RAIL VEHICLES

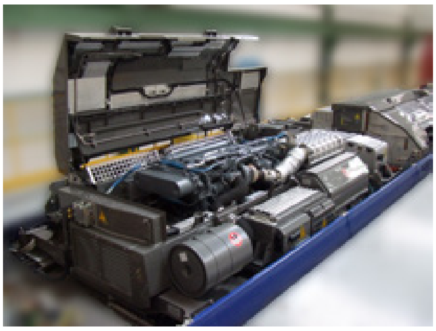
# Roof installation of railway engines

**MAN's D2676 LE621 engine provides the ideal prerequisites for the innovative drive technology of the Regiolis from Alstom: thanks to the compact dimensions and low weight of the vertical MAN engine, the complete drive package comprising diesel engine and generator, air filter, cooling plant, exhaust system, electrical and electronic control systems can be arranged on the roof of the vehicle. The improved access considerably simplifies servicing while at the same time, the end-to-end low floor section realized inside the vehicle noticeably improves passenger comfort.**



**The problem**

In classic railcars, the drive units are usually installed beneath the floor. This arrangement means that by comparison with separate drive modules, there is no additional loss of passenger space. A major disadvantage, however, is that this engineering design entails the use of steps to enter the compartments because an end-to-end low floor section cannot be realized.



The specification of the French manufacturer Alstom to MAN as the supplier of the engine for the power pack was to enable the realization of this end-to-end low-floor section in its railway vehicle Regiolis (title picture).

What is special about this installation is that the four or six drive systems, each comprising a diesel engine with flanged-on generator, cooling system and controls, are arranged on the roof of the vehicle. The requirement formulated in the operator's specifications is for an engine as compact and light as possible. EC Stage III B, in force since 2012, had

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to be fulfilled without the use of a second operating fluid at the same or even lower levels of fuel consumption than engines in predecessor or comparable projects. In addition, besides the issue of noise avoidance, protection against fire is of central importance, not least due to the planned installation area on the roof. Acceptance of the engines in accordance with UIC 623 is required. The Regiolis from Alstom will be operated from 2013 on by SNCF in France as a suburban train on routes with heavy traffic and short distances between stops. The adaptation of an engine whose origins were in road transport for use as a railway engine means fulfilling a different set of requirements: the load spectrum of a railway engine differs significantly to that of a truck engine, besides which there can be rapid and frequent alternations between the operating points. In addition, different laws with regard to exhaust emissions apply [1].

**The solution**

Due to the roof installation it is possible to realize an almost end-to-end low-floor section inside the vehicle. It is possible to dispense completely with a service hatch accessible from a passenger compartment, something which is necessary for underfloor drive systems. In order to be able to install the drive systems on the roof and not raise the center of gravity too far, all components have to be as light as possible. With a weight of 1,125 kg, the D2676 LE621 engine meets this requirement [Table 1: Technical specifications of the engine]: A drive package weighs only 3,600 kg. Because space on the vehicle's roof is limited, all components must be as compact as possible. The PM-Kat® integrated in the drive package requires no more space than the conventional exhaust silencer as fitted on truck applications. (Fig. 2: drive

**MAN D2676 LE621 for Regiolis from Alstom**

| | |
|---|---|
| Arrangement and number of cylinders | In-line six-cylinder |
| Engine design | Vertical |
| Homologation to UIC-623 / -624 | Yes / yes |
| Rating | 338/460 kW/hp |
| At engine speed | 1,800 rpm |
| Max. torque | 2,200 Nm |
| At engine speed | 1,000-1,400 rpm |
| Bore | 126 mm |
| Stroke | 166 mm |
| Length | 1,630 mm |
| Width | 970 mm |
| Height | 1,030 mm |
| Dry weight | 1,125 kg |
| Exhaust-gas status | EC Stage III B |

Table 1: Technical specifications of the MAN D2676 LE621 engine for Regiolis from Alstom

