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MAN Diesel & Turbo Company in brief

MAN Diesel & Turbo SE, based in Augsburg, Germany, is the world’s leading provider of large-bore diesel and gas engines and turbomachinery. The company employs around 15,000 staff at more than 100 international sites, primarily in Germany, Denmark, France, Switzerland, the Czech Republic, India and China. The company’s product portfolio includes two-stroke and four-stroke engines for marine and stationary applications, turbochargers and propellers as well as gas and steam turbines, compressors and chemical reactors. The range of services and supplies is rounded off by complete solutions like ship propulsion systems, engine-based power plants and turbomachinery trains for the oil & gas as well as the process industries. Customers receive worldwide after-sales services marketed under the MAN PrimeServ brand.

MAN Diesel & Turbo can look back on more than 250 years of industrial history with the roots of the company, and indeed of the entire MAN Group, stretching back to 1758 and the St. Anthony ironworks that laid the foundation for the development of the coal and steel industry in the Ruhr region. While focus initially remained on ore mining and iron production in the German Ruhr region, mechanical engineering became the dominant branch of business in Augsburg and Nuremberg.

In Augsburg, on 10 August 1893, Rudolf Diesel’s prime model, a single 10-foot (3.0 m) iron cylinder with a flywheel at its base, ran on its own power for the first time. Diesel and MAN engineers spent four more years making improvements and, in 1897, presented another model with a tested efficiency of 26%, in contrast to the 10% efficiency of the steam engine.

MAN Diesel & Turbo is a company in the Power Engineering business area of MAN SE.
Generating Success
The economic solution
Power generation employing large reciprocating engines is an increasingly popular solution in a world of rapidly expanding demand for electrical power. With our advanced technology and extensive experience in power plant planning and construction globally, MAN Diesel & Turbo is a reliable partner for all categories of electricity producers and all scopes of supply:

- From single engines and generating sets to complete made-to-measure power plants with EPC (Engineering – Procurement – Construction) scope, acting as main contractor/consortium leader
- From major national utilities to operators of municipal or industrial cogeneration plants and independent power producers (IPPs), operating power purchase agreements (PPAs).

Power plants from MAN Diesel & Turbo offer:
- Highest fuel efficiency
- Low maintenance, high reliability
- Excellent power quality and security
- Operational flexibility, from base load to standby
- Rapid construction from earthworks to first kWh
- Wide fuel flexibility
- Wide scope for thermal energy recovery
- Resilience against “hot and high” locations
- Modular concept for flexible capacity expansion

Quality and reliability = availability
Precise manufacturing and thorough testing guarantee the reliability and operational safety of the diesel and gas engines at the heart of MAN Diesel & Turbo power plants. Robustness, reliability, ease of operation and maintenance are the preconditions for availabilities above 8,000 hours per year.
An efficient, low emission power plant delivered quickly and at an attractive price – the ultimate combination

Welcome to MAN Diesel & Turbo’s modularised, state of the art gas power plant.

Equipped with MAN V35/44G or MAN V35/44G TS engines in a Combined Heat and Power (CHP) setup, this plant can generate electricity, heat and steam with a total efficiency of up to 95%*. To maximize efficiency, heat from cooling water, lubrication oil, exhaust gas and even the power house can be used to develop an individual solution for each requirement.

The power plant complies with a wide range of emissions legislations including TA-Luft and IED regulations valid for Europe from 2017. This is achieved through an integrated catalyst that reduces both NOx and CO.

The power plant is based on a modular concept therefore it can be easily adapted to the individual power plant requirements. The modular concept allows MAN Diesel & Turbo to offer fast delivery time and attractive pricing.

This unique combination of attributes means MAN Diesel & Turbo gas power plants offer attractive solutions for base and peaking operations in regulated grids; for isolated power plants in island operations as well for industrial customers with captive CHP needs.

*Acc. to ISO 3046-1, for 60°C/120°C flow temperature of district heating system, without own consumption
MAN V35/44G TS CHP plant module
The MAN two-stage gas engines – Pace setters in power output and efficiency

Gas engines are claiming an increasing share of the market for electrical power generation: Thanks to their operational flexibility, clean combustion, high efficiencies, low emissions and the attractive price of natural gas.

To further strengthen our position in this segment, MAN Diesel & Turbo introduces the latest improvements in its gas engine portfolio to the market: Our both 2-stage gas engines; the MAN V35/44G TS and the MAN V51/60G TS with their superior efficiency.

The MAN V35/44G TS and the MAN V51/60G TS are spark ignited two-stage turbocharged gas engines. The MAN V35/44G TS is available in 12V and 20V-cylinder versions with outputs of $7.4 \text{ MW}_{\text{mech}}$ and $12.4 \text{ MW}_{\text{mech}}$ whereas the MAN V51/60G TS can be delivered in 18-cylinder versions with outputs of $18.9 \text{ MW}_{\text{mech}}$ and $20.7 \text{ MW}_{\text{mech}}$. In single cycle applications, the MAN V35/44G TS reaches a mechanical efficiency up to 51.1 \%.

The gas engines are optimized for stationary power needs up to 300 MW. If required, heat recovery systems or combined cycle solutions can be implemented.

The idea behind two-stage turbocharging is simple: two turbochargers upstream from the engine, one after the other. This results in significant increase in efficiency and output.

For this concept, we use two strong in-house products: The continuous improvement of our well-known gas engines, the MAN V35/44G and the MAN V51/60G, combined with MAN designed and manufactured two-stage turbocharger unit.
The turbochargers are the core of this innovation and MAN Diesel & Turbo is the only engine manufacturer that designs and builds its own turbochargers for large engines. This enables us to achieve the perfect matching of engine and turbochargers leading to the superior performance of the MAN V35/44G TS and MAN V51/60G TS.

Further major benefits of MAN two-stage gas engines:
- Highest single cycle efficiency in the market
- Highest power output in the market
- Short start-up and power ramp up times
- Excellent load response
- Easy maintenance/high availability
- If optimized for heat utilization (CHP): > 90% total efficiency
BHKW VW Brunswick, Germany

The highly efficient gas engine MAN 20V35/44G in CHP (combined heat and power) application delivers about 10 MW electrical output and 9 MW thermal energy. The power plant covers the base load demand of heat and electricity of the Volkswagen factory in Brunswick, Germany in an annual use efficiency of 80%. The plant emission limits are according the strict TA-Luft regulation and common European standards. This means a great improvement: compared to the before used energy supply, 90,000 tons of CO₂ can be saved per year. The CHP power plant reaches an efficiency level of 84% and is capable to react flexibly on the variable load requirements of the Volkswagen site.
The MAN scope included engineering procurement and construction services comprising beside the Genset with their auxiliary modules all process relevant equipment and systems up to the tie-in points of the VW Factory. Furthermore, MAN provided the full service of the commissioning for the power supply and above all the very challenging heat system in combination with the back-up heat boilers and the heat supply- control system of the factory.

<table>
<thead>
<tr>
<th>Customer:</th>
<th>VW Kraftwerk GmbH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Type:</td>
<td>Industry</td>
</tr>
<tr>
<td>Application:</td>
<td>Combined heat and power for own consumption &amp; grid</td>
</tr>
<tr>
<td>Location of Installation:</td>
<td>Brunswick, Germany</td>
</tr>
<tr>
<td>Engine Type:</td>
<td>1 x MAN 20V35/44G</td>
</tr>
<tr>
<td>Fuel:</td>
<td>Gas</td>
</tr>
<tr>
<td>Output:</td>
<td>10.4 MW&lt;sub&gt;e&lt;/sub&gt; &amp; 9.1 MW&lt;sub&gt;therm&lt;/sub&gt;</td>
</tr>
<tr>
<td>Commercial Operation:</td>
<td>07/2015</td>
</tr>
<tr>
<td>MAN’s work scope:</td>
<td>EPC without civil (Engineering, procurement, construction and commissioning services)</td>
</tr>
</tbody>
</table>
Thika, Kenya

The independent energy production company Thika Power Ltd., a subsidiary of Matelec Group of Lebanon, has selected MAN Diesel & Turbo to build a diesel power plant in Thika City, situated near Kenya’s capital city, Nairobi. The plant, which supplies energy to Kenya Power & Lighting Co., was commissioned in Summer 2013 and full handed in the beginning of 2014. MAN supplies, within an EPC-Consortium, the equipment, engineering, plant design, supervision of installation work and commissioning services for this engine based combined cycle power plant.

The Thika Power plant is the first on the African continent which is using an engine with combined cycle technology – delivered by MAN Diesel & Turbo. Five MAN 18V48/60 four-stroke engines are at its heart producing electricity,
whereas the waste heat is used to drive a MAN MARC®2 steam turbine which generates a further 7.7 MW of electricity. The combination of diesel engines and a steam turbine improves the efficiency of the power plant, producing 9.5 percent more electricity from the same fuel consumption. The power plant produces a total output of 88 MW.

<table>
<thead>
<tr>
<th>Customer:</th>
<th>Thika Power Limited</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Type:</td>
<td>IPP</td>
</tr>
<tr>
<td>Application:</td>
<td>Combined cycle; base load power for grid</td>
</tr>
<tr>
<td>Location of Installation:</td>
<td>Thika, Kenya</td>
</tr>
<tr>
<td>Engine Type:</td>
<td>5 x MAN 18V48/60 + 1 x MAN MARC®2 steam turbine</td>
</tr>
<tr>
<td>Fuel:</td>
<td>HFO</td>
</tr>
<tr>
<td>Output:</td>
<td>88 MW</td>
</tr>
<tr>
<td>Commercial Operation:</td>
<td>09/2014</td>
</tr>
<tr>
<td>MAN’s work scope:</td>
<td>EPC: Equipment, engineering, supervision of installation work and commissioning</td>
</tr>
</tbody>
</table>
Belawan, Indonesia

MAN Diesel & Turbo equipped a newly constructed power plant in Belawan, Indonesia’s third-largest city in the north of Sumatra. This plant is equipped with four of the world’s most powerful four stroke engines, the MAN 18V48/60 TS, operating on heavy fuel oil and provides a capacity of 77 MW.

The MAN 18V48/60 TS achieves an outstanding level of efficiency through the principle of two-stage turbocharging, where a low-pressure and a high-pressure turbocharger are arranged in series. This two-stage turbocharging delivers vastly more charge air than conventional turbochargers, allowing more flexible use of the engine. Depending on its operating
mode, fuel consumption can be reduced by up to 3.5 percent at 100% load. Alternatively, the engine’s power can be boosted by 14 percent – while using the same amount of fuel and generating 20 percent fewer nitrous oxide emissions. This makes the MAN 18V48/60 TS one of the most efficient and cleanest engines in its class.

<table>
<thead>
<tr>
<th>Customer:</th>
<th>PT Berkat Bima Sentana</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Type:</td>
<td>IPP</td>
</tr>
<tr>
<td>Application:</td>
<td>Base load power for grid</td>
</tr>
<tr>
<td>Location of Installation:</td>
<td>Medan, Indonesia</td>
</tr>
<tr>
<td>Engine Type:</td>
<td>4 x MAN 18V48/60 TS</td>
</tr>
<tr>
<td>Fuel:</td>
<td>HFO</td>
</tr>
<tr>
<td>Output:</td>
<td>77 MW</td>
</tr>
<tr>
<td>Commercial Operation:</td>
<td>08/2013</td>
</tr>
<tr>
<td>MAN’s work scope:</td>
<td>Gensets plus mechanical and electrical components</td>
</tr>
</tbody>
</table>
Power Product Overview

Engineering the Future – since 1758.
MAN Diesel & Turbo
Liquid Fuel Engines

Large liquid fuel engines from MAN Diesel & Turbo are the most fuel efficient combustion engines available. With mechanical efficiencies up to 49.4%, they offer an excellent fuel economy as a firm basis for low emissions. Thus, they are an ideal solution for electricity generation at base load, peak load and self-supply.

By using liquid fuel stored in a tank farm on site, liquid fuel power plants are independent of fixed infrastructures, such as gas pipelines, and less affected by fuel supply fluctuations. In terms of economic considerations, the heavy fuel oil (HFO) commonly used in larger liquid fuel engine power plants is traditionally cheaper than distillate diesel fuels.

Fossil fuels usable in liquid fuel engines from MAN Diesel & Turbo include crude oil, heavy (residual) fuels and distillate diesel oils. Renewable fuels include vegetable oils, animal fats and second-generation bio fuels (such as biomass-to-liquid fuels).
Gas Fuel & Dual Fuel Engines

Gas is an increasingly popular option for power generation. One reason is the growing availability via gas grids or LNG transport by ships. Another is its value for money, as gas is generally cheaper than liquid fuels. A key advantage of gas engine power plants is their flexibility: they can be activated rapidly, making them an excellent source of peak or base load power. Additionally, gas has a very low environmental impact. Low emissions and high efficiency in energy productions play a key role in investment decisions.

MAN Diesel & Turbo designs and produces spark fired gas engines which make it possible to exploit all the benefits of gas in power generation. Our dual fuel engines offer users the possibility of switching smoothly and seamlessly from gas to liquid fuel operation (and vice versa).
Power Product Overview

Two-stroke licence business

Speed r/min | Engine type
-------------|------------------
102.9-103.4K | 98MC-S
102.9-109.1K | 90MC-S
102.9-103.4K | K80MC-S
107.1-109.1K | 80MC-S
150.0-150.0K | 60MC-S
176.5-180.0K | 50MC-S
211.8-214.3K | L35MC-S

Power, speed and gross efficiency of the ME-S, ME-GI-S and ME-LGI-S type engines are the same as for the corresponding MC-S engines. Please contact MAN Diesel & Turbo in Copenhagen or the engine builder for technical engine data for your specific project, including project specific emission requirements.

Technical data

All engine types from 35 to 98-bore mentioned in the programme are available as dual fuel engines under the designation ME-GI-S or ME-LGI-S. Power, speed and gross efficiency of the ME-S, ME-GI-S and ME-LGI-S type engines are the same as for the corresponding MC-S engines. Please contact MAN Diesel & Turbo in Copenhagen or the engine builder for technical engine data for your specific project, including project specific emission requirements.
Engine Design

- **MC-S**
  Two-stroke diesel engines equipped with a mechanically driven camshaft controlling the fuel oil pumps and exhaust valves. These engines operate on liquid fuels only.

- **ME-S**
  Two-stroke diesel engines designed with electronic control of the combustion process, i.e. fuel injection timing, exhaust valve actuation, starting valves and cylinder lubrication. These engines operate on liquid fuels only.

- **ME-GI-S**
  Dual fuel engines operating on high flash point gaseous fuel oil and pilot oil. These engines operate on any high-calorific gas that can be compressed to 300 or 400 bar at 45°C and be injected into the combustion chamber in a single phase.

- **ME-LGI-S**
  Dual fuel engines operating on low flash point liquid gas fuels and pilot oil.
MAN Diesel & Turbo covers the specific needs of the power generation industry with its comprehensive range of modularized, but also custom made equipment including industrial gas turbines from 6–13 MW and steam turbines from 1 to 160 MW.

Our steam turbines serve combined heat and power (CHP), waste-to-energy (WtE), engine combined cycle (CC)*, concentrated solar power (CSP), biomass and pulp & paper applications.

MAN Diesel & Turbo gas turbines are suitable for combined cycle, cogeneration (process steam, district heating, cooling), base load, peak shaving and emergency.

*for more details concerning CC, please see in chapter “Power Plant Solutions” page 64
MAN Diesel & Turbo offers various turbine models and sizes such as condensing type turbines, backpressure turbines and admission/extraction turbines.

**Special purpose steam turbines for power generation (1–160 MW)**

<table>
<thead>
<tr>
<th>Power range</th>
<th>Max. steam inlet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>1–160 MW</td>
</tr>
<tr>
<td></td>
<td>140 bar (2,031 psi), 540°C (1,004°F)</td>
</tr>
</tbody>
</table>

**MARC® steam turbines for power generation (1–40 MW, non API)**

<table>
<thead>
<tr>
<th>Power range</th>
<th>Max. steam inlet</th>
</tr>
</thead>
<tbody>
<tr>
<td>MARC® 1</td>
<td>≤4.5 MW</td>
</tr>
<tr>
<td></td>
<td>65 bar (870 psi), 480°C (896°F)</td>
</tr>
<tr>
<td>MARC® 2</td>
<td>4–10 MW</td>
</tr>
<tr>
<td></td>
<td>100 bar (1,450 psi), 520°C (968°F)</td>
</tr>
<tr>
<td>MARC® 4</td>
<td>10–20 MW</td>
</tr>
<tr>
<td></td>
<td>110 bar (1,885 psi), 520°C (968°F)</td>
</tr>
<tr>
<td>MARC® 6</td>
<td>15–40 MW</td>
</tr>
<tr>
<td></td>
<td>120 bar (1,740 psi), 530°C (986°F)</td>
</tr>
</tbody>
</table>
Power Product Overview
Gas turbines

The gas turbine portfolio is comprised of the mature THM Gas Turbine family in the 9-13 MW range as well as a newly developed gas turbine MGT6100 with power outputs of up to 7 MW.

