiration
: two air filters with two hot-film air mass meters, twin-turbo: two electrically-controlled Garrett GT1852V variable vane turbochargers, two side-mounted intercoolers (2xSMIC), two cast alloy intake manifolds

fuel system & engine management
: Pumpe Düse (PD) diesel direct injection: one underfloor electric fuel lift pump, two camshaft-driven low pressure fuel pumps supplying common fuel rails (one per cylinder bank), ten camshaft-actuated UI-P1 2,050 bars (29,730 psi) Unit Injectors with solenoid-actuated nozzles, 72° injection interval; two Bosch EDC16 32-bit electronic engine control units (ECUs) working on the 'master/slave' method

exhaust system
: water-cooled exhaust gas recirculation (EGR), air-gap insulated cast iron exhaust manifolds, two close-coupled ceramic catalytic converters, two main underfloor oxydising catalytic converters, EU3 emissions compliant

dimensions
: length: 544 millimetres (21.4 in)

4.9 DIN-rated motive power & torque output, ID codes
: 230 kilowatts (313 PS; 308 bhp) @ 3,750 rpm; 750 newton metres (553 ft·lbf) @ 2,000 rpm — AJS, BLE, BKW (North America)

5.0 DIN-rated motive power & torque outputs, ID codes
: 230 kilowatts (313 PS; 308 bhp) @ 3,750 rpm; 750 newton metres (553 ft·lbf) @ 2,000 rpm — AYH, BWF
: 258 kilowatts (351 PS; 346 bhp) @ 3,500 rpm; 850 newton metres (627 ft·lbf) @ 2,000 rpm — CBWA: Touareg R50

4.9 applications
: Volkswagen Phaeton 4motion (AJS: 12/02-10/06), Volkswagen Touareg (BKW: 11/03-11/04, BLE: 11/04->)

5.0 application
: Volkswagen Touareg (AYH: 11/02-11/06, BWF: 12/06-02/09), Touareg R50 (CBWA: 08/07->)

**awards**

was winner of the "Above 4.0-litre" category for two consecutive years in the 2003 and 2004 annual competition for International Engine of the Year.

## *Twelve cylinder diesels*

### 6.0 V12 48v TDI CR DPF 368kW


Front view of the installed V12 TDI engine in the Audi Q7 V12 TDI quattro

A world first. Wholly developed by quattro GmbH, AUDI AG's private high performance specialist subsidiary, and built at Audi Hungaria Motor Kft. in Győr, Hungary, this Turbocharged Direct Injection (TDI) V12 engine is a road-going development of the unit in the 24 Hours of Le Mans winning Audi R15 TDI. It features common rail direct injection, and includes the same cylinder bore and piston stroke as the latest 3.0 V6 TDI CR. This engine has created the most powerful sport utility vehicle (SUV) in its class - the Audi Q7 V12 TDI quattro.

identification

parts code prefix: 05A

engine configuration & engine displacement

60° V12 engine, Turbocharged Direct Injection (TDI) turbodiesel; 5,934 cubic centimetres (362.1 cu in); bore x stroke: 83.0 by 91.4 millimetres (3.27 in × 3.60 in), stroke ratio: 0.91:1 - undersquare/long-stroke, 494.5 cc per cylinder; 90 millimetres (3.54 in) cylinder spacing; 17 millimetres (0.67 in) cylinder bank offset; compression ratio: 16.0:1; two oil coolers (one: water/oil, the other: air/oil); four coolant radiators; water-cooled alternator

cylinder block & crankcase

GJV-450 compacted vermicular graphite cast iron (GJV/CGI); nodular graphite reinforced cast iron bedplate frame with seven main bearings and four bolts per bearing, die-forged chrome and molybdenum steel alloy crossplane crankshaft, diagonally fracture-cracked forged connecting rods, aluminium forged Mahle pistons, two-part cast aluminium alloy baffled oil sump

cylinder heads & valvetrain

composite lower section made from low-pressure die cast aluminium alloy with integrated intake and exhaust ports, middle section for guiding engine oil flow, and the top section is a pressure-cast ladder frame for the overhead camshafts; four valves per cylinder, 48 valves total, low-friction roller finger cam followers with automatic hydraulic valve clearance compensation, 2x double overhead camshaft (2xDOHC - two overhead camshafts per cylinder bank, 'quad cam') - the exhaust camshafts driven from the flywheel side via a two-stage chain drive utilising three 3/8" simplex roller chains, and the inlet camshafts driven from the exhaust camshafts by gears at the front of the engine; two unequal-length swirl-inducing switchable inlet ports, siamesed unequal-length exhaust ports

aspiration

two air filters, two hot-film air mass meters; 'biturbo': two water-cooled turbochargers with electrically-controlled Variable Turbine Geometry (VTG) (one turbo per cylinder bank) and an electronically-regulated boost pressure of up to 2.6 bars (38 psi), two all-alloy side-mounted intercoolers (2xSMIC); cast alloy intake manifold with dual adjustable turbulance flaps

fuel system & engine management

Bosch 2,000 bars (29,010 psi) common rail (CR) (one rail per cylinder bank) direct injection: with two chain-driven high pressure fuel pumps, fuel cooler for return line, eight combustion chamber-sited eight-hole (0.12 millimetres (0.0047 in)) piezo injectors with multi-pulse injection (up to five injection operations per piston cycle, including pre- and post- ignition injection); two Bosch EDC electronic engine control units (ECUs) working on the 'master and slave' concept; water-cooled vacuum-actuated exhaust gas recirculation (EGR) with up to 50% recirculation rate at partial engine load; European Euro5 emissions standard compliant

exhaust system

double flow exhaust pipes with two catalysts and two diesel particulate filters (DPF); two lambda sensors, two exhaust gas temperature sensors

dimensions

length: 684 millimetres (26.9 in) (just 166 mm (6.5 in) longer than the V8 TDI),

DIN-rated motive power & torque output, ID code

368 kilowatts (500 PS; 493 bhp) @ 4,000 rpm - 62.0 kW (84.3 PS; 83.1 bhp) per litre; 1,000 newton metres (738 ft·lbf) @ 1,750-3,000 rpm — CCGA

application

Audi Q7 V12 TDI quattro (09/08->)