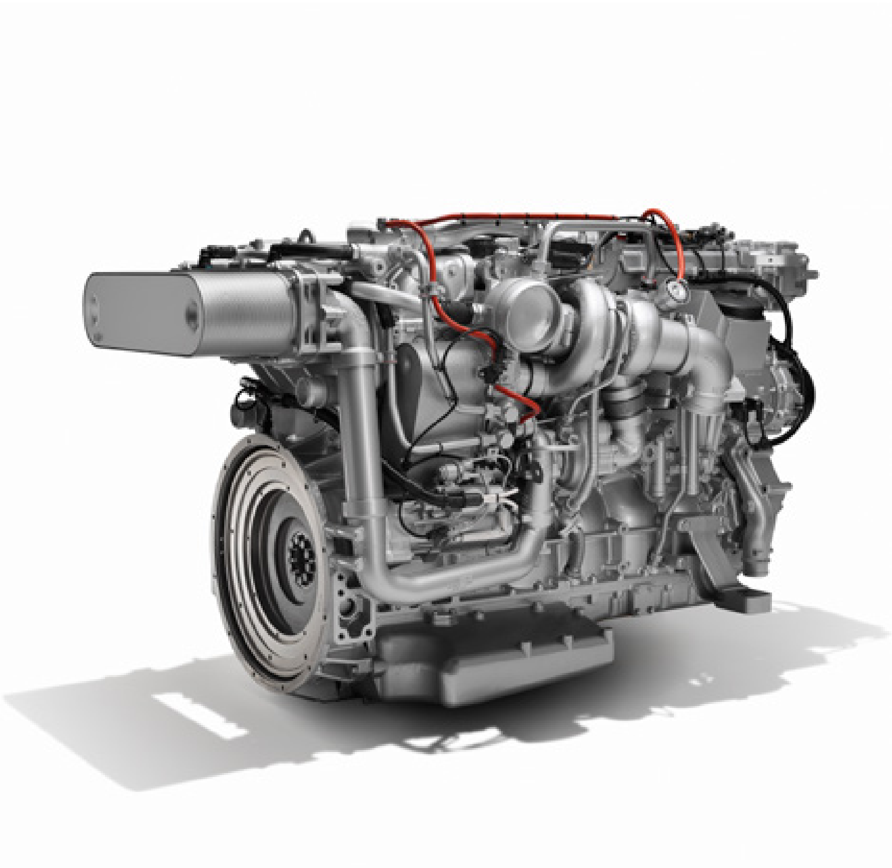

Fig. 1: MAN D2676 LE621: light and compact design - ideal for roof installation

system)
Due to the diesel-electric drive, the engine has to react very quickly to changes - also to transient changes - in load as well as to alternating loads. The control parameters in the engine control unit have to be adjusted accordingly for this type of operation in order to ensure both favorable fuel consumption and suitably dynamic power delivery. High average and ignition pressures necessitate rigid crankcase and cylinder-head design.