<table>
<thead>
<tr>
<th>THM Model</th>
<th>1304–10 N</th>
<th>1304–12 N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator Drive (at generator terminals)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Output</td>
<td>kWe</td>
<td>10,080</td>
</tr>
<tr>
<td>Efficiency</td>
<td>%</td>
<td>29.2</td>
</tr>
<tr>
<td>Heat Rate</td>
<td>kJ/kWh</td>
<td>12,330</td>
</tr>
<tr>
<td>Exhaust Gas Data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exhaust gas temperature</td>
<td>°C / °F</td>
<td>490 / 914</td>
</tr>
<tr>
<td>Exhaust gas flow</td>
<td>kg/s / lb/s</td>
<td>46.5 / 103</td>
</tr>
<tr>
<td>Emissions (ref. to 15% O₂ dry)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOx</td>
<td>mg/Nm³</td>
<td>50</td>
</tr>
<tr>
<td>CO</td>
<td>mg/Nm³</td>
<td>&lt;10</td>
</tr>
</tbody>
</table>

*for gas turbines equipped with DLE Combustion System
### MGT6100 Generator Drive

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Output</td>
<td>6.63 MW</td>
</tr>
<tr>
<td>Efficiency</td>
<td>32.2%</td>
</tr>
<tr>
<td>Heat Rate</td>
<td>11,190 kJ/kWh</td>
</tr>
<tr>
<td>Exhaust gas flow</td>
<td>26.2 kg/s</td>
</tr>
<tr>
<td>Exhaust gas temperature</td>
<td>505 °C</td>
</tr>
<tr>
<td>Fuel flow</td>
<td>1,540 kg/h (LHV = 48 MJ/kg)</td>
</tr>
<tr>
<td>Heat input</td>
<td>20.6 MJ/s</td>
</tr>
</tbody>
</table>

### Emissions (ref. to 15% O₂ dry)

<table>
<thead>
<tr>
<th>Emission</th>
<th>mg/Nm³</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>CO</td>
<td></td>
<td>&lt;30</td>
</tr>
</tbody>
</table>

Load Range: 50–100

Above data valid under ISO 3977 conditions
Power Product Overview
Scope of supply

MAN Diesel & Turbo is your reliable partner in all aspects of power plant construction. We offer the complete range of engine-based power plant equipment. The customer can choose from our wide array of products based on specific needs: from single engine with or without mechanical and electrical auxiliaries to EPC power plants ready for operation.

This includes:

- **Services**
  Services are includable in all of our scopes. The range of the different services vary depending on the selected scope of supply. For information on our services, please refer to page 131.

- **Engine**
  This scope includes the engine configured, to your individual needs and complete with the engine control system SaCoS.

- **Genset**
  This scope includes the engine and alternator, as well as connection between the engine and alternator, the base frame and an engine gallery for service and maintenance.

- **Basic ES (Equipment Supply)**
  This scope includes the Genset(s) plus the engine related mechanical auxiliaries. The Genset control and interface panel can be included as an option.
- **Extended ES & EC (Equipment Supply & Electric and Control)**
  This scope includes the Basic ES plus the plant-related mechanical auxiliaries. This includes the MV and LV equipment as well as the station transformers.

- **Basic EPC (Engineering, Procurement and Construction)**
  This scope includes the Extended ES & EC plus engineering and procurement for the entire mechanical and electrical equipment of the power plant. This includes cable routing, HV equipment, special mechanical/process solutions, 3D-planning, piping and steelworks.

- **Extended EPC**
  This scope includes a complete power plant, ready for operation. This includes all engineering services as well as project management, site management, supervision and commissioning.

For civil activities and erection on site construction, we work together with reliable local partners.
Power Plant Solutions

Definitions

MAN four-stroke diesel engines are designed to provide optimum fuel flexibility. The engines are the ideal source of power, whether you want to build a gas power plant, an oil power plant, or even a green power plant, burning liquid biofuels.

Liquid fuels: Diesel, HFO, liquid biofuel and crude oil
Gaseous fuels: Natural gas

For further information regarding the possibility of using these fuels according to particular specifications, please contact MAN Diesel and Turbo.

Ambient conditions
Under consideration of a minimum relative air humidity, the stated consumption figures refer to the following reference conditions according to ISO 3046-1:

- Ambient air pressure 1,000 mbar
- Ambient air temperature 25°C (77°F)
- Charge air temperature According to engine type, corresponding to 25°C cooling water temperature before charge air cooler

Engine and Genset power
The engine and Genset power is stated in kW. Ratings are given according to ISO 3046-1:2002. Figures for gas engines refer to natural gas with a methane number ≥ 80 unless otherwise stated. Electric power calculations are based on nominal alternator efficiency according to IEC 60034 in the corresponding power range and a power factor of 1.0.
Heat rate
The figures are given for 100% load and without engine driven pumps. Attached pumps will require additional fuel consumption. The tolerance for guarantee is +5% as per ISO 3046. Please note that the additions to fuel consumption must be considered before the tolerance for guarantee is taken into account. Unless otherwise specifically stated, figures for liquid fuel operation are based on HFO. Basis for reference conditions, see section: “Ambient condition”.

Conversions to different heat rates and efficiency units:
- from kJ/kWh to BTU/KWh → with factor 0.9478
- from kJ/kWh to g/KWh → with factor 1/LHV (acc. to ISO 3046-1:2002 LHV: 42.7 MJ/kg)
- from kJ/kWh to efficiency in % → with factor [(1/3600)-1 *100]

Lube oil consumption
Figures for specific lube oil consumption are specified with a tolerance of 20%.

Compliance with emission guidelines and legislation
The relevant emission guidelines, for which the listed performances are valid, are presented with the relevant performance data table for each engine. Unless otherwise stated, the relevant emissions apply to World Bank 2007/2008 for liquid fuel power plants and to World Bank 2007/2008 or German TA-Luft for gas fuel power plants.

Dimensions and masses
The masses stated correspond to the complete unit (including alternator). The total weight varies depending on the alternator make. All masses given are without lube oil and cooling water filling. Dimensions and weights given are for guidance only and are subject to change without notice. The length of the Genset unit depends on the alternator make.

Please contact MAN Diesel & Turbo if:
- higher requirements for emissions levels, such as the EU-Directive, are in effect
- special requirements of the plant for heat recovery exist
- special requirements on media temperatures of the engine exist
Power Plant Solutions
HFO/diesel fuel power plants

MAN engines are capable of running on the widest range of liquid fuels. The engines for HFO and diesel fuel power plants have an extraordinary robust design that makes them highly reliable.

Benefits:
- Efficiency: highly efficient combustion engines available – with mechanical efficiencies up to 49.4%
- Low emissions, fulfillment of worldwide environmental regulations; below World Bank limits
- High reliability
- Ease of maintenance: longest safe interval between major overhauls and minimal daily maintenance
- High operational flexibility, from standby to base load
- Reliable power supply under all conditions – insensitivity to hot and high-altitude locations
- Power range from 428 up to 21,103 kWₑ/unit
- Power plants with an output of more than 300 MWₑ
- Modular concept for flexible capacity extension
- Long lifetime
Liquid Fuel Specifications

Diesel fuel oil

Diesel fuel oil (DFO) – based on ISO F DMB. (ISO 8217 : 2012). The usability of DFO depends on its conformity with the key properties listed below:

- Density at 15°C < 900 kg/m³
- Kinematic viscosity at 40°C 2.0 … 11 mm²/s
- Pour point, winter quality < 0 °C
- Pour point, summer quality < 6 °C
- Flash point (Pensky Martens) > 60 °C
- Total sediment fraction < 0.10% wt.
- Water content < 0.3% vol.
- Sulphur content < 2.0% wt.
- Ash content < 0.01% wt.
- Coke residue (MCR) < 0.3% wt.
- Cetane number or cetane index > 35
- Hydrogen sulphide < 2 mg/kg
- Total acid number < 0.5 mg KOH/g
- Oxidation stability < 25 g/m³
- Lubricity (wear scar diameter) < 520 µm

Choloma III Power Plant Honduras, 14 × MAN 18V48/60
Heavy fuel oil

The HFO specified in the following chapters represent the fuel on which diesel engines can operate satisfactorily.

Fuel system related characteristic values

The fuel system of the plant is designed to operate on the basis of the following fuel oil specifications based on ISO 8217:2012:

- Viscosity (at 50°C) max. 700 mm²/s
- Density (at 15°C) max. 1010 kg/m³
- Sulphur content max. 4.5%-wt.
- Ash content max. 0.015%-wt.
- Flash point max. 60 °C
- Pour point max. 30 °C
- Coke residue (Conradson) max. 20% wt.
- Vanadium max. 450 mg/kg
- Water max. 0.5% vol.
- Sediment (potential) max. 0.1% wt.
- Aluminium and silicon (total) max. 60 mg/kg
- Total acid number max. 2.5 mg KOH/g
- Hydrogen sulphide max. 2 mg/kg
- Asphaltene content max. 2/3 of coke residue % wt (Conradson)
- Sodium sodium < 1/3 vanadium, sodium < 100 mg/kg
- CCAI number max. 870

The current fuel oil characteristics are not sufficient for estimating the combustion properties of the fuel oil. This means that service results depend on oil properties that cannot be known beforehand. This especially applies to the tendency of the oil to form deposits in the combustion chamber, gas passages and turbines. It may, therefore, be necessary to rule out some oils that cause difficulties.

The fuel must be free of admixtures not based on mineral oil, e.g. coal oil or vegetable oils, free of tar oil and lubricating oil, and any chemical waste, solvents and polymers.

Treated heavy fuel oil at engine inlet

- Inorganic foreign particles < 5 µm and < 20 mg/kg
- Aluminium + silicon content < 15 mg/kg
- Water < 0.2% vol.
Power Plant Solutions
HFO/diesel fuel power plants

- MAN 51/60
- MAN 48/60TS
- MAN 48/60
- MAN 32/44CR TS
- MAN 32/44CR
- MAN 28/32S
- MAN 27/38S
- MAN 23/30S
- MAN 21/31S
- MAN 16/24S
**MAN 51/60**

<table>
<thead>
<tr>
<th>Bore 510 mm, Stroke 600 mm</th>
<th>9L</th>
<th>12V</th>
<th>14V</th>
<th>18V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed</td>
<td>rpm</td>
<td>500/514</td>
<td>500/514</td>
<td>500/514</td>
</tr>
<tr>
<td>Frequency</td>
<td>Hz</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
</tr>
<tr>
<td>Electr. Genset power</td>
<td>kW</td>
<td>9.290</td>
<td>12,411</td>
<td>14,480</td>
</tr>
</tbody>
</table>

**Electr. Genset Heat Rate at 100% load**

<table>
<thead>
<tr>
<th>Liquid fuel (WB2007/2008)</th>
<th>kJ/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7,602</td>
</tr>
<tr>
<td></td>
<td>7,543</td>
</tr>
<tr>
<td></td>
<td>7,543</td>
</tr>
<tr>
<td></td>
<td>7,528</td>
</tr>
</tbody>
</table>

**Lube Oil Consumption**

<table>
<thead>
<tr>
<th>kg/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.8</td>
</tr>
<tr>
<td>5.0</td>
</tr>
<tr>
<td>5.9</td>
</tr>
<tr>
<td>7.6</td>
</tr>
</tbody>
</table>

**Dimensions**

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>mm</th>
<th>9L</th>
<th>12V</th>
<th>14V</th>
<th>18V</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>10,545</td>
<td>9,835</td>
<td>10,835</td>
<td>13,148</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>4,805</td>
<td>4,950</td>
<td>5,150</td>
<td>5,410</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>15,350</td>
<td>14,785</td>
<td>15,985</td>
<td>18,558</td>
</tr>
<tr>
<td>W</td>
<td></td>
<td>2,970</td>
<td>4,700</td>
<td>4,700</td>
<td>4,700</td>
</tr>
<tr>
<td>H</td>
<td></td>
<td>6,030</td>
<td>6,530</td>
<td>6,530</td>
<td>6,530</td>
</tr>
<tr>
<td>Genset dry mass</td>
<td>t</td>
<td>225</td>
<td>276</td>
<td>318</td>
<td>381</td>
</tr>
</tbody>
</table>

Weights and dimensions are subject to final application

The 51/60 liquid fuel engine is especially designed for a later upgrade to a 51/60DF dual fuel engine or 51/60G gas engine. Therefore this engine is designated for power plants running initially on liquid fuel only, before gas is available. The engine is optimized for pure liquid fuel operation which leads to a significant reduction in SFOC compared to the 51/60DF in liquid mode.
MAN 48/60TS

Bore 480 mm, Stroke 600 mm

<table>
<thead>
<tr>
<th>Operation mode</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed rpm</td>
<td>500/514</td>
<td>500/514</td>
<td>500/514</td>
</tr>
<tr>
<td>Frequency Hz</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
</tr>
<tr>
<td>Electr. Genset power kW</td>
<td>18,654</td>
<td>19,543</td>
<td>21,319</td>
</tr>
</tbody>
</table>

Electr. Genset heat rate at 100% load

| World Bank 2007/2008 kJ/kWh | 7,419 | 7,463 | 7,678 |

Lube oil consumption kg/h

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.5</td>
<td>9.9</td>
<td>10.8</td>
<td></td>
</tr>
</tbody>
</table>

Dimensions

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Unit</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>mm</td>
<td>13,148</td>
<td>13,148</td>
<td>13,148</td>
</tr>
<tr>
<td>B</td>
<td>mm</td>
<td>5,410</td>
<td>5,410</td>
<td>5,410</td>
</tr>
<tr>
<td>C</td>
<td>mm</td>
<td>24,510</td>
<td>24,510</td>
<td>24,510</td>
</tr>
<tr>
<td>W</td>
<td>mm</td>
<td>4,700</td>
<td>4,700</td>
<td>4,700</td>
</tr>
<tr>
<td>H</td>
<td>mm</td>
<td>9,023</td>
<td>9,023</td>
<td>9,023</td>
</tr>
<tr>
<td>Genset dry mass</td>
<td>t</td>
<td>407</td>
<td>407</td>
<td>407</td>
</tr>
</tbody>
</table>

Weights and dimensions are subject to final application
**MAN 48/60**

**Bore 480 mm, Stroke 600 mm**

<table>
<thead>
<tr>
<th></th>
<th>12V</th>
<th>18V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed</td>
<td>rpm</td>
<td>500/514</td>
</tr>
<tr>
<td>Frequency</td>
<td>Hz</td>
<td>50/60</td>
</tr>
<tr>
<td>Electr. Genset power</td>
<td>kW</td>
<td>12,411</td>
</tr>
</tbody>
</table>

**Electr. Genset heat rate at 100% load**

<table>
<thead>
<tr>
<th></th>
<th>12V</th>
<th>18V</th>
</tr>
</thead>
<tbody>
<tr>
<td>World Bank 1998</td>
<td>kJ/kWh</td>
<td>7,543</td>
</tr>
<tr>
<td>World Bank 2007/2008</td>
<td>kJ/kWh</td>
<td>7,630</td>
</tr>
</tbody>
</table>

**Lube oil consumption**

<table>
<thead>
<tr>
<th></th>
<th>12V</th>
<th>18V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg/h</td>
<td>6.3</td>
</tr>
</tbody>
</table>

*Engine also available with two-stage turbocharging, please see 48/60TS*

**Dimensions**

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>9,835</th>
<th>13,148</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>4,950</td>
<td>5,410</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>14,785</td>
<td>18,568</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>4,700</td>
<td>4,700</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>6,250</td>
<td>6,530</td>
</tr>
<tr>
<td></td>
<td>Genset dry mass</td>
<td>273</td>
<td>375</td>
</tr>
</tbody>
</table>

*Weights and dimensions are subject to final application*
### MAN 32/44CR TS

**Bore 320 mm, Stroke 440 mm**

<table>
<thead>
<tr>
<th>Operational setup</th>
<th>1</th>
<th>2</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed rpm</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
</tr>
<tr>
<td>Frequency Hz</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
</tr>
<tr>
<td>Electr. Genset power kW</td>
<td>7,063</td>
<td>7,534</td>
<td>11,796</td>
<td>12,608</td>
</tr>
</tbody>
</table>

**Electr. Genset heat rate at 100% load**

| World Bank 2007/2008 kW/kWh | 7,422 | 7,444 | 7,406 | 7,413 |

**Lube oil consumption kg/h**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>2.4</th>
<th>2.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.8</td>
<td>2.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Dimensions**

<table>
<thead>
<tr>
<th>A</th>
<th>mm</th>
<th>9,335</th>
<th>11,765</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>mm</td>
<td>3,790</td>
<td>3,945</td>
</tr>
<tr>
<td>C</td>
<td>mm</td>
<td>13,125</td>
<td>15,710</td>
</tr>
<tr>
<td>W</td>
<td>mm</td>
<td>4,820</td>
<td>4,820</td>
</tr>
<tr>
<td>H</td>
<td>mm</td>
<td>5,755</td>
<td>5,755</td>
</tr>
<tr>
<td>Genset dry mass t</td>
<td>147</td>
<td>190</td>
<td></td>
</tr>
</tbody>
</table>

*Weights and dimensions are subject to final application*
**MAN 32/44CR**

**Bore 320 mm, Stroke 440 mm**

<table>
<thead>
<tr>
<th></th>
<th>12V</th>
<th>20V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed</td>
<td>750/720 rpm</td>
<td>750/720 rpm</td>
</tr>
<tr>
<td>Frequency</td>
<td>50/60 Hz</td>
<td>50/60 Hz</td>
</tr>
<tr>
<td>Electr. Genset power</td>
<td>7,063/6,828 kW</td>
<td>11,796/11,403 kW</td>
</tr>
</tbody>
</table>

**Electr. Genset heat rate at 100% load**

<table>
<thead>
<tr>
<th></th>
<th>World Bank 2007/2008 kJ/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7,683</td>
</tr>
</tbody>
</table>

**Lube oil consumption**

|                      | 3.6/3.5 kg/h | 6.0/5.8 kg/h |

**Dimensions**

<table>
<thead>
<tr>
<th></th>
<th>A (mm)</th>
<th>B (mm)</th>
<th>C (mm)</th>
<th>W (mm)</th>
<th>H (mm)</th>
<th>Genset dry mass (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12V</td>
<td>7,055</td>
<td>4,376</td>
<td>11,431</td>
<td>4,200</td>
<td>5,000</td>
<td>117</td>
</tr>
<tr>
<td>20V</td>
<td>9,575</td>
<td>4,376</td>
<td>13,951</td>
<td>4,260</td>
<td>5,200</td>
<td>172</td>
</tr>
</tbody>
</table>

*Weights and dimensions are subject to final application*
### MAN 28/32S

**Bore 280 mm, Stroke 320 mm**

<table>
<thead>
<tr>
<th></th>
<th>16V</th>
<th>18V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed</td>
<td>rpm</td>
<td>750/720</td>
</tr>
<tr>
<td>Frequency</td>
<td>Hz</td>
<td>50/60</td>
</tr>
<tr>
<td>Electr. Genset power</td>
<td>kW</td>
<td>3,674/3,517</td>
</tr>
</tbody>
</table>

**Electr. Genset Heat Rate at 100% load**

| World Bank 2007/2008 | kJ/kWh | 8,142/8,134 | 8,142/8,134 |

**Lube Oil Consumption**

|                      | kg/h     | 1.5-3.0    | 1.6-3.4    |

**Dimensions**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>A</th>
<th>6,116</th>
<th>6,626</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>3,822</td>
<td>4,081</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>9,938</td>
<td>10,707</td>
</tr>
<tr>
<td></td>
<td></td>
<td>W</td>
<td>2,470</td>
<td>2,470</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H</td>
<td>3,574</td>
<td>3,574</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Genset dry mass</td>
<td>t</td>
<td>62.2</td>
</tr>
</tbody>
</table>

*Weights and dimensions are subject to final application*
## MAN 28/32S

<table>
<thead>
<tr>
<th>Bore 280 mm, Stroke 320 mm</th>
<th>5L</th>
<th>6L</th>
<th>7L</th>
<th>8L</th>
<th>9L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed (rpm)</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
</tr>
<tr>
<td>Frequency (Hz)</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
</tr>
<tr>
<td>Electr. Genset power (kW)</td>
<td>1,056/1,008</td>
<td>1,267/1,210</td>
<td>1,478/1,411</td>
<td>1,707/1,630</td>
<td>1,921/1,833</td>
</tr>
</tbody>
</table>

### Electr. Genset Heat Rate at 100% load

| World Bank 2007/2008 (kJ/kWh) | 8,460/8,429 | 8,460/8,429 | 8,460/8,429 | 8,373/8,342 | 8,373/8,342 |

### Lube Oil Consumption (kg/h)

| 0.7-1.1 | 0.8-1.3 | 0.9-1.5 | 1.0-1.8 | 1.2-2.0 |

### Dimensions

<table>
<thead>
<tr>
<th>A (mm)</th>
<th>B (mm)</th>
<th>C (mm)</th>
<th>W (mm)</th>
<th>H (mm)</th>
<th>Genset dry mass (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,279</td>
<td>2,400</td>
<td>6,679</td>
<td>2,370</td>
<td>2,684</td>
<td>32.6</td>
</tr>
<tr>
<td>4,759</td>
<td>2,510</td>
<td>7,269</td>
<td>2,370</td>
<td>2,684</td>
<td>36.3</td>
</tr>
<tr>
<td>5,499</td>
<td>2,680</td>
<td>8,179</td>
<td>2,390</td>
<td>2,874</td>
<td>39.4</td>
</tr>
<tr>
<td>5,979</td>
<td>2,770</td>
<td>8,749</td>
<td>2,419</td>
<td>2,874</td>
<td>40.7</td>
</tr>
<tr>
<td>6,199</td>
<td>2,690</td>
<td>8,889</td>
<td>2,489</td>
<td>3,034</td>
<td>47.1</td>
</tr>
</tbody>
</table>

Weights and dimensions are subject to final application.

---

![Diagram of MAN 28/32S engine](image)
### MAN 27/38S

<table>
<thead>
<tr>
<th>Parameter</th>
<th>5L</th>
<th>6L</th>
<th>7L</th>
<th>8L</th>
<th>9L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bore 270 mm, Stroke 380 mm</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
</tr>
<tr>
<td>Engine speed rpm</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
</tr>
<tr>
<td>Frequency Hz</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
</tr>
<tr>
<td>Electr. Genset power kW</td>
<td>1,552/1,455</td>
<td>1,921</td>
<td>2,241</td>
<td>2,561</td>
<td>2,881</td>
</tr>
<tr>
<td>Electr. Genset Heat Rate at 100% load</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>World Bank 2007/2008 kJ/kWh</td>
<td>8,056/8,012</td>
<td>8,056/8,012</td>
<td>8,056/8,012</td>
<td>8,056/8,012</td>
<td>8,056/8,012</td>
</tr>
<tr>
<td>Lube Oil Consumption kg/h</td>
<td>0.7-1.3</td>
<td>0.8-1.6</td>
<td>0.9-1.8</td>
<td>1.1-2.1</td>
<td>1.2-2.4</td>
</tr>
<tr>
<td>Dimensions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A mm</td>
<td>4,346</td>
<td>4,791</td>
<td>5,236</td>
<td>5,681</td>
<td>6,126</td>
</tr>
<tr>
<td>B mm</td>
<td>2,486</td>
<td>2,766</td>
<td>2,766</td>
<td>2,986</td>
<td>2,986</td>
</tr>
<tr>
<td>C mm</td>
<td>6,832</td>
<td>7,557</td>
<td>8,002</td>
<td>8,667</td>
<td>9,112</td>
</tr>
<tr>
<td>W mm</td>
<td>2,293</td>
<td>2,293</td>
<td>2,420</td>
<td>2,420</td>
<td>2,420</td>
</tr>
<tr>
<td>H mm</td>
<td>3,712</td>
<td>3,712</td>
<td>3,899</td>
<td>3,899</td>
<td>3,899</td>
</tr>
<tr>
<td>Genset dry mass t</td>
<td>40.0</td>
<td>44.5</td>
<td>50.4</td>
<td>58.2</td>
<td>64.7</td>
</tr>
</tbody>
</table>

Weights and dimensions are subject to final application
### MAN 23/30S

#### Engine Specifications

<table>
<thead>
<tr>
<th></th>
<th>5L</th>
<th>6L</th>
<th>7L</th>
<th>8L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bore 225 mm, Stroke 300 mm</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Engine speed</strong> rpm</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
</tr>
<tr>
<td><strong>Frequency</strong> Hz</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
</tr>
<tr>
<td><strong>Electr. Genset power</strong> kW</td>
<td>710/682</td>
<td>852/818</td>
<td>995/954</td>
<td>1,137/1,091</td>
</tr>
</tbody>
</table>

#### Electr. Genset Heat Rate at 100% load

<table>
<thead>
<tr>
<th></th>
<th>5L</th>
<th>6L</th>
<th>7L</th>
<th>8L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>World Bank 2007/2008</strong> kJ/kWh</td>
<td>8,540/8,496</td>
<td>8,540/8,496</td>
<td>8,540/8,496</td>
<td>8,540/8,496</td>
</tr>
</tbody>
</table>

#### Engine Specifications

<table>
<thead>
<tr>
<th></th>
<th>6L</th>
<th>7L</th>
<th>8L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bore 225 mm, Stroke 300 mm</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Engine speed</strong> rpm</td>
<td>900</td>
<td>900</td>
<td>900</td>
</tr>
<tr>
<td><strong>Frequency</strong> Hz</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td><strong>Electr. Genset power</strong> kW</td>
<td>1,008</td>
<td>1,176</td>
<td>1,344</td>
</tr>
</tbody>
</table>

#### Electr. Genset Heat Rate at 100% load

<table>
<thead>
<tr>
<th></th>
<th>6L</th>
<th>7L</th>
<th>8L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Liquid fuel (WB2007/2008)</strong> kJ/kWh</td>
<td>8,584</td>
<td>8,584</td>
<td>8,584</td>
</tr>
</tbody>
</table>

#### Lube oil consumption kg/h

<table>
<thead>
<tr>
<th></th>
<th>5L</th>
<th>6L</th>
<th>7L</th>
<th>8L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>0.4-0.7</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>0.5-1.0</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>0.6-1.2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>0.7-1.4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Dimensions

<table>
<thead>
<tr>
<th>Cyl. No.</th>
<th>5L</th>
<th>6L</th>
<th>6L</th>
<th>7L</th>
<th>7L</th>
<th>8L</th>
<th>8L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>r/min</strong></td>
<td>720/750</td>
<td>720/750</td>
<td>900</td>
<td>720/750</td>
<td>900</td>
<td>720/750</td>
<td>900</td>
</tr>
<tr>
<td><strong>A</strong> mm</td>
<td>3,369</td>
<td>3,738</td>
<td>3,738</td>
<td>4,109</td>
<td>4,109</td>
<td>4,475</td>
<td>4,475</td>
</tr>
<tr>
<td><strong>B</strong> mm</td>
<td>2,155</td>
<td>2,265</td>
<td>2,265</td>
<td>2,395</td>
<td>2,395</td>
<td>2,480</td>
<td>2,340</td>
</tr>
<tr>
<td><strong>C</strong> mm</td>
<td>5,524</td>
<td>6,004</td>
<td>6,004</td>
<td>6,504</td>
<td>6,504</td>
<td>6,959</td>
<td>6,815</td>
</tr>
<tr>
<td><strong>W</strong> mm</td>
<td>1,690</td>
<td>1,690</td>
<td>1,768</td>
<td>1,715</td>
<td>1,888</td>
<td>1,715</td>
<td>1,888</td>
</tr>
<tr>
<td><strong>H</strong> mm</td>
<td>2,402</td>
<td>2,402</td>
<td>2,466</td>
<td>2,466</td>
<td>2,466</td>
<td>2,466</td>
<td>2,466</td>
</tr>
<tr>
<td><strong>Genset dry mass</strong> t</td>
<td>18.5</td>
<td>19.7</td>
<td>19.7</td>
<td>23.0</td>
<td>23.0</td>
<td>25.5</td>
<td>25.5</td>
</tr>
</tbody>
</table>

*Weights and dimensions are subject to final application.*

---

Power Plant Solutions 45
## MAN 21/31S

### Bore 210 mm, Stroke 310 mm

<table>
<thead>
<tr>
<th>Engine speed</th>
<th>5L</th>
<th>6L</th>
<th>7L</th>
<th>8L</th>
<th>9L</th>
</tr>
</thead>
<tbody>
<tr>
<td>rpm</td>
<td>1,000/900</td>
<td>1,000/900</td>
<td>1,000/900</td>
<td>1,000/900</td>
<td>1,000/900</td>
</tr>
<tr>
<td>Frequency</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
</tr>
<tr>
<td>Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electr. Genset power</td>
<td>kW</td>
<td>1,056</td>
<td>1,267</td>
<td>1,478</td>
<td>1,707</td>
</tr>
<tr>
<td>rpm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electr. Genset power</td>
<td>kW</td>
<td>1,056</td>
<td>1,267</td>
<td>1,478</td>
<td>1,707</td>
</tr>
</tbody>
</table>

### Electr. Genset Heat Rate at 100% load

<table>
<thead>
<tr>
<th>World Bank 2007/2008</th>
<th>kJ/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7,926/</td>
</tr>
<tr>
<td></td>
<td>7,917</td>
</tr>
</tbody>
</table>

### Lube Oil Consumption

<table>
<thead>
<tr>
<th>kg/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4-0.9</td>
</tr>
</tbody>
</table>

### Dimensions

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>W</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>3,959</td>
<td>2,041</td>
<td>6,000</td>
<td>2,110</td>
<td>3,070</td>
</tr>
<tr>
<td>4,314</td>
<td>2,036</td>
<td>6,350</td>
<td>2,110</td>
<td>3,070</td>
</tr>
<tr>
<td>4,669</td>
<td>1,971</td>
<td>6,640</td>
<td>2,110</td>
<td>3,170</td>
</tr>
<tr>
<td>5,024</td>
<td>2,266</td>
<td>7,290</td>
<td>2,180</td>
<td>3,170</td>
</tr>
<tr>
<td>5,379</td>
<td>2,741</td>
<td>8,120</td>
<td>2,180</td>
<td>3,170</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Genset dry mass</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23.0</td>
</tr>
</tbody>
</table>

Weights and dimensions are subject to final application.
MAN 16/24S

<table>
<thead>
<tr>
<th>Bore 160 mm, Stroke 240 mm</th>
<th>5L</th>
<th>6L</th>
<th>7L</th>
<th>8L</th>
<th>9L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed</td>
<td>rpm</td>
<td>1,000/1,200</td>
<td>1,000/1,200</td>
<td>1,000/1,200</td>
<td>1,000/1,200</td>
</tr>
<tr>
<td>Frequency</td>
<td>Hz</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
</tr>
<tr>
<td>Electr. Genset power</td>
<td>kW</td>
<td>432/480</td>
<td>547/634</td>
<td>638/739</td>
<td>730/845</td>
</tr>
</tbody>
</table>

Electr. Genset heat rate at 100% load

<table>
<thead>
<tr>
<th>World Bank 2007/2008</th>
<th>kB/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8,673/8,496</td>
</tr>
<tr>
<td></td>
<td>8,673/8,496</td>
</tr>
<tr>
<td></td>
<td>8,673/8,496</td>
</tr>
<tr>
<td></td>
<td>8,673/8,496</td>
</tr>
<tr>
<td></td>
<td>8,673/8,496</td>
</tr>
</tbody>
</table>

Lube oil consumption kg/h

<table>
<thead>
<tr>
<th></th>
<th>0.2-0.4</th>
<th>0.2-0.5</th>
<th>0.3-0.6</th>
<th>0.3-0.7</th>
<th>0.3-0.8</th>
</tr>
</thead>
</table>

Dimensions

<table>
<thead>
<tr>
<th>A</th>
<th>mm</th>
<th>2,807</th>
<th>3,082</th>
<th>3,557</th>
<th>3,832</th>
<th>4,107</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>mm</td>
<td>1,400</td>
<td>1,490</td>
<td>1,585</td>
<td>1,680</td>
<td>1,680</td>
</tr>
<tr>
<td>C</td>
<td>mm</td>
<td>4,207</td>
<td>4,572</td>
<td>5,142</td>
<td>5,512</td>
<td>5,787</td>
</tr>
<tr>
<td>W</td>
<td>mm</td>
<td>1,464</td>
<td>1,464</td>
<td>1,478</td>
<td>1,478</td>
<td>1,478</td>
</tr>
<tr>
<td>H</td>
<td>mm</td>
<td>2,337</td>
<td>2,337</td>
<td>2,415/2,337</td>
<td>2,415</td>
<td>2,415</td>
</tr>
<tr>
<td>Genset dry mass</td>
<td>t</td>
<td>9.8</td>
<td>10.5</td>
<td>12.0</td>
<td>13.7</td>
<td>14.5</td>
</tr>
</tbody>
</table>

Weights and dimensions are subject to final application
Gas engines – a popular choice
There are many good reasons why gas is an increasingly popular option for power generation. First of all, it is widely available via gas pipeline or LNG transport by ships, and it is generally cheaper than other fossil fuels. Secondly, a key advantage of engine-based gas power plants is their flexibility: they can be activated rapidly, making them an excellent source of peak load power. A third reason is the low environmental impact of gas. Low emissions and high efficiency in energy productions play a key role in investment decisions. Gas has a very low environmental impact, making it possible to meet strict emissions limits or take advantage of green power incentives. Because it burns so cleanly, gas power plants can be built close to urban areas. MAN Diesel & Turbo’s gas engines are a great choice to exploit all the benefits of gas in power generation.