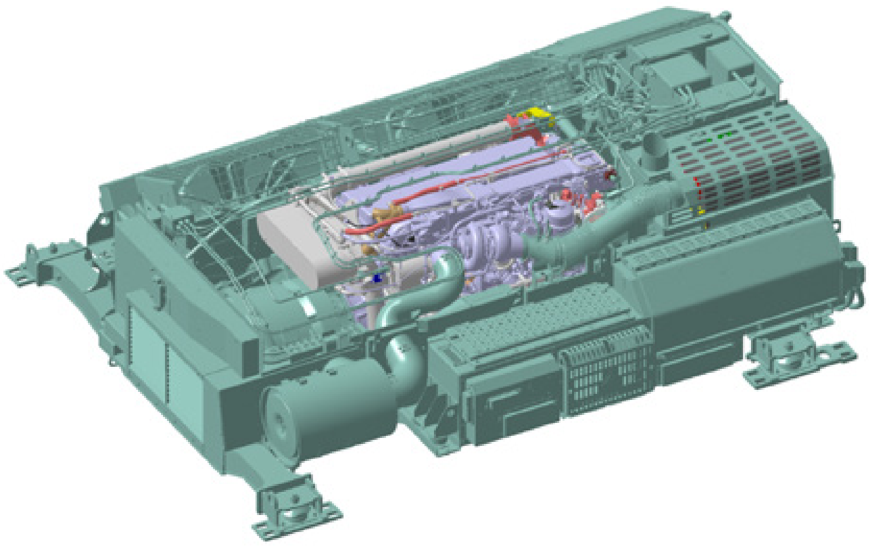

Fig. 2: 3-D view of the drive system showing (clockwise) the engine/generator, cooling system, hydraulic-oil tank, expansion tank for cooling system, PM-Kat, electronic and electrical systems, air filter, air ducts for generator

### Concept and design of the engine's basic components

The crankcase must withstand ignition pressures of 190 bars. To ensure that it does, the crankcase is made from high-quality vermicular graphite cast iron ("GJV"). GJV combines the good casting properties of lamellar graphite cast iron with the very good mechanical-physical properties of spheroidal graphite cast iron [2]. The cylinder liners are replaceable, enabling a straightforward, economical overhaul of the engine. The MAN D20/D26 series implement cracked main bearing shells and connecting rods, allowing MAN to design the crankcase in a closed box form. Moreover, the positive-locking fracture faces absorb transverse loads outstandingly.

A solid crankshaft is driven by the pistons via forged connecting rods made from high-strength steel. Cast counterweights balance the crankshaft and ensure that the engine runs smoothly and harmoniously. Just like the main bearing caps, the connecting rods are cracked. Given the hard usage, they are put to in a railway engine, the pistons are implemented in one-piece forged steel. This construction provides high pressure stability and resistivity to thermal cycling. The pistons are cooled via a ring-shaped cooling duct, in the vicinity of the ring carrier, into which engine oil is injected by the oil nozzles.

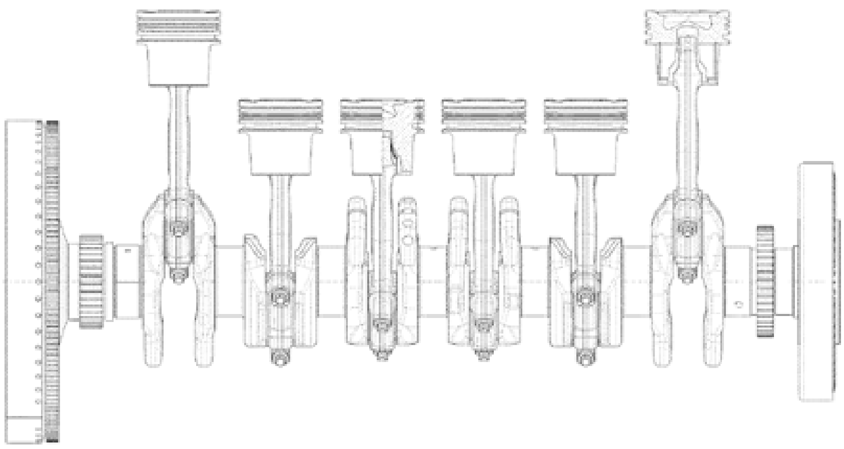

Fig. 3: 2-D view of crank drive with connecting rods and pistons

The D26 employs a continuous cylinder head made from GJV with an overhead camshaft that operates the four valves per cylinder via roller rocker arms. The air-manifold housing for distributing charge air to the cylinders is integrated into the cylinder head, which makes sealing the charge-air supply on the cylinder head very straightforward. Coolant and oil are supplied separately to the cylinder head and the crankcase so that no operating fluids need to pass through the cylinder-head gasket. This makes it