Full fuel flexibility
Perhaps there is a need for electricity, however the gas needed is not yet reliably available. In this case, a power plant based on our dual fuel engines can be operated efficiently (and with reliable fuel availability by storing it in tanks) in liquid fuel mode. When gas is available, the plant can be switched to gas operation mode without retrofit requirements or other discontinuances. Dual fuel engines from MAN Diesel & Turbo allow you to switch smoothly and seamlessly from gaseous fuel to liquid fuel operation (and vice versa), giving you full fuel flexibility. They can operate on a wide range of available natural gases as well as liquid fuels. If one kind of fuel becomes difficult to obtain or prices move beyond reach, our dual fuel engines can simply be switched to another source of fuel. This allows you to profit from the benefits of gaseous fuels, even if the gas supply is not certain.
Benefits

- Operational flexibility: can be activated very rapidly and offers best performances
- High cost efficiency, environmentally friendly and clean: high efficiency and low emissions, e.g. low CO₂ emissions, low NOₓ emissions, almost no SOₓ emissions, almost no particle emissions
- Gas fuel costs are often lower than those burning liquid fossil fuels
- Retrofits: for several engine types, a conversion from operation with liquid fuel to operation with natural gas can be provided
- Fuel flexibility: our dual fuel power plants run on gas, diesel or HFO. If one fuel becomes difficult to obtain or gets too expensive, you can simply switch to another source of fuel
- Reliable output: dual fuel engines can be changed over from gas to liquid fuel operation and vice versa at full load without any output and speed fluctuations
- High and stable ratings in hot and high locations.

Natural Gas Fuel Specifications

<table>
<thead>
<tr>
<th>Natural gas</th>
<th>Unit</th>
<th>MAN 35/44DF</th>
<th>MAN 35/44G</th>
<th>MAN 35/44G TS</th>
<th>MAN 51/60DF</th>
<th>MAN 51/60G</th>
<th>MAN 51/60G TS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorific value (NCV)</td>
<td>Min.</td>
<td>MJ/Nm³</td>
<td>32.4</td>
<td>28.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methane number (MN)</td>
<td>-</td>
<td>-</td>
<td>≥ 70</td>
<td>≥ 80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen sulphide content (H₂S)</td>
<td>mg/Nm³</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total sulphur content</td>
<td>mg/Nm³</td>
<td>30</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle concentration</td>
<td>Max.</td>
<td>mg/Nm³</td>
<td>50</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle size</td>
<td>µm</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total fluorine (fluor gas) content</td>
<td>mg/Nm³</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total chlorine content</td>
<td>mg/Nm³</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nm³ corresponds to one cubic meter of gas at 0 °C and 101.325 kPa.
Gas qualities

- Natural Gas H [36/92]
- Natural Gas L [32/88]
- Biogas [23/133]
- Methane [36/100]
- Ethane C₂H₆ [65/44]
- Propane C₃H₈ [93/34]
- Ethene C₂H₄ [60/15]
- Propene C₃H₆ [88/19]
- Butane C₄H₁₀ [124/10]

Efficiency Reduction and possibly Power Derating

- Rated Power
- No operation

N m³ corresponds to one cubic meter of gas at 0 °C and 101.325 kPa

**MAN 18V51/60G**
Discover the power of MAN’s gas technology

Engineering the Future – since 1758.

MAN Diesel & Turbo
Power Plant Solutions
Gas fuel/DF engines

- MAN 51/60G TS
- MAN 51/60G
- MAN 51/60DF
- MAN 35/44G TS
- MAN 35/44G
- MAN 35/44DF
- MAN 28/32S DF
### MAN 51/60G TS

**Bore 510 mm, Stroke 600 mm**

#### Operational setup

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed rpm</td>
<td>500/514</td>
<td>500/514</td>
</tr>
<tr>
<td>Frequency Hz</td>
<td>50/60</td>
<td>50/60</td>
</tr>
<tr>
<td>Electr. Genset power kW_{el}</td>
<td>18,654</td>
<td>20,431</td>
</tr>
</tbody>
</table>

#### Electr. Genset heat rate at 100% load

| Optimized for power generation (TA Luft) | kW_{el} | 7,183 | 7,315 |
| Optimized for combined heat and power (TA Luft) | kW_{el} | – | 7,356 |

#### Lube oil consumption

|                     | kg/h | 6.6 | 7.2 |

#### Dimensions

<table>
<thead>
<tr>
<th>A</th>
<th>mm</th>
<th>13,148</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>mm</td>
<td>5,410</td>
</tr>
<tr>
<td>C</td>
<td>mm</td>
<td>24,510</td>
</tr>
<tr>
<td>W</td>
<td>mm</td>
<td>4,700</td>
</tr>
<tr>
<td>H</td>
<td>mm</td>
<td>9,023</td>
</tr>
<tr>
<td>Genset dry mass</td>
<td>t</td>
<td>407</td>
</tr>
</tbody>
</table>

*Weights and dimensions are subject to final application*
MAN 51/60G

Bore 510 mm, Stroke 600 mm

18V

Operational setup

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed (rpm)</td>
<td>500/514</td>
<td>500/514</td>
</tr>
<tr>
<td>Frequency (Hz)</td>
<td>50/60</td>
<td>50/60</td>
</tr>
<tr>
<td>Electr. Genset power (kW)</td>
<td>18,654</td>
<td>20,431</td>
</tr>
</tbody>
</table>

Electr. Genset heat rate at 100% load

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimized for power generation, (TA Luft)</td>
<td>7,244</td>
<td>7,376</td>
</tr>
<tr>
<td>Optimized for combined cycle, (TA Luft)</td>
<td>7,244</td>
<td>7,376</td>
</tr>
<tr>
<td>Optimized for combined heat and power (TA Luft)</td>
<td>–</td>
<td>7,416</td>
</tr>
</tbody>
</table>

Lube oil consumption (kg/h)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lube oil consumption</td>
<td>6.6</td>
<td>7.2</td>
</tr>
</tbody>
</table>

There is a special variant of the MAN 51/60 engine optimized for liquid fuel operation, offering easy modification to DF or G. For more information about this engine please see page 37.

Dimensions

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>mm</td>
<td>13,148</td>
</tr>
<tr>
<td>B</td>
<td>mm</td>
<td>5,410</td>
</tr>
<tr>
<td>C</td>
<td>mm</td>
<td>18,558</td>
</tr>
<tr>
<td>W</td>
<td>mm</td>
<td>4,700</td>
</tr>
<tr>
<td>H</td>
<td>mm</td>
<td>6,530</td>
</tr>
<tr>
<td>Genset dry mass</td>
<td>t</td>
<td>373</td>
</tr>
</tbody>
</table>

Power Plant Solutions  55
**MAN 51/60DF**

<table>
<thead>
<tr>
<th>Bore 510 mm, Stroke 600 mm</th>
<th>9L</th>
<th>12V</th>
<th>14V</th>
<th>18V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed</td>
<td>rpm</td>
<td>500/514</td>
<td>500/514</td>
<td>500/514</td>
</tr>
<tr>
<td>Frequency</td>
<td>Hz</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
</tr>
<tr>
<td>Electr. Genset power</td>
<td>kW</td>
<td>8,847</td>
<td>11,796</td>
<td>13,790</td>
</tr>
</tbody>
</table>

**Electr. Genset heat rate at 100% load**

<table>
<thead>
<tr>
<th></th>
<th>9L</th>
<th>12V</th>
<th>14V</th>
<th>18V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid fuel (WB2007/2008)</td>
<td>kJ/kWh</td>
<td>7,689</td>
<td>7,689</td>
<td>7,673</td>
</tr>
<tr>
<td>Gas fuel (WB2007/2008)</td>
<td>kJ/kWh</td>
<td>7,456</td>
<td>7,456</td>
<td>7,442</td>
</tr>
<tr>
<td>Gas fuel (TA-Luft)</td>
<td>kJ/hWh</td>
<td>7,508</td>
<td>7,508</td>
<td>7,493</td>
</tr>
</tbody>
</table>

**Gas fuel: Incl. pilot fuel.**

**Lube oil consumption**

<table>
<thead>
<tr>
<th></th>
<th>kg/h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>5.6</td>
</tr>
<tr>
<td></td>
<td>7.2</td>
</tr>
</tbody>
</table>

There is a special variant of the MAN 51/60 engine optimized for liquid fuel operation, offering easy modification to DF or G. For more information about this engine please see page 37.

**Dimensions**

<table>
<thead>
<tr>
<th></th>
<th>mm</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10,545</td>
<td>9,835</td>
<td>10,835</td>
<td>13,148</td>
</tr>
<tr>
<td>B</td>
<td>4,805</td>
<td>4,950</td>
<td>5,150</td>
<td>5,410</td>
</tr>
<tr>
<td>C</td>
<td>15,350</td>
<td>14,785</td>
<td>15,985</td>
<td>18,558</td>
</tr>
<tr>
<td>W</td>
<td>2,970</td>
<td>4,700</td>
<td>4,700</td>
<td>4,700</td>
</tr>
<tr>
<td>H</td>
<td>6,030</td>
<td>6,530</td>
<td>6,530</td>
<td>6,530</td>
</tr>
<tr>
<td>Genset dry mass</td>
<td>t</td>
<td>225</td>
<td>276</td>
<td>318</td>
</tr>
</tbody>
</table>

Weights and dimensions are subject to final application.
**MAN 35/44G TS**

**Bore 350 mm, Stroke 440 mm**

<table>
<thead>
<tr>
<th></th>
<th>12V</th>
<th>20V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed (rpm)</td>
<td>750/720</td>
<td>750/720</td>
</tr>
<tr>
<td>Frequency (Hz)</td>
<td>50/60</td>
<td>50/60</td>
</tr>
<tr>
<td>Electr. Genset power (kW)</td>
<td>7,299/6,945</td>
<td>12,214/11,599</td>
</tr>
</tbody>
</table>

**Electr. Genset heat rate at 100% load**

<table>
<thead>
<tr>
<th></th>
<th>12V</th>
<th>20V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimized for power generation (TA Luft) (kJ/kWh)</td>
<td>7,187</td>
<td>7,158/7,172</td>
</tr>
<tr>
<td>Optimized for combined cycle (TA Luft) (kJ/kWh)</td>
<td>7,187</td>
<td>7,158/7,172</td>
</tr>
<tr>
<td>Optimized for combined heat and power (TA Luft) (kJ/kWh)</td>
<td>7,391</td>
<td>7,361/7,375</td>
</tr>
</tbody>
</table>

**Lube oil consumption (kg/h)**

<table>
<thead>
<tr>
<th></th>
<th>2.4/2.5</th>
<th>4.1/4.2</th>
</tr>
</thead>
</table>

**Dimensions**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>mm</td>
<td>9,028</td>
</tr>
<tr>
<td>B</td>
<td>mm</td>
<td>4,330</td>
</tr>
<tr>
<td>C</td>
<td>mm</td>
<td>13,358</td>
</tr>
<tr>
<td>W</td>
<td>mm</td>
<td>4,925</td>
</tr>
<tr>
<td>H</td>
<td>mm</td>
<td>5,200</td>
</tr>
<tr>
<td>Genset dry mass</td>
<td>t</td>
<td>144</td>
</tr>
</tbody>
</table>

Weights and dimensions are subject to final application
## MAN 35/44G

### Bore 350 mm, Stroke 440 mm

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed</td>
<td>rpm</td>
<td>750/720</td>
</tr>
<tr>
<td>Frequency</td>
<td>Hz</td>
<td>50/60</td>
</tr>
<tr>
<td>Electr. Genset power</td>
<td>kW</td>
<td>10,420/10,027</td>
</tr>
</tbody>
</table>

### Electr. Genset heat rate at 100% load

<table>
<thead>
<tr>
<th>Optimization</th>
<th>kJ/kWh</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimized for power generation (TA Luft)</td>
<td></td>
<td>7,375</td>
</tr>
<tr>
<td>Optimized for combined cycle (TA Luft)</td>
<td></td>
<td>7,493</td>
</tr>
<tr>
<td>Optimized for combined heat and power (TA Luft)</td>
<td></td>
<td>7,447</td>
</tr>
</tbody>
</table>

### Lube oil consumption

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg/h</td>
<td>3.6–3.7</td>
</tr>
</tbody>
</table>

### Dimensions

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>mm</td>
<td>9,564</td>
</tr>
<tr>
<td>B</td>
<td>mm</td>
<td>4,592</td>
</tr>
<tr>
<td>C</td>
<td>mm</td>
<td>14,156</td>
</tr>
<tr>
<td>W</td>
<td>mm</td>
<td>4,448</td>
</tr>
<tr>
<td>H</td>
<td>mm</td>
<td>4,500</td>
</tr>
</tbody>
</table>

**Genset dry mass**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t</td>
<td>145</td>
</tr>
</tbody>
</table>

*Weights and dimensions are subject to final application*
### MAN 35/44DF

<table>
<thead>
<tr>
<th>Bore 350 mm, Stroke 440 mm</th>
<th>6L</th>
<th>8L</th>
<th>10L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed (rpm)</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
</tr>
<tr>
<td>Frequency (Hz)</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
</tr>
<tr>
<td>Electr. Genset power (kW)</td>
<td>3,107/2,989</td>
<td>4,143/3,987</td>
<td>5,189/4,993</td>
</tr>
</tbody>
</table>

#### Electr. Genset heat rate at 100% load

| Liquid fuel (WB2007/2008) (kJ/kWh) | 8,064 | 8,064 | 8,047 |
| Gas fuel (WB2007/2008) (kJ/kWh)   | 7,534 | 7,534 | 7,518 |

*Liquid fuel: HFO or diesel fuel. Gas fuel: Incl. pilot fuel*

#### Lube oil consumption (kg/h)

- 1.5–1.6
- 2.0–2.1
- 2.6–2.7

#### Dimensions

<table>
<thead>
<tr>
<th>A (mm)</th>
<th>B (mm)</th>
<th>C (mm)</th>
<th>W (mm)</th>
<th>H (mm)</th>
<th>Genset dry mass (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6,485</td>
<td>7,545</td>
<td>11,750</td>
<td>4,163</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>5,265</td>
<td>6,407</td>
<td>13,952</td>
<td>4,369</td>
<td>103</td>
</tr>
<tr>
<td></td>
<td>2,539</td>
<td>2,678</td>
<td>16,161</td>
<td>4,369</td>
<td>118</td>
</tr>
</tbody>
</table>

*Weights and dimensions are subject to final application*
## MAN 28/32S DF

<table>
<thead>
<tr>
<th>Bore 280 mm, Stroke 320 mm</th>
<th>5L</th>
<th>6L</th>
<th>7L</th>
<th>8L</th>
<th>9L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed (rpm)</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
<td>750/720</td>
</tr>
<tr>
<td>Frequency (Hz)</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
<td>50/60</td>
</tr>
<tr>
<td>Electr. Genset power (kW)</td>
<td>950/</td>
<td>1,140/</td>
<td>1,330/</td>
<td>1,520/</td>
<td>1,710/</td>
</tr>
<tr>
<td></td>
<td>950</td>
<td>1,140</td>
<td>1,330</td>
<td>1,520</td>
<td>1,710</td>
</tr>
</tbody>
</table>

### Lube oil consumption (kg/h)
- 0.6–1.0
- 0.7–1.2
- 0.8–1.4
- 1.0–1.6
- 1.0–1.8

### Dimensions

<table>
<thead>
<tr>
<th>A</th>
<th>mm</th>
<th>4,321</th>
<th>4,801</th>
<th>5,281</th>
<th>5,761</th>
<th>6,241</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>mm</td>
<td>2,400</td>
<td>2,510</td>
<td>2,680</td>
<td>2,770</td>
<td>2,690</td>
</tr>
<tr>
<td>C</td>
<td>mm</td>
<td>6,721</td>
<td>7,311</td>
<td>7,961</td>
<td>8,531</td>
<td>8,931</td>
</tr>
<tr>
<td>W</td>
<td>mm</td>
<td>2,388</td>
<td>2,388</td>
<td>2,388</td>
<td>2,388</td>
<td>2,388</td>
</tr>
<tr>
<td>H</td>
<td>mm</td>
<td>2,835</td>
<td>3,009</td>
<td>3,009</td>
<td>3,009</td>
<td>3,009</td>
</tr>
<tr>
<td>Genset dry mass (t)</td>
<td></td>
<td>32.6</td>
<td>36.3</td>
<td>39.4</td>
<td>40.7</td>
<td>47.1</td>
</tr>
</tbody>
</table>

Weights and dimensions are subject to final application.

---

![Diagram of MAN 28/32S DF engine dimensions: A, B, C, H, W]
There is no better partner for generating green power out of liquid bio fuels than MAN Diesel & Turbo. Biofuels are fuels generated from biomass. Basic materials could be renewable vegetable substances, such as oil seeds, corn, etc., or animal fat and oil waste. By running a MAN Diesel & Turbo engine, these substances can be used for generating green energy. The clear advantages of fuels derived from waste products are not only the low price, but they are also environmentally friendly. They are even CO$_2$ neutral, generate considerably less particle emissions than HFO and emit practically no sulphates. This makes them a very attractive source of energy.

MAN Diesel & Turbo has had engines running on liquid bio fuel since 1994. Our engines can burn a wide range of substances normally considered as waste. Vegetable oils, animal fats, used cooking oil, frying fat and tallow can all be used as fuel for our engines when filtered. This is documented by a long list of satisfied green power customers.

Benefits
- Clean: environmentally friendly, small carbon footprint if coming from sustainable sources
- Cheap: if derived out of waste products such used frying fat or tallow
- High efficiency: MAN Diesel & Turbo engines achieve high performances, even on difficult fuels

Selected references
- Electrawinds - Oostende, Belgium, 1 × MAN 18V48/60 + 2 × MAN 18V32/40
- Electrawinds - Mouscron, Belgium, 1 × MAN 18V48/60
- Topec 1-2, Netherlands, 2 × MAN 18V28/32
- Sirma, Italy, 2 × MAN 6L28/32 H
- Giordano, Italy, 1 × MAN 9L27/38
## Bio Fuel Specifications

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirement</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density/15 °C</td>
<td>900 – 930 kg/m³</td>
<td>DIN EN ISO 3675, EN ISO 12185</td>
</tr>
<tr>
<td>Flash point</td>
<td>&gt; 60 °C</td>
<td>DIN EN 22719</td>
</tr>
<tr>
<td>Lower calorific value</td>
<td>&gt; 35 MJ/kg (typical: 37 MJ/kg*)</td>
<td>DIN 51900-3</td>
</tr>
<tr>
<td>Viscosity/50 °C</td>
<td>&lt; 40 (corresponds to viscosity/40 °C&lt; 60 cSt)</td>
<td>DIN EN ISO 3104</td>
</tr>
<tr>
<td>Cetane number</td>
<td>&gt; 40</td>
<td>FIA</td>
</tr>
<tr>
<td>Coke residue</td>
<td>&lt; 0,4 %</td>
<td>DIN EN ISO 10370</td>
</tr>
<tr>
<td>Sediment content</td>
<td>&lt; 200 ppm</td>
<td>DIN EN 12662</td>
</tr>
<tr>
<td>Oxidation stability (110 °C)</td>
<td>&gt; 5 h</td>
<td>ISO 6886</td>
</tr>
<tr>
<td>Phosphorus content</td>
<td>&lt; 15 ppm</td>
<td>ASTM D3231</td>
</tr>
<tr>
<td>Na + K content</td>
<td>&lt; 15 ppm</td>
<td>DIN 51797-3</td>
</tr>
<tr>
<td>Ash content</td>
<td>&lt; 0,01 %</td>
<td>DIN EN ISO 6245</td>
</tr>
<tr>
<td>Iodine Number</td>
<td>&lt; 125g/100g</td>
<td>DIN EN 14111</td>
</tr>
<tr>
<td>Water content</td>
<td>&lt; 0,5 %</td>
<td>EN ISO 12537</td>
</tr>
<tr>
<td>TAN (total acid number)</td>
<td>&lt; 5 mgKOH/g (TAN 5 mgKOH/g ~ 2.5 % FFA)</td>
<td>DIN EN ISO 660</td>
</tr>
<tr>
<td>Cold Filter Plugging Point</td>
<td>&lt; 10°C below lowest temperature in fuel system</td>
<td>EN 116</td>
</tr>
</tbody>
</table>

### Bio Fuel Engines Technical Data

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Speed r/min</th>
<th>Power output [kW el.]</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAN 48/60</td>
<td>500 – 515</td>
<td>0 – 5,000</td>
</tr>
<tr>
<td>MAN 28/32S</td>
<td>720 – 750</td>
<td>5,000 – 10,000</td>
</tr>
<tr>
<td>MAN 27/38S</td>
<td>720 – 750</td>
<td>10,000 – 15,000</td>
</tr>
<tr>
<td>MAN 23/30S</td>
<td>720 – 750 – 900</td>
<td>15,000 – 20,000</td>
</tr>
<tr>
<td>MAN 21/31S</td>
<td>900 – 1,000</td>
<td>20,000 – 25,000</td>
</tr>
<tr>
<td>MAN 16/24S</td>
<td>1,000 – 1,200</td>
<td>25,000</td>
</tr>
</tbody>
</table>
In order to fulfil the requirements of high efficiency and environmental regulations for power production, MAN Diesel & Turbo has developed a combined cycle process for stationary power plants utilizing the exhaust gas of diesel and gas engines for production of additional electrical energy by operating a MAN MARC® steam turbine.

This additional electrical energy increases the net efficiency of the power plant of at least 3 percentage points. Other significant short and long term impacts of the system:

- It generates more profit
- It increases the amount of electricity generated by the power plant of at least 8% without additional fuel consumption
- Short return on investment
- It limits the exhaust gas emissions to the atmosphere

MAN Diesel & Turbo is the only company building large engines and steam turbines within the same company. This ensures an optimum power plant efficiency and the customer gets both key components from one supplier.

References

- Atlas Power, Pakistan, 11 × MAN 18V48/60 + 1 steam turbine
- Hubco Power, Pakistan, 11 × MAN 18V48/60 + 1 steam turbine
- Thika, Kenya, 5 × MAN 18V48/60 + 1 steam turbine
- Tobene, Senegal, 5 × MAN 18V48/60 + 1 steam turbine
Heat balance of a CC process

Example for a CC power plant
(any other engine configuration is possible)

<table>
<thead>
<tr>
<th>No. and engine type</th>
<th>8 x MAN 18V48/60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single cycle net plant output</td>
<td>143,965 kW</td>
</tr>
<tr>
<td>Single cycle net efficiency</td>
<td>44.8%</td>
</tr>
<tr>
<td>Steam turbine Genset power</td>
<td>12,050 kW</td>
</tr>
<tr>
<td>CC net plant output</td>
<td>155,865 kW</td>
</tr>
<tr>
<td>CC net plant efficiency</td>
<td>48.4%</td>
</tr>
</tbody>
</table>

Water cooled condenser
Reference Project

**Customer:**

**Application:**

**Location:**

**No. and engine type:**

**Plant output:**

**Fuel:**

**Commissioning:**

**Operation & Maintenance**

**Thika Power Limited**

**Base load power plant, Combined Cycle**

**Thika, Kenia**

**5 x MAN 18V48/60B + 1 x MAN MARC® 2 steam turbine**

**88 MW**

**HFO**

**August 2013**

Management support agreement for 6 years
When electricity is generated in gas or diesel engine-based power plants, waste heat at different temperature levels is produced. MAN Diesel & Turbo offers different technologies to convert this waste heat into a useful energy form.

Combined Heat and Power (CHP) is the simultaneous generation of electricity and useful heat from a single fuel source close to its point of use. Combined Cooling, Heat and Power (CCHP) refers to the concurrent generation of electricity, heat and cooling. Both technologies – CHP and CCHP – are well-established, highly-efficient, cost-effective and environmentally-friendly solutions making an important contribution to the global energy demand.

MAN Diesel & Turbo’s engine-based CHP and CCHP plants are designed to meet the overall thermal demand of the end consumer and can be used for a wide range of thermal applications – whether at industrial, city-wide or at individual building levels.

The heat extracted from the engine’s exhaust gases can be utilized for steam or hot water generation required in the textile, food, paper and chemical industries. By including an exhaust gas or hot water driven absorption chiller, chilled water can be produced to run central air conditioning systems in hospitals, hotels and office blocks. The heat extracted from exhaust gas, the engine lube oil, the engine jacket water and the charge air cooling circuits can be utilized for hot water generation, e.g. used in a district heating network for heating purposes.

**Benefits**

- Lower energy costs through more efficient utilization of primary energy
- Improved environmental quality through reduced emissions of pollutants
- Recovered waste heat for a wide range of sustainable thermal applications
- Operational flexibility acc. to changes for heat and electricity demand
Hot water generation for different applications

Energy flow diagram for hot water applications*

* Based on MAN 20V35/44G ISO 3046 conditions and efficiencies valid for: Return line temperature 60°C, Supply line temperature 120°C
# Power Plant Solutions

## CHP reference VW Braunschweig

<table>
<thead>
<tr>
<th>Customer:</th>
<th>VW Kraftwerk GmbH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outputs:</td>
<td>10.4 MW electrical</td>
</tr>
<tr>
<td></td>
<td>9.1 MW thermal</td>
</tr>
<tr>
<td>Overall efficiency</td>
<td>84%</td>
</tr>
<tr>
<td>Genset</td>
<td>MAN 20V35/44G</td>
</tr>
<tr>
<td>Fuel</td>
<td>natural gas</td>
</tr>
<tr>
<td>Recovered heat utilisation</td>
<td>process heat utilization building heating</td>
</tr>
</tbody>
</table>

*MAN 20V35/44G*
Further references:

- MAN Augsburg, Germany, 1 x MAN 12V32/40G
- Electrawinds, Belgium, 1 x MAN 18V48/60
- Voestalpine, Austria, 2 x MAN 12V32/40DF
- Mosoblenergogas, Russia, 2 x MAN 18V32/40G
- Mosoblenergogas Extension, Russia, 1 x MAN 18V32/40G
The environmental policy of many countries worldwide generally calls for a higher share of renewable energy sources in their power generation concepts to reduce emissions and the high share of fossil fuels in the electricity generation mix.

Moreover, wind power, hydroelectricity and solar power are attractive sources of renewable energy – they are free, widely available and don’t produce greenhouse gases.

However, all renewable energy sources rely entirely on one thing to behave: the weather. Hydro-generators need rain to fill up dams to supply flowing water. Wind turbines need wind to turn the blades. Photovoltaic or solar collectors require clear skies and sunshine to generate electricity. As these basic conditions often vary in availability, energy production varies with them. This makes it tricky if electricity is needed steadily and reliably, e.g. in case of island and micro grids or remote applications such as mining sites.

MAN Diesel & Turbo and its strong partners combine both types of energy in hybrid power plants. Renewable energy sources hybridized with liquid fuel or gas fuel engines are the perfect synergy to take the advantages of both electricity sources. The renewable energy share delivers free electricity with a green footprint and highly efficient engines care for reliable base load supply or flexible backup for obtaining a continuous power output.

Of course, the higher the share of renewable energy sources the more complex is the balancing of the plant, therefore a sophisticated plant management system takes care of demand-oriented electricity supply. It is possible to add renewables to your engine based power plant in order to achieve fuel savings or even hybridize up to 100% peak renewable penetration.
Benefits:

- Reliable, decentralized power supply with low emissions and low fuel consumption
- Optimal operational costs solution for each site
- Very short start-up time of the MDT engines → constant and reliable power supply
- Highly scalable system enabling a staged renewable integration approach
- High Up-time and availability with up to 100% peak renewable penetration in isolated microgrids
- By use of biofuels, 100% CO₂-neutral hybrid system is possible

References:

- WEB Bonaire, Netherlands Antilles, 5 x MAN 9L27/38 in cooperation with 11 MW wind power
Sometimes, a power barge can be the best and quickest solution when electrical energy is needed on short notice in remote areas or areas struck by natural disaster. The land-based resources needed to construct a power station may not be available, and transport over water may be the only way to get large equipment to the site. A floating power station can be entirely self-contained and can installed relatively quickly at any locations accessible by water such as harbors, coastal regions or sites near rivers for supplying critically needed electricity independently of local resources or infrastructure. MAN Diesel & Turbo power barges are offered with all of our diesel and gas engine types from the 32-bore series to the 51-series.

*Esperanza Power Barge*
Benefits

- Simple and straightforward location of the power station where power is required
- Support rapid infrastructure development in remote regions
- Short building times: 70 MW power station can be installed in less than 12 months
- Reduced reliance on poor or non-existent local capacities
- Unaffected by landslides and earthquakes
- Independence from local infrastructure
- Minimum operator investment risk and advantage in financing thanks to the mobility, versatility and adaptability of this type of plant

Examples/references

- Margaritha II in Nicaragua, 4 x MAN 18V48/60
- Esperanza in Guatemala, 7 x MAN 18V48/60
- Karadeniz Powerships, supply of engines and equipment for Karadeniz:
  - Doğan Bey: 3 x MAN 14V48/60
  - Irem Sultan: 6 x MAN 18V51/60DF
  - Fatmagül Sultan: 11 x MAN 18V51/60DF
  - OrhanBey: 11 x MAN 18V51/60DF

Karadeniz Powership
MAN Diesel & Turbo has more than 20 years of experience in building small power plants with our worldwide partners. A small power plant usually means a plant with single or multiple units of approximately 1-4 MW/unit. The basic idea of the concept is to keep overall costs as low as possible by working with a high degree of standardization and using as much local equipment and manpower as possible.

“Low costs for us – low costs for you”

The partner concept is basically a concept where we work with local or international partners, who then build power plants based on our Gensets and our basic documentation and engineering. The remaining plant equipment and civil works are then delivered either by the partner or the customer, as the case may be. MAN Diesel & Turbo has a great interest in maintaining the relevant standard and quality of all plants equipped with our Gensets. For this reason, we provide partners and customers with our standard documentation, enabling the builder to complete the plant and the user to operate the plant successfully.

*Ambatovy power plant with 9 x MAN 7L27/38 is located on Madagascar*
When fast start-up and supreme reliability really matters, diesel engines have always been the technology of choice. In nuclear power plants, this is no different. Diesel engines are the key components of the generating sets for the safety of a nuclear plant.

Under the S.E.M.T. Pielstick brand, MAN Diesel & Turbo has been producing PA and PC diesel engines since 1946. The first 400 mm bore engine was installed in 1951 on a land-based power plant. To date, more than 4400 units of the PC class and more than 10,000 units of the PA class engines have been produced and installed worldwide. This means a huge accumulated number of starting and loading up sequences as well as running hours, possibly providing the S.E.M.T. Pielstick brand with the largest experience in this particular field of use of diesel engines.

MAN Diesel & Turbo’s PC2 and PA6 diesel engines have been certified for nuclear application in countries such as China, France, India, Japan, Korea, Russia, USA.
The MAN PC2.6 B N and the MAN PA6 B N have been granted the nuclear qualification only after stringent testing according to the IEEE 387, RCC-E and KTA standards, involving 100-300 consecutive hot and cold starts. Both the PC2 engine and the PA6 engine can operate under seismic conditions. The nuclear power Genset business is centralized in MAN Diesel & Turbo France, which has been granted the ISO 9001:2000 certification by the BVQI and the ISO 14001:2004 certification by LRQA as well.