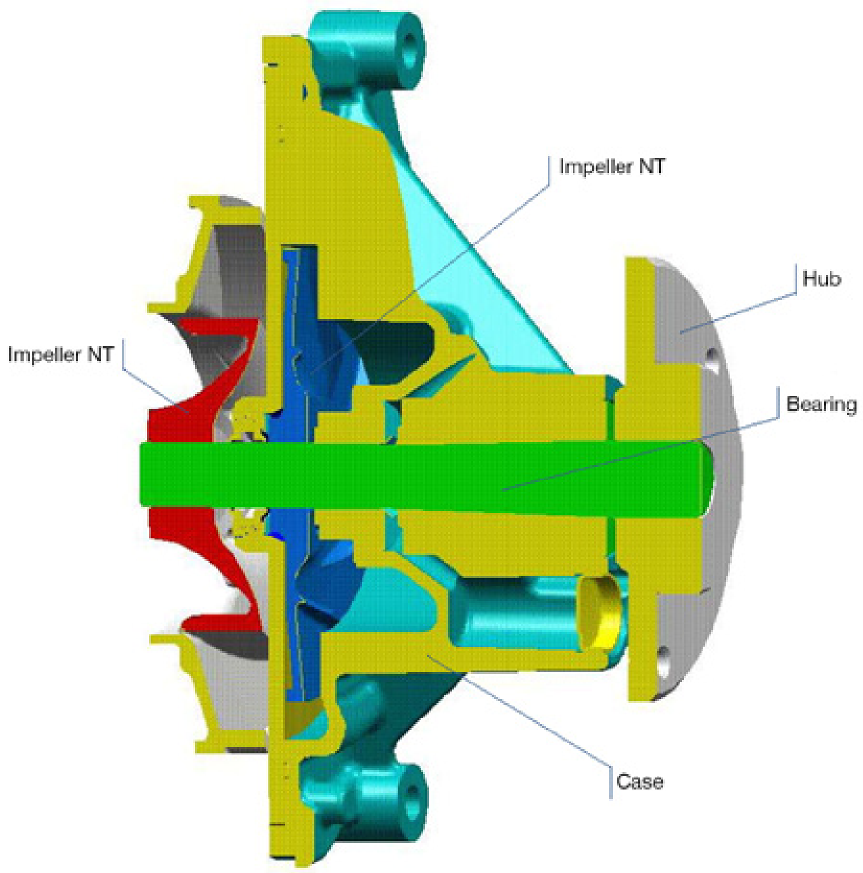


Fig. 4: 3-D view of double-flow water pump with integrated low temperature pump

possible to use a simple beaded metal gasket for the cylinder head.

**Coolant and oil circuits**

The engine cooling system consists of two separate coolant circuits. The larger coolant pump supplies the engine cooling circuit with high temperature coolant while the smaller supplies the charge-air cooling circuit and the electrical EGR servomotor with low temperature coolant [Fig. 4: double-flow water pump]. This enables the cooling circuits to be adjusted optimally to the changing boundary conditions of the customer's cooling system. The coolant pump for the engine cooling circuit is implemented in two parts, with its impeller located in the coolant pump connector housing. The coolant pump itself contains only the impeller and the integrated low temperature pump. Thanks to this design, the coolant pump can be realized with a comparatively low weight, which simplifies disassembly and re-assembly in the case of an overhaul.

For optimal utilization of installation space, the oil cooler and filter, as well as the coarse and fine oil separators of the crankcase breather (blow-by separator) are located together in a single housing - the oil module. The oil is cooled by means of an oil-water heat exchanger, downstream from which the cooled and cleaned oil is separated into two separate circuits, one each for the cylinder head and the crankcase. Oil is separated from the blow-by gas by means of a stack of rotating discs: centrifugal force accelerates the droplets onto the inner wall of the housing, from where they flow back into the sump. The cleaned air is fed back into the charge-air circuit. The separator is equipped with a hydraulic drive and this oil also flows back to the



## Diesel engine programme for rail applications

MAN offers efficient 6- and 12-cylinder diesel engines for use in railcars, tracks and shunting locomotives, railway maintenance vehicles and power supply. They generate power outputs from 257 kW (350 hp) for railcars and 265 kW (360 hp) for locomotives to 735 kW (1,000 hp), while engines for rail power generation are rated between 230 kW and 543 kW (313 hp and 738 hp). MAN engines are compact to install – either conventionally in the drive module or in a space-saving manner under the floor or in the roof. Their clear advantages lie in a fast pick-up and economy in continuous operation – in compliance with the various exhaust-gas standards applying throughout the world.