Benefits
- Outstanding reliability and availability
- Well-proven technology
- Certified according to all relevant standards
MAN PC2.6 B N

<table>
<thead>
<tr>
<th>Engine type</th>
<th>12V</th>
<th>14V</th>
<th>16V</th>
<th>18V</th>
<th>20V</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCR kWm</td>
<td>8,640</td>
<td>10,500</td>
<td>12,000</td>
<td>13,500</td>
<td>15,000</td>
</tr>
<tr>
<td>(maximum continuous rating) kWm</td>
<td>8,380</td>
<td>10,185</td>
<td>11,640</td>
<td>13,095</td>
<td>14,550</td>
</tr>
</tbody>
</table>

**Consumption 100% load**

<table>
<thead>
<tr>
<th>Engine</th>
<th>Genset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat rate</td>
<td>7,771 kJ/kWhm</td>
</tr>
<tr>
<td>Specific lube oil consumption</td>
<td>0.3 – 0.6 kg/cyl.h</td>
</tr>
</tbody>
</table>

**Dimensions**

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm</td>
<td>5,960</td>
<td>6,700</td>
<td>7,440</td>
<td>-*</td>
<td>-*</td>
</tr>
<tr>
<td>mm</td>
<td>7,850</td>
<td>8,590</td>
<td>9,550</td>
<td>-*</td>
<td>-*</td>
<td></td>
</tr>
<tr>
<td>mm</td>
<td>3,900</td>
<td>3,900</td>
<td>4,000</td>
<td>-*</td>
<td>-*</td>
<td></td>
</tr>
<tr>
<td>mm</td>
<td>3,715</td>
<td>3,715</td>
<td>4,075</td>
<td>-*</td>
<td>-*</td>
<td></td>
</tr>
<tr>
<td>mm</td>
<td>3,950</td>
<td>3,950</td>
<td>3,950</td>
<td>-*</td>
<td>-*</td>
<td></td>
</tr>
<tr>
<td>mm</td>
<td>11,890</td>
<td>12,630</td>
<td>13,590</td>
<td>-*</td>
<td>-*</td>
<td></td>
</tr>
<tr>
<td>Genset dry mass</td>
<td>t</td>
<td>210</td>
<td>245</td>
<td>280</td>
<td>-*</td>
<td>-*</td>
</tr>
</tbody>
</table>

Weights and dimensions are subject to final application

*Skid mounted, generator included, valid only for 12, 14 and 16 cylinders*

Nominal generator efficiencies: 97%

* Available on request
MAN PA6 B N

<table>
<thead>
<tr>
<th>Engine type</th>
<th>12V kWm/kWe</th>
<th>16V kWm/kWe</th>
<th>18V kWm/kWe</th>
<th>20V kWm/kWe</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 Hz at 900 rpm</td>
<td>4,200/4,074</td>
<td>5,600/5,432</td>
<td>6,300/6,111</td>
<td>7,000/6,790</td>
</tr>
<tr>
<td>50 Hz at 1,000 rpm</td>
<td>4,440/4,307</td>
<td>5,920/5,742</td>
<td>6,660/6,460</td>
<td>7,400/7,178</td>
</tr>
</tbody>
</table>

Consumption 100% load

<table>
<thead>
<tr>
<th>Heat rate</th>
<th>60 Hz at 900 rpm (kWm/kWe)</th>
<th>50 Hz at 1,000 rpm (kWm/kWe)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8,412 / 8,672</td>
<td>8,497 / 8,760</td>
</tr>
<tr>
<td>Specific lube oil consumption</td>
<td>0.11 – 0.22 kg/cyl.h</td>
<td>0.10 – 0.21 kg/cyl.h</td>
</tr>
</tbody>
</table>

Dimensions

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>mm</th>
<th></th>
<th>mm</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>9,500</td>
<td>10,656</td>
<td>11,390</td>
<td>11,986</td>
</tr>
<tr>
<td>B</td>
<td>8,920</td>
<td>9,840</td>
<td>10,300</td>
<td>10,760</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>3,695</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td>2,825</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genset dry mass</td>
<td>t</td>
<td>70</td>
<td>80</td>
<td>90</td>
</tr>
</tbody>
</table>

Weights and dimensions are subject to final application

Nominal generator efficiencies: 97%. All dimensions and masses are approximate and subject to change without prior notice.
Two-Stroke Licence Business

Engineering the Future – since 1758.
MAN Diesel & Turbo
MAN Diesel & Turbo Engines

MAN Diesel & Turbo designs MAN B&W two-stroke low speed diesel engines and MAN four-stroke small bore Gensets for stationary application.

The design is based on continuous development to meet the customers requirements in the following focus areas:

- Highest fuel efficiency
- Low maintenance costs
- High reliability
- Operational flexibility – from base load to standby
- Wide fuel flexibility
- Wide scope for thermal energy recovery
- Insensitivity to high ambient temperatures and high-altitude locations
- Modular concept for flexible capacity expansion

The MAN Diesel & Turbo engines of our design are characterised by robustness, reliability, simple operation and easy maintenance, which are prerequisites for achieving an availability of more than 8,000 hours per year.

The engines of our design are sold and built by licensees (engine builders) located worldwide.
Two-Stroke Licence Business

Definitions
MAN B&W two-stroke low speed diesel engines are designed to provide optimum fuel flexibility and are an ideal source of power, whether operating on gas, liquid fuel or liquid biofuel.

Liquid fuels: HFO, diesel, crude biofuel and crude oil.
Gaseous fuels: Natural gas and ethane.
Liquid gas fuels: LPG, DME, methanol and ethanol.

Engine and GenSet power
Engine and generator power figures are stated in kW. Ratings are given according to ISO 3046-1:2002. The electrical power has been calculated based on a standard generator efficiency according to IEC 60034 in the corresponding power range and at a power factor of 0.9. This is for guidance only as it is to be confirmed by the selected generator maker.

Nominal rating
The engine ratings quoted are valid up to tropical conditions:
- Blower inlet temperature 45ºC
- Blower inlet pressure 1,000 mbar
- Charge air coolant temperature 32ºC

If the engine should operate under more demanding ambient conditions, please contact MAN Diesel & Turbo, Copenhagen or the engine builder.

Engine application
The engine ratings and speeds shown are based on generator drive application. For other drives, such as mechanical drive of mills, pumps, compressors, etc., please contact MAN Diesel & Turbo, Copenhagen, or the engine builder. The diesel generating set ratings and heat rates shown depend on the actual generator make and are for guidance only.
Site specified rating

\[ L_1 \geq \text{site specified rating} \geq L_2 \]

The engine may be operated without restriction at any load up to site specified rating. Operating at overload rating, i.e. 110% of the site specified rating, is permissible for one hour every 12 consecutive hours.

Engine heat rate

The figures specified in the table refer to mechanical output and to ISO 3046/1-2002 ambient conditions:

- Blower inlet temperature \(25^\circ\text{C}\)
- Blower inlet pressure 1,000 mbar
- Charge air coolant temperature \(25^\circ\text{C}\)

If the engine should operate under other ambient conditions, please contact MAN Diesel & Turbo, Copenhagen, or the engine builder.

Fuel oil consumption guarantee – MC-S engines

The MCR engine heat rate guaranteed by MAN Diesel & Turbo is subject to a tolerance of ±5% at ISO 3046/1-2002 ambient conditions. If the engine is operated under other ambient conditions or if the engine is equipped with emission control systems, TCS and/or BCST, please contact MAN Diesel & Turbo, Copenhagen, or the engine builder.

Lubricating oil consumption

The system oil consumption varies for the different engine sizes and operational patterns. Typical consumptions are in the range from negligible to 0.1 g/kWh.

Turbocharger selection

Two-stroke low speed engines can be delivered with MAN Diesel & Turbo, ABB Turbo Systems Ltd. or Mitsubishi Heavy Industries, Ltd. turbochargers as standard.
Engine Design

- **MC-S**
  Two-stroke diesel engines provided with a mechanically driven camshaft controlling the fuel oil pumps and exhaust valves. These engines operate on liquid fuels only.

- **ME-S**
  Two-stroke diesel engines designed with electronic control of the combustion process, i.e. fuel injection timing, exhaust valve actuation, starting valves and cylinder lubrication. These engines operate on liquid fuels only.

- **ME-GI-S**
  Dual fuel engines operating on high flash point gaseous fuel oil and pilot oil. These engines operate on any high-calorific gas that can be compressed to 300 or 400 bar at 45°C and be injected into the combustion chamber in a single phase.

- **ME-LGI-S**
  Dual fuel engines operating on low flash point liquid gas fuels and pilot oil.
MAN B&W Two-Stroke Engines

Guiding biofuel specification

The engine data stated are valid using liquid biofuel according to the guiding specification (maximum values at the inlet to the centrifuging plant):

<table>
<thead>
<tr>
<th>Designation</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density at 15°C</td>
<td>kg/m³</td>
<td>1,010</td>
</tr>
<tr>
<td>Kinematic viscosity at 50°C</td>
<td>cSt</td>
<td>55</td>
</tr>
<tr>
<td>Flash point</td>
<td>°C</td>
<td>≥60</td>
</tr>
<tr>
<td>Carbon residue</td>
<td>% (m/m)</td>
<td>22</td>
</tr>
<tr>
<td>Ash</td>
<td>% (m/m)</td>
<td>0.15</td>
</tr>
<tr>
<td>Water</td>
<td>% (m/m)</td>
<td>1.0</td>
</tr>
<tr>
<td>Sulphur</td>
<td>% (m/m)</td>
<td>5.0</td>
</tr>
<tr>
<td>Vanadium</td>
<td>ppm (m/m)</td>
<td>600</td>
</tr>
<tr>
<td>Aluminium/silicon</td>
<td>mg/kg</td>
<td>60</td>
</tr>
<tr>
<td>Sodium plus potassium</td>
<td>ppm (m/m)</td>
<td>200</td>
</tr>
<tr>
<td>Calcium</td>
<td>ppm (m/m)</td>
<td>200</td>
</tr>
<tr>
<td>Lead</td>
<td>ppm (m/m)</td>
<td>10</td>
</tr>
<tr>
<td>TAN (total acid number)</td>
<td>mg KOH/g</td>
<td>&lt;25</td>
</tr>
<tr>
<td>SAN (strong acid number)</td>
<td>mg KOH/g</td>
<td>0</td>
</tr>
</tbody>
</table>

* Iodine, phosphorus and sulphur content according to agreement with the manufacturer of the emission control system.

For other biofuel qualities, please contact MAN Diesel & Turbo, Copenhagen, or the engine builder.
MAN B&W Two-Stroke Engines

Guiding fuel specification

The engine data stated are valid using marine diesel oil or heavy fuel oil according to the guiding specification (maximum values at inlet to centrifuging plant):

Designation Diesel engines ISO8217:2010(E) rmk700

- Density at 15°C kg/m³ 1,010
- Kinematic viscosity at 50°C cSt 700
- Flash point °C ≥60
- Carbon residue % (m/m) 20
- Ash % (m/m) 0.15
- Water % (m/m) 0.50
- Sulphur % (m/m) 5
- Vanadium mg/kg 450
- Aluminium/silicon mg/kg 60
- API gravity (min) °API *
- Sodium mg/kg 100
- Calcium ppm (m/m) 200
- Lead ppm (m/m) 10

Free from used lube oil and calcium > 30 and zink > 15 mg/kg - or calcium > 30 and phosphorus > 15 mg/kg.

For operation on other fuel qualities, please contact MAN Diesel & Turbo, Copenhagen, or the engine builder.
MAN B&W Two-Stroke Engines

Guiding gas specification

The engine data stated are valid using liquid gas or gaseous gas according to the guiding specification (maximum values at inlet to centrifuging plant):

Designation

- Lower calorific value (LCV) MJ/kg Minimum 38 MJ/kg if operation on maximum gas fuel is to be obtained. Below 38 a higher pilot fuel oil amount might be required.
- Gas methane number No limit
- Methane content (% volume) No limit
- Hydrogen sulphide (H₂S) (% volume) Max. 0.05
- Hydrogen (H₂) (% volume) No limit
- Water and hydrocarbon condensates (% volume) 0
- Ammonia (mg/Nm³) Max. 25
- Chlorine + flourines (mg/Nm³) Max. 50
- Particles or solid content (mg/Nm³) Max. 50
- Particles or solid size (μm) Max. 5
- Gas inlet temperature (°C) 45 ± 10
- Gas pressure According to MAN Diesel & Turbo specification

For other gas qualities, please contact MAN Diesel & Turbo, Copenhagen, or the engine builder.
Dual fuel engines

All engine types from 35 to 98-bore mentioned in the Power Plants Programme are available as dual fuel engines under the designation ME-GI-S or ME-LGI-S.

Technical data

Power, speed and gross efficiency of the ME-S, ME-GI-S and ME-LGI-S type engines are the same as for the corresponding MC-S engines. Please contact MAN Diesel & Turbo in Copenhagen or the engine builder for technical engine data for your specific project, including project specific emission requirements.
Two-stroke low speed diesel engine of MAN B&W design in combined cycle
Part load behaviour

![Graph showing efficiency vs load percentages for single cycle, single cycle with TCS, and combined cycle with TCS.]

**Engine emissions**

The data are valid for engines without emission control. For information on emission controlled engines, please contact MAN Diesel & Turbo, Copenhagen, or the engine builder.

**Turbo compound system (TCS)**

The turbo compound system, subject to the use of high-efficiency turbochargers, can be applied on the K98, K90, K80, K60MC/ME-S engine types as well as on the K80MC/ME-S9 engine types. The use of a TCS system allows a reduction of up to 4% of the combined heat rate, depending on the site ambient conditions.

For detailed information, please contact MAN Diesel & Turbo, Copenhagen, or the engine builder.
Utilization of the energy sources of the diesel engine

MAN B&W two-stroke low speed stationary diesel engines can be optimized to the following fields of energy production:
- District heating/cooling
- Freshwater

The diesel engine can provide energy for district heating/cooling or freshwater production utilizing:
- Heat from scavenge air cooling
- Heat from jacket cooling
- Heat from lube oil cooling

For further technical information about this topic, please contact MAN Diesel & Turbo, Copenhagen, or the engine builder.

Extent of delivery

The final and binding extent of delivery of MAN B&W two-stroke diesel engines is to be supplied by our licensees, the engine builders, who are to be contacted in order to plan the execution of the actual project.

In order to facilitate negotiations between the end-user, contractor and engine maker, a guiding “Extent of Delivery” (EoD), ref. publication no. 2030-0001-07ppr Jun 2014, is available. This publication specifies the recommendations for MAN Diesel & Turbo’s basic and optional executions for the engine proper, and it is subject to modification without notice in the interest of the technical progress.

Please note that the licensees may select a different extent of delivery as their standard.
## Engine Type Designation

<table>
<thead>
<tr>
<th>7 K 80 M E -GI -S 9</th>
</tr>
</thead>
</table>

- **Mark number**
- **Design**
  - $S$: Stationary
  - (blank): Fuel oil only
  - $GI$: Gas injection high flash point gas fuel
  - $LGI$: Gas injection for low flash point gas fuel
- **Fuel injection concept**
  - $E$: Electronically controlled
  - $C$: Camshaft controlled
- **Concept**
- **Engine programme series**
- **Diameter of piston in cm**
- **Stroke/bore ratio**
  - $L$: Long stroke
  - $K$: Short stroke
- **Number of cylinders**
Power Product Overview
MAN B&W low speed engines

- MAN B&W K98MC-S
- MAN B&W K90MC-S
- MAN B&W K80MC-S9
- MAN B&W K80MC-S
- MAN B&W K60MC-S
- MAN B&W K50MC-S
- MAN B&W L35MC-S
**MAN B&W K98MC-S**

**Site Rating**

- \( L_1 \): Power optimized
- \( L_2 \): Fuel economy optimized

**Bore 980 mm, Stroke: 2,400 mm**

**Power and Heat Rate**

<table>
<thead>
<tr>
<th>Speed ( r/min )</th>
<th>103.4</th>
<th>102.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency ( Hz )</td>
<td>50</td>
<td>60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Layout points</th>
<th>( L_1 )</th>
<th>( L_2 )</th>
<th>( L_1 )</th>
<th>( L_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>kW(_m)</td>
<td>kW(_e)</td>
<td>kW(_m)</td>
<td>kW(_e)</td>
<td>kW(_m)</td>
</tr>
<tr>
<td>10 K98MC-S</td>
<td>56,800</td>
<td>55,380</td>
<td>45,400</td>
<td>44,265</td>
</tr>
<tr>
<td>11 K98MC-S</td>
<td>62,480</td>
<td>60,920</td>
<td>49,940</td>
<td>48,690</td>
</tr>
<tr>
<td>12 K98MC-S</td>
<td>68,160</td>
<td>66,455</td>
<td>54,480</td>
<td>53,120</td>
</tr>
<tr>
<td>14 K98MC-S</td>
<td>79,520</td>
<td>77,530</td>
<td>63,560</td>
<td>61,970</td>
</tr>
</tbody>
</table>

**Heat Rate at MCR**

<table>
<thead>
<tr>
<th>kW(_m)</th>
<th>kW(_e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7,390</td>
<td>7,130</td>
</tr>
<tr>
<td>7,580</td>
<td>7,310</td>
</tr>
</tbody>
</table>

Up to 4% heat rate reduction is obtainable depending on actual site ambient conditions.

**Lubricating and Cylinder Oil Consumption**

| Cylinder oil consumption | 0.6 - 1.2 g/kWh |
MAN B&W K90MC-S

Site Rating

- L₁: Power optimized
- L₂: Fuel economy optimized

Bore 900 mm, Stroke: 2,300 mm

Power and Heat Rate

<table>
<thead>
<tr>
<th>Speed (r/min)</th>
<th>107.1</th>
<th>109.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (Hz)</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Layout points</td>
<td>L₁</td>
<td>L₂</td>
</tr>
<tr>
<td></td>
<td>kWe</td>
<td>kWm</td>
</tr>
<tr>
<td>7 K90MC-S</td>
<td>31,080</td>
<td>30,300</td>
</tr>
<tr>
<td>8 K90MC-S</td>
<td>35,520</td>
<td>34,630</td>
</tr>
<tr>
<td>10 K90MC-S</td>
<td>44,400</td>
<td>43,290</td>
</tr>
<tr>
<td>11 K90MC-S</td>
<td>48,840</td>
<td>47,620</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Speed (r/min)</th>
<th>103.4</th>
<th>102.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 K90MC-S</td>
<td>51,480</td>
<td>50,193</td>
</tr>
</tbody>
</table>

Heat Rate at MCR

<table>
<thead>
<tr>
<th></th>
<th>kJ/kWhₑ</th>
<th>kJ/kWhₑ</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWe</td>
<td>7,340</td>
<td>7,090</td>
</tr>
<tr>
<td>kWₑ</td>
<td>7,530</td>
<td>7,270</td>
</tr>
</tbody>
</table>

With TCS

Up to 4% heat rate reduction is obtainable depending on actual site ambient conditions.