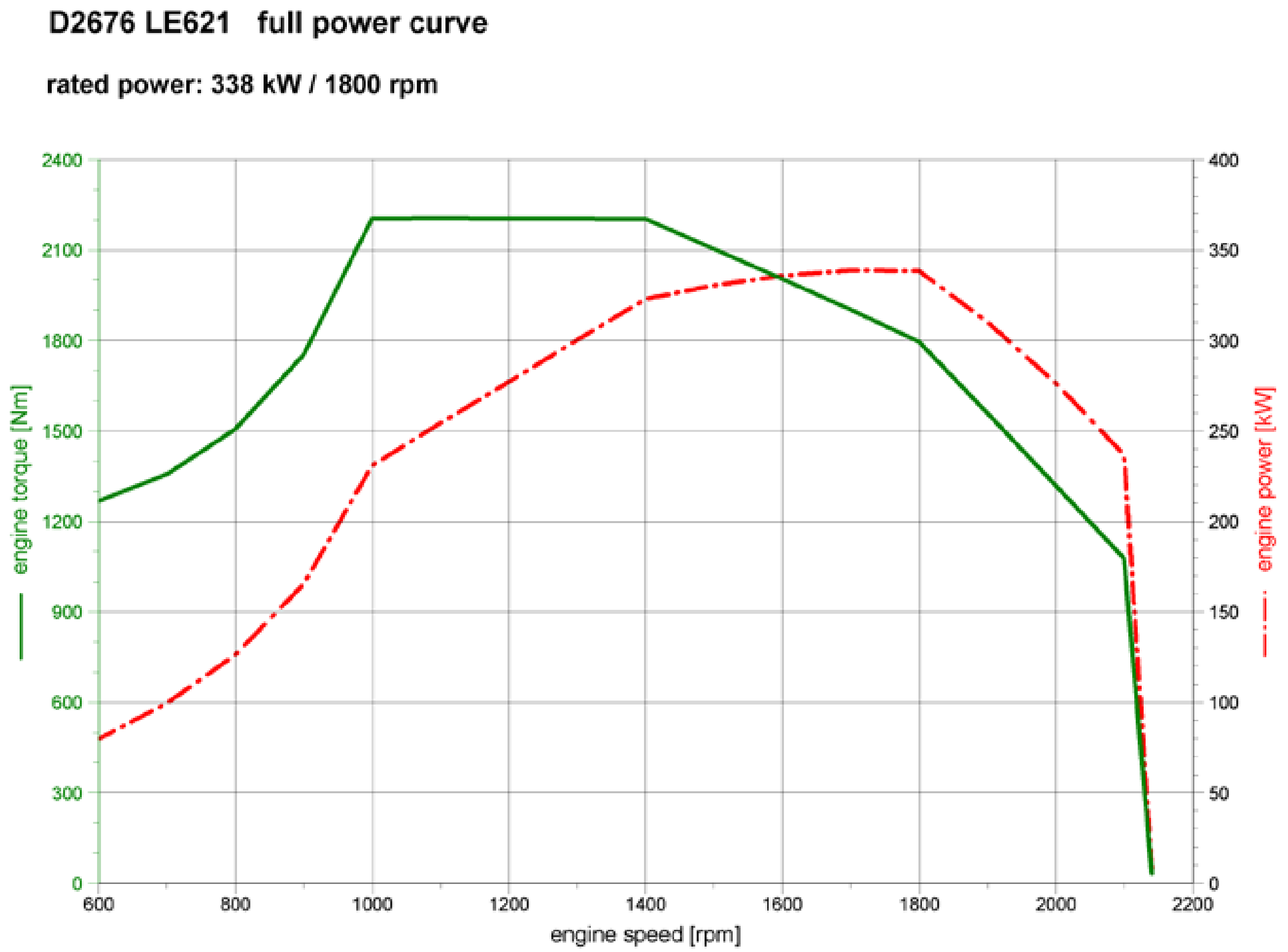


Diagram 1: Full-load curves 600 - 2,150 rpm



oil circuit. At a throughflow of 160 litres per minute, the efficiency of the separator is greater than 98% [3].