Lubricating and Cylinder Oil Consumption

| Cylinder oil consumption | 0.6 - 1.2 g/kWh |
MAN B&W K80MC-S9

Site Rating

- $L_1$: Power optimized
- $L_2$: Fuel economy optimized

Speed

Bore 800 mm, Stroke 2,600 mm

Power and Heat Rate

<table>
<thead>
<tr>
<th>Speed (r/min)</th>
<th>103.4</th>
<th>102.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (Hz)</td>
<td>50</td>
<td>60</td>
</tr>
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Heat Rate at MCR

<table>
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<tr>
<th>kWm</th>
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<tbody>
<tr>
<td>kWe</td>
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</table>

With TCS

Up to 4% heat rate reduction is obtainable depending on actual site ambient conditions.

Lubricating and Cylinder Oil Consumption

Cylinder oil consumption: 0.6 - 1.2 g/kWh
**MAN B&W K80MC-S**

**Site Rating**

- **L₁**: Power optimized
- **L₂**: Fuel economy optimized

**Bore 800 mm, Stroke 2,300 mm**

**Power and Heat Rate**

<table>
<thead>
<tr>
<th>Speed r/min</th>
<th>107.1</th>
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**Heat Rate at MCR**

<table>
<thead>
<tr>
<th>kWm</th>
<th>kWp</th>
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<tbody>
<tr>
<td>kJ/kWh</td>
<td>7,340</td>
</tr>
<tr>
<td>kJ/kWh</td>
<td>7,090</td>
</tr>
</tbody>
</table>

**With TCS**

Up to 4% heat rate reduction is obtainable depending on actual site ambient conditions.

**Lubricating and Cylinder Oil Consumption**

Cylinder oil consumption: 0.6 - 1.2 g/kWh
MAN B&W K60MC-S

Site Rating

L₁ : Power optimized
L₂ : Fuel economy optimized

Speed

Bore 600 mm, Stroke 1,740 mm

Power and Heat Rate

<table>
<thead>
<tr>
<th>Speed r/min</th>
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<tbody>
<tr>
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<td>23,165</td>
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<td>23,165</td>
<td>21,360</td>
<td>20,825</td>
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Heat Rate at MCR

<table>
<thead>
<tr>
<th>kWₘ</th>
<th>kWₑ</th>
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</thead>
<tbody>
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<td>kJ/kWhₘ</td>
<td>7,170</td>
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<tr>
<td>kJ/kWhₑ</td>
<td>7,360</td>
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</table>

With TCS

Up to 4% heat rate reduction is obtainable depending on actual site ambient conditions.

Lubricating and Cylinder Oil Consumption

Cylinder oil consumption 0.6 - 1.2 g/kWh
MAN B&W K50MC-S

Site Rating

L₁ : Power optimized
L₂ : Fuel economy optimized

Speed

Bore 500 mm, Stroke 1,370 mm

Power and Heat Rate

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<thead>
<tr>
<th>Speed r/min</th>
<th>L₁</th>
<th>L₂</th>
<th>L₁</th>
<th>L₂</th>
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<td>kWₘ</td>
<td>kWₑ</td>
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<tr>
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<td>kWₘ</td>
<td>kWₑ</td>
<td>kWₘ</td>
<td>kWₑ</td>
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<td>10,005</td>
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<td>12,225</td>
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<td>16,615</td>
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<td>19,795</td>
<td>16,240</td>
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</table>

Heat Rate at MCR

| kW/m | 7,430 | 7,170 | 7,430 | 7,170 |
| kW/e | 7,620 | 7,360 | 7,620 | 7,360 |

Lubricating and Cylinder Oil Consumption

Cylinder oil consumption 0.6 - 1.2 g/kWh
MAN B&W L35MC-S

Site Rating

- L₁: Power optimized
- L₂: Fuel economy optimized

Speed

Bore 350 mm, Stroke 1,050 mm

Power and Heat Rate

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<th>L₁ kWₑ</th>
<th>L₂ kWₘ</th>
<th>L₂ kWₑ</th>
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<th>L₂ kWₘ</th>
<th>L₂ kWₑ</th>
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<td>5,200</td>
<td>5,070</td>
<td>4,160</td>
<td>4,055</td>
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<td>4,990</td>
<td>4,120</td>
<td>4,015</td>
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<td>5,850</td>
<td>5,705</td>
<td>4,680</td>
<td>4,560</td>
<td>5,760</td>
<td>5,690</td>
<td>4,635</td>
<td>4,520</td>
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<tr>
<td>10 L35MC-S</td>
<td>6,500</td>
<td>6,340</td>
<td>5,200</td>
<td>5,070</td>
<td>6,400</td>
<td>6,240</td>
<td>5,150</td>
<td>5,020</td>
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<td>6,970</td>
<td>5,720</td>
<td>5,575</td>
<td>7,040</td>
<td>6,865</td>
<td>5,665</td>
<td>5,520</td>
</tr>
<tr>
<td>12 L35MC-S</td>
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<td>7,605</td>
<td>6,240</td>
<td>6,085</td>
<td>7,680</td>
<td>7,490</td>
<td>6,180</td>
<td>6,025</td>
</tr>
</tbody>
</table>

Heat Rate at MCR

| kW/kWhₘ | 7,390 | 7,130 | 7,390 | 7,130 |
| kW/kWhₑ | 7,580 | 7,310 | 7,580 | 7,310 |

Lubricating and Cylinder Oil Consumption

| Cylinder oil consumption | 0.6 - 1.2 g/kWh |
MAN Diesel & Turbo is a world leader in the design and manufacture of large exhaust gas turbochargers for low-, medium- and high-speed diesel and gas engines. Our decades of experience and expertise in the development of this crucial engine component has resulted in world-leading turbocharger technology that you can rely on to get the job done.

The integral development and design of engine and turbocharger results in world and market leading turbocharger technology.

**Product Portfolio:**

MAN TCA, MAN TCR, MAN TCX, MAN ETB, MAN ECOCHARGE

- Extended component lifetime
- Condition-based component maintenance
- Easy to maintain and service
- Long intervals between overhauls
- Material optimized for all fuels and gases
- Variable turbine geometry as an option
- Compact dimensions for easy installation on the engine
- A one-stop service for engine and turbocharger
- Knowledgeable partners in more than 150 service stations worldwide

**Applications**

- Marine propulsion
- Marine Gensets
- Power generation
- Excavator/Mining/Off-Road
- Locomotive
- Mechanical drive
MAN TCR22 turbochargers with VTA on MAN 20V32/44CR engine
Steam and Gas Turbines for Power Plants

Engineering the Future – since 1758.
MAN Diesel & Turbo
Bioenergy is renewable energy made available from biological sources. Biomass is any organic material which has stored sunlight in form of chemical energy such as wood, straw, manure, sugarcane or many other by-products from a variety of agricultural processes. Bioenergy contributes to reduce atmospheric methane and carbon emissions as well as fossil fuel consumption and strengthen energy security due to its steady availability.

MAN Diesel & Turbo offers for bioenergy plants a highly comprehensive range of steam turbines (2–40 MW) with proven performance and high availability. In industrial biomass plants, the efficiency of combined heat and power plays an important role. MAN Diesel & Turbo is well prepared to optimize the complete water/steam-cycle in close cooperation with its customers.

**Selected Biomass References**

<table>
<thead>
<tr>
<th>Order year</th>
<th>Country of Installation</th>
<th>Customer</th>
<th>MDT equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>Sweden</td>
<td>Andritz</td>
<td>Steam turbine-generator set MARC-2 H03</td>
</tr>
<tr>
<td>2013</td>
<td>Germany</td>
<td>Elsflether Bioenergie GmbH</td>
<td>Steam turbine-generator set MARC 2-C11</td>
</tr>
<tr>
<td>2012</td>
<td>France</td>
<td>Dalkia France</td>
<td>Steam turbine-generator set MARC-2 C11</td>
</tr>
<tr>
<td>2012</td>
<td>Romania</td>
<td>Fritz Egger GmbH &amp; Co.</td>
<td>Steam turbine-generator set MARC-4 C11</td>
</tr>
</tbody>
</table>
Steam Turbines for Power Plants

Concentrated solar power (CSP)

The requirement to produce CO₂ neutral electricity by using renewable energy sources has created various innovative solutions. One of these solutions is concentrated solar power (CSP), established especially in sun-rich countries.

In CSP power plants mirrors reflect the solar radiation to a receiver. Different technologies exist for the extraction of this energy. Sunlight is converted via mirrors and receivers into heating directly vaporizing water into steam or increasing the temperature of thermo oil or molten salt. By way of water fed heat exchangers steam is produced and expanded in a steam turbine driving a generator.

In CSP power plants efficiency plays a major role due to high overall investment costs and renewable energies feed-in legislation. MAN Diesel & Turbo is well prepared to optimize the complete water/steam-cycle in close cooperation with its customers. Depending on the plant concept-re-heat (two casings) or single casing steam turbines, both with up to 8 bleeds for pre-heating purposes, can be supplied. MAN Diesel & Turbo offers more than 10 steam turbines for solar power generation with a power output range of 4 up to 125 MW.

Selected CSP References

<table>
<thead>
<tr>
<th>Order year</th>
<th>Country of Installation</th>
<th>Customer</th>
<th>MDT equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Les Borges Blanques, Spain</td>
<td>UTE Termosolar Borges</td>
<td>Steam turbine-generator MARC 6-R05 (water-cooled condenser)</td>
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<tr>
<td>2011</td>
<td>Viellena, Spain</td>
<td>UTE Termosolar</td>
<td>Steam turbine-generator set (reheat)</td>
</tr>
<tr>
<td>2010</td>
<td>Palma del Rio, Spain</td>
<td>UTE Termosolar</td>
<td>Steam turbine-generator set (reheat)</td>
</tr>
<tr>
<td>2009</td>
<td>Kanchanaburi, Thailand</td>
<td>Thai Solar Energy</td>
<td>Steam turbine-generator MARC 2-C04 (water-cooled condenser)</td>
</tr>
<tr>
<td>2008</td>
<td>Alcudia de Guadix, Spain</td>
<td>Solar Millenium AG</td>
<td>Steam turbine-generator set (reheat)</td>
</tr>
<tr>
<td>2008</td>
<td>Shams, UAE</td>
<td>PJSC</td>
<td>Steam turbine-generator set</td>
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</tbody>
</table>
Steam Turbines for Power Plants

Pulp & paper

The pulp & paper industry is mainly situated in North America, Scandinavia, East Asia and South America. It uses wood as raw material to produce pulp, paper and other cellulose-based products.

Steam turbines that are utilized in the pulp & paper industry have an important function in the plant process. Thanks to the highly comprehensive range of efficient and custom-made steam turbines, MAN Diesel & Turbo is well prepared for our customer demands. We offer controlled and uncontrolled extractions and are able to provide all relevant equipment for the steam turbine generator set (i.e. generator and condenser).

In 2009 MAN Diesel & Turbo supplied two steam turbines with 98 MWel and 60 MWel power output to the South American market.

<table>
<thead>
<tr>
<th>Order year</th>
<th>Country of Installation</th>
<th>Customer / Operator</th>
<th>MDT equipment</th>
</tr>
</thead>
<tbody>
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<td>2009</td>
<td>Santa Fe, Chile</td>
<td>CMPC</td>
<td>Steam turbine-generator set</td>
</tr>
<tr>
<td>2009</td>
<td>Laja, Chile</td>
<td>CMPC</td>
<td>Steam turbine-generator set</td>
</tr>
</tbody>
</table>
Steam Turbines for Power Plants

Waste-to-Energy (WtE)

Waste-to-Energy (WtE) refers to treatment and conversion of waste sources into electricity or/and heat. In many WtE plants the objective is waste removal by incineration rather than landfill. The heat generated by this combustion process can be used for power generation resulting in additional profit for the operator. WtE activities in Europe intensified after the 2005 EU Directive prohibiting landfill of non-treated waste.

Depending on the customer requirements, MAN Diesel & Turbo can include parts of the water-steam-cycle into its scope of supply. This is in addition to the steam turbine generator. Examples of such typical additional deliveries may include heating condensers, air-cooled condensers, pre-heaters, bypass stations and some connecting pipe work. A special
operational requirement that we encounter in the WtE business is long-term turbine bypass operation. For this requirement turbine blading design can be adapted.

Electrical power generation based on waste incineration is an example of an application for MAN steam turbines. In 2011 MAN Diesel & Turbo delivered the biggest steam turbine generator set for a WtE plant in the U.K. with a power output of 80 MWel.

Selected Waste-to-Energy References

<table>
<thead>
<tr>
<th>Order year</th>
<th>Country of Installation</th>
<th>Customer</th>
<th>MDT equipment</th>
</tr>
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<tbody>
<tr>
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<td>2012</td>
<td>Hørsholm, Denmark</td>
<td>I/S Nordforbrænding</td>
<td>Steam turbine-generator set MARC 2-H03</td>
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<td>2011</td>
<td>Oxfordshire, U.K.</td>
<td>CNIM</td>
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</table>
MAN Provides Green Power

In the near future, the new energy economy will see greater use of intermittent renewable power generation sources such as wind and solar power. This will go hand in hand with the use of highly flexible and efficient decentralized plants, offering power for peak demands and so-called “dispatchable” power for grid stabilization in response to the volatility of wind and solar. Highly efficient simple cycle, combined cycle (CC) and combined heat and power (CHP) solutions provide a fast-operating reserve in a time window of 5-10 minutes, form part of MAN Diesel & Turbo’s development focus to provide best-practice, state-of-the-art solutions to meet customer demand.

MAN Diesel & Turbo SE is proud to offer best-in-class industrial gas and steam turbines and gas engines for compact combined cogeneration plants. Best-in-class efficiency, optimum part load efficiency and high flexibility are their key benefits for sustainable and environmentally friendly power conversion problems in public and industrial facilities.

### Simple Cycle: Flexible and reliable power generation solution

Simple cycle power plants (SCPP) provide flexible and reliable solutions to enable the grid to respond quickly to flexible load demands. They consist of a single or multiple gas turbine driven generator set(s). The main components of the gas turbine are the air compressor, the combustor and the turbine, which drives both the air compressor and an electric power generator. SCPP are often used in remote areas as decentralized local power generation sets and as emergency or peaking units.
Fast start-up and variable loads with maximum performance and lowest emissions

More than ever before, MAN Diesel & Turbo’s development focus is on the environmental performance of our gas turbines. Using MAN’s unrivalled grasp of large engine technology, we aim to make our turbines progressively cleaner, more powerful and more efficient with MAN’s new Advanced Can Combustor (ACC) DLN technology.

MAN Diesel & Turbo’s gas turbine portfolio for power generation covers the range of 6–13 MW. The focus is on robust operation, high availability, fast start-up as well as start reliability and the capability for quick transient load responses.

Your direct benefits:

- Best-in-class efficiency in the 7 MW power range combining the “Best of two worlds” – robust heavy duty and aero-engine design
- Green power: Lowest emission levels in class with nearly single-digit NO\textsubscript{x} levels down to 50% part load with advanced MAN ACC DLN technology
- Reliable and robust part load behavior at highest-in-class performance levels
- Stable and clean solutions for wide range of fuels in the short run
- Fast ramp-up, in less than 9 minutes
- High reliability and availability level
Long overhaul cycles
- Modular design for ease of maintenance
- Emergency availability, e.g. black start units

**Combined Cycles: Enhanced efficiency for energy-intensive industries**

Energy prices are rising consistently, while legal requirements to reduce emissions such as greenhouse gases are becoming stricter. Combined cycle processes consist of the gas turbine powered generator, WHRU and the steam turbine which is driven by the waste heat of the gas turbine. This means a higher gain in electricity at the same amount of fuel burnt. Efficiency enhancement and OPEX reduction are the main drivers for compact Combined Cycle Power Plants (CCPP) with MAN components. MAN’s power generation units for Combined Cycle Power Plants offer advantages for independent on-site power generation in industrial applications, where processes can be combined to recover and utilize the gas turbine exhaust heat.

Besides the industrial applications, small combined cycle units are thought to have a bright future in the new energy market because of increased flexibility in the decentralized power generation market.

**Best-in-class gas turbines and custom steam turbines at top efficiency levels**

MAN Diesel & Turbo provides top-ranking gas turbines in the 6–13 MW range optimized for combined applications. Besides gas turbines as the main driver of CCPP, MAN Diesel & Turbo offers a comprehensive range of efficient steam turbines in the 2–160 MW power range. MAN Diesel & Turbo provides all major components of the steam turbine generator set such as generators, condensers, oil units, instrumentation and controls. Up to three steam admission and extraction ports are possible for various district heating requirements.