**Injection system**

Diesel fuel is injected into the D2676 LE621 by a common-rail system from BOSCH at a maximum injection pressure of 1,800 bars. Fuel flows from the tank to the pre-supply pump via the fuel filter system (KSC). After being filtered, it then flows to the high-pressure pump, an oil-lubricated three-piston CP 3.4H+, which generates the requisite high pressure and supplies the rail with fuel. The rail acts as a pressure accumulator for injection. The fuel passes from the rail via injector lines and pressure pipe sockets to the individual injectors, which are controlled by the EDC in accordance with an operating map. There are up to three injections per combustion cycle.

**Exhaust and charge-air systems**

Two in-line exhaust-gas turbochargers are responsible for the pressure-controlled supply of combustion air to the engine. At low engine speeds, the high-pressure stage is charged solely with exhaust gas. This increases the percentage to which the cylinders are filled and a steep increase in torque is achieved. At high engine speeds, some of the exhaust gas bypasses the high-pressure turbine via a wastegate. This results in a greater charge in the low-pressure stage. The energy of the exhaust gas is consistently made use of, hence the good fuel-consumption values and low-particulate combustion. This railway application employs electronically controlled EGR with a lambda probe. The recirculation of cooled exhaust gases makes a low peak combustion temperature possible, so that fewer nitrogen oxides are formed. Under dynamic conditions, EGR control adjusts the rate of exhaust-gas recirculation to the optimum for every operating point of the engine. This guarantees particularly high efficiency and economical diesel consumption [4].

**Combustion design**

Control of the engine is carried out by a BOSCH EDC7C32. The MAN D2676

LE621 complies with emission standard Stage 3B in accordance with Directive 97/68/EC in Cycle C1 and F and is certified as per UIC 623 and UIC 624. It is operated in speed-control mode and drives a permanently-excited magnet generator. Both the monitoring of the engine as well as cold start mapping are adapted to the requirements of railway operation in order to cope adequately with the additional mass in the form of the generator coupled to the engine during the start process. Diagram 1 shows the full-load curves for torque and power. Fuel consumption at rated power is 217 g/kWh, at best point it is a mere 190 g/kWh.

**Exhaust-gas aftertreatment systems**

There are various different strategies for reducing the exhaust gases emitted by a diesel engine [5]. Due to the customer's specifications, the choice in this case fell on an engine with two-stage turbocharging and EGR in conjunction with a PM-KAT® filter. The PM-KAT® is a continuously operating, self-regenerating separator system with open channels. The exhaust gas initially flows through a catalytic converter part where nitrogen monoxide NO is oxidized to nitrogen dioxide $NO_2$. In the second stage, the soot particles are separated out into a sintered metal fleece. The trapped soot particles are oxidized using the $NO_2$ formed in the first stage and converted to carbon dioxide $CO_2$ and water $H_2O$. Servicing the PM-KAT® filter is not required [6]. All the components of the filter system are completely integrated into an exhaust silencer available as standard. ■

**Thanks**

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## Conclusion

In the D2676 LE621 an engine has been specially developed for operation in Regiolis from Alstom. MAN fulfills the requirements to be met by an engine installed in the roof with a sensible combination of existing and newly developed technologies. By using extremely high quality GJV it was possible to design a compact, lightweight crankcase and cylinder head. An ingenious arrangement of attachments such as the generator, water pump and power take-off enables efficient utilization of the installation space available. Dispensing with a second operating fluid means that there is no need to reserve any installation space for the SCR tank. An additional advantage in terms of weight is gained by employing the PM-Kat® already integrated into the silencer as an element of the selected exhaust technology. For this purpose, technologies that are already in series production and their appropriately adapted components are used. In this way it becomes economically viable to develop engines even for applications requiring relatively small volumes.

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