**Your direct benefits:**
- Improved overall electric energy output
- Electrical efficiency levels up to 45-50%
- Reduced greenhouse gas and NOx emissions
- Possible savings in OPEX for energy-intensive industries
- Maintenance and overhaul by one single provider
- High efficiency
- High reliability and availability level
Cogeneration/CHP: All from one fuel source

Combined heat and power (CHP), or cogeneration, is the most efficient and cleanest process for generating power and process heat from a single fuel source. CHP systems are designed to meet the facility’s thermal and electrical load requirements and greatly enhance the facility’s operational efficiency and flexibility. CHP power plants utilize a gas engine or gas turbine to drive an electrical generator while the exhaust waste heat of the gas turbine is used to produce steam in a steam generator which can be used directly for district heating. CHP systems are manifold and can also support cooling (absorption refrigeration) processes for e.g. food processing industry plants. CHP systems are often used for decentralized power generation.

MAN at the heart of power plants: fuel conversion rates of more than 80%

This efficient and economical method of energy conversion achieves significant primary energy savings compared with separate installation of power and heat generation equipment.

MAN Diesel & Turbo provides CHP systems which are tailor-made and optimized for the facility’s demand. Total plant efficiencies exceeding 80%
have been proven. MAN Diesel & Turbo CHP plants provide stand-alone decentralized power generation solutions and process heat supply in manufacturing plants, food processing plants and other industrial facilities.

**Your direct benefits:**

- Increased plant efficiency exceeding 80% with best-in-class MAN gas turbines as system driver
- High efficiency: reduced fuel consumption due to high CHP efficiency (low OPEX)
- Fast ramp-up, in less than 9 minutes (gas turbine only)
- Low greenhouse gas emissions
- High power density (small foot print)
- High reliability and availability level
- Modular plant design to ease overhaul
- Supply of multiple energy sources (electric power, steam, heat, cooling and drying)
- Emergency availability, e.g. black start units

High performance data in compliance with local government grants.

**Steam Generation**
## Hot Water Generation (District Heating)

![Diagram of hot water generation](image)

### Reference

<table>
<thead>
<tr>
<th>Order year</th>
<th>Country of Installation</th>
<th>Customer / Operator</th>
<th>Scope of delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>China, Shanghai</td>
<td>SAE / VW China</td>
<td>4x MGT6200 gas turbine packages</td>
</tr>
<tr>
<td>2011</td>
<td>Germany, Rheinberg</td>
<td>Solvin (Solvay/BASF)</td>
<td>CHP Power Plant (MGT6200, generator, HRSG)</td>
</tr>
</tbody>
</table>
Emissions Reduction

Engineering the Future – since 1758.
MAN Diesel & Turbo
Emissions Reduction

In recent years, local and global regulations covering exhaust emissions from internal combustion engines have become increasingly stringent. These regulations mainly focus on NO$_x$, HC, SO$_x$, particle and sound emissions and the surveillance thereof. MAN Diesel & Turbo has developed the power plant technology to ensure full compliance.

This technology is available for new build as well as for existing power plants as a retrofit solution.
Emissions Reduction
Selective catalytic reduction (SCR) of NO$_x$

Catalytic after-treatment of the exhaust breaks down harmful NO$_x$ into harmless nitrogen and water. A reducing agent is injected into the exhaust flow, upstream from a catalytic converter. Together with the catalyst, this agent causes the breakdown of the NO$_x$. With SCR, the engine can operate at partial and full load with maximum efficiency. With this technology a NO$_x$ reduction ratio of up to 97% is achievable.

MAN Diesel & Turbo developed a standardized portfolio of SCR systems together with leading catalyst developers and producers, applying the experience of several successful projects.
Emissions Reduction
CO, HC & CH₂O oxidation catalysts

Where excellent thermal efficiency is required and/or emission limits for carbon monoxide, hydrocarbons or formaldehyde are given in combination with low sulfur fuels (gas or liquid), oxidation catalysts are the key to success.

Based on the individual requirements, MAN will select the best oxidation catalyst for your application according to function and price from a series of different coated catalysts. A monitoring system will indicate when the catalyst has to be cleaned or replaced.

Oxidation catalysts can be easily combined with SCR systems, if necessary.

The main reactions in oxidation catalyst systems are:

<table>
<thead>
<tr>
<th>Reaction Type</th>
<th>Chemical Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide</td>
<td>CO + ½ O₂ → CO₂</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td>CₙHₙ + (m + n/4) O₂ → m CO₂ + n/2 H₂O</td>
</tr>
<tr>
<td>Aldehydes, Ketones, etc.</td>
<td>CₙHₙO + (m + n/4 - 0.5) O₂ → m CO₂ + n/2 H₂O</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H₂ + ½ O₂ → H₂O</td>
</tr>
</tbody>
</table>
SO\textsubscript{X} emissions are caused by the sulphur content in the fuel and cannot be influenced by the engine. Any sulphur burned in the combustion process will be emitted as SO\textsubscript{X}. Low-sulphur fuel is usually expensive and not always available, and removing sulphur from the fuel can be costly. The sulphur has to be removed from the exhaust using the appropriate technique to adhere different emission limits.

**Two established methods are available:**
- Conditioned dry scrubbing with hydrated lime powder
- Dry scrubbing with sodium bicarbonate powder

The choice of a suitable desulfurization method depends mainly on the water and absorbent availability.

Dry SO\textsubscript{X} scrubber with bag filter (Dantherm)
Due to the ash content and combustion characteristics of the fuel especially in heavy fuel oil applications, particle emissions will occur. Where necessary, to reduce these already low particle emissions further, two different systems are available:

**Electrostatic precipitator (ESP):**
The best solution for high exhaust temperature applications is electofiltration, the electostatic attraction of ionized particles.

**Bag filtration:**
Where low exhaust temperatures are given, for example in CHP applications, bag filters are applicable. If necessary, these can be easily combined with a DeSO$_x$ system.

**Emission monitoring**
To fulfill local regulations regarding proof of exhaust emissions and to ensure ideal operation of exhaust treatment units MAN Diesel & Turbo will choose the best solution in terms of price and practicality to fulfill your needs. The function and reliability of these systems has been proven in a number of installations.
The specification of the requirements of acoustically relevant equipment follows of the acoustical design of a power plant in its particular environment.

The reduction of the sound emissions is achieved by means of appropriate sound attenuation (silencers) and damping (of buildings and equipment) as well as by use of low-emission equipment (radiator coolers, transformers, compressors, etc.).

Factory and site acceptance tests are made to verify the fulfillment of the requirements of the equipment and the plant as a whole.
Service with Passion

MAN | PrimeServ
MAN PrimeServ is MAN Diesel & Turbo’s highly efficient and customer-oriented service brand with more than 115 service centers worldwide, offering first-class 24/7 technical support and customer service.

**MAN PrimeServ Solution Overview**

1. Genuine Spare Parts  
2. Retrofit & Upgrade  
3. Technical Service & Repair  
4. Service Agreements  
5. Additional MAN PrimeServ Solutions  
6. MAN PrimeServ Academies

**1. Genuine Spare Parts**  
Choosing genuine MAN Diesel & Turbo spare parts offers many benefits: Our spare parts are produced with the same care and quality as the parts of our new engines. As our customer, you profit from state-of-the-art technology since our spare parts are continuously developed on the basis of our ongoing research. MAN PrimeServ supports you with tailor-made spare part concepts which are created according to your specific requirements. We deliver our parts whenever and wherever you need them, including a 24h delivery service for urgent requests.

**2. Retrofit & Upgrade**  
Broad range of solutions updating engines in-service to latest standards, i.e. in order to meet recent emission levels and to lower operation costs not only for MAN engines, but also for third-party engines.  
- Fuel conversion retrofits, such as liquid fuel oil to dual fuel, liquid fuel oil to gas or special fuel (e.g. bio fuel)  
- Measures improving fuel and lube oil savings and emission reductions, enhancing engine lifetime and reliability (Common Rail, SCR-systems, DeSOₓ-scrubbers, MDO/MGO upgrades, etc.)
· Updating monitoring and controlling equipment in order to optimize engine safety and performance
· Upgrade from engine single-stage turbocharging to two-stage version
· Upgrade with WHR (Waste Heat Recovery) systems e.g. from standard power plant to DCC (Diesel Combined Cycle) or ORC (Organic Rankine Cycle)

3. Technical Service & Repair
Our Technical Service is providing technical assistance for our customers’ operating and maintenance personnel. Whether a request is for advice on instructions or working procedures, assistance in planned and unplanned maintenance, breakdown support, optimization of operations or handling warranty matters.
Special, skilled engineers for the respective engine types, who are also familiar with the applications in power generation, are dedicated to render “a helping hand” for customers’ personnel. Furthermore, Technical Service is the home base for our field service engineers and superintendents worldwide.

4. Service Agreements
PrimeServ O&M has a wide portfolio of Service Agreements. The basic agreements are flexible so that they can be adapted to meet the specific needs of any project. The portfolio is grouped into two categories:
4.1 Long Term Service Agreements (LTSA)

The LTSA program is a series of long-term contractual relationships in which MAN PrimeServ supports the customer with maintenance services and spare parts.

Time and Material Agreement (TMA)

A TMA is a frame agreement, outlining the terms and conditions for any services or supplies ordered by the customer. The customer is responsible for logistics planning and orders spare parts and service when needed.

Benefits of the TMA
- Pre-agreed upon terms and conditions
- Reduced order processing times
- Price predictability

Basic Maintenance Agreement (BMA)

With a Basic Maintenance Agreement (BMA) the customer is assigned a designated contract manager who is responsible for the scheduling and logistics of each maintenance, as well as monitoring customer needs and work execution. It is a long-term arrangement covering the supply of spare parts and superintendent services on site for specified planned maintenance intervals within a predefined period.

Benefits of the BMA package
- Preferred pricing
- Key account relationship
- Collaborative maintenance planning
- MAN responsibility for spare parts and service logistics
- Regular meetings on management level
Accelerated Maintenance Agreement (AMA)

In the Accelerated Maintenance Agreement (AMA), downtime for planned maintenance is minimized by using a pit-stop style approach to maintenance. Strategic spare parts are kept in stock on site for rapid exchange during maintenance, reducing the scheduled outage time. After the exchange, the engine is returned to service and the removed parts undergo reconditioning and quality inspection before being added to the strategic stock of spares parts.

Additional benefits of the AMA package
- Reduced downtime for planned maintenance
- Preferential pricing on strategic spare part packages
- Option for full maintenance crew from MAN
- Strategic stock for reducing unscheduled maintenance outages

Performance Maintenance Agreement (PMA)

The Performance Maintenance Agreement (PMA) covers both planned and unplanned maintenance. The contract is structured so that Prime-
Serv O&M and the customer are aligned and incentivized to meet certain pre-defined performance goals. In addition, the scope typically includes online monitoring, periodic on-site support, priority access to spare parts, as well as logistics support to minimize unscheduled events.

Additional benefits of the PMA package
- Availability commitments
- Price predictability for scheduled and unscheduled maintenance
- Priority access to long lead spare parts
- Faster troubleshooting and error elimination
- Regular data reporting and analysis sharing

4.2 Operation & Maintenance Agreements (O&MA)
The O&MA program is a series of long-term contractual relationships in which PrimeServ O&M plays a large role in the management and operation of complete power plant facilities on top of the maintenance services.
O&M Support Agreement (OMSA)
The Operation & Maintenance Support Agreement (OMSA) is an advisory agreement in which PrimeServ O&M arranges for one or more operation and maintenance specialists to provide guidance to the customer during the mobilization and operation of the power plant.

Benefits of an OMSA
- Management and supply of spare parts and service
- On site support from experienced professional(s)
- On-the-job mentoring
- Proven methods and procedures

O&M Management Agreement (OMMA)
The Operation & Maintenance Management Agreement (OMMA) embeds PrimeServ O&M staff into key management positions in the customer’s operation and maintenance organization. During the operation period PrimeServ O&M staff will assume the key positions and authority to manage the customer’s organization in the execution of all administration, operation and maintenance activities.

Benefits of an OMMA
- Management responsibility of the complete facility on a 24/7 basis
- On site mentoring
- Management and supply of all plant spare parts and related services
- Downtime commitments for scheduled maintenance

Full Operation & Maintenance Agreement (FOMA)
The Full Operation & Maintenance Agreement (FOMA) is a holistic solution in which PrimeServ O&M manages, operates and maintains the complete facility on behalf of the customer. The scope typically includes mobilization services prior to the start of commercial operations such as the hiring of the staff, staff and plant outfitting, establishment of computerized maintenance management systems and development of standard procedures. From the start of commercial operations PrimeServ O&M is responsible for the management, operations and maintenance of the full power plant facility including daily operations, routine maintenance, major overhauls, feedstock and inventory management.
Benefits of an FOMA
- Responsibility of the entire facility on a 24/7 basis
- Performance commitments
- Proven operation & maintenance practices
- Single point of responsibility
- Local solution, global support

5. Additional MAN PrimeServ Solutions
MAN PrimeServ also has several additional solutions within its portfolio which can be included in any of the Service Agreements or ordered separately.

Performance Assessment (Audit)
Performance Assessment modules include the evaluation of technical equipment, the organizational structure, staff skills and competency, operations and maintenance practices.

Online Service
The PrimeServ Online Service securely transfers key engine data from any place in the world to the PrimeServ headquarters. Engine experts analyze the data and provide the customer with written recommendations. The experts can also provide engine operators with remote support by accessing real-time engine data.

Computerized Maintenance Management System
A Computerized Maintenance Management System (CMMS) is a software program which helps optimize maintenance planning. Selected modules are setup to organize all data and processes related to maintenance activities including the planning of spare part requirements and workflows, as well as the simplification of warehouse management and purchasing control.
MAN Diesel & Turbo provides analysis for engine fluids and non-metallic materials such as fuel, lubricating oil and cooling water. Testing is conducted in accordance with common standards for operating fluids such as ISO8217 for fuels.

PrimeServ\textsuperscript{Lab}\textsuperscript{*}

The condition and cleanliness of the turbine of an exhaust turbocharger have a decisive influence on the efficiency and the performance of the combustion process and hence on the service data of the engine. By using PrimeServGran the turbine of the exhaust turbocharger can be cleaned at operating load and grants optimal operating values.

6. MAN PrimeServ Academies

We train technical personnel of our customers in the disciplines operation, maintenance and troubleshooting in our 13 PrimeServ Academies and even on site. The participants are guided through hands-on exercises on full-scale machinery including simulators. Customer’s benefit: well-trained personnel keeps downtime of machinery at the lowest possible level and influences safety, resulting in reduced accident rates. Standard and customized training is offered worldwide.
Power plant projects usually require huge investments and therefore need long-term financing. Banks, especially those not in the top 100, may have difficulties obtaining long-term (10 years) refinancing on the capital markets. As a member of the MAN Group, we have relationships with a large number of international first class banks and together with our national export credit agencies (Euler Hermes Deutschland AG, Coface, EKF) we can provide you with long-term financing at very attractive rates. Only long-term financing makes huge investments possible.

Below you can find a chart explaining the typical structure of such financing.

* The requirement for an additional guarantee depends on the loan amount and the credit standing of the customer.

The local guarantor can be a local bank or the parent company of the customer which has a credit standing acceptable to the banks and ECAs.
Advantages:

- Long-term financing up to 10–12 years from the taking over of the plant
- Fixed interest rates available
- Diversification of the financing basis – access to the international capital markets
- Companies that are accepted by ECAs without additional guarantee, get access to cheap long-term funds, which are much more attractive than the ones available in their local market
- Loan amount up to 85% of the contract value plus 100% of the ECA premium
- Interest during construction can be capitalized and included in the financing
- Financing is available in all major currencies
- MAN has access to banks that are in a position to finance bigger tickets. MAN can in addition form banking consortia that are able to finance very big power plants

Usual conditions:

- ECA coverage is generally linked to equipment sourced from the country of the ECA. However, there are cooperation agreements in place which allow for multi-sourcing under one ECA policy
- Local content can be included in the financing up to 23% of the contract value
- ECA cover is subject to an acceptable credit check and a satisfactory environmental due diligence
- Repayments in semi-annual installments, grace period 6 months

Such type of financing can also be granted to IPPs after a detailed feasibility study. The loan term can in such cases be extended to 14 years with some flexibility in the repayment stream if the average loan term does not exceed 14 years. Fixed interest rates are possible, thus eliminating the interest rate change risk.

This type of financing also covers the construction period.

With our worldwide presence and our long-lasting relationships with leading international banks, including development banks, we can offer you tailor-made financing solutions for your business.
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F: MAN Diesel & Turbo Four-stroke license
FS: MAN Diesel & Turbo Four-stroke SEMT Pielstick license
TC: MAN Diesel & Turbo Turbocharger license